

*Full Length Research Paper*

# Evaluation of tillage practices on selected soil chemical properties, maize yield and net return in O. R. Tambo District, South Africa

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The costs of maize production per ha in the Eastern Cape Province are escalating due to an increase in mechanization and input costs. Conservation agriculture (CA) has been identified as one of the systems that can reduce costs of production and improve maize productivity. Most farmers in the district still require tangible evidence on the benefits and impacts of minimal soil disturbance. Hence it was necessary to conduct this comparison between tillage practices on maize productivity. Ten projects under conventional tillage (CT) were randomly selected from maize cropping in three local municipalities of the Eastern Cape Province in South Africa. Minimum tillage (MT) demonstration fields on maize production measuring 1 to 5 ha were conducted in the aforementioned local municipalities and were compared to project under conventional tillage. Minimum tillage recorded an increase in P (46 mg/L) and K (227 mg/L) concentration; whereas Ca (395.6 mg/L) and Mg (406.75 mg/L) concentration were higher under conventional tillage at 0 to 10 cm soil sampling depth. Soil pH was not affected by tillage practices. Minimum tillage recorded an average increase in maize yield from 2.3 to 4.78 tons per ha compared to 4.16 tons per ha under conventional tillage. The greatest gross margin was observed from minimum tillage (US \$273.92) compared to conventional tillage which had the lowest (US \$207.02) gross margin. The short term comparison between the tillage practices revealed that minimum tillage had higher levels of P and K soil macro elements, increase in maize grain yield and subsequent high net benefits relative to conventional tillage. Therefore, it is necessary to scale up the adoption of minimum tillage in the district coupled with crop rotation and residue retention so that the majority of farmers can realize its benefits.

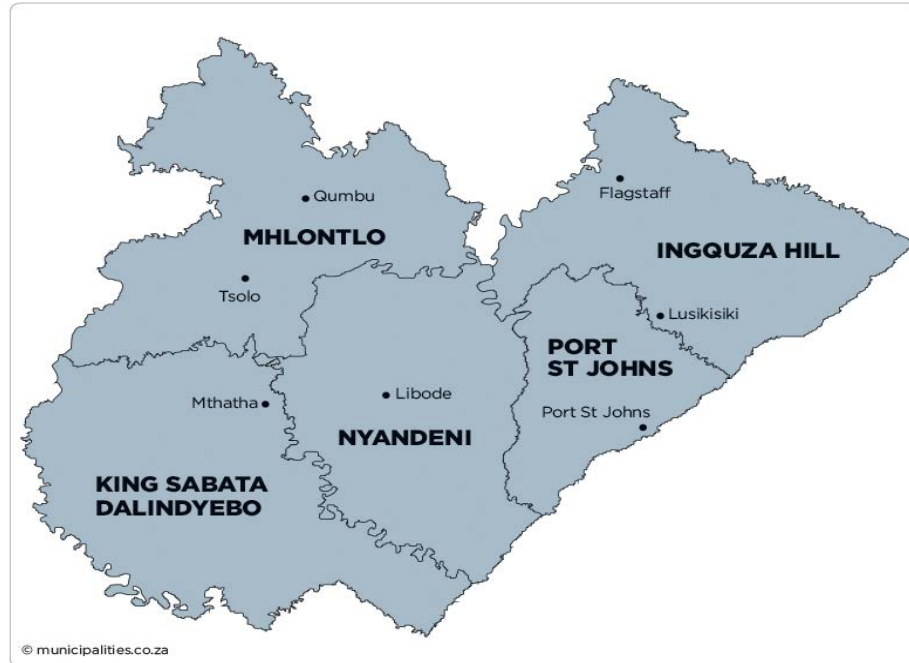
**Key words:** Gross margin, tillage, nutrients, yield.

## INTRODUCTION

Traditionally, farmers practice conventional tillage with ploughs, discs and harrows. It is believed that in order to obtain a uniform and loose seedbed that is weed-free, it is necessary to till the soil (Six et al., 2004). The loss of

organic material in turn influences chemical, biological and physical properties of the soil and therefore has a direct influence on overall soil health (Williams et al., 2020). Tilling the soil expose the carbon to oxygen,

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**Figure 1.** Map of O.R Tambo district

allowing it to burn off into the atmosphere. Soil cultivation for agricultural production is one of the most notable land use change that has led to significant losses of carbon (C) from soil (Guo and Gifford, 2002). Conventional tillage practices, especially ploughing disturb aggregates and contribute to soil organic matter depletion (Aziz et al., 2013). Tillage systems with minimized soil disturbance are reported to increase the occurrence and the stability of macro-aggregates compared to CT soils (Paustian et al., 2000). According to Six et al. (2000), there can be more than double the amount of macro aggregates in a no-till system in comparison to conventional tillage system. Routine tillage with its associated soil degradation also has a strong potential to increase the impact of droughts as the soil becomes less fertile and less able to infiltrate rainfall or irrigation water.

Minimum tillage or no tillage recommended under CA, promotes the accumulation of organic carbon in soils, known as C sequestration, thereby mitigating on climate change. Globally, agricultural soils are estimated to potentially sequester 0.4-0.8PgC per year by adopting conservation agriculture practices (Lal, 2004). Conversion from conventional tillage (CT) to no-tillage (NT) is considered to be one of the potentially efficient strategies (Six et al., 2004). Reduced tillage also results in better aggregate stability and thereby results in better protection of soil organic carbon and thus higher soil organic carbon content in the long term.

Conservation agriculture has the capacity to increase infiltration and efficient use of rainfall, sustained

productivity, increased profits and food security while preserving and enhancing the environment and the resource base (FAO, 2016). Majority of famers in the district still require tangible evidence on the benefits and impacts of CA. They need to know - will CA significantly increase productivity and food security for their families? Will CA help them save on production costs and generate income? Hence it was necessary to conduct this comparison between tillage practices on maize productivity. Therefore, the main aim of the study was to determine the effects of tillage practices on selected soil nutrient availability, crop yield and system profitability.

## METHODOLOGY

### Study sites

Ten projects under conventional tillage were randomly selected from maize cropping in three local municipalities namely Ingquza, Mhlontlo and Nyandeni (Figure 1). Minimum tillage (MT) demonstration fields (1-5ha) on maize production conducted in the aforementioned local municipalities were compared to project under conventional tillage (CT). Annual rainfall of the above mentioned areas ranges from 750 to 1000 mm. These sites are characterized by deep well drained soils and have high potential for maize production.

### Field and laboratory measurements

Soil samples were taken in each demonstration field (20 soil samples) prior planting and after harvesting of summer maize at 10 cm soil depth using an auger. Soil samples were sent to Dohne



**Plate 1.** Minimum tillage and Conventional tillage system.

Laboratory for nutrient and chemical analysis of P, K, Ca, Mg, Zn and pH. The samples were stored in a cold room (4°C) until use. Before laboratory work, soil samples were air dried, sieved with a 2 mm sieve. Olsen P was determined using a continuous flow analyzer (San 2++ Skalar CFA, Skalar Analytical B.V., The Netherlands) employing the ammonium molybdate – antimony potassium tartrate – ascorbic acid method after extraction with 0.5 M sodium bicarbonate (NaHCO<sub>3</sub>) (AGRILASA, 2004). Extractable K, Mg, Ca and Zn were determined after extraction with 1M ammonium nitrate (NH<sub>4</sub>NO<sub>3</sub>) solution as described in AGRILASA (2004). The cations were then analysed using Inductively Coupled Plasma – Optical Emission Spectrometer (ICP-OES, Varian Inc., The Netherlands). Soil pH was determined using a WTW pH 526 meter (Eutech instruments, Singapore) in a 1:2.5 (v/v) soil water ratio.

Conventional tillage projects were ploughed and disked to make a fine seed bed before the initial crop establishment whereas MT demonstration fields were sprayed with glyphosate at a rate of 2 liters per ha and followed by ripping before planting (Plate 1). Herbicide was applied again 30 days after planting for post emergence weed control. A cypermethrin insecticides was used to control maize stalk borer and other insects at a dosage rate of 150 ml per ha. A medium growth prolific roundup ready maize cultivar (PAN 6R-680R) was planted, targeting a population of 40 000 plants ha<sup>-1</sup> recommended under dry land productions. Fertilizer mixture totaling 4 bags of 2:3:4 (30) were applied during planting and side dress with 3 bags of lime ammonium nitrate (LAN 28%). Maize was left to mature and dry on the field and was later harvested, shelled and weighed to give grain yield. Net plot area of 10 m × 6 m in each ha both under CT and MT was used for yield determination.

#### Maize economic analysis

The profitability of each tillage practices on maize productivity was done using Gross Margin analysis (CIMMYT, 1988). South African

Futures Exchange (Safex) market price for yellow maize of US\$148.32 per ton was used (Grain SA, 2017). Revenue was the product of the safex market price of maize and the adjusted crop yield (less 10%) from each tillage practices. The total variable costs (TVC) for each tillage practice (CT and MT) were calculated by summing-up the tillage, inputs and labor costs incurred. The gross margin (GM) for each tillage practice on maize productivity was the difference between the revenue and the total variable costs on per ha basis.

## RESULTS AND DISCUSSION

Soil chemical properties were affected by tillage practices where minimum tillage recorded an increase in terms of P (34.59 mg kg<sup>-1</sup>) and K (170.68 mg kg<sup>-1</sup>) (Figures 2 and 3); whereas Ca (301.98 mg kg<sup>-1</sup>) and Mg (310.50 mg kg<sup>-1</sup>) were higher under CT (Figures 4 and 5). Lowest values of P (10.5 mg kg<sup>-1</sup>) and K (119.96) recorded in CT could be due to the inversion of top soil during ploughing which shifts less fertile subsoil to the surface. Results were in agreement with the finding by Mtyobile et al. (2019) who indicated that P levels were significantly affected by tillage at 5-10 cm and 10-20 cm soil depths and in all the depths, no-till resulted in higher extractable P levels than CT. A study by Njaimwe (2010) revealed that high P stratification on soil surface under no-till was attributed to limited soil mixing with no-till as opposed to tilled soils. The higher K concentration under no-till compared to CT was as reported by Houx et al. (2011) for the upper soil layer in a long term tillage experiment. Hickman (2002) also observed that K tended to be reduced in the CT plots compared to no-till. An increase in K levels in

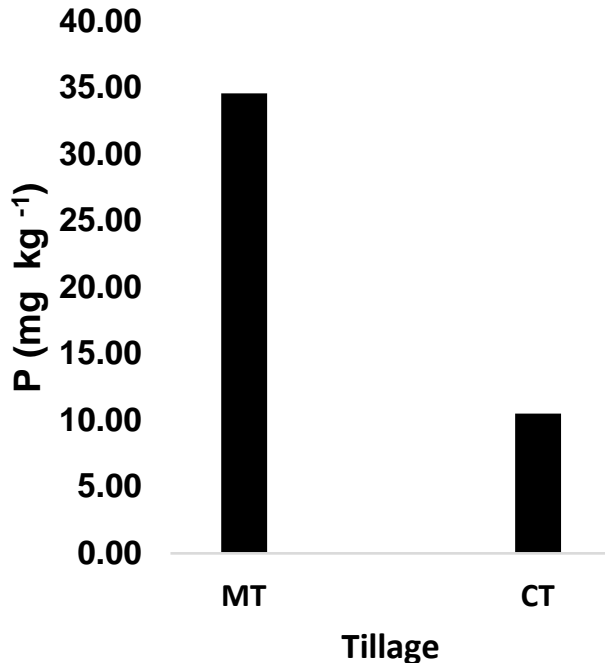


Figure 2. Tillage effect on P.

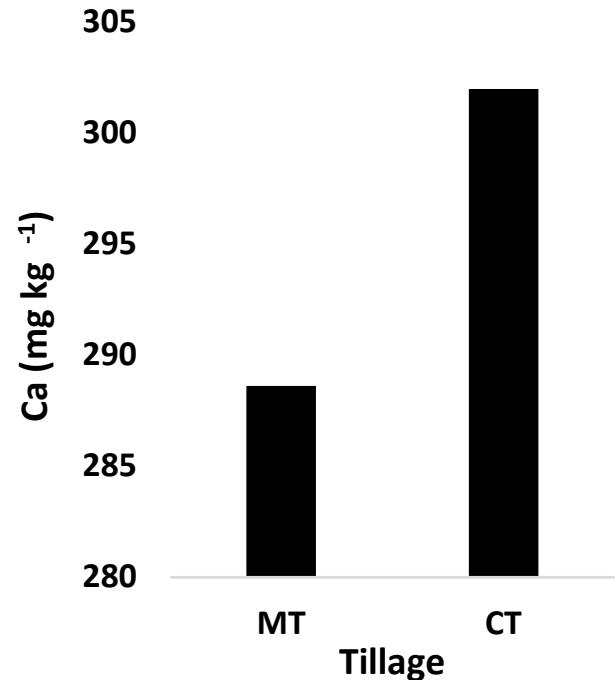


Figure 4. Tillage effect on Ca.

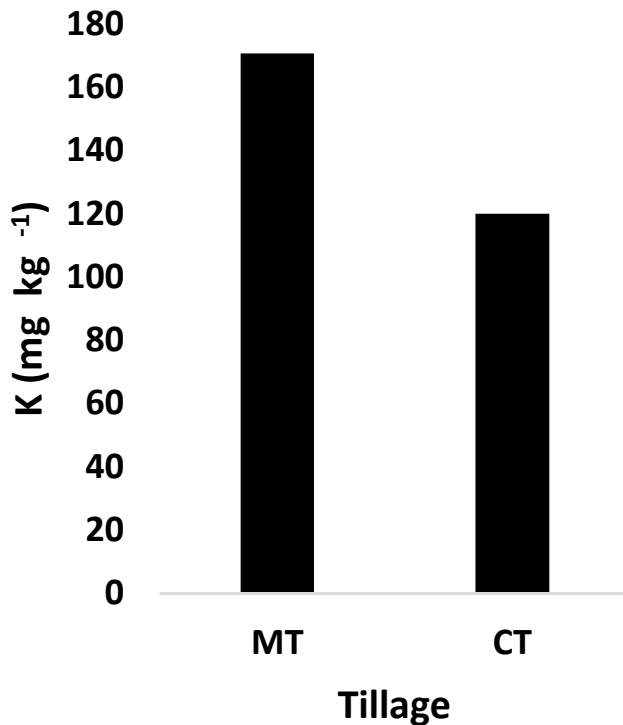


Figure 3. Tillage effect on K.

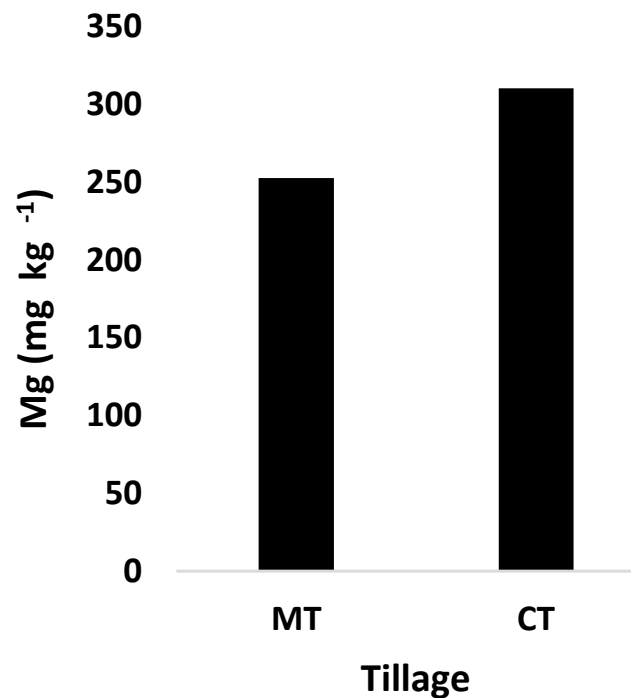


Figure 5. Tillage effect on Mg.

continuous maize plots is in agreement with findings by Reeves (1997). There was no difference in Zn and pH levels (Figures 6 and 7 between the tillage practices.

Results revealed that soil pH was not affected by tillage practices (Figure 7). This is however in contrast to other reports of decreased pH in MT systems compared to

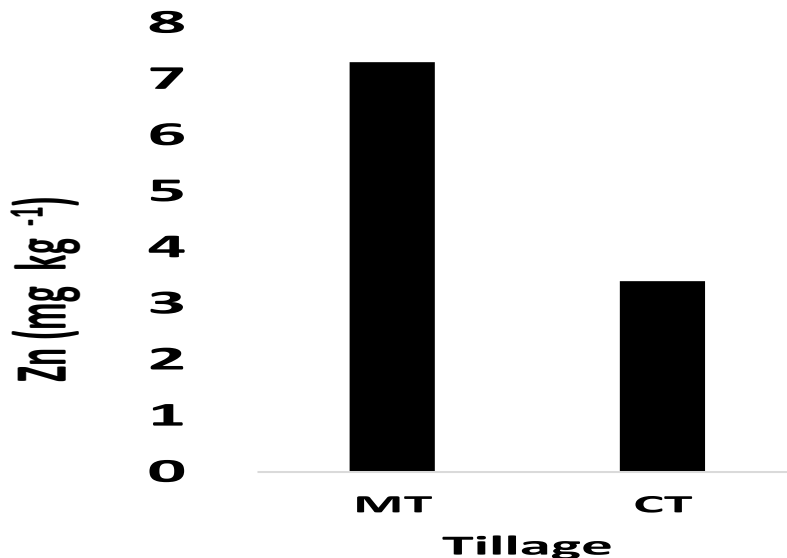


Figure 6. Tillage effect on Zn.

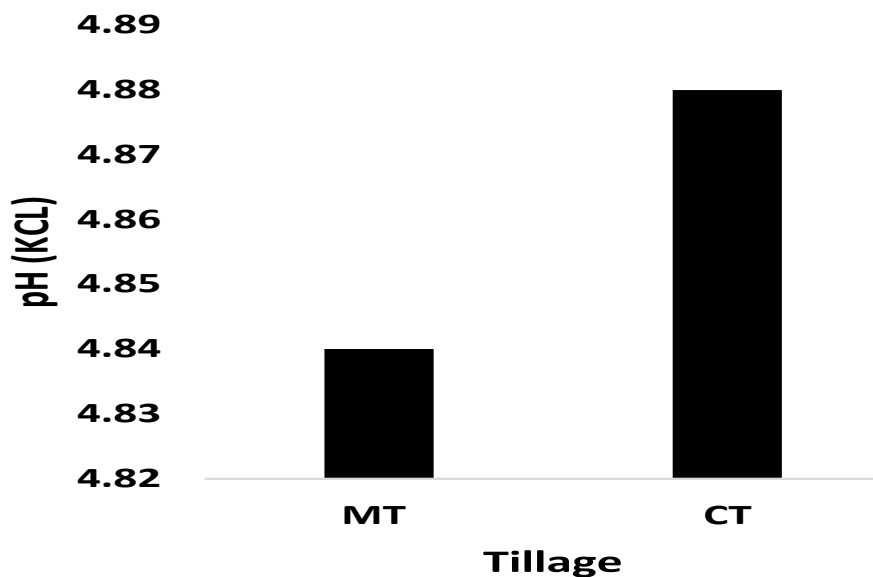


Figure 7. Tillage effect on pH.

Rahman et al. (2008). The slight decrease in pH under MT (Figure 7) could be attributed to accumulation of organic matter in the upper few centimeters causing increases in the concentration of electrolytes and reduction in pH (Rahman et al., 2008).

The highest yield observed under CT was 5.31 tons per ha and lowest yield was 3.21 tons per ha (Table 1). Conversely, MT had the highest yield of 6.31 tons per ha and lowest yield of 2.30 tons per ha. Minimum tillage recorded an average increase in maize yield of 4.78 tons per ha compared to 4.16 tons per ha under CT (Table 1).

Higher maize grain yield observed under MT could be associated with improvement of P and K concentration to moderate levels compared to CT. Phosphorous is one of the essential soil elements limiting crop production in the Eastern Cape (Mandiringana et al., 2005). Phosphorus is reported to play a very important role in flower formation and seed production and other functions (Gichangi, 2007).

Total variable costs were higher under MT (US \$435,07) than CT (US \$410,01). Increasing costs under MT were brought about by higher usage of herbicide in

**Table 1.** Maize grain yield (tons/ha).

Year	Local Municipality	Project name	Conv Tillage	Project name	Minimum tillage
2016/2017	Ingquza	Twazi	4.13	Nkozo	4.00
		Gqina maize project	5.12	Gqina	5.50
		Xhophozo B	4.21	Rwantsana	4.50
	Mhlontlo	Mcetyana	5.31	Lujecweni	5.20
		Mbinja	3.21	Mnga	4.40
	Nyandeni	Mchwebeni	3.24	Xhanga farming	4.60
		Vukani	3.51	Phako	5.04
		Nkanga	5.29	Njike S	2.30
		Hluleka	3.75	Philani	6.31
		Njezweni	3.78	NLanga project	5.95
<b>Total Average Yield (tons/ha)</b>			<b>4.16</b>		<b>4.78</b>

**Table 2.** Maize enterprise budget analyses.

Item	Unit	Price	Quantity	Cost	Quantity	Cost
<b>A. Revenue</b>						
Maize grain	kg	0,15	4780	US \$708,99	4160	US \$612,58
<b>B. Variable costs</b>						
Maize	kg	6,14	12,5	US \$76,81	12,5	US \$76,81
Basal fertilizer	kg	0,44	200	US \$88,99	200	US \$88,99
Topdressing	kg	0,39	150	US \$58,80	150	US \$58,80
Herbicide	l	5,56	2	US \$11,12	2	US \$11,12
Insecticide	l	7,77	0,15	US \$1,17	0,15	US \$1,17
Ripping	ha	52,18		US \$52,18		
Ploughing	ha	52,18			985	US \$52,18
Discing	ha	39,73		US \$39,73	750	US \$39,73
Planting	ha	37,08		US \$37,08	700	US \$37,08
Pre-spray	ha	20,29		US \$20,29		
Post spray	ha	20,29		US \$20,29	383	US \$20,29
<b>Total input costs</b>				<b>US \$411,23</b>		<b>US \$386,17</b>
Total labour	day	150	3	US \$23,84		US \$23,84
<b>Total variable costs</b>				<b>US \$435,07</b>		<b>US \$410,01</b>
<b>C. Returns</b>						
<b>Gross margin</b>				<b>US \$273,92</b>		<b>US \$207,02</b>

initial application of MT (Table 2). The greatest gross margin was observed from MT (US \$273,92) compared to CT which had the lowest (US \$207,02) gross margin (Table 2). An increase in GM was due to an increase in maize revenue recorded under MT. Overall costs of production had increased under MT due to higher input use particularly the herbicide.

However, the costs of production under MT are expected to decrease overtime when residues are retained on soil surface to suppress weeds and ensure

soil fertility improvement. Also the non-utilization of a ripper in the subsequent season will reduce the costs of production. Although the cost of producing maize is high under MT, the higher yield gains achieved with this technology resulted in significantly better returns to production compared to CT. Results are in agreement with the findings by Muzangwa (2016), who reported that maize-wheat-soybean crop rotation under CT with residue removal had the least net benefit whilst the greatest net benefits were observed from maize-wheat-

soybean crop rotation under NT with residue retention.

## CONCLUSION AND RECOMMENDATIONS

The practice of MT resulted in higher P and K soil macro elements, increase in maize grain yield and subsequent high net benefits relative to CT. Minimum tillage can be recommended as the most viable options for smallholder CA farmers in O.R Tambo District to improve maize grain. Long term studies are required to study the trend of soil chemical properties in the soil profile and its effect on crop production. Increased research and extension effort to promote CA among both smallholder and large scale commercial farmers should be carried out. It is therefore necessary to scale up the adoption of CA in the district so that the majority of farmers can realize its benefits.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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