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Evaluating manual conservation agriculture systems in southern Africa

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ABSTRACT

Future threats of climate variability and change and accelerated soil degradation in southern Africa have increased the need for more sustainable and "climate-smart" agriculture practices. Manual systems of conservation agriculture (CA) based on seeding into planting basins or direct seeding techniques have received increased attention over the last decade. However, a critical review of the pros and cons of the different manual seeding systems under different agro-ecologies has been lacking. This paper aims at analysing different manual seeding systems in areas extending from central Mozambique to central Malawi. Results show that CA systems perform differently in contrasting agro-ecological environments. Direct seeded treatments had greater maize yields than conventional tillage practices by an average of 12–27% and outperformed the conventional practice in nine out of fourteen yield comparisons. Basin planted treatments performed well only in Sofala and Manica (15%) with yield penalties of −9% in Tete. The strongest factor influencing maize grain yields in the more variable areas of Manica and Sofala was the quality of season and the location, whereas tillage treatment and location were more important in the higher rainfall areas of Tete. Direct seeding systems out-yielded other treatments in areas of higher rainfall and responded better to a favourable environment than conventional tillage practices. CA systems, especially direct seeding in Malawi, Manica and Sofala, showed greater financial returns to investments and labour productivity due to reduced labour costs and higher yields. Labour savings of up to 43 labour days ha^{-1} could be achieved with direct seeded treatments in Malawi. The results of this research clearly highlight the need for site-specific recommendations and adaptation of CA systems to different agro-ecological environments. Blanket recommendations of one CA system across many agro-ecologies, as has often been done in the past, will only lead to underperformance of CA in some areas and rejection by smallholder farmers if yield benefits are not achieved.

1. Introduction

Unreliable climatic conditions, frequent droughts and potential future impacts of climate change in southern Africa (Lobell et al., 2008; Cairns et al., 2013) together with continued population growth (Godfray et al., 2010) have increased the need for more resilient, water conserving and sustainable cropping systems (Pretty et al., 2011). Conservation agriculture (CA) is one of such systems (Thierfelder et al., 2015a,b). Originally developed in the Americas and Australia, CA combines three basic principles (a) minimum soil disturbance to avoid soil inversion by the hoe or the mouldboard plough; (b) crop residue retention of available plant material on the soil surface and (c) diversification through crop rotations or associations to reduce and overcome pest and disease problems associated with monocultures, and for nutrient management (Kassam et al., 2009).

Since the beginning of the millennium, an increasing number of organizations have started to promote systems based on the principles and practices of CA in southern Africa (Sims et al., 2012; Wall et al., 2013; Thierfelder et al., 2015b). CA systems provide short and long term benefits which have been summarized in recent reviews (Wall, 2007; Kassam et al., 2009; Thierfelder et al., 2015b). CA has immediate positive benefits on infiltration, available soil water and evaporation (Thierfelder and Wall, 2009) and reductions in surface run-off and soil erosion (Munyati, 1997). In the longer term, increases in productivity of CA systems (Thierfelder et al., 2013) have been observed, sometimes with incremental increases in soil carbon (Nyamadzawo et al., 2009; Thierfelder and Wall, 2012), although the latter may depend on the site conditions, soil type and residue management (Govaerts et al., 2009). Despite the positive benefits reported, the universal

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suitability, feasibility and applicability of CA for smallholder farmers in southern African have also been questioned by Giller et al. (2009) and others (Arslan et al., 2013; Andersson and D'Souza, 2014). Amongst the challenges highlighted are the difficulties in retaining sufficient crop residues (Valbuena et al., 2012); weed control in the initial years of CA; the lack of equipment and critical inputs and the lack of knowledge on how to practice CA under this environment (Wall, 2007).

Hence, there is a strong need to provide regionally generated data to increase the general knowledge about the benefits and challenges of different CA systems, as well as to provide entry points for farmers to adopt CA (Baudron et al., 2015). A comprehensive analysis about the benefit and challenges of different manual systems is currently missing.

Most farmers in east and southern Africa rely on maize (*Zea mays* L.) as the staple crop. Maize is grown to a large extent under subsistence farming and accounts for 50–90% of the population's caloric intake (Dowswell et al., 1996). The remaining crops produced for human consumption are sorghum (*Sorghum bicolor* L.), cassava (*Manihot esculenta* Crantz), sweet potatoes (*Ipomoea batatas* (L.) Lam.), various grain legumes and vegetables. In southern Africa, maize is traditionally planted after land preparation with a hand hoe or the mouldboard plough (Fowler and Rockström, 2001). Maize is often grown in continuous monocultures or in unbalanced rotations without retaining sufficient crop residues (Mapfumo and Giller, 2001; Thierfelder and Wall, 2010).

Planting basins for example are a manual CA seeding technology originating from the Zai pit system in the Sahel (Lahmar et al., 2012). The Zai pit system was developed to increase the capture of run-off water and improve infiltration (Zougmoré et al., 2014). The system was locally developed and adapted by the Zimbabwean Farmer Brian Oldrieve in the 1990s (Oldrieve, 1993). Farmers attracted to basins normally do not have access to draft animals. Basins are promoted to be permanent and should remain in place for many years. In practice, they often shift from their exact location year after year. Basins are dug over the dry season with hand-hoes (locally called badza in Zimbabwe and Malawi or the chaka hoe in Zambia) to reduce labour demands at the onset of the rains. Recent studies by Bunderson et al. (2015) in Malawi indicate that the labour for digging basins of the size recommended by the Conservation Farming Unit (Aagard, 2011) is five times higher than for the traditional system of splitting and rebuilding ridges with hand hoes. It is generally acknowledged that digging basins can be very laborious in the first year, but thereafter the basins are maintained and only need to be reopened (CFU, 2003). A key advantage is that basins improve the efficiency and effectiveness of application of animal manure or compost when available.

In Zambia the common practice is to dig the basins deeper than in Zimbabwe with the aim of mechanically breaking the perceived existence of shallow hardpans (CFU, 2003; Aagard, 2009). Zimbabwean farmers, encouraged by a number of organisations, are of the view that over time the plants will break up hardpans and therefore smaller planting basins are recommended to reduce the amount of labour for digging.

In summary, basins enable timely planting, precise placement of seed, fertilizer and/or manure and reduce soil disturbance in comparison to full tillage systems. However, to qualify for the definition of CA, they need to be complemented with the principles of residue retention and crops rotations or associations.

A key criticism of basins is the high labour costs for digging which can prohibit adoption, even though it is a one-off operation (Rusinamhodzi, 2015). Another major criticism is that the fixed position of basins is not compatible with the spacing requirements of different crops grown by farmer, such as grain legumes and tobacco. This limits the suitability of basins for crop rotations and intercropping.

Manual direct seeding system are characterized by seeding with a pointed stick (dibble stick) (Ngwira et al., 2013a; Thierfelder et al., 2013) or a manual Jabplanter (Irmaǫs Fitarelli machinas, Brazil) at recommended plant spacings. In contrast to the basin system, direct seeding is done after the first effective rainfalls and without the need for other land preparation except for distributing crop residues. Crop residues are left on the soil surface without disrupting the seeding because planting is direct through the residues. Soil disturbance is generally considered as less than 1% and the soil surface is maintained to a large extent undisturbed. Many would describe this system as no-till because the only disturbance to the soil is to make a small planting hole. The system is also very flexible for use with a wide range of crops and cropping systems where the row and in-row spacing can be adjusted according to the needs and agronomy of the specific crops and the cropping strategy used.

The objective of this paper is to compare the two manual CA seeding systems, basins planting and manual direct seeding, in comparison with conventionally tilled systems on the productivity of maize and labour. The comparison evaluates the advantages and disadvantages of each system from the perspective of the smallholder farmer. The aim is to contribute knowledge on more site-specific adaptations of manual seeding systems in response to different agro-ecologies in southern Africa.

Table 1
Site description of ten on-farm sites in Mozambique and three on-farm sites in Malawi.

Province (region)/country	District	Site name	Elevation (m.a.s.l.)	Treatments	Crops	Duration	Rainfall	Soil texture	*N*
Manica and Sofala province/Mozambique	Nhamatanda	Lamego Segredo	21	CP, BA, DS	Mz, Cp	2009–2014	551 (±281)	LS	6
	Nhamatanda	Lamego Ndeja	20	CP, BA, DS	Mz, Cp	2011–2014	883 (±190)	LS	5
	Báruè	Malomwe	586	CP, BA, DS	Mz, CP	2009–2014	1024 (±420)	SL	5
	Buzi	Madjiga	46	CP, BA, DS	Mz, CP	2009–2012	712 (±70)	LS	5
	Báruè	Nhamizhinga	622	CP, BA, DS	Mz, Cp	2009–2014	1215 (±223)	SL	6
	Báruè	Mussianharo	571	CP, BA, DS	Mz, Cp/Sb	2012–2014	1124 (±203)	SL	6
	Gondola	Pumbuto	542	CP, BA, DS	Mz, Cp	2011–2014	929 (±196)	LS	5
Tete province/Mozambique	Tsangano	Gimo	1435	CRT, BA, DS	Mz, Cb	2011–2014	1147 (±84)	SL	6
	Angonia	Ulongue	1269	CRT, BA, DS	Mz, Cb	2009–2014	872 (±255)	SL	6
	Angonia	Nzewe	1388	CRT, BA, DS	Mz, Cb	2011–2014	893 (±233)	SL	6
Central and southern region/Malawi	Balaka	Chimbalanga	565	CRT, BA, DS	Mz, Mz/Pp	2011–2014	619 (±161)	SL	6
	Ntcheu	Chagwamomwe	830	CRT, BA, DS	Mz, Mz/Pp	2011–2014	657 (±76)	SL	6
	Salima	Tembwe	880	CRT, BA, DS	Mz, Mz/Pp	2011–2014	676 (±169)	SCL	6

Notes: m.a.s.l. = meters above sea level; CP = conventional practice; BA = planting basins; DS = direct seeding; CRT = conventional ridge tillage; Mz = maize, Cp = cowpea; Sb = soybean; Pp = pigeonpea; LS = loamy sand; SL = sandy loam; SCL = Sandy clay loam; N = sample size at each on-farm location during yearly yield assessment. Rainfall is expressed as average annual rainfall with the standard deviation in brackets. The sampled households are selected from communities of 100–200 households and represent a coverage of 3–6% of the population at each site.