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Infiltration and planting pits for improved water management and maize yield in semi-arid Zimbabwe

Innocent Wadzanayi Nyakudya[a,*], Leo Stroosnijder[b,1], Isaiah Nyagumbo[c,2]

[a] Crop Science Department, Bindura University of Science Education, P. Bag 1020, Bindura, Zimbabwe
[b] Soil Physics and Land Management Group, Wageningen University, P.O. Box 47, 6700 AA, Wageningen, The Netherlands
[c] CIMMYT Southern Africa Regional Office, P.O. Box MP 163, Mt Pleasant, Harare, Zimbabwe

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ABSTRACT

Realising that rainwater harvesting (RWH) improves crop productivity, smallholder farmers in semi-arid Zimbabwe modified contour ridges traditionally used for rainwater management by digging infiltration pits inside contour ridge channels in order to retain more water in crop fields. However, scientific studies on crop yield benefits of infiltration pits have not been conclusive. Combining field-edge RWH methods such as contour ridges with infiltration pits with in-field practices may enhance crop yield benefits. Thus, the objective of the study was to assess soil moisture and maize yield improvement of combining infiltration and planting pits. Field experiments were conducted in Rushinga, Zimbabwe for three seasons at three sites using a split-plot design: main-plot factor, field-edge rainwater management method (RWMM); and split-plot factor, tillage method. Soil moisture content was measured weekly using gravimetric and Time Domain Reflectometry (TDR) methods. A household and field survey to establish farmers' perceptions, typology and availability of field-edge RWMM was conducted. In order to share experiences and enhance stakeholders' learning, field days were held. Lateral movement of soil water was measured up to 2 m downslope from infiltration pits, hence infiltration pits did not improve maize yield and soil moisture content in the cropping area. Maize yield (kg ha^{-1}) was 45% higher under conventional tillage (2697) than planting pits (1852) but the yield gap decreased from 90 to 30% in the first and third year respectively. The value of infiltration pits is in reducing soil erosion by water and growing high value horticultural crops inside and close to pits, a view shared by host farmers and other stakeholders. Planting pits are an option for farmers without access to draught power and a fall-back method. Research is required to determine soil moisture, maize yield benefits and waterlogging risk in fields with underlying impermeable layers that enhance lateral flow of water.

1. Introduction

Rainwater harvesting (RWH) can contribute to rainfed crop productivity (Kauffman et al., 2003; Vohland and Barry, 2009); and it is recommended for combating land degradation (Siegert, 1994; Vohland and Barry, 2009); and meeting Millennium Development Goals in Africa (Kahinda et al., 2008; Ochola and Kerkides, 2003). Rainwater harvesting practices are a range of technologies for collecting and storing water for productive uses (Kahinda et al., 2008; Siegert, 1994). Practices which store and use water on-site, i.e. within the field are called *in-situ* practices (Stroosnijder et al., 2008). In these techniques the water source is overland flow from micro-catchment areas (Lövenstein, 1994; Siegert, 1994). *In-situ* RWH bridges the gap between rainfall events by increasing the amount of water stored in the soil for plant use through collecting runoff water and allowing it to infiltrate into the soil profile. In Eastern and Southern Africa the priority crops should include maize (*Zea mays* L.), the most important cereal crop in the region (Barron, 2004; Jamil et al., 2012; Magorokosho et al., 2003).

The need for co-management of soil fertility has been iterated (Giller et al., 2006a; Mupangwa et al., 2006; Rockström, 2000; Tittonell et al., 2007; Vanlauwe and Giller, 2006; Zingore et al., 2007). It is envisaged that RWH will lower the risk of crop failure and encourage investments in soil fertility (Rockström, 2000). However, the benefits have to be realised within a short period since

* Corresponding author. Tel.: +263 772 773 746.
E-mail addresses: pupunege@yahoo.com (I.W. Nyakudya), Leo.Stroosnijder@wur.nl (L. Stroosnijder), i.nyagumbo@cgiar.org (I. Nyagumbo).
[1] Tel.: +31 6 452 254 68.
[2] Tel.: +263 772 238 284.

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Fig. 1. Maize crop growing in a field with contour ridges modified by inclusion of infiltration pits.

poor people cannot afford long-term investments (Stroosnijder et al., 2008).

Semi-arid areas of Zimbabwe, agroecological regions IV and V, annual rainfall 450–650 mm and less than 450 mm respectively (Vincent and Thomas, 1960) cover more than 60% of total land area and 74% of the communal areas land (Whitlow, 1980). Total formal, communal and resettlement irrigation land area stands at 11,860 ha and informal irrigation schemes account for between 15,000 and 30,000 ha (Makadho et al., 2006) compared to ±1.5 million hectares of land grown to maize annually; thus in Zimbabwe's smallholder farming systems maize is mostly rainfed.

A trail of crop failures in semi-arid areas in the 1990s forced farmers to experiment with different RWH techniques in order to mitigate droughts and mid-season dry spells. The technologies have been promoted mainly by Non-Governmental Organisations (NGOs) since the early 1990s. However, the benefits of these technologies with regard to their effectiveness in increasing soil moisture and improving crop yields have not been adequately quantified (Motsi et al., 2004; Mugabe, 2004; Mupangwa et al., 2006).

Modifications to traditional rainwater management techniques such as contour ridges are among initiatives triggered by recurrent crop failure due to drought and dry spells in semi-arid Zimbabwe. Contour ridges were designed to control soil erosion by safely disposing runoff water and they have been in existence since the introduction of the plough in the 1920s (Whitlow, 1988; Wilson, 1995). A contour ridge consists of an upstream channel and downstream ridge (Critchley et al., 1992; Elwell, 1981) (Fig. 1). A standard contour ridge has the following dimensions: gradient (1:250); channel width (1.70 m); channel depth (0.23 m); embankment height (0.23 m) and embankment width (1.70 m) (Elwell, 1981).

Alterations to contour ridges in order to retain more rainwater in crop fields include construction of infiltration pits inside channels of contour ridges (Maseko, 1995; Motsi et al., 2004; Mugabe, 2004; Mupangwa et al., 2006; Mutekwa and Kusangaya, 2006); construction of dead level contours (Mupangwa et al., 2006; Mupangwa et al., 2012a); deepening the contour ridge channel and constructing ties in the contour ridge channel forming check dams.

This study focused on infiltration pits (Fig. 1) and planting pits (planting basins). Infiltration pits are rectangular trenches excavated at intervals in the channels of contour ridges for collecting runoff water, storing it and allowing it to infiltrate and presumably flow through the soil layers. There is wide variability in both recommended and observed infiltration pits dimensions. Wide variability in infiltration pits dimensions partly reflects differences in farmers' preferences and could also be a result of absence of generally acceptable standard dimensions. The trenches are often rectangular because they tend to follow the shape of contour ridges. Infiltration pits were adopted by most farmers in southern Zimbabwe (Hagmann et al., 1999; Hughes and Venema, 2005; Mutekwa and Kusangaya, 2006). In a study covering southern and northern Zimbabwe, Motsi et al. (2004) reported that infiltration pits were preferred to retention trenches (*fanya juus*) by farmers. *Fanya juus* are ridges within cultivated land where trenches are dug and the excavated soil is placed upslope (Makurira et al., 2009; Motsi et al., 2004). The channel depth is usually 0.5–0.6 m with ties at 10-m intervals.

Experimental research on infiltration pits in Zimbabwe has produced mixed results, and available information is inadequate to explain the causes of the differences in results. Further research is therefore needed in order to avail accurate and consistent information to farmers and policy makers. Motsi et al. (2004) reported soil moisture and maize yield benefits averaging 2.4 t ha^{-1} under infiltration pits compared to 1.5 t ha^{-1} under conventional tillage on sandy loam to sandy soils in Mudzi district in northern Zimbabwe, and Gutu and Chivi districts in southern Zimbabwe. Mugabe (2004) observed soil moisture benefits up to 11.8 m downstream of the pits with most benefits being experienced within 3.4 m of the infiltration pits on sandy loam soil in fields with less than 2% slope in southern Zimbabwe. Mupangwa et al. (2012a) reported soil moisture benefits at 2 m upslope and 3 m downslope from the centre of the infiltration pits in dead level contours on sand to loamy sand soils in fields with 1% slope in southern Zimbabwe.

It is difficult to conceive how infiltration pits benefit crops given their location at edges of fields which are on average 20–25 m wide. Knowledge from soil physics and hydrology suggests that in a homogenous soil profile most of the water infiltrates downwards below the pit to recharge the water table without significant lateral movement into the rootzone of the cropping area. In our view the value of infiltration pits is more in sustainable land management through combating land degradation caused by soil water erosion, and improving farm water use efficiency by cropping close to or inside the infiltration pits than soil water and field crops yield benefits.

Planting pits are planting holes dug using the hand hoe as part of the conservation farming system. The soil from the pit is placed at the downstream side of the pit creating a 'damming effect' for retaining the water collected in the pit. Planting pits resemble zaï pits used in West Africa (Anschütz et al., 2003; Shaxson and Barber, 2003; Twomlow et al., 2008). Mupangwa et al. (2012b) used a spacing of 0.9 m × 0.6 m with each planting pit measuring 0.15 m (length) × 0.15 m (width) × 0.15 m (depth). Farmers' Association of Community self-help investment Groups (FACHIG), an NGO that has been operating in northern Zimbabwe for more than ten years recommends planting pits measuring 0.20–0.25 m (diameter) and 0.15 m (depth). From 2010/2011 through 2012/2013 season planting pits were being promoted in Zimbabwe countrywide by the Zimbabwean Conservation Agriculture Task Force (ZCATF) coordinated by the Food and Agriculture Organisation of the United Nations (FAO) Emergency Office in Zimbabwe with various NGOs as implementing partners. This was part of a campaign that started during the 2004/2005 season (Twomlow et al., 2008). Planting pits were selected for this study because they are an option for farmers without access to adequate draught power and are a fall-back tillage method in the event of disasters that wipe out livestock as for example the 1991/1992 drought and cyclone Eline in 2000.

The rationale for considering planting pits only is that most farmers in Rushinga district only practised conservation agriculture as far as digging planting pits. Therefore, in line with the argument by Giller et al. (2009) that constraints for farmers to adopt all principles of conservation agriculture make it necessary to evaluate