An Assessment of Soil Fertility Management Issues in Koma and Kareta Watershed, Loma Bosa District, Dawro Zone, Southern, Ethiopia.

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ABSTRACT

Changes in traditional ways of cropping and fertility maintenance have posed a serious threat to the sustainability of soil fertility in the mid hills of Ethiopia. This paper tries to bring to the front different issues directly or indirectly related to the sustainability of soil fertility based on a study carried out in Koma Watershed, Dawro zone in 2018. Data was collected through questionnaire survey and focus group discussion and interpretation made using simple statistical tools and logical discussions. Cultivation of short growing season varieties of crops supplemented with high rates of chemical fertilizers has substantially increased the cropping intensity in rainfed Agriculture in Koma*. Farm yard manure (FYM) is used in higher proportion than chemical fertilizers both in Koma and Kareta. Nonetheless, Koma land gets lower amount of FYM and higher amount of chemical fertilizers compared to Kareta. Farmers are practicing the traditional method of preparing FYM. Erosion in Kareta and sedimentation in Koma lands are the major threats to soil fertility but no adequate prevention and restoration measures are carried out to cope with these threats. Farmers have not only conserved natural forests but also, planted fodder trees in their farmlands. Nearly half of the demand for forest products is met from the private farmland, which has considerably reduced the pressure on nearby forests. Farmers have markedly positive perceptions regarding the fertilizer application, cropping pattern and importance of forests in farming system.*

Key Words: *Chemical fertilizer, Cropping pattern, Farm yard manure, Forest products, Soil erosion*

INTRODUCTION

In Ethiopia, since the beginning of settled agriculture, farmers have traditionally followed integrated soil fertility management practices that were built into the indigenous methods of farm management. Interdependence between crops, livestock, forests, fodder and compost is the key issue in hill farming systems (Temeshgen et al, 2017, Pandey et. al., 1995; Vaidya et. al., 1995). Sustainability of hill farming systems depends on a net transfer of nutrient from the forest to farm fields through fodder and leaf litter to stall-fed animals. The dung produced is mixed with leaf litter to make compost manure which, in the past was the only means available for maintaining an already low level of soil fertility (Mahat, 1987; Hunsen et al, 2017). The decline in forest cover has been associated with increased soil erosion, lowered soil fertility, and reduced agricultural productivity. Farmers have clearly perceived the problems they are facing due to a declining supply of essential forest products from the common forest land and thus reacted to the situation by increasing the quantity of trees on their private land (Khan et al, 2013).

Traditional practice of farm yard manure (FYM) or compost applications was the primary means of maintaining soil fertility in the hills of Ethiopia until the past few decades when chemical fertilizer came into play. Despite being a relatively new practice, the use of chemical fertilizers has increased steadily over the years since their introduction in the early 1970's (Pandey, 1993 cited in Sherchan and Gurung, 1995). Though farmers are apprehensive about the use of chemical fertilizer, they are obliged to apply more and more of it to maintain the crop productivity. Farmers' long experience of managing soils in different areas is expressed by their site dependent use of compost and fertilizers. On Northern Ethiopia with low organic matter and nitrogen content, compost application tends to be increased the contents in the areas. Only a tenth of the composts applied in kareta whereas the rest is used in the lower fertility Koma land (Wymann, 1991). They practice approaches like terracing, bunds, runoff ditches, intercropping, and fertility maintenance for soil conservation (Carver, 1995).

Agriculture is a soil-based industry that extracts nutrients from the soil. Thus, effective approaches to slow the removal and return nutrients to the soil will be required in order to maintain and increase crop productivity and sustain agriculture for the long term (Gruhn et al, 2000). In the highlands of Ethiopia, surface soil erosion and

leaching of the soil nutrients are the main causes of soil fertility degradation. Country's annual population growth rate during the decade 1991- 2011 was been 2.5% (CSA, 2004). Rapidly growing food demand of the country has compelled the farmers to change traditional patterns of natural resource use. Agricultural intensification, conversion of marginal land into agriculture and intensive use of forests have been identified as processes that lead to soil fertility problems in the highlands of Ethiopia (Shah and Schreier, 1995). Hence, the present day challenge is to find ways to meet the needs of a growing population while maintaining the natural resource base, despite the prevailing difficult terrain, fragile mountain ecosystem and land constraints. The objective of, this paper tries to explore various facets related to sustenance of soil fertility. Specifically, it explores the mechanisms of soil fertility loss, existing practices to maintain soil fertility, the role of forest in soil fertility and farmers' perceptions regarding soil fertility issues.

2. MATERIALS AND METHODS

2.1. Study area description

The study was conducted at the Koma and Kareta watershed, which is located in Loma Bossa district of Dawro Zone in the Southern Nations and Nationality Regional State (SNNPRS). It is located between 6°57′0″N–6°59′30″N latitude and 37°11′0″E–37°17′0″E longitude, with an altitude ranging from 1279 to 1561 meters above sea level. It is at about 365km from Hawassa city in the southern direction and at about 546km southwest of Addis Ababa by the Shashemene to Wolita road. They were out of the 108 watersheds in Loma district and covered 937ha out of the total area of 117,043ha in the district. The area is marked by 15.9% gentle slope, 43.4% moderate slope, 26.5% moderately steep slope, 10.5% steep slope, and 3.7% mountainous terrain (Loma agriculture office, 2018). About 54% of total area in the watershed was managed under different conservation practices.

Its total area is about 937ha covering most of the parts of Gumar Kocho, olo woyde and Lala Ambe,Deneba Bola Village Development Committee (VDC). There are 16 settlements with altogether 592 households. Koma and Kareta is the main stream in the watersheds, which flows from south to north and drains into the Gibe-3 River. The watershed area consists of moderately steep to very steep slopes. Moderately steep slopes are almost completely cultivated by the farmers while very steep slopes are mainly covered by natural forests.

2.2. Data Collection and Analysis

For gathering data regarding farming practices, land degradation, forest products consumption and farmer's perception, the entire population residing in the watershed constituted the sample population and each household was considered as a unit for sampling. The sample size was determined using the Cochran's Formula (Cochran, 1977).

$$n = \frac{Nt2pq}{Nd2 + t2pq}$$

Where, n = Sample Size, N = Total Household Numbers, t = Abscissa of the normal curve, p = Proportion of sample of population estimated, q = 1 – p, d = Margin of error Fifty out of the total 592 households were selected for the semi-structured interview at 95 percent confidence level with 96 percent expected rate of occurrence at a reliability of ±5 percent. Group discussions with local people including elderly people, women and disadvantaged people were carried out to get more information on the subject. Simple statistical tools like mean and percentage have been used to analyze and interpret the numeric information obtained while the descriptive information has been logically interpreted. Farmers' perception which was obtained in the Likert Scale is analyzed using Index of Perceived Agreement (IPA). IPA has been calculated by the weighted average of all the responses and their respective frequencies and brought it to a single figure in between 0 and 1.

IPA = Strongly Disagree (0.10) + Disagree (0.33) + Don't Know (0.55) + Agree (0.77) + Strongly Agree (1.0)

Interpretation is then made by classifying the obtained IPA values into five different classes namely; strongly agree, agree, neutral, disagree and strongly disagree.

3. RESULTS AND DISCUSSION

3.1. Soil Fertility Loss

3.1.1. Intensive Cropping Pattern

Cropping patterns and intensities differed according to land use type. In Kareta irrigated land four different cropping patterns are being practiced commonly. If possible, people always prefer to grow two crops of paddy in a single year, if not, they go for an alternate crop like maize, haricot bean or winter vegetables instead of a second crop of paddy. Gradually people are getting attracted towards growing winter vegetables in the Kareta land. In the non-irrigated Koma land, however, the general phenomenon is to raise a single crop of paddy each year. In the Koma land, major crop raised is maize. Either haricot bean or vegetables or both are grown to complete a year of rotation along with maize. In the Koma land, sometimes people also practice mixed cropping, especially maize and the beans. The cropping patterns observed in this study in Kareta and Koma were similar to those reported by Kebede Wolqa, (2011).

Despite being a relatively new practice, vegetable farming is rapidly becoming popular in the watershed area. Easy access to the road head is presumed to be the key reason behind the successful adoption of vegetable farming. Altogether 86% of households are involved in either summer or winter vegetable farming. Winter vegetables are mostly grown in the Kareta land where irrigation is available. In the Koma land, the vegetables are mostly grown in the summer season. Generally, people with irrigated Kareta land grow vegetables to a larger extent. Both the Kareta and Koma lands are left fallow for about four months in a year during the winter season, unless there is irrigation availability. The irrigated lands, however, are cultivated almost throughout the year. Introduction of short growing season crop varieties and chemical fertilizer have boosted the agricultural intensification.

3.1.2. Soil Erosion

Soil erosion in the watershed is one of the major problems associated with the soil fertility decline, especially in the upland. Local peoples' responses confirm this statement. Ninety-four percent of households reported the presence of one or the other type of erosion in two watershed lands. Incidences of sheet erosion and rill erosion were reported by 84% and 78% of the households, respectively. Twenty-two and sixteen percent of households reported the problem of gully formation in the Koma and Kareta land respectively. The problem of gully is severe along the foot trails. Riser and bund failure during heavy rainfall is another common and serious scenario in the both Koma and Kareta land. The sloppy terrain itself and the practice of intensive cultivation in higher slope classes have a combined effect to wash away the top soil from the Koma land every year during the summer greater than Kareta.

Although to a lesser degree compared to Koma land, the problem of soil erosion in the Kareta land also exists. River cutting, flooding and sedimentation are frequent in Kareta during rainy season. Sedimentation and flooding are problems associated only with Kareta land with 36% respondents reporting the occurrence of sedimentation and 48% of them presenting incidences of flooding in the Kareta. Four percent even reported incidences of landslide in the Kareta land. The results depict that there exists a serious problem of soil erosion in both Koma and Kareta land. Selassie et al,(2014) have also elaborated almost similar sort of results from the highlands of the country, where 53% respondents reported that Koma land is more prone to erosion while 12% reported the same for the Kareta land as well.

3.2. Soil Fertility Maintenance

3.2.1. FYM and Chemical Fertilizers

Application of FYM in the farm lands is a traditional practice of maintaining soil fertility. Since, almost all households in the area raise livestock they have no problem in applying FYM in their farmland. In fact, every household applies FYM to their lands in the same rate as it is produced. Very few cases were identified when people have actually purchased the FYM from others. Farmers were not found to practice improved techniques for the FYM preparation. Dumping of FYM in open spaces and exposing it to sun, wind and rain in the field for several days before ploughing results in loss of considerable amounts of soil nutrients in it through volatilization and leaching (bewket and Teferi, 2009).

Since the introduction of chemical fertilizers in the area nearly 20 years ago, after the plan of Agriculture leaded industry polices, use of chemical fertilizers has been increasing in Ethiopia. At present, almost all households use chemical fertilizers in most of the major crops. As suggested by ATA,(2014), lower altitude, easy accessibility, and proximity to the market are the likely reasons behind such a high use of chemical fertilizers in the area. Major fertilizer types being used are urea, ammonium sulphate, Diammonium phosphate (DAP) and potash. Farmers apply huge amount of fertilizer, especially urea for paddy crops. Rates of application of FYM and chemical fertilizers in Kareta and Koma land are presented in (Table 1). By volume, rate of FYM application is much higher than that of chemical fertilizers in both Kareta and Koma land. Ratio of chemical fertilizer to FYM is 1:2.5 in Kareta while it is 1:11 in Koma land. FYM application rate is higher in Koma (22.1 tons/ha/yr) than in Kareta (16.7 tons/ha/yr). But application rate of either type of chemical fertilizer is approximately three times more in Kareta than in Koma.

DAP (Kg/ha/yr) 120.0, 44.8, 40.0, 12.8 Use of Crop Residues People in the study area are found to use crop residues in a variety of ways. Thirty-nine percent of the crop residues are used to feed the livestock, 31 % is used for fuel, 16% is burnt on lands, and remaining 12% is incorporated in the soil without burning. Crop residues incorporated in the soil are considered to be of great nutrient value. Incorporating the crop residues in the soil while preparing the land directly increase fertility of the soil by returning back the soil elements which are being drawn from the soil by plants. Burning of crop residues in the soil can decrease nitrogen supply in a short-term but it can also create favorable condition for nitrogen fixation by microbes. Use of larger portion of crop residues as feed and fuel is actually lowering the demand for forest products like fodder and fuel wood. Thus, local people are making proper use of crop residues by helping in soil fertility maintenance and in offsetting the demand for forest products. Land management practices like terracing, construction of small diversion channels, and scrapping of terrace risers are common in the Koma and Kareta watershed. Terracing, run-off ditches, intercropping and fertility maintenance are the primary approaches of on-field methods to prevent upland erosion in the highland of Ethiopia (Temesgen et al, 2017). Slope is controlled and manipulated through the construction of terraces. Koma land in the area is either outward terraced or without any terraces. Despite the problem of soil erosion, outward-facing terraces are constructed by the farmers to avoid water logging, for easy ploughing and lesser labor requirement (Kebede et al,2011). Kareta lands are given good care by the people from the view of terracing as compared to Bari lands. This indicates inadequate land management precautions on sloping terrain in order to check the runoff velocity.

In few cases, farmers have constructed small diversion channels to cut off rainwater from the Koma lands. In the terraced land, particularly in Kareta, scrapping of terrace risers is generally carried out before raising of crops. Farmers' believe that it helps not only in the addition of organic content into the soil but also in maintaining risers and bunds. Without further investigation, however, it would be premature to say whether this practice helps to maintain the riser or degrades its strength. Some restorative measures are being carried out for the damage made by the riser and bund failures in the Koma land and riverside cutting in the Kareta land. Damaged terraces are repaired by cutting and leveling process. In few incidences, river cutting is rehabilitated by building stone walls and embankments.

3.3. Contribution of forest products

Amongst the forest products being collected regularly, demand for fodder takes first place. Demand for timber is not included here because it is not collected regularly. All the households are involved in collecting fodder from their own farmlands and nearby forests. Average annual demand for fodder per household is 26.06 tons (Table 2). Forty-eight percent of the fodder requirement is met from the farmland while remaining is fulfilled from the forest land. Ninety-four percent of the total households collect bedding materials from the forests and farm lands. On an average, each household requires 2.99 tons of bedding materials per year. Seventy-eight percent of the total requirement of the bedding material is met from the forest land and the remaining portion is fulfilled from the farm land (Table 2). Twenty-six percent of the households do collect the leaf litter also. Annual requirement of leaf litter per household is 1.22 tons, out of which, 84.36% comes from forests and the remaining from farm lands.

The findings indicated in (table 2) show that there is an enormous and constant flow of forest products from forest lands to the farming system in the form of fodder, leaf litter and bedding material. These products are ultimately mixed up into the soils in order to enhance its productivity. This is why forest has been considered as an integral part of the farming system and therefore, it would not be otherwise to affirm that sustainability of the farming system depends on the continuous supply of these products. Forest plays a significant role in the hill farming systems, particularly for animal husbandry (Selassie et al, 2014). Farmers have protected the natural

trees in the farm land and even planted several types of fodder trees. It is a positive sign since it will help in relieving the pressure on the forest to a certain degree.

3.4. Farmer's Perception on soil fertility

Chemical Fertilizer, FYM and Soil Fertility The statement "use of chemical fertilizer degrades the soil physical quality" got an index (IPA) of 0.73 which shows that farmers are fairly sure that the chemical fertilizers ultimately lead to soil physical property deterioration (Table 3). They have also realized that the response of crops to the use of chemical fertilizers is decreasing and that they have to apply more and more of the fertilizers every year. In the Ethiopia south western region, people are apprehensive about the use of chemical fertilizer as they believe that these cause soil compaction, which hinders other farming operations. Even then, they prefer to use chemical fertilizers due to easy availability and immediate positive result of chemical fertilizers, thereby eliminating the labor intensive cattle raising practice (Selassie et al, 2014). In contrast, people are very much positive about the use of FYM in their farmlands. The statement "the combination of chemical fertilizers and organic manure (FYM) helps to maintain nutrient balance in the farm lands" was strongly agreed upon by the farmers allotting it an index of 0.82.

Cropping Pattern and Soil Fertility Farmers' perception is neutral (index of 0.46) for the statement "soils are exhausted due to shortening of fallow periods" (Table 3). They seem confused regarding the effect of fallow periods on soil fertility. People expressed positive perceptions towards mulching practices when linked to soil fertility. The statement "the positive role of mulching in soil fertility" got an index of 0.71. Despite the positive perceptions mulching practice is being adopted very rarely in the watershed. People have a fairly positive perception on the effects of burning of crop residues in the soil fertility which shows that they would prefer to burn the crop residues rather than to incorporate it into the soil without burning.

3.5. Forest, Soil Erosion and Soil Fertility relationship

People bear a strong positive perception towards forests and its importance in farming system. The statement "rapid depletion of forests results in soil erosion and flooding" got an index value of 0.85 (Table 3). High level of awareness and good knowledge among the people regarding the multiple benefits of forest is also evident from the involvement of large number of households in planting trees on their farmlands. People are quite positive about the construction of terraces in the farm lands. The statement "role of terraces in the maintenance of soil fertility by checking soil erosion" got a high index of 0.83 while "role of top soil in production and the impact of soil erosion on top soil" got very high index of 0.95. This means that people are well aware of the importance of top soil and at the same time are aware that the runoff washes away the fertile top soil from their lands.

4. CONCLUSION AND RECOMMENDATION

Cropping intensity has increased substantially over the last few decades due to the availability of chemical fertilizers, fast growing crops varieties and irrigation facility. Winter vegetable farming in the irrigated Kareta land is getting momentum over the recent years which have further increased the application rate of chemical fertilizers. Almost every household applies both FYM and chemical fertilizers in farm lands. Ratio of FYM application is higher than that of chemical fertilizers. Yet, the gap is closer in Kareta where FYM is used in lower rate and chemical fertilizers are used in higher rate compared to Bari. Process of FYM preparation is the same which has been inherited from the age old practice. FYM quality can be increased by better decomposition and the N-content can be increased by at least 2 to 3 times from about 0.5% N to 1.5% through proper management of urine and manure (SSMP, 2002).

Sheet erosion and rill erosion are very common in Koma land while sedimentation and flooding are the problems in Kareta land, especially during the summer. Farmers are aware about the problem, however, sufficient measures have not been taken to prevent and restore the land. Soil amendments are necessary to ameliorate the overall physical and chemical conditions in degraded sites. The combination of N-fixing fodder trees, lime application and nitrogen fixing crops appears to be an appropriate recipe for low input reclamation (Shah et al. 1995).

There is a high demand for the forest products like fodder, bedding materials and leaf litter which are ultimately acting as the inputs to the soil fertility through FYM. Less than 50 percent of the total requirement is supplied from the private farm land and people have to depend on forest for the rest demand. It means that a significant proportion of the forest product requirement is met from the farm land thereby offsetting the pressure on the

nearby forests. Growing trees on private farm land should still be emphasized, thereby, bringing the dependence upon the nearby forests to a minimum. Farmers are apprehensive about the use of chemical fertilizer while they are positive about the application of FYM. They have positive perception regarding effects of most of the beneficial cropping patterns. Nevertheless, they are indifferent about effects of fallowing in soil fertility. They have strong belief regarding the importance of forests and terracing practices in soil conservation. They need to gain confidence about the impacts of different cropping patterns and conservation practices than at present and will require further support from the development partners and facilitators.

COMPETING INTEREST

The authors declare that they have no competing of interest regarding publication of this paper.

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TABLES

Table 1. Average (Mean) Application Rate of Farm Yard Manure (FYM) and Chemical Fertilizers Type of Fertilizer Kareta and Koma

Type of Fertilizer	**Kareta**		**Koma**	
	Mean	Standard Deviation	Mean	Standard Deviation
FYM (Ton/ha/yr)	16.7	5.2	22.1	7.0
Urea (Kg/ha/yr)	400.0	135.5	123.3	49.9
Ammonium Sulphate (Kg/ha/yr)	140.0	39.6	40.0	11.4
DAP (Kg/ha/yr)	120.0	44.8	40.0	12.8

Table 2: Contribution of forest products and total demand of products in tons for % of household

Forest Products	Household percentage	Total Demand of products (tons)	Supply of products (tons)	
			From Farmland	From Forest
Leaf Litter Bedding	26	1.22	0.23 (15.6)	0.99 (84.4)
materials	94	2.99	0.67 (22.4)	2.32 (77.6)
Fodder	100	26.06	11.94 (47.6)	14.12 (52.4)

Note: FiguTablere in the parenthesis indicates the percentage of the total demand

Table 3. Index of Perceived Agreement (IPA) of the Statements Related to Soil Fertility Issues

Statements	**IPA**	**Overall Response**
Use of chemical fertilizer degrades soil physical quality	0.73	Agree
A combination of chemical fertilizer and organic manure helps to maintain nutrient balance	0.82	Strongly Agree
Mulching helps to maintain soil fertility	0.71	Agree
Burning of crop residues increases soil fertility	0.65	Agree
Soils are exhausted due to shortening of fallow periods	0.46	Neutral
Rapid depletion of forest resources results in soil erosion and flooding	0.73	Agree
Top soils are essential for production, but they are removed by soil erosion	0.95	Strongly Agree
Terraces helps to maintain soil fertility	0.83	Strongly Agree