

Integrated Nutrient Management for Enhancing and Sustaining Soil Fertility and Crop Productivity in Ethiopia

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Abstract

Agriculture remains the mainstay of Ethiopia's economy. It contributes a large share of the national products growth. Despite the importance of this sector, soil fertility depletion and soil quality decline have been threatening the ecological and economic sustainability of crop production. In order to improve soil fertility, soil nutrient have been replenished through organic input, chemical application, or combination of both sources. The objective of this paper was to review effect of integrated nutrient management in improving soil fertility and productivity of major crops in Ethiopian context. Soil fertility management practices such as animal manure, crop residues, crop rotation, mineral fertilizer, compost etc to cope with declining soil fertility, which differ among farmers and among locations. Therefore, the use of integrated soil fertility management strategy with inclusion and combination of chemical fertilizer, organic input and using improved crop varieties 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, this is wise and needed to be followed.

Keywords: Integrated nutrient management, Crop production, Soil fertility.

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Introduction

Agriculture is the basis of most of the population and major driver of the national economy in Ethiopia. It accounts about 42 percent of the GDP, about 85 percent of employment and 90 percent of the total export earnings of the country (CSA, 2016). Increasing agricultural productivity is necessary to feed the increasing population by increasing land productivity (Tareke and Nigusse, 2008). One of the central challenges to achieving food security and poverty reduction in Ethiopia is low agricultural productivity as a result of soil fertility decline. Because soil fertility is one of the biggest challenges, an obvious strategy is to increase fertilizer application and promote good agronomic practices to enhance productivity. As a result, national annual fertilizer use grew from 3,500 t to about 140,000 t by the early 1990s, and reached about 200,000, 400,000, 550,000 t in 1994, 2005, and 2010, respectively. The total amount of fertilizer available for application will exceed one million tons in the 2012/13 cropping year (Tefera *et al.*, 2012).

Soil fertility loss is caused by many factors such as entire crop harvest from the field, severe erosion, low soil organic matter content, limited fertilizer input and inappropriate land management (Getachew *et al.*, 2016). Application of chemical fertilizers did not get attention because there is a broad recognition that soil fertility decline is a major production constraint in the country (Amede, 2006). In addition, soil acidity that induce phosphorus fixation and aluminum toxicity are the main constraints of Ethiopian high land soils (Getachew *et al.*, 2006). This is particularly apparent in soils with pH less than 5.5, the effect being attributed mainly to nutrient deficiency and toxicity. In these soils, plants unable to obtain phosphate due to fixation except enough is applied (Marschner, 2011). Soil organic carbon decline is another constraint that diminish crop production in the country. Amede *et al.*, (2002) showed that nutrient availability, soil water content, nutrient cycling and nutrient stock improved by addition of organic materials.

However, the use of dung as fuel instead of fertilizer is estimated to reduce Ethiopia's agricultural gross domestic product by 7% (Gebreegziabher, 2007), which calls for introducing alternative energy sources into the rural systems. There is also strong competition for crop residue between soil fertility, animal feed and cooking fuel, and little is remaining to the soil. Although legumes are known to add N and improve soil fertility, the frequency of legumes in the cropping system in Ethiopian highlands is less than 10% (Getachew *et al.*, 2014), which implies that the probability of growing legume on the same land is only once in ten years. Studies suggested that future strategies for increasing crop productivity should focus on agricultural intensification through increased use of external inputs and managing the available nutrient resources more efficiently and in a sustainable way (Gruhn *et al.*, 2000; Tilman *et al.*, 2002).

The recent paradigm shift in soil fertility management intervention indicates that integrated soil fertility management is one of the eco-friendly, cost effective and adaptive soil fertility management techniques that enable smallholder farmers to overcome the many limitations of the various soil fertility management techniques (Vanlauwe *et al.*, 2015). Integrated use of various soil fertility amendment inputs aims at alleviating the limiting

nutrients problem and improving their availability through interactions with the mineral soil and reducing the P sorption capacity of the soil (Sanchez, 2002). However, due to the continuous decrease in organic matter and nutrient content of the soil, the importance of integrated nutrient management for efficient utilization of nutrient and long-term maintenance of soil fertility has been required (Haileselassie, 2005).

Combining different farming systems and agronomic practice can help address the problems of soil fertility decline instead of concentrating on chemical fertilizer alone, integrating different practices which are acceptable and minimize the expenditure of poor farmers like green manure, crop rotation, intercropping, compost in combining with mineral fertilizers and improved varieties. Therefore, the Objectives of this paper is to review the effect of integrated nutrient management in improving soil fertility and productivity of major crops in Ethiopian context.

Soil Nutrient flows and Balance in Ethiopia

Soil nutrient availability changes over time. A nutrient balance for a system consists of the sum of nutrient inputs minus the sum of nutrient outputs. This system always represents a particular spatial scale, and it can range from a small soil aggregate to the country level. Various studies on soil nutrient flows and balance has been conducted at different time and location in Ethiopia. Study conducted by Stoorvogel and Smaling (1990) revealed that annual nutrient mining in Ethiopia was -41 kg N, -6 kg P and -26 kg K ha⁻¹yr⁻¹. Nutrient balance studied by FAO (2003) based on specific land/water classes showed that the nutrient depletion rate of Ethiopia at national level was -47N, -7P and -32 K kg ha⁻¹. These were about twice as much as the average depletion rates for Sub Saharan Africa -22 kg N, -2.5 kg P and -15 kg K ha⁻¹ yr⁻¹ (Stoorvogel and Smaling, 1990) and indicates the magnitude of soil nutrient depletion in Ethiopia.

In the highlands of Ethiopia, Nutrient balance as assessment conducted by van Beek *et al.*, (2016) showed that the high potential areas for agricultural productions are currently exposed to severe nutrient depletion. Studies on nutrient flow in the Central highlands of Ethiopia revealed that the nutrient balance in different soil fertility classes varied from -20 to -185 kg N, from +11 to -83 kg P and from +23 to -245 kg K ha⁻¹ yr⁻¹ (Balesh, 2005), and the average annual soil loss from agricultural land is estimated to be 137 tons ha⁻¹ yr⁻¹, which is approximately an annual soil depth loss of 10 mm (Gete *et al.*, 2010). These indicate that major nutrients outflow far exceeds inflows in a range of soil types which results negative nutrient balances. The same finding reported by Gedefa (2018) also indicated that the nutrient depletion of -7 to -10 kg N, 1.5 to -0.1 kg P and -12 to -19 kg K ha⁻¹ yr⁻¹ and were observed under different classes of land units.

Major Cause of Soil Nutrient Decline

Soil fertility depletion occurs when conditions that support soil's health are not maintained and the components which contribute to fertility are removed and not replaced. In agriculture, soil fertility depletion can be occurred due to excessively intense cultivation with inadequate soil management (Ethiosis, 2015). The main causes of soil fertility decline include nutrient removal through entire crop harvests, uncontrolled soil erosion, low soil organic matter and inherent soil fertility, limited application of appropriate types of fertilizers and inappropriate land management practices (Getachew *et al.*, 2016).

The severity of the problem is partly attributed to topographic and climatic variables (Wood, 1993). But it has been severely intensified by anthropogenic factors, such as land use/land cover change, overgrazing, over cultivation, farming of fragile steep slopes and inappropriate soil management practices (Adugnaw, 2014). According to Taye and Yifru (2010) report, soil degradation and nutrient depletion due to inadequate soil management have gradually increased and become serious threats to agricultural productivity in Ethiopia due to the strong association that exists between land use and soil properties, land use change from natural ecosystem to agricultural landscape is one of the major human induced factors that threatens soil nutrient in Ethiopia (Woldeamlak, 2003; Tsehaye & Mohammed, 2013). Continuous cropping and inadequate replacement of nutrients removed in crop harvest or lose through erosion and leaching has been the major causes of soil fertility decline (Adamu, 2013; Hilette *et al.*, 2015). This is particularly evident in the intensively cultivated high-potential areas that are mainly concentrated in the highlands of Ethiopia (Hilette *et al.*, 2015).

Soil Fertility Management Approaches

In Ethiopia, several efforts were made to improve soil fertility and agricultural productivity under the framework of national economic development strategy of the country, known as Agriculture Development Led Industrialization, that has been underway since the mid-1990s (Kassa, 2003). The Participatory Demonstration and Training Extension System (PADETS) and the National Agricultural Extension Intervention (NAEI) programs are major examples of this (Spielman *et al.*, 2011). These programs mainly aimed to improve chemical fertilizer supply and extension services to smallholder farmers in order to promote agricultural production and productivity (Kassa, 2003).

However, in the country farmers often do not apply adequate amounts of fertilizers. Not only is the fertilizer

dose but its management is very important for increasing the productivity and fertilizer use efficiency (Amare and Adane, 2015). It is important to keep soil characteristics in mind when establishing a fertility management plan.

Many researchers reviewed that the soil is heavily degraded and it would thus take centuries to recover (Mulugeta, 2005; Wassie, 2016). But according to evidences suggested by Aseffa, (2005), smallholder farmers are maximizing returns from their limited land and capital, minimize production risks, diversify sources of income, provide food, and increase productivity. This is because Ethiopian farmers are endowed with diverse systems of soil fertility improvement suited to the various agro-ecologies of the country and sustain family livelihood. The longer years of this mixed farming goes side by side with local soil fertility management practices (Aseffa, 2005; Hagos *et al.*, 1999) such as animal manure, crop residues, crop rotation, mineral fertilizer, compost etc to cope with declining soil fertility, which differ among farmers and among locations (Elias, 2002).

Application of Mineral Fertilizers

Inorganic fertilizers are very important in the cultivation of crops and are increasingly used. This increase is due to shortage of animal manures and residues and the increasing knowledge of their value. Inorganic fertilizers will remain a key component of soil nutrient replenishment and an essential element of any agricultural development strategy or plan to increase food production. In Ethiopia, demonstrations about fertilizer effects on major cereal crops started in the 1960s through programs such as the Freedom from Hunger Campaign. The results from these programs showed the positive benefits of fertilizer addition, and most of the focus was on N and P. Despite the recognition for the need to increase fertilizer use in Ethiopia, fertilizer consumption was still below 20 kg ha⁻¹ (Yirga and Hassan, 2013), which is related to several factors such as education, access to credit, and livestock ownership (Yirga and Hassan, 2013) and also poor marketing and inadequate profitability from inorganic fertilizer use is another factor (Birhan, 2012).

A survey conducted in the Central Highlands of Ethiopia showed that fertilizer use was low but more fertilizer was used in the wheat/ teff cropping systems in the Mid - Highlands compared to the Upper Highlands (Yirga and Hassan, 2013). Only 30 to 40% of Ethiopian smallholder farmers use fertilizer, and those that do only apply 37 to 40 kg on average per hectare, which is significantly below the recommended rates (MoA, 2012).

N and P are the major elements widely used in Ethiopia and positively affecting crop yield and yield parameters. Numerous authors conducted research on influence of environment on variety, timing, doses, and types of fertilizer applications have been reported to have effects on durum wheat grain yield as well as grain quality (Leta *et al.*, 2007). Increasing levels of N and P application and their interaction significantly and positively affected grain yield and concentration of N and P in the plant (Birtukan, 2016). An experiment conducted at Sinana district on farmer's field revealed positive effects of different nitrogen fertilizer rates (0, 23, 46 and 69 kg ha⁻¹) on crop phenology, yield and yield related traits, nitrogen uptake parameters and grain protein content of durum wheat. The result showed that nitrogen rates had significant effect on yield, yield related traits, nitrogen uptake parameters and protein content (Elias, 2002).

Even though, NPK are the three major nutrients required by crops in large quantities for normal growth and development, K fertilizer is rarely available in the Ethiopian fertilizer market. This is because of the historical generalization that Ethiopian soils are believed to contain enough K (Murphy, 1968). Recent studies in Ethiopia showed positive crop responses to potassium application. Haile *et al.*, (2009) reported significant increases of potato yield following application of K fertilizer on acidic soils of Chench, southern Ethiopia. The authors also showed that increasing the rate of K application to 150 kg ha⁻¹ increased tuber yield from 15 t ha⁻¹ in the control (no application) to 57.2 t ha⁻¹. Results from field trials in Ethiopian soils showed positive crop responses to K application. For example, coffee yield increased from 1038 kg ha⁻¹ in the control without K to 1311 kg ha⁻¹ when K was applied at 62 kg ha⁻¹ in Jimma (Melke and Itana, 2015).

Amendment of Organic Source

Organic fertilizers contribute directly to the accumulation of soil organic matter (SOM) and providing vital plant nutrients for plant, could hold water and serve as storage for dry season and especially supportive for sandy soils which contain nutrients in a small amount and they are also important for soil organisms. The addition of organic amendments such as animal dung, green manures and crop residues could maintain or enhance soil quality, improve the nutrient pool and enhance crop productivity (Bationo *et al.*, 2007). It also plays a key role in nutrient availability and nutrient recycling by adding nutrients to the soil, influencing mineralization-immobilization patterns, serving as an energy source for microbial activities and as precursors to soil organic matter, reducing the P absorption of the soil, and reducing leaching of nutrients and making them available to crops over a longer period of time (Amede *et al.*, 2002).

Compared with inorganic fertilizers nutrients are released slowly from organic resources and provide a continuous supply of nutrients over the cropping season (Mark *et al.*, 2007). The major Organic inputs used in Ethiopia for soil fertility management includes livestock manures, crop residues, organic refuse from household, compost, green manures and any plant biomass harvested from the farm environment (Amelework,

2017). Application of organic amendments in the form of farm/home yard manure and green manure or these processed in the form of compost have always been used by Ethiopian smallholder farmers to enhance fertility and soil physical properties (Edward, 2005). However, the use of dung as a fuel instead of as a fertilizer has reduced Ethiopia's agricultural GDP by 7% (Zenebe, 2007). According to the author there is also strong competition for crop residues for use as animal feed and cooking fuel and little is remaining for the soil. Organic fertilizers were regarded as important, but it was realized that organic fertilizers would not be available in sufficient amounts and cannot meet nutrient required by crops to increase food production.

The most common strategy for coping soil infertility problem is the use of inorganic fertilizer (N and P) available in the market. But this strategy is highly constrained by high cost, low purchasing power of smallholders and limited access to credit, and environmental problems. Thus, a strategy that also considers the available resources like organic resources (green manure) needs to be developed. In view of the current worldwide shortage of chemical fertilizers and its anticipated adverse effect on food production, the endeavor to discover and develop efficient techniques of utilizing organic materials or their combination as fertilizer is urgently needed (Timsina, 2018).

Use of Bio-fertilizer

Integration of multipurpose N-fixing legumes into farming systems commonly improves soil fertility and agricultural productivity through symbiotic associations between leguminous crops and *Rhizobium*. However, the contribution of N-fixation to soil fertility varies with the types of legumes grown, the characteristics of the soils, and the availability of key micronutrients in soil to facilitate fixation and the frequency of growing legumes in the cropping system (Giller, 2001). Although perennial legumes are known to fix more N than annual legumes (Amede *et al.*, 2002), the most prominent ones contributing to the N enrichment of soils in Ethiopia are annual legumes, including faba beans, peas, and chick peas.

Some food legumes (e.g. *Phaseolus vulgaris*) are known to fix N below their own N demands and may not contribute much to replenish the soil with additional nutrients. On the other hand, perennial legumes, including those refereed as legume cover crops, could produce up to 10 t ha⁻¹ dry matter and fix up to 120 kg N ha⁻¹ per season (Amede *et al.*, 2002).

Research results from Kulumsa research station in Ethiopia also indicated that wheat grain yield was enhanced by dicot-rotations compared to cereal rotations (Gorfu and Feyisa, 2006). Results of a long-term experiment indicated that faba bean as a precursor crop increased mean grain yield of wheat by 660 -1210 kg ha⁻¹ at Kulumsa and 350 - 970 kg ha⁻¹ at Asassa compared to continuous wheat. The highest wheat grain yield was recorded after faba bean in two-course rotation and in first wheat after faba bean in three-course rotation. From economic point of view, a three-course rotation with either faba bean or rapeseed was found as an appropriate cropping sequence in a wheat-based cropping system. Moreover, a study at Holetta showed that incorporation of vetch in the crop rotation significantly increased wheat grain yield after vetch by 98-202% compared to wheat after wheat (Woldeab, 1990). The efficiency of applied NP fertilizer was also enhanced in the field rotated with vetch. In an experiment conducted to determine N₂ fixation in three sites in Arsi highlands, the amount of N fixed by faba bean ranged from 139-210 kg ha⁻¹ (Gorfu *et al.*, 2000). This, in turn, resulted in substantial mean soil N balance that ranged from 12 - 58 kg N ha⁻¹ after the seed had been removed but all faba bean residues were incorporated in the soil.

Integrated Soil Nutrient Management

Integrated soil fertility management refers to a set of soil fertility management practices that necessarily include the use of chemical fertilizer, organic inputs, and improved crop varieties 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.

The basic concept underlying integrated nutrient management is the maintenance or adjustment of soil fertility/productivity and of optimal plant nutrient supply for sustaining the desired level of crop productivity (FAO, 1995). The objective is to accomplish this through optimization of the benefits from all possible sources of plant nutrients, including locally available ones, in an integrated manner while ensuring environmental quality. This provides a system of crop nutrition in which plant nutrient needs are met through a pre-planned integrated use of mineral fertilizers; organic manures/fertilizers e.g., green manures, recyclable wastes, crop residues, and FYM; and biofertilizers. The appropriate combination of different sources of nutrients varies according to the system of land use and the ecological, social, and economic conditions at the local level (Roy *et al.* 2006). The combined addition of organic and mineral fertilizers, which forms the basis of integrated soil fertility management (ISFM), can improve crop yields and soil fertility (Vanlauwe *et al.*, 2001).

Effect of Integrated Nutrient Application in Improving Soil Fertility and Crop Yield

Soil management practices for sustainable use can be best practiced through the adoption of an ISFM practice. "ISFM is an integrated approach that seeks to enhance agricultural productivity and improve ecosystem services

for sustainable future use through combined application of soil fertility management practices, and the knowledge to adapt these to local conditions to maximize fertilizer and water use efficiency” (Sanginga and Woome, 2009).

Integrated soil fertility management plays a critical role in both short-term nutrient availability and longer-term maintenance of soil organic matter and sustainability of crop productivity in most smallholder farming systems in the tropics. Under Ethiopian conditions, particularly in the high land conditions, integrated soil nutrient management can give better yield as high as balanced application of fertilizers and significantly higher yields than traditional cultivation methods. The two-year study result reported by Getachew (2014) in central high lands of the country showed that the integrated application of compost or manure with half the recommended NP fertilizer rate resulted in a comparable yield of wheat and tef as that of full NP dose, which could be considered as an alternative option for sustainable soil health and crop productivity. Some review indicated that the use of integrated soil nutrient management with inclusion and combination of different organic fertilizers such as manure, compost, crop rotation, soil conservation practice such as minimum tillage, tied ridging residue management and other practices together with chemical fertilizers and improved germplasm increase crop yield and maintain the fertility of the soil (Belay ,2015).

Various experiments have been conducted to evaluate crop response to the applications of organic and inorganic nutrient sources in different parts of the country. Positive interactions between both inputs have often been observed and they are needed in the long term to sustain soil fertility and crop production (Getachew *et al.*, 2016). According to MoA *et al.*, (2019) report application of inorganic fertilizers together with organic manures were increased the total N content of soil than when used individually. The integration of the two sources not only increases the nutrient content of soils, but also improves general condition of soils (Girma and Zeleke ,2017).

Different study been conducted under different soils conditions. Application of green manure in combination with mineral fertilizer under Nitisols of South region of the country showed optimum yield and yield components of bread wheat (Haile, 2012). Edom *et al.*, (2017) obtained maximum yield and yield components of the same crop under vertisol condition by applying phosphorus and compost. Evidence from field experiment in northern region of the country also revealed that applications 6 t ha⁻¹ FYM and 46/46 kg ha⁻¹ N/P₂O₅ chemical fertilizer were more effective than sole application of both of them for improving wheat yield and enhancing soil productivity (Assefa ,2017). Similarly, different combinations of N/P fertilizer 9/10/0, 32/10/4, 32/10/8, 9/10/8 and 64/20/0 kg ha⁻¹ N/P and FYM t ha⁻¹, respectively, were studied in Wolmera, Ethiopia to determine their effects on the growth and yield of wheat.

Table 1: Effects of N, P and FYM on wheat yield on Nitisols of central Ethiopian highland.

| Treatments N/P kgha ⁻¹ FYM tha ⁻¹ | Moderately Fertile soil | | Poor Soil | |
|--|-------------------------|------------------------|-------------------------|---------------------------|
| | GY(t/ha) | BY(t ⁻¹ ha) | GY (t ⁻¹ ha) | BY (t. ha ⁻¹) |
| 9/10/0 | 2.63c | 7.10c | 1.63c | 5.06c |
| 9/10/8 | 3.05b | 8.56b | 2.15b | 6.23b |
| 32/10/4 | 3.27ab | 9.18ab | 2.29b | 6.37b |
| 32/10/8 | 3.44a | 9.77ab | 2.59a | 7.45a |
| 64/20/0 | 3.46a | 10.06a | 2.78a | 8.18a |
| LSD0.05 | 0.34 | 1.38 | 0.23 | 0.96 |

Source: (Getachew and Chilot,2009)

Results showed that on moderately fertile soil, significantly higher grain and biomass yields were obtained from the application of 64/20/0, 32/10/8 and 32/10/4 kg N/P and FYM t ha⁻¹, while on poorly fertile soil, 64/20/0 and 32/10/8 kg N/P and FYM t ha⁻¹ resulted in significantly higher wheat grain yield (Getachew and Chilot ,2009). (Table .1).

Different rates of vermicompost along with chemical fertilizers gave significant improvement in total N, available P, exchangeable K, Ca, Mg and available S and micronutrients (Molla *et al.*,2018 and Zemen *et al.*, 2018). Thus, the technology not only supply essential nutrients and amends soil but also have some positive interaction to increase yield as well as improve nutrient use efficiency of crops by reducing environmental hazards (FAO, 2006; Tolera *et al.*, 2018).

The integrated use of NP and compost gave higher yields than application of either NP or FYM alone for maize production (Negassa et al., 2004a). Similarly, Study carried out by Abdissa et al., (2018) for two consecutive years in Eastern Wellega indicated that Combined application of VC at 2.5 t ha⁻¹ and chemical P fertilizer at 20 kg ha⁻¹ with lime at 4 t ha⁻¹ improve soil nutrient status and enhanced grain yield and yield components of maize plant under acidic soils. Field study under taken by Admasu and Tadesse (2018) at Kulumsa Agricultural Research Center during 2014 to 2015 cropping season showed integrated use of organic fertilizers (half recommended vermicompost at rate of 2.5 tonha⁻¹ and half recommended inorganic NP fertilizers at the rate of 37/15 kg N/P ha⁻¹) gave economically optimum wheat yield. In south western region of Ethiopia, Endris and Dawid (2015) also obtained significant maize yield difference in response to 50% recommended NP (100 kg Urea and100 DAP ha⁻¹) with 50% compost (2 t ha⁻¹) application which result in grain yield of 4772.8 kg ha⁻¹.

Application of FYM every 3 years at a rate of 16 t ha⁻¹ supplemented by NP fertilizer annually at a rate of 20–46 Kg N–P₂O₅ ha⁻¹ was recommended for sustainable maize production around Bako area (Tolessa, 1999). Furthermore, the integrated use of coffee by-products and N fertilizer increased N uptake and grain yield of maize in Hawassa, southern Ethiopia. Coffee residues and N fertilizer positively influenced soil moisture, soil nitrogen and organic matter, grain, and water use efficiency of maize (Tenaw, 2006).

Application of 4 t FYM ha⁻¹ incorporated with 75/60 kg of N/P ha⁻¹ was an economical and profitable combination in boosting hybrid maize (BH-140) yield in West Hararghe zone, eastern Ethiopia (Zelalem, 2014). Furthermore, the integrated use of 5 t ha⁻¹ of compost either with 55/10 or 25/11 kg of N/P ha⁻¹ was economical for maize production in Bako Tibe district (Negassa et al., 2004b). Similarly, applications of the full recommended doses of NP fertilizers integrated with 5t ha⁻¹ crop residue were advised to improve the fertility of these soils for sustainable maize production in Haramaya area (Heluf *et al.*, 1999). The integration of biogas slurry and NP fertilizer produced significantly higher grain yield of maize and improved soil physico-chemical properties. Biogas slurry at 8 t ha⁻¹ with 50% recommended N/P kg ha⁻¹ (100/50 kg ha⁻¹ of urea/DAP) or 12 t biogas slurry ha⁻¹ alone was recommended for maize production (Tolera *et al.*, 2005a, 2005b).

In terms of integrating cropping sequence with NP and FYM, studies show that intercropping of maize with climbing bean with integrated application of 69/10 kg NP ha⁻¹ with 4 - 8 t FYM ha⁻¹ gave better grain yields and is recommended for sustainable production of component crops (Abera, 2013). N, P, and organic matter content of the soil was improved with integrated use of NP and FYM in intercropping maize climbing beans (Tolera *et al.*, 2010). The production of maize following sole haricot bean with the recommended fertilizer rate gave higher mean grain yield and is recommended for sustainable production of maize in the region (Tolera, 2012). Similarly, improved grain yield of maize was obtained from maize planted with application of half and full recommended rate of nitrogen fertilizer following soil incorporated soybean and faba bean precursor crop biomass, highlighting the importance of additional nitrogen application in the cropping sequence (Tolera, 2016). Therefore, the use of legume crop significantly reduced the application of N fertilizers for different cereal production.

Isreal *et al.*, (2018) concluded that combined use of organic manure and inorganic fertilizers results in significant difference in bulk density, particle density, pH, Organic carbon, available nitrogen, available phosphorus, and available potassium, available Zinc, and available Sulfur beside improving yields of crops. Experiment conducted by Abdissa *et al.*, (2018) pointed out that addition of vermicompost at rate of 15 t ha⁻¹ significantly ($P < 0.05$) improved contents of soil bulk density, total porosity, total organic carbon, total N, P, K, Ca, Zn and Mn substantially compared with control plots. The interactions between chemical fertilizer and organic matter improve soil fertility by restocking nutrients lost through leaching and by modifying the pH of the rhizosphere and making unavailable nutrients available (Vanlauwe *et al.*, 2001; 2015).

Table 2: The effect of organic and inorganic fertilizer application on tef productivity

| Treatment | pH | N% | P (ppm) | OC % |
|---------------------------|-------|-------|---------|-------|
| Recom.NP (69/60) | 6.3 | 0.23 | 26.48 | 2.83 |
| CC | 6.53 | 0.3 | 28.41 | 3.39 |
| FYM | 6.54 | 0.32 | 28.19 | 3.42 |
| VC | 6.45 | 0.28 | 28.57 | 3.12 |
| 50% VC + 50% CC | 6.4 | 0.27 | 27.11 | 2.99 |
| 50% VC + 50% FYM | 6.42 | 0.267 | 28.75 | 3.02 |
| 33% VC + 33% CC + 33% FYM | 6.52 | 0.267 | 29.44 | 3.06 |
| 50% VC + 50% NP | 6.41 | 0.273 | 28.12 | 3.26 |
| 50% CC + 50% NP | 6.32 | 0.267 | 24.44 | 2.9 |
| 50% FYM + 50% NP | 6.48 | 0.267 | 23.7 | 3.05 |
| LSD (0.05) | 0.147 | 0.043 | NS | 0.287 |

Source:(Girma and Gebreyes,2017)

Similarly, Girma and Zeleke (2017) concluded that integrated use of different sources of organic and inorganic fertilizer have significant improvement in the overall condition of the soil as well as agricultural productivity if best alternative option is adopted in the area. Soil chemical properties such as pH, organic carbon (OC) and N were significantly ($P < 0.05$) affected by the application of different rate of organic and inorganic fertilizers (Girma and Gebreyes, 2017).

Integrated soil fertility management plays a critical role in both short-term nutrient availability and longer-term maintenance of soil organic matter. Study conducted by Mulugeta et al., (2018) indicated that positive result was obtained by combining different ratio of NP fertilizer with organic of materials on soil fertility status and yield of tef in halaba werede. Field experiment by Getachew *et al.*, (2014) also pointed that the application of organic or organic together inorganic fertilizers improved fertility status of the soil.

Table 3: The effect of organic and inorganic fertilizer application on soil nutrient content

| Treatments | pH | OC (%) | N (%) | P(ppm) | NO ₃ -N(ppm) | NH ₄ -N(ppm) |
|---|------|--------|-------|--------|-------------------------|-------------------------|
| Control | 5.19 | 1.29 | 0.17 | 7.75 | 6.23 | 5.93 |
| Farmers NP rate 23/10 | 5.09 | 1.56 | 0.17 | 8.40 | 6.98 | 7.00 |
| Rec.NP 69/20 | 5.33 | 1.79 | 0.18 | 11.85 | 9.43 | 8.38 |
| 50% rec.NP (30/10) +50% manure + 50% compost | 5.55 | 2.30 | 0.19 | 11.20 | 10.70 | 12.90 |
| 50% manure + 50% compost | 5.48 | 2.22 | 0.18 | 10.25 | 10.13 | 8.40 |
| F-Probability | NS | ** | * | * | * | ** |
| LSD0.05 | 0.31 | 0.27 | 0.01 | 2.73 | 3.53 | 3.03 |

Source : (Getachew *et al.*, 2014)

Study conducted by Getachew *et al.*, (2014) in central high lands of Ethiopia for two consecutive years under vertisol condition indicated that the highest tef grain yield (3144.8kg ha⁻¹) was obtained from the applications of half doses of vermicompost (4.8t ha⁻¹) and half doses of the recommended nitrogen and phosphorus fertilizers (34.5kg ha⁻¹ N and 30kg ha⁻¹ P followed by (2846 kg ha⁻¹) full dose of recommended N and P rates (69kgN ha⁻¹ and 60kg P ha⁻¹). Fig1.

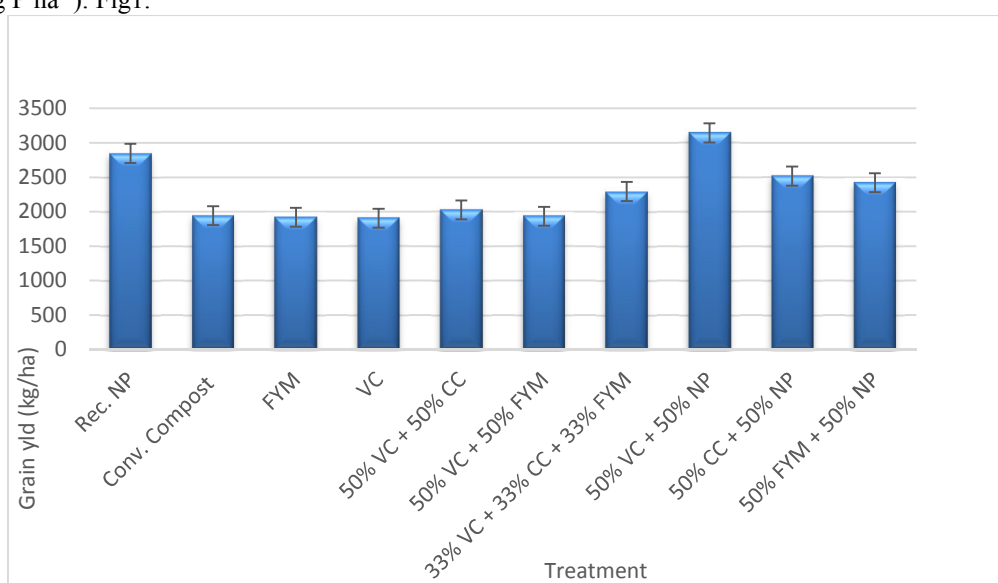


Figure 1: The effect of Organic and Inorganic Fertilizer on Tef Yield in Ginchi area
 Source: (Girma and Gebreyes, 2017)

The synergistic effect of applied lime with organic and inorganic plant nutrient sources influenced crop response and nutrient availability. Integrated use of lime at 611kg ha⁻¹ + 2.5 t ha⁻¹ compost along with 50 % of soil test-based fertilizer recommendation (NPSB at 75 kg ha⁻¹, kcl at 50 kg ha⁻¹, N at 16 kg ha⁻¹) for barley was responded positively and significantly. Thus, the highest grain yield of barley (5385.59 Kg ha⁻¹) was obtained with integrated use of lime with full recommended dose of organic and inorganic nutrients (Woubshet *et al.*, 2017). Getachew *et al.*, (2012) observed crop availability of essential plant nutrients under integrated nutrient application under Nitosol of Central High Land.

Nitrogen, phosphorus and FYM rates were evaluated on the vertisols of South Tigray in the period 2013–2014 on grain yield of barley (Assefa, 2015). It was recommended that application of 46/46 N/P2O₅ kg ha⁻¹ with 8 t ha⁻¹ gave 18% and 100% yield more than the blanket fertilizer recommendation in the area (46/46 N/P2O₅ kg ha⁻¹) and the control. Barley grain yield was investigated for a response to bio-slurry compost and chemical fertilizer in the Tigray region from 2001-2005 (Edwards *et al.*, 2007). Application of bio-slurry compost produced the highest yield of 3,535 kg ha⁻¹ with an advantage of 67.2% over the control. However, the use of chemical fertilizer produced a barley grain yield of 1,832 kg ha⁻¹ with a yield advantage of 36.7% over the control.

Other studies conducted to evaluate effective rhizobia isolates and strains for different agro-ecologies in Ethiopia indicated that biological N fixation (BNF) could play an important role in increasing food production through increasing yield of crops and forages. According to Hailemariam and Tsige, (2006), Faba bean yield increases of 51-158% were reported on Nitosols at Holeta, Central high land due to the combined application of 20 kg P ha⁻¹ with strain over non-inoculated ones. Figure 2.

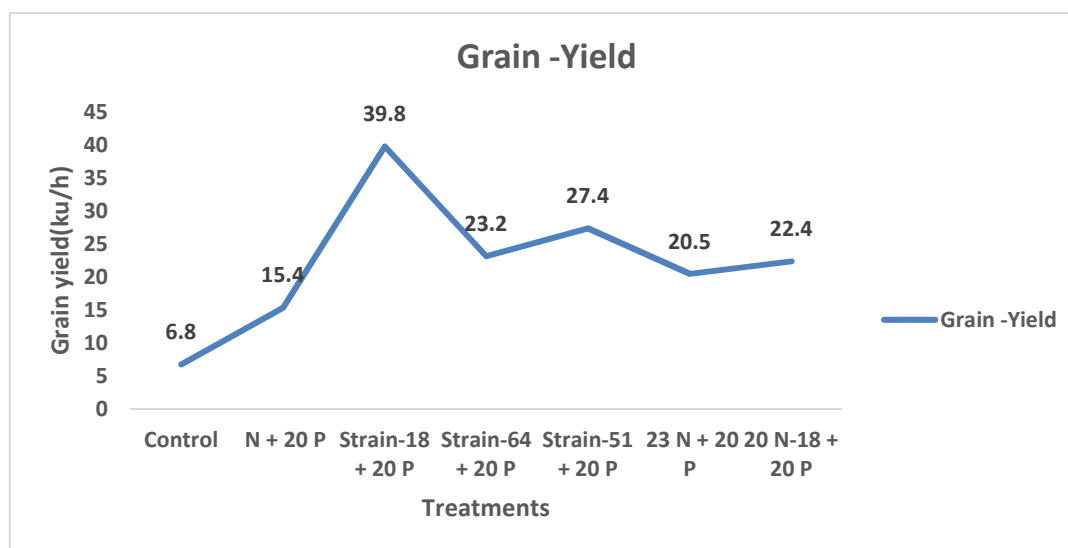


Figure 2. Evaluation of effectiveness of rhizobia isolates and strains on Yields of Faba bean
 Source:(Hailemariam and Tsige, 2006)

Conclusions and Recommendations

Poor Soil fertility management is one of the core problems that deteriorate Ethiopian agriculture and leads 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 severe erosion, nutrient removal through entire crop harvests, low soil organic matter, overgrazing etc. Integrated use of different fertilizer sources with appropriate cropping sequence can improve soil fertility and crop productivity and could bring about sustainable crop production. Integrated use of soil management technologies help reduces considerable amount of inorganic fertilizers and save costs invested on chemical fertilizers. Therefore, integrated soil fertility management is a desirable option to alleviate soil fertility problems to utilize available organic and inorganic nutrients and help smallholder farmers produce crops at reduced cost and make crop production and productivity sustainable. Integrated use of soil fertility management technologies is not well known in the country. Hence:

- Advising, training, and assisting the farmers in using locally available materials that economize the cost paid for chemical fertilizer for soil fertility management is a paramount importance for sustainable crop production.
- Integrated soil fertility management technology should be scaled up and promoted on farmer's field for maintaining high yields, improving the soil fertility, preventing environmental contamination, and sustaining agricultural production over the long term.

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