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Review

Conservation tillage of rainfed maize in semi-arid Zimbabwe: A review

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ABSTRACT

Food security in Sub-Saharan Africa, particularly in semi-arid tropics (41% of the region; <800 mm annual rainfall often coming in storms and >6 months of dry season) is threatened by droughts, dry spells and infertile soils. In Zimbabwe, 74% of smallholder farming areas are located in semi-arid areas mostly in areas with soils of low fertility and water holding capacity. The dominant crop in these areas, maize (*Zea mays* L.), is susceptible to drought. Under smallholder farming in Zimbabwe, conventional tillage entails cutting and turning the soil with a mouldboard plough thereby burying weeds and crop residues. Seed is planted by hand into a furrow made by the plough, ensuring that crops germinate in relatively weed free seedbeds. Inter-row weed control is performed using the plough or ox-drawn cultivators and hand hoes. Conventional tillage has been criticised for failure to alleviate negative effects of long dry spells on crops and to combat soil loss caused by water erosion estimated at 50 to 80 t ha^{-1} yr^{-1}. Therefore, conservation tillage has been explored for improving soil and water conservation and crop yields. Our objective was to determine the maize yield advantage of the introduced technology (conservation tillage) over conventional tillage (farmers' practice) based on a review of experiments in semi-arid Zimbabwe. We use a broad definition of conservation tillage instead of the common definition of $\geq$30% cover after planting. Eight tillage experiments conducted between 1984 and 2008 were evaluated. Conventional tillage included ploughing using the mouldboard plough and digging using a hand hoe. Conservation tillage included tied ridging (furrow diking), mulch ripping, clean ripping and planting pits. Field-edge methods included bench terraces (fanya juus) and infiltration pits. Results showed small yield advantages of conservation tillage methods below 500 mm rainfall. For grain yields $\leq$2.5 t ha^{-1} and rainfall $\leq$500 mm, 1.0 m tied ridging produced 144 kg ha^{-1} and mulch ripping 344 kg ha^{-1} more than conventional tillage. Above 2.5 t ha^{-1} and for rainfall >500 mm, conventional tillage had $\geq$640 kg ha^{-1} yield advantage. Planting pits had similar performance to ripping and conventional tillage but faced digging labour constraints. Experiments and modelling are required to test conservation tillage seasonal rainfall thresholds. Constraints to adoption of conservation tillage by smallholder farmers necessitate best agronomic practices under conventional tillage while work on adoption of alternative tillage methods continues.

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1. Introduction

The present food insecurity and projected population growth in Sub-Saharan Africa (SSA) demand change from low yielding farming systems towards greater production and sustainability (Kauffman et al., 2003; Wallace, 2000), particularly in semi-arid tropics (<800 mm annual rainfall often coming in storms, >6 months of dry season) where food security is threatened by frequent droughts, dry spells (Steiner and Röckstrom, 2003) and infertile soils (Sanchez, 2002). Food production has to increase under dwindling water resources (Bouman, 2007; Cai and Rosegrant, 2003). Therefore, water productivity in rainfed agriculture must improve if food production is to keep pace with population growth (Bouman, 2007).

Semi-arid zones of SSA cover about 41% of the region (Sanchez, 2002). Low crop yields in semi-arid areas are mainly due to poor temporal and spatial rainfall distribution rather than absolute water shortage (Barron, 2004; Barron and Okwach, 2005; Kahinda et al., 2008; Muhammad and Reason, 2004; Ochola and Kerkides, 2003; Rockström, 2000). Even though rainfall is low and poorly distributed, low productivity in rainfed smallholder agriculture in semi-arid tropics is more due to management-related sub-optimal performance than low physical potential (Rockström and Falkenmark, 2000; SIWI, 2001). Stable yield increases from 0.5–2 t ha^{-1} are achievable (Rockström et al., 2003). Over 50% of rainwater is lost by surface runoff and evaporation (Steiner and Röckstrom, 2003). The high surface runoff is caused by crust and pan formation, high intensity rainfall, and poor soil cover (Fowler and Rockström, 2001). Water use efficiency (transpiration/rainfall × 100%) is less (15–30%) in SSA (Falkenmark and Röckstrom, 2004) than in comparable climates in the USA (±50%) (Stroosnijder and Slegers, 2008). Water productivity can be improved through maximizing plant water availability and dry spell mitigation using supplementary irrigation (Rockström et al., 2003). However, limited areal extent, competing claims for water (Cai and Rosegrant, 2003; Vohland and Barry, 2009), and prohibitive development costs (Stroosnijder et al., 2012) limit the role of irrigation.

Zimbabwe's semi-arid areas, known as Natural Regions (NR) IV and V, with annual rainfall of 450–650 mm and less than 450 mm respectively (Central Statistical Office, 2008), cover 64% of the country (25 million hectares) (Whitlow, 1980). The rainy season is unimodal and stretches from November to March/April and the dry season occurs from April/May to October. A few showers may fall during the dry period but high evapotranspiration results in no effective rainfall and the soil undergoes extreme desiccation except at the foot of some slopes where the water table maybe close to the soil surface.

Although fertile soils occur including the Vertisol group (total exchangeable bases per 100 g clay (S/C > 60) and cation exchange capacity per 100 g clay (E/C) >60), belonging to the Pellustert large group in the US taxonomy and Eutric vertisols in FAO classification and Silliatic group (Zimbabwean classification), S/C ≥31 and E/C ≥35 including Typic Rhodustalf, Entic Eutrochrept in the US taxonomy and Chromic luvisol and Chromic Cambisol in the FAO classification (Nyamapfene, 1991); most soils in semi-arid Zimbabwe are infertile sands derived from basic gneiss (Grant, 1981; Vogel, 1992). These less fertile soils include Fersiallitic group (Zimbabwean classification) with S/C values 6–30 and E/C 12–35 which includes Oxic Paleustalf in the US taxonomy and Ferralic Cambisol and Ferralic Arenosol in the FAO classification and Regosol group (Zimbabwean classification) characterised by a deep sandy profile with less than 10% silt plus clay within the upper 2 m which includes isothermic, ustoxic and quartzipsamment in US taxonomy and Ferri-Luvic Arenosol in FAO taxonomy. The Lithosol group, which includes soils having <0.25 m depth equivalent to Lithic Ustorthent in the US taxonomy and Eutric Leptosol in FAO classification (Nyamapfene, 1991) constitutes soils whose agronomic potential is limited mostly by shallow depths.

Prior to the land reform in 2000 Zimbabwe's agricultural sector was dualistic with 4500 commercial farms and over 1 million smallholder farmers (Rukuni, 2006). The large-scale commercial farmers (LSCF) occupied over 10 million hectares of land mainly in areas with better soil fertility and rainfall than the estimated 18 million hectares for the smallholder farmers. The dual structure was created by the colonial regime from the 1890s through 1970s. Even after the land reform programme, most smallholder farming takes place on communally owned land (communal areas) and is typified by a mixture of rainfed small-scale subsistence and commercial production (Wright et al., 1998). Communal ownership confers individual rights to plots for houses, gardens and fields with shared but unlimited access to grazing land. Due to the systematic segregation by the colonial regime, an estimated 74% of the communal land is located in the semi-arid areas (Muir-Leresche, 2006) mostly in areas with soils of low inherent fertility and water holding capacity. Tillage methods discussed in this paper are targeted at these smallholder farmers.