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Effects of Bush Clearing and Tillage Methods on Some Soil Chemical Properties in Epemakinde, Southwestern Nigeria

NYAUDOH U. NDAEYO
Department of Agronomy, University of Uyo, Uyo Nigeria
E-mail: dr_nundaeyo@yahoo.com; Telephone: 2348023285242

ABSTRACT

The effects of bush clearing and tillage methods and their interactions on soil organic matter and macronutrients were investigated for three cropping cycles (1995/96 to 1997/98) on a primary forest area of Southwestern Nigeria. The bush clearing methods were: Bulldozed and windrowed (BW), Bulldozed not windrowed (BNW) and Clear-fell, slashed and burned (CSB), while Conventional (CT), Minimum (MT), Traditional (TT) and Zero (ZT) were the tillage methods. Adjoining natural forest was also incorporated as a treatment to serve as a control. The bush clearing and tillage methods, which were randomly distributed within the main-and sub-plots, constituted main-and sub-treatments. Results revealed a greater decline in the soil organic matter, macro-nutrients, cation exchange capacity and base saturation in BW plots than in BNW and CSB plots throughout the investigation period. The CSB conserved 22, 23, 15, 21, 5 and 11% more soil organic matter, total N, available P, K, Ca and Mg (0 - 15 cm soil depth) respectively than BW after the first cropping cycle. Similar trends were maintained in subsequent years. Among the tillage methods, ZT conserved soil organic matter and macro-nutrients more than other tillage methods. The ZT indicated 9 - 14% and 16 - 32% more total N and organic matter in 1995/96; 11 - 26% and 14 - 38% in 1996/97; and 7 - 21% and 6 - 34% in 1997/98 (0 - 15 cm soil depth) than other tillage methods. The available P, Mg, K, cation exchange capacity and base saturation followed the same trend. The interactive effects of bush clearing and tillage methods were significant on the chemical properties. The CSB + ZT or TT combination conserved soil nutrients the most. The CSB being slow inefficient and laborious and would hardly fit in soil improvement program. The adoption of BNW + MT combination would therefore be more appropriate in primary forests of the humid tropics.

Key Words: Bush clearing; Tillage methods; Chemical properties; Nigeria

INTRODUCTION

The tropical soils are physically fragile, highly weathered and leached, low in water–and nutrient–holding capacities, low in cation exchange capacity (CEC) and nutrient reserves (Couper, 1992) and therefore demand much care and nurturing before these can be productive. Consequently, maintenance of soil fertility in the tropical rainforest under continuous land use becomes a more serious agricultural constraint in the face of the increasing population, which for instance is now put at over 120 million in Nigeria alone (Ndaeyo *et al.*, 2001). The effect has been a marked reduction in the natural fallow period with a consequent fall in soil fertility. Moreover, leaching and erosion, once the vegetative cover is removed, are the most devastating in affecting the productivity of the tropical soil and the crops grown on it (Agboola, 1985). Unfortunately, most arable systems, especially those involving complete tree clearing, mechanical tillage and continuous cultivation, disturb the surface soil and predispose it to the weathering (Lal, 1984). The disruption of the existing fragile ecosystem with the use of heavy farm equipment, to intensify agricultural production has resulted in declined soil fertility unable to support crop production. Findings of some researchers on appropriate bush clearing and tillage methods in the tropics indicated local specificity leading to seemingly contradictory conclusion. Olaniyan (1990) observed that if soil is deprived of its vegetation cover through bulldozing or improper bush clearing methods, the chemical properties, including soil organic matter would be affected to the detriment of its fertility status. Seubert *et al*. (1977) showed that the low organic matter was due to topsoil disruption in the process of stumping and windrowing. Another study reported a decrease in organic matter of 30% in one year following bush clearing and burning of an Ultisol in the Amazon (Sanchez *et al*., 1983).

Investigation by Agboola (1994) on an Alfisol in Nigeria indicated that loss of soil organic matter and plant nutrients was extremely rapid, once the vegetation has been cleared irrespective of the soil type. There is also the problem of acidification in tropical soils following forest removal, which is further aggravated by a decrease in nutrient recycling from the deeper horizons, increased leaching/losses of divalent cations in eroded soils and surface runoff also due to the removal of the interception of forest canopy (Agboola, 1985).

A tillage operation induces profound changes in soil fertility. Intense tillage leads to high oxidation of organic matter (Doran, 1980) with resultant soil structural deterioration and oxidation and reduction of the potential nutrients supply (Hulugalle *et al.,* 1985). The trends and magnitude of their effects are nevertheless known to vary among soils and ecological regions, which could be transient to long lasting (Iwuafor & Kang, 1993). However, higher concentration of organic C, total N, extractable P, exchangeable Ca, Mg and K have been noticed in the surface soil of zero tilled than tilled plots (Dick, 1983). In spite of all these conflicting findings, very little has been done to identify or develop sustainable nutrient supply system (s) in the tropical rainforest ecology. This implies that considerable nutrient and soil management research is still desirable in order to develop bush clearing and tillage system (s) that would be both productive and sustainable. Therefore, the study reported here was conducted to assess the influence of some bush clearing and tillage methods on some soil chemical properties in a primary forest of Southwestern Nigeria.

MATERIALS AND METHODS

The study site. The study was conducted on a 2-hectare land of IBSRAM's, experimental field located at the Ondo State Afforrestation Project in Epemakinde (4^0 5' E & 6^o 45' N), Southwestern Nigeria. It is a highly forested area underlain by sedimentary deposit of coastal plain sands. The soils, as characterized by Agboola and Ogunkunle (1993), are Ultisols and Alfisols (with *Typic Kandiudult* & *Typic Kandiudalf* as the Modal profiles, respectively). The original thickness of the topsoil before clearing was 20 cm and the soil profile characteristics are shown in Table I. They are slightly to fairly acidic (pH 4.9 - 6.7); medium textured (sandy loam to sandy clayey loam top & sandy clayey loam to sandy clayey/clay below) and moderately well structured (granular per crumb top & sub-angular blocky below). The rainfall pattern is bimodal with long (April – August) and short (September – November) rainy seasons separated by a short dry spell of un-certain length usually during the month of August. The mean daily temperature ranges from 25^oC - 37^oC and the annual temperature is 24^oC - 26^oC, while the relative humidity was between 65% and 80%. The study site remained under high forest for over 70 years with standing tree trunks (boles) circumference ranging from 3 - 6 m. The land is gently sloping with gradient < 5% in most parts.

Experimental design. The bush clearing study started in 1994 with the initial operation of line tracing to demarcate the characterized land into three blocks of nine plots each. Each plot measured 40 x 30 m with 3 m and 4 m inter-plot and inter-block spacings, respectively. The three bush clearing methods investigated were: Bulldozed and windrowed (BW), bulldozed not windrowed (BNW) and cutting with powered saw followed by slashing and burning (CSB). The windrowed debris, were arranged along the inter-block and-plot spaces, while slashing, which was done manually, involved cutting down the under-growing shrubs, saplings, stragglers and vines. However, Aiyelari and Agboola (1998) have adequately documented details of the three bush clearing methods. In 1995, four tillage treatments: conventional (CT), minimum (MT), Traditional (TT) and zero (ZT), were imposed across each of the three bush clearing treatments and also replicated three times. The bush clearing treatments were randomly assigned to the main-plots, while the tillage treatments were also randomly assigned to the subplots, i.e., each bush clearing method in each replicate received the four tillage treatments. Each subplot was separated from the other by 2 m. Throughout the investigation period, the MT and CT plots were prepared with a tractor mounted disc plough that is ploughed once (at about 25 cm soil depth), but the CT plots were further harrowed once (at about 25 cm soil depth), while the MT plots were not harrowed. Plots that received ZT treatment had no mechanical soil manipulation but only involved manual clearing (with machetes), followed by burning of the debris after sun drying. Traditional tillage treatment involved manual clearing as in ZT, followed by the making of mounds prepared with traditional (native) hoe. A tractor mounted plough and harrow were used for the ploughing and harrowing operations. The tillage treatments were randomly assigned to the sub-plots at the beginning of the study. However, in the assessment of the macronutrients, the adjoining natural forest (NF) was also incorporated as a treatment to serve as a control (a check) and equally replicated three times.

Soil sampling and analysis. Composite soil cores (i.e., one mixed sample per subplot & per depth) were taken from 15 randomly selected points within each plot (1200 m^2) at two depths (0 – 15 cm & 15 – 30 cm) before planting and after every cropping cycle (i.e., after each year's harvesting). The soil samples were air-dried, ground and sieved through a 2 mm sieve before analyzing for the following parameters: Organic matter (OM), estimated by first determining organic carbon (OC) using the procedure of Nelson and Somers (1982) and then multiplying OC value by a factor of 1.724 (Odu *et al*., 1986); total N by the microkjeldahl method (Bremner & Mulvaney, 1982), while available P was determined by Bray's P_l method (Tel & Rao, 1982). Exchange acidity was determined using Yaun (1959) method. K^+, Ca^{2+}, Na^+ and Mg^{2+} were first extracted using 1 N NH_4 OAC, and determined by the flame photometer, while Mg was read from atomic absorption spectrophotometer. The CEC was determined as the sum of exchangeable bases and the exchange acidity, while base saturation was obtained as the percent of the total exchangeable bases to the effective CEC. Data generated were subjected to analysis of variance procedure and treatment means that indicated significant differences were separated using the least significant difference at $P < 0.05$ (Gomez & Gomez, 1984).

RESULTS

Total nitrogen, soil organic matter and available phosphorus. The total N and organic matter content at 0 - 15 cm soil depth were significantly higher ($P < 0.05$) in the CSB bush clearing method than in both BW and BNW (Figs. 1a, 1b, 2a & 2b). Data revealed that after the first (1995/96), second (1996/97) and third (1997/98) cropping cycles, total N in CSB (Fig. 1a & 1b) was higher than that of BW by 23%, 18% and 21% and soil organic matter (Fig. 2a & 2b) higher by 22%, 2% and 23%, respectively. The available P content (0 – 15 cm) only differed among bush clearing methods at the end of the third cropping cycle (Fig. 3a). The CSB method had 12 - 15% more available P than the other two bush clearing methods. At a lower soil depth (15 – 30 cm), similar trends were observed (Fig. 3b). Natural forest treatment continuously indicated the highest values for total N, soil organic matter and available P. Among the tillage methods, ZT indicated the highest total N and soil organic matter values at 0 – 15 cm soil depths throughout the cropping cycles and irrespective of the bush clearing methods (Fig. 1a & 2a). The ZT tillage method indicated 9 - 14% and 16 - 32% more total N and soil organic matter than other tillage methods in 1995/96, by 11 - 26% and 14 - 38% in 1996/97 and 7 - 21% and 6 - 34% in 1997/98. The total N and soil organic matter contents at lower soil depth (15 – 30 cm) followed the same trends (Fig. 1b & 2b). Specifically, when the initial value of total N (0.30 100 g^{-1}) at 0 – 15 cm was compared with the value obtained after the first cropping cycle (1995/96), it revealed 43%, 33% and 27% decrease in the plots that had BW, BNW and CSB bush clearing methods, respectively (Fig. 1a). In 1996/97 (second cropping cycle), the declines were 53%, 43% and 44%; and 63%, 60% and 53% in 1997/98 (third cropping cycle). At lower depth (15 – 30 cm), total N in BW, BNW and CSB plots also declined by 50%, 43% and 29% compared with the initial value (0.44 g 100 g^{-1}) after the first, second and third cropping cycles, respectively. Similarly, when the total N values for the different tillage methods (0 – 15 cm) were averaged across the three bush clearing methods and compared with the initial total N value, it indicated that the use of conventional (clean) tillage led to more decline than other tillage methods. The declines on the CT plot were 40%, 53% and 63% after the first, second and third cropping cycles, respectively (Fig. 1a). At lower soil depth (15 – 30 cm), the values of total N also decreased more in CT plot than in other plots by 50, 64 and 57% after the first, second and third cropping cycles, respectively relative to the initial value (0.14 g 100 g^{-1}).

The values of organic matter (0 – 15 cm) after the first cropping cycle were 33%, 17% and 13% less than the initial value (3.73 g 100 g^{-1}) in the BW, BNW and CSB, respectively (Fig. 2a). After the second and third cropping cycles, it decreased by 17%, 16% and 14% (for the second cycle) and by 36%, 30% and 17% (for the third cycle), in the BW, BNW and CSB plots, respectively. At lower soil depth, organic matter concentration decreased by 18%, 16% and 13% in the BW, BNW and CSB plots in 1995/96; 20%, 18% and 15% in 1996/97; and by 26%, 22% and 17% in 1997/98 (Fig. 2b) compared to the initial value. Organic matter concentration dropped more in conventionally tilled plots (0 – 15 cm) than in other plots by 39%, 41% and 44% after the first, second and third cropping cycles, respectively (Fig. 2a) relative to the initial value (3.73 g 100 g^{-1}). Similarly, at lower soil depth, it decreased by 26%, 25% and 32% in CT plot relative to the initial value (2.34 g 100 g^{-1}).

The values of available P (0 – 15 cm) after the first cropping cycle revealed uniform decline of 44% (Fig. 3a) in the entire bush clearing methods compared with the initial value (5.84 mg kg^{-1}). At 15 - 30 cm soil depth, it decreased by 50%, 45% and 38% in the BW, BNW and CSB plots, respectively (Fig. 3b) after the first cropping cycle relative to the initial value (2.35 mg kg^{-1}). Similar trends were also

Table I. Morphological Properties of the Soils at Epemakinde, Ondo State of Nigeria

Pedon	Horizon	Depth (cm)	Colour (moist)	Boundary	Structure	Texture	Concretionary nodules
(i)	A	0-10	10YR3/4	d.w	1,m,san	SL	n
	Btl	10-40	10YR3/6	d,w	2,m,sab	C	n
	B	40-85	10YR3/6	d,w	2,m,sab	C	n
	Bt2	85-140	2.5R3/8	-	2,c,sab	C	n
(ii)	A	0-18	SYR3/4	c.w	2,m,sab	SL	n
	Btl	18-48	SYR4/6	d,w	2,c,sab	SCL	f
	Bt2	48-70	SYR5/8	d,w	2,c,sab	C	f
	Bt3	70-106	SYR/6	d,w	3,c,sab	C	m
	B	106-160	7.5YRS/8	-	2,m,sab	C	f
(iii)	A	0-17	10YR4/3	c.w	2,f,sab	SL	n
	Btl	17-32	7.5YR3/4	c,w	2,m,sab	SCL	n
	Bt2	32-57	9.5YR5/6	c,w	2,m,sab	C	m
	Bt3	57-100	7.5YR5/6	c,w	2c,sab	C	f
	B	100-106	10R6/6	-	2,c,sab	SL	f

Legend	Boundary	Structure	Concretionary nodules
	c Clear	1 Weak	n None
	d Diffuse	2 Moderate	f Few
	w Wavy	f fine	m Many
		m Medium	Texture
		c Coarse	SL Sandy Loam
		g Granular	C Clay
		cr Crumb	SCL Sandy Clay Loam
		sab Subangular blocky	

Source: Agboola and Ogunkunle (1993)

Fig. 1 . Effects of bush clearing and tillage methods on soil total nitrogen at (a.) 0-15 cm (b.) 15-30 cm soil depth. Bars = LSD (P < 0.05)

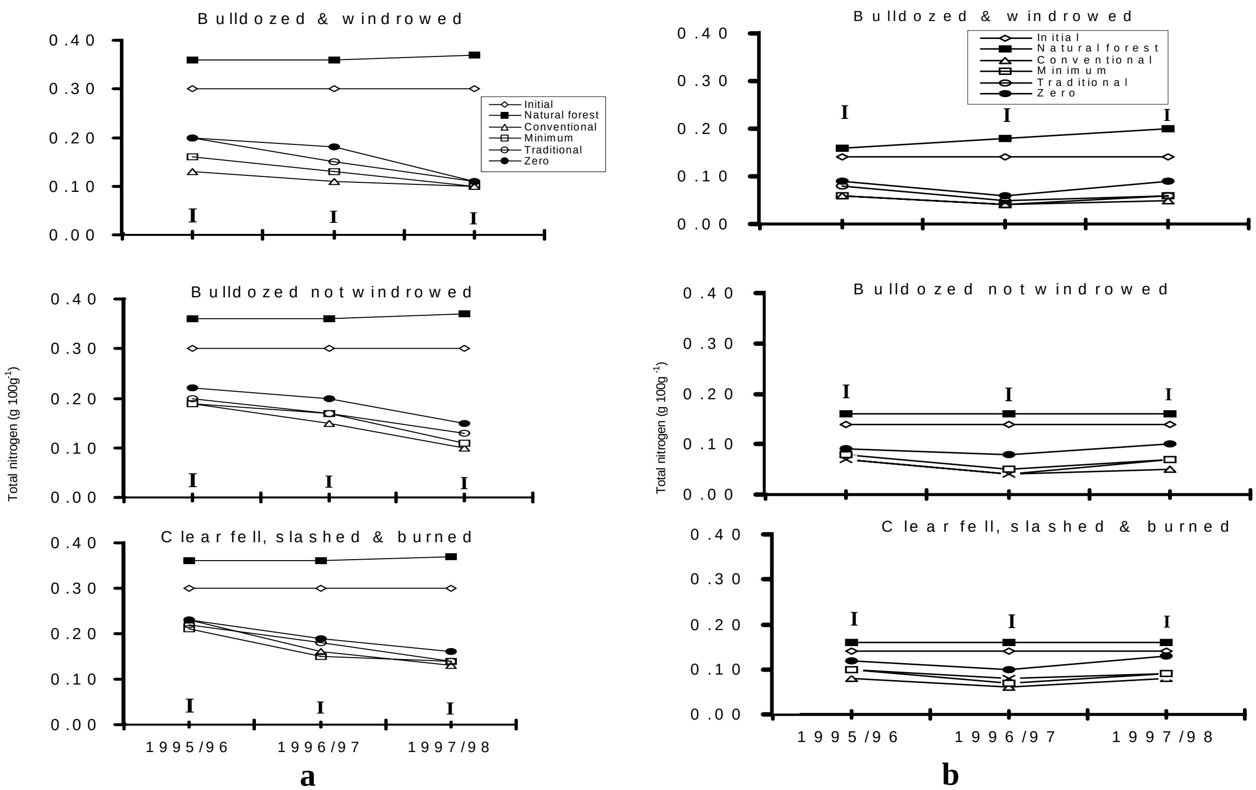


Fig. 2. Effects of bush clearing and tillage methods on organic matter at (a.) 0-15 cm (b.) 15-30 cm soil depth. Bars = LSD (P < 0.05), ns = not significant

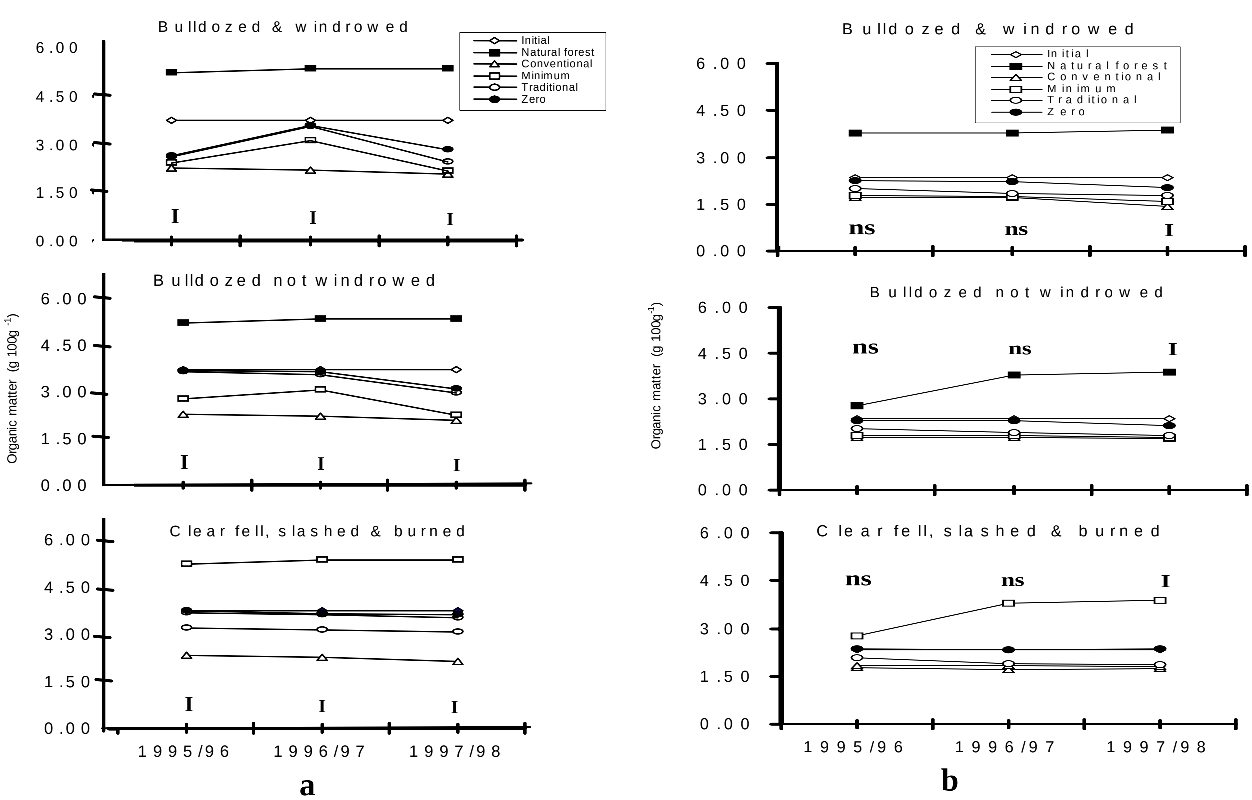


Fig. 3a. Effects of bush clearing and tillage methods on available phosphorus at 0-15 cm soil depth. Bars = LSD (P < 0.05). ns = not significant

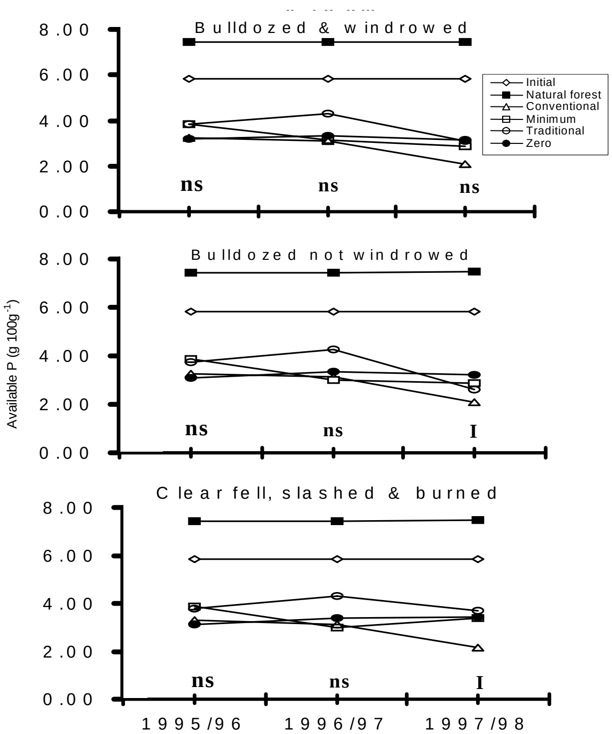
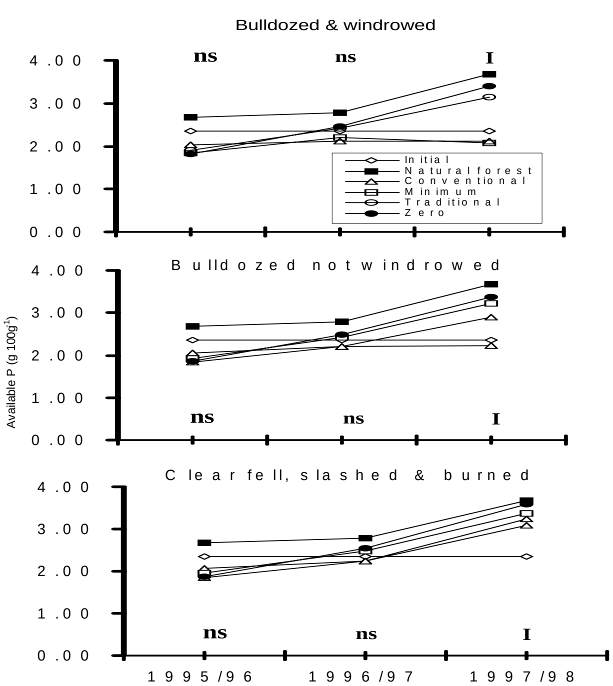


Fig. 3b. Effects of bush clearing and tillage methods on available phosphorus at 15 - 30 cm soil depth. Bars = LSD (P < 0.05). ns = not significant



observed after the second and third cropping cycles. Available P also declined more in CT plots by 12%, 17% and 43% after the first, second and third cropping cycle, respectively. At lower soil depth (Fig. 3b), available P value also declined more in the CT plot by 13% and 9% after the first and second cropping cycles but increased by 8% after the third cropping cycle relative to the initial value (2.35 mg kg^{-1}). The bush clearing and tillage methods interaction effects on the total N, soil organic matter and available P were significant ($P < 0.05$). The highest total N and soil organic matter contents were observed in CSB + ZT combination at both soil depth. The available P at 0 – 15 cm did not however maintain a clear pattern.

Calcium (Ca), magnesium (Mg) and potassium (K). The Ca and Mg contents at 0 – 15 cm soil depths did not differ significantly among the three bush clearing methods at the end of the first and second cropping cycles (Figs. 4a & 5a). However, at the end of the third cropping cycle, the Ca and Mg contents in CSB were 11 - 17% and 25 - 42% higher than in the other bush clearing methods, respectively. The K content (0 - 15 cm) was lower in BW (Fig. 6a) by 11 - 21%, 10 - 15%, and 14 – 27% than in other bush clearing methods after the first, second and third cropping cycles, respectively. Also at lower soil depth (15 – 30 cm), Ca and K values were lowest in BW (1.71 & 0.25 cmol kg^{-1}) and highest in CSB (1.75 & 0.29 cmol kg^{-1}) after the first cropping cycle (Figs. 4b & 6b). A similar trend was observed after the second and third cropping cycles. The Mg content (15 – 30 cm) was only significantly different among the bush clearing methods after the second and third cropping cycles (Fig. 5b). Among the tillage methods, Ca, Mg and K were significantly higher in ZT than CT, MT and TT at both soil depths (Figs. 4a – 6b) irrespective of the bush clearing methods. The mean values across the bush clearing methods revealed that at 0 – 15 cm soil depth, ZT contained 4 – 16%, 4 – 41% and 21 – 54% more Ca (Fig. 4a) after the first, second and third cropping cycles than other tillage methods. A similar trend was observed at 15 – 30 cm depth (Fig. 4b). The above status quo was also maintained for potassium (Figs. 6a & 6b).

When the initial value of Ca (2.47 cmol kg^{-1}) was compared with the values of Ca (0 – 15 cm) obtained after the first cropping cycle, it indicated that Ca concentration in the BW plot dropped most (10%) but increased in the second and third cropping cycle by 15% and 3%, respectively (Fig. 4a). At lower soil depth, Ca concentration increased above the initial value (1.59 cmol kg^{-1}) throughout the study period irrespective of the bush clearing method (Fig. 4b). When the values of Ca obtained from the different tillage methods (0 – 15 cm) were averaged across the three bush clearing methods and compared with the initial value (2.47 cmol kg^{-1}), it showed that the use of conventional (clean) tillage method led to more decline than other tillage methods. The declines were 18%, 17% and 35% after the first, second and third cropping cycles, respectively (Fig. 4a). At 15 – 30 cm depth, Ca did not maintain a clear pattern. values of Ca in CT plots decreased by 2% after the first cropping cycle, whereas it increased by

3 and 2% after the second and third cropping cycle respectively compared to the initial value (1.59 cmol kg^{-1}).

The Mg concentration (0 – 15 cm) also dropped most in the BW plots by 62%, 57% and 56% (Fig. 5a) after the first, second and third cropping cycles, respectively relative to the initial value (0.21 cmol kg-^{1}). At lower depth, Mg value decreased by 50%, 43% and 42% in the BW plot than others after the first, second and third cropping cycles (Fig. 5b), respectively compared to the initial value. The Mg value (0 – 15 cm) dropped most in CT tilled plots by 62 - 67% after the study (Fig. 5a) relative to the initial value. Similar trends were observed at 15 – 30 cm depths.

The concentration of K (0 – 15 cm) decreased most in the BW plots (by 62%, 56% & 51% after the first, second & third cropping cycles, respectively) compared to the initial value (Fig. 6a). At 15 – 30 cm depths, K value also dropped by 27%, 24% and 15% in the BW plots after the first, second and third cropping cycles, respectively compared to the initial value (0.34 cmol kg-^{1}). An average across the different tillage methods revealed that K content (0 – 15 cm) declined most in CT than others by 29%, 27% and 26% relative to the initial value (0.39 & 0.37 cmol kg^{1}). At lower soil depth, K values also declined most in CT plots compared to the initial K value (0.34 cmol kg^{1}). The bush clearing and tillage methods interaction effects on Ca, Mg and K were significant ($P < 0.05$). The combination of CSB + ZT conserved Ca, Mg and K the most.

CEC and base saturation. The CEC and base saturation contents as influenced by the different bush clearing and tillage methods are presented in (Figs 7a to 8b). The CEC at 0 – 15 cm only differed significantly among the bush clearing methods after the second and third cropping cycles (Fig. 7a). At both soil depths, the CSB bush clearing methods conserved more CEC than the other bush clearing method after the second and third cropping cycles (Figs. 7a & 7b). The base saturation at 0 – 15 cm did not differ among the bush clearing methods after the first, second and third cropping cycles (Fig. 8a). A similar trend was observed for base saturation at 15 - 30 cm soil depth (Fig. 8b). Among the tillage methods, ZT conserved CEC and base saturation better at both soil depths.

The CEC (0 – 15 cm) declined more in the BW plot than other plots by 16%, 3% and 27% after the first, second and third cropping cycles, respectively (Fig. 7a) compared with the initial value (3.62 cmol kg^{-1}). At lower soil depths (15 – 30 cm), a similar trend was observed (Fig. 7b) when the CEC values for the different tillage methods were averaged across the three bush clearing methods and compared with the initial value (3.62 cmol kg-^{1}). It revealed 21, 23 and 36% decrease in CEC after the first, second and third cropping cycles, respectively.

Base saturation values (0 – 15 cm) decreased relative to the initial value (94.48 g 100 g^{-1}) irrespective of the bush clearing methods although it was more pronounced in the BW plots (Fig. 8a). Similar pattern was maintained at lower soil depth (Fig. 8b). When the base saturation content (0 – 15 cm) for the different tillage methods were assessed and compared with the initial value, it revealed 4 - 6% reduction in CT plot than other plots (Fig. 8b). Similar decreases were

Fig. 4a. Effects of bush clearing and tillage methods on calcium at 0 – 15 cm soil depth. Bars = LSD (P < 0.05), ns = not significant

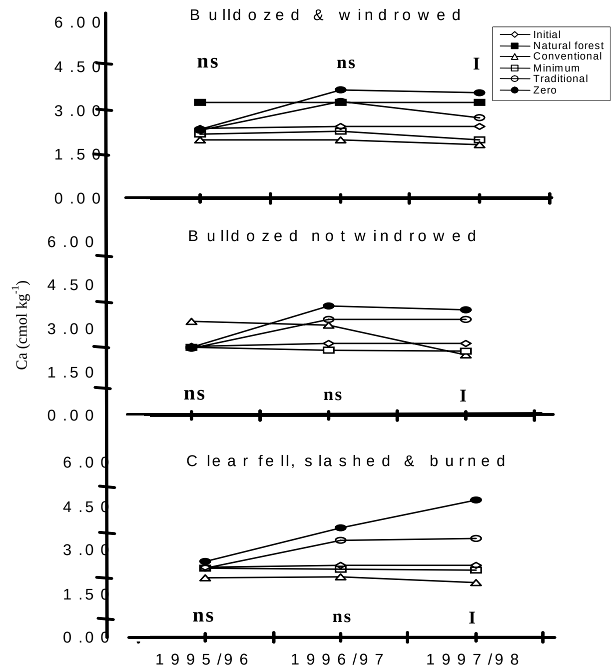


Fig. 4b. Effects of bush clearing and tillage methods on calcium at 15 – 30 cm soil depth. Bars = LSD (P < 0.05), ns = not significant

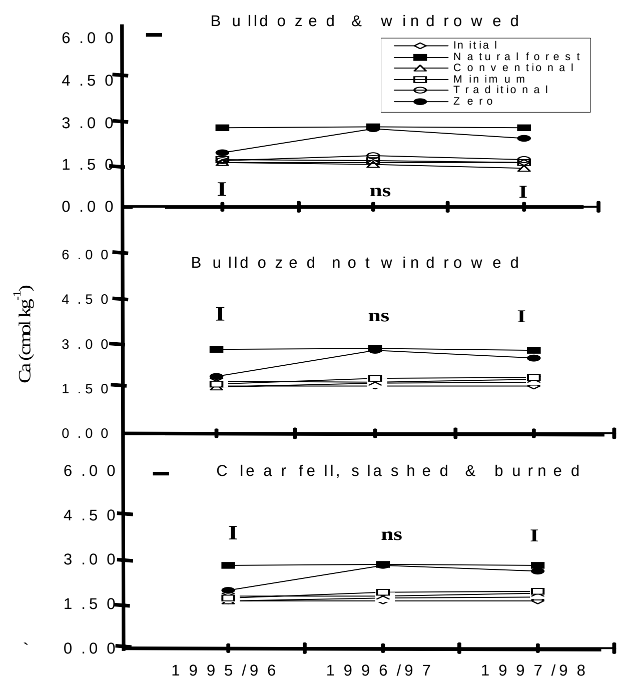


Fig. 5a. Effects of bush clearing and tillage methods on magnesium at 0 – 15 cm soil depth. Bars = LSD (P < 0.05). ns = not significant

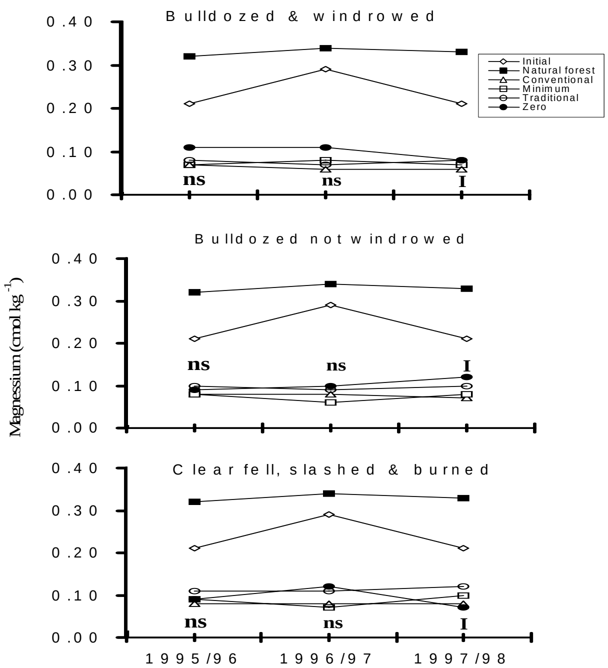
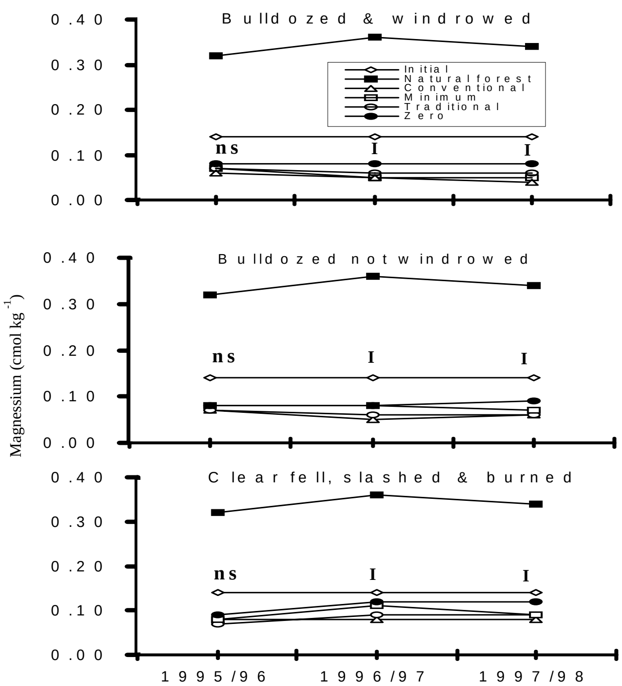


Fig. 5b. Effects of bush clearing and tillage methods on magnesium at 15-30 cm soil depth. Bars = LSD (P < 0.05). ns = not significant



also observed at 15 - 30 cm soil depth (Fig. 8a). The interaction effects of bush clearing and tillage methods on CEC and base saturation were significant with CSB + ZT

Fig. 6a. Effects of bush clearing and tillage methods on potassium at 0-15 soil depth. Bars = LSD (P < 0.05)

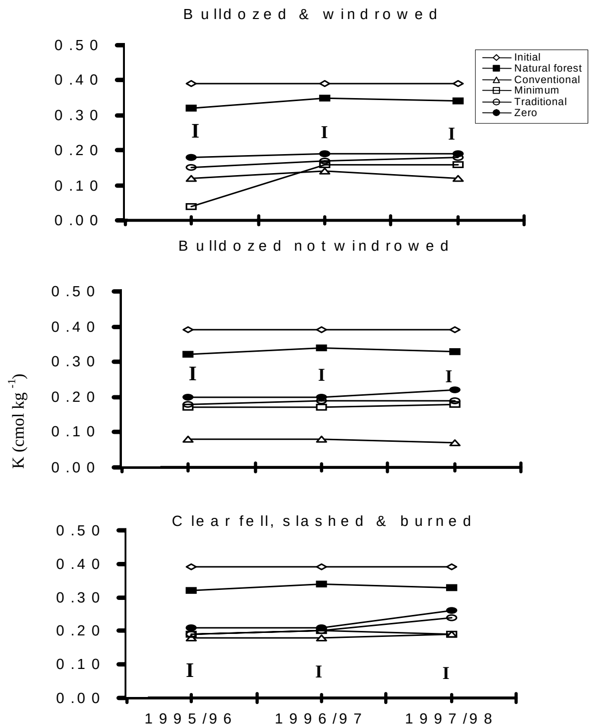
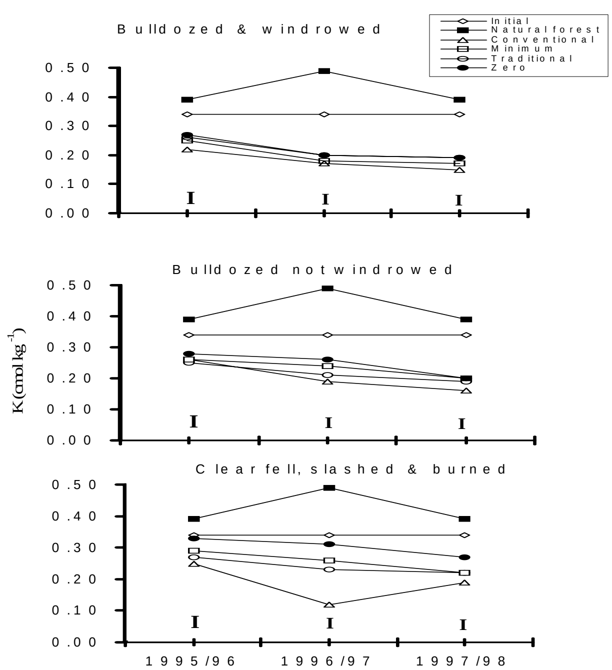


Fig. 6b. Effects of bush clearing and tillage methods on potassium at 15-30 cm soil depth. Bars = LSD (P < 0.05)



conserving more CEC and base saturation than other bush clearing and tillage combinations.

Fig. 7a. Effects of bush clearing and tillage methods on CEC at 0-15 cm soil depth. Bars = LSD (P < 0.05). ns = not significant

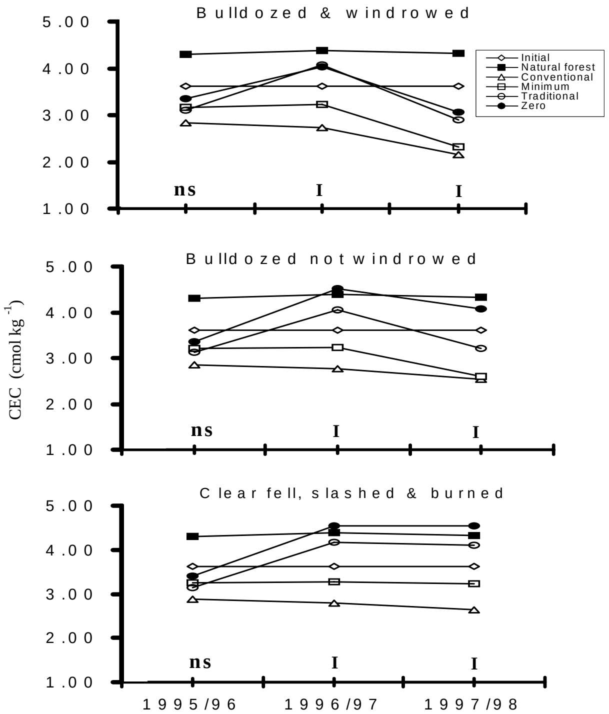


Fig. 7b. Effects of bush clearing and tillage methods on CEC at 15-30 cm soil depth. Bars = LSD (P < 0.05)

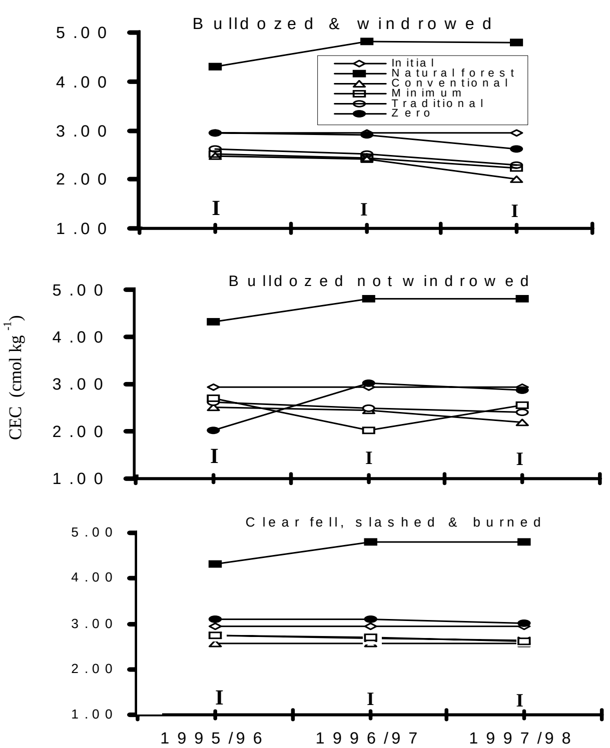


Fig. 8a. Effects of bush clearing and tillage methods on base saturation at 0-15 cm soil depth. Bars = LSD (P < 0.05), ns = not significant

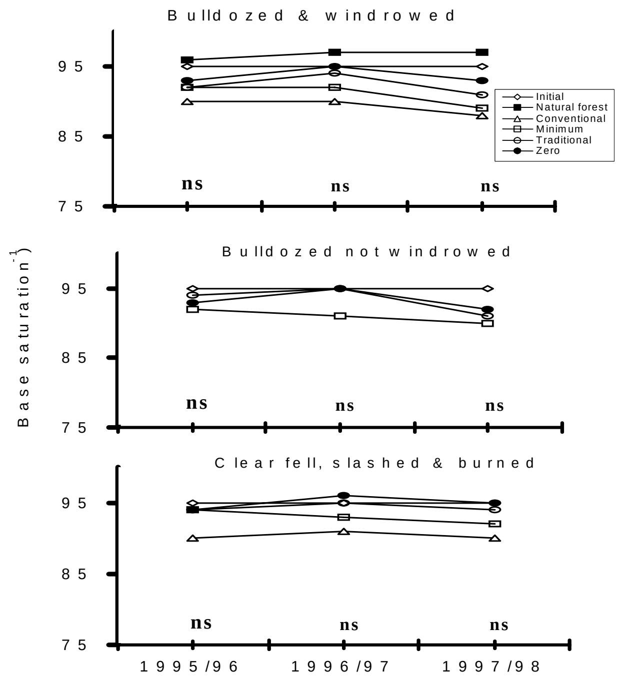
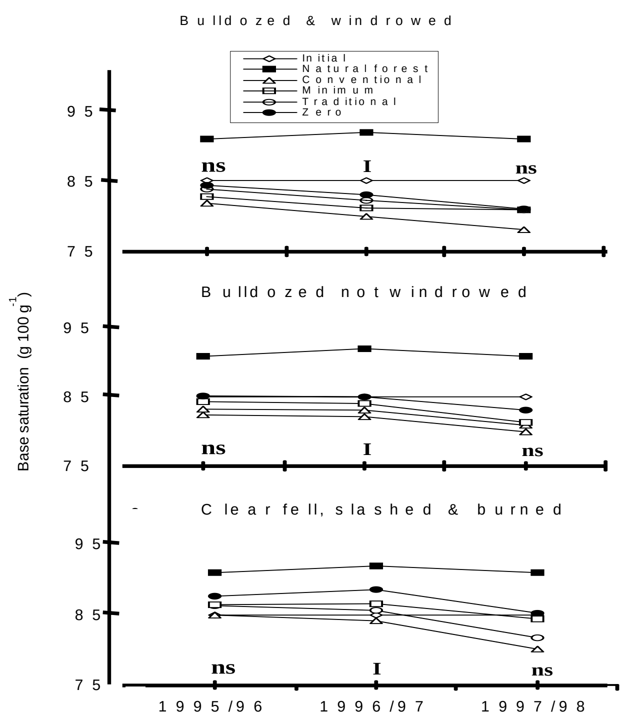


Fig. 8b. Effects of bush clearing and tillage methods on base saturation at 15-30 cm soil depth. Bars = LSD (P<0.05), ns = not significant



DISCUSSION

The depletion in soil organic matter and soil macro-nutrients with time was more pronounced in the BW bush clearing method apparently due to the complete removal of the vegetation cover and the subsequent exposure of topsoil to the erosive effects of torrential rainfall typical of the study area (humid tropics), particularly before crop canopy closure. These findings are in concurrence with those of Seubert *et al.* (1977) and Lal and Cummings (1979) in other agro-ecologies. Moreover, the unconscious disruption and removal of the topsoil and soil organic matter during the windrowing operation also contributed to the above observations. Soil organic matter has been established to be the life wire for the sustainability of tropical soils (Agboola, 1985). The CSB clearing method conserved soil organic matter and nutrients better than BW and BNW. However, the CSB was observed to be slow, laborious and inefficient in that it requires more working hours and/or human days thereby being rather costlier. Aiyelari and Agboola (1998) made similar observations and concluded that CSB clearing method is laborious and time consuming but guarantees longer life span for tropical soils under continuous cropping. Generally, the use of CT tillage method depleted the organic matter and soil nutrients the most, whereas ZT showed the least depletion. The seemingly slow release of soil organic matter and nutrients in the MT and TT tillage methods compared to the CT could be responsible for this. The CT method has been reported to cause rapid break down of soil structure and accelerate the loss of soil organic matter through erosion, increased biological activity and the oxidative processes (Agboola, 1994).

CONCLUSIONS

Complete removal of the vegetation cover in the BW bush clearing method caused significant adverse changes in soil chemical properties compared to BNW and CSB, The process of windrowing, which disturbs the topsoil was responsible for the low soil fertility status with time under BW. The trends of relationships between bush clearing and tillage methods revealed that BW + CT combination depleted soil OM and nutrients more than the others. If BW + CT bush clearing and tillage method combination is to be adopted, there must be a corresponding use of some external inputs e.g., fertilizers after the second cropping cycle if surface feeder crop like maize is grown. The use of CSB + TT or ZT conserved soil nutrients and organic matter better than BW + CT combination through slow release of nutrients. However, CSB + TT or ZT is rather laborious and inefficient thereby being costlier. It would be more appropriate to adopt the BNW + MT combination in the primary forests of the humid tropics.

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