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Integrating scientific and farmers' perception towards evaluation of rain-fed agricultural technologies for sorghum and cowpea productivity in Central Kenya

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Soil fertility degradation remains the major biophysical cause of declining per capita crop production on smallholder farms in Central Kenya highlands. A study was conducted to compare farmers' perception and biophysical data on selected water harvesting and integrated soil fertility management technologies on sorghum (*Sorghum bicolor* (L.) Moench) and cowpea (*Vigna unguiculata* L.) production in Central highlands of Kenya. Three hundred and seventy one smallholder farmers were invited to evaluate thirty six plots laid out in Partially Balanced Incomplete Block Design (PBIBD) replicated three times. The treatment which was ranked best overall rated as 'good' by the farmers was farmers practice with a mean score of (2.78) and yielding (3.5 t/ha) under sorghum alone plus external soil amendment of 40 kg P /ha+20 kg N /ha. This was closely followed by tied ridges and contour furrows overall rated as 'good' by the farmers under sorghum alone plus external soil amendment of 40 kg P /ha+20 kg N /ha+manure 2.5 t/ha and 40 kg P /ha+40 kg N /ha+manure 5 t/ha both with a mean score of (2.7) and yielding (3.0 t/ha) and (2.9 t/ha) respectively. Generally, all experiment controls were overall scored as 'poor' yielding as low as 0.3 t/ha to 0.6 t/ha. Therefore, integration minimal addition of organic and inorganic inputs on highly valued traditional crops with adequate rainfall under normal farmers practice in semi arid lands could be considered as an alternative option contribution to food security in central highland of Kenya.

Key words: Food security, water harvesting, integrated soil fertility management, Central Kenya.

INTRODUCTION

Smallholder farms in Central highlands of Kenya are characterized by unreliable rainfall distribution and declining soil fertility that are unsuitable for sustainable rain-fed agriculture in semi-arid lands (SALs) (Miriti, 2011). Approximately 83% of Kenya's land surface is classified as ASALs, that is characterized by low and erratic rainfall (100-900 mm per annum) which is not suitable for sustainable rain-fed agriculture. Agricultural production is affected by the high variability of rainfall onset, distribution and frequent droughts which usually

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occur during the growing season, often resulting in depressed yields and persistent crop failures (Keating et al., 1992; Miriti et al. 2012). Agricultural intensification requires the maintenance of soil physical, chemical and biological quality. The loss of nutrients through plant nutrient mining, removal of crop residues, erosion, leaching or volatilization, and the deterioration of soil physical properties can independently or interactively result in yield reduction (Bielders et al., 2002). Appropriate technologies need to be employed on the basis of their ability to maintain soil fertility (mulching; e.g., Batiano et al., 2004), to conserve the soil against soil losses by wind erosion (mulching or ridging), and to improve soil physical conditions in the topsoil. This suggests that only low-input technologies may be currently suitable and need to be adopted through a known crop intensification technologies that could be enhanced in Arid and semi-arid lands (ASALs) of Kenya. Therefore more research is needed to find out comparison of scientific research as compared to farmers perceptions towards these technologies.

Soil fertility degradation is a major biophysical cause of declining per capita crop production and food security on smallholder farms in Central Kenya (Bationo et al., 2004; Kimani et al., 2007). The soil fertility decline is as a result of a combination of processes such as high rates of soil erosion, nutrient leaching, removal of crop residues, continuous cultivation of the land without adequate fertilization and fallowing (Njeru et al., 2011; Okalebo et al., 2006). The average annual loss in soils nutrients of 42 kg Nitrogen (N), 3 kg Phosphorus (P) and 29 kg Potassium (K) ha^{-1} in Kenya is among the greatest in Africa (Smaling et al., 1997). The rising cost of inputs has led to many smallholder farmers reducing or abandoning the use of chemical fertilizer altogether in Central Kenya (Gachimbi, 2002). The Kenyan ASALs are also experiencing low crop production due to a combination of biophysical problems such as factors such as low rainfall, surface sealing, unavailability of high quality manure, declining soil fertility due to continuous cultivation and crust formation that reduces soil water availability to crops (Gicheru, 2002; Gitau, 2004). Several recent studies have yielded little evidence on occurrence of dry spells to increase the frequency of rain water use efficiency in ASALs of Africa (Stroosnijder, 2009). This has been contributed by mixed crop-livestock systems being currently projected to see reduction in crop production throughout most East Africa regions due to climate change by 2050 (Thornton et al., 2010). Therefore, food security situation is expected to continue deteriorating and could worsen in future if water harvesting and integrated soil fertility technologies are not taken up quickly particularly in Kirinyaga West District of Central Kenya. Traditional crops such as sorghum and cowpea are considered as the crop for the future which can contribute to food security (Fongod et al., 2012).

Improving agricultural productivity is crucial for resolving food crises, enhancing food security and accelerating pro-poor growth. Most food security research and development programmes tend to focus high and medium potential on promoting technologies for a limited number of major crops such as maize and beans in high potential areas, and neglected the high valued traditional crops which are drought tolerant and provides local nutrition in the vulnerable areas. Yet, sorghum and cowpea are locally important for food and household nutrition, and provide income opportunities for the most vulnerable people and women in particular. These premium crops have potential to diversify the farming systems, adapt to spread risks and are more resilient to climatic variations and climate change. This study assessed the farmer's evaluation on selected water harvesting and integrated soil fertility management technologies on sorghum and cowpea productivity in Ndia West division of Kirinyaga West District in Central highland of Kenya.

MATERIALS AND METHODS

Figure 1 shows Ndia West division of Kirinyaga West District indicating the location of the study site in central Kenya. The figure also shows the level of poverty level in this areas and this indicates the need for employing water harvesting and integrated soil fertility management technologies in the area.

Site description

The study was conducted in Ndia West division of Kirinyaga West District which represents an area of declining potential occupying total area of 1437 km^2. The District lies between latitudes 0°1° and 1°40° south and longitudes 37° and 38° east at an altitude of 1,480 to 6,800 m above the sea level. The total population of the district is 509,157 individuals out of which 30.2% are considered food poor. The population density is 309 people per km. The district has about 97,970 farm families working in the agricultural sector occupying about 96,938 farm holdings with an average farm size of 1.25 ha per family (Government of Kenya, 2007). There are four major Agro-ecological zones (AEZs) in the District (LH1, UM1, UM2 and UM3), with maize-beans, horticulture, French beans, dairy, coffee and banana production being the major crops. It receives a mean rainfall between 900-2,700 mm per annum and has temperatures of between 14 and 30°C. The soils in this district are volcanic which are known as andisols favorable for maize crop production. In addition, the district has two rain seasons- long and short rains between March-June and July-December respectively. The question is how to ensure that this area that previously was high potential does not continue to deteriorate into a low potential area (Jaetzold et al., 2007).

Soil physical characteristics of Kirinyaga West District

The results of the three types of soil texture sand (13%), silt (78%) and clay (10%) has indicated that the soil types is silty loams in Kirinyaga West District.

Experimental design

The treatments were arranged in a factorial structure each

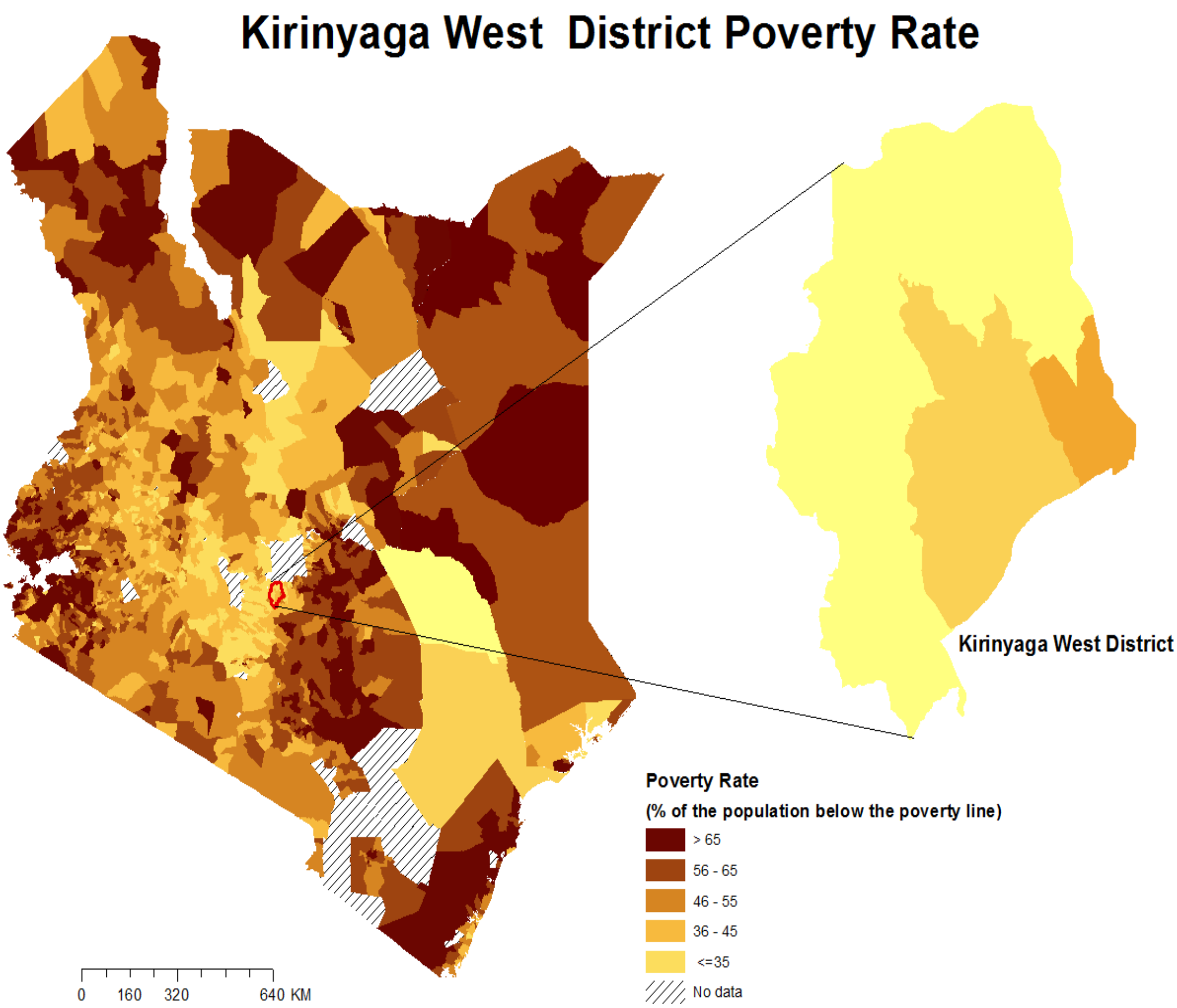

Figure 1. Map of Kenya showing the study area in Kirinyaga West District of Central Kenya.

treatment being a combination of one of the 3 levels of water harvesting techniques, cropping systems were 2 levels and the soil fertility amendment options were 6 levels thus giving a total of 36 treatments.

Water harvesting techniques (3 levels) includes:

1. Tied ridges;
2. Contour furrows, and
3. Conventional tillage/farmers practice.

Cropping systems (2 levels) includes:

1. Sole sorghum (Gadam)
2. Sorghum and cowpea (M66) intercrop;

Soil fertility amendment options (6 levels) includes:

1. Control
2. 40 kg P /ha+40 kg N /ha
3. 40 kg P /ha+20 kg N /ha
4. 40 kg P /ha+40 kg N /ha+Manure 5 t/ha
5. 40 kg P /ha+20 kg N /ha+Manure 2.5 t/ha
6. Manure 5 t/ha

They were laid out in a Partially Balanced Incomplete Block Design (PBIBD) with six incomplete blocks per replicate each containing six treatments, replicated 3 times making a total of 108 plots. Treatments were assigned to blocks randomly. The plot size was 6 m × 4 m. The dry land sorghum (Gadam) and cowpea (M66) varieties were used as the test crops. Then at the end of the short rain 2011 season, smallholder farmers were invited for a field day to evaluate each plot by scoring in a scale of good, fair and poor according to their own observation on crop performance and this was compared with scientific data collected on crop productivity. They were all given equal opportunity to evaluate 108 plots in the field experiment. They were also asked the kind of water harvesting and soil fertility management they used in their farms.

Data analysis

Social data was coded and analyzed by use of SPSS version 17. Data was analyzed by use of descriptive analysis where frequencies of scores for each treatment were computed. Dependency tests were also conducted to find out if there was a relationship between gender and the treatment score. The difference between treatment scores and gender was declared

Table 1. Distribution (%) of water harvesting technologies practiced in Ndia West Division.

Types of water harvesting	(%)
Tied ridges	34.7
Contour furrow	28.2
Convectional tillage	34.7
Others	2.4
Total	**100**

N=371.

significant at P ≤ 0.05. The biophysical data on crop yield was analyzed using statistical Analysis of Variance (ANOVA) using SAS version 8. Differences between treatment effects were declared significant at P ≤ 0.05.

RESULTS

Water harvesting technologies available in Ndia West division

Table 1 shows water harvesting technologies which were in use on-farm in Ndia West Division, Kirinyaga West District. The table indicate that tied ridges and convectional tillage were the widely used means of water harvesting technologies where (34.7%) of respondents used them on their farms while (2.4%) of respondents did not use any of the above technologies.

Farmer’s evaluation on treatment performance

In Ndia division, the farmers' criteria for distinguishing plots was on a scale of good, fair and poor that included crop yield and performance. Table 2 underscore the value of taking into consideration the visual and morphological crop characteristics used by farmers as a key criterion for scientific crop evaluation and development during short rains 2011. The table show that treatment under farmers practice with sorghum alone plus soil amendment of 40 kg P /ha+20 kg N /ha attracted the highest preference of farmers who rated it as ‘good’ with a mean score of 2.78 and was ranked number one out of 36 treatments. This was followed by tied ridges and contour furrows under sorghum cropping system plus the same soil amendment of 40 kg P /ha+20 kg N /ha+manure 2.5 t/ha both with a mean score of 2.7. Also contour furrow under sorghum cropping system with optimal application of fertilizers and manure was also ranked under ‘good’ category. The results show that all the technologies ranked ‘good’ included combination of fertilizers and manure, or stand alone application.

The results further indicate that the overall rating of top 8 treatments was rated in the ‘good’ category by the smallholder farmers. This was contrary to the experiment controls which were rated as ‘poor’ treatment. The results further indicated that the experiment controls with tied ridges were rated in the ‘fair’ category.

Treatment score by gender

The results indicated that there was no significant difference ($p \geq 0.05$) regarding scoring by gender in all the 36 treatments of experiment which were ranked in the scale of good, fair and poor. However, there was a highly significant difference ($p<0.001$) on rating of treatments by smallholder farmers in Ndia Division, Kirinyaga West District.

Field experiment results

The result in Table 3 underscore the scientific crop evaluation from the field experiment during short rains 2011. The results show the effect of various water harvesting and integrated soil fertility management options for sorghum and cowpea productivity on biomass and grain yield. the table shows three types of water harvesting, two cropping system and six fertility amendment levels but only fertility levels that differed significantly from one another (p=0.0001) in terms of sorghum grain yield. The three levels of water harvesting and the two cropping systems did not differ significantly in terms of grain yield among themselves (p=0.8413) and (p=0.7168) respectively. The total dry matter amount varied significantly among levels of cropping system and fertilizer application (p= 0.0216 and 0.0001) respectively. However the total dry matter amount did not vary significantly across water harvesting methods (p=0.5743). The sorghum biomass were significantly different among cropping system (p=0.0020) while water harvesting and fertility levels did not differ significantly (p=0.3930 and 0.0698).

Combination effect

The results further indicated that sorghum without manure application did not differ significantly in yield production with plots that did not receive fertilizer application. However, plots that received fertilizer and no manure gave slightly higher sorghum yield as compared to plots that received manure and no fertilizer (Table 2). The highest sorghum yield (3.5 t/ha) was recorded from farmer practice in sole sorghum cropping system with external nutrient replenishment of 40 kg P /ha+20 kg N /ha, followed by 3.0 t/ ha under tied ridges, sole sorghum cropping system with combination of half rate of fertilizer and manure. In the third place were three treatments (2.9 t/ha) under tied ridges and contour furrow, sole cropping system in both water harvesting and one intercrop under contour furrows with all under maximum nutrient

Table 2. Farmers' rating on water harvesting, cropping systems and ISFM technologies in Ndia division.

Water harvesting	Cropping systems	Soil fertility management regimes	Mean score	Mean rank	Overall rating
Farmers practice	Sole crop	40 kg P/ha+20 kg N/ha	2.78	2893.87	Good
Tied ridges	Sole crop	40 kg P/ha+20 kg N/ha+Manure 2.5 t/ha	2.7	2763.26	Good
Tied ridges	Sole crop	40 kg P/ha+40 kg N/ha+Manure 5 t/ha	2.7	2767.22	Good
Contour furrows	Sole crop	40 kg P/ha+20 kg N/ha+Manure 2.5 t/ha	2.68	2753.38	Good
Contour furrows	Intercrop	40 kg P/ha+20 kg N/ha+Manure 2.5 t/ha	2.63	2667.23	Good
Farmers practice	Sole crop	Manure 5t/ha	2.62	2641.8	Good
Tied ridges	Intercrop	40 kg P/ha+20 kg N/ha+Manure 2.5t/ha	2.6	2590.86	Good
Tied ridges	Sole crop	40 kg P/ha+40 kg N/ha	2.53	2480.37	Good
Farmers practice	Sole crop	40 kg P/ha+20 kg N/ha+Manure 2.5t/ha	2.49	2443.79	Fair
Tied ridges	Intercrop	40 kg P/ha+40 kg N/ha+Manure 5t/ha	2.49	2462.85	Fair
Contour furrows	Sole crop	40 kg P/ha+40 kg N/ha	2.48	2403.52	Fair
Farmers practice	Sole crop	40 kg P/ha+40 kg N/ha	2.46	2384.7	Fair
Tied ridges	Sole crop	40 kg P/ha+20 kg N/ha	2.45	2397.72	Fair
Tied ridges	Intercrop	40 kg P/ha+40 kg N/ha	2.44	2310.8	Fair
Contour furrows	Intercrop	40 kg P/ha+20 kg N/ha	2.43	2368.56	Fair
Tied ridges	Sole crop	Manure5t/ha	2.43	2338.03	Fair
Farmers practice	Intercrop	40 kg P/ha+40 kg N/ha	2.39	2280.98	Fair
Farmers practice	Intercrop	40 kg P/ha+20 kg N/ha	2.37	2243.88	Fair r
Farmers practice	Intercrop	40 kg P/ha+40 kg N/ha+Manure 5 t/ha	2.37	2256.27	Fair
Contour furrows	Sole crop	Manure 5t/ha	2.34	2208.08	Fair
Contour furrows	Intercrop	40 kg P/ha+40 kg N/ha+Manure 5 t/ha	2.33	2180.3	Fair
Contour furrows	Sole crop	40 kg P/ha+20 kg N/ha	2.31	2155.78	Fair
Farmers practice	Intercrop	Manure 5t/ha	2.31	2139.53	Fair
Contour furrows	Sole crop	40 kg P/ha+40 kg N/ha+Manure 5 t/ha	2.29	2123.15	Fair
Contour furrows	Intercrop	40 kg P/ha+40 kg N/ha	2.28	2107.65	Fair
Tied ridges	Intercrop	40 kg P/ha+20 kg N/ha	2.27	2098.91	Fair
Farmers practice	Intercrop	40 kg P/ha+20 kg N/ha+Manure 2.5 t/ha	2.03	1740.38	Fair
Contour furrows	Intercrop	Manure 5t/ha	2.02	1687.24	Fair
Tied ridges	Intercrop	Manure 5t/ha	2	1686.05	Fair
Farmers practice	Sole crop	40 kg P/ha+40 kg N/ha+Manure 5t/ha	1.76	1385.2	Fair
Tied ridges	Sole crop	Control	1.74	1412.16	Fair
Tied ridges	Intercrop	Control	1.56	1160.19	Fair
Contour furrows	Sole crop	Control	1.47	1053.38	Poor
Contour furrows	Intercrop	Control	1.32	865.29	Poor
Farmers practice	Sole crop	Control	1.18	677.2	Poor
Farmers practice	Intercrop	Control	1.08	534.38	Poor

N=371; Test statistics: Kruskal-H test; Chi-square =1237.5; d.f =35; p=0.000.

replenishment of 40 kg P /ha+20 kg N /ha . However the four treatments yield did not differ significantly from one another ($p<0.05$). The lowest sorghum yield (< 2.0 t/ha) was observed in treatments regarded as 'control' with neither fertilizer nor manure regardless of other intervention (water harvesting method or cropping system). Total dry matter was more in plots with farmer practice, sole cropping and maximum (40 kg N/ha) N fertilizer application but no manure (7.7 t/ha), followed by (7.1 t/ha) from plots under tied ridges, sole cropping with half rate (20 kg N/ha) fertilizer and (2.5t/ha) manure. Others that did well in total dry matter production were treatments under farmer practice, sole and intercrops with half rate of (20 kg N/ha) N fertilizers and (2.5 t/ha) manure (6.9 t/ha). All these top producers did not differs significantly from one another ($p<0.05$).

DISCUSSION

Farmer's evaluation on treatment performance

The results (Table 1) indicated that 34.7% of the respondents both used tied ridges and convectional

Table 3. The effects of water harvesting, cropping system and soil fertility regimes on sorghum yields in Ndia division.

Water harvesting method	Cropping system	Soil fertility management regimes	Total dry matter (t/ha)	Biomass+husks (t/ha)	Grain yield (t/ha)
Farmer practice	Sole crop	40 kg P/ha+20 kg N/ha	7.0	3.5	3.5
Tied ridges	Sole crop	40 kg P/ha+20 kg N/ha+manure 2.5 t/ha	7.1	4.1	3.0
Contour furrows	Sole crop	40 kg P/ha+40 kg N/ha	6.4	3.5	2.9
Tied ridges	Sole crop	40 kg P/ha+40 kg N/ha	6.3	3.4	2.9
Contour furrows	Intercrop	40 kg P/ha+40 kg N/ha	6.0	3.1	2.9
Farmer practice	Sole crop	Manure 5 t/ha	6.6	3.8	2.8
Farmer practice	Sole crop	40 kg P/ha+40 kg N/ha	7.8	5.1	2.7
Contour furrows	Sole crop	40 kg P/ha+20 kg N/ha+manure 2.5t/ha	6.1	3.4	2.7
Farmer practice	Intercrop	40 kg P/ha+40 kg N/ha	4.9	2.2	2.7
Tied ridges	Intercrop	40 kg P/ha+20 kg N/ha+manure 2.5t/ha	5.8	3.2	2.6
Tied ridges	Intercrop	40 kg P/ha+40 kg N/ha+manure 5t/ha	5.6	3.0	2.6
Contour furrows	Intercrop	40 kg P/ha+20 kg N/ha	4.9	2.3	2.6
Farmer practice	Intercrop	Manure 5 t/ha	6.2	3.7	2.5
Contour furrows	Sole crop	40 kg P/ha+40 kg N/ha+manure 5t/ha	5.9	3.4	2.5
Tied ridges	Sole crop	Manure 5 t/ha	6.7	4.3	2.4
Contour furrows	Intercrop	40 kg P/ha+20 kg N/ha+manure 2.5t/ha	5.7	3.3	2.4
Tied ridges	Intercrop	40 kg P/ha+20 kg N/ha	5.7	3.3	2.4
Contour furrows	Sole crop	Manure 5 t/ha	4.9	2.5	2.4
Farmer practice	Intercrop	40 kg P/ha+20 kg N/ha+manure 2.5t/ha	6.0	3.7	2.3
Contour furrows	Intercrop	40 kg P/ha+40 kg N/ha+manure 5t/ha	7.9	5.6	2.3
Contour furrows	Intercrop	Manure 5 t/ha	5.4	3.1	2.3
Farmer practice	Intercrop	40 kg P/ha+20 kg N/ha	6.2	4.0	2.2
Farmer practice	Sole crop	40 kg P/ha+20 kg N/ha+manure 2.5t/ha	6.2	4.1	2.1
Tied ridges	Sole crop	40 kg P/ha+20 kg N/ha	5.8	3.7	2.1
Tied ridges	Intercrop	40 kg P/ha+40 kg N/ha	5.2	3.1	2.1
Farmer practice	Sole crop	40 kg P/ha+40 kg N/ha+manure 5t/ha	5.1	3.0	2.1
Tied ridges	Intercrop	Manure 5 t/ha	5.0	2.9	2.1
Contour furrows	Sole crop	40 kg P/ha+20 kg N/ha	6.0	4.0	2.0
Tied ridges	Sole crop	40 kg P/ha+40 kg N/ha+manure 5t/ha	5.9	3.9	2.0
Farmer practice	Intercrop	40 kg P/ha+40 kg N/ha+manure 5t/ha	5.7	3.7	2.0
Tied ridges	Sole crop	Control	1.7	1.1	0.6
Tied ridges	Intercrop	Control	1.5	0.9	0.6
Contour furrows	Sole crop	Control	1.9	1.4	0.6
Contour furrows	Intercrop	Control	2.4	1.9	0.5
Farmer practice	Sole crop	Control	1.4	1.0	0.4
Farmer practice	Intercrop	Control	1.0	0.7	0.3
Means			5.6	3.3	2.3
CV			19.0	25.3	22.9
LSD			1.96	1.54	0.98

tillage as their main land preparation methods and soil fertility management on their on-farm. This was followed by contour furrows 28.2%. This could be as a result of lack of knowledge on water harvesting methods they use when growing sweet potatoes and tobacco in the area. The consistently high preference (Table 2) by farmers on overall rating as 'good' on farmers practice, tied ridges and contour furrow under sorghum alone with organic and inorganic inputs at half dose application of Nitrogen was an indication that farms in Kirinyaga West district require minimal nutrient replenishment. Soil fertility degradation is one of the major problems facing crop productivity in central Kenya. It is defined by Stocking and Murnaghan (2000) as the loss of soil physical and nutritional qualities. It has been an issue of concern throughout central Kenya, and cuts across many different soils and crops (Okalebo et al., 2007). Integrated soil fertility management (ISFM) has been cited by many authors, including Okalebo et al. (2007), Gumbo (2006) and Raab (2002), as the key approach in raising productivity levels in agricultural systems while maintaining the natural resource base. It is described by Vanlauwe and Zingore (2011) as a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity in this region. Because of the pressing need for global food security, many articles have been published which relate ISFM to the production of annual food crops like maize (Ikerra et al., 2007; Kimani et al., 2007), and rice (Kaizzi et al., 2007), giving lesser attention to perennial crops like coffee. It is no longer wondering then that the role of ISFM for sorghum and cowpea in central Kenya and the socio-economic perception of it have not been studied to any significant detail. Studies by Mugendi et al. (2010) and Gachimbi (2002) have also reported that farms in central Kenya require nutrient replenishment every season from manures, fertilizers and also from return of crop residue in their farms. It has also been reported by Njeru et al. (2010) and Mairura et al. (2007) that soil fertility can be accessed through visual observation of crop performance and yield. Therefore, soil fertility degradation has emerged as the most limiting factor in all the cropping systems of central Kenya. This is however, a very generic perception which needs to be studied in detail by targeting specific locations and farming communities in the region.

The results (Tables 2 and 3) further indicate that water harvesting technologies played a major role in moisture conservation where most of the technologies were highly ranked by the farmers. Soil desiccation is either caused by low and unreliable rainfall, poor water harvesting techniques and unsustainable farming practices in central Kenya. Low and declining soil fertility arises from continuous cultivation where levels of soil replenishment, by whatever means, are too low to mitigate the process of soil mining, whereby the soil fertility is not replaced by new inputs together with appropriate water harvesting structures on-farm (Shisanya et al., 2009). Kimani et al. (2004) has also reported that no matter how effectively other constraints are remedied, per-capita food production in central will continue to decrease unless soil fertility depletion is addressed. These results are in agreement with those reported by Miriti et al. (2012) found that farmer perception can be fairly compared with scientific data especially when soil fertility is closely related to the soil's water holding capacity.

The results (Table 2 and 3) from the farmers responded and biophysical data shows that the best four treatments of tied ridges, contour furrow and farmers practice under intercrop of sorghum and cowpea were generally ranked fairly and they were dominated by sole cropping system with soil amendment of 40 kg P/ha+20 kg N/ha+Manure 2.5t/ha. Studies have indicated that most African soils are inherently low in organic carbon (<20 to 30 mg kg^{-1}) due to; low root growth of crops and natural vegetation, continuous cultivation of crops and rapid turnover rates of organic materials with high soil temperature and microfauna (Bationo and Waswa., 2011). Furthermore, there are indications that up to 0.69 tons loss of carbon ha^{-1} $year^{-1}$ in the soil surface layers are common in Africa even with high levels of organic inputs (Nandwa, 2003). For a long-term productivity of agro-ecosystems and protection of the environment, it is necessary to develop and implement management strategies that maintain the quality of soil, through integrated soil fertility management options (Godsteven et al., 2013).

Eghball and Power (2005) has also reported similar results that a general increase in organic carbon after application of manure and mineral fertilizer over time can improve crop productivity. These results further indicate that a combination of both organic and inorganic fertilizers is better at improving soil fertility compared to their sole applications. These results are in agreement with those reported by Kathuku et al. (2011) that there was an increase in yield and soil nutrient availability in soil that was added mineral N fertilizer combined with manure when compared to their sole applications. The manure only treatment showed a reduction in crop yield in the first season and this could have resulted from the reaction of P with organics in manure to form more stable compounds making it unavailable for plant uptake (Waldrip et al., 2012). These findings are in line with Yuste et al. (2007) who reports that the higher the carbon inputs added to the soil the higher the soil respiration. Therefore, in order to increase crop productivity, and reduce production risks, better use of available rainfall and improved nutrient use efficiency is required in central Highlands of Kenya.

The results (Tables 1 and 3) have indicated that all experiment intercrops were basically ranked fairly by the farmers. This could be as a result of nutrient competition since cowpeas are heavy nutrient miners as they are associated with interspecific competition in mixed stands. The same results have been reported by Katsaruware et al. (2009) that crop yield reduction can be experienced in intercrops where they are associated with interspecific competition in mixed stands and the absence of interspecific competition in the monocrops. The results further indicate that probably intercropping sorghum with cowpea depressed sorghum yields which influenced farmers to rank them in fair category. This outcome for sorghum (Table 2 and 3) could be in line with reports for maize from Kenya (Nadar, 1984) and in Tanzania (Jensen et al., 2003) where maize grain yields reduction of 46-57 and 9% occurred when maize was intercropped with cowpea due to the competition for moisture between the two crops. Alternatively due to slow mineralization of manure which could graduate to good category with given number of seasons (Lekasi et al., 2003). The results by Miriti (2011) reported that cowpea was a nutrient competitor for maize production in semi-arid areas of eastern Kenya. The results (Tables 2 and 3) had a very clear trend on farmer's perception and crop yield that for all those treatments regarded as 'controls' were poorly ranked by the farmers and had lower crop yields regardless of water harvesting and cropping system. This is in line with cultivation in the same piece of land for a continuous cultivation results to nutrient depletion and requires nutrient replenishment (Mugwe et al., 2009; Miriti et al., 2003). Land degradation as a result of various biophysical factors contributing to reduction in agricultural productivity has contributed to farmers being discouraged from adoption of these water conservation structures due to labour shortage and land tenure uncertainty (Demelash and Stahr, 2010).

Conclusion

The results reported in the study demonstrate that smallholder farmers' knowledge can provides a consistent treatment evaluation. There was clear evidence from the study that no difference was noted in terms of scoring of treatments by gender in Ndia Division, Kirinyaga West District. Therefore, both genders could be used by agricultural extension services and researchers for evaluation of other related scientific work in this study area. Kirinyaga West district is characterized by low and erratic rainfall and generally fragile ecosystems which are not suitable for sustainable rain-fed agriculture. The results have indicated that there are needed to incorporate various water harvesting technologies and minimum soil nutrient supplements during seasons with low rainfall distribution regardless of water harvesting technology employed in semi-arid areas. This also suggests that only low-input technologies are currently suitable and need to be adopted through a known crop intensification technologies that could be enhanced in these areas of central highland of Kenya. The results have also demonstrated a very clear message to smallholder farmer, extension services and other stakeholders that there is need for water harvesting technologies and nutrient replenishment on-farm every season for increased sorghum and cowpea productivity in central highland of Kenya.

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