THE EFFECT OF LAND CLEARING BY BULLDOZING ON SOME PHYSICAL PROPERTIES OF A FOREST SOIL

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ABSTRACT

The effects of land clearing by bulldozing on some physical properties of a forest soil (Haplic Acrisol) were studied. Bulk density was significantly affected by bulldozer clearing. The percentage increases in bulk density at the bulldozed site over the forested control site were 9, 16, 19 and 11 for the 0 - 7.5cm, 7.5 - 15cm, 15 - 22.5cm and 22.5 - 30cm soil depth respectively. Soil compaction at the bulldozed site penetrated to a depth of 30 cm with the major compactive effect felt at the 15 - 22.5 cm depth. Total porosity was significantly higher at the forest site than the bulldozed site. Relative to the forested control site, bulldozed clearing decreased total porosity in the 0 - 7.5 cm, 7.5 - 15 cm, 15 - 22.5 cm and 22.5 - 30 cm depth by 11, 12, 17 and 11 per cent respectively. Bulldozer clearing altered the sandy loam texture of the forest site to sandy clay loam. The mean steady-state infiltration rate was significantly higher at the forest site than the bulldozed site. Bulldozer clearing reduced the mean infiltration rate by 85 per cent.

Keywords: Bulk density, Total porosity, Infiltration rate, soil compaction, Bulldozer clearing.

INTRODUCTION

The productivity of forest soils in the humid tropics is significantly influenced, among other factors, by soil physical properties. These properties, including bulk density total porosity, pore-size distribution, infiltration rate, saturated hydraulic conductivity and available water capacity, undergo immediate and drastic degradation when the forest cover is removed either manually or mechanically [1]; [2]; [3]. The effects of land clearing by heavy machinery on soil physical properties are due to soil structure deterioration and removal of topsoil which contains most of the soil's organic matter [4].

The order of degradative change in soil physical properties due to land clearing methods was found to be manual clearing < tree pusher < shear blade < tree pusher/root rake [3]. On an Ultisol in Nigeria, soil compaction increased to 30 cm soil depth with shear blade and 20cm with manual clearing. Compared with the forested control, shear blade and manual clearing increased the bulk density in the 0-10cm layer by 22 and 14 per cent respectively. Three months after clearing, the steady state infiltration rates were 89, 20 and 32 mm h^{-1} in the forested control, shear blade and manually cleared plots respectively [5].

Although manual clearing, with its associated drudgery, is less disruptive to soil properties and maintains the productive capacity of the soil [6], [7], it is slow, labour-intensive and less efficient, and in regions with shortage of labour, can be more costly than mechanical clearing. Because of these, most farmers in veloping countries tend to seize the slightest opportunity to hire bulldozer operators who may happen to be working on new roads and constructional sites within the vicinity of their farmsteads to clear their farmlands. Although improper use of land clearing machinery on farmlands may be the underlying cause in the decline of soil productivity, the subject has received very little research attention in the humid tropical Africa in general and Ghana in particular. Consequently information needed on changes in soil physical properties caused by land clearing techniques for evolving appropriate land management practices for sustainable crop production is scarce.

This study was therefore conducted to investigate the effect of clearing forest land by bulldozing on some soil physical properties.

MATERIALS AND METHODS

The study was conducted at one of the newly cleared experimental fields of the Crops Research Institute of Ghana, at Fumesua near Kumasi (Latitude 06^0 34' N and Longitude 01^0 31' W) within the moist semi-deciduous forest zone.

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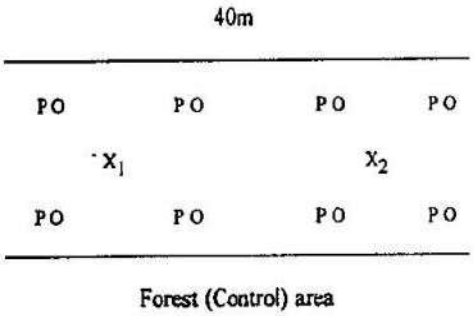
The soil is Akroso series classified as Haplic Acrisol [16]. At the forest site and at the 0-15 cm and 15-30 cm soil depths, the respective pH (1:2.5 soil/water) was 4.4 and 4.2, and per cent organic matter was 1.9 and 1.2. The corresponding values at the bulldozed site were 4.6 and 4.0 for pH and 1.5 and 0.93 for organic matter. Because of the relevance of the effect of bulldozing on soil surface conditions, the per cent organic matter content at 0 - 7.5 cm depth as well as litter and worm casts accumulation were assessed. The organic matter values were 2.1 and 1.8 for the forest and bulldozed sites respectively. Using a quadrat size of $0.32m^2$, 10 sites were randomly sampled for worm casts and 5 sites for litter. While no litter nor worm casts were recorded at the bulldozed site, the forest site gave 1.5 kg m^{-2} worm casts and 0.93 kg m^{-2} litter.

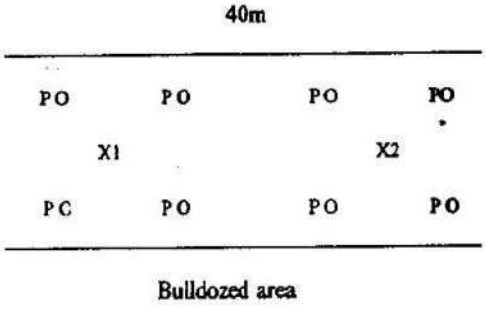
The vegetation was a young secondary forest (about 10 years) consisting of a number of trees with *Baphia nitida, Funtumia elastica, Anthodcleista* sp., *Albizzia* sp, and *Elaeis guineensis* as the predominant species. The understorey consisted of shrubs, herbaceous species and climbers.

A part of the forest was cleared in August, 1993, using a Caterpillar D-6 bulldozer with a shear blade attachment. The felled vegetation was windrowed downslope to the edge of the experimental field. This operation and the stumping of the field that followed resulted in a significant disturbance and scraping of the surface soil with its mat of forest litter.

In October 1993, a sample strip measuring 5m wide and 40m long with a slope of 2.5 per cent was delineated within the forest (control) and the adjacent bulldozed site for the study. The sampling points for the parameters studies are shown in Figure 1.

Figure 1. Approximate Sampling Points in both the Forest and Bulldozed Sample Strips.





LEGEND

- O - Bulk Density
- p - Particle Size Distribution
- X_1 - Infiltration Rate

The data were analysed using the student's t-test and the significant differences between the means were determined.

Bulk density was determined by the core method [8] to a depth of 30 cm at 7.5 cm increments.

Total porosity was calculated by using the bulk density values and a particle density of 2.65 Mg m^{-3} [9]

Particle-size distribution was determined by the hydrometer method [10].

Infiltration rate was measured with a double ring infiltrometer [11]. The inner and outer rings were 30 and 60 cm in diameter respectively. The results of the infiltration tests were analysed using Philip's equation [17] to compare soil water sorptivity and transmissivity.

RESULTS AND DISCUSSION

Bulk Density and Total Porosity

Mean soil bulk density (Table 1) generally increased with depth at the forest site with values ranging from 1.09 to 1.34 Mg m^{-3}. A similar trend was observed at the bulldozed site to a depth of 22.5 cm after which bulk density, 1.19 - 1.52 Mg m^{-3}, decreased.

Tabl ..: Effect of land clearing by bulldozing on bulk density and total porosity

S .i properties	Clearing method	Soil Depth cm 0 - 7.5	7.5 - 15.0	15.0-22.5	22.5-30.0
	Forest	1.09(0.01)	1.18(0.01)	1.28(0.01)	1.34(0.004)
Bulk density ($Mg\ m^{-3}$)	Bulldozed	1.19(0.01)	1.37(0.02)	1.52(0.01)	1.49(0.02)
	LSD (0.05)	0.02	0.03	0.02	0.04
Total Porosity (%)	Forest	58.87(0.21)	55.38(0.22)	51.56(0.25)	49.29(0.14)
	Bulldozed	52.24(0.44)	48.49(0.53)	42.83(0.49)	43.92(0.72)
	LSD(0.05)	1.05	1.25	1.18	1.58

Standard error is given in parenthesis

Bulk density at all depths was significantly greater at the bulldozed than the forest sites. The percentage increases in bulk density at the bulldozed site over that of the forest were 9, 16, 19 and 11 for the 0-7.5 cm, 7.5-15 cm, 15-22.5 cm and 22.5-30 cm depth respectively. This implies that both surface and subsurface compaction occurred under bulldozer clearing with the major effect felt at the 15-22.5 cm depth. Similar observations have been reported [12]; [5]. The wheel traffic and the exertion of the weight of the bulldozer on the soil, acting in concert with the scraping and significant soil disturbance resulting from the improper use of the bulldozer may account for the soil compaction [5]; [13]. Soil compaction reduces root penetrability, aeration, infiltration and percolation of water into the soil and crop yield [14]; [15]. The lower bulk density at the forest site may be accounted for by the high earthworm activity implicit in the accumulation of worm casts and by the abundance of surface mat of litter which not only cushioned the soil against raindrop impact, but, through decomposition, enhanced the organic matter content of the soil.

While the above factors which accounted for the low bulk density at the forest site resulted in a significantly higher total porosity, those responsible for increased bulk density or compaction decreased total porosity.

Thus total porosity (Table 1) ranged from 49 to 59 per cent and 43 to 52 per cent at the forest and bulldozed sites respectively. At all depths, porosity was significantly higher at the forest than the bulldozed site. The percentage decrease in porosity due to bulldozer clearing was 11, 12, 17 and 11 at the 0-7.5 cm, 7.5-15cm, 15-22.5cm and 22.5-30cm depths respectively.

Particle-Size Distribution

The results (Table 2) show that bulldozer clearing significantly affected the sand and clay contents at the 0-15 cm and 15-30 cm depths. While the sand content was greater at the forested control than bulldozed site, the latter site recorded a greater clay content. At both sites the sand content decreased with increasing soil depth while the clay increased as a result of downward migration of finer particles from the topsoil. There was however no significant difference in the silt content at both sites. The significant variation in the particle-size distribution altered the texture of the soil from sandy loam at the forested control site to sandy clay loam at the bulldozed site. Under the stable conditions of a forest, the texture of a soil horizon is more or less permanent. However, the texture may change under situations of significant soil disturbance as occurred at the bulldozed site where the forest clearance was accompanied by scraping and mixing of the topsoil with the more clayey subsoil. A similar observation has been reported by [15]. In contrast, [7] and [5] observed no change in soil texture after mechanically clearing forest. It would therefore appear, as concluded by [15], that topsoil removal and the mixing of topsoil and subsoil during land clearing are probably more a function of the bulldozer operator than the clearing method.

TABLE 2: Effect of land clearing by bulldozing on particle-size distribution in the 0-15 and 15-30 cm soil depth

	Sand		Silt		Clay		Texture	
Clearing Method	0-15	15-30	0-15	15-30	0-15	15-30	0-15	15-30
	%							
Forest	74(1.29)	68.50(0.96)	11.50(0.50)	12(0.01)	14.50(1.26)	19.50(0.96)	sl	sl
Bulldozed	67.70(0.29)	58.70(0.87)	10.30(0.17)	10.55(1.07)	22.00(0.46)	30.75(1.84)	scl	scl
LSD (0.05)	3.24	3.16	ns	ns	3.28	3.31		

Standard error is given in parenthesis

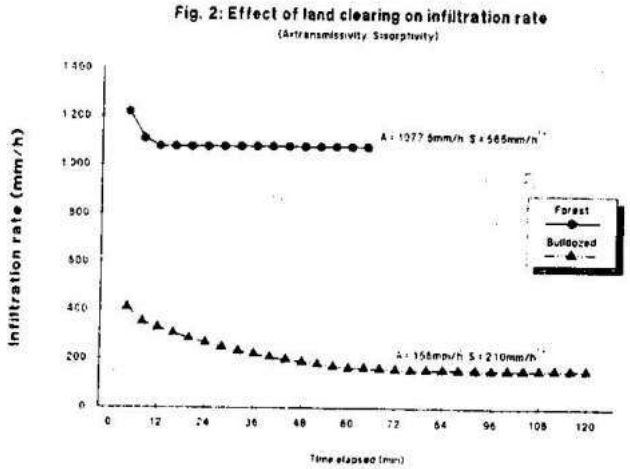
ns Not significant
sl sandy loam
scl sandy clay loam

Training of bulldozer operators in the art of clearing land, particularly those for agricultural purposes, is therefore essential for controlling the adverse changes in soil physical properties.

Infiltration Rate

In order to obtain the steady-state infiltration rate after each sampling point, infiltration rate was plotted against time elapsed (Figure 2). The initial rapid infiltration decreased with time during the water application and tended to approach a constant value at

Fig 2.



about 11 and 80 minutes at the forest and bulldozed sites respectively with the mean infiltration rate (Table 3) being significantly higher at the former site. The low bulk density, the high total porosity and organic matter content, the high earthworm activity and the observed dense mat of roots and litter at the forest floor may account for the higher infiltration rate.

Table 3: Effect of land clearing by bulldozing on infiltration rate (mm h^{-1})

Land clearing method	Infiltration rate mm h^{-1}
Forest	1071.25 (6.25)
Bulldozed	159.00 (3.00)
LSD (0.05)	29.83

The high steady-state infiltration rate at the forested control site was reduced by 85 per cent by the bulldozer clearing. This reduction may be attributed to soil compaction, low organic matter and the apparent loss of earthworm activity at the bulldozed site.

CONCLUSIONS

The results of this study indicate the following:

1. Bulk density was significantly higher at the bulldozed than the forested control site.
2. Under the apparent stable conditions of a forest, bulk density tends to increase with increasing depth.
3. Soil compaction at the bulldozed site penetrated to a depth of 30 cm with the major compactive effect of bulldozer clearing felt at 15-22cm depth.
4. Total porosity was significantly higher at the forested control than the bulldozed site.
5. Bulldozer clearing significantly affected particle-size distribution and changed the texture of the soil from sandy loam at the forested control site to sandy clay loam at the bulldozed site.
6. The scraping of topsoil and the heaping and mixing of topsoil and subsoil appear to be more a function of the bulldozer operator than the method of land clearing. The need to train operators in the proper use of land clearing machines is a prerequisite for reducing the degradation of soil physical properties.
7. The mean steady-state infiltration rate was significantly higher at the forest site than the bulldozed site. Bulldozer clearing reduced the mean infiltration rate by 85 per cent.
8. Bulldozer clearing degraded soil physical properties.

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