World Journal of Advanced Engineering Technology and Sciences

eISSN: 2582-8266

Cross Ref DOI: 10.30574/wjaets

Journal homepage: https://wjaets.com/

(Research Article)

Check for updates

Effects of common tillage practices on soil moisture retention within a crop rooting zone in a sandy loam soil

Rebaone Dintwe, Cecil Patrick * and Gilbert Kabelo Gaboutloeloe

Department of Agricultural & Biosystems Engineering, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana.

World Journal of Advanced Engineering Technology and Sciences, 2022, 05(02), 029–033

Publication history: Received on 11 December 2021; revised on 15 March 2022; accepted on 17 March 2022

Article DOI: https://doi.org/10.30574/wjaets.2022.5.2.0076

Abstract

Several reports states that global warming is likely to be about 1.0 °C above pre-industrial conditions and may even reach 1.5 °C between 2030 and 2052. It is therefore envisaged that as a result, climate change will intensify and rainfed arable conditions will become more unpredictable particularly in semi-arid conditions like those of Botswana due to increased heat stress resulting due to evaporative soil water losses. Considering this, several countries have therefore been experimenting with different climate smart technologies with a view to find suitable ones for arable crop production. A study was carried out at Botswana University of Agriculture & Natural Resources (BUAN) fields in 2014 to investigate the effects of different common tillage methods practiced in Botswana and how they influenced the resultant soil moisture retention. A Completely Randomized Block Design field study comprising Mouldboard ploughing, Disc ploughing, Chisel ploughing all at 200 mm depth and a no-till control were compared. During the study, soil moisture content measurements for each tillage method were taken during different sampling dates.

The results showed that the no-till method retained more soil moisture when compared to the other 3 tillage methods. It retained 10%, 20% and 29% more moisture than the Disc, Chisel and Mouldboard ploughing respectively.

Keywords: Tillage Practices, Moisture Retention, Sandy Loam; Evaporative Moisture Loss

1. Introduction

Agriculture plays a very important role in the economy of Botswana. More than 80% of the population is involved in agriculture. The government considers arable farming as a key area for employment creation and income generation for most rural families. Climate is a key factor in determining crop production with rainfall and temperatures as the main elements. Botswana has a semi-arid climate with the average annual rainfall ranging from 250 mm in the South-west to 650 mm in the North-west. Further, rainfall is seasonal, unreliable and varies from year to year [2]. Because of low and unreliable rainfall in over much of the country, it is crucial that every effort be made to utilize the little that falls in arable areas. Key to this utilization is to carry out soil tillage activities timely and correctly.

Soil tillage is the mechanical manipulation of the soil to develop a desirable soil structure for a seedbed and related crop growing conditions [2]. Excessive and unnecessary tillage operations are not only costly but may be harmful to the soil structure [3]. Mechanical manipulations of the soil are usually meant to improve the physical hydrology properties and to enhance its capacity to store or retain water [4]. When in the soil, water is acted upon by forces of gravity and of capillary suction. In the unsaturated zone, capillary suction usually dominates in controlling water retention. If this were not the case, water would simply drain away under gravity after rainfall and no plants could grow. The common tillage

* Corresponding author: Rebaone Dintwe, Cecil Patrick
Department of Agricultural & Biosystems Engineering, Botswana University of Agriculture and Natural Resources, Private Bag 0027, Gaborone, Botswana.

systems employed in Botswana have up till now included the following: Mouldboard plough, harrow and planting, Disc plough, harrow and planting, Disc harrow and planting, Chisel / Subsoil ripping and rip-line planting and Broadcast plant and mouldboard or disc plough. Whilst all these methods are associated with some form of soil loosening and the short-term benefits of increasing soil porosity together with accelerated decomposition of buried organic matter, soil inversion inevitably result in the exposure of the sub-surface of the soil which tend to promote a more rapid upward water movement away from the cropping zone. This occurrence must be viewed in the context of findings from several studies and reports indicating that global warming is likely to be about 1.0 °C above pre-industrial conditions and may even reach 1.5 °C between 2030 and 2052 [1]. If the scenario actualizes, and climate change intensifies, rainfed arable conditions will become more unpredictable together with the uncertainties of growing arable crops. The general thinking is that none of the tillage systems stated above would be applicable as they are. Some form of adaptation is required if they are to remain relevant particularly in relation to moisture retention. Several countries have therefore been experimenting with different climate smart technologies with a view to find suitable ones for the sustenance of arable crop production. In Botswana, there is increased interest in other tillage systems which have shown promise in different countries such as No-till and Conservation Agriculture (CA). These systems are still being explored and have not taken root in the country. The two do not only require new machinery, but a different approach to arable agriculture and will require some time and extension resources to demonstrate and promote adoption by farmers. This study was conceptualized with a view to investigate the extent to which some common tillage systems practiced in Botswana, will retain water within the crop rooting zone when compared to a No-till one. The following hypotheses were tested:

- Soil moisture retention is inversely proportional to soil disturbance or inversion.
- A no-till system of tillage results in less soil disturbance and therefore will retain more soil moisture in the crop rooting zone.
- Mouldboard ploughing will result in the least soil moisture retention in the crop rooting zone due to the extent of soil inversion achieved by the method of tillage.

The specific objectives of this study were, therefore, to:

- Determine soil moisture retention capabilities within the crop rooting zone of the No-till, Disc, Chisel and Mouldboard ploughing tillage systems under a sandy loam soil.
- Determine the relationship between soil moisture retention and soil bulk density within the crop rooting zone of the No-till, Disc, Chisel and Mouldboard ploughing tillage systems under a sandy loam soil.

2. Material and methods

2.1. Description of the study area

The field study was carried out at Sebele Content farm near Gaborone (latitude 24° 34‘29’’S and longitude 25° 56‘29’’E, at an altitude of 994 m above sea level) in Botswana (Figure 1).

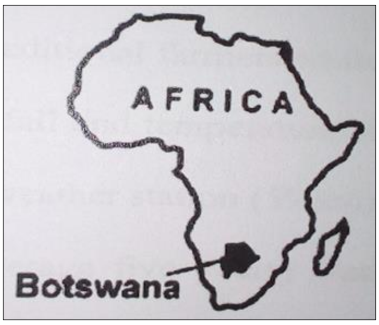

Figure 1 Location of study area in Africa

The climate is semi-arid with an average annual rainfall of 538 mm [5]. Prolonged dry spells during rainy seasons are common and rainfall tends to be localized [6]. Solar radiation levels range from 14.6 MJ/m^2 in June to 26.2 MJ/m^2 in December. The soils are sandy loam of medium coarse structure, shallow ferruginous with relatively low water holding capacity averaging 1.62 Mg/m^3 in bulk density. Four treatments replicated three times were compared i.e. Mouldboard ploughing, Disc ploughing, Chisel ploughing all at a depth of 200 mm and No-till or direct planting as the control. The four treatments were arranged in 21 m x 21 m plots with 1 m in between to reduce plot effects. The field was kept weed free and devoid of residue throughout the study period.

2.2. Soil moisture retention measurements

Soil moisture retention in the crop rooting zone was measured with 12 micro-lysimeters (Figure 2 and 3) made from rigid polyvinyl chloride (PVC) pipes, measuring 105 mm internal diameter, 180 mm deep and 2.5 mm wall thickness, with one of the edges beveled to facilitate penetration into the soil. A micro-lysimeter wrapper consisting of a tubular-shaped structure of PVC similar in shape to the micro-lysimeter, but of a larger 145 mm internal diameter was also made (Figures 2C, 3A and B).

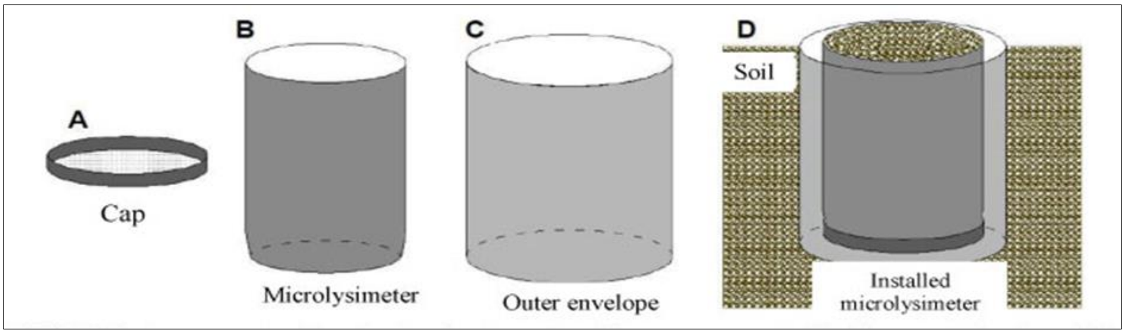

Figure 2 Components of a micro-lysimeter system for measurement of soil moisture in which (A) is a cap to avoid drainage, (B) is micro-lysimeter, (C) is outer envelope, and (D) is installed micro-lysimeter. (Source: Danilton ET. Al [7])

Figure 3 Micro-lysimeter installed with the outer envelope in detail (B) and micro-lysimeter weighing (C). (Source: Danilton et. al [7])

The micro-lysimeter was then filled with a soil monolith obtained by penetration into the profile from the tip of the beveled edge, using light strokes with a mallet on a small wooden board positioned at the opposite end of the beveled edge, up to a depth such that 0.5 cm of the lysimeter was left protruding above ground surface to preclude surface runoff water and rainfall splash into the lysimeter. To facilitate the penetration and preserve the soil structure, the walls of the micro-lysimeter were lubricated with a small amount of vegetable oil [7].

This procedure was adopted to ensure that any change in mass of the ML was due only to water loss from the soil [8]. Evaporation from the micro-lysimeter (E_{ML}) was calculated from the following relationship:

$$E_{ML} = \frac{\Delta MML}{A\ ML} + P \text{(equation 1)}$$

Where
E_{ML} - soil evaporation measured with micro-lysimeter (mm).
ΔM_{ML} – micro-lysimeter variation of mass (kg).
A_{ML} – micro-lysimeter surface area with a value of 0.00785 m^2, and
P - Precipitation, mm obtained from a near-by rain gauge

3. Results and discussion

The soil moisture retention capabilities of the different tillage systems were measured as moisture loss within the crop rooting zone and are given in Tables 1 and 2. The accompanying soil density values are also shown in the same Tables.

Table 1 Means of evaporative moisture losses and bulk densities measured across four tillage treatments

Tillage System	Moisture Loss (g)	Bulk Density (g/cm3)
No-Till	7.96[a]	1.62[a]
Chisel Plough	10.58[b]	1.59[b]
Disc Plough	11.48[b]	1.54[c]
Mouldboard Plough	14.18[c]	1.49[d]
CV (%)	2.88	

Note: Numbers with different alphabetic letters in each column are significantly different at 95% confidence level.

There was an inversely proportional relationship between soil moisture loss and soil bulk density in the crop rooting zone. As soil moisture loss increases, soil bulk density decreased. This means that more soil moisture is lost when soil bulk density is low and vice versa. In the chisel and disk ploughed plots, no statistical differences were observed. However, the differences were significant between no–till and mouldboard ploughed treatments indicating that tillage system has valuable effect on top-soil properties, and, consequently on soil moisture evaporation. The degree of variation between them stood at 6.22 g. Mechanical disturbance of soil, caused by soil tillage, changes the soil structure and pore size distribution in the tilled layer and underneath [9]. There were significant statistical differences among all tillage treatments in terms of soil bulk density. This means that the different tillage systems did not loosen the soil within the crop rooting zone to the same degree. High soil bulk density is an indicator of low soil porosity and soil compaction. High soil bulk density impacts available water capacity, root growth, and movement of air and water through soil [10]. Soil compaction increases soil bulk density and therefore could be accompanied by a reduction in crop yields and available vegetative cover required to protect soil from erosion. Soil bulk densities of the different tillage systems were significantly different. In the ploughing treatments, soil bulk density was lowest in the mouldboard. The analysis from the research showed that soil bulk density has great influence on evaporative soil moisture loss within the crop rooting zone. A tillage system with an ideal bulk density was found to be the No-Till at 1.62 g/cm^3. Increasing soil bulk density resulted in an increased capacity to retain moisture or on the flip side, tillage systems which opened the soil to a larger degree, resulted in a less capability to retain soil moisture within the crop rooting zone [11].

Calculations of soil water evaporation for all tillage systems further showed the ability of the No – till system to better retain the existing soil water (Table 2). The water would subsequently become available for crop production.

Table 2 Means of soil water which evaporated across the different tillage systems calculated using equation 1

Tillage System	Means of Soil Water Evaporation (mm)
No – Till	8.03 mm
Chisel Plough	17.27 mm
Disk Plough	26.42 mm
Mouldboard Plough	32.62 mm

Calculations showed that the water lost from the No-till system, Disk, Chisel and Mouldboard ploughs were found to be 10, 20, 31 and 39 % respectively. The difference between the best and the worst performing system totaled 29 %, which reflects vastly better moisture conservation ability with the No–till system. This ability is again attributable to the significantly less soil inversion and minimal soil disturbance and reduction in soil bulk density within the crop rooting zone.

4. Conclusions

Based on the field results from this study, the following conclusions are drawn:

- The No-tillage system retained 10%, 20% and 29% more moisture in the crop rooting zone when compared to the commonly practiced tillage systems of Disc, Chisel and Mouldboard ploughing respectively when tested under a sandy loam soil.
- There was an inverse correlation between soil moisture retained and soil bulk density in the crop rooting zone across the different tillage systems tested.

Recommendation

Since Botswana has a semi-arid climate with an average annual rainfall ranging from 250 mm in the South-west to 650 mm in the North-west and that the rainfall is seasonal, unreliable and varies from year to year, the use of the No-till system should be explored as a soil moisture retention strategy.

Compliance with ethical standards

Acknowledgments

The authors would like to thank the Botswana University of Agriculture & Natural Resources (BUAN) for allowing the use of the University farm and laboratories for this study.

Disclosure of conflict of interest

We the authors of this paper hereby declare that there are no competing interests in this publication.

References

[1] Byakatonda J, Parida BP, Kenabatho PK, Moalafhi DB. Analysis of rainfall and temperature time series to detect long-term climatic trends and variability over semi-arid Botswana. Journal of Earth System Science 2018; 127(2): 25.

[2] Baipusi WJ, Kayombo B, Patrick C. Evaluating different soil tillage surface conditions on their water harvesting potential in Botswana. African Journal of Rural Development. 2016; 1(1): 91-97.

[3] Mahdi A. Frequent tillage and its impact on soil quality. 2004; IC – 492/13, 78-79. 2004.

[4] Rashidi MA. Effect of different tillage methods on grain yield and yield components of maize (Zea mays L.). Soil Science Society of America Journal. 2007; 57: 1586 - 1595.

[5] Bekker RT, de Wilt PV. Contribution to the soil and vegetation classification of Botswana: Soil mapping and advisory services project. Field Document FAO/UNDP, Government of Botswana. 1991; 34: 66.

[6] Moroke TS, Dikinya O, Patrick C. Comparative assessment of water infiltration of soils under different tillage systems in eastern Botswana. Physics and Chemistry of the Earth. 2009; 34, 316-323

[7] Danilton LF, Rogério T, de F, Bruno PL. Test of a microlysimeter for measurement of soil evaporation. Eng. Agric., Jaboticabal. 2012; 32(1): 80-90.

[8] Evett S, Warrick A, Matthias A. Wall material and capping effects on microlysimeter temperatures and evaporation . Soil Science Society of America Journal. 1995; 59(2): 329-336.

[9] Farkas C, Birkás M, Várallyay G. Soil tillage systems to reduce the harmful effect of extreme weather and hydrological situations. Biologia. 2009; 64: 624-628.

[10] El Atta HA, Aref IM. Effect of terracing on rainwater harvesting and growth of Juniperus procera Hochst. Ex Endlicher. International Journal of Environmental Science and Technology. 2010; 7(1): 59-66.

[11] Bedi K, Kayombo B, Patrick C, Gaboutloeloe G. The Influence of Soil Surface Conditions and Rainfall Intensity on Run-off Generation Potential in Semi-Arid Botswana. International Journal of Plant and Soil Science. 2016; 13(1) 1-7