Physics and Chemistry of the Earth 66 (2013) 123–130

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Assessing crop yield benefits from in situ rainwater harvesting through contour ridges in semi-arid Zimbabwe

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ARTICLE INFO

Article history:
Available online 30 September 2013

Keywords:
Rainwater harvesting
Semi-arid
Crop yield
Zhulube
Maize
Soil moisture

ABSTRACT

Rainwater harvesting through modified contour ridges known as dead level contours has been practiced in Zimbabwe in the last two decades. Studies have shown marginal soil moisture retention benefits for using this technique while results on crop yield benefits are lacking. This paper presents results from a field study for assessing the impact of dead level contours on soil moisture and crop yield carried out from 2009 to 2011 within the Limpopo River Basin. The experiments were carried out on two study sites; one containing silt loam soil and another containing sandy soil. Three treatments constituting dead level contoured plots, non-contoured plots and plots with the traditional graded contours were used on each site. All the three treatments were planted with a maize crop and managed using conventional farming methods. Planting, weeding and fertiliser application in the three treatments were done at the same time. Crop monitoring was carried out on sub plots measuring 4 m by 4 m established in every treatment. The development of the crop was monitored until harvesting time with data on plant height, leaf moisture and crop yield being collected. An analysis of the data shows that in the site with silt loam soil more soil moisture accumulated after heavy rainfall in dead level contour plots compared to the control (no contours) and graded contour plots ($P < 0.05$). However the maize crop experienced an insignificantly ($P > 0.05$) higher yield in the dead level contoured treatment compared to the non-contoured treatment while a significantly ($P < 0.05$) higher yield was obtained in the dead level contoured treatment when compared with a graded contoured treatment. Different results were obtained from the site with sandy soil where there was no significant difference in soil moisture after a high rainfall event of 60 mm/day between dead level contour plots compared to the control and graded contour plots. The yield from the dead level contoured treatment and that from the graded contoured treatment were comparable and both not significantly ($P > 0.05$) higher than that from the non-contoured treatment. This suggests that adopting dead level contours as an in situ rainwater harvesting technique results in crop yield benefits in fields with soil type conditions that enable runoff generation but is not likely to have benefit in soils with low runoff generation.

1. Introduction

In situ rainwater harvesting is a rain fed farming practice that has been developed in many parts of the world to store water in the soil profile within the cropped field (Falkenmark et al., 2001). There are several in situ rainwater harvesting technologies in use including planting basins, conservation tillage, half moons and contour ridges which are sometimes known as bunds (Ngigi, 2003; Mupangwa et al., 2006; Makurira, 2010). In situ rainwater harvesting operates by collecting the surface runoff component of rainfall from a surrounding catchment area and storing the water in the root zone of the crop (Tecle, 2004). This increases the infiltration component of rainfall and in turn improves the soil water content in the root zone. Soil water together with soil fertility are among the major limiting factors for crop production in resource poor smallholder farmers in sub Saharan Africa (Mupangwa, 2009; Rockström, 2000). Soil water availability affects the rate of plant nutrient uptake and the rate of evapotranspiration which in turn has an effect on crop yield. Many parts of sub Saharan Africa are semi-arid receiving low or poorly distributed rainfall and have limited access to irrigation water. Rainwater harvesting is therefore adopted as an innovative way to improve soil water and hence crop production.

In situ rainwater harvesting is commonly found among resource poor farmers in semi-arid conditions of India, Asia and East Africa. The technology has also been introduced in low rainfall

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http://dx.doi.org/10.1016/j.pce.2013.09.008

areas of some parts of Southern Africa (Wiyo et al., 1999; Mupangwa et al., 2006). In Masvingo and Matebeleland South Provinces of Zimbabwe dead level contour ridges (DLC) have been introduced as a rainwater harvesting technique following frequent droughts that were experienced in most parts of Zimbabwe during the last two decades (Mupangwa, 2009). Introduction of DLC in Zimbabwe was an innovation of nongovernmental organisations after farmers saw no logic in disposing of precious water from the field through standard graded contour ridges. The DLC is a modification of the standard graded contour ridge (GC) that was designed to safely dispose runoff from the field to mitigate against soil erosion (Elwell, 1981; Hagmann, 1996).

Studies on dead level contours have shown marginal benefit in soil moisture retention (Mupangwa et al., 2011; Mugabe, 2004). Soil moisture benefit alone does not guarantee crop benefit as the extra soil moisture may not be high enough to cause an increase in crop yield. The need to investigate the effect of dead level contours on crop yield is therefore imperative. Mutekwa and Kusangaya (2006) investigated crop yield benefits from rainwater harvesting in Chivi District of Masvingo Province of Zimbabwe using a questionnaire survey. The study established that farmers in Chivi District perceived that there are crop yield benefits derived from using dead level contours. Another study on crop yield benefits in Zimbabwe was done by Mupangwa (2009) who studied crop yield in fields with water conservation treatments of planting basins, riper tillage and double ploughing which were located in dead level contoured fields in Gwanda District of Matebeleland Province. The study by Mupangwa (2009) did not compare crop yield from a DLC plot with other treatments and hence provide no evidence of the impact of DLC on crop yield. Literature survey failed to locate studies that compared the effect of DLC on crop yield to that of other treatments especially the GC originally designed for soil conservation.

This paper presents the results of a farmer-based study aimed at assessing the impact of contour ridges on soil moisture, crop growth and yield. This was done by comparing soil moisture, crop growth and yield for plots with DLC and GC with non-contoured plots. The study was carried out in the semi-arid Insiza District of Matebeleland South Province of Zimbabwe.

2. Materials and methods

2.1. Location of study area

The study was carried out in Zhulube Catchment, a small left bank sub catchment of Mzingwane Catchment in Zimbabwe which is part of the Limpopo River Basin (Fig. 1). It is located in the communal areas of Insiza District of Matebelaland South Province. Rainfall is low averaging 540 mm/a and characterised by mid-season dry spells occurring during the period January to February when the crops are at flowering and grain filling stages where the highest amount of water is required (Chibulu, 2007).

The soils in Zhulube range from coarse grained sands to loamy sands and clay loams with stones intertwined with the sand, silt and clay material. The sand soils are mainly of granitic origin while the loam and clay soils are associated with mopane trees. The soils have poor nutrient levels. Zhulube is characterised by an undulating terrain with moderate to steep slopes. The geology is dominated by granite rocks with several rock outcrops scattered throughout the catchment.

2.2. Experimental design

Two farmer fields one with silt loam soil (field A) and the other with a sandy soil (field B) were selected for the experiments based on evenness (uniform slope and uniform soil type) of the field and willingness of farmers to participate in the experiment. The location of the selected farmers is shown in Fig. 1. Three DLC and three GC each measuring 20 m long and spaced 20 m apart were arranged as shown Fig. 2. Each contour ridge comprises of a trench that is 1 m wide and 0.4 m deep with the excavated soil thrown downslope. Contour ridges for DLC plots were constructed along contour lines at approximately zero gradient therefore retaining the runoff that is received by the trench. The contour ridges for GC plots were also constructed along contour lines but at a slope of approximately 5% to effectively drain water from the field. A plot with no contour ridges was located in between the DLC and GC.

A maize crop SC401 seed variety was planted in each plot and was managed under the conventional farmers' practice. Conventional farmers practice in Insiza District involves ploughing with a single furrow mould board plough after sufficient rains have been received normally during the month of December. Seed is placed at a spacing of 20–30 cm along the row following the plough and the rows spaced 90 cm apart. Planting following the plough is done to locate the seed deeper so that it will not suffer from moisture stress before or soon after emergence. Planting was done on 04 December 2009 and 05 December 2009 in the first year while in the second year it was done on 07 December 2010 and 08 December 2010 for field B and A respectively. The rainfall received during the 7 days before planting was 42 mm in 2009 and 38 mm in 2010. The seasonal total for the year 2009/2010 between 01 October and 31 March was 405 mm while that for the year 2010/2011 was 485 mm (Fig. 3). Runoff amounts of 63 mm/season in field A and 7.5 mm/season in field B were measured from runoff plots during the 2010/2011 season.

Manual weeding was done by loosening the soil using a hoe and pulling out the weeds. Fertiliser was applied at the farmers preferred rates of 200 kg/ha Compound D basal fertilizer (8%N, 14% P_2O_5,7%K_2O) and 200 kg/ha Ammonium Nitrate (34.5% N) top dressing in the sand soil. This is equivalent to 85 kg N/ha. In the loam soil only Ammonium Nitrate was applied at a rate of 200 kg/ha being equivalent to 69 kg N/ha. The recommended rate of fertilizer application in Zimbabwe is 300 kg/ha Ammonium Nitrate (34.5% N) and 300 kg/ha Compound D basal fertiliser (8%N, 14% P_2O_5, 7%K_2O) (Mupangwa, 2009) which is equivalent 128 kg N/ha. Twomlow et al. (2008) proposed micro dosing at a rate of 17 kg N/ha which is equivalent to 50 kg/ha Ammonium Nitrate (34.5% N). The farmers preferred rate was considered acceptable as it was still lower than the recommended rate of 128 kg N/ha but higher than the micro dosing rate of 17 kg N/ha proposed by Twomlow et al. (2008).

Table 1 shows the measured chemical and physical properties of the soil in the field plots before commencement of the study. The soil in both fields was slightly acidic with pH of 5.3 in sandy soil (field B) and 5.9 in silt loam soil (field A) which is favourable for maize production. Maize grows well in slightly acidic soils with a pH ($CaCl_2$) above 5.0 (Nyamangara et al., 2000). The water holding capacity indicates that field A would retain more moisture compared to field B. The high water holding capacity in field A can be explained by the higher clay content in field A compared to field B. Despite the high water holding capacity of the soil in field A the actual soil moisture storage would be limited by the soil depth. The soil layer in field A was shallow ranging from 0.4 m to 0.7 m in all the plots. In field B the soil depth was deeper than 1.5 m throughout the field. Field A was more fertile with a clay content 10 milli-equivalents percent (me%) and a potassium content of 0.43 me% compared to field B with a clay content of 3 me% and a potassium content of 0.39 me%.

2.3. Data collection

Soil moisture was measured at an interval of once a week at 13 locations along each treatment using a Gopher Soil Moisture