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Review

# Conservation agriculture and its impact on soil quality and maize yield: A South African perspective

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ABSTRACT

Sub-Saharan Africa is faced with the challenge of improving current food security on highly degraded land. At the same time, the region has to develop strategies to ensure future food security for the increasing population under worsening climate change. Conventional tillage (CT) has for many years resulted in the deterioration of soil quality through depletion of soil organic matter. This review of literature provides an overview of the impact of conservation agriculture (CA) on soil quality with particular emphasis on key soil physical, chemical and biological properties. This paper also discusses impact of CA on yield, highlighting South African research gaps since the adoption is still very low in the country. The review of numerous studies indicated that soil quality and yield improvements are possible in CA although some negative results have also been reported under contrasting environments. Yield under CA were recognised to be resilient to seasonal rainfall variability compared with CT because of its ability to conserve water. CA is particularly relevant to the South African maize production given high levels of soil degradation, water scarcity and low soil fertility status. This review of literature demonstrated that CA can have substantial positive environmental, financial, social and health benefits for South Africa and the world. However, more research on CA is required from different agroecological zones and socio-economic contexts since maize is the biggest produced crop in South Africa.



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## 1. Introduction

The world population continues to increase and it is projected to reach 9.1 billion by 2050 (FAO, 2009a). This increase is expected to come mostly from the developing world with Sub-Saharan Africa highlighted on top of the list (United Nations, 2009). Therefore, the pressing need to ensure increased food supply and food security on the limited amount of land in the region is obvious. Moreover, land resource in the region is continuously losing its value as a medium for crop growth. According to FAO (2010a), southern Africa has high levels of soil degradation and a decline in soil fertility, which threatens crop productivity. Reportedly soil degradation level in South Africa is severe and 41% of the cultivated land is highly degraded (Bai and Dent, 2007). Droughts in these areas often worsen the situation, resulting in complete crop failures (FAO, 2009b), especially for poor-resourced smallholder farmers, who are often situated in marginal areas of agricultural crop production (Mabhaudhi et al., 2013).

South Africa is a water scarce country with erratic rainfall distribution and an annual precipitation of less than 500 mm/year (IWMI, 1996), which is far below than the world average of 860 mm/year (DWAF, 2002). In the long run, climate change is predicted to have negative impact with more frequent and prolonged drought and higher temperatures (FAO, 2010b). The combination of these problems put more pressure on limited arable land and available fresh water needed for food production. This is of great concern when viewed in the context of climate change and impact this will have on agricultural production and vulnerability of subsistence farmers and poor urban communities concerning food security (Thierfelder et al., 2014). This is most likely because the incidence of crop failure will probably rise due to extreme weather events (Schulze, 2011). In response to these challenges, conservation agriculture (CA) has been proposed by many researchers (Hobbs, 2007; Hobbs et al., 2008; Giller et al., 2009) to buffer these effects because of its powerful mechanism to adapt by increasing resilience to land degradation, drought and increasing water use efficiency (FAO, 2009b).

FAO (2010b) has defined CA as a concept for resource saving agricultural productivity that strive to achieve acceptable profits together with high and sustained production levels while concurrently saving the environment. The three central themes around CA are based on systematic crop rotation, permanent soil cover by crop residues and minimum tillage and/or zero-tillage (Rusinamhodzi, 2015). The benefits associated with CA include crop sequence intensification (Brouder and Gomez-Macpherson, 2014), better use of the cropping season window permitted by earlier field entry (Hobbs et al., 2008), increase soil organic carbon (SOC) (Rusinamhodzi, 2015), soil moisture retention while sharply reducing run-off, soil erosion and surface soil temperatures (Findlater, 2013). According to FAO (2011), the long term effects of CA when practiced comprehensively include improved crop yields and reduction of the production costs. Crop rotation allows for inclusion of the crops that can increase soil fertility, for example leguminous crops (Hobbs et al., 2008) and it is also practiced to reduce the impact of pest and diseases which are more problematic in monocultural cropping systems (Kirkegaard et al., 2008). The practice specifically decreases farm sensitivity to weather variability through improving water retention and reducing water logging (Thierfelder and Wall, 2010). Therefore, increased soil water retention makes it a more reliable system for crop production in water scarce or dry countries such as South Africa and many parts of Sub-Saharan Africa.

The estimates have, however, shown that the level of adoption of CA use in South Africa is still very low (36 800 ha) compared to USA (26 500 000 ha), Argentina (25 553 000 ha), Brazil (25 502 000 ha) and Australia (17 000 000 ha) which have massive adoption of this technological advancement (Friedrich et al., 2012). In Sub-Saharan Africa, South Africa is on top of the list of countries adopting CA, followed by Zambia (200 000 ha), Mozambique (152 000 ha) and Zimbabwe (139 300 ha) (Friedrich et al., 2012). Although the adoption of CA in South Africa is the highest in the Sub-Saharan Africa, it only constitutes 2.8% of the country's arable land. Various initiatives has been recently undertaken by Agricultural Research Council (Anon., 2014), farmer's organisations and government to implement CA adoption in South Africa, however, these initiatives have not yet gained momentum or penetrated in most poor-resourced small scale farmers found in different socio-economic and agroecological regions of South Africa. Factors which frequent limits its adoption by smallholder farmers in other African countries includes, competing uses for crop residues (crop-livestock mixed farming), increased labour demands for weeding and lack of access to external input such as herbicides and inorganic fertilizers (Giller et al., 2009) which form parts of CA backbone. In commercial farming systems, FAO (2010a) reported that mind set of farmers, extension and policy makers who still believe that crop growing is synonymous with plowing and making the field clean, has contributed to its slow adoption. Clean seedbeds are part of the cause of soil degradation and yield reduction due exposure of soil to wind and water erosion. Inadequate CA knowledge and skills, retaining residues, weed control, availability of equipment