Integration of Organic and Inorganic Soil Fertility Improvement Inputs for Improved Crop Yields in Central Highlands of Kenya

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Abstract: Production of agricultural products has lagged behind population growth in most parts of sub-Saharan Africa. The problem is associated to a decline in soil productivity that is a consequence of continuous cultivation with no or inadequate external soil fertility enhancement inputs. This is a common situation in central highlands of Kenya where over 90% of farmers are resource poor smallholders and the soils are characterised by low levels of nitrogen and phosphorus. The situation is worsened by cultivation methods, which are more of nutrients mining rather than nutrient conservation. The whole scenario contributes to inadequate food production leading to hunger and poverty among the farming communities. In seeking for an environmentally viable and economically feasible technology(ies) for combating soil nutrients depletion, farmer-managed on-farm trials using readily available inorganic and organic resources were conducted within the main maize/coffee/dairy land use systems of central Kenya. The soil fertility improvement resources were identified in focused survey conducted prior to field experimentation with aim of taking an inventory of soil fertility status and the most readily available soil fertility improvement opportunities for smallholder farmers. Farmyard manure (FYM) and Tithonia diversifilia biomass were found to be the most readily available organic resources and were both applied at an equivalent N content of 60kg ha^{-1}, same as the inorganic fertilizers N recommendation for the area. Maize (Zea mays L. Var. Hybrid 513) was the crop and besides assessing the biophysical crop performance, the trials had also an objective of assessing socio-economic effects of organic, inorganic and their (organic-inorganic) combinations to improve crop productivity. Application of recommended rates (60kg of both N and P ha^{-1}) of inorganic fertilisers gave an average maize grain yield of 7.5 Mg ha^{-1} and USD 681 total net benefits (NB). This was closely followed by integration of Tithonia biomass and 30kg ha^{-1} of both N and P ha^{-1} with 6.8 Mg ha^{-1} grain yield and USD 520 net benefits. The survey found that majority of farmers can not afford to buy and apply enough inorganic fertilisers, hence, a recommendation was put forwards for smallholder farmers to embark on integration of organic and inorganic soil fertility improvement resources for an improved food security in the region.

Keyword: soil fertility, inorganic fertilizers, organic fertilizers, inorganic + organic fertilizers combinations

1 Introductions

The greatest agricultural challenge facing Kenya today is the production of adequate agricultural products to meet the demand for the rapidly growing population and in particular, in the densely populated central highlands with over 500 persons km^{-1} (Government of Kenya, 1994). The central highlands of Kenya are characterised by complex farming systems dominated by perennial cash crops, food crops and livestock (Micheni, *et al*., 1999). The soils are deep, well drained, weathered Humic nitisols with moderate to high inherent fertility (Jaetzold and Schmidt,1983). Over time, the soil productivity has declined due to continuous cropping with little nutrient replenishment, leading to non-portability the newly developed agricultural technologies and crop varieties (Ikombo, 1984). Use of inorganic fertilizers is generally low, less than 20 kg N and 10 kg P ha^{-1} (Muriithi, *et* *al*., 1994). This amount is inadequate to meet the crop nutritional requirements for optimum crop yields. Due to the high cost of inorganic fertilizers and low prices of farm produce, over 80% of the farmers use farmyard manure (FYM) to improve soil fertility and crop productivity (Maize Data Base, 1993). The usefulness of FYM is however limited by its variability and often-low nutrient concentrations and also the large quantities (5 Mg • ha^{-1}—10 Mg • ha^{-1}) needed to provide adequate nutrients (Kihanda, 1996; Nzuma, *et al*., 1998).

Survey on technologies used for soil fertility improvement in the central highlands of Kenya indicates that majority of farmers (>95%) in the region are aware of the low soil fertility as a major constraint to their agricultural production (Muriithi, *et al*., 1994; Kapkiyai, *et al*., 1998). The region is in the predominantly maize growing zones or upper midlands (UM_1/UM_2) with an altitude of approximately 1,500m asl and annual mean temperature of about 20℃. The annual rainfall varies from 1,200 to 1,600mm and falls in two seasons, the long rains (LR) lasting from March through June and short rains (SR) from October through December. Majority (82%) of interviewed farmers indicated that biomass from short duration agroforestry herbaceous/woody tree species have potentials for improving soil productivity. Everybody (100% of the respondent) indicated to have had applied FYM or inorganic fertilizers in their farms albeit in insufficient quantities to meet the crop nutrient requirements (Muriithi, *et al*., 1994). Research work by Nziguheba, *et al*. (1998), Gachengo (1996), Mugendi, *et al*. (1999), and Mutuo, *et al*. (2000) reported positive results from the use of biomass from Tithonia, Calliandra, Leucaena and other agroforestry shrubs for soil fertility replenishment (Palm, 1995). Similarly, Mugendi, *et al*. (1999) notes that application of leafy biomass from high nitrogen rich plant species reduced the rate of soil fertility decline. Application of leafy biomass and subsequent improvement in crop dry matter was associated to total soil carbon, nitrogen, phosphorus, potassium and minor nutrients improvement. The biomass of a fast growing agroforestry herbaceous plant, Tithonia diversifolia which is commonly used for farm external/internal boundary hedge has been shown to improve soil productivity and improve crop yields substantially in western Kenya (Amadalo, *et al*., 1995). This manuscript highlights findings from two-year participatory on-farm trials on integrated soil fertility management strategies conducted in the predominantly maize growing zones (UM_1/UM_2) of central highlands of Kenya.

2 Methodologies

Field activities were conducted in two phases in two sites (Kiawanja and Maragwa) found within the main tea/coffee/maize/dairy land use systems (LUS). The first phase entailed a participatory focused survey to inventorize the constraints and opportunities for soil productivity, and field experimentation to evaluate and validated the biophysical and economic potency of the locally most available soil fertility improvement resources.

The survey was conducted in January—February, 2000 period and had a sample size of 80 farmers from both sites. A semi-structured questionnaire was used to collect the information, which was later synthesised to highlight the soil fertility constraints and the locally available soil fertility improvement resources in the area. The identified most readily available resources were taken to be the treatments for participatory on-farm trials to evaluate and validate with farmers the most feasible soil fertility enhancement option(s) for smallholder farmers in central highlands of Kenya. Immediately after the survey, farmers' meetings were convened to synthesise the results and develop possible action plans for soil fertility improvement using the identified most readily available resources. Majority of farmers who attended the meeting were those who participated in the survey and it was very easy to explain the identified soil fertility constraints/opportunities and the way forwards. The meetings were also meant to bring farmers together and sensitise them to form a farmer research groups and nominate the first sets of field trial-participating farmers.

Twenty trial farmers (10 farmers from each site) were initially nominated to conduct trials in their farms. Each of the farmers was requested to co-opt 10 follower farmers to help or participate in the general trial activities and evaluation. Criteria for farmers selection was willingness of the farmer to use inorganic/organic fertilisers, availability of organic soil fertility improvement inputs within his/her farm, willingness of the farmer to welcome other farmers in his/her farm, and good farm accessibility by other farmers and research/extension officers throughout the year. Soil samples were taken for every farm that the trials were to be conducted and analysed to characterize the soil on nutrients availability to the crops. The trials were based on a randomized complete block design with each farm in a site being a replicate. Thus, there were 10 replicates in Kiawanja and 10 in Maragwa site. Medium maturity maize (*Var.* H513) was used as a test crops and planted at six rows of 10 hills each in a plot of 3.75m × 2.70m. FYM, *Tithonia* biomass, inorganic fertilizer [N_{23} : P_{23} : K_0 at 60kg • ha^{-1} of both N and P] and unfertilized control were the three main treatments. Other treatments were [FYM + 30kg • ha^{-1} of both inoganic N and P] and [*Tithonia* biomass + 30kg • ha^{-1} of both N and P]. The amount of applied FYM and *Tithonia* biomass was based on the material's N content and the area recommendation of 60kg • ha^{-1} N to the crop. The day-to-day trial management (planting, weeding, harvesting and evaluation) were jointly carried out by researchers, farmers and members of agricultural extension staff.

3 Results

Discussions with farmers in the survey on identification and prioritise constrains and opportunities for soil fertility improvement resources showed that farmers are aware of the low soil productivity leading to reduced agricultural production and their perception on soil nutrient dynamics (Figure 1). It was the farmers feeling that nutrient mining through continuous cultivation with little or no soil nutrient management was the major reason for continuous decline in agricultural productivity. Combinations of inorganic+organic were indicated as the feasible options for soil nutrient management. Analysis of soil samples showed that the average soil pH levels for Kiawanja and Maragwa sites were below 5 and the available nitrogen and phosphorus were insufficient (less than 0.3% N and 0.2% P). The average levels of N and P were 0.24% and 0.14%, respectively for Kiawanja soils while Maragwa soils had 0.21%, 0.15%, respectively.

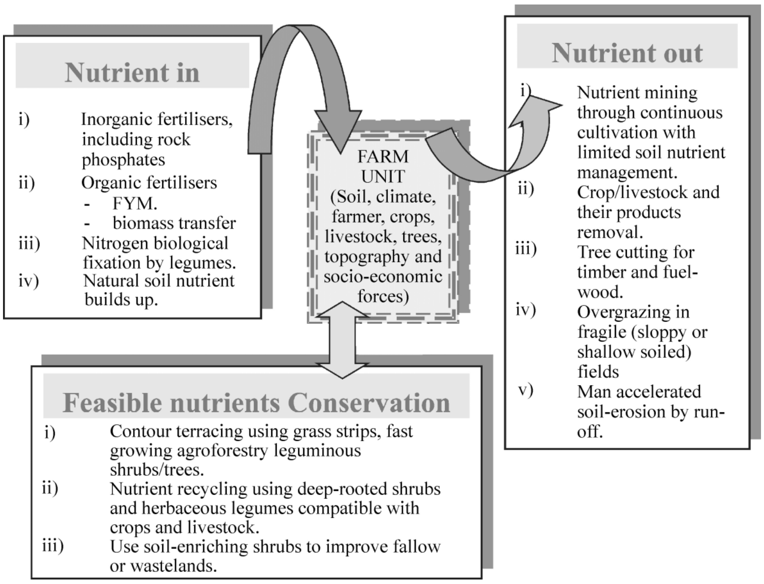

Fig.1 Farmers' perceptions on soil nutrient dynamics at farm level

Farmyard manure (FYM) was the most widely used soil fertility improvement resource in both sites (Table 1). Inorganic fertilisers were also used but at lower rates (20kg • ha^{-1}) than the recommended rate of 60 kg • ha^{-1} of both N and P. This was associated to the recession in coffee industry and the general low returns from the farm investments leading to extremely difficult for farmers to raise money to buy sufficient fertilisers for their farms. Credits from the co-operative societies are also limited.

Table 1 Availability and affordability of soil fertility improvement resources in Central Kenyan highlands

Input	% farmers in the region		Source	Level applied
	Availability	Affordability		
Inorganic fertilisers (N & P)	72	25	— Markets — Co-operative societies (credit)	Insufficient
FYM	95	92	— On-farm	Insufficient
Tithonia	88	82	— On-farm	Insufficient

The second and third most available soil fertility improvement resources were *Tithonia* biomass and inorganic fertilisers, respectively. Availability of FYM, *Tithonia* and inorganic fertilisers was reported by 95%, 88% and 72% and affordability/accessibility by 92%, 82% and 25%, respectively of the interviewed farmers. There was a general decline in the affordability/accessibility from the percent availability of soil fertility resources by farmers. For example, the response percent inorganic fertilisers availability was 72% while the affordability/accessibility of the same was only 25% (Table 1). Reasons attributed to low use of the various resources varied from one resource to another (Table 2).

Table 2 Reasons for insufficient application of soil fertility improvement inputs

Soil fertility improvement inputs	Source	Average required $season^{-1}$	Average applied $season^{-1}$	Why insufficient applied
1) Farm Yard Manure	— On-farm	5—10 tons • ha^{-1}	> 2 tons • ha^{-1}	Limited production. Poor preparation and handling of manure. High labour demand for manure preparation and transportation to the farm. Other alternative uses, e.g. application to cash crops or sale to generate some income.
2) Tithonia biomass	— On-farm	2—3.5 tons • ha^{-1}	> 300kg • ha^{-1}	Not found in all farms. High labour demand for harvesting, transportation, chopping and application. Not available when seriously required. Other alternative uses, e.g. used as fodder. Less knowledge on *Tithonia* as a soil fertility improvement resource.
3) Inorganic fertilizers (N and P)	— Local markets — Co-operative societies credit)	60 kg • ha^{-1} of both N and P	> 20 kg • ha^{-1}	High cost. Applied in cash generating crops such as coffee, tea and horticultural crops.

The survey was followed by a three-season on-farm evaluation of the three most available soil fertility improvement resources (FYM, *Tithonia*, and inorganic fertilizers) in 15 farms across the central Kenyan highlands. The average maize (test crop) grain yields was 4.5Mg • ha^{-1} (Figure 2). Application of recommended rate of inorganic fertilizer (60kg • ha^{-1} of both N and P) and a combination of [3

Mg • ha^{-1} *Tithonia* biomass + 30 kg • ha^{-1} of both N and P] gave 7.5 and 6.4 Mg • ha^{-1} grain yields, respectively. The two yields were not significantly (p=0.05) different. The average grain yield from control was 1.8 Mg • ha^{-1} and significantly (o=0.5) differed from the yields other treatments. A general conclusion drawn from the results was that the recommended rate of inorganic fertilizers or a combination of [*Tithonia* biomass + half rate of recommended rate of inorganic N and P] have a potential for improved maize production in central highlands of Kenya.

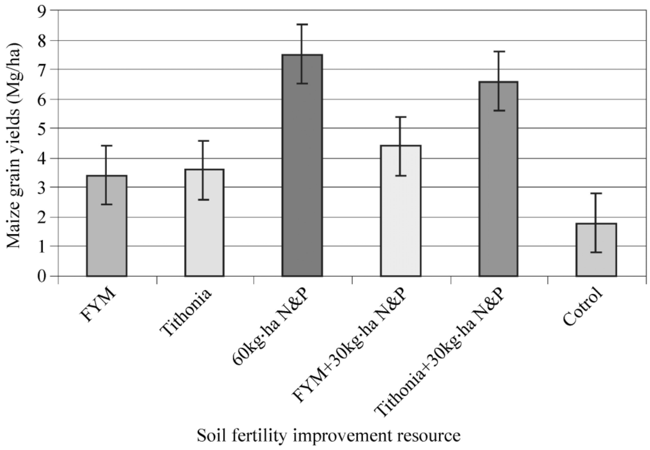

Fig.2 Maize grain yields (Mg • ha); average of 3 seasons from 15 farms in central Kenya highlands

4 Socio-economics

One of the reasons leading to the acceptance of new technologies by farmers is their profitability. For example, a farmer would like to know the monetary gains by adopting an agricultural option A, and not B. In most situations technologies with higher benefits are adopted first. Collection of economic information for this write-up was done at different times of the season. For instance, the cost of seeds, weed control and crop removal from the field were recorded during planting, weeding and harvesting time, respectively. The main sources of the data were farmers, extensionists and agro-input stockists. Table 3 gives the net-benefits summary of growing maize under various soil fertility management strategies. The analysis assumed that labour for carrying out various farm activities was always hired and tools were brought to the farm by the labourers. It was also assumed that the average annual interest rate for money in a bank savings account was 12% and that the medium maturity maize (H513) took 5 months from planting to harvesting/selling.

Table 3 Summary of economic analysis for maize production in central Kenya highlands

Treatment	Total Cost (TC)	Total Benefits (TB)	Net Benefit (NB) = TB–TC	Profitability Ranking	Food Security Ranking
	US Dollars				
FYM	317	483	166	5	5
Tithonia	357	527	170	4	3
60kg • ha^{-1} N&P	352	1033	681	1	4
FYM+30kg • ha^{-1} N&P	342	640	298	3	2
Tithonia+30kg • ha^{-1}N&P	376	896	520	2	1
Control	227	279	52	6	6

The inorganic input of N and P at the rate of 60 kg • ha $^{-1}$ gave the highest net benefit of USD 681 (Table 3). The second and third best in terms of net benefits were [Tithonia + 30kg • ha^{-1} of both N and P] and [FYM + 30 kg • ha^{-1} of both N and P] treatments with USD 520 and 298, respectively.

5 Conclusion

Reduced land productivity in central highlands of Kenya is a common phenomenon. The problem is due to low soil nutrients, a situation aggravated by cultivation with little or no addition of soil fertility improvement inputs. The major soil nutrients (mostly N and P) are insufficient in the region and therefore nutrients from external sources needs to be applied for an improved agricultural production by the smallholder farmers. The situation may be arrested through use inorganic fertilizers and organic materials from the fast growing and nutrient rich agroforestry tree species such as *Tithonia diversifolia*. Integration organic and inorganic inputs proved to be the most feasible option for food security for resource limited smallholder farmers. The recommended rate of 60kg • ha^{-1} of both N and P of inorganic of fertilizer gave the highest maize yields. Thus farmers with high resource endowment may adapt it while those with low resource endowment are encouraged to grow maize under organic/inorganic combinations of soil fertility management.

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