Chapter 16
Integrating Farmers and Scientific Methods for Evaluating Climate Change Adaptation Options in Embu County

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Abstract Potential for promoting sorghum crop as a climate change adaptation strategy for rain-fed agriculture in Embu County, Kenya was evaluated using farmer perceptions and scientific methods. Three hundred and sixty six smallholder farmers participated in the evaluation. The treatments which were overall rated as 'good' are tied ridges with a mean score of 2.9 and mean rank (2,873.87). Under this treatment sorghum grain yield of 3.7 t ha^{-1} was recorded with application of 40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1}. This was closely followed by tied ridges and contour furrows overall rated 'good' best three under the same soil fertility management options with a mean score ranging from 2.65 to 2.8 and yielding 2.7–3.7 t ha^{-1}. However, the treatments which were rated as 'poor' were experiment controls with a mean score below (1.43), mean rank (1,101.24) and yielding as low as (0.7 t ha^{-1}). Therefore, integration of organic and inorganic inputs under various water harvesting technologies could be considered as an alternative option towards food security under climate change for semi-arid areas of Embu County.

Keywords Climate change mitigation · Food security · Rain-fed agriculture · Soil amendments

Introduction

Agricultural productivity has been impaired by climate change, declining soil fertility, degradation of natural resources, inefficient markets, weak institutions and policies in semi-arid areas of Kenya. In Kenya, over 13 million of the 38 million

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people live below the poverty line of less than U.S$1 a day. Agriculture is the mainstay of the Kenyan economy contributing approximately 55 % of Gross Domestic Production (GDP). The sector further provides 80 % employment, accounting for 60 % of the exports and 45 % of the government revenue (Ragwa et al. 1998). The government in Kenya has put in place the Agricultural Input Subsidy Program (AISP) to support farmers so that they can access inputs such as inorganic fertilizers. In its "Vision 2030", the government also spells out the desire to use agriculture as the vehicle to transform the country to industrialization (CAADP 2008). However, more than 80 % of Kenya is classified as arid and semi-arid areas characterized by low and erratic waterfall, high evaporation rates and soils that are unsuitable for sustainable rain-fed agriculture (Miriti et al. 2012; Fongod et al. 2012).

Failure of rainfall is the main cause of persistent rural poverty (Miriti et al. 2012). The dry spell analysis indicates that potentially yield-limiting dry spells occur at least in 75 % of the seasons during a 20-year period (GoK 2007). Drought is also another risk to crop failure which has led to reluctance by farmers to invest on crop land (KARI 2009). Therefore irrigation, to maintain soil water content within the plant root zone at an optimal level may be the only option for adapting to climate change in these areas. However, the same is not feasible to most smallholder farmers because they either lack resources to invest in irrigation technologies or water not available for irrigation. This situation could be ameliorated through adoption of on-farm rain water harvesting and integrated nutrient management techniques as alternative option for mitigating impacts of prolonged dry spells. Incorporating highly valued traditional crops that are tolerant to drought into these farming systems is another option.

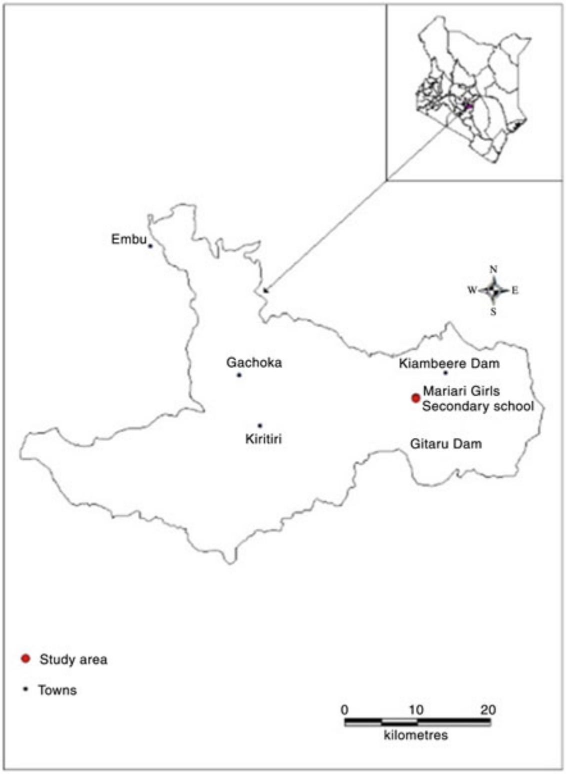
The challenge now remains on how to maximize agricultural production in semi-arid areas of Embu County in the face of climate change. The low crop production is also often associated with lack of appropriate farming practices that are suited to the fragile ecosystems to cope with climate change challenges (Bationo et al. 2004; Mbogoh 2000). Most of the smallholder farms are characterized by nutrient mining as a result of harvest and residue removal (Mugendi et al. 2003; Bielders et al. 2002) as well as lack of resources to invest in mineral fertilizers. Very little nutrient replenishment is practiced in Eastern Kenya (Mugendi et al. 2010). The recommendation of African Fertilizer Summit (2006) 'to increase the fertilizer use from the current 8–50 kg ha^{-1} nutrient by 2015' reinforces the role of fertilizer as a key entry point for increased crop productivity and attaining food security in Embu County. However, most farmers cannot afford to buy inorganic fertilizers due to their high prices (Sanginga et al. 2009; Crews and Peoples 2004). These inappropriate farming systems practiced by farmers are leading to land degradation and lack of appropriate rain water harvesting and conservation technologies are resulting in low crop yields (Njeru et al. 2011a, b; Kimani et al. 2007). Therefore, food security situation is expected to continue deteriorating and could worsen in future if climate change adaptation options are not taken up quickly in semi-arid areas of Embu County. Therefore this study assessed the comparison of farmer's evaluation and scientific method on various climate change mitigation technologies for increased sorghum productivity at Kiritiri Division, Mbeere District in Embu County.

Materials and Methods

Study Site Location and Description

The study was conducted in Kiritiri Division, Mbeere South Sub-County which lies in the southeastern slopes of Mt. Kenya (Fig. 16.1). It lies between latitude 0.91672°S and Longitude 37.4768°E to the North and between Latitude 0.4733°S and Longitude 37.91238°E to the South. The district lies at an altitude of 800 m a.s.l with an average rainfall of 700–900 mm, temp of 21.7–22.5 °C. The predominant soil type is ferralsols. Kiritiri division, Mbeere south District is generally a low potential dry zone. It is covered by three agro-ecological zones; the marginal cotton zone (LM4); the lower midland livestock-millet zone (LM5); and the lowland livestock millet zone (L5) (Jaetzold et al. 2007). The study was conducted in agro-ecological zone (LM4/5) in Long rains 2011, 2012 and short rain 2011.

Fig. 16.1 Shows the study site in Mbeere South Sub-County in the map of Kenya



Experimental Design

The treatments were arranged in a factorial structure, each treatment being a combination of one of the 3 levels of water harvesting techniques (Tied Ridges, contour furrows and conventional tillage/farmers Practice), 2 levels of cropping systems (Sole sorghum-Gadam, Sorghum and cowpea (M66) intercrop) and 6 levels of soil fertility amendment options (Control, 40 kg P ha^{-1} + 40 kg N ha^{-1}, 40 kg P ha^{-1} + 20 kg N ha^{-1}, 40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}, 40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1} and manure 5 t ha^{-1}) thus giving a total of 36 treatments. 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 with plot size of 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 with 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 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

Farmer's Evaluation on Treatment Performance

In Kiritiri 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 16.1) 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 Long rains 2011, 2012 and short rain 2011.

Table 16.1 Farmers' rating of water harvesting, cropping systems and ISFM technologies

Water harvesting	Cropping systems	Soil fertility management regimes	Mean score	Mean rank	Overall rating
Tied ridges	Sole crop	40 Kg P ha^{-1} + 20 Kg N ha^{-1} + Manure 2.5 t ha^{-1}	2.9	2,873.87	Good
Contour furrows	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1}	2.8	2,787.23	Good
Tied ridges	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1}	2.74	2,763.39	Good
Contour furrows	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1}	2.65	2,753.45	Good
Tied ridges	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1}	2.64	2,677.23	Good
Contour furrows	Sole crop	Manure 5 t ha^{-1}	2.63	2,621.8	Good
Tied ridges	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	2.61	2,560.8	Good
Tied ridges	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1}	2.53	2,490.58	Good
Contour furrows	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	2.51	2,443.79	Good
Tied ridges	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	2.49	2,462.85	Fair
Tied ridges	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1}	2.48	2,403.52	Fair
Contour furrows	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1}	2.47	2,384.7	Fair
Contour furrows	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1}	2.45	2,397.72	Fair
Tied ridges	Sole crop	Manure 5 t ha^{-1}	2.44	2,310.8	Fair
Tied ridges	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1}	2.43	2,368.56	Fair
Contour furrows	Intercrop	Manure 5 t ha^{-1}	2.43	2,338.03	Fair
Contour furrows	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1}	2.38	2,280.98	Fair
Contour furrows	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	2.37	2,243.88	Fair
Contour furrows	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1}	2.37	2,256.27	Fair
Tied ridges	Intercrop	Manure 5 t ha^{-1}	2.35	2,248.08	Fair
Farmers practice	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1}	2.32	2,170.3	Fair
Farmers practice	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1}	2.31	2,145.78	Fair
Farmers practice	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1}	2.31	2,138.53	Fair
Farmers practice	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1}	2.29	2,115.15	Fair

(continued)

Table 16.1 (continued)

Water harvesting	Cropping systems	Soil fertility management regimes	Mean score	Mean rank	Overall rating
Farmers practice	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1}	2.28	2,102.65	Fair
Farmers practice	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	2.27	2,075.92	Fair
Farmers practice	Sole crop	Manure 5 t ha^{-1}	2.23	1,765.56	Fair
Farmers practice	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	2.02	1,621.56	Fair
Farmers practice	Intercrop	Manure 5 t ha^{-1}	2.0	1,615.85	Fair
Farmers practice	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1}	1.74	1,524.25	Fair
Tied ridges	Sole crop	Control	1.43	1,101.24	Poor
Tied ridges	Intercrop	Control	1.43	1,095.52	Poor
Contour furrows	Sole crop	Control	1.42	1,085.25	Poor
Contour furrows	Intercrop	Control	1.38	954.2	Poor
Farmers practice	Sole crop	Control	1.19	658.86	Poor
Farmers practice	Intercrop	Control	1.03	568.27	Poor

(N = 366), *Test statistics* Kruskal-H test; Chi-square = 1,212.6; d.f = 35; p = 0.000

The results in Table 16.1 show that treatments under tied ridges with sorghum alone plus soil amendment of 40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1} attracted the highest preference of farmers who rated it as ‘good’ with a mean score of 2.9 and was ranked number one out of 36 treatments. The experimental results (Table 16.2) also indicated that the same treatment had the highest amount of grain yield (3.7 t ha^{-1}). This was followed closely by contour furrows under the same cropping system and soil fertility amendment option (Tables 16.1 and 16.2) rated as ‘good’ with grain yield (3.5 t ha^{-1}). The results (Tables 16.1 and 16.2) further shows that all the treatments rated as ‘Good’ by the farmers were also the highest in grain yield ranging from 2.7 to 3.7 t ha^{-1}. The results show that all the technologies ranked ‘good’ included minimal combination of fertilizers and manure, or stand alone fertilizer application. However, the treatment which was rated by majority farmers as ‘poor’ was experiment control under farmers practice with sorghum and cowpea intercrop with a mean score of (1.03), mean rank (568.27) and yielding as low as (0.4 t ha^{-1}). Generally, all experiment controls were overall scored as ‘poor’ yielding as low as 0.4–0.7 t ha^{-1}.

Treatment Score by Gender

The results indicated that there was no significant difference ($P \geq 0.05$) regarding scoring by gender groups 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 Mbeere District.

Field Experiment Results

The results underscore the scientific crop evaluation from the field experiment during 2012 Long rains. The results in Table 16.2 show performance of three types of water harvesting, two cropping system and six fertility levels but only 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).

Table 16.2 The effects of water harvesting, cropping system and soil fertility regimes on sorghum yields in Kiritiri division

Water harvesting	Cropping system	Soil fertility management regimes	Stover + husks (t ha^{-1})	Grain yield (t ha^{-1})
Tied ridges	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1}+Manure 2.5 t ha^{-1}	3.5	3.7
Contour furrows	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1}+Manure 2.5 t ha^{-1}	3.5	3.5
Tied ridges	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1}+Manure 2.5 t ha^{-1}	3.5	3.1
Contour furrows	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1}	3.4	3.1
Tied ridges	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1}	3.4	3.1
Contour furrows	Sole crop	Manure 5 t ha^{-1}	3.5	2.9
Tied ridges	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	3.2	2.9
Tied ridges	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1}	3.4	2.8
Contour furrows	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	3.2	2.7
Tied ridges	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	3.2	2.6
Contour furrows	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1}	3.1	2.6
Contour furrows	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1}	3.0	2.6
Tied ridges	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1}	3.0	2.6
Contour furrows	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	3.0	2.5
Tied ridges	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1}	3.4	2.5
Contour furrows	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1}	3.3	2.5
Contour furrows	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1}	3.3	2.4
Tied ridges	Sole crop	Manure 5 t ha^{-1}	3.2	2.4
Contour furrows	Intercrop	Manure 5 t ha^{-1}	3.2	2.4
Tied ridges	Intercrop	Manure 5 t ha^{-1}	3.2	2.3
Farmers practice	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1}	3.1	2.3
Farmers practice	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1}	2.9	2.3
Farmers practice	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1}	3.5	2.2
Farmers practice	Sole crop	40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1}	3.6	2.2

(continued)

Table 16.2 (continued)

Water harvesting	Cropping system	Soil fertility management regimes	Stover + husks (t ha^{-1})	Grain yield (t ha^{-1})
Farmers practice	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1}	3.2	2.2
Farmers practice	Intercrop	40 kg P ha^{-1} + 20 kg N ha^{-1}	3.3	2.2
Farmers practice	Sole crop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	2.9	2.2
Farmers practice	Intercrop	40 kg P ha^{-1} + 40 kg N ha^{-1} + Manure 5 t ha^{-1}	4.0	2.1
Farmers practice	Intercrop	Manure 5 t ha^{-1}	3.9	2.1
Farmers practice	Sole crop	Manure 5 t ha^{-1}	3.7	2.0
Tied ridges	Sole crop	Control	1.2	0.7
Tied ridges	Intercrop	Control	0.9	0.7
Contour furrows	Sole crop	Control	1.3	0.7
Contour furrows	Intercrop	Control	1.8	0.6
Farmers practice	Sole crop	Control	1.5	0.5
Farmers practice	Intercrop	Control	0.8	0.4
Means			2.9	2.2
CV			24.8	22.4
LSD			1.51	0.85

Combination Effect

The results further indicated that sorghum without manure application did not differ significantly in yield with treatments 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 16.2). The highest sorghum yield (3.7 t ha^{-1}) was recorded from tied ridges under sole sorghum cropping system with application of 40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1}, followed by 3.5 t ha^{-1} under contour furrow under the same soil amendment practice. In the third place were three treatments (3.1 t ha^{-1}) under tied ridges and contour furrow and the top seven treatments yield did not differ significantly from one another ($p < 0.05$). The lowest sorghum yield (<2.0 t ha^{-1}) was observed in treatments regarded as 'control' with neither fertilizer nor manure regardless of other intervention (water harvesting methods or cropping systems). The total dry matter and biomass were highest in tied ridges under sole cropping of soil fertility amendment of 40 kg P ha^{-1} + 20 kg N ha^{-1} + Manure 2.5 t ha^{-1} (7.7 t ha^{-1}) and (3.5 t ha^{-1}) respectively. All these top producers did not differ significantly from one another ($p < 0.05$) except from the experiment controls.

Discussions

Farmer's Evaluation on Treatment Performance

The consistently high preference (Table 16.1) by farmers on overall rating as 'good' and high grain yields (3.7 t ha^{-1}) on tied ridges and contour furrow under sorghum alone with a minimum combination of organic and inorganic inputs at half dose application of Nitrogen and manure. This was an indication that minimal nutrient replenishment was required in all the season in Mbeere district. Studies by Mugendi et al. (2010) and Gachimbi (2002) have also reported that farms in Mbeere require nutrient replenishment every season from manures, fertilizers and from of crop residue return in their farms. It has also been reported by Njeru et al. (2009, 2010, 2013) and Mairura et al. (2007) that soil fertility can be accessed through visual observation on crop performance and yield and therefore farmers were able to evaluate all the treatments to their level best. The results (Tables 16.1 and 16.2) further shown that water harvesting technologies that integrates soil fertility management technologies played a major role in moisture conservation and increased crop productivity and were also ranked highly by the farmers. This is in agreement with what Miriti et al. (2012) has further found that farmer perception on soil fertility is closely related to the soil's water holding capacity.

The results (Tables 16.1 and 16.2) shows that the third and the fourth treatments of tied ridges and contour furrow under sorghum and cowpea intercrop with the same soil fertility management options were dominated by their sole cropping systems. This could be 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 and Manyanhaire (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 and this influenced farmer's decision on crop performance. This outcome for sorghum (Tables 16.1 and 16.2) 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 needed a number of seasons to meet the level of nutrient competition (Lekasi et al. 2003). The results by Miriti (2011) have also shown that cowpea was also a nutrient competitor for maize production in semi-arid areas of eastern Kenya. Therefore, the results had a very clear relationship on their comparison on farmer's perception and crop yield. However, all those treatments regarded as 'controls' were poorly rated by the farmers and they had lower crop yields. The farmers practice under sorghum and cowpea intercrop were rated as 'poorly' with the lowest grain yield. This is in line with continuous cultivation of the same piece of land as this will lead to nutrient depletion and requires nutrient replenishment (Mugwe et al. 2009; Miriti et al. 2003). This has led to land degradation contributing to reduced crop production as a result of failure of rainfall distribution in semi-arid areas of Embu County. The farmers are being discouraged from adoption of these water conservation structures as a result of labour shortage and land tenure uncertainty (Demelash and Stahr 2010). Therefore, land productivity can be improved by employing of appropriate agricultural technologies which suit these semi-arid areas of Mbeere south District, Embu County.

Conclusions

The results reported in the study demonstrate that smallholder farmers' knowledge can provide a consistent treatment evaluation as compared to biophysical data. This demonstrated clear evidence from the study that there was a relationship of treatment rating by farmers with the scientific findings. However, there was no difference noted in terms of scoring of treatments by gender. Therefore, both genders could be used by agricultural extension services and researchers to evaluate other related scientific work in this study area. Mbeere south district is characterized by low and erratic rainfall and generally fragile ecosystems which are not suitable for sustainable rain-fed agriculture. The results have demonstrated the need to incorporate selected water harvesting and integrated soil fertility management technologies on sorghum and cowpea production in the season under low rainfall distribution in semi-arid areas. This will 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. 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 to increase sorghum and cowpea productivity.

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