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Field Soil Moisture Content under Conventional Tillage and Conservation Agriculture Practices in Liselo, Namibia

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ABSTRACT

This article focuses on the results of the trials developed to monitor the short-term effects of conventionally tilled practices (CP) versus Conservation Agriculture (CA) on soil quality and crop productivity under conditions of the major cropping systems in central, north-central and north-eastern regions of Namibia. The objective of the trials was to test the hypotheses that (a) CA treated plots have a significant higher water infiltration and soil moisture content (b) the CA principles (minimum tillage, soil cover and crop rotation or intercropping) have a significant influence on soil moisture content eventually leading to greater crop productivity. Results from Liselo in the Zambezi region of Namibia on the effects of tillage methods on soil moisture content are as follows. Conventional mouldboard ploughing (CPa), Sub-soiling with a Magoye ripper (SS-M) and Manual tillage using Dibble stick with mulch (MDS-M) were some of the treatments tested among others. Tillage systems appeared to have significantly affected ($P<0.05$) soil moisture in the 0-30 and 0-60 cm soil depths over the study period. Plots subsoiled with Magoye Ripper (SSM) (14.9mm) had 3.47% higher average soil moisture content in the 0-30cm soil depth and 3.05% higher moisture in the 0-60 cm soil depth than conventional ploughing. Manual tilling with a dibble stick (MDS-M) and conventional tilling with a plough (CTa) were found to be insignificantly different from each other with soil moisture averages of 14.1 mm and 14.4 mm in the 0-30 cm soil depth, respectively, and 39.3 mm for both in the 0-60cm soil depth, respectively.

Results suggest that some tillage methods and CA practices have the potential to increase water conservation and contribute to reduction of risk of crop failure, as was observed where subsoiled plots had more soil moisture content than conventionally tilled plots.

Keywords

Conventional Tillage, Conservation Agriculture, run-off, Soil moisture content, Total infiltration.

Introduction

Tillage is the preparation of the soil for the production of crops used for human consumption, animal feed and/or for the improvement of the soil. Tillage methods [1], climatic factors especially rainfall distribution and reliability [2] influence available soil moisture which is key for plant growth and development and a number of the soil's physical properties such as soil hydraulic properties, water flow, and path and the stability of the biotic factors [3]. Tillage comes in many types, forms and variations. Based on percentage residue cover left on the soil surface and tillage methods, tillage is divided into three main categories, namely Intensive tillage usually referred to as Conventional tillage, the second category called Reduced tillage and the last category known as No tillage [4].

Tools often used for tillage include, rippers, jab-planters, mouldboard ploughs to name a few. In Namibia, tillage is largely done using the hand hoe and the more common animal drawn mouldboard plough introduced in the early 20th century from Europe and tractor drawn ploughs, methods commonly referred to as Conventional Tillage (CT). Conventional Tillage is by far the most common practice used among small holder farmers [5]. However, CT is reported to be an unsustainable long term tillage method especially in more intensive production systems as it contributes to reduced poor soil water retention ability, inefficient natural resource use, soil degradation and contribute to global temperature increase [6]. Conservation Agriculture (CA), on the other hand is a crop management system based on three principles of minimal soil disturbance, crop rotation or intercropping and permanent soil cover with crop residues or growing plants [7-9]. Contrary to CT and complementary to Conservation Agriculture (CA) one also finds Conservation tillage. Conservation Tillage is an ecological approach to soil management and seedbed preparation involving mechanical inversion of the soil [10]. Conservation tillage is divided into three major categories: No-till, strip tillage, and ridge tillage. No-till involves no use of ploughs or disks and targets 30% or greater ground cover, strip tillage involves planting crops in strips and ridge tillage is a combination of no-till and conventional tillage and the crops are planted in ridges [4]. CA is said to be a less energy intensive system as compared to conventional tillage and can help conserve/retain moisture [11], and eliminate organic matter loss, reduce erosion and lead to improved crop yields among others [12]. Conservation of natural resources in recent decades has developed into a key global objective and a major national aim for Namibia as well. Due to climate change, the use of land, soil and its resources must be continuously and thoroughly monitored, managed and mitigated against damage as erratic weather patterns are projected to become increasingly worse [13]. It is reported that from Southern and Eastern Africa of the total rainfall that falls annually around 30–50% of it is lost through evaporation from unprotected soil surfaces and another 10–25% is lost to runoff [14]. Purcell, et al., 2007, highlighted that soil moisture stress resulting from high moisture loss through evaporation, dry spells and drought is one of the major limiting factors in crop production as it influences many biochemical and physiological plant processes [15]. For sustainable and increased agricultural crop productivity, agriculture being a sector that is absolutely dependent on the goods and services supplied by the natural environment [16], it is critical that good maintenance and improvement of soil quality is undertaken [17]. Crop residues when left as mulch in the field and growing of leguminous crops as intercrops or rotational crops protect the soil by providing a physical barrier to soil movement, allow soil and organic matter accumulation [18], improving some soil characteristics [19] and enhance soil chemical properties. Crop residues as mulch in the field also improve soil air circulation; improve water infiltration and lower loss of soil moisture [18] and ultimately leading to increased crop yields [20]. Reduced tillage practices such as ripping and sub-soiling have the potential to mitigate the effect of dry spells and moisture stress and improve soil moisture retention, which if not managed carefully all too often result in negative impact on crop productivity and/or may lead to crop failure.

Materials and Methods

The research took place at Liselo Research Station (17.524745°S; 24.238707°E) in the Zambezi Region of Namibia (Figure 1). The station lies 964m above mean sea level in a hot, sub-humid region with mean annual temperature of 21.3°C and mean annual rainfall of 600-700mm. The site predominantly has loamy sand to sand with pH of 5.3. A total rainfall of 499.9 mm was recorded in the first cropping season (2016/17) and 521 mm in the following season.

Figure 1: Location of Liselo Research Station (LRS) in Namibia.

The experiment consisted of eight tillage treatments in a randomized complete block design set-up with four replications with dimensions of total trial size of: 49mx160m (7840m^2) and each plot size of: 20mx10m (200m^2).

Six CA/Minimum tillage treatments were compared to two CT treatments of farmers' practices, seeded in tilled land with no crop residue retention. Treatments tested were; CPa = Conventional ploughing (mouldboard, animal traction), RIBT-C = Ripping with a Baufi animal traction ripper – Cowpea intercrop, RIBT-L = Ripping with a Baufi animal traction ripper – Cowpea intercrop, RIBT = Ripping with a Baufi animal traction ripper, SSM = Sub-soiling with a Magoye ripper, DS-M = Direct seeding with an animal traction direct seeder, BA-M = Basin Planting, MDS-M =

Manual tillage with a Dibble stick. Maize (*Zea mays,* Commercial hybrid maize variety Zamseed 606) was the principal crop and cowpea (*Vigna unguiculata* L. Walp.) an important secondary crop used in rotation with maize.

Figure 2: Plot prepared with an animal drawn Mouldboard Plough for the treatment CPa (Left). Plot ripped with an animal drawn Magoye Ripper for the treatment SSM (Center). Maize and cowpea, 12weeks after seeding in the first season (Right).

Maize was planted as a continuous crop on two-thirds of each plot with the other one-third of the plots planted with continuous sole cowpea. The one-third plot of maize neighboring cowpea eventually rotated with the one-third cowpea section in the second season. Commercial hybrid maize variety Zamseed 606 and the commercial cowpea variety BIRA were seeded on 14-16 December 2016, in the first season and seeded on December 7, 2017, in the second season. Basal fertilizer at a rate of 150 kg /ha NPK (2:3:2) was applied to all treatments at seeding and placed next to the plant station except when seeded with the animal traction direct seeder, where fertilizer was dribbled in the row by the seeder for maize.

Top-dressing with 150 kg ha^{-1} Urea was done to all maize plants of all treatments as a split application on January 23, 2017 and February 06, 2017 for the first season and on January 15, 2018 and February 15, 2018 in the second season. Access tubes were installed in all plots for the purpose of soil moisture measurement collection, one per plot and readings taken using a capacitance probe (PR-2 probes, Delta-T Devices Ltd., UK). Moisture measurements were taken once a week during the dry season and twice per week during the rainy season and calculated as mean soil moisture content in millimeters (mm).

Results and Discussion

Rainfall in the 2016/17 cropping season was erratic, unreliable and barely predictable with a short rainy season totaling 499.9 mm/a, a season during which a dry spell of two weeks and six days was experienced (Figure 3). In the second season 2017/18, rainfall was again erratic with especially low rain incidences at the early stages of the season and still managing a total of 521 mm (Figure 3).

Tillage methods and mulch/residue management did appear to have impacted soil moisture in the 0-30cm and 0-60cm soil depth, similar to findings by Gicheru et al., in 2004 and Fuentes et al., in 2003 [1,21].

Higher soil moisture contents in the minimum tillage treatment subsoiling with Magoye Ripper (SSM) in both the 0-30 and 0-60 cm soil depth may have resulted of the ridges and furrows harvesting rain water coupled with mulch which according to Mutema et al., [18] as found in the NSCA project (2012-2014) where furrowing was found to enable infield water harvesting by concentrating rain water in the base of the furrow, increasing moisture by 75% (MAWF brochure). Furrowing was also found to improve air circulation, develop root zone and improve water infiltration. Conventional Tilled (CTa) treatment had the least soil moisture content in both the 0-30 and 0-60 cm soil depth in the second season, highlighting CTa's poor soil water retention as discovered and described by Fernández et al., in 2009 [6].

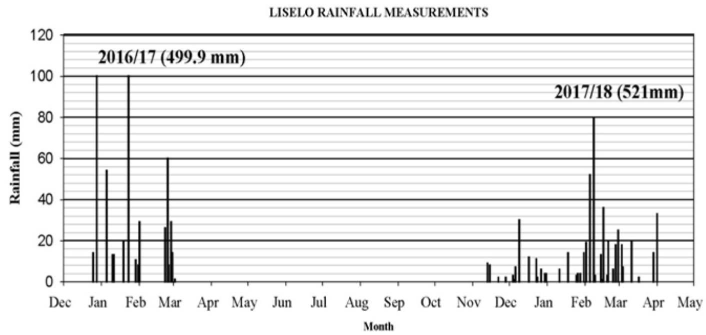

Figure 3: Rainfall Recorded the first and second seasons.

Mean soil moisture content over the entire research period.

TREATMENT	Soil moisture content (mm)	
	0-30 cm Soil Depth	0-60 cm Soil Depth
CTa	14.4 ^{AB}	39.3 ^{B}
RIBT-C	12.1 ^{D}	35.4 ^{E}
RIBT-L	13.8 ^{B}	37.8 ^{C}
RIBT	12.9 ^{D}	36.4 ^{D}
SSM	14.9 ^{A}	40.5 ^{A}
DS-M	13.6 ^{BC}	38.7 ^{BC}
BA-M	13.6 ^{BC}	38.6 ^{BC}
MDS-M	14.1 ^{AB}	39.3 ^{B}
P	0.0000	0.0000
Different letters indicate groups (A, B, etc.) in which the means are not significantly different from one another and are not comparable across seasons.		

Figure 4: Soil Moisture of the Systems Trial in the 0-30and 0-60 cm soil depth throughout the study period at LRS.

Significant mean soil moisture differences ($P<0.05$) were observed among different tillage systems in the 0-30 and 0-60 cm soil depth over the study period (Figure 4). Plots subsoiled with Magoye ripper (SSM) had the highest average soil moisture content in both soil depth with 14.9 mm and 40.5 mm for 0-30 cm and 0-60 cm soil depth, respectively (Figure 4). Plots tilled with Dibble Sticks (MDS-M) and those conventionally tilled were found to be insignificantly different from each other in both depths though dibble stick plots were mulched while conventionally tilled plots were not mulched and had differences in the level of soil disturbance.

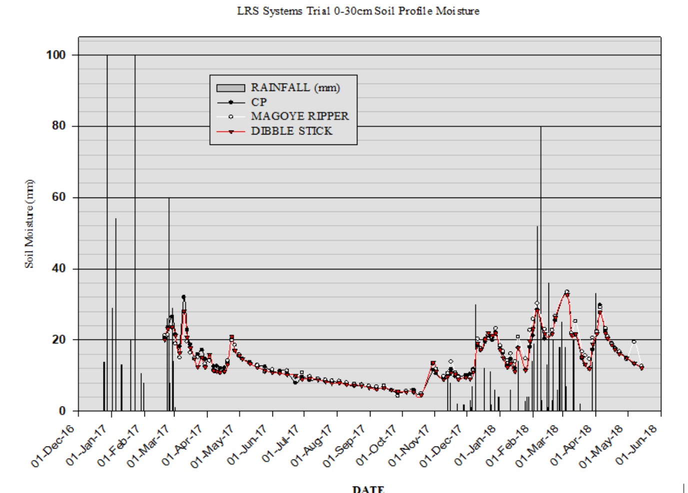

Figure 5: Treatment soil moisture content comparison over the study period for the CA Systems Trial in the 0-30cm soil depth at LRS.

Throughout the study period, soil moisture content was observed to be fairly similar between all three treatments though conventionally tilled (CPa) plots appeared to have higher soil moisture in both soil depth at the onset until the start of dry season when the subsoiled with Magoye ripper (SSM) surpassed it. Dry spells during the rainy seasons and over the course of the dry season (May to November) were the key periods during which differences were observed as subsoiled plots appeared to have the higher soil moisture, while dibble stick and conventionally tilled plots had similar readings.

Low humidity is known to increase rate of evaporation especially on uncovered soils, in this case the conventionally tilled plots as compared to minimum tilled and mulched subsoiled and dibble stick plots. The site of the experiment was predominately sandy, low in organic carbon and this could have been a big influencing factor for the resultant similar average soil moisture content of the treatments during the rainy seasons. Over the rain fed months, November to April of the second season, the trend continued with subsoiled higher and dibble stick and conventionally tilled plots frequently switching places (Figures 5 & 6).

Peak soil moisture readings in the 0-30 cm soil depth were recorded on the 10^{th} of March 2017 in the first season, subsoiling peaking at 33.4 mm, dibble Stick at 33.7 mm and conventional tillage having peak soil moisture reading of 33.5 mm. In the 0-60 cm soil depth conventionally tilled plots peaked at 66.6 mm (March,10^{th} 2017) in the first season, while subsoiling (69.3 mm) and Dibble stick (69.3mm) plots peaked in the second season on February 5, 2018, and April, 5 2018, respectively (Figure 6). A study between the years 2005 to 2007 in neighboring Zimbabwe and Zambia showed that on average, soil moisture was higher throughout the season in most minimum tillage treatments than in the conventionally tilled plots. In the soil moisture analysis for the 0-60cm soil depth, the conventionally tilled peaked in the first season, while, the two minimum tillage treatments both peaked in the second season, a possible treatment response to duration of implementation. While in the soil moisture analysis for the 0-30cm soil depth, all three treatments of interest peaked in the second season. Minimum tillage treatments appeared to take longer than the conventionally tilled plots to reach full potential.

Conclusion and Recommendations

Tillage systems appeared to have significantly affected ($P<0.05$) soil moisture in the 0-30 and 0-60 cm soil depth over the study period, similar to findings by Gicheru et al., in 2004 and Fuentes et al., in 2003. Plots subsoiled with a Magoye Ripper (SSM) (14.9mm) had 3.47% higher average soil moisture content in the 0-30cm soil depth and 3.05% higher moisture in the 0-60 cm soil depth than conventional ploughing.

This may have been a result of the ridges and furrows harvesting rain water coupled with mulch, which according to Mutema et al., [18] improves air circulation, develops root zone and improves water infiltration. *Manual tilling with a dibble stick (MDS-M) and conventionally tilling with a plough (CTa) were found to be insignificantly different from each other regarding soil moisture content.* Conventional tilled plots had the least soil moisture content in both the 0-30 soil depth in the second season, highlighting conventional tillage's poor soil water retention capabilities as discovered and described by Fernández et al. in 2009 [6].

The results did in partiality portray that minimum tillage systems conserve more soil moisture. Generally, Minimum tillage treatments had higher mean soil moisture than conventionally tilled treatments especially over dry period/season and throughout the second season. Application of mulch and crop rotation appeared to positively influence mean soil moisture over the study period compared to not mulched and not practicing rotation.

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