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Effects of selected soil and water conservation technologies on nutrient losses and maize yields in the central highlands of Kenya

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ABSTRACT

Mitigating nutrient loss is a prerequisite of sustainable agriculture in the tropics. We evaluated three soil and water conservation technologies (mulching, minimum tillage and tied ridging) for two cropping seasons (long rains 2011, short rains 2011) at two sites in the central highlands of Kenya. The objectives were: to determine effects of the technologies on runoff, sediment yield and nutrient loads in sediment, and to assess influence of the technologies on maize yields. Experimental design was a randomized complete block with 3 treatments replicated thrice. At the beginning of experiment, soil was sampled at 0–15 cm depth and analyzed for pH, N, P, K, C, Ca and Mg. Mulch was applied at a rate of 5 t ha^{-1}. Runoff was sampled, sediments extracted by drying in oven at 105 °C, and analyzed for NPK and C loads. Data were subjected to analysis of variance using SAS 9.1.3 and means separated using Fishers' LSD at 5% level of significance. Results showed reduced nutrient losses with the technologies. In Meru South, sediment yield was reduced by 41 and 7% during long rains 2011 ($p = 0.03$), and by 71 and 68% during short rains 2011 ($p = 0.01$) under mulching and minimum tillage, respectively. Runoff and maize yields were positively influenced by mulching. In Mbeere South, sediment yield was lower under soil and water conservation technologies. Runoff was reduced by 52 and 49% during long rains 2011 and by 51 and 30% during short rains 2011 under tied ridging and mulching respectively, compared with control. Total crop failure occurred during long rains 2011 due to erratic rains. During short rains 2011 tied ridging and mulching increased maize yield by 94 and 75%, respectively, compared with control. This study highlights the importance of analyzing soil and water conservation technologies within rain-fed farming systems perspective in response to declining food production and supports a focus on tied ridging and mulching.

1. Introduction

Nutrient management is a key challenge for global food production (Powlson et al., 2011). Per capita food availability in Sub-Saharan Africa (SSA) has decreased over time leading to wide spread food insecurity (Beintema and Stads, 2006). Over 80% of agriculture in SSA is rain-fed with the bulk under smallholder farming (Rockström, 2000). Small-scale farmers are faced with challenges of increasing population pressure, food insecurity, very low levels of agricultural productivity and rapid natural resource degradation associated with nutrient depletion through soil erosion and excessive runoff (Rockström, 2000). Majority of the small-holder farmers in the central highlands of Kenya depend on rain-fed agriculture (Mugwe et al., 2009). Maize productivity in the area has declined in the recent past leading to poor crop yields (Mucheru-Muna et al., 2007). The decline is attributed to inadequate use of external inputs, poor agricultural water management, degraded soil quality and erratic rainfall. Therefore, the challenge of solving the problem of food insecurity in the area involves addressing soil nutrient and water depletion in the region.

Erosion by water is the primary cause of soil quality degradation in the central highlands of Kenya (Okoba and Sterk, 2006). Negative impact of erosion on topsoil depth, soil organic carbon content, nutrient status, soil texture and structure, available water holding capacity and water transmission characteristics was long recognized by Lal (1997). Sanchez and Jama (2002) identify soil fertility depletion resulting from soil erosion as the fundamental biophysical cause for declining per capita food production on smallholder farms. Further to erosion, there are risks related to rainfall variability in the study area (Schreck and Semazzi, 2004). Extreme rainfall variability characterized by high rainfall intensities, few rain events, and poor spatial and temporal distribution

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have a direct impact on soil productivity especially nutrient levels, runoff and soil water holding capacity (Brouder and Volenec, 2008). These impacts have the potential to severely affect people's livelihoods, particularly, due to dependency on rain-fed agriculture and limitations of technological capabilities (Osman-Elasha, 2007).

Apart from soil nutrient loss, water deficit is a significant factor that hinders crop productivity (Bossio et al., 2010). Increased soil moisture availability through reduced runoff and soil loss is hence important (Ngigi et al., 2006). Water scarcity is more pronounced in semi arid regions of Sub Saharan Africa where agriculture is rainfed and faces threat from frequent dry spells and droughts (Rockström, 2000). Mbeere south sub-county is such an area. There is therefore an urgent need to increase nutrient and water availability to crops grown by smallholder farmers in developing countries. According to Bossio et al. (2010), soil erosion, nutrient depletion and other forms of land degradation reduce water productivity, nutrient use efficiency and hence agricultural productivity. Stroosnijder (2009) emphasizes that plant production suffers because water is not available due to deteriorated physical properties of soil.

In order to overcome biophysical constraints causing low yields in rain-fed farming systems in the central highlands of Kenya, there is need for appropriate soil and water management technologies. Mulching, tied ridging and minimum tillage technologies have been used in different parts of the world (Araya and Stroosnijder, 2010). In the study area, studies by Mugendi et al. (2006), Okoba and Sterk (2006), Mucheru-Muna et al. (2007), Mugwe et al. (2009) and Shisanya et al. (2009) have focused on integrated soil fertility management. However, little attention has been given to the potential of soil and water conservation technologies in combating soil degradation and enhancing agricultural water management. Soil erosion and runoff have been approached from environmental perspective and off site effects rather than plot scale. For these practices to be recommended to smallholders in the area, they have to be tested. In this paper, we report on a study investigating the potential of mulching, tied ridging and minimum tillage on combating runoff, soil and nutrient loss, and increasing maize yields.

2. Materials and methods

2.1. Experimental site description

This study was conducted in Meru South sub-county, Tharaka-Nithi County and Mbeere South sub-county, Embu County (Fig. 1). The two sites in the Central Highlands of Kenya have contrasting soil fertility and highly variable rainfall patterns (Mucheru-Muna et al., 2010). In Meru South, experimental site was Kigogo primary school (00°23′ S, 37°38′ E) while the site in Mbeere South was Machang'a secondary school (00°47′26.8″ S; 37°39′45.3″ E). Kigogo lies in Upper Midland Agro-ecological Zones 2 and 3 (Jaetzold et al., 2007) on eastern slopes of Mount Kenya at an altitude of 1500 m above sea level (a.s.l.). It is majorly a maize growing zone with smallholdings of 1.2 ha per household on average. Population pressure (569 inhabitants km^{-2}) pushed people to marginal areas (Mucheru-Muna et al., 2010) such as Mbeere South. Agriculture is characterized by smallholder mixed farming activities comprising of cash crops, food crops, trees and livestock (Shisanya et al., 2009). Kigogo was representative of high potential areas while Machang'a represented low potential areas of the central highlands of Kenya. Machang'a is situated in Lower Midland Agro-ecological Zones 3, 4 and 5 and Inner Lowland 5 on the eastern slopes of Mount Kenya at an altitude between 700 and 1200 m a.s.l (Jaetzold et al., 2007). Cropping systems are maize-based with beans as the preferred legume intercrop although cowpea, groundnut and green grams are gaining importance. Rapid population growth has resulted in expansion into fragile area and low-potential lands being taken under cultivation, reduced fallow periods and systematic degradation (Mucheru-Muna et al., 2010).

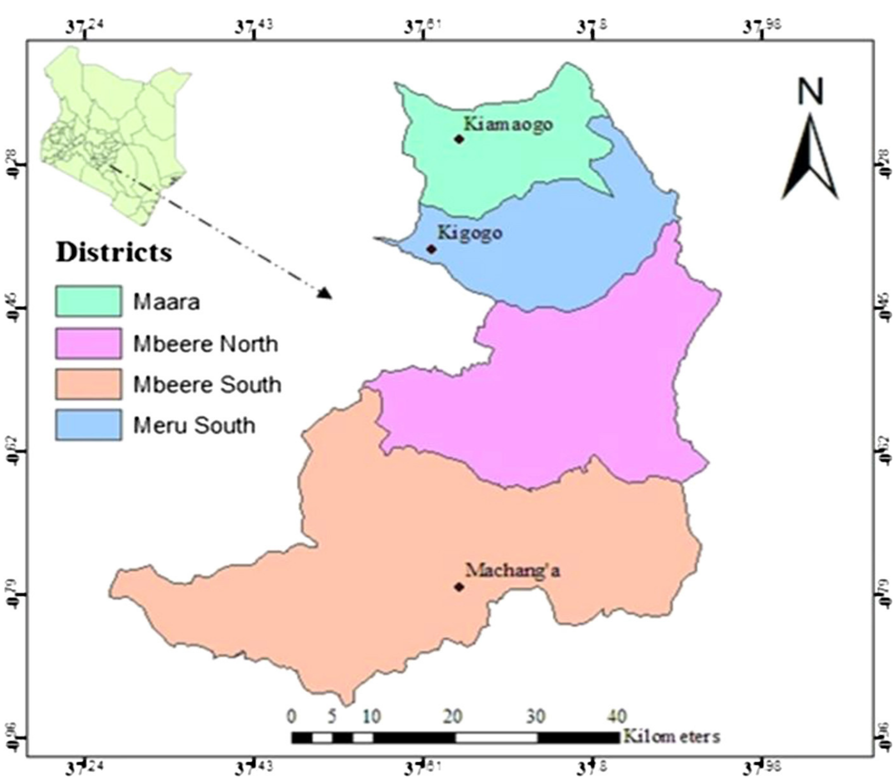

Fig. 1. Map of the study area.