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Adapting conservation agriculture to climate change variability: An overview of sorghum and cowpea production in Kirinyaga west county

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Abstract Rain-fed agricultural productivity has continually declined due to unpredictable and unreliable rainfall patterns in Kirinyaga West County. The decline in food productivity has been as a result of inadequate understanding of intra-seasonal rainfall variability to develop optimal cropping calendar. A study was conducted to access the effect of various water harvesting and integrated soil fertility management technologies for enhanced sorghum (*Sorghum bicolor* (L.) Moench) and cowpea (*Vigna unguiculata* L.) productivity in Kirinyaga West County, Central Kenya. The field experiment was laid out in Partially Balanced Incomplete Block Design (PBIBD) with a total of 36 treatments replicated three times. The treatments of tied ridges and contour furrows under sorghum alone plus external soil amendment of 40 Kg P /ha + 20 Kg N /ha + manure 2.5 t/ha had the highest grain yield ranging from 3.3 t/ha to 3.6t/ha. The soil fertility levels differed significantly from one another (p=0.0001) in terms of sorghum grain yield. Generally, all experiment controls had the lowest grain yields as low as 0.4 t/ha to 0.6 t/ha. Therefore, integration of minimal organic and inorganic inputs under various water harvesting technologies could be considered as an alternative option towards food security as a way of climate change mitigation options for Kirinyaga West County in Central Kenya.

Key words: Climate change, food security, soil amendments

Introduction

Rain-fed agricultural productivity has continually declined due to unpredictable and unreliable rainfall patterns in Kirinyaga West County. The decline in food productivity has as a result of inadequate understanding of intra-seasonal rainfall variability to develop optimal cropping calendar. According to IPPC (2007) have indicated that to understanding spatio-temporal rainfall patterns rainfall has been directly implicated to combating extreme poverty and hunger through agricultural enhancement. The amount of soil-water available to crops depends on rainfall onset, length and cessation which influence the successfulness or failure of a growing season (Seleshi & Zanke, 2004).

The soil-water is an indispensable requirement for crop growth from sowing to maturity (Khuram & Rasul, 2011). Therefore, climatic parameters and rainfall in particular are prime inputs of improving food security among smallholder farmers of Kirinyaga West County. This is particularly important in central highlands of Kenya where agricultural productivity is principally rain-fed yet highly variable (Jury, 2002). The lower parts of central Kenya continue to experience elevated rainfall variations, persistent dry spells, prolonged droughts and high annual potential evapo-transpiration (2000-2300 mm year^{-1}) (Micheni *et al.,* 2004). This is basically enough rainfall for crop production in this region; however, it is poorly re-distributed over time and has negative effect on crop performance (Kimani *et al.,* 2003). According to Meehl *et al.* (2007) 25% of the annual rainfall often falls within a couple of rainstorms, that crops suffer from water stress, often leading to complete crop failure. Therefore irrigation, to maintain soil water content within the plant root zone at an optimal level may be the only option for climate change mitigation in these areas. This is not feasible to most smallholder farmers because they either lack resources to invest in irrigation technologies or water not available for irrigation lower parts of Kirinyaga west district.

This situation could be ameliorated through adoption of on-farm rain water harvesting and integrated nutrient management techniques as alternative option for mitigating prolonged drought and drought spells. This can also be achieved by incorporating highly valued traditional crops in these farming systems.

Several recent studies have yielded little evidence on occurrence of dry spells to increase the frequency of rain water use efficiency in semi-arid areas to cope-up with climate change in Africa (Stroosnijder, 2009). This has been contributed by mixed crop-livestock systems being currently projected to see reduction in crop production as a result of drought throughout most East Africa regions due to climate change by 2050 (Thornton *et al.,* 2010).

The challenge now remains on how to maximize any drop of rain water which falls on the ground to increase agricultural production in semi-arid areas of Embu County. The low crop production is also often associated with lack of appropriate farming practices that are suited to the fragile ecosystems to cope-up with climate change challenges (Mbogoh, 2000; Bationo *et al*., 2004). Most of the smallholder farms are characterized by nutrient mining as a result of crop harvest and residue removal (Bielders *et al*., 2002; Mugendi *et al*., 2003) as well as lack of resources to invest in mineral fertilizers or very little nutrient replenishment is practiced Eastern Kenya (Mugendi *et al*., 2010; Fongod *et al*., 2012). The recommendation of African Fertilizer Summit (2006) 'to increase the fertilizer use from the current 8 to 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 Kirinyaga West County. Alternatively most farmers cannot afford to buy inorganic fertilizers due to their high prices (Crew & people, 2004; Sanginga *et al*., 2009). Due to these inappropriate farming systems, they lead to land degradation as a result of soil erosion, use of inappropriate rain water harvesting and conservation technologies result to low crop yields (Kimani *et al*., 2007; Njeru *et al*., 2011a and 2011b). Therefore, food security situation is expected to continue deteriorating and could worsen in future if climate change mitigation options are not taken up quickly in semi-arid areas of Embu County. Therefore this study assessed the the effect of various water harvesting and integrated soil fertility management technologies for enhanced sorghum and cowpea productivity in Kirinyaga West County, Central Kenya.

Materials and methods

Figure 1 shows Ndia West division of Kirinyaga west district indicating the location of the study site in central Kenya.

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 $0^0 1^o$ and $0^o 40^o$ south and longitudes 37^o and 38^o east at an altitude of 1,480 metres to 6,800 metres 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^2. 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) and the study was conducted in (AEZ) 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 ranging from 14 ^{0}C to 30 ^{0}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

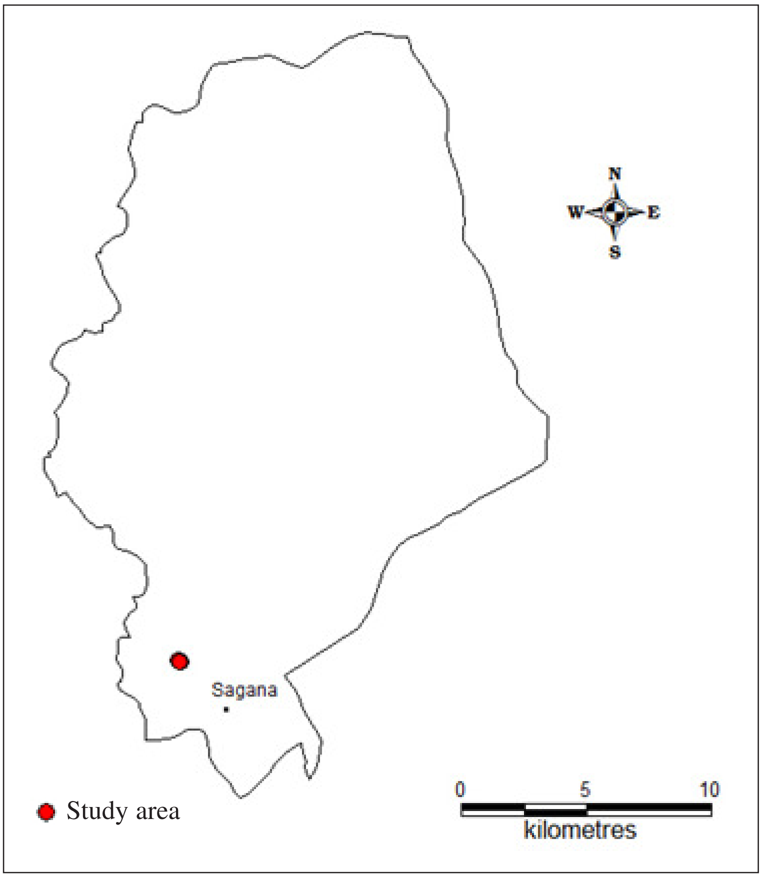

Figure 1. Map showing study site in Kirinyaga West district.

between March-June and July-December respectively (Jaetzold *et al*., 2007).

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 + 40Kg N /ha, 40 Kg P /ha + 20 Kg N /ha, 40 Kg P /ha + 40Kg N /ha + Manure 5 t/ha, 40 Kg P /ha + 20 Kg N /ha + Manure 2.5 t/ha and manure 5t/ha 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 6m x 4m. 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. The difference between treatment scores and gender was declared 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 $P< 0.05$.

Table 1. 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	Total dry matter (t/ha)	Biomass + husks (t/ha)	Grain yield (t/ha)
Tied ridges	Sole crop	40 kg P/ha +20 kg N/ha +manure 2.5 t/ha	7.1	3.5	3.6
Contour furrows	Sole crop	40 kg P/ha+20 kg N/ha +manure 2.5 t/ha	7.0	3.5	3.5
Tied ridges	Intercrop	40 kg P/ha+20 kg N/ha +manure 2.5 t/ha	6.9	3.5	3.4
Contour furrows	Intercrop	40 kg P/ha+20 kg N/ha+ manure 2.5 t/ha	6.7	3.4	3.3
Tied ridges	Sole crop	40 kg P/ha+20 kg N/ha	6.6	3.4	3.2
Contour furrows	Sole crop	Manure 5t/ha	6.6	3.5	3.1
Tied ridges	Sole crop	40 kg P/ha+40 kg N/ha+ manure 5 t/ha	6.2	3.2	3.0
Tied ridges	Sole crop	40 kg P/ha+40 kg N/ha	6.4	3.4	3.0
Contour furrows	Sole crop	40 kg P/ha+40 kg N/ha +manure 5 t/ha	6.1	3.2	2.9
Tied ridges	Intercrop	40 kg P/ha+40 kg N/ha +manure 5 t/ha	6.1	3.2	2.9
Contour furrows	Sole crop	40 kg P/ha+40 kg N/ha	5.9	3.1	2.8
Contour furrows	Sole crop	40 kg P/ha+20 kg N/ha	5.8	3.0	2.8
Tied Ridges	Intercrop	40 kg P/ha+20 kg N/ha	5.7	3.0	2.7
Contour furrows	Intercrop	40 kg P/ha+40 kg N/ha +manure 5 t/ha	5.6	3.0	2.6
Tied ridges	Intercrop	40 kg P/ha+40 kg N/ha	5.9	3.4	2.5
Contour furrows	Intercrop	40 kg P/ha+40 kg N/ha	5.8	3.3	2.5
Contour furrows	Intercrop	40 kg P/ha+20 kg N/ha	5.8	3.3	2.5
Tied ridges	Sole crop	Manure 5 t/ha	5.6	3.2	2.4
Contour furrows	Intercrop	Manure 5 t/ha	5.6	3.2	2.4
Tied ridges	Intercrop	Manure 5 t/ha	5.6	3.2	2.4
Farmers practice	Intercrop	40 kg P/ha+20 kg N/ha +manure 2.5 t/ha	5.5	3.1	2.4
Farmers practice	Sole crop	40 kg P/ha+20 kg N/ha	5.2	2.9	2.3
Farmers practice	Sole crop	40 kg P/ha+40 kg N/ha	5.8	3.5	2.3
Farmers practice	Sole crop	40 kg P/ha+20 kg N/ha +manure 2.5 t/ha	5.9	3.6	2.3
Farmers practice	Intercrop	40 kg P/ha+40 kg N/ha	5.4	3.2	2.2
Farmers practice	Intercrop	40 kg P/ha+20 kg N/ha	5.5	3.3	2.2
Farmers practice	Sole crop	40 kg P/ha+40 kg N/ha +manure 5 t/ha	5.1	2.9	2.2
Farmers practice	Intercrop	40 kg P/ha+40 kg N/ha +manure 5 t/ha	6.1	4.0	2.1
Farmers practice	Intercrop	Manure 5t/ha	6.0	3.9	2.1
Farmers practice	Sole crop	Manure 5t/ha	5.7	3.7	2.0
Tied ridges	Sole crop	Control	1.8	1.2	0.6
Tied ridges	Intercrop	Control	1.5	0.9	0.6
Contour furrows	Sole crop	Control	1.8	1.3	0.5
Contour furrows	Intercrop	Control	2.3	1.8	0.5
Farmers practice	Sole crop	Control	2.0	1.5	0.5
Farmers practice	Intercrop	Control	1.2	0.8	0.4
Means			5.2	2.9	2.2
C V			18	24.8	22.4
LSD			1.92	1.51	0.65

Field experiment results. Results in Table 1 underscore the scientific crop evaluation from the field experiment during Long rains 2011. The results also show 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 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 1). The highest sorghum yield (3.6 t/ha) was recorded from tied ridges under sole sorghum cropping system with external nutrient replenishment of 40 Kg P /ha + 20 Kg N /ha + Manure 2.5t/ha, followed by 3.5 t/ ha under contour furrow under the same soil amendment practice. The top eight 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 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 +20Kg N/ha +Manure 2.5t/ha (7.1 t/ha) and (3.5 t/ha) respectively.

Discussion

Treatment performance. There is a consistently results on high grain yields, biomass and total dry matter at 3.6 t/ ha, 3.5 t/ha and 7.1 t/ha respectively in tied ridges under sorghum alone with a minimum combination of organic and inorganic inputs at half dose application of Nitrogen and manure (Table 1). This was an indication that minimal nutrient replenishment was required in all the season in Kirinyaga West County. Studies by Gachimbi (2002) and Mugendi *et al*. (2010) have also reported that farms in central Kenya highlands require nutrient replenishment every season from manures, fertilizers and from of crop residue return in their farms.

It has also been reported by Mairura *et al.* (2007) and Njeru *et al*. (2010, 2009) that soil fertility can be also be accessed through visual observation on crop performance and yield. Furthermore, water harvesting technologies and integrates soil fertility management technologies played a major role in moisture conservation and increased crop productivity (Table 1). This is in agreement with what Mucheru-Muna *et al*. (2009) and Miriti *et al*. (2012) found that, by incorporation of water harvesting and legumes on-farm they can enhance crop productivity in Eastern Kenya. In addition, the results show 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 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 and this influenced farmer's decision on crop performance. This outcome for sorghum (Table 1) 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 met the level of nutrient competition (Lekasi *et al*., 2003). Findings by Miriti, (2011) have also shown that cowpea was also a nutrient competitor for maize production in semi-arid areas of eastern Kenya. The experiment control farmers practice under sorghum and cowpea intercrop was the lowest in 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 (Miriti *et al*., 2003; Mugwe *et al*., 2009). This has lead to land degradation contributing to reduced crop production as a result of failure of rainfall distribution in semi-arid areas of Kirinyaga West County.

However, farmers are discouraged from adopting these water conservation structures as a result of labour shortage and land tenure uncertainty in their farms (Demelash & Stahr, 2010). Therefore, land productivity can be improved by employing of appropriate agricultural technologies which suit these lowlands of Kirinyaga West County, Central Kenya.

Conclusion

The results reported in the study demonstrate clear evidence from the study that there is need to incorporate water harvesting and integrated soil fertility management technologies on sorghum and cowpea productivity. 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 nutrient replenishment on-farm every season to enhance sorghum and cowpea productivity. Therefore, integration of minimal organic and inorganic inputs under various water harvesting technologies could be considered as an alternative option towards food security as a way of climate change mitigation options for Kirinyaga West County in Central Kenya.

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