# Use of farmer-prioritized vertisol management options for enhanced green gram and tomato production in central Kenya

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**Abstract**

Green grams (Phaseolus aures L.) and tomato (Solanum lycopersicum L) are widely grown in the vertisols of the Mwea Irrigation Scheme alongside the rice fields. Green grams can fix nitrogen (biological nitrogen fixation) and are grown for its highly nutritious and curative seeds while tomatoes are grown for its fruit rich in fibres, minerals and vitamins. The two can be prepared separately or together in a variety of ways including raw salads and/or cooked/fried. They together form significant delicacies consumed with rice which is the major cash crop grown in the black cotton soils. The crops can grow well in warm conditions but tomato is fairly adaptable except under excessive humidity and temperatures that reduce yields. Socio-economic prioritization by the farming community and on-farm demonstrations of soil management options were instituted to demonstrate enhanced green gram and tomato production in vertisol soils of lower parts of Kirinyaga County (Mwea East and Mwea West districts). Drainage management was recognized by the farming community as the best option although a reduced number of farmers used drainage and furrows/ridges, manure, fertilizer and shifting options with reducing order of importance. Unavailability of labour and/or financial cost for instituting these management options were indicated as major hindrances to adopt the yield enhancing options. Labour force was contributed to mainly by the family alongside hiring (64.2%) although 28% and 5.2% respectively used hired or family labour alone. The female role in farming activities dominated while the male role was minimal especially at weeding. The youth role remained excessively insignificant and altogether absent at marketing. Despite the need for labour at earlier activities (especially when management options needed to be instituted) it was at the marketing stage that this force was directed. Soils were considered infertile by 60% but 40% indicated that their farms had adequate fertility. Analysis showed that ridging and application of farm yard manure and fertilizer improved fertility, crop growth and income considerably. Phosphate and zinc enhancement reduced alkalinity and sodicity. Green gram and tomato yields increased under ridges and farm yard manure application by 17-25% which significantly enhanced household income.

## Introduction

Green grams (Phaseolus aurous L.) and tomato (Solanum lycopersicum L) are widely grown in the vertisols of the Mwea Irrigation Scheme alongside the rice fields in Kenya. While green grams are grown for its seed which are highly nutritious; tomatoes are grown for its fruit and can be prepared together to form various delicacies. Green-grams contain a portion of every amino-acid and is rich in Calcium, Phosphorus, Magnesium, folate and Vitamins A and C. It also has low fat protein (14g per cup), high fiber (0.15g per cup) and a low glycemic index

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that lowers the risk of diabetes and is easily digestible. It also has several curative abilities and useful for the sick (e.g. against cholera) and expectant and lactating mothers. The crop can also fix nitrogen and is adaptable to drought conditions and inferior soils. Tomato has fibers, minerals and vitamins C and K and is used as raw salads and/or cooked/fried with most vegetables. It has antioxidants that have curative abilities against breast, colon and prostate cancers. The crop grows well in warm conditions but is fairly adaptable except under excessive humidity and temperatures that reduce yields.

Vertisols and vertic soils which are associated with glaring limitations to crop production due to their chemical and physical properties cover 43 million hectares in 28 countries in Africa (Broncyijk, 1991). These and other associated soils in the highlands of East Africa, occur at altitudes of 1000-3000 m above sea level and in Kenya occupying 5% of the country's landmass (2.8 million hectares) of which about 80% located in Arid and Semi-Arid Lands (ASALs) (Debele, 1983). In these areas mean monthly maximum temperatures rarely exceed 30°C and the minimum temperature is usually below 15°C. In the single peaked rainfall areas, the temperatures are relatively high during March and May. In the rainy months of June to September, the mean maximum temperature is around 20°C. In the highlands of East Africa receiving bimodal rainfall (example Nairobi, Kenya), temperatures are more or less uniform throughout the year (Virmani, 1987).

Some of the most common management problems of vertisols include; poor drainage and water logging, runoff and soil erosion, difficult tillage and unsuitability for land preparation implements and low organic carbon and nitrogen (Dudal R and Bramao, 1965; Tekele, Dinky and Lascano, 2012). There are various challenges and limitations encountered while attempting to use vertisols related to their associated shrinking, swelling and cracking dynamics that need to be taken into account (Tekele, Dinky and Lascano, 2012). Jutzi (1988) and Baudyapadhyay et al., (2003) outline conservation of water using tied-ridges, excess water storage and evacuation, gulley control and split-application of nitrogenous fertilizers as options for enhancing productivity of vertisols.

Macharia et al., (1998) attempted to develop an appropriate drainage system to remove surplus water early in the season to allow early and timely planting of crops for maximum yield, the development of appropriate land-shaping implement for the removal of surplus soil surface water, and the determination of economically suitable fertilizer types and rates for application on different crops grown. One option they recommend is that of addressing water harvesting and drainage issues tackled together in dry-land Vertisol areas. This should be followed by an introduction of crops tolerant to water logging and perennial fruit trees. Animal power has been suggested to be able to reduce labour requirements for "early" (before rainfall onset) land preparation and instituting additional structures amongst other required activities (Latham and Ahn 1987). This option can however be also challenging since even the livestock may be too weak due to shortages of pasture preceding the on-coming season. It is therefore particularly commendable to use low-cost inputs (fertility, labour) especially noting the usually low resource availability amongst the populations residing in semi-arid areas in Africa (Food and Agricultural Organisation, 1972). Vertisols in semi-arid lands in the Ethiopian highlands have been reported to be able to sustainably produce at least 2 crops per year when correct and timely management options that is, use of ox-plough for land preparations to enhance surface drainage, use of new cropping systems and low cost phosphates sources and legumes for nitrogen are pursued (Virmani, Sahrawat and Burford, Undated). Virmani (1987) indicates that the appropriate functionality of vertisols would depend on cultural, socio-economic and ecological potential of any targeted area.

In an attempt to overcome these problems there is widespread use of animal power for tilling but this can only commence after the first rains when the soil can be penetrated by the plough so plough/planting is practiced and a secondary pulse crop is planted two or three weeks later. These causes delayed planting with resulting loss in yield potential. It is therefore pertinent to identify a mechanized means for land preparation. A tractor hire service for each country could essentially solve this problem. Investigations on vertisol management in Kenya have previously focused on influencing biophysical characteristics with a test crop to determine if these lead to any changes in crop performance (Ikitoo, 2008, Sigunga, 1997).

Previously some management strategies have been attempted including a feasibility study in 2010-2012 (District Agricultural Engineer, 2014). Later water harvesting was done by use of constructed water pans using soil compaction instead of sheet linings. These were not successful because the vertisols were found to be 3 meter deposits overlying highly filtrating soils. Also attempted was installation of PVC pipes from the major rivers to irrigate these areas for crop production but there were financial constraints. Crops grown in the areas in order of importance include maize, beans, bananas, fruit trees rice and agriculture. However, some water working water pans (5,000m3) have been constructed in April 2012 which can be used in these proposed activities.

**Table 1 :** Selected household characteristics in vertisol occupied target area

| District | Division | Total area km² | Total area Area | Targeted Population | Targeted House-holds |
|---|---|---|---|---|---|
| Mwea East | Tabere | 512,8 | 85,3 | 9818 | 2688 |
| Mwea west | Kangai | 39,3 | 13,1 | 3719 | 1236 |

This work entailed a study of management options which addressed problems of waterlogging, low response to fertilizer and hence low crop production, low fertility through instituting ridges and application of nitrogen fertilizers and farm-yard manure in lower Kirinyaga County (Mwea East and Mwea West districts) where vertisols occupy over 50% of the districts. The objective of the work was to evaluate biophysical and economic implications of using prioritized-vertisol management options in Mwea. Specifically, this included; to investigate, using a check-list, the socio-economic problems associated with green gram and tomato production in vertisols, to demonstrate a handful of the vertisol management options with farmers and other stakeholders and to show-case enhanced soil, crop and economic characteristics associated with management options.

## Materials and Methods

*Study Area*

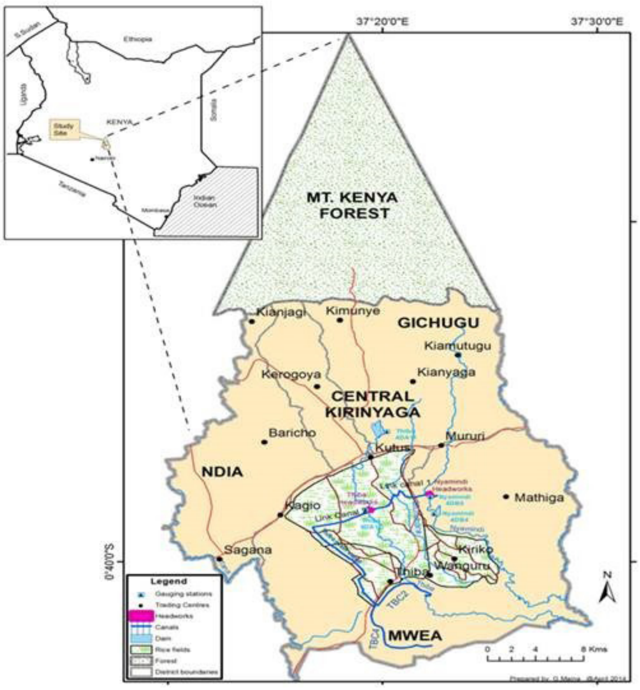


**Figure 1**: Location of Mwea, Kirinyaga (Source: Serede et al., 2015)

The area of study comprised of Kirinyaga central district which covers 35,880 km² as a pilot vertisol covered area. The district has a population of 104,437 with a density of 733.2 persons per square km (**Figure 1**). It mainly lies across a number of agro-ecological zones namely UM1, LH1, and Tropical Alpine zones in the upper reaches of the district. Vertisols in Kirinyaga central occur in two locations namely Kanyekini and Koroma which cover 11,840 Km2 which is about 30% of the total area. The experiments were laid in the vertisol areas of Kirinyaga County where farmers practice rain-fed subsistence farming. They mainly grow maize, green grams, cowpeas and tomatoes. **Table 1** shows some selected population characteristics of vertisol occupied zone in Kirinyaga.

*Questionnaire*

A questionnaire developed through consultation with scientists, administrative personnel and farmers attempted to address socio-economic aspects related to the general management of vertisols was administered to a sample of 95 farmers (which was 63.3% of the targeted number; that is 150). The intended interviewees who were selected randomly from the list of the 3,924 households provided by the local extension office were deemed to be representative of the residents who practiced available management options in the vertisol-occupied area. The above outlined characteristics are represented for the institution of the on-farm demonstrations whose results were deemed applicable to the household characteristics in the target area.

Administering of the questionnaire was done by the scientists, local technical assistants and extension personnel. The Statistical Package for Social Sciences (SPSS) Version 20 was used to analyze the questionnaire data collected by a socio-economic scientist.

*On-farm demonstrations*

Two (2) trials were instituted in three seasons that is, 2 in the long (March-June) rains of 2013 and 2014 and 1 in short (November-February) rains of 2013/14 at Mwea East and Mwea West districts belonging to identified farmers' groups which were Kiamanyeki United in Mwea East, and Ngothi Village SHG in Mwea West. Green grams were used as the test crop at Kiamanyeki while tomato


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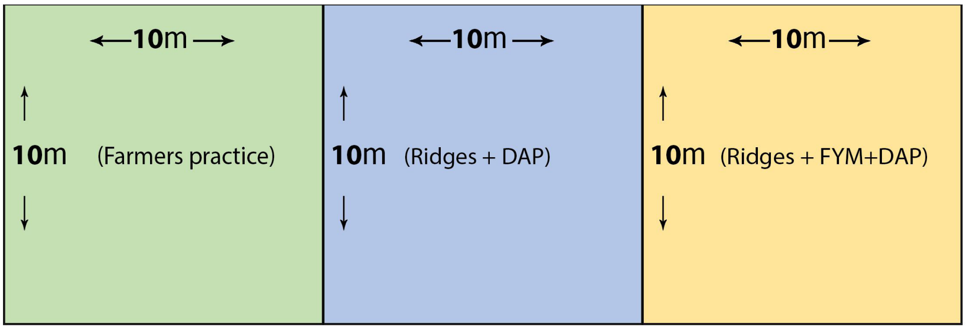


**Figure 2**: Treatments for the Vertisol trials

was used at Ng'othi. The 2 groups represented a total of 90 households (total number of members within the groups). Three vertisol management strategies were laid at each of the sites represented by the farmer groups. These were represented by (a) Farmer practice; (b) Ridges + Di-ammonium phosphate (DAP) and (c) ridges + FYM + DAP in 10 by10 m plots (**Figure 2**).

The test crops used were green grams (Variety N26) and tomato (Safari variety). Ten (10 t/ha) of FYM provided by the farmer group was ploughed into the plot before planting. The spacing for the green grams was 45 x 20 cm while the tomato was spaced at 100 x 50 cm and these crop-specific inter-row spacing constituted the ridge spacing in the two ridging plots. The green-gram rows were 15 while those of the tomato were 14. The ridges were also constructed as per crop spacing with at least 6" height. Diamonium phosphate (DAP) was applied at 70kg/ha at planting. The depth of the ridges was at least 6 inches high and the planting of the seed was done along the slope of the ridges (neither on top nor on the bottom of the ridges). Crop protection schedule was carried out as the need arose with applying pesticides.

The plot with FYM was applied at the rate of 70kg per plot which is equivalent to the documented recommended rates of 10t/acre and was provided by the farmers. This was applied and dug into the soils before instituting the ridges and furrows for sowing the seeds. Basal DAP fertilizer was applied at planting in the two intervention plots at the rate of 70 kg per hectare. The farmer practice plot remained with their usual practices in farms.

An initial soil fertility characterization status at the beginning of the experiment was taken to determine later if there will be any changes as a result of interventions instituted. Additional soil samples were taken to determine changes if any for analysis.

Data was collected from a net plot of 10 m x 10 m with the following measurements.

1. Date of planting
2. Days to emergence
3. Height at 30 days after emergence
4. Days to 50% flowering
5. Days to harvest (indicate first date of harvest in case of tomatoes)

Economic evaluation of crop yields obtained against costs of production (including fertilizers prices, and labour input for its application, cost of farm yard manure and its application, and labour for instituting ridges) was carried out to determine effects of different instituted management options. Some costs remained constant and these included, land preparation, planting, spraying, weeding and harvesting in all the three plots and they were not included in the calculation.

## Results

*Household characteristics*

About 80% of the farmers interviewed were males while the rest were females. Farms which were mainly hired (82%) varied in sizes between 2 to 8 acres with the majority falling between 2 to 5 acres while half of which was used for farming by all the households. Household sizes varied between 1 and 8 with 37% having five members. Majority of the households (80 %) had between 2 and 5 persons with other categories having fewer members (**Figure 3**).

*Crop choices*

The farmers reported growing rice (about 60%), maize (23%), tomato (13%) and green grams (3.1%) as main crops in declining order of importance. These crops were grown mainly for generation of income (54.7%) and food (29.4%). **Figure 4** shows green grams grown under farmers' practice. Appropriate agronomic practices (use of certified seeds, nutrition, moisture and pest management and cropping pattern) are important requirements for managing utilization of vertisols.

*Management options*

The management options instituted and are popular included structures such as ridges and furrows, fertilizers and manure or their combinations against farmers practice to compare crop performance and soil physical char-


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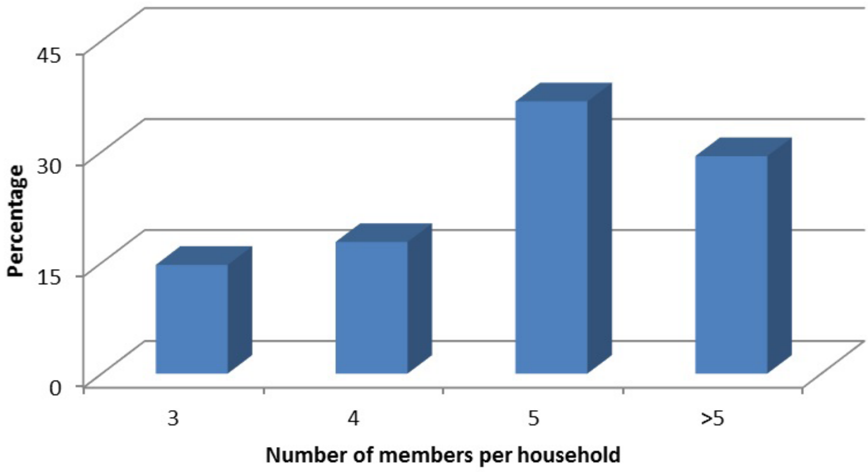


**Figure 3**: Categories of household composition in Mwea

**Figure 4**: Green grams showing farmers' practice

acteristics. Nine management options were identified by farmers as indicated in **Table 2** with manure/FYM, drainage, fertilizer and shifting options in decreasing order of importance.

*Source of labour*

The labour in the farms were both from the family and hired (64.2%) although 28% used hired labour alone while only 5.2% used family labour alone. Supplementing labour was recognized as a yield enhancing option except for two farmers who said they would not enhance yields. Of the farm activities, males dominated while females and youth disappeared almost completely at marketing. The male role was minimal at weeding while the youth role remained insignificant and altogether absent at marketing (**Table 3**).

84% of the farmers however did not appreciate constraints in labour with only 15% recognizing that as a constraint. 74% used the ox-plough while 25.2% used both the plough and hand labour. There were no constraints in accessing and/or controlling animal power in 50 households but 44 households had some difficulty in accessing these.

*Tools*

No issues arose due to hire and maintenance costs in majority of the households except one where this problem arose and no credit facilities existed for these services. Spares for tools were expensive and lowering these costs was suggested as a measure to sort this.

*Fertility*

On fertility, 60% responded that their soils are not fertile enough while 40% indicated enough fertility. However, all used fertilizers of one form or a combination of various types. Seventeen households prioritized the use of Calcium ammonium nitrate (CAN) while 40 households used mainly sulphate of ammonium (SA). Farmers who had used Di ammonium phosphate (DAP), Muriate of

**Table 2 :** Vertisol management options in Mwea

| Management option | # responses | % | # using options | % |
|---|---|---|---|---|
| Drainage | 61 | 64.21 | 27 | 28.42 |
| Manure/FYM | 14 | 14.73 | 42 | 44.21 |
| Fertilizer use | 4 | 4.22 | 14 | 14.73 |
| Shift planting options (including, population, planting date etc) | 2 | 2.11 | 7 | 7.36 |
| Water harvesting/Irrigation | 4 | 4.22 | Not mentioned | NA |
| Ridging/Furrows/Terraces | 2 | 2.11 | 1 | 1.11 |
| Use tolerant/Suitable crops | 1 | 1.05 | Not mentioned | NA |
| Avoid use of unfavourable area/period | 2 | 2.11 | Not mentioned | NA |
| Use tractor/Ox plough | 1 | 1.05 | Not mentioned | NA |

**Table 3 :** Distribution of gender roles in various activities in Mwea

| Activity | % Male | % Female | % Youth |
|---|---|---|---|
| Land preparation | 66.3 | 25.3 | 2.1 |
| Planting | 55.8 | 37.9 | 3.2 |
| Weeding | 52.6 | 38.9 | 3.2 |
| Harvesting | 54.7 | 41.1 | 3.2 |
| Marketing | 90.5 | 6.3 | 0.0 |

**Table 4 :** Agronomic results of on-farm trials in Mwea

| Treatment | Farm/Site | Planting date | Plant height (cm) | Days to flowering | Days to maturity | Yield ton/ha |
|---|---|---|---|---|---|---|
| Farmers practice (1) | Kiamanyeki | 4/16/2013 | 12.5 | 44 | 91 | 1.7 |
| | Ngothi Farm | 4/22/2013 | 13.0 | 45 | 91 | 2.1 |
| Ridging and DAP (2) | Kiamanyeki | 4/16/2013 | 17.0 | 44 | 91 | 3.8 |
| | Ngothi Farm | 4/22/2013 | 11.0 | 49 | 96 | 2.9 |
| Ridges +FYM +DAP (3) | Kiamanyeki | 4/16/2013 | 22.5 | 44 | 91 | 3.1 |
| | Ngothi Farm | 4/22/2013 | 9.0 | 52 | 98 | 3.7 |


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**Figure 5**: Well managed green gram field (Notice poorer performance mid-left)

**Table 5 :** Intervention-enhanced soil chemical characteristics at Mwireri farm

| | Management Practices | Ridges + DAP + FYM | Ridges + DAP | Farmers' practice |
|---|---|---|---|---|
| **Fertility status** | pH | 7.34 | 7.46 | 7.29 |
| | Tot N% | 0.25 | 0.24 | 0.23 |
| | Org C. % | 2.44 | 2.35 | 2.30 |
| | K me % | 0.18 | 0.16 | 0.16 |
| | Ca me % | 9.09 | 8.01 | 5.01 |
| | Mn me % | 0.33 | 0.29 | 0.23 |
| | Na ppm | 1.18 | 0.98 | 0.60 |
| | Ec mS/cm | 1.04 | 0.72 | 0.79 |

Potash (MOP), and Mavuno each agreed these would improve soils for better crop performance.

**On-Farm Demonstration**

*Crop performance*

**Table 4** shows the results of the on-farm demonstration plots . The plant height for green grams (Kiamanyeki) was higher in the two intervention plots by 4.5 and 10.0cm for treatments 2 and 3 and yielded higher, that is 123% and 82% respectively. There was however no difference in days-to-flowering in the three treatments. At Ngothi, although the tomato plant heights were lower for the plots to which FYM and DAP were applied; these flowered later and yielded higher by 38% and 76% for the respective applications. **Figure 5** shows the performance of green grams under FYM application on the foreground compared to the non-FYM application portion immediately behind it.

**Table 5** shows some enhanced differences shown in the various management options. Both DAP application and FYM enhanced pH, Tot Nitrogen (N), Organic Carbon, Potassium (K), Calcium (Ca), Manganese (Mn), Sodium (Na) and Electrical conductivity (Ec) of soils at Mwireri farm.

*Economic evaluation*

Results of economic evaluation are shown in **Table 6.** With farmers' practice whereby local seed is used and neither FYM, DAP nor ridging is done, there was yield of 2.1kg and 1.7kg of tomato and green gram respectively. When, however, ridges were instituted along with DAP the yields jumped to 3.8kg and 2.9kg for the respective crops and would bring an additional income of Ksh 467, 695 and 104, 345 per acre for ridging + DAP and Ksh 397, 930 and 134,880 per acre for ridging + FYM + DAP for the respective crops. These translated to 178% and 143% and 144% and 185% more income for the respective intervention options and crops.


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**Table 6 :**Economic evaluation of the instituted options at Mwea

| Interventions | Inputs | Rate/Unit used/ obtained | Cost per unit | Total cost/income |
|---|---|---|---|---|
| **Farmers practice** | Seed (green grams) | 0.5 kg | Not used | - |
| | (Tomato) | 0.5 kg Tin | Not used | - |
| | Ridging | 4 Man days | Not done | - |
| | DAP fertilizer | 50 Kg | Not used | - |
| | DAP application | Man day | Not used | - |
| | Tomato yield | 2.1* Tons | 125,000KES | 262,500KES |
| | Green gram yields | 1.7* Tons | 38,500KES | 65,450 KES |
| **Ridges + DAP** | Seed (green grams) | 0.5 kg | 400 KES | 400 KES |
| | (Tomato) | 0.5 kg Tin | 600 KES | 600 KES |
| | Ridging | 4 Man days | 260 KES | 1040 KES |
| | DAP fertilizer | 50 Kg | 2,500 KES | 5000 KES |
| | DAP application | 1 Man day | 260 KES | 260 KES |
| | Tomato yield | 3.8* Tons | 125,000KES | 475,000KES |
| | Green gram yields | 2.9*Tons | 38,500KES | 111,650 KES |
| **Ridges + DAP + FYM** | Seed (green grams) | 0.5 kg | 400 KES | 400 KES |
| | (Tomato) | 0.5 kg Tin | 600 KES | 600 KES |
| | Ridging | 4 Man days | 265 KES | 1040 KES |
| | DAP fertilizer | 50 Kg | 2,500 KES | 5000 KES |
| | DAP application | 1 Man day | 265 KES | 265 KES |
| | FYM application | 1Ton | 265KES | 265 KES |
| | Tomato yield | 3.1* Tons | 25,000KES | 387,500KES |
| | Green gram yields | 3.7* Tons | 38,500KES | 142,450 KES |

## Discussion

*Socio-economic evaluation*

In view of the farm sizes being predominantly small (2-5 acres); it is important that there are significant economic returns to the management interventions used. Enhanced productivity is applicable more to male-headed households (80%) than female headed households

(20%) and hired farms (82%) than those which are self-owned (18%). It is recommended that high-value crops like tomato be grown in order to realize the areas potential for even alleviating the prevalent food insecurity. Other reasons given by farmers for choice of crops they grow included resistance to water logging, suitability for the environment and higher yields. International Soil Reference and Information Centre (2015), for example, also report increased wheat and hoarse bean yields of 150% and 300%, respectively under improved vertisol management options.

*Management options*
Despite having several (9) management options at the farmers discretion (**Table 2**) only a reduced number used drainage and furrows/ridges while a higher number used manure, fertilizer and shifting options. It is necessary to institute strategies in farmers' fields with a quick maturing crop variety (green grams) since rice is already established and researched adequately by Mwea Integrated Agricultural Development (MIAD) centre working within the National Irrigation Board (NIB).

*Labour*
High labour demand and cost for instituting these options was mentioned by all the farmers as a hindrance to adoption but they were recognized as yield enhancing options except for two farmers who responded that they would not enhance yields. Due to the labour constraints instituting and maintaining ridges as a management option would be most sustainable for households having 5 members per household (37% of the population i.e. 142 households) (**Figure 1**).

Despite the need for labour at earlier farm activities (especially when management options need to be instituted) it was at the marketing stage that this force was directed. Goe (1987) Jutzi et al., (1987) and Macharia et al., (1998) have indicated animal traction and improvised plough implements respectively to enhance land preparation and ridging and eventual yield improvement in vertisols.

*On-farm evaluation*
The plant height for green grams (Kiamanyeki) was generally higher in the ridging + DAP and the ridges + DAP + FYM treatments. This can be attributed to better nutrition and water management in the two intervention plots. At Ngothi, these two interventions extended the flowering period and ensured higher tomato yields. Ikitoo (2008) and Sigunga (1997) report similar enhanced crop yields in vertisols in Kenya. Improvements in soil chemical characteristics were also reported with pH, total N, organic carbon K and C but also major economic returns in crop production. Use of organic inputs such as FYM should be particularly enhanced to improve crop nutrition since it is not only available but currently underutilized.

## Conclusion

The socio-economic survey reveals that challenges associated with crop production in vertisols are dependent on household characteristics such as members per household, farm sizes and the manner in which family and hired labour are utilized. Interventions should therefore particularly be targeted to medium sized farmholds (i.e. 2-5acres), the youth and households with 5 members per household to have high impact.

If local seed is used and neither FYM, DAP nor ridging is done on vertisols at Mwea, both tomato and green gram yields and income would remain relatively low and even uneconomical to raise. When, however, the ridging + DAP are instituted with additional extra labour the yields and incomes would increase by 81% and 19% for tomato and green grams respectively. A further institution of FYM to the vertisols would increases these yields and income by 48% for tomato and by 29% for the green grams.

Despite having several soil management options at his/her disposal a few simple agronomic combinations that are manageable and demonstrated and up/out scaled by all stakeholders gives representative results that can be easily adopted under the farmers' socio-economic conditions. A clearly enhanced soil, crop and economic conditions arise from using these management options as is demonstrated that would cover the constraints of labour and physical impediments recognized in the vertisols.

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## Conflict of Interests
The authors hereby declare that there are no conflicts of interest.

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