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Original Research Article

Effect of water conservation measures on soil moisture and maize yield under drought prone agro-ecological zones in Rwanda

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ABSTRACT

This study was conducted to assess agricultural practices for generating maximum maize productivity in drought prone agro-ecological zones. The experiment was conducted in Cyili sub-catchment in Southern Province of Rwanda, which has an irregular rainfall distribution and a prolonged dry season. The experimental design consisted of a randomized design and each treatment was replicated three times. Findings from this study revealed that maize grain yield and yield components, such as plant height, cob diameter and length, number of leaves, 100 grain weight, and yield per plant were highly significantly affected ($P < 0.001$) by all water conservation methods tested. Only germination rate was not significantly impacted ($p > 0.05$). Supplementary irrigation treatment increased maize yield production to 11,982 kg ha^{-1}. Mulching increased yield significantly to 8089 kg ha^{-1}. Ridges yielded 5937 kg ha^{-1}, and rainfed treatment yielded 4755 kg ha^{-1} of maize. Based on Pearson's correlation coefficients, grain yield and yield components were positively correlated and statistically significant ($p < 0.001$) under various water conservation methods. Supplementary irrigation through rainwater harvesting was found to be a more promising option for maize growers to mitigate dry spell and stabilize maize production in rainfall deficient agro-ecological conditions not only in Rwanda, but in sub-Sahara Africa.

1. Introduction

Drought is a prolonged period of short precipitation resulting water deficiencies and lack of soil moisture to support crop production (Solh & van Ginkel, 2014), in the World is the most hazard from climate change which frustrates the productivity of agricultural crops (Muhammad, Muhammad, & Cengiz, 2015). Every year there is a loss of 25% crop yield globally caused by severe drought (Bankole et al., 2017) and 36 million people in sub-sahara Africa are experiencing severe food shortage because of the drought (Nazareth, 2016; WaterAid, 2017).

Maize crop was ranked as a third place cereal consumed in the world after wheat and rice (Olaniyan, 2015), and first yield and productive cereal (FAOSTAT, 2015). Maize is an important food crop in sub-sahara Africa, 300 million people in sub-sahara Africa are consider maize a primary source of food crop and livelihood (Macauley, 2015). It occupied 17% of cultivated land (FAOSTAT, 2015) and 21% in East Africa (Ndlovu, 2013). In Rwanda maize is among of six priority crop (wheat, rice, banana, cassava, potatoes) the government of Rwanda has been selected in the program of land consolidation and crop intensification (CIP) in 2007 to transform subsistence agriculture into intensive agriculture (MINAGRI, 2013). Maize was the first cereal crop in Rwanda occupied 16.8% of arable land during the cropping season (A), 2017 followed by sorghum (2,4%), rice (1.9%) and wheat (0.2%) (NISR, 2017).

However, maize is very sensitive to drought at different growth stages from germination to maturity (Muhammad et al., 2015). As a matter of fact, the maize germination rate is reduced under drought stress conditions due to low water absorption and metabolic enzymatic activation decline (Gharoobi, Ghorbani, & Nezhad, 2012). In the development growth stages of maize drought affect cell division and cell proliferation (Muhammad et al., 2015), while in the reproductive stage drought affecting tassel, embryo, endosperm development, ear, pollination, fertilization grail filling and resulting the loss of crop yield (DuPlessis, 2003). While most of sub Saharan Africa maize production is based on rainfed systems (Gebrehiwot & Gebrewahid, 2016), there is a need to find out alternative soil moisture conservation strategies to mitigate drought effects. In these regards mulching, tied ridges, terracing, bunding, rain water harvesting and supplementary irrigation

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method are some of the methods with high soil water conservation potential.

Mulching, ridges and supplementary irrigation through rain water harvesting from surface runoff were used in this study. Mulching is a common method farmers use to cover the soil surface for the purpose of retaining moisture in the soil, reduce soil temperature to contain evaporation and to improve soil fertility or organic matter content (Gicheru, 1994; Li & Gong, 2002). Supplementary irrigation adds a partial volume of water to the plants in the critical time to improve soil moisture (Oweis, Hachum, & Kijne, 1999) while, contour ridges is regarded as water harvesting methods in semi-arid regions. It transforms the land into small pockets called tied ridges or soil bund called furrows and is very useful to stabilize yield (Bargar et al., 1999; SUSTAINET, 2010). The objective of this study was to identify the better method of water conservation measures in a bid to generate maximum maize grain yield in hotter and dryer regions where maize is grown. The study will contribute to mitigate soil moisture content deficiencies and hence enhance maize productivity in drought prone agro-ecological zones.

2. Research methods

2.1. Description of the study area

The study was conducted in Cyili sub-catchment (02°34'32.52''S and 29°51'52.23''E with elevations varying between 1467 and 1604 masl). Cyili sub-catchment is located in Huye and Gisagara districts of Southern Province of Rwanda. The area is characterized by steep slopes ranging from 16% to slightly above 60% (Uwizeyimana, Karuku, Mureithi, & Kironchi, 2018), that were reformed into bench terraces in 2013 by Rural Sector Support Project (RSSP) Through the Ministry of Agriculture and Animal Resources of Rwanda (MINAGRI). Fig. 1 shows the location of the study area in the administrative map of Rwanda. The catchment has the total area of 4.30 km^2, with the total number of household's farmers around 1114.

The catchment has a wide range soil type characteristics and climate similar to the central plateau (middle altitude) of the country. The dominant soil types are Luvisols, Alisols, and Cambisols according to the Food Agriculture Organization of the United Nations (FAO, 2003). Based on climate, topography of country is classified in sub-humid and belongs to Mayaga agro-ecological zone (IX) of country with extreme spatial and temporal rainfall distribution (Verdoodt & Van Ranst, 2006). The catchment receives the annual rainfall of around 1141.1 mm at Rubona station. Rainfall are bimodal, the long rain period occurs in March to May and the short in mid-September to mid-December every year. The mean annual temperature ranges from 14.2 °C to 24.8 °C. The land is suitable for cereal crops such as maize (*Zea mays*), sorghum (*Sorghum bicolor*), and rice (Oryza sativa) in the marshland, root and tuber crops such as cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas)* and yam (*Dioscorea alata*), grain legumes such as groundnuts (*Arachis hypogaea)* and soybean (*Glycine max*), and fruit trees such as avocados (*Persea americana*) and coffee (*Coffea arabica*) (MINAGRI, 2010).

2.2. Experimental design

Field activities started by land preparation, involving ploughing, harrowing, in August and September 2016, land was flat with radical terrace. The experiment was arranged in completely randomized design (CRD) with 4 treatments consisting of 4 different soil water conservation methods: A: rainfed (control or check); B: rainfed + mulching; C: rainfed + contour ridges and D: rainfed + supplemental irrigation. Each treatment was replicated three times as shown in Fig. 2

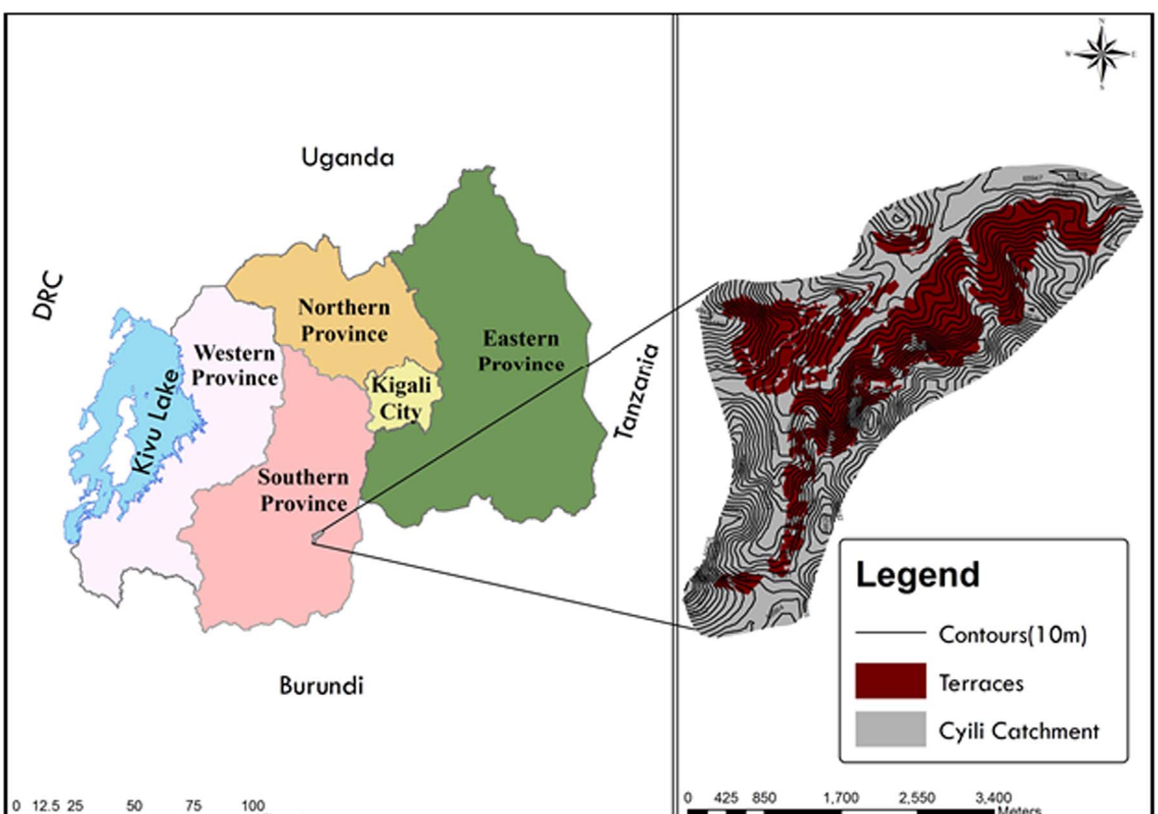

Fig. 1. Cyili sub-catchment location in Rwanda.

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