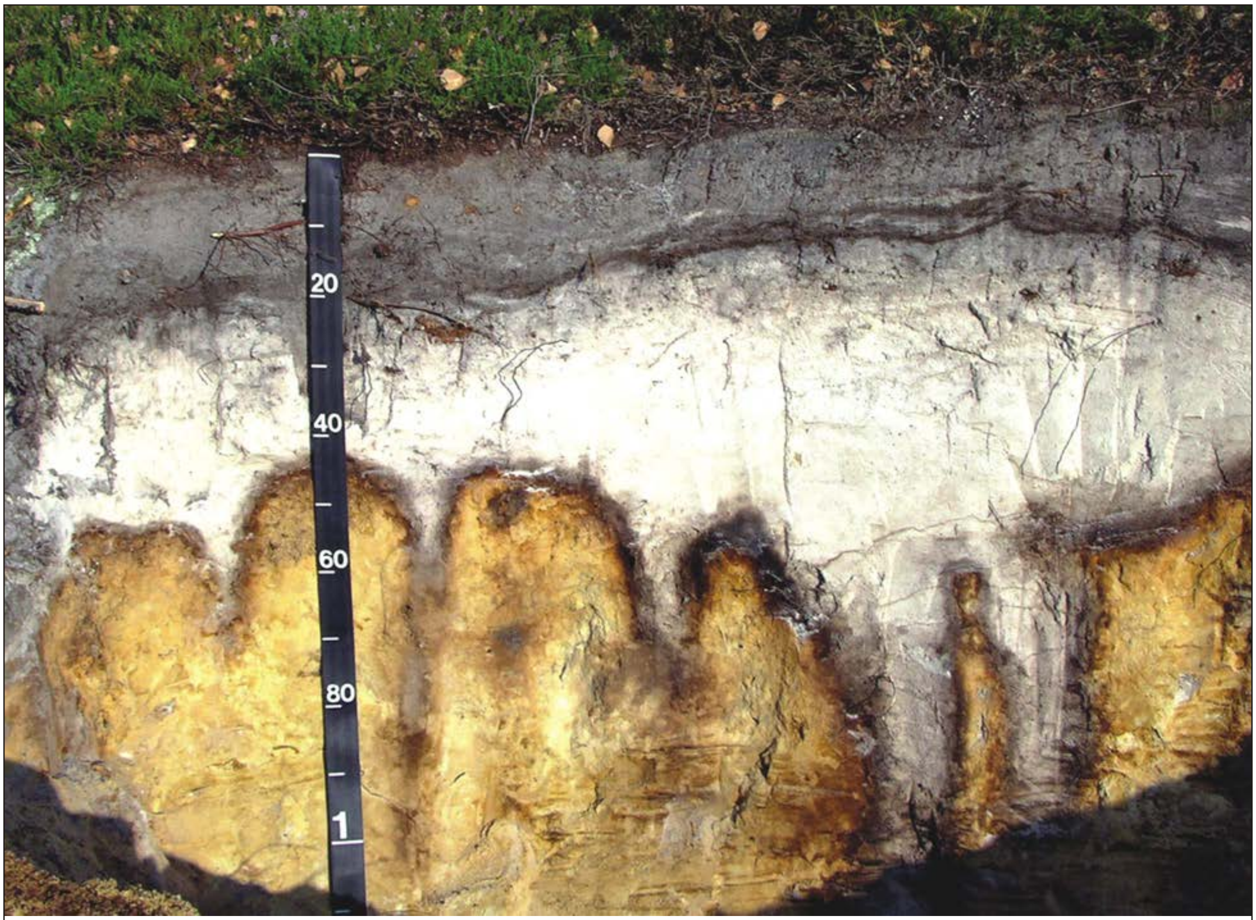

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Integrated Soil Fertility Management for Better Crop Production in Ethiopia

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ABSTRACT

In Ethiopia, Agriculture still constitutes the major part of the country's economy, yet the agriculture is facing a number of problems. Hence farmers are entangled in a vicious circle of ecological degradation, poverty and starvation. The causes to these rooted problems are the land degradation exhibited in form of soil fertility loss as initiated by different factors as deforestation, overgrazing and with a result of soil erosion, sedimentation, pollution, etc. The intention of this study is to discuss the status of soil fertility in country, the causes to soil fertility loss and find better solutions of soil fertility decline. As the topography of the country is rugged with varying types of soils, particularly the highland where about 90% of the arable land is concentrated, problems such as soil erosion, poor and continuous cultivation are the major causes to soil fertility decline. Therefore, the use of integrated soil fertility management with inclusion and combination of manure, compost, crop rotation, soil conservation practices such as minimum tillage, tied-ridging, residue management and other practices together with chemical fertilizer and improved germplasms gives the better production and keeps the soil fertility status to a better level. The practice being under taken by the Government which is the use of fertilizers in blanket recommendation is not successful as a result of agro-climate, soil and the socio-economic condition of the farmer, resorting to sustainable integrated soil fertility management to get maximum yield without compromising the soil fertility status in the future is wise and need to follow.

Key words: Soil fertility loss, soil erosion, continuous cultivation, integrated soil fertility management

INTRODUCTION

Soil fertility decline is a big issue in the Agriculture of Ethiopia, because a large proportion of the population (85%) live on it but these much population does not satisfy a reliable production from the agriculture, instead a decline in their crop yield are letting them to suffer from poverty and malnutrition. Studies indicated that in some parts of Ethiopia farmer suffer from lack of what to eat particularly in months starting from June up to September (Demeke, 2003). Farmers in most parts of the country actually work hard, in seasons of the year when the rainfall is favourable for their cropping; regardless of their effort they get very little which does not help them escape their subsistence way of living.

The fault with this agricultural problem is very intricate in nature, the complexity arises from various condition of the country such as the agro-climate, topography of the lands, the soil types and socio-economic status of the farming community and the combination of these; the overall effect of which is finally reflected by soil fertility decline and reduction in yield of crops. In the expansion process of the agriculture farmers deforest the existing forests and bring a new form of land use and on their agricultural land they almost take no organic matter management. In other case for their livestock production, they undertake an overgrazing process and bare the land of grasses which leads the land to be liable to further degradation through erosion. Hence, all these problems cause a loss in soil fertility of the country; on average Ethiopia losses about 42 t ha^{-1} $year^{-1}$ soil. With this amount of top soil a number of plant nutrients including organic matter are removed. Over years the remaining subsoil, soil left over from erosion, is difficult to work and generally unproductive (Alemayehu *et al*., 2006).

The loss in soil fertility is further aggravated by continuous cultivation which leads to nutrient mining of the soils. As the population increases the farming system such as the shifting cultivation and fallowing which use to be practiced by farmers is now a days discontinued to continuously feed the large number of family. Even if farmers have indigenous knowledge how to manage their farms but the resource they posses limit them no to do the managements such as organic matter management by leaving the crop residue on the field and also to apply the cow dung or manure to their field (Beyene, 2011).

There are a number of researches done by different stakeholders to address the problems of soil fertility but most of these concentrate on application of different types of mineral fertilizers and pesticides for which the farmer is very far away to afford them. Irrespective of the different local research studies in Ethiopia until now the fertilizer application undertaken by farmers is based on a National level forwarded by the Government. And it is based on some general soil studies, for immediate solution of production problems of the country and this National fertilizer recommendation is known as the blanket recommendation but it now found to be antiquated practice that cannot address the local condition of the farmers.

If scholars have to do a research to address the problems of the farming community, it should be in collaboration/participation of the farmer himself, in the manner that he/she is able to analyze the problem and understand the solutions given on his farm by interpreting to his own standard.

It is investigated that the farmer's practices and perceptions/knowledge's are very valuable, for example farmers realized in some parts of Ethiopia that the fertilizer application to give a better yield for cereal cultivation the cereal should follow a rotation of some kind of legume crop and this is found to be true to crops like teff and wheat. Therefore combining the different farming systems and agronomic practices can help to address the problems of soil fertility decline. Instead of concentrating on mineral fertilizers alone, integrating the different practices which are acceptable and minimize the expenditure of those poor farmers, like agro-forestry or green manure such as *Erythrina bruice*, crop rotations, intercropping and soil conservation practices, in combination with application of mineral fertilizer and use of improved crop germplasms is helpful.

SOIL FERTILITY STATUS OF ETHIOPIAN SOILS

In the different regions of Ethiopia there exist various topographic, climatic or agro-climatic and soil conditions. These varying conditions together with socio-economic status of the society, creates various factors that cause soil fertility decline with varying degrees. Therefore, the soil fertility status of Ethiopia cannot simply be generalized, because there are different local soil fertility statuses which may range from fertile soil to highly infertile soil. But in general the soils of most sub-Saharan Africa particularly the east African soil are generalized as infertile with "Orthodoxy". Orthodoxy is to mean that infertility of the soil in this region is an apparent phenomenon which does not need any proof or in the original saying "The existence, the extent and causes of soil fertility problem are accepted without question" (Abera and Belachew, 2011).

Soil fertility and productivity is more than just plant nutrients and can be defined as "The physical, biological and chemical characteristics of a soil, for example its organic matter content, acidity, texture, depth and water-retention capacity all influence fertility" (Gruhn *et al*., 2000). Because these attributes differ among soils and soils differ in their quality. Some soils, because of their texture or depth, for example, are inherently productive because they can store and make available large amounts of water and nutrients to plants (Gruhn *et al*., 2000). Conversely, other soils have such poor nutrient and organic matter content that they are virtually infertile.

Even if the soil fertility status of Ethiopia is not documented well, its low fertility status can be exhibited, by some of macronutrient and organic matter, CEC and pH levels of the different areas.

As already stated above the soil fertility status in Ethiopia various among the different condition, for example the variation in the agro-ecological zones and variations within plots in a farm is indicted in Table 1 (Sanginga and Woomer, 2009).

Fertility status also can vary between contrasting fields that are within the same soil types, for example soils around homestead are relatively fertile to soils which are far away from homestead (outfields) (Getachew and Chilit, 2009) (Table 2).

To strengthen the before mentioned explanation, a study was made at Ethiopian highlands which indicates that there is variation in fertility status of soils between homestead and outfield areas in enset (*Ensete ventricosom*) growing. The result suggests that the variation in soil fertility is not only due to nutrient deficiency (unavailability) but it is also due to existence or absence of soil organic matter (Amede and Taboge, 2005).

In the four year study (2001-2004) on enset (*Ensete ventricosom*) on farmers field, where farmers are groped as resource rich (G_1) and resource poor (G_3), based on their capability of allocation of resources to their agricultural enterprise, there is an observed variation ii soils among groups and type of farms. In the study the yield components and nutrient contents of the enset are compared for the homestead and outfield plantations. Hence, it is found that the homestead soil have significantly higher contents of macronutrients such as N, P, K and Ca but the enset plant took up 150% greater amounts of the macronutrients for the outfields than the homestead however, the yield components of the enset declined by 90% for height and reduced by 50% for pseudo-stem diameter in outfield farm relative to the homestead (Amede and Taboge, 2005).

The decline in the yield components is a reflection of the fewer amounts of organic matter in the outfield which resulted in low water holding and retention capacity of the soil, with consequence of decline in the yield components of enset due to moisture stress, rather than nutrient stress (Amede and Taboge, 2005). Whatever, it is the outfield soils is infertile or have lost its fertility in terms of its organic matter content relatively.

Table 1: Soil fertility status variation between agro-ecological zones and between plots within a farm

	Status of the soil fertility metrics		
Agro-ecological zone	pH	Organic C (g kg^{-1})	Total N (g kg^{-1})
Equatorial Savanna	5.3	24.5	1.6
Guinea Savanna	5.7	11.7	1.4
Sudan Savanna	6.8	3.3	0.5
Field within a farm			
Home garden	6.7-8.3	11-22	0.9-1.8
Village field	5.7-7.0	0.5-0.9	0.5-0.9
Bush field	5.7-6.2	0.2-0.5	0.2-0.5

Source: Sanginga and Woomer (2009)

Table 2: Variation in soil fertility status between contrasting fields of the same soil type (Nitisols, West Shewa)

Field type	pH	N (%)	P (ppm)	K	Ca	Mg	CEC
				------------Meq/100 g soil------------			
Field near to home	5.50	0.24	17.93	2.20	12.76	2.63	29.80
Field far from home	4.60	0.16	8.40	1.41	8.95	1.76	19.51

Source: Getachew and Chilit (2009)

Table 3: Soil pH, organic carbon and total nitrogen by area

Areas	Status of the soil fertility metrics pH	Organic C (%)	Total N (%)
Melkassa	7.0-8.2	0.8-1.5	0.1- 0.15
Miesso	7.3-7.8	0.7-0.9	0.04-0.1
Arsi Negelle	6.5-7.9	1.3-2.1	0.1-0.2
Wolenchiti	7.5-8.5	0.8-2.0	0.1-2.2
UAAIE	8.2-8.5	>1	2.1-2.4
Adami Tulu	>7.3	0.8-1.7	0.1-0.15

Source: Cited by Zelleke *et al*. (2010)

Even if the enset plant absorbed approximately adequate amounts of nutrient, however there occurred a yield decline as observed on its yield components. Here it can be seen that the fertility status of the soil in the farmers own field is lower due to less organic matter content of soil which resulted in moisture stress of the soils (Amede and Taboge, 2005).

An organic matter depletion of the soils is a wide spread problem in Ethiopia, investigation cited by Zelleke *et al*. (2010) by area indicate that soils of the different areas can be rated as low concerning their organic matter and total nitrogen content (Zelleke *et al*., 2010) (Table 3).

A soil to be productive it need to have an organic carbon content in range of 1.8-3.0% to achieve a good soil structural condition and structural stability (Charman and Roper, 2007). In the same document it is tabulated that a soil with organic carbon of 1% and less is considered as low to extremely low. The nitrogen rating of soil is also indicated as high when its soil concentration is in range of 0.25-0.5% but can be considered as low below these values (Bruce and Rayment, 1982). Therefore, it can be seen that both the amount of organic carbon and nitrogen in most areas of the country is low to be suitable for better crop production.

On the other hand a study made at Southeast Ethiopia, on soil fertility status based on farmers fertility naming indicate that, soil samples taken at different depths and analysed using standard laboratory procedures have shown difference in fertility status. Farmers fertility naming goes in conformity with the laboratory analysis, even if farmers use qualitative method to class the fertility status of the soils (Belachew and Abera, 2010).

The clay content of the soil increases down the depth but the pH, organic matter content and total nitrogen decreases down the soil depth. However, on rating the soil fertility status based on the laboratory analysis using parameters such as Organic Carbon (OC%), Cation Exchange Capacity (CEC), pH and some nutrients indicate the soil of the southeast is low to medium in its organic carbon content, low to medium in total nitrogen, lower to medium in CEC and adequate pH (Belachew and Abera, 2010). Based on the results it can be generalize that the fertility status of the southeast soils is low to medium in fertility but not fertile or very fertile.

In a study made at typic Hapluusterts in north Tigray, Ethiopia the soil is depleted of its major nutrients and it can be considered as soils with low fertility status. All soils under this study in the region are deficient with nutrients such as N, P and micronutrients (Kebede and Yamoah, 2009). The soils of East Africa in general are highly degraded and posses relatively lower amounts of some important crop nutrients such as the soil organic matter and total nitrogen which are very determining nutrients from crop production point of view (Okalebo, 1987).

MAJOR CAUSES TO LOSS OF SOIL FERTILITY IN ETHIOPIA

Few decades ago most soils of Ethiopia were covered by vegetation and the fertility of the soil was better off, for example in the 1960-70s. But with an increasing population the pressure on lands escalated, through deforestation, overgrazing and continuous cropping with the fallowing system discontinued. Hence, most soils lost their fertility, in terms of the physical property and chemical properties such as macronutrient, micronutrient and organic matter depletions (Donahue, 1972).

For all the fertility losses there are various causes in the different regions of the country, in totality the major causes to soil fertility decline is a land degradation which is caused through the different agents such as soil erosion, deforestation, overgrazing, sedimentation, continuous farming and pollution. The major causes to soil erosion and sedimentation are not only high intensities of rainfall and floods but the problem is much aggravated by deforestation and overgrazing, in the absence of the two, soil erosion and sedimentation will remain to the minimum (Demeke, 2003).

The major cause for soil fertility decline has been explained in figure above (Demeke, 2003) but for convenience of this review I concentrated on two issues the soil erosion and continuous, cultivation as major causes of soil fertility decline; because the other causes are the contributors for the two major causes soil erosion and continuous cultivation in relation to soil fertility decline.

In most parts of Africa particularly the East Africa, the major causes to soil fertility decline are the soil erosion, poor organic matter management, continuous cultivation, etc. In study made in Kenya, the causes to soil fertility decline are give different scores and then ranked to screen out the major cause and it is found that erosion is the first major cause to the problem (Kathuku *et al*., 2006) (Table 4).

Soil erosion: Soil erosion is described as the process as a loss of nutrient rich clay and organic matter in rain drop splash , impoverishing the upper top soil and while subsequent erosion peels off the upper soil layers (Miller and Donahue, 1997).

In Ethiopia due to surface topographic condition of most arable lands which concentrates in the highland, the problem of soil erosion is a serious one. In this condition Ethiopia losses a top soil of about 137 t ha^{-1} year^{-1}, when this amount of soil is estimated in terms of soil depth it is about 10 mm (Okigbo, 1986). The rate of top soil loss is very high in Ethiopia compared to rate of top soil

Table 4: Pair-wise ranking of causes of overall decline in soil fertility in Kenya

Causes of fertility decline	SE	CC	IOM	ICRP	PTP	UIF	POM	Score	Rank
SE		SE	SE	SE	SE	SE	SE	6	1
CC			CC	CC	PTP	UIF	CC	3	4
IOM				ICRP	PTP	UIF	POM	0	7
ICRP					ICRP	UIF	POM	2	5
PTP						UIF	POM	2	6
UIF							POM	4	3
POM								4	2

Source: Kimani *et al*. (2003), SE: Soil erosion, CC: Continuous cultivation, IOM: In-adequate organic fertilizer, ICRP: Improper crop rotation practice, PTP: Poor tillage practice, UIF: Use of in-appropriate fertilizer, POM: Poor organic matter management formation, under agricultural condition in general the soil loss is about 10 mm ha^{-1} $year^{-1}$ and formation of this depth of soils takes place in about 200 years (Okigbo, 1986).

Vegetation cover determines the extent of soil erosion in Ethiopia, because of the rugged topography of Ethiopia, hence agricultural fields are most susceptible to erosion effects as they are practiced on slopping lands; moreover under semi-arid conditions, there is normally sparse ground cover at the onset of rains, leading to relatively severe rates of runoff and soil loss (Esser *et al.*, 2002). Under Ethiopian condition we can see that croplands are more vulnerable to erosion and soil loss (Table 5).

When the top soil is removed by erosion, the clay content of the remaining soil increases but the organic matter content decreases which is an indication of unfavourable condition and loss of soil fertility. Study made at different times on Vertisols of Ethiopia indicates the loss of top soil results in high clay content, because as a soil depth increases the clay content of the Vertisols soil increase (Philor, 2011).

The loss of top soil results in loss of different soil nutrients for example the macronutrient nitrogen, with a consequence of yield losses. A study in South and East Africa on two cereal crop Maize and Wheat indicates that there is a significant loss of crop yield for these crops due to loss of Nitrogen from the soil (Nabhan *et al.*, 1999) (Table 6).

There are different types of soil erosions, like wind erosion, water erosion, etc but water erosion is the major one causing soil fertility problem in Ethiopia. It is estimated that the national soil removal by water erosion is about 1493 million tons per annum however, the magnitude varies among individual fields and the maximum removal may go as high as 300 t ha^{-1} $year^{-1}$. The same study on crop land estimate indicates that the average soil loss rate goes to about 42 t ha^{-1} year which is about 4 mm in terms of soil depth removed (Hurni, 1993). It is estimated also that the rate of soil removal calculated in the crop land, is able to wear away the whole profile in about 100-150 years, provided that the depth of soil profile is kept to 60 cm (Hurni, 1993).

On a study made at Digil micro-catchment Ethiopia, the soil erosion is high enough to form rills and the total amount of rill formed is shown in Table 7. In connection with the rills formed the soil

Table 5: Estimated rates of soil loss in Ethiopia for different land use and vegetation classes

Land cover type from LUPRD	Area (%)	Estimated soil loss (10^3 kg ha^{-1} $year^{-1}$)	(10^9 kg $year^{-1}$)
Cropland	13.1	42	672
Perennial crops	1.7	8	17
Grazing and browsing land	51.0	5	312
Currently unproductive	3.8	70	325
Currently uncultivable	18.7	5	114
Forests	3.6	1	4
Wood and bush land	8.1	5	49
Total	100.0	136	1493

Source: Hurni (1988)

Table 6: Calculated loss in grain yield due to losses in nitrogen through erosion

	Yield lost N lost (kg/kg)	Range of nutrient loss N (kg ha^{-1})		Range of nutrient loss N (kg ha^{-1})	
Crop	Crop response ratio	Low	High	Low	High
Maize	9.6	36	429	0.345	4.12
Wheat	6.9	36	429	0.248	2.96

Source: Nabhan *et al.* (1999)

Table 7: Total length and volume of rills and damaged area

Rill parameter	Measured quantities
Length of rill (m)	861.00
Volume (m^3)	98.50
Damaged area (m^2)	432.70
Damaged area out of total area (%)	1.02

Table 8: Soil erosion caused by different categories of rills

Size of the rills	No. of rills	Total soil loss (m^3)
Small	12	26.81
Medium	17	40.80
Large	5	30.89
Total	34	98.50

Source: Woldeamlak (2003)

Table 9: Land cover change in the Digil watershed between 1957 and 1982

Land cover	Area in ha (1957)	Total (%)	Area in ha (1982)	Total (%)	Change between 1957 and 1982 (%)
Forest	13.5	1.62	14.2	1.70	+5.2
Woodlands	234.7	28.11	118.6	14.21	-49.5
Shrub lands	79.6	9.53	127.7	15.30	+60.0
Croplands	300.4	35.98	543.5	65.09	+80.9
Grazing lands	206.7	24.76	10.9	1.31	-94.7
Settlements	-	-	20.0	2.39	+100.0
Total	834.9	100.00	834.9	100.00	-

Source: Woldeamlak (2003)

loss in the micro catchment area is also indicated in Table 8, the rate of soil loss in the micro catchment here is relatively less than the average rate of soil loss in cropped lands that is 42 t ha^{-1} $year^{-1}$ (Woldeamlak, 2003).

The major cause for the soil losses and rill formation is the change in land cover/use. In the Digil micro-catchment, the land cover change between 1957 and 1985 is shown in Table 9 (Woldeamlak, 2003).

Over the twenty-five years considered, the major changes were the increase of the cropland and shrub land areas at the expense of the open grazing and woodland areas. Unexpectedly, the forest cover showed an increase but only very slightly. This increase is attributable to the reforestation and forestation activities during the derg regime and the planting of trees at the household level (Woldeamlak, 2003).

In a study made in the North Western Ethiopia, about perception of farmers based on their experience of yield reduction due to loss of soil fertility; majority of the farmers explained that their land is losing its fertility from year to year and now they have reached to level of food insecurity (Demeke, 2003). They also stated that the major cause for their soil fertility loss is the soil erosion.

In the same study about 81% of the respondents, perceive the major cause for loss of their soil fertility is caused by erosion which in turn is caused by removal of vegetation, intensive cultivation, etc. (Demeke, 2003).

In other study at Beressa watershed, Central highlands of Ethiopia, about perception of farmers on causes of soil erosion and causes to decline in yield of crops indicated that most farmers perceive the major cause of erosion is erosive rainfall and the cause to decline in yield is due to rainfall shortage or drought followed by loss of soil fertility. It does not mean that the farmer's perception

Table 10: Farmers perception of causes for soil fertility loss in beressa watershed

Farmers response	Debele n = 54	Wushawushagn n = 59	Faji n = 34	Total n = 147
Causes of soil erosion				
Erosive	44	40	40	41
Slope steepness	33	26	44	34
Damaged conservation structures	16	10	8	11
Tillage/lack of vegetation cover	nr	4	4	4
Causes of productivity decline				
Rainfall shortage	67	73	45	62
Fertility decline	8	13	23	15
Continuous cultivation	14	7	19	13
Soil erosion	8	4	nr	6
Frost	2	nr	13	8
Others	2	4	nr	3

nr: No response. Average are taken only of those who responded. Source: Amsalu and de Graaff (2006)

is exactly right but it helps scholars to understand the farmer's level of awareness and then study the right causes for erosion and decline in crop yield to fill the gap of the farmers so that they can take the appropriate decision on their own farm (Amsalu and de Graaff, 2006) (Table 10).

Evidences from different sources indicate that for most occurrences soil erosion and its consequent soil losses, the land cover/land use change played the major role. Different types of vegetations and forests are cleared and deforested for different immediate purposes (Berry, 2003). In Ethiopia over the past few decades a large proportion of forest lands and other vegetations are cleared and deforested.

The Ethiopian Highlands Research Study (EHRS) concluded that water erosion (sheet and rill) are the most important process and that in mid 1980's 27 million ha or almost 50% of the highland area was significantly eroded, 14 million ha seriously eroded and over 2 million ha beyond reclamation. Erosion rates were estimated at 130 t ha^{-1} $year^{-1}$ for cropland and 35 t ha^{-1} $year^{-1}$ average for all land in the highlands but even at the time these were regarded as high estimates. Sutcliffe produced new lower estimates for soil erosion but emphasized the much greater importance of nutrient loss (Berry, 2003).

The erosion hazard is aggravated by nutrient mining by crops, extended farming on sloping areas, shortened fallow system and reduced vegetative cover, depletion of soil organic matter and mismanagement of crop lands. The general consensus is that the exhaustive nature of the farming system in Ethiopia accompanied by environmental crisis (erosion, drought and deforestation) caused a sharp decline in soil fertility of arable lands throughout Ethiopia (Berry, 2003).

The annual net nutrient depletion is estimated to exceed 30 kg nitrogen, 20 kg potassium and equivalent amount of phosphorus from Arable lands of Ethiopia, Kenya, Rwanda and Zimbabwe (Smaling, 1993). On low input soils, losses at this order of magnitude may cause a significant yield decrease within a short period of time. The causes responsible for the nutrient loss from arable lands are multifold, soil erosion being the most important factor (Smaling, 1993).

Continuous cropping: Continuous cropping or monoculture and intensive cultivation of crops can significantly decrease the nutrient level of the soil and its total fertility for a particular crop under cultivation; which, finally leading to a decrease in yield of the crops. A study made on maize crop in the Oxysols of Brazil indicated that the yield of maize crop declined considerable when it was mono-cropped on the same field for 60 years (Thornton *et al*., 1995).

The major reason for the decline in yield is due to nutrient depletion of the soil as a result of continuous absorption of similar nutrients from the same soil root zones by the same crop that is not supported with fertilizer application or soil organic matter management (Thornton *et al.*, 1995).

In Ethiopian highlands where about 90% of the arable land is situated, people cultivate their lands with similar types of crops without application of fertilizers until recently (Hurni, 1988). It has be studied continentally that soil nutrient depletion arising from continuous cropping together with removal of crop residues, low external inputs and absence of adequate soil nutrient saving and recycling technologies results to land degradation (Bojo and Cassells, 1995).

The aggregated national scale nutrient imbalances due to continuous cropping were 41 kg ha^{-1} $year^{-1}$ for N, 6 kg for P and 26 kg for K (Stoorvogel and Smaling, 1990). It has long been known that SOM and other soil properties decline rapidly following tropical forest clearance, burning and subsequent cultivation (Nye and Greenland, 1960).

A research done, on the Highlands of Ethiopia by Mulugeta (2004) in the Munessa-shashement forest which is located in the eastern escarpment of the central Ethiopia Rift Vally indicate that, there is soil nutrient depletion as a result of land use change from a forest state to subsequent cultivation of the land, where the depletion was plotted again chronosequence of farm field converted from a tropical Agromontane forest. At the first phase of the land use change that is up to 26 years there was no decline of the organic carbon as well as Nitrogen and different cations, however with long period of field cultivation there happened a decline in the Organic carbon, Nitrogen, available Phosphorous, Exchangeable Potassium, Calcium, Magnesium, etc., (Mulugeta, 2004).

Mulugeta (2004) cited and also explained that volcanic soils (Andosols) are less liable to nutrient depletion when exposed to land use change, hence the soil in the research area is Andosols and the change in degradation was not rapid compared to other areas with different soil types and the change in nutrient depletion is also slower below the 40 cm soil depth; the change is significant mostly in the soil depth of up to 10 cm, since there was a high stock of organic carbon in the lower depths.

The result in Munessa forest can generally explain the Highlands conditions of most Ethiopia, because most cultivable lands in these areas are started by deforestation of existing forest and converting it in to cultivable lands which is called as the land use change. In the same research it was found that the nitrogen removed from the soil by crops is 44 kg ha^{-1} and the nitrogen applied to the field is 35 kg ha^{-1} in the locality (Mulugeta, 2004). Therefore, depletion of nutrient or land degradation by continuous cropping can now be understood when organic management and application of nutrients is lower.

CURRENT SOLUTIONS GIVEN TO RECLAIM SOIL FERTILITY

As a solution to soil fertility problem the Ethiopian Government as a first try to solve the problem in a national level, have forwarded, fertilizer recommendation for the two major macronutrients the nitrogen and phosphorous at a rate of 100 and 50 kg ha^{-1} in the form of urea and DAP, respectively (Abera and Belachew, 2011). However, this recommendation is unable to solve the problem as expected because the soil under each agro-ecologic condition is variable or even the soil conditions in a single farm is variable, so managing such condition under the blanket recommendation is not valuable. Above all the farmer can't afford this blanket recommendation hence about 87% of farmers apply lesser fertilizer rate of 50 kg ha^{-1} urea totally leaving the DAP (Abera and Belachew, 2011) and still the Government is making an effort to have agro-ecology based fertilizer recommendations for some of the major nutrients limiting crop production (Zelleke *et al.*, 2010).

There are also many efforts in the form of researches and various projects to improve the livelihood of the small holder farming community to reverse the fertility of the soil and increase productivity per unit land. This is being under taken by Governmental and Non-governmental organizations; here we want to comment that the results from the best researches and projects should be included in the agriculture policy of the country to come to effect.

SIGNIFICANCE OF INTEGRATED SOIL FERTILITY MANAGEMENT

Integrated soil fertility management refers to a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity (Vanlauwe *et al.*, 2010).

In Ethiopia it is a well known fact that, fertilizer recommendation is based on a National level, forwarded by the government which is known as the blanket recommendation. This recommendation doesn't consider the local condition, regardless of the various researches done under different local conditions, hence it remained partially unsuccessful and it is thought by farmers that increasing yield through fertilizer application is very difficult and unachievable by their capacity (Abera and Belachew, 2011). That is because the green revolution thought by the government of Ethiopia incurs the farmer in to high costs of fertilizers and pesticides, even if a credit facility is provided to the farmer, he/she can't afford the cost as the yield obtained is not balancing it well. Moreover the recommendation doesn't consider the farmers local condition.

Hence, the principle of green revolution in Ethiopia under the blanket recommendation is not successful under most conditions, then more researches has to be done under farmers condition with his own participation in such a manner that the research is able to minimize the different sorts of local problems, by reducing the soil fertility loss and decline in productivity, under what is called the integrated soil fertility management (Abera and Belachew, 2011).

How to apply integrated soil fertility management: It should be applied in a manner that all sorts of soil fertility losses are minimized, such as the soil erosion and nutrient mining from the soil and causes that result for these two major problems.

IFDC-Africa promotes ISFM through a participatory and process-oriented approach that builds on a solid understanding of local settings, indigenous knowledge and scientific expertise and targets at different spatial and temporal scales both technological and institutional change. The complexity of farmer reality requires much emphasis on farmer experimentation and participatory learning and building of partnerships between soil fertility management stakeholders (farmers, credit providers, input dealers, research and extension agencies, government) from village to district to national level (Marco and Maatman, 2002).

In a research done at Gonuno, in Wolayita, in participatory approach with farmers it is identified that the following steps as part of integrated nutrient management can be applied to keep the soil fertile and productive (Amede *et al.*, 2001): (1) Implement physical and biological measures to minimize soil loss caused by water erosion, (2) Analysis of the soil to identify the limiting soil-related factor (nutrients, pH and alike), (3) Increase soil organic matter content by incorporating crop residues and manure into the soil and growing legume cover crops, (4) Improve the water holding capacity of the soil by contour ploughing, minimum tillage and adding organic matter, (5) Increase soil nutrient levels with applications of mineral and organic fertilizers and by growing N-fixing legumes and (6) Use crop rotation, intercropping and relay cropping schemes to minimize losses and enhance fertility, with combinations of deep and shallow-rooted crops and by growing soil enriching species with those that deplete the soil.

Integrated soil fertility management in yield of crops: Under Ethiopian condition particularly in the highlands, integrated soil fertility management can give better yields as high as balanced application of fertilizer and significantly higher yields than the traditional cultivation method other than the integrated methods. For instance in Benishangul Gumuz region a research done on two woredas Agalo meti and Sirba indicates that a combination of few Agronomic management practices like tillage (not local type), application of manure and compost resulted in higher yields of different varieties of maize (Vaje, 2007).

In the study ploughing alone significantly ($p<0.05$) improved the average maize yield in 2002 from 7.9-9.5 t ha^{-1}. Ploughing and adding either manure or compost also resulted in significantly higher yield in 2002 (10.1 and 10.0 t ha^{-1}, $p<0.05$). However, there was no significant difference among the three best treatments (Vaje, 2007).

In Nitisols of South Ethiopia, a study by the Hawassa Agricultural Research centre indicate that using Erythrina bruice as a green manure crop either its biomass alone or in combination with mineral fertilizer is found to increase the yield and yield components of bread wheat (Haile, 2012). *Erythrina bruice* is a nitrogen fixing plant which fix's the nitrogen through its leaves; this tree is endemic to Ethiopia and is a fast growing nutrient rich plant particularly high with nutrient contents on NPK (Haile, 2012).

Combined data analysis of the two seasons revealed that there was a highly significant ($p = 0.0001$) difference among treatments in their effect on grain yield of maize (Haile, 2012) (Table 10). Application of 5 and 10 t ha^{-1} of *E. bruci* biomass significantly increased the grain yield of wheat by 82 and 127% over the control, respectively. Similarly, application of the recommended dose of NP fertilizer ($N_{46}P_{40}$) has significantly increased the grain yield by 145% over the control. There was no statistically significant difference between plots that received sole application of *E. bruci* biomass at 10 t ha^{-1} and recommended dose of fertilizers. However, the highest grain yield was obtained from plots that received combined application of *E. bruci* biomass+inorganic fertilizer applied at 10+$N_{23}P_{20}$, 5+$N_{46}P_{40}$ and 10 ton ha^{-1}+$N_{46}P_{40}$. These treatments increased the grain yield of wheat by 173, 190 and 227% over the control respectively (Haile, 2012).

It is a well known fact that use of green manure increase the yield of crops, however it is not practical by most farmers, for most reasons that most trees provided for this purpose are exotic and the trees are slow growing and research attention is not given in this area, etc. (Haile, 2012). Regardless being a fast growing tree reaching up to 6 m height within 3 months, *E. bruci* has a very important agro-forestry attributes such as, spreading leaves, source of large quantities of swiftly decomposable litters, vigorous re-growth, copious coppicing as well as rapid recovery after a spell of prolonged drought (Teketay, 1994; Negash, 2002).

In Western Hararghe which is situated in Eastern Ethiopia, it is investigated that the major problem for decline in crop productivity is the decline in soil fertility (Bekeko, 2013a). Since to recover the soil to its productive state it is not enough to apply mineral fertilizer alone, therefore integrated nutrient management is considered for the area (Bekeko, 2013b).

The Haramaya University then, in its four years study at Chiro campus (2008-2011) investigated the application of enriched Farm Yard Manure (FYM) in combination with mineral fertilizers can increase the productivity of hybrid maize (BH-140). Based on the study a combination of 4 t ha^{-1} FYM+75 kg N ha^{-1} with 60 kg P ha^{-1} performed best among others, with maize yield of 8.16 t ha^{-1}. It is indicated also that application of 10 t ha^{-1} FYM alone can give as equal yield as 100 kg N ha^{-1} and 100 kg P ha^{-1} together (Bekeko, 2013a). In the area there are a number of districts such as Chiro, Doba, Tullo, Mesela, Gemechis, Kuni, Boke Habro and Daro Labu, where soil productivity is severely constrained by poor soil fertility and poor crop management practices. Yield is too small usually less than 2 t ha^{-1} as compared to a potential yield of over 5 t ha^{-1} in the region (Bekeko, 2013b).

Not only the FYM in combination with mineral fertilizer is important in reversing soil fertility but also the practice of minimum/zero tillage and residue management in combination with mineral fertilizer application is helpful in reversing soil fertility and hence the crop productivity. In a five years study (2000-2004) in western Ethiopia, the use of zero tillage with residue retention on the field (MTRR) is the best practice as compared to zero tillage with residue removal (MTRV) and the Conventional Tillage (CT) (Debele, 2011). In the study three nitrogen fertilizer rates are applied in combination with the tillage systems. The principal rate of nitrogen fertilizer being 92 kg N ha^{-1} and the other two rates are 25% greater than and 25% less than the principal rate. Even if in the first two years there is no difference between MTRR and MTRV both of which are significantly higher than CT, in the next consecutive years the reality is reflected in that the yield of maize in MTRR went superior over the two MTRV and CT this is due to a gradual build-up of soil fertility (Debele, 2011).

The study reflects that the integration of minimum/zero tillage and residue management together with mineral fertilizer gives an advantage over the conventional fertilizer application.

In some semi-arid regions of Ethiopia where there is shortage of soil moisture due to shortage of rainfall the use of tie-ridging at sowing period and application of mineral fertilizer increased the yield sorghum. An experiment conducted in the Aberegalle sub-district in Tigray with split plot design on different tillage practices and fertilizer applications have main plot treatments of *Shilshalo* (traditional ridge without ties) for broadcasted planting (SBP), tied-ridging at planting (TR0WAP), tied-ridging at four weeks after planting (TR4WAP), zero tillage (ZT) and *Shilshalo* for row planting (SRP). Two fertilizer rates of nitrogen (N) and Phosphorus (P) as 0-0 N P ha^{-1} (without fertilizer, F1) and 32-10 kg N P ha^{-1} (with fertilizer, F2) treatments, are the sub-plots (Tesfahunegn, 2012).

The result then indicated that tie-ridging in combination with fertilizer application is the best practice than other tillage practice even with fertilizer applications. The experiment conducted for two years (2002-2003) on two local sorghum varieties *Woitozira* and *Chibal* (*Sorghum bicolor* L. Moench) showed an increase in yield in range of 7-48% for tie-ridging at planting with fertilizer application relative to the other treatments (Tesfahunegn, 2012). The main reason here is that the moisture conservation capability of the tillage practice, since the area is semi arid tie-ridging starting from planting period is more advantageous than tie-ridging after four weak and ridging without tie making.

For an integration to be made there are a number of option even within one category for example, in manure application we can have enriched manure, Farm yard manure, green manure and again taking green manure alone we can have many different options of legume crops that probably match the agro-climate, fast growing ability and easily decomposable. In Agro forestry system we can have alley cropping, hedge cropping, etc; within tillage system we can have zero tillage with residue retention or removal, minimum tillage and the conventional tillage, tie rigging or soil and water conservation measures such as couture cultivation, strip cropping, terracing, etc. organic matter management of the soil, compost application, use of high yielding germplasms; use of mineral fertilizer and a combination of some of this or many of them can help in reversing the decline in fertility of the soil and hence crop productivity, all of which should be done with active participation of the farmer.

CONCLUSION

In Ethiopia the major causes to soil fertility decline are the soil erosion, continuous cultivation and low nutrient application that increase the imbalance of soil nutrients from year to year. In some cases it is observed that the loss of organic matter together with the loss of top soil aggravates the problem of soil water retention resulting in moisture stress rather than nutrient deficiency.

In Ethiopia, the majority of farmers use less amount of fertilizer even to that of National blanket recommendation, because of its high cost; even if farmers are able to afford the cost of fertilizer it will not be sustainable. It is known that as the application of fertilizer proceeds through years the increase in yield of crop start to decrease in the long run, because fertilizer itself degrades the soil by increasing acidity, hence application of lime becomes important in the long run.

It is not successful also because the recommendation does not consider the tangible local conditions which becomes complex for management due to intricate combinations of agro-climate, the soil, topography and the socio-economic condition of various locations. Therefore the blanket recommendation and other fertilizer and pesticide application alone in Ethiopia are not a sufficient solution to the existing problem in the face of the farmer and in the face of reality. The solution should be the one which considers the complex interactions of agro-climate, soil and the topographic environmental condition of the locality.

Integrated soil fertility management then can to some extent consider the various local conditions and can adapt both local and scientific technologies to solve the problem of the site in question. It is important then to analyze the complex interactions and effects of the agro-climate, soil and the environment with the various agronomic practices. Once the interactions and effects are understood, it will be advisable to insert agronomic practices and important inputs which are efficient to the local condition. As the knowledge to the interaction and other technologies increases the efficiency of the agronomic practice will also increase and finally increasing the yield of crops.

Agronomists that intend to do a research should focus on participatory research approach on farmer's field rather than individual researches on off-farm fields, if the objective is to solve the problems of the majority of small holding farmer. For example as erosion is the major cause to soil fertility losses then agronomic practices that can serve as soil conservation practice like conservation tillage, various cropping systems, organic matter application need to be implemented together with integration of other sustainable practices. As discussed above developed countries have critically analysed that intensification of agriculture with chemical fertilizers and pesticides and improved germplasm alone is not sustainable system of production from environment, human health and even from production point of views. So we don't have to go through increased yield by fertilizer and pesticide and finally reverse back to declining yield as a result of soil degradation by chemical fertilizers, such as the soil acidity environmental pollution, etc. Hence, it is better to proceed our way towards the sustainable system of crop and other productions, through the integrated soil fertility management.

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