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Dead level contours and infiltration pits for risk mitigation in smallholder cropping systems of southern Zimbabwe

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ABSTRACT

The persistent droughts, dry spells, and chronic food insecurity in semi-arid areas necessitate the introduction of more robust rainwater harvesting and soil water management technologies. The study reported here was conducted to assess the influence of dead level contours and infiltration pits on in-field soil water dynamics over two growing seasons. A transect consisting of six access tubes, spaced at 5 m interval, was established across each dead level contour with or without an infiltration pit before the onset of the rains. Two access tubes were installed upslope of the contour while four tubes were installed on the downslope side. Dead level contours with infiltration pits captured more rainwater than dead level contours only resulting in more lateral soil water movement. Significant lateral soil water movement was detected at 3 m downslope following rainfall events of 60–70 mm/day. The 0.2–0.6 m soil layer benefited more from the lateral soil water movement at all the farms. Our results suggest that dead level contours have to be constructed at 3–8 m spacing for crops to benefit from the captured rainwater. It is probably worth exploring strip cropping of food and fodder crops on the downslope of the dead level contours and infiltration pits using the current design of these between-field structures. With the advent of *in situ* rainwater harvesting techniques included in some conservation agriculture practices it will benefit smallholder cropping systems in semi-arid areas if these between-field structures are promoted concurrently with other sustainable land management systems such as conservation agriculture.

1. Introduction

Rainfed crop production plays a pivotal role in the developing countries where the majority of the people depend on agriculture for their livelihoods (Verchot and Cooper, 2008). It is projected that rainfed farming will account for 40% of growth in cereal production by 2021–2025 (Rosegrant et al., 2002). In the Southern African Development Community (SADC) region human population is growing at 2.4% per annum while crop output from the smallholder farming sector is declining (Chilonda et al., 2007). The decrease in crop output from the smallholder farming sector is related to climatic and socio-economic constraints faced by households in the region.

Rainfall is the major climatic factor that influences crop production in the smallholder sector under semi-arid environments (Thomas et al., 2007). Rainstorms are often spatially distributed, varying highly even within a few square kilometres (Usman and Reason, 2004; Love et al., 2008). Temporal rainfall distribution is poor during most growing seasons resulting in soil water deficits at critical stages of crop development. These rainfall characteristics are likely to continue haunting the smallholder agricultural sector of sub-Saharan Africa in the face of climate variability. The African continent has been identified as one part of the world to be hit hard by climate change (Jones and Thornton, 2003).

Rainwater harvesting, a method of collecting surface runoff from a catchment area and storing the water in the root zone of a cultivated area for crop growth (Lie et al., 2004), can play a critical role in reducing production risk in rainfed agriculture. In the semi-arid areas rainwater harvesting could be a source of water for smallholder cropping systems (Falkenmark et al., 2001; Irshad et al., 2007). Traditionally smallholder farmers in Zimbabwe have been using the graded contour ridge for safely diverting excess water from the field (Mutekwa and Kusangaya, 2006). A standard graded contour ridge is pegged at a gradient of 1:250 and contour ridges are usually spaced at 20–30 m apart on gentle slopes (Hughes and Venema, 2005).

Techniques that capture rainwater, reduce surface runoff and promote infiltration have traditionally been used in Africa (Reij et al., 1996). In Africa other rainwater harvesting systems exist such as the *Trus* system in Sudan, the *Zai* system in Mali

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and Burkina Faso, and the *Tassa* system in Niger (Mandiringana et al., 2003). In South Africa extensive research work has been conducted on runoff in-field rainwater harvesting using basins and mulch under semi-arid conditions (Botha et al., 2003) and used by smallholder farmers in marginal areas with maize and a variety of vegetables.

Dead level contours, pegged at zero gradient, are an appropriate between-field technique for harvesting runoff water for crop production. The purpose of a dead level contour is to retain runoff water in the contour hoping that soil water will move into cropped field by lateral flow (Hughes and Venema, 2005). To improve the ability of the dead level contour in retaining runoff, water infiltration pits are dug along the contour often at 10 m interval and a standard infiltration pit measures 2 m long, 1 m wide and 0.5–1 m deep (Hughes and Venema, 2005).

Efforts by international research organisations, Non-Governmental Organisations (NGOs) and Government Agricultural Departments continue in finding a combination of appropriate technologies that reduce the impact of harsh climatic factors on livelihoods of smallholder farmers. In Gwanda district of southern Zimbabwe dead level contours and infiltration pits are being promoted by Practical Action Southern Africa. The design of the dead level contours includes having an infiltration pit at intervals along the contour. Dead level contours and infiltration pits have been explored in other semi-arid districts of Zimbabwe (Motsi et al., 2004; Mugabe, 2004). Results from these studies have shown that dead level contours and infiltration pits can contribute towards soil water status in the cropped field. In a study by Mugabe (2004) rainwater captured by the infiltration pits replenished soil water on the upslope and downslope sides of the infiltration pit.

Our study in Gwanda district was designed to assess the influence of dead level contours and infiltration pits on soil water patterns on the upslope and downslope sides of dead level contours with or without infiltration pits. The specific objectives of the study were (1) to measure the profile soil water content at 7 and 2 m upslope, and at 3 and 8 m downslope of the dead level contours with and without infiltration pits throughout the growing season and (2) to determine the extent to which soil water moves laterally from contours into the cropped field. This paper reports on the soil water changes observed at 2 and 7 m upslope, and 3 and 8 m downslope of the dead level contours during 2006/2007 and 2007/2008 growing seasons.

2. Materials and methods

2.1. Site description

Gwanda district lies in the Mzingwane catchment which is part of the Limpopo river basin and receives annual rainfall of less than 450 mm (Unganai, 1996; FAO, 2004). Rainfall season is unimodal and begins in November/December and ends in March/April. The cropping season experiences periodic dry spells particularly in January and is followed by a dry season that stretches from May to September. The predominant soils in Gwanda district are coarse-grained sands to loamy sands and clay loams to clay with minor occurrences of vertisols (Anderson et al., 1993). The soils are classified as Eutric/Dystric Regosols and Chromic Luvisols according to FAO/UNESCO classification, and as Ustalfic Haplargid and Lithic/Ustic Torriorthent according to Soil Taxonomy (Nyamapfene, 1991; FAO, 2004). Landform is almost flat to undulating pediplain with some local hills and rock outcrops. Vegetation consists of *Colophospermum* mopane as the dominant tree species with scattered associated tree species of *Commiphora spp, Combretum apiculatum* and *Adonsonia digitata*. Farming system consists of crop-livestock enterprises and the major crops grown include cereals such as maize (*Zea mays* L.), sorghum (*Sorghum bicolour* (L.) Moench) and pearl millet (*Pennisetum glaucum* (L.) R.Br.) and legumes namely bambara nut (*Vigna subterranean (L) Verdc*), groundnut (*Arachis hypogaea* L.) and cowpea (*Vigna unguiculata* (L.) Walp). The predominant livestock species include cattle (*Bos indicus*), goats (*Capra hircus*), donkeys (*Equus asinus*), chickens (*Gallus domesticus*) and turkeys (*Melleagris gallopavo*).

2.2. Experimental setup

The experiment was established at four farms located in ward 17 of Gwanda district, southern Zimbabwe. Two farms (Moyo and Ncube) had dead level contours only while the other two (Dube and Siziba) had dead level contours and infiltration pits. The treatments were the rainwater harvesting structure (dead level with or without infiltration pit) × distance (2 and 7 m upslope; 3 and 8 m downslope) where soil water measurements were taken and each farm was used as a replicate in this study. Soil water was monitored in PVC access tubes inserted at varying depths depending on the physical characteristics of the soil profile at each farm. In the 2006/2007 growing season a single transect of access tubes was setup across the dead level contours and infiltration pits in conventionally ploughed fields which were under maize, sorghum, pearl millet and groundnut crops. In the 2007/2008 growing season two transects of access tubes, one along conventionally ploughed field and another along unploughed field, were setup at each farm in order to separate the effect of tillage from that of contours on soil water measured at each distance from the contour. The 15 mm PVC access tubes were installed at 2 and 7 m from the centre of the dead level contour with or without infiltration pit on the upslope side (Fig. 1). On the downslope side of the dead level contour with or without infiltration pit access tubes were installed at 3 and 8 m from the centre of the contour. Spacing of access tubes on either side of the dead level contour allowed soil water to be measured up to the middle of the cropped field. The access tubes were inserted to depths varying from 0.5 to 0.8 m across the four farms. Depth of access tubes was restricted by the presence of a stony layer in the profile at three of the four farms. At each farm access tubes were installed in October and maintained for the subsequent seasons and the donkey-drawn plough was controlled to avoid damaging access tubes during ploughing operations. The dead level contours averaged 0.9–1.0 m wide and 0.3 m deep across the four farms. The infiltration pits averaged 1–1.5 m long, 0.5–1.0 m wide and 0.3–0.4 m deep across the two farms (Dube and Siziba). Soil samples were collected between 3 and 8 m from the contour at 0.15 m depth interval up to 0.60 m for texture determination. Soil texture for each farm was determined by

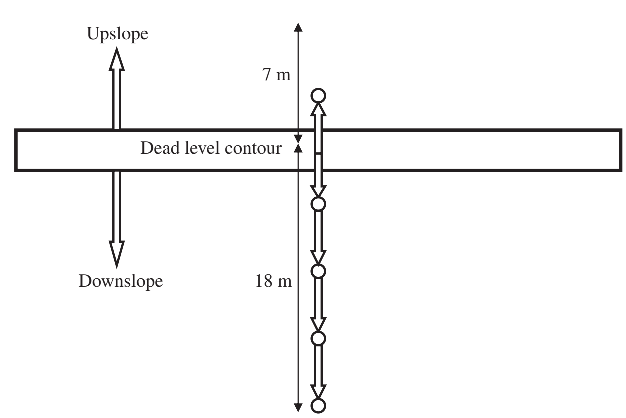

Fig. 1. Schematic diagram of the setup of access tubes across dead level contours at each farm in Gwanda district.