Comparative assessment of water infiltration of soils under different tillage systems in eastern Botswana

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ABSTRACT

Water infiltration is an important component of water balance for improving crop production potential in dryland soil tillage systems in Botswana, particularly in the eastern region. Hardsetting soils common in arable lands of Botswana, often require some kind of tillage such as mouldboard ploughing, chiselling and ripping to improve waterharvesting and crop growth conditions. The objective of this study was to compare ponded cumulative infiltration, steady state infiltration rate and sorptivity of soils cultivated using deep ripping, single and double mouldboard ploughing. This study was conducted on Chromic Luvisols (sandy loam), Haplic Luvisols (sandy clay loam), Ferric Luvisols (clay loam), and Ferric Arenosols (sand). Infiltration was measured using double ring infiltrometer method for 4 h. Although infiltration was smaller on traffic line of deep ripping system at all sites, it was only significantly ($P < 0.05$) different on Ferric Luvisols and Ferric Arenosols. Compared with conventional ploughing, steady state infiltration was greater but not significantly ($P > 0.05$) different under deep ripped. Cumulative and steady state infiltration rate was greater under sandy than loamy soils, smaller under double ploughing compared with single ploughed and deep ripped soils. Sorptivity was not significantly ($P > 0.05$) different among tillage systems but was greater under sandy than sandy loam soils. Information on tillage and infiltration can improve implementation of waterharvesting technologies and crop production in Botswana.

1. Introduction

Patterns of rainfall common in semiarid regions in particular Botswana are high intensity storms leading to excess water in a short period of time. Impacts of heavy rainstorms include destruction of soil structure by raindrops that lead to crusted soil surface and increased runoff. For certain high intensity rainfalls, runoff can be as high as 50% and can decrease soil water infiltration (L&WMP, 1992) and limit water available to crops. The presence of a thin compacted layer in the topsoil can reduce infiltration rate and enhances runoff and soil erosion (Willcocks, 1981; FAO, 1993). Thus, the ability of a soil to infiltrate rainwater and store it in the soil is of great importance in determining the amount of runoff and soil water storage for crop production (Hudson, 1987; Unger and Skidmore, 1994). Possible tillage options to reduce runoff and increase infiltration on croplands are roughened soil surface to increase surface water retention, surface residue management, and ripping or subsoiling. That is, change soil surface characteristics as well as chemical and physical properties in the soil profile.

Most arable soils in Botswana are characterized by petroferric dense layers, low organic matter content, low nutrient content and low pH or are typically ferruginous tropical soils. Hardsetting soils are generally characterized as massive or structureless and shrink and set hard on drying, reducing macroporosity that conduct water during infiltration process (Willcocks, 1979; Mullins et al., 1990). Causes of hardsetting or hard-cemented soils are acidity, low fertility and low organic matter content, and inappropriate tillage operations. Textural properties of hardsetting soils range from loamy sand to sandy clay with low shrink–swell capacity and can pack to high bulk density values on drying. In consideration of relatively compacted surface soil layers with low infiltration capacity, low vegetation cover and high intensity rainfall patterns, runoff potential is high particularly in eastern Botswana.

Mouldboard ploughing (10–20 cm depth) is a conventional soil tillage practice in Botswana (L&WMP, 1992; Persaud et al., 1992). Deep tillage (>20 cm soil depth) is often needed on poorly drained or hardsetting soils to improve water infiltration and seedbed conditions for plant growth (Baver, 1966; Willcocks, 1981). Further non-inversion tillage operation such as chisel ploughing or ripping can decrease soil strength while causing little damage to soil

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structure on fragile soils (Willcocks, 1979). Deep ripping is defined as a mechanical manipulation of soil to break up or pierce highly compacted and root restrictive, impermeable or slowly permeable soil layers (Baver, 1966). The effectiveness of deep ripping depends on soil texture, soil water content, compaction depth, compaction extent and ripper tine spacing and type. Dry soil ripping shatters the soil and effectively loosens compacted soils although the costs increase with depth and soil dryness (Richards et al., 1995; Lacey et al., 2001). Generally, subsoiling clay accomplish very little benefits because of the puddling action of the subsoiler (Willcocks, 1979; Bornman et al., 1989).

In deep ripping systems of silt loam textured soils, infiltration can be increased and has been shown to be directly related to structural stability (Tisdall and Adem, 1986), bulk density (Patel and Singh, 1981) and pore structure (Ankeny et al., 1990). Thus, tillage alters soil pore size and geometry and consequently influences soil water transmission and storage on silt loam soils (Drees et al., 1994; Lal et al., 1994). The effects of ripping are not permanent but long-term correction may be done using vertical mulching (Marshall and Holmes, 1979) or using gypsum and liming (Richards et al., 1995). Soil surface crusting inhibited seedling emergence (Summer and Stewart, 1992) while compacted subsoil reduced root development, and low water holding capacity limited crop establishment and crop yields (Willcocks, 1979; Hamblin, 1985). Although bulk density was greater under no tillage, ponded infiltration was equal or greater than tilled soils of silt loam texture (Ehlers, 1975; Sauer et al., 1990).

Hydraulic properties that dominate water entry into the soil surface and movement in the soil profile are sorptivity, infiltration and hydraulic conductivity and may be used to evaluate tillage operations. Infiltration rate was successfully used to characterize tillage techniques on sandy clayey loam soils (Topaloğlu, 1999). Infiltration rate may be defined as the volume flux of water flowing into the soil profile per unit surface area of the soil (Hillel, 1980). Soil infiltration capacity is initially high and tends to constantly decrease until it asymptotically approaches a constant rate termed final or steady state infiltration rate. The steady state infiltration rate represents saturated hydraulic conductivity of the soil. When water delivery to the soil is less than infiltration capacity, the supply rate determines the infiltration rate. If water delivery exceeds infiltration capacity, surfaces conditions determine the infiltration rate and excess water is lost as runoff.

Sorptivity is water uptake by the soil in the absence of gravitational effects (Philip, 1957a). It is a theoretically and physically based hydrologic parameter that can be rapidly measured in the field (Smile and Knight, 1976; Walker and Chong, 1986). Sorptivity provides the water absorption rates and varies with soil water content and soil void ratio and thus can be a good indicator of how tillage affects soil structure.

The objective of this study was to compare the effect of single mouldboard ploughing, double mouldboard ploughing, deep ripping, and permanent traffic lines between riplines on infiltration capacity and sorptivity under different soil types.

2. Materials and methods

2.1. Site description

Four sites with different soil types were selected at Sebele near Gaborone, Tswidi (Pelotshetlha) in Kanye area and Sese near Jwaneng during the 1988/1989 cropping season. The four soil types were classified as follows: (a) Chromic Luvisols (FAO, 1998) or Haplustalf (Soil Survey Staff, 1998); (b) Ferric Luvisols (FAO, 1998) or Paleustalf (Soil Survey Staff, 1998); (c) Haplic Luvisols (FAO, 1998) or Haplustalf (Soil Survey Staff, 1998) and (d) Ferric

Arenosols (FAO, 1998), or Quartzipsamments (Soil Survey Staff, 1998). In Sebele, the experiment was conducted at two sites on Chromic Luvisols (Sebele 1) and Ferric Luvisols (Sebele 2). The soils in Sebele and Haplic Luvisols at Tswidi developed from granite parent material (DAFS, 1981). Ferric Luvisols (or sandy clay loam soils) have poor internal drainage while Chromic Luvisols (sandy loam soils) are well drained (Joshua, 1990). Selected soil properties at the experimental sites are presented in Table 1. Soils at Sese were the Kalahari sands (Ferric Arenosols) that developed from aeolian deposits. They were very deep, sandy in texture, have single grain structure and well drained.

2.2. Tillage treatments and experimental design

This was the first season during which the tillage experiment was conducted. Tillage treatments were as follows: (1) single mouldboard ploughing and planting (conventional); (2) double ploughing with early spring mouldboard ploughing with first rains followed by second mouldboard ploughing on the day of planting; and (3) deep ripping consisted of cultivated strips (riplines) that were permanently laid out 1.5 m apart and about 40 cm wide (DLFRS, 1974, 1980; Persaud et al., 1992). The strips were ripped to 50–60 cm deep and crops were planted on these riplines. The area between the riplines was the traffic line and was never cultivated except for shallow scraping with a blade harrow to control weeds. The traffic lines served as passage area for any field operation and were also meant to generate runoff and concentrate rainwater onto crops planted on the riplines. At Sebele 2 double ploughing was not done.

The experiment was laid out as randomised complete block design with two replicates and tillage systems randomised within the blocks. The size of the plot was 40 m by 15 m. At each site, phosphorus was applied at 20 kg ha^{-1} and grain sorghum (*Sorghum bicolour* Moech (L.), var. segaolane) was planted. Tillage, planting and harvest dates are given in Table 2. Infiltration measurements were conducted once on each replicate. In the deep ripping treatment, infiltration tests were done on both riplines and traffic lines.

2.3. Infiltration tests

Field infiltration measurements were determined using double ring infiltrometers using procedure described by Joshua (1990) and Green et al. (1986). The infiltration rate was measured by

Table 1
Selected surface soil (0–20 cm) chemical and physical properties of Chromic Luvisol (Sebele 1), Ferric Luvisol (Sebele 2), Haplic Luvisol (Tswidi) and Ferric Arenosols (Sese) under different tillage systems in eastern Botswana (data obtained from DLFRS (1980), Persaud et al. (1992), Persaud (1990), and DAR soil laboratory data base)

Soil property	Site			
	Sebele 1	Sebele 2	Tswidi	Sese
pH (CaCl$_2$)	5.0	5.8	4.8	6.5
OC (%)	0.4	0.31	0.50	0.1
CEC (cmol g^{-1})	3.2	6.5	4.5	2.9
P (ppm)	19	23	7.5	<1
BD (kg m^{-3})	1.68	1.58	1.62	1.60
PAWC (mm m^{-1})	89	80	84	59
Sand (%)	79.5	60.9	84.0	92.8
Silt (%)[a]	7.4	10.7	7.5	1.5
Clay (%)[a]	13.1	28.4	8.5	5.6
Textural class	Sandy loam	Sandy clay loam	Clay loam	Sand
Slope (%)	0.3	3.8	<1.0	<1.0

OC, organic carbon (Walkley and Black, 1934); CEC, cation exchange capacity (Rhoades, 1982); P, Bray 2 available phosphorus (Bray and Kurtz, 1945); BD, bulk density (Blake and Hartge, 1986) and PAWC, plant available water capacity.

[a] Particle size analysis (Gee and Bauder, 1986).

Table 2
Dates of cultural operations and planting density at Sebele 1, Sebele 2, Tswidi and Sese during 1988/1989 cropping season

Operation	Site			
	Sebele 1 (SL)	Sebele 2 (SCL)	Tswidi (CL)	Sese (S)
Dates of operation				
Deep ripping	14/09/1988	14/09/1988	12/10/1988	12/10/1988
Mouldboard ploughing	20/11/1988	20/11/1988	05/12/1988	05/12/1988
Planting	01/12/1988	22/12/1988	05/12/1988	05/12/1988
Harvest	19/04/1989	19/05/1989	31/05/1989	24/05/1989
Infiltration experiments	16/02/1989	11/02/1989	29/12/1988	01/01/1989
Planting Density (plants ha^{-1})				
Single ploughing	50000	NA	54000	45000
Double ploughing	53000	NA	57000	45000
Deep ripping	34000	NA	37000	24000

NA, data not available; SL, sandy loam; SCL, sandy clay loam; CL, clay loam and S, sand.

observing the decreasing water level within the inner ring. Water in the outer ring was kept at approximately the same level as in the inner ring to prevent lateral flow to promote vertical water movement in the soil. Steady state infiltration rates were derived from plots of cumulative infiltration versus time. Cumulative infiltration was described using the following equation described by Hillel (1980):

$$I = at^n \qquad (1)$$

where I is cumulative infiltration (L), t is time (T), and a and n are empirical constants that are specific to soil conditions and depend on soil texture, moisture contents, bulk density and other soil properties. Cumulative infiltration was calculated after 240 min. To determine a and n constants, logarithm on both sides of Eq. (1) taken to obtain:

$$\log(I) = \log(a) + n \log(t) \qquad (2)$$

Plotting $\log(I)$ versus $\log(t)$ enables obtaining values of n (slope) and $\log(a)$ from the y-intercept. The value of a was obtained from antilog(a), i.e.:

$$a = 10^{\log(a)} \qquad (3)$$

Integrating Eq. (1), yields instantaneous infiltration rate described by:

$$\frac{dI}{dt} = ant^{n-1} \qquad (4)$$

Inserting values of a and n into Eq. (4), steady infiltration rate at 240 min of different tillage systems were calculated.

2.4. Sorptivity

For early stage (<30 min), infiltration calculated using equation described by Philip (1957a), i.e.:

$$I = S_o t^{1/2} \qquad (5)$$

where I is cumulative infiltration (L), S_o is sorptivity (LT$^{1/2}$) and t is time (T). Therefore, sorptivity value was calculated from the slope of a plot of cumulative infiltration, I versus square root of the elapsed time, $t^{1/2}$ (Talsma, 1969).

Statistical analyses on all variables were conducted using analysis of variance (ANOVA) for randomised complete block design (SAS, 2007). The mean separation test used Fisher's protected least significant difference (Steel and Torie, 1980).

3. Results and discussions

3.1. Rainfall

Rainfall occurs between October and April (Bhalotra, 1987) and coincides with cropping season. Seasonal rainfall during the 1988/1989 cropping season at Sebele 1, Sebele 2, Tswidi and Sese was 589, 573, 503, and 480 mm, respectively (Fig. 1). Total rainfall was within the long-term average rainfall of 525 mm at Sebele and 400 mm in the Kanye and Jwaneng area (Bhalotra, 1987). At Sebele, Sese and Tswidi, rainfall events that were less than 15 mm were 55%, 30% and 39% of total rainfall, respectively. Rain-
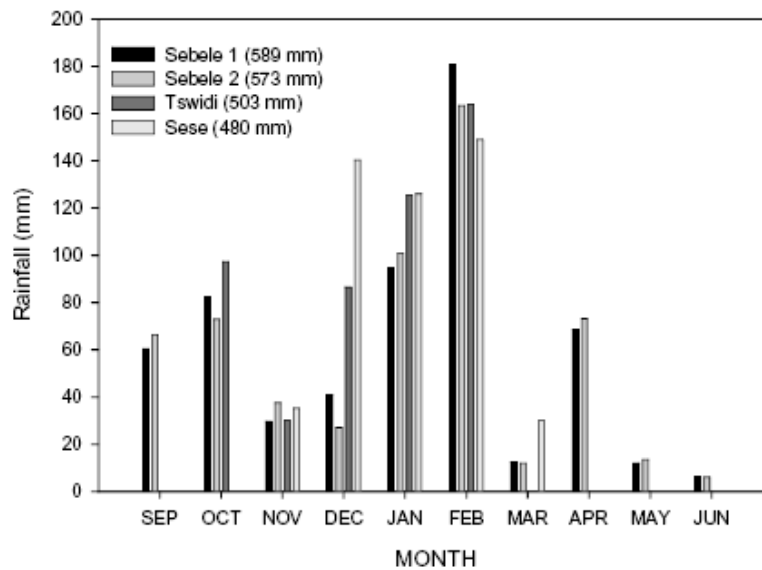

Fig. 1. Monthly rainfall at Sebele 1, Sebele 2, Tswidi and Sese during the 1988/1989 crop season in southeastern Botswana. Number in brackets are seasonal rainfall at each site.

fall events that are less 15 mm are prone evaporation under semi-arid environment and may reduce effective rainfall. Rainfall events that were greater 40 mm constituted 16%, 9% and 22%, respec-

Table 3
The effect of tillage system on sorghum grain yield during 1988/1989 cropping season grown on Chromic Luvisol (Sebele 1), Haplic Luvisol (Tswidi) and Ferric Arenosols (Sese) under different tillage systems in eastern Botswana (adapted from Persaud (1990))

Tillage system	Site		
	Grain yield (kg ha^{-1})		
	Sebele 1	Tswidi	Sese
Single ploughing	1996a	1452a	2805a
Double ploughing	2674b	1331a	2251a
Deep ripping	1689ac	1142a	864b
LSD (0.05)	660	1056	731
CV (%)	17	11	22
P (>F)	*	NS	**

LSD, least significant difference; CV, coefficient of variation; NS, not significantly different ($P > 0.05$); *, $P < 0.05$; **, $P < 0.01$ and same letters within each column indicate no significant differences at $P < 0.05$.

tively. Rainfall during the experimental period was fairly well distributed and had potential to support a crop growth fairly well.

3.2. Soil properties

Arable farming in Botswana is generally conducted on semiarid tropical soils. Selected arable soil properties at experimental sites in eastern Botswana are presented in Table 1. Inherent low fertility, low pH and crust prone soils result in low crop yields. Organic carbon content is typically less than 1% and together with low pH, makes the soil fragile and susceptible to degradation. Soils were moderately deep at Sebele and Tswidi and very deep at Sese (Table 1). The slope covered a narrow range (0–4%) and under such conditions, continuity of slope and soil surface conditions controls rainwater infiltration and runoff (L&WMP, 1992). More efficient use of rainwater and nutrient as well as conservation farming practices is essential for improving crop production in Botswana.

3.3. Sorghum grain yield

Grain sorghum (*S. bicolour* L. Moench; Segaolane var.) was used as test crop in this study. The effect of tillage systems on sorghum
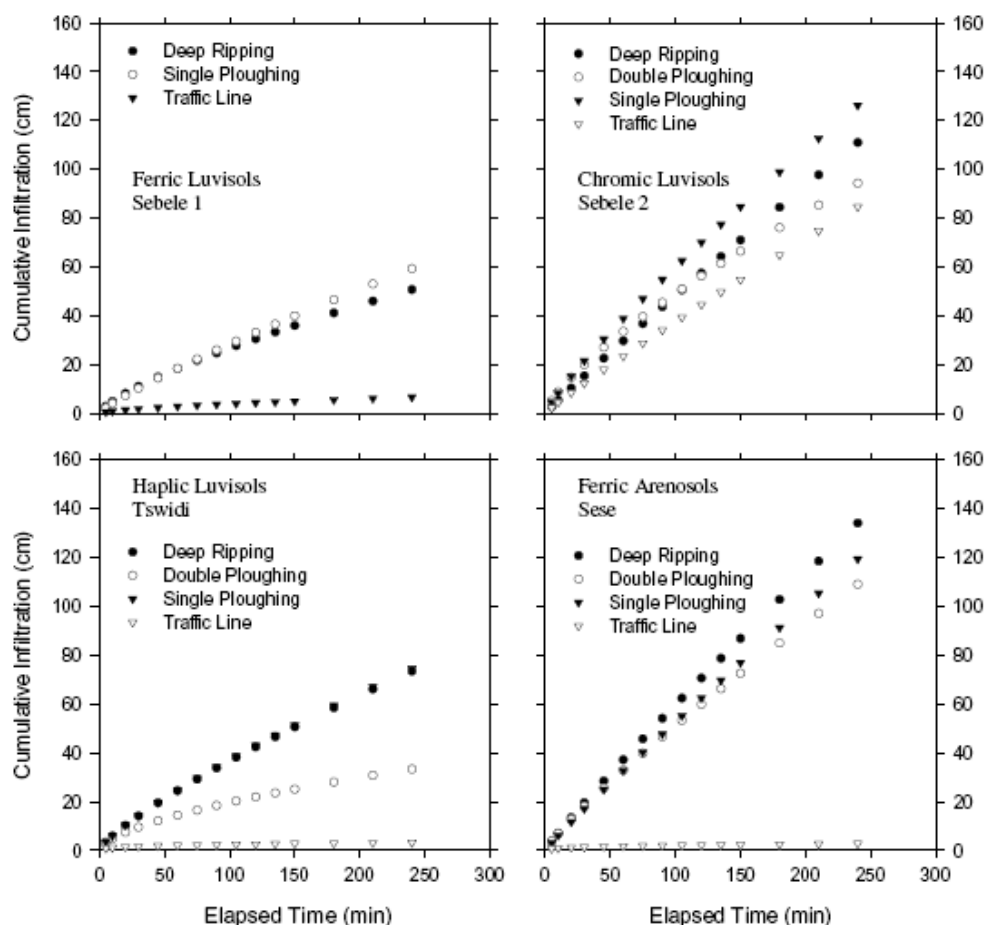

Fig. 2. Infiltration patterns on Chromic Luvisol (Sebele 1), Ferric Luvisol (Sebele 2), Haplic Luvisol (Tswidi) and Ferric Arenosols (Sese) under different tillage systems in southeastern Botswana.

grain yield is presented in Table 3. At Tswidi, tillage did not significantly ($P > 0.05$) affect sorghum grain yield (Table 3). Tillage significantly ($P < 0.05$) affected grain yield of sorghum at both Sebele 1 and Sese. At Sebele 1, there were no significant ($P > 0.05$) differences between deep ripping and conventional ploughing and was significant ($P < 0.05$) under ploughing. Sorghum grain yield was not significantly ($P > 0.05$) different conventional and double ploughing at Sese (Table 3) but was significantly ($P < 0.05$) smaller deep ripping (Table 3). Compared with mouldboard ploughing, sorghum grain yield was smaller by 26%, 18% and 65% at Sebele 1, Tswid and Sese, respectively.

3.4. Cumulative infiltration

The influence of tillage on cumulative water infiltration on different soils types is presented in Fig. 1 and Table 3. At Sebele 1 (sandy loam), and Tswidi (clay sandy loam) cumulative water infiltration was not significantly ($P > 0.05$) different among tillage systems, and between tillage treatments and traffic lines (Table 3). At Sebele 2 (sandy clay loam) and Sese (sand), cumulative infiltration was also not significantly ($P > 0.05$) different among tillage systems but was significantly ($P < 0.05$) smaller under traffic lines compared with tillage systems. Infiltration was highly variable as indicated by CV that ranged from 11% to 43% (Table 3) and this probably explains lack of significant differences between tillage systems. The aim of traffic line was to generate runoff into riplines where crops were planted. The greatest potential to generate runoff into ripped soils and increase available soil water for crops was on sandy clay loam (Sebele 2) and sand (Sese) (see Fig. 2).

Cumulative water infiltration was greatest under deep ripping, followed by conventional, double ploughing and was least under traffic lines at all sites (Fig. 1). Average cumulative infiltration after 4 h was 120, 102, 63 and 55 cm at Sese (Ferric Arenosols), Sebele 1 (Chromic Luvisols), Sebele 2 (Ferric Luvisols) and Tswidi (Haplic Luvisols), respectively. Notably, Kalahari fine sandy (Sese) and sandy loam (Sebele 1) had the greatest average cumulative infiltration. Sandy soils have larger pores that highly influence infiltration, particularly under ponded infiltration where gravity forces dominate water movement. In contrast, soils with loamy texture at Sebele 2 and Tswidi had lower infiltration. In fact Ferric Luvisols at Sebele 2 were classified as having poor internal drainage (DAFS, 1981) and had patched water tables in some places within the experimental plot (see Table 4).

3.5. Infiltration rate

Infiltration rate is the amount at which water enters the soil at the surface (Hillel, 1980) and it determines potential for surface storage or ponding, soil water storage or runoff during rainfall or irrigation. Steady state (or final) infiltration rates under different

tillage systems in different soils are presented in Table 5. At Tswidi (texture), there were no significant ($P > 0.05$) differences among tillage systems, and between tillage systems and traffic lines. Also, lack of significant ($P > 0.05$) differences between deep ripping and conventional ploughing was observed at Sebele 2 but infiltration was significantly ($P < 0.05$) smaller on traffic lines. There were no significant ($P > 0.05$) differences between deep ripping and conventional ploughing and between double ploughing and traffic lines at Sebele 1. At Sese, infiltration rate was not significantly ($P > 0.05$) different between deep ripping and conventional ploughing, and between conventional and double ploughing but was significantly ($P < 0.05$) smaller under traffic lines compared with tilled soil.

Average steady state infiltration rates were 11, 14, 23 and 27 cm h^{-1} on Ferric Luvisols (Sebele 2), Haplic Luvisols (Tswidi), Chromic Luvisols (Sebele 1) and Ferric Arenosols (Sese), respectively. Steady state infiltration rates from double ring method ranging from 3 to 15 cm h^{-1} are considered moderate to moderately high (Landon, 1984). Infiltration rates on heavier textured soils (Sebele 2 and Tswidi) were smaller compared with light textured (Sebele 1 and Sese). Infiltration rate data can assist in designing waterharvesting systems such as deep ripping by determining the size of area of traffic lines, the area from which rainwater is harvested. Except at Sese, infiltration rate on deep ripping and conventional ploughing was statistically the same.

3.6. Sorptivity

Sorptivity values under different tillage and soils are presented in Table 6. There were no significant ($P > 0.05$) differences between treatments at Sebele and Tswidi. At Sese, there also no significant ($P > 0.05$) among tillage systems but sorptivity was significantly ($P < 0.05$) smaller on traffic lines. Average sorptivity values across tillage systems were 3.88, 4.52, 2.35 and 2.52 cm min$^{-1/2}$ at Sese

Table 5
Steady state (4 h) infiltration rate (cm h^{-1}) on Chromic Luvisol (Sebele 1), Ferric Luvisol (Sebele 2), Haplic Luvisol (Tswidi) and Ferric Arenosols (Sese) under different tillage systems in eastern Botswana

Tillage	Site			
	Sebele 1	Sebele 2	Tswidi	Sese
Deep ripping	26.34a	9.14a	14.74a	30.62a
Double ploughing	17.53b	–	12.36a	23.64ab
Conventional	25.90a	12.42a	14.72a	27.68b
Traffic line	19.57b	1.01b	0.27a	0.74c
LSD (0.05)	5.69	6.22	14.85	6.37
CV (%)	8.00	19.24	21.70	9.70
P (>F)	*	*	NS	**

LSD, least significant difference; CV, coefficient of variation; SL, sandy loam; SCL, sandy clay loam, clay loam; S, sand, the same letter within each column indicate no significant differences; NS, not significant; *, $P < 0.05$; **, $P < 0.01$.

Table 4
Four-hour cumulative infiltration (cm) on Chromic Luvisol (Sebele 1), Ferric Luvisol (Sebele 2), Haplic Luvisol (Tswidi) and Ferric Arenosols (Sese) under different tillage systems in eastern Botswana

Tillage	Site			
	Sebele 1 (SL)	Sebele 2 (SCL)	Tswidi (CL)	Sese (S)
Deep ripping	113.02a	50.13a	73.66a	132.56a
Double ploughing	94.32a	–	40.83a	109.08a
Conventional	122.54a	59.18a	74.05a	118.57a
Traffic line	85.18a	6.73b	3.21a	7.33b
LSD (0.05)	37.70	34.56	65.55	32.57
CV (%)	11.41	20.76	42.97	11.13
P (>F)	NS	*	NS	**

LSD, least significant difference; CV, coefficient of variation; SL, sandy loam; SCL, sandy clay loam, clay loam; S, sand; the same letter within each column indicate no significant differences; NS, not significant; *, $P < 0.05$; **, $P < 0.01$.

Table 6
Sorptivity (cm min$^{-1/2}$) on Chromic Luvisol (Sebele 1), Ferric Luvisol (Sebele 2), Haplic Luvisol (Tswidi) and Ferric Arenosols (Sese) under different tillage systems in eastern Botswana

Tillage	Site			
	Sebele 1 (SL)	Sebele 2 (SCL)	Tswidi (CL)	Sese (S)
Deep ripping	3.87a	2.61a	2.70a	4.28a
Double ploughing	4.87a	–	1.76a	3.67a
Conventional	4.83a	2.43a	2.59a	3.70a
Traffic line	3.06a	0.47a	0.16a	1.03b
LSD (0.05)	1.84	3.13	2.95	0.98
CV (%)	13.94	39.70	51.63	9.78
P (F)	NS	NS	NS	NS

LSD, least significant difference; CV, coefficient of variation; SL, sandy loam; SCL, sandy clay loam, clay loam; S, sand, the same letter within each column indicate no significant differences and NS, not significant.

(Ferric Arenosols), Sebele 1(Chromic Luvisols), Tswidi (Haplic Luvisols) and Sebele 2 (Ferric Luvisols), respectively. Sorptivity in sandy soils (CV < 13%) was less variable than in sandy loam (CV = 39–52%) (see Table 5). Sorptivity values were similar between conventional and double ploughing at Sebele 1 (iiii) and Sese (sand). Except at Sebele 1, sorptivity was reduced by at least 73% compared with tillage (see Fig. 3).

Sorptivity was linearly related to void ratio of silty soils (Walker and Chong, 1986). Since tillage affect surface soil structure, sorptivity measurements can be used to asses soil compaction or the potential water uptake in arable lands. In this study, sorptivity values differentiated between cultivated soils and traffic lines (Table 6 and Fig. 4). At Sebele 2 (sany clay loam), Tswidi (clay loam) and Sese (sand) the differences between cultivated soils and traffic lines was large and only marginal at Sebele 1 (sandy loam). The differences of sorptivity values between soils tilled with tines (deep ripping) and mouldboard plough (conventional and double ploughing) were small at all sites. Under ponded water infiltration, sorptivity values were greatest under sandy (Sese and Sebele 1) than sandy loam soils (Sebele 2 and Tswidi).

4. Summary and conclusions

Cumulative ponded infiltration and steady state infiltration rate were similar under deep ripping and conventional ploughing but greater as compared with double ploughing. On traffic lines, infiltration was consistently smaller than on ploughed or ripped soils. Except on sandy loam soil (Sebele 1), cumulative infiltration decreased by at least 73% on traffic lines compared with tillage systems. Sorptivity was highly variable and was not affected by tillage. High intensity rainfall and dense Luvisols increase the potential of water loss by runoff on arable lands of eastern Botswana.

Soils of arable lands in Botswana have low organic matter content and poor structural stability and the effects of cultivation disappear as the soil consolidates during the growing or rainy season. Using non-inversion tillage methods such as chisel and deep ripping can minimize destruction of soil structure and improve water infiltration over extended periods. Retaining or increasing crop residue on the soil surface or the use of lime and gypsum can reduce re-compaction of hardsetting soils and increase crop production in Botswana.
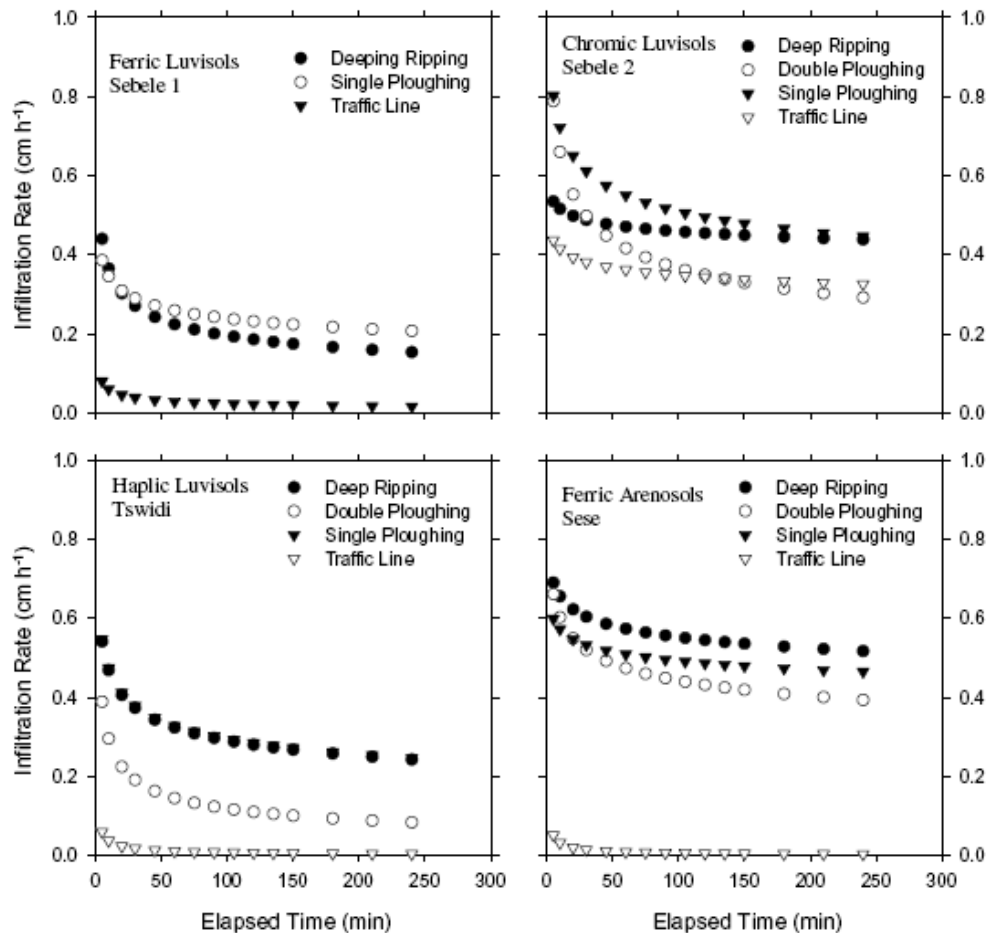

Fig. 3. Infiltration patterns on Chromic Luvisol (Sebele 1), Ferric Luvisol (Sebele 2), Haplic Luvisol (Tswidi) and Ferric Arenosols (Sese) under different tillage systems in southeastern Botswana.
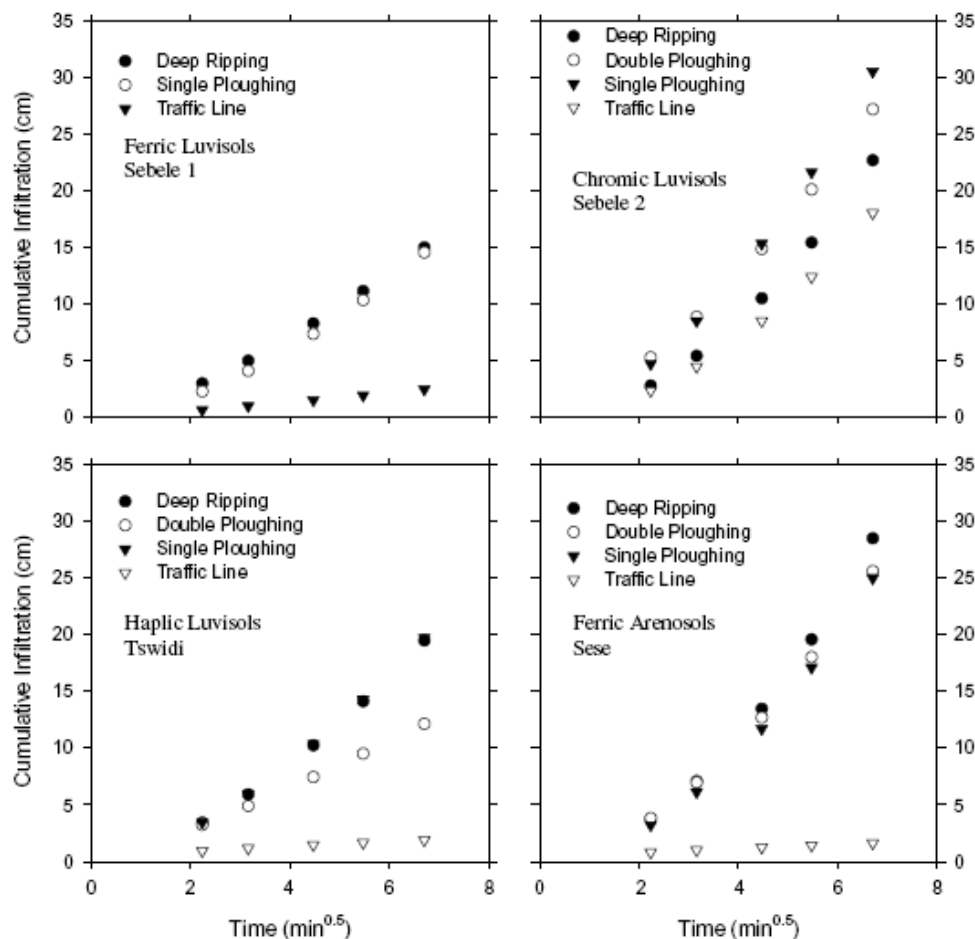
Fig. 4. Cumulative infiltration versus square-time (between 0 and 45 min) on Chromic Luvisol (Sebele 1), Ferric Luvisol (Sebele 2), Haplic Luvisol (Tswidi) and Ferric Arenosols (Sese) under different tillage systems in southeastern Botswana.

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