Drought-Tolerant Crops in Kirinyaga County, Kenya: Climate-Smart Agriculture Adaptation Strategies

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Abstract

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 Kirinyaga County of Kenya. Three hundred and seventy-one smallholder farmers were invited to evaluate 36 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 treatment was closely followed by water harvesting technologies tied ridges and contour furrows overall rated as "good" by the farmers. These being under cultivation of 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, integrating organic and inorganic inputs on sorghum production under farmers' practice could be an alternative option contributing to food security in central highland of Kenya.

Keywords

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 semiarid lands (SALs) (Miriti 2011). Approximately 83% of Kenya's land surface is classified as arid and semiarid lands (ASALs) that are characterized by low and erratic rainfall (100–900 mm per annum) which is not suitable for sustainable rain-fed agriculture. Agricultural production is highly affected by the high variability of rainfall onset in short and long rain season, distribution and frequent droughts that usually 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., Bationo et al. 2000), 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 semiarid lands (ASALs) of Kenya. Therefore, more research is needed to find out the comparison of scientific research as compared to farmers' perceptions toward 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 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 soil 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 like 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 rainwater 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 County. Traditional crops such as sorghum and cowpea are considered as the crop for the future that 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 programs 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 provide 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 subcounty in central highland of Kenya. This study was conducted to compare farmers' perception and biophysical data on selected water harvesting and integrated soil fertility management technologies on sorghum and cowpea production in Kirinyaga County of Kenya.

Materials and Methods

Site Description

The study was conducted in Ndia West division of Kirinyaga County which represents an area of declining potential occupying total area of 1437 km^2. The County lies between latitudes 0^0 1^1 and 0° 40^1 south and longitudes 37° and 38^1 east at an altitude of 1480 meters to 6800 meters above the sea level. The total population of the County is 509,157 individuals out of which 30.2% are considered food poor. The population density is 309 people per km^2. The County 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 agroecological zones (AEZs) in the County (LH1, UM1, UM2, and UM3), but the study was done in UM3, with maize-beans, horticulture, French beans, dairy, coffee, and banana production being the major crops. It receives a mean rainfall between 900 and 2700 mm per annum and has temperatures of between 14 °C and 30 °C. The soils in this County are volcanic which are known as andisols favorable for maize crop production. In addition, the County has two rain seasons – long and short rains between March and June and July and December, respectively.

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

Soil Physical Characteristics of Kirinyaga West County

The results of the three types of soil texture such as sand (13%), silt (78%), and clay (10%) have indicated that the soil types are silty loams in Kirinyaga County.

Experimental Design

The treatment were arranged in a factorial structure each treatment being a combination of one of the three levels of water harvesting techniques, cropping systems were two levels and the soil fertility amendment options were six levels thus giving a total of 36 treatments.

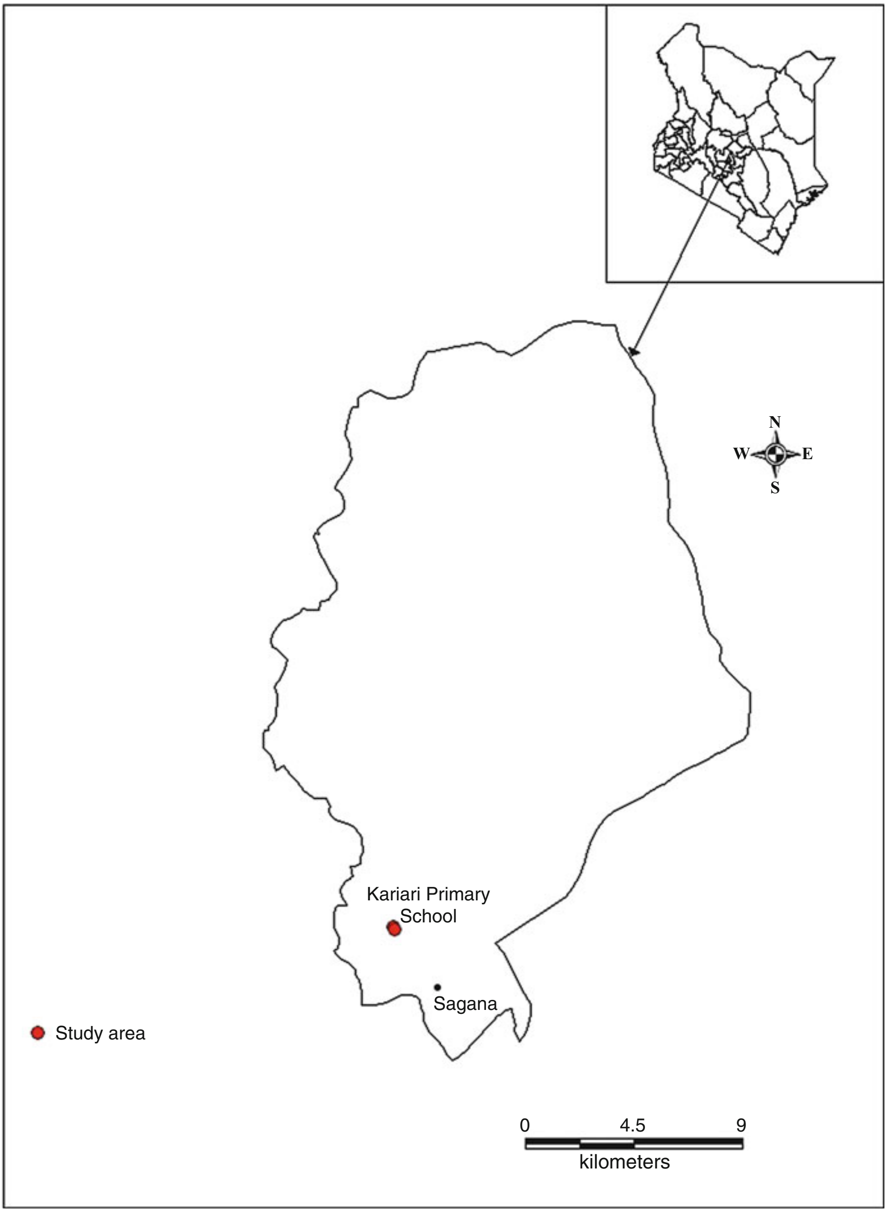

Fig. 1 Map of Kenya showing the study area in Kirinyaga County of Central Kenya

- **Water harvesting techniques (three levels)**
  - Tied ridges
  - Contour furrows
  - Conventional tillage/farmers' practice

- **Cropping systems (two levels)**
  - Sole sorghum (Gadam)
  - Sorghum and cowpea (M66) intercrop
- **Soil fertility amendment options (six levels)**
  - Control
  - 40 Kg P/ha + 40 Kg N/ha
  - 40 Kg P/ha + 20 Kg N/ha
  - 40 Kg P/ha + 40 Kg N/ha + manure 5 t/ha
  - 40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha
  - 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 three times making a total of 108 plots. Treatments were assigned to blocks randomly. The plot size was 6 m $\times$ 4 m. The dryland 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 the use of SPSS version 17. Data was analyzed by the 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 significant at $P \leq 0.05$. 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 $P \leq 0.05$.

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 County. Tied ridges and convectional tillage were the widely used means of water harvesting technologies where 34.7% of respondents

Table 1 Household (%) practicing water harvesting technologies in Ndia West division

Household distribution of different water harvesting technologies practiced	(%)
Tied ridges	34.7
Contour furrow	28.2
Convectional tillage	34.7
Others	2.4
Total	**100**

(N = 371)

used them on their farms while 2.4% of respondents did not use any of the above technologies (Table 1).

Farmer's Evaluation on Treatment Performance

In Ndia West division, the farmers' criteria for distinguishing plots was on a scale of good, fair, and poor that included crop yield and performance. The findings (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.

Table 2 shows 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 1 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 that ranked "good" included a combination of fertilizers and manure or standalone application.

The results further indicate that the overall rating of the top eight 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

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 West division, Kirinyaga West County.

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

Water harvesting	Cropping systems	Soil fertility management regimes	Mean rank	Overall rating
Farmers' practice	Sole crop	40 Kg P/ha + 20 Kg N/ha	2893.87	Good
Tied ridges	Sole crop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	2763.26	Good
Tied ridges	Sole crop	40 Kg P/ha + 40 Kg N/ha + manure 5 t/ha	2767.22	Good
Contour furrows	Sole crop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	2753.38	Good
Contour furrows	Intercrop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	2667.23	Good
Farmers' practice	Sole crop	Manure 5 t/ha	2641.8	Good
Tied ridges	Intercrop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	2590.86	Good
Tied ridges	Sole crop	40 Kg P/ha + 40 Kg N/ha	2480.37	Good
Farmers' practice	Sole crop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	2443.79	Fair
Tied ridges	Intercrop	40 Kg P/ha + 40 Kg N/ha + manure 5 t/ha	2462.85	Fair
Contour furrows	Sole crop	40 Kg P/ha + 40 Kg N/ha	2403.52	Fair
Farmers' practice	Sole crop	40 Kg P/ha + 40 Kg N/ha	2384.7	Fair
Tied ridges	Sole crop	40 Kg P/ha + 20 Kg N/ha	2397.72	Fair
Tied ridges	Intercrop	40 Kg P/ha + 40 Kg N/ha	2310.8	Fair
Contour furrows	Intercrop	40 Kg P/ha + 20 Kg N/ha	2368.56	Fair
Tied ridges	Sole crop	Manure5t/ha	2338.03	Fair
Farmers' practice	Intercrop	40 Kg P/ha + 40 Kg N/ha	2280.98	Fair
Farmers' practice	Intercrop	40 Kg P/ha + 20 Kg N/ha	2243.88	Fair
Farmers' practice	Intercrop	40 Kg P/ha + 40 Kg N/ha + manure 5 t/ha	2256.27	Fair
Contour furrows	Sole crop	Manure 5 t/ha	2208.08	Fair
Contour furrows	Intercrop	40 Kg P/ha + 40 Kg N/ha + manure 5 t/ha	2180.3	Fair
Contour furrows	Sole crop	40 Kg P/ha + 20 Kg N/ha	2155.78	Fair
Farmers' practice	Intercrop	Manure 5 t/ha	2139.53	Fair
Contour furrows	Sole crop	40 Kg P/ha + 40 Kg N/ha + manure 5 t/ha	2123.15	Fair

(*continued*)

Table 2 (continued)

Water harvesting	Cropping systems	Soil fertility management regimes	Mean rank	Overall rating
Contour furrows	Intercrop	40 Kg P/ha + 40 Kg N/ha	2107.65	Fair
Tied ridges	Intercrop	40 Kg P/ha + 20 Kg N/ha	2098.91	Fair
Farmers' practice	Intercrop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	1740.38	Fair
Contour furrows	Intercrop	Manure 5 t/ha	1687.24	Fair
Tied ridges	Intercrop	Manure 5 t/ha	1686.05	Fair
Farmers' practice	Sole crop	40 Kg P/ha + 40 Kg N/ha + manure 5 t/ha	1385.2	Fair
Tied ridges	Sole crop	Control	1412.16	Fair
Tied ridges	Intercrop	Control	1160.19	Fair
Contour furrows	Sole crop	Control	1053.38	Poor
Contour furrows	Intercrop	Control	865.29	Poor
Farmers' practice	Sole crop	Control	677.2	Poor
Farmers' practice	Intercrop	Control	534.38	Poor

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

Field Experiment Results

The results (Table 3) underscore the scientific crop evaluation from the field experiment during short rains 2011. The results further indicate the effect of various water harvesting and integrated soil fertility management options for sorghum and cowpea productivity on biomass and grain yield.

The results (Table 2) indifca 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 was significantly different among cropping system ($p = 0.0020$), while water harvesting and fertility levels did not differ significantly ($p = 0.3930$ and 0.0698).

Treatment Effect at all Levels of Interactions

The results further indicated that sorghum without manure application did not differ significantly in yield production with plots that did not receive fertilizer application.

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

Water harvesting method	Cropping system	Soil fertility management regimes	Total dry matter T/Ha	Grain yield T/ha
Farmer practice	Sole crop	40 Kg P/ha +20 Kg N/ha	7.0	3.5
Tied ridges	Sole crop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	7.1	3.0
Contour furrows	Sole crop	40 Kg P/ha +40 Kg N/ha	6.4	2.9
Tied ridges	Sole crop	40 Kg P/ha +40 Kg N/ha	6.3	2.9
Contour furrows	Intercrop	40 Kg P/ha +40 Kg N/ha	6.0	2.9
Farmer practice	Sole crop	Manure 5 t/ha	6.6	2.8
Farmer practice	Sole crop	40 Kg P/ha +40 Kg N/ha	7.8	2.7
Contour furrows	Sole crop	40 Kg P/ha +20 Kg N/ha + manure 2.5 t/ha	6.1	2.7
Farmer practice	Intercrop	40 Kg P/ha +40 Kg N/ha	4.9	2.7
Tied ridges	Intercrop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	5.8	2.6
Tied ridges	Intercrop	40 Kg P/ha +40 Kg N/ha + manure 5 t/ha	5.6	2.6
Contour furrows	Intercrop	40 Kg P/ha +20 Kg N/ha	4.9	2.6
Farmer practice	Intercrop	Manure 5 t/ha	6.2	2.5
Contour furrows	Sole crop	40 Kg P/ha +40 Kg N/ha + manure 5 t/ha	5.9	2.5
Tied ridges	Sole crop	Manure 5 t/ha	6.7	2.4
Contour furrows	Intercrop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	5.7	2.4
Tied ridges	Intercrop	40 Kg P/ha +20 Kg N/ha	5.7	2.4
Contour furrows	Sole crop	Manure 5 t/ha	4.9	2.4
Farmer practice	Intercrop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	6.0	2.3
Contour furrows	Intercrop	40 Kg P/ha +40 Kg N/ha + manure 5 t/ha	7.9	2.3
Contour furrows	Intercrop	Manure 5 t/ha	5.4	2.3
Farmer practice	Intercrop	40 Kg P/ha +20 Kg N/ha	6.2	2.2
Farmer practice	Sole crop	40 Kg P/ha + 20 Kg N/ha + manure 2.5 t/ha	6.2	2.1
Tied ridges	Sole crop	40 Kg P/ha +20 Kg N/ha	5.8	2.1
Tied ridges	Intercrop	40 Kg P/ha +40 Kg N/ha	5.2	2.1
Farmer practice	Sole crop	40 Kg P/ha +40 Kg N/ha + manure 5 t/ha	5.1	2.1
Tied ridges	Intercrop	Manure 5 t/ha	5.0	2.1
Contour furrows	Sole crop	40 Kg P/ha +20 Kg N/ha	6.0	2.0
Tied ridges	Sole crop	40Kg P/ha +40Kg N/ha + manure 5 t/ha	5.9	2.0
Farmer practice	Intercrop	40 Kg P/ha +40 Kg N/ha + manure 5 t/ha	5.7	2.0

(*continued*)

Table 3 (continued)

Water harvesting method	Cropping system	Soil fertility management regimes	Total dry matter T/Ha	Grain yield T/ha
Tied ridges	Sole crop	Control	1.7	0.6
Tied ridges	Intercrop	Control	1.5	0.6
Contour furrows	Sole crop	Control	1.9	0.6
Contour furrows	Intercrop	Control	2.4	0.5
Farmer practice	Sole crop	Control	1.4	0.4
Farmer practice	Intercrop	Control	1.0	0.3
Means			5.6	2.3
CV			19.0	22.9
LSD			1.96	0.98

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, there 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 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 2.5 t/ha manure. Others that did well in total dry matter production were treatments under farmer practice, sole crop, 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 differ significantly from one another ($p < 0.05$).

Discussions

Farmer’s Evaluation on Treatment Performance

The results (Table 1) indicated that 34.7% of the respondents both used tied ridges and convectional tillage as their main land preparation methods followed by contour furrows 28.2%. This was because 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 of treatments 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 County require minimal nutrient replenishment. 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 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. The results further indicate that water harvesting technologies played a major role in moisture conservation where most of the technologies were highly ranked by the farmers. This is in agreement with what Miriti et al. (2012) has further found that farmer perception of soil fertility is closely related to the soil's water holding capacity.

The results (Table 2) from the farmers' responses show 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 also dominated by sole cropping system (Table 3) from the field experimental results. This could be because 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 and Manyanhaire (2009) that crop yield reduction can be experienced in intercrops where they are associated with interspecific/nutrient 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 influencing farmers to rank them in fair category. This outcome for sorghum (Tables 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 yield 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 semiarid areas of Eastern Kenya. The results (Tables 2 and 3) had a very clear trend on farmer's perception and crop yield that 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 labor shortage and land tenure uncertainty (Demelash and Stahr 2010).

Conclusion

The results reported in the study demonstrate that smallholder farmers' knowledge can provide a consistent treatment evaluation on crop yield. There was clear evidence from the study that no difference was noted in terms of scoring of treatments by gender in

Ndia West division, Kirinyaga West County. Therefore, both genders could be used by agricultural extension services and researchers for evaluation of other related scientific work in this study area. The results have demonstrated that Kirinyaga West County 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 is a need to incorporate various water harvesting technologies and minimum soil nutrient supplements during seasons with low rainfall distribution regardless of water harvesting technology employed in semiarid 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 a need for water harvesting technologies and nutrient replenishment on-farm every season for increased sorghum and cowpea productivity in central highland of Kenya.

Limitation

During the research period, there was a big challenge on rainfall distribution where the crop did not perform very well during the first season of the experiment in the County. It was within this season where it was reported with a lot of stem borer infestation, but they were controllable by spraying pesticides.

References

Bationo A, Kimetu J, Ikeera S, Kimani S, Mugendi D, Odendo M, Silver M, Swift MJ, Sanging N et al (2004) The African network for soil biology and fertility: new challenges and opportunities. In: Bationo A (ed) Managing nutrient cycles to sustain soil fertility in sub-Saharan Africa. Academy Science Publishers and Tropical Soil Biology and Fertility Institute of CIAT, Nairobi, pp 1–23

Bielders CL, Michels K, Bationo A et al (2002) On-farm evaluation of ridging and residue management options in a Sahelian millet cowpea intercrop. Soil quality changes. Soil Use Mgmt 18:216–222

Demelash M, Stahr K (2010) Assessment of integrated soil and water conservation measures on key soil properties in south Gonder, north-western highlands of Ethiopia. Soil Sci Evntal Mgmt 1:164–176

Fongod AGN, Mih AM, Nkwatoh TN et al (2012) Morphological and agronomic characterization of different accessions of sweet potatoes (*Ipomoea batatas*) in Cameroon. Inter Res J Agric Sci Soil Sci 2:254–245

Gachimbi LN (2002) Technical report of soil survey and sampling results: Embu-Mbeere Countys, Kenya. LUCID working paper series number: 9. KARI-kabete, Nairobi, Kenya

Gicheru PT (2002) The effect of different soil management practices on crust formation, soil moisture conservation and crop growth in Machang'a area, Mbeere County, Kenya. PhD thesis. University of Nairobi, Kenya

Gitau AN (2004) Mechanical behaviour of hardsetting Luvisal soil. PhD thesis, University of Nairobi, Kenya

GOK (2007) The Kenya vision 2030; a competitative and prosperous Kenya. Government of Kenya. Ministry of planning and national development, Nairobi

Jensen JR, Bernhard RH, Hansen S, McDonagh J, MØberg JP, Nielsen NE, Nordbo E et al (2003) Productivity in maize based cropping systems under various soil-water-nutrient management strategies in semi-arid Alfisol environment in East Africa. Agric Water Mgt 59:217–237

Katsaruware RD, Manyanhaire IO (2009) Maize-cowpea intercropping and weed agronomy and soil science: Madison, WI, USA. Suppression in leaf stripped and detasselled maize in Zimbabwe. Electron J Environ Agric Food Chem 8(11):1218–1226

Keating BA, Wafula BM, Watiki JM et al (1992) Exploring strategies for increased productivity. The case for maize in semi-arid eastern Kenya. In: Proceeding of symposium held in Nairobi, Kenya, 10–11 December 1990. Goanna Pry Ltd, Canberra, pp 90–99

Kimani SK, Esilaba AO, Odera MM, Kimenye L, Vanlauwe BJ, Batiano A et al (2007) The effect of organic sources of nutrients on maize yield in three Countys of Central Kenya. In: Batiano A (ed) Advances in integrated soil fertility management in sub-Sahara Africa, challenges and opportunities. Springer, Dordrecht, pp 283–288

Lekasi JK, Tanner JC, Kimani SK, Harris PJC et al (2003) Cattle manure quality in Maragwa County, Central Kenya: effect of management practices and development of simple method of assessment. Agric Ecos Environ 94:289–298

Mairura FS, Mugendi DN, Mwanje JI, Ramisch JJ, Mbugua PK, Chianu JN et al (2007) Integrating scientific and farmers' evaluation of soil quality indicators in Central Kenya. Geoderma 139:134–143

Miriti JM (2011) Effect of conservation tillage on water and nitrogen use efficiency in maize-cowpea cropping systems in semi-arid eastern Kenya. PhD Thesis. University of Nairobi, Kenya

Miriti JM, Kironchi G, Esilaba AO, Heng LK, Gachene CKK, Mwangi DM et al (2012) Yield and water use efficiencies of maize and cowpea as affected by tillage and cropping systems in semi-arid Eastern Kenya. Agri water Mgt 115:148–155

Miriti JM, Thomas DB, Gachene CCK et al (2003) Soil chemical properties, sunflower growth and yields as affected by tillage, compost and mulch application. East Afr Agric J 68(3):159–163

Mugendi E, Gitonga N, Cheruiyot R, Maingi J et al (2010) Biological nitrogen fixation by Promiscous Sobean (Glycine max L. Merril) in the central highlands of Kenya: response to soil Amendends. World J Agric Sci 6:381–387

Mugwe J, Mugendi D, Mucheru-Muna M, Merckx R, Chianu J, Vanlauwe B et al (2009) Determinants of the decision to adopt integrated soil fertility management practices by smallholder farmers in the central highlands of Kenya. Exp Agric 45:61–75

Nadar HM (1984) Intercropping and intercrop component interaction under varying rainfall conditions in eastern Kenya. II: maize/cowpea intercrop. East Afri Agri J 44:176–181

Njeru PNM, Maina I, Miruka M, Amboga JS, Gitari J, Rono B, Mahasi M, Murithi F et al (2011) Soil fertility characterization of smallholder farms under group and individual management in Central Kenya. Proceedings on held at Maputo, Mozambique on 10th to 13th Octomber. Afri Crop Sci Conf Prod 10:1–4

Njeru PNM, Hjalten J, Kimani SK et al (2010) A book on the effect of push-pull management and different fertilization strategies on maize crop yield in Central Kenya. Lambert Acadamic publishers, Saarbrücken SSBN 978-3-8433-6376-1

Okalebo JR, Othieno CO, Woomer PL, Karanja NK, Semoka JRM, Bekunda MA, Mugendi DN, Muasya RM, Bationo A, Mukhwana EJ et al (2006) Available technologies to replenish soil fertility in East Africa. Nutr Cycl Agroecosyst 76:153–170

Smaling EMA, Nandwa SM, Jansen BH et al (1997) Soil fertity is at stake. In: Replenishing soil fertility in Africa, Special publications no. 51. American Society of Agronomy, Crop Science Society of America, Madison

Stroosnijder L (2009) Modifying land management in order to improve efficiency of water use in the African highlands. Soil Till Res 103:247–256

Thornton PK, Jones PG, Alagarswamy G, Andresen J, Herrero M et al (2010) Adopting to climate change: agricultural system and household impact in East Africa. Agric Syst 103:73–82