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RESEARCH ARTICLE

Soil organic carbon dynamics of improved fallow-maize rotation systems under conventional and no-tillage in Central Zimbabwe

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Abstract Fallowing increases soil organic carbon (SOC) during the fallowing phase. However, this benefit is lost quickly during the cropping phase. The objective of this study was to evaluate SOC dynamics of an improved fallow-maize rotation under no-tillage (NT) and conventional tillage (CT) from time of fallow termination, through the next two cropping seasons. The treatments studied were improved fallows of *Acacia angustissima* (*A. angustissima*) and *Sesbania sesban* (*S. sesban*), natural fallow and continuous maize. Our hypothesis is that fallowing maintained higher SOC and lower soil bulk densities through the cropping phase when compared with continuous maize system and that NT maintained higher SOC when compared with CT. Soil organic carbon was significantly greater under fallows than under continuous maize from fallow termination to the end of the second cropping season. Soil organic carbon for the 0–5 cm depths was 11.0, 10.0, 9.4 and 6.6 g kg^{-1} for *A. angustissima*, *S. sesban*, natural fallow and continuous maize, respectively at fallow termination. After two cropping seasons SOC for the same depth was 8.0, 7.0, 6.1, 5.9 g kg^{-1} under CT and 9.1, 9.0, 8.0, 6.0 g kg^{-1} under NT for *A. angustissima*, *S. sesban*, natural fallow and continuous maize, respectively. Total SOC stocks were also higher under fallows when compared with continuous maize at fallow termination and after two cropping seasons. Soil bulk densities were lower under fallows when compared with continuous maize during the period of study. We concluded that fallows maintained greater SOC and NT sequestered more SOC than CT. *Acacia angustissima* was the better tree legume fallow for SOC sequestration when compared with *S. sesban* or natural fallow because it maintained higher SOC and lower bulk densities after two seasons of maize cropping.

Keywords Bulk density · Legume fallows · SOC stocks · Tillage

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Introduction

Most soils found in the smallholder farming areas of Zimbabwe have very low SOC. These soils, mainly granite derived coarse sandy soils, are associated with high decomposition rates of organic matter as they offer poor physical protection against oxidation. To maintain production on these soils, many smallholder farmers add leaf litter collected from forests, leaf pruning's from indigenous trees and composts to improve their soil fertility as natural fallow cycles are becoming unsustainable for replenishing soil fertility and structural stability. Jurion and Henry (1969) estimated that approximately 10–20 years of natural grass fallow would be needed in order to restore soil fertility and structural stability after 1 or 2 years of cropping (crop to fallow ratio of 1:10). As a result most farmers have been adopting improved fallows as an agroforestry technology for soil fertility improvement in the shortest possible time. Improved fallows have become an important agroforestry practice for increasing soil fertility and SOC (Lal 1989; Kiepe 1995; Alegre and Rao 1996; Kwesiga and Beniest 1998). Soil organic carbon stocks under improved fallows were estimated to increase by up to 5 t ha^{-1} when compared with monoculture practices of continuous maize (Sanchez et al. 1997; Sanchez and Jama 2000).

Soil organic carbon plays an important role in the soil's biological properties (e.g. provision of substrate and nutrients for microbes), chemical properties (e.g. buffering and reducing pH changes) and physical properties (e.g. stabilisation of soil structure). The aggregation between soil particles largely depends on SOC (Haynes and Swift 1990; Beare et al. 1994; Six et al. 2002; Bronick and Lal 2005), thus increasing SOC may help prevent soil structural degradation by increasing the physical stability (Dexter 1988). Management practices such as improved fallowing add large amounts of organic matter and are important for aggregate formation and stability, as they promote the build-up of SOC (Alegre and Rao 1996).

However, soil disturbance from tillage is a major cause of SOC losses during the cropping phase of most fallow-maize rotation (Pereira et al. 1958; McVay et al. 2006). Grandy and Robertson (2006) observed that years of soil regeneration can be lost after a single tillage event. In southern Africa, conventional tillage (CT) mainly involving mouldboard ploughing using ox or donkey drawn plough often causes structural degradation (Nyagumbo 1998; Vogel 1992) and a decline in soil organic matter (Chuma and Hagmann 1995). Soil organic carbon declines rapidly under tillage, hence eroding rapidly the gains of fallowing of fallow-maize rotation systems. To reduce these losses large amounts of organic residues should be returned to the soil (Beare et al. 1994; Sainju et al. 2006). The use of sustainable tillage practices should also be explored as a mean of reducing SOC losses. No tillage (NT) cropping systems are an example of sustainable tillage practices and they increase SOC and aggregate stability when compared with CT (Elwell 1989; Chuma 1993; Six et al. 2000; Mrabet 2002). The rates of SOC loss in improved fallows under conservation tillage systems such as NT were estimated to be 1.1 mg ha^{-1} yr^{-1} while for CT systems the losses were estimated to be as high as 5.6 mg ha^{-1} yr^{-1} (Benneh et al. 1996). In a study carried out in Nigeria, Lal (1976) demonstrated that deterioration in soil physical properties can be drastically reduced by managing fallows cover using NT systems.

Most work done so far in agroforestry in Zimbabwe has concentrated on soil fertility and yield benefits of fallowing in improved fallows-maize rotations under CT systems (Mafongoya and Dzowela 1999; Chikowo et al. 2003; Mapfumo et al. 2005; Chikowo et al. 2006). Although some work on conservation tillage has been done in Zimbabwe (Vogel 1992; Chuma 1993; Munyati 1997; Nyagumbo 1998), there are very few studies that have evaluated the effects of conservation tillage practices on SOC dynamics in improved fallow-maize rotation systems in Zimbabwean soils. Thus the objectives of this study were to evaluate the dynamics of SOC under different fallows, from fallow termination through termination through a 2-year cropping phase of a fallow-maize rotation systems subjected to CT and NT.

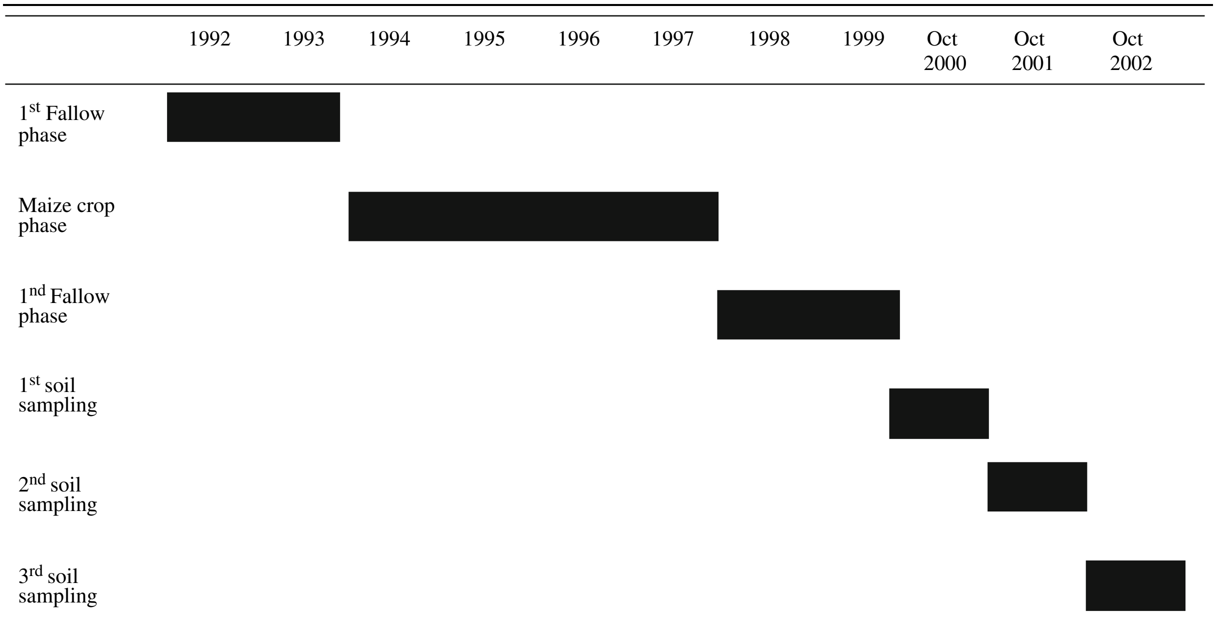
Material and methods

Experimental design

The study was conducted at the Domboshawa Training Centre in Zimbabwe (19°35′ S, 31°14′ E and 1,474 m altitude). The mean annual rainfall is 750 mm, usually received from November to April. The soils are classified as Alfisols (soil taxonomy) or Lixisols (FAO). The soil texture is sandy clay loam, with 22% clay, 71% sand and 7% silt. Selected chemical properties of the soil at the beginning of the experiment in 0–30 cm layer were: pH (0.01 M $CaCl_2$) = 4.8, C = 6 g kg^{-1}, N = 0.4 g kg^{-1}, extractable P = 3.8 mg kg^{-1} and exchangeable K = 0.03 $mmol_c$ kg^{-1} (Mafongoya and Dzowela 1999). The experiment was first established in the 1992 season from virgin land that was previously used as grazing land. The treatments studied were; fallow treatments of *Acacia angustissima* (*A. angustissima*), and *Sesbania sesban* (*S. sesban*), a natural fallow and continuous maize (*Zea mays*). Improved fallows of *A. angustissima* and *S. sesban* were planted from seedlings that were raised in nurseries at inter-row and in-row distance of 1 m, while natural fallow was mainly grass which grew naturally. The treatments were replicated three times and arranged in a complete randomised block design. All plots were 12 × 9 m and the fallow plots were under either a legume or natural grass fallow for 2 years. After the first 2 years of fallowing, all the plots were cropped to maize for 4 years, from 1994 to 1998. During the cropping phase, all plots were cultivated using an ox-drawn plough. After the end of 4 years of cropping, a new 2-year fallow phase was reinstated in November 1998 and the fallow period ended in October 2000 (Table 1). A continuous maize treatment was included as a control on plots with same dimensions as the fallow plots at the initiation of the experiment in 1992 and was maintained through out the study period.

At the end of the fallow period in October 2000, the woody biomass was removed from the plots while leaf litter, fresh leaves and twigs were left in the plots. Total above ground litter additions from leaves, litter and twigs, after 2 years of fallowing were 10 Mg ha^{-1} and 5.7 Mg ha^{-1}, for *A. angustissima* and *S. sesban* respectively (Chikowo et al. 2006). In addition, *A. angustissima* produced approximately 1.5 Mg ha^{-1} leafy biomass annually as coppices or shoots which grow from stumps after the tree is cut and these were pruned and left in the plots. In the natural fallow plots, litter additions were nil, as all the standing biomass was burnt to facilitate land preparation. All plots were randomly subdivided into conventional tillage (CT) and no-till (NT) subplots of 6 × 4.5 m. Conventional tillage was using an ox-drawn mouldboard plough to a depth of 15–20 cm while NT involved opening planting holes using a hand hoe. For both CT and NT, maize was planted and weeded twice using hand hoeing which disturbed the top 5 cm of the soil. Samples for SOC determination and bulk density measurements were collected in October 2000, 2001 and 2002. The first sampling (October 2000) coincided with the termination of the fallows, while the next two samplings were done to investigate SOC dynamics after the first and the second cropping seasons (Table 1).

Table 1 A timeline showing the management systems that were applied from initial fallow establishment (1992) to October 2002



Oct, October. The study focused on the residual effects of the 2nd fallow phase that was established in 1998 and terminated in 2000. The first sampling (October 2000) coincided with the termination of the fallows, while the next two samplings (October 2001 and 2002) were done to investigate SOC dynamics after the first and the second cropping seasons

Organic carbon

Soil samples for SOC determination were collected from the 0–5, 5–10 and 10–20 cm depths using an auger. The samples were air dried before finely ground to pass through a 0.5 mm sieve and then used for SOC determination. Soil organic carbon was determined using the modified Walkley-Black procedure (Nelson and Sommers 1982), which involved wet combustion of organic matter with a mixture of potassium dichromate and sulphuric acid at about 125°C. The residual dichromate was titrated against ferrous sulphate. Soil organic carbon stocks were calculated from multiplying bulk density by depth (Lal and Kimble 2001) and the results were expressed as Mg ha^{-1} C.

Bulk density

Soil samples for bulk density determination were collected from the 0–5, 5–10 and 10–20 cm depths using metal cores (Lal and Kimble 2001). Bulk density was calculated as the mass of oven dry soil divided by the volume of the soil as shown in Eq. 1.

$$\rho_b, \ (\mathrm{Mg\,m^{-3}}) = \mathrm{Ms}/\mathrm{V_t} \quad (1)$$

where: Ms = mass of oven dry soil and V_t = total volume of soil.

Results

Soil organic carbon concentrations were significantly higher under fallows when compared with continuous maize at the end of the fallow period (October 2000) and this difference persisted throughout the cropping phase (Table 2). Among the fallows themselves, SOC concentrations differed significantly and *A. angustissima* had the highest total SOC concentrations while natural fallow had the least (Table 2), showing that improved fallowing was better than natural fallow for SOC sequestration. When comparing the two improved legume tree fallows, *Acacia angustissima* had higher SOC concentrations when compared with *S. sesban* and this showed that coppicing legume tree fallows are a better option for long-term SOC amelioration when compared to a none coppicing legume tree fallow. After 2 years of cropping, SOC concentrations decreased for all the fallow treatments but there were no significant changes in SOC concentrations for the continuous maize system over the 2 years.

The corresponding SOC stocks remained significantly higher under fallows when compared with continuous maize system from the end of the fallow period through to the end of the second cropping season (Table 3). Among the fallow treatments, SOC stocks were significantly higher under improved fallows when compared with natural fallow, with *A. angustissima* apparently having the highest total SOC stocks (Table 3). These results showed that fallowing is important for SOC build up as shown by high SOC concentrations and stocks under fallows. The net SOC sequestered under the different fallows and tillage systems are shown in Table 4. Soil organic carbon stocks were higher under improved fallows at fallow termination when compared to

Table 2 Soil organic carbon (g kg^{-1}) for 0–5, 5–10 and 10–20 cm depths (October 2000–2002)

Depth (cm)	October 2000				October 2001 CT				October 2001 NT				October 2002 CT				October 2002 NT			
	AA	SS	NF	CM	AA	SS	NF	CM	AA	SS	NF	CM	AA	SS	NF	CM	AA	SS	NF	CM
0–5	11.0	10.0	9.4	6.6	8.8	7.8	8.0	6.5	9.0	9.1	8.6	6.5	8.0	7.0	6.1	5.9	9.1	9.0	8.0	6.0
5–10	9.4	8.9	8.8	6.1	8.0	7.0	7.2	6.0	8.9	8.0	7.9	6.0	8.0	7.1	6.2	6.0	8.9	8.0	6.9	6.1
10–20	9.2	8.9	8.8	5.9	7.8	6.7	6.5	6.0	8.8	7.2	6.8	5.9	7.4	6.4	6.1	5.9	8.9	7.4	6.2	6.0
LSD($P < 0.05$)	0.59 (treatment*); 0.51(depth*); (treatment × depth*)				0.55 (treatment*); 0.42 (tillage*); 0.39 (depth); 0.28 (treatment × depth*); 0.58 (treatment × tillage)								0.45 (treatment*); 0.32 (tillage*); 0.28 (depth*); 0.29 (treatment × depth*); 0.64 (treatment × tillage)							

AA, *Acacia angustissima*; CM, continuous maize (*Zea Mays*); CT, conventional tillage; NF, natural fallow; NT, no-tillage; SS, *Sesbania sesban*; *, shows significant effects at $P < 0.05$. October 2000 = data is from plots after two years of improved fallow, natural fallow or continuous maize; 2001 and 2002 data represent changes that occurred subsequently after growing NT or CT maize on these same plots for 1 and 2 years respectively

Table 3 Soil organic carbon stocks (Mg ha^{-1} C) for 0–5, 5–10 and 10–20 cm depths (October 2000–2002)

Depth (cm)	October 2000				October 2001 CT				October 2001 NT				October 2002 CT				October 2002 NT			
	AA	SS	NF	CM	AA	SS	NF	CM	AA	SS	NF	CM	AA	SS	NF	CM	AA	SS	NF	CM
0–5	7.7	7.5	6.0	4.3	5.8	5.3	5.4	4.5	6.0	6.1	5.8	4.5	5.4	4.7	4.5	4.1	6.0	5.6	4.4	4.1
5–10	6.5	6.8	5.7	4.2	5.3	4.8	4.9	4.2	5.6	5.5	5.3	4.2	5.5	4.8	4.6	4.3	6.1	5.5	5.1	4.3
10–20	12.1	11.1	10.1	8.4	10.4	9.2	9.1	8.7	11.1	10.0	9.2	8.6	10.2	9.0	8.6	8.4	11.0	9.4	10.0	8.5
Total	26.3	25.4	21.8	16.9	21.5	19.3	19.4	17.4	22.7	21.6	20.3	17.3	21.1	18.5	17.7	16.8	23.1	20.5	19.2	16.9
LSD($P < 0.05$)	0.46 (treatment*); 0.40 (depth*); 0.03 (treatment × depth);				<0.40 (treatment*); 0.26 (tillage*); 0.03 (depth*); 0.51(treatment × depth*); 0.50 (treatment × tillage)								1.4 (treatment*); 1.01 (tillage); 0.25 (depth*); 0.69 treatment × depth*); 2.02 (treatment × tillage)							

AA, *Acacia angustissima*; CM, continuous maize (*Zea Mays*); CT, conventional tillage; NF, natural fallow; NT, no-tillage; SS, *Sesbania sesban*; *, shows significant effects at $P < 0.05$. October 2000 = data is from plots after 2 years of improved fallow, natural fallow or continuous maize; 2001 and 2002 data represent changes that occurred subsequently after growing NT or CT maize on these same plots for 1 and 2 years respectively

natural fallow. These stocks all declined over the 2 years of cropping. However, the decline was more rapid under natural fallow and non-coppicing *S. sesban* when compared to coppicing *A. angustissima.*

Tillage had significant effects on SOC (both concentrations and stocks) and after two cropping seasons CT had lower SOC when compared with NT for all fallow treatments and this showed more accelerated SOC loss, mineralisation and decomposition under CT when compared with NT. Soil organic carbon was higher for the surface layers and this was attributed to the accumulation of organic plant litter, high concentration of plant roots and the decomposition of which possibly increased SOC levels. The results showed no significant tillage effects on SOC under continuous maize system after 2 years of cropping. However, SOC decreased significantly for all the fallow treatments after two post-fallow cropping seasons, showing the adverse effects of cropping on SOC that accumulated in fallow soils during the fallowing phase.

Bulk density did not vary among fallow treatments at fallow termination. However, it was significantly higher under continuous maize when compared with fallow treatments. After two cropping seasons bulk density of fallows remained significantly lower when compared with continuous maize (Table 5). Soil bulk density increased from fallow termination to the end of the second cropping season for all fallows treatments, but the increase was greater under *S. sesban* and natural fallow when compared with *A. angustissima*. Tillage did not result in significant changes in bulk density for improved legume tree fallow of *A. angustissima.* However for *S. sesban* and natural fallow, bulk density increased significantly under CT when compared with NT for the 5–10 and 10–20 cm depth and this showed that CT practices damaged the soil structure in a relatively short space of time when compared with NT. Continuous maize did not show significant differences in bulk density between CT and NT after two cropping seasons and this showed that continuous maize did not respond to conservation tillage management after only 2 years. On the other hand, the lack of significant differences in bulk density following CT and NT in *A. angustissima* fallow shows the resilience of coppicing legume fallow trees species to change as it maintained lower bulk density even after 2 years of cropping. Soil bulk density was lower in the top

Table 4 Net SOC sequestered (Mg ha^{-1} C) at 0–20 cm depth by different fallows above that of the continuous maize system (October 2000–2002)

Depth	October 2000			October 2001 CT			October 2001 NT			October 2002 CT			October 2002 NT		
(cm)	AA	SS	NF	AA	SS	NF	AA	SS	NF	AA	SS	NF	AA	SS	NF
0–5	3.40	3.15	1.68	1.33	0.71	0.88	1.71	1.63	1.24	1.27	0.58	0.38	1.68	1.32	0.82
5–10	2.32	2.56	1.52	1.26	0.63	0.70	1.87	1.25	1.10	1.26	0.56	0.32	1.84	1.19	0.80
10–20	3.36	2.64	2.39	1.99	0.61	0.40	3.50	1.45	0.76	1.86	0.64	0.16	3.39	0.94	0.41
Total	9.08	8.35	5.59	4.58	1.95	1.98	7.08	4.33	3.10	4.39	1.78	0.86	6.91	3.67	2.03

AA, *Acacia angustissima*; CT, conventional tillage; NF, natural fallow; NT, no-tillage; SS, *Sesbania sesban*. October 2000 = data is from plots after two years of improved fallow, natural fallow or continuous maize; 2001 and 2002 data represent changes that occurred subsequently after growing NT or CT maize on these same plots for 1 and 2 years respectively

0–5 cm and 5–10 cm for most treatments studied, however, for the 10–20 cm soil layer there was a sudden increase in the in bulk density and this could be due to the development of a pan at this depth. The pan may also be attributed to clay eluviations from the surface layer to the lower depths.

Discussion

Fallowing is important for improving SOC concentrations, SOC stocks and soil structure when compared with continuous maize cropping systems (Sanchez et al. 1997; Young 1997). Fallowing with either legume trees or with natural vegetation can result in a build up of SOC during the fallowing phases (Pereira and Beckley 1952; Mapa and Gunasena 1995; Alegre and Rao 1996; Young 1997; Mafongoya and Dzowela 1999; Nyamadzawo et al. 2006). Fallows were also observed to be more preservative of residue carbon than monoculture systems (Gregorich et al. 2001). However, among the fallow systems, fallowing using natural vegetation would result in slower build up of SOC when compared with improved fallowing e.g. using legume trees (Jurion and Henry 1969). This is because legumes tree fallows grow faster, and therefore add huge amounts of biomass and they also fix nitrogen. Among the leguminous tree fallows, coppicing *A. angustissima* was the better fallow when compared with *S. sesban* because it sequestered more SOC during the fallowing phase and also through coppicing during the cropping phase.

The introduction of cropping after 2 years of fallowing resulted in a decline in SOC levels in all fallow treatments. Although natural fallow sequestered significant SOC that was comparable to improved fallows at fallow termination (Salako et al. 2001; Nyamadazwo et al. 2006), planted fallows of *A. angustissima* and *S. sesban* are more suitable as short term fallows because they also improve soil nutrient status and chemical fertility better than natural fallow (Chikowo et al. 2006). Of the two legume tree fallows, SOC decreased faster under non coppicing tree fallows (*S. sesban*) when compared with *A. angustissima* and this shows further that coppicing fallows are better fallows than non coppicing fallows for SOC sequestration as they continued growing even during the cropping phase (Mobbz and Cannell 1995). The biomass that *A. angustissima* produced also decomposed slowly when compared with biomass from *S. sesban*, (Mafongoya et al. 1997) and this could have result higher SOC concentrations and stocks under *A. angustissima*.

This study compared two tillage systems (CT and NT) and showed that NT maintained higher SOC than CT (Vogel 1992; Chuma 1993; Benneh et al. 1996; Munyati 1997; Nyagumbo 1998). The mixing of soil organic material and soil during tillage increased the exposure of the SOM to microbial attack (Woomer and Swift 1994; Unger 1997). The high SOC under NT was attributed to shallower tillage caused minimal soil disturbance (Campbell et al. 1995; Bissonette et al. 2000). Angers et al (1997) measured SOC under NT and CT and found that NT had higher SOC at the 0–10 cm than CT. Beare et al (1994) also found higher soil organic matter under NT than under CT and similar observations were also reported by Cater et al (1990), Alberts and Neibling (1994) and Chuma and Hagman (1995). High levels of SOC were also attributed to lack of incorporation of surface residues relative to the soil inversion and placement

Table 5 Soil bulk densities (Mg m^{-3}) for 0–5, 5–10 and 10–20 cm depths (October 2000–2002)

Depth	October 2000				October 2001 CT				October 2001 NT				October 2002 CT				October 2002 NT			
(cm)	AA	SS	NF	CM	AA	SS	NF	CM	AA	SS	NF	CM	AA	SS	NF	CM	AA	SS	NF	CM
0–5	1.28	1.33	1.33	1.37	1.31	1.34	1.35	1.39	1.33	1.35	1.34	1.39	1.34	1.35	1.35	1.39	1.32	1.33	1.33	1.39
5–10	1.30	1.34	1.36	1.38	1.33	1.36	1.37	1.41	1.34	1.36	1.35	1.41	1.36	1.38	1.38	1.41	1.35	1.35	1.35	1.40
10–20	1.30	1.37	1.38	1.43	1.34	1.38	1.40	1.45	1.35	1.39	1.37	1.45	1.38	1.42	1.43	1.45	1.38	1.39	1.39	1.45
LSD($P < 0.05$)	0.02 (treatment*); 0.02(depth*); 0.03 (treatment × depth*)				<0.001 (treatment*); 0.007 (tillage); 0.01 (depth*); 0.02 (treatment × depth); 0.01 (treatment × tillage*)								0.03 (treatment*); 0.02 (tillage*); 0.01 (depth*); 0.02 (treatment × depth); 0.04 (treatment × tillage)							

AA = *Acacia angustissima*, CM = continuous maize (*Zea Mays*), CT = conventional tillage, NF = natural Fallow, NT = no-tillage, SS = *Sesbania sesban*, * = shows significant effects at $P < 0.05$. October 2000 = data is from plots after two years of improved fallow, natural fallow or continuous maize; 2001 and 2002 data represent changes that occurred subsequently after growing NT or CT maize on these same plots for 1 and 2 years respectively

at this depth by the mouldboard plough (VandenBygaart et al. 2002).

Fallowing also improves soil structure and maintained lower soil bulk density and porosity, (Algre and Rao 1996; Lal 1989). Fallowing using trees also reduced bulk density by breaking the plough layer, in addition to increasing SOM. This study showed that tree legume fallows had lower bulk densities when compared with natural fallow, indicating the superiority of former in improving physical environment. Under continuous maize system, bulk density was high, and this could be attributed to CT, which was practised during the previous 12 years of cropping with little or no biomass additions. Continuous tillage using ox-drawn plough could have resulted in increased soil bulk density and promoted the development of a plough layer, as shown by high bulk density at the 10–20 cm depth, while fallowing cycles allowed the soil to regenerate hence reducing the soils bulk density.

After 2 years of NT there were no signification changes in bulk density under the continuous maize system. This lack of response to changes in land management over a 2-year period showed that continuous maize cropping systems required much longer time for soil properties to be restored. However, for *S. sesbania* and natural fallow, bulk density increased significantly under CT when compared with NT and this showed that CT practices damaged the soil structure when compared with NT. The same was observed by Pereira et al (1958) who found that improvements are achieved during a fallow period under grass are rapidly lost during the arable phase. No tillage systems were reported to be beneficial in reducing the rate of decline in soil physical properties (Ogborn 1982; Sainju et al. 2006). Improved legume tree fallow of *A. angustissima* maintained lower bulk densities through out the 2 years of cropping showing the resilience of the fallow system, thus *A. angustissima* is considered a good legume fallow species.

The SOC accumulated during fallowing decreased in the short term due to tillage (Pereira and Beckley 1952), in medium to long term because of biodegradation (Woomer and Swift 1994) and soil erosion (Nyamdzawo et al. 2003). The net increase in SOC is the difference between net mineralisation and net sequestration (VandenBygaart et al. 2002), hence farmers should incorporate conservation tillage into fallow-maize rotation systems because they reduce

SOC mineralisation and increase SOC sequestration (Angers et al. 1997; Zotarelli et al. 2005; Grandy and Robertson 2006). The integration of improved fallowing practices and NT may be a possible solution to the problem of rapid losses in SOC. Other related benefits will include reducing soil bulk density and maintaining the soil structure. Maintaining of soil structure over a longer period may also make it possible to increase the number of years under cropping from the current recommended 2 years (Mafongoya and Dzowela 1999) to 3–4 years.

Conclusions

Fallowing improves organic C concentration and stocks in the soil when compared with continuous maize cropping. Although natural fallow showed structural improvements and had accrued SOC concentrations and SOC stocks that were comparable to those improved fallows at fallow termination, improved legume tree fallows are superior because they improved soil fertility within a much shorter period and maintained soil structural stability for a longer period. Coppicing fallows (e.g. *A. angustissima*) are the best fallow species because they add more organic carbon to soil and maintain it for a longer period.

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