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Changes in the Characteristics of a Degraded Paleustult Under Fallow in Southwestern-Nigeria

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ABSTRACT A paleustult in SW-Nigeria was continuously cultivated for about 15 years and this resulted in physical and chemical degradation of the soil. The potentials of two shrub species: *Leucaena leucocephala* and *Gliricidia sepium;* a herb: *Chromolaena odoratum* and a grass: *Panicum maximum*, in the regeneration of the soils' physical and chemical properties' were assessed. Results showed that the ultisol under C. *odoratum* and P. *maximum* has significantly lower ($p < 0.05$) gravel content (5.5%), and higher clay content (21.5%) than in other plots. Similarly, the erodibility indices for the soils under *C. odoratum* and *P. maximum* were significantly lower ($P < 0.05$) than in other plots. Total porosity was significantly lower ($P < 0.05$) in the soils that were continuously cultivated than those under fallow. *L. leucocephala* significantly increased the organic matter, available-P, exchangeable Ca & K content of the soil than other plant species. Next in potential to improve the physical and chemical properties of the degraded soil is *Gliricidia sepium* while the grass fallow appeared to be the least effective. It is suggested that to improve the physical and chemical properties of the degraded soils and reduce the length of fallow period in the region, *L. leucocephala, G. sepium* and *C.odoratum* could be cultivated as fallow species instead of the usual bush fallow system. The result will be significant reduction in the length of fallow period, more intensive and productive landuse, increase in crop yield and this will translate into increased income to farmers and at the same time ensure sustainable environment.

INTRODUCTION

Soil degradation is a process that lowers the current and/or potential capability of soil to produce goods or services. The process causes a decrease in the quality of soils, and in the context of small-scale farmers, the primary soil degradative process is physical degradation

(Lal, 1977; Moorman and Greenland, 1980). Research on West African soils suggests that a physically degraded agricultural soil has significant reduction in both the transmission (>30/µm) and retention (4-30/µm) pores (Mensah-Bonsu and Lal, 1982; Hulugalle et al., 1984; Hulugalle, 1988a) i.e. an evidence of compaction. In addition, high values of bulk density and soil temperature, and low values of infiltration rate, total porosity and soil water retention are also indicative of soil compaction. Soil compaction is partly caused by raindrop impact on exposed soils (Kowal and Kassam, 1977; Lal, 1987) and by human, animal and mechanical traffic (Sabel-Koschella, 1987). Rainfall impact also results in breakdown of surface soil aggregates leading to the formation of surface seals. Soil compaction and surface seals both reduce infiltration rate, which in turn increases water-runoff and soil erosion during the high intensity rainstorms characteristic of this region (Jones and Wild, 1975; Lal, 1987; Sabel-Koschella, 1987). Water runoff and erosion may also be increased through saturated overland flow due to decreases in total porosity brought about by soil compaction (Lal, 1987). In general, physical degradation results in increases in soil temperature and soil erosion, both of which in turn results in rapid decreases in organic matter and nutrients (Lal, 1976, 1977; Wilson et al., 1982; Juo and Lal, 1977). Lal (1976) noted that organic carbon losses under cropping in eroded sediments ranged from 20 to 800 kgha^{-1}, and similar losses were also reported for exchangeable Ca, Mg, K, N and P. Associated with nutrient and organic C losses are decreases in soil pH and increases in exchangeable Mn, and closely associated with the changes in soil physical and chemical properties are decreases in populations of beneficial macrofauna (e.g worms) and microflora (e.g. actinomycetes) and increases in population of harmful soil fauna (Caveness, 1984; Cassel and Lal, 1992). Chemi-cally and biologically degraded soils are therefore characterised by low levels of soil organic matter, exchangeable basic cations (Ca, Mg, K), effective CEC, pH, N, P, beneficial microfauna and

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macrofauna, and high levels of total acidity (Al + H) and exchangeable Mn. The focus of this study however is restricted to physical and chemical changes in a paleustult following the establishment of multipurpose shrubs and a grass as fallow species. This is because Pieri (1992) reported that short-term fallow without appropriate measure of improving soil fertility could not regenerate soils exhausted by intensive cropping. Consequently, it is important to embark upon planting of fallow crop which has the capability of raising soil organic matter and thus soil fertility. The use of such crops is now encouraged in crop production. Proper management of fallow crops improves physical and chemical properties of soil, suppresses obnoxious weed plants, reduces erosion and sustains crop yields at reasonable extent (Singh, 1974; Okigbo and Lal, 1977). The initial purpose of establishing the shrub species, *Leucaena leucocephala* and *Gliricidia sepium*, was to serve as source of feed to the then confined experimental sheep and goat project, while the lack of sufficient facilities led to the abandonment of the land area previously grown to maize and cassava for upward of 15years. Shortly after going into fallow, different portions of the land were overgrown with *Chromolaena odoratum* and the grass *Panicum maximum*. Therefore, about three years into the fallow period, physical and chemical properties of the soil under different vegetation cover were assessed with a view to understanding the potentials of the different plant species in bringing about desirable changes in the physical and chemical properties of the soil. Adjacent land area still being cultivated was also investigated to determine the current physical and chemical status of the soil.

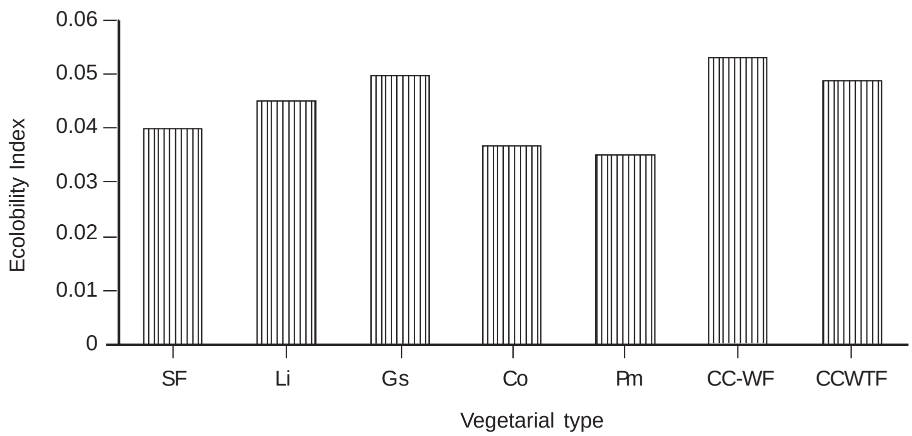
MATERIALS AND METHODS

The study was conducted at the Teaching and Research Farm (T&R-F) of Obafemi Awolowo University (O. A. U), Ile-Ife. Ile-Ife is geographically located on latitude 7^0 23' N and longitude 4^0 37' E. The rainfall pattern is bimodal with peaks in July and September/October, and annual precipitation is between 1200mm and 1500mm with over 1800mm in some very rainy years. Daily temperatures do not fluctuate considerably with a maximum of between 27^0C and 35^0C, and a minimum of between 18.9^0C and 23.3^0C. The area lies within the basement complex and the underlying rock consists of granites, gneisses, and undifferentiated schists (Smyth and Montgomery, 1962). Soils of the study area were mapped and grouped as Iwo Association (Symth and Montgomery, 1962), and classified as ferruginous tropical soils

(D' Hoore, 1964), Tropudalf (Ojanuga, 1975) and as Paleustult (Okusami and Oyediran, 1985). The plots containing all the fallow plant species were established on soils classified as Iwo series (Paleustult) and lie within the same physiographic position (mid-slope), in the Animal Science section of the T&R-F. Similar soils under secondary forest were located within the Soil Science section of the T&R-F. Composite 0-15cm soil samples were collected and thoroughly homogenised before subsampling for laboratory analysis. Composite soil samples taken from each plot (different land use type) were replicated four times, thus 28 composite soil samples were collected. Bulk density was determined by the core method as detailed in soil survey laboratory methods manual (USDA/NRCS/NSSC, 1996) while total porosity was estimated by the method of Vomocil (1965). The soil samples meant for laboratory analysis were air-dried, gently crushed and passed through a 2-mm sieve. The fine earth fraction (less than 2-mm) was retained for analysis. The pH, organic matter and particle size distribution were determined following the procedure in soil survey laboratory methods manual (USDA/NRCS/NSSC, 1996). Erodibility indices were computed using the static laboratory test method, as contained in Aneke (1991). Available-P, exchangeable Ca, K, and A1 were determined using the procedure in methods for soil and plant analysis (IITA, 1979). The data were subjected to analysis of variance and the test of significance of the means was by the Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

The physical properties of the soils under different fallow plant species, secondary forest and continuous cultivation are presented in Table 1. Soils under the secondary forest (SF), *P. maximum* and *C. odoratum* have significantly lower gravel content of 5.5%, 6.0% and 5.5% respectively, than those under *L. leucocephala* (23.5%), continuously cultivated with (16.5%) or without (19.5%) fertilizer application. In the same vein, the percentage clay content is highest in soils under *C. odoratum*, and *P. maximum* (21.5% each) and followed by the secondary forest (19.5%). Generally, continuously cultivated soils have the least clay contents. Aina (1979) similarly reported that cultivated soils have more sand and less silt and clay in the top 15cm compared to those under fallow. Further supporting the particle size distribution data are the erodibility indices. The indices for soils under *C. odoratum* and *P. maximum* were significantly lower (P≤ 0.05) than those of secondary forest (Fig. 1). Apparently, *C. odoratum* because of its aggressive growth nature produces sufficient ground cover to prevent removal of clay particles by erosion, while the binding influence of *P. maximum* roots on soil is considered to be responsible for the ability of the grass to effectively check erosion. *Chromoleana odoratum* is said to be very aggressive and that it could take up a whole land within 2 or 3 years (Adediran et al., 2003). *P.maximum* and *C. odoratum* were reported to perform well in highly degraded soils of low pH (Lal et al., 1979; Juo and Lal, 1977) while *L. leucocephala* and *G. sepium* were observed to perform best as hedgerow species for alley farming (Kang et al., 1981) on a highly eroded low fertility Alfisol. Information about their performance when used as fallow species is not readily available. However, from this pilot study, *P. maximum* and *C. odoratum* performed significantly better in checking soil erosion than *L. leucocephala* and *G. sepium* on the degraded Paleustult. The two species (*P. maximum* and *C. odoratum*) appeared to be superior in their ability to check erosion within 2 to 3 years of their establishment than secondary forest of several



(SF = Secondary Forest; Li = *L. leucophaea*; Gs = *G. sepium*; Co = *C. odoratum*; Pm = *P. maximum*; CC-WF = Continuous cultivation with fertilizer application; and CC-WTF = continuous cultivation without fertilizer application)

Fig. 1. Soil erodibility index under different vegetation

Table 1: Soil physical properties under the different land-use types

Landuse type	*Soil parameter*					
	Gravel	*Sand*	*Silt*	*Clay*	*B. density*	*T. porosity*
	(%)				*(g/cc)*	*(%)*
Secondary forest	5.5[e]	68.5[c]	12.0[a]	19.5[b]	1.24[d]	53.3[d]
L. leucocephala	23.5[a]	73.5[b]	8.0[b]	18.5[c]	0.94[f]	64.5[a]
G. sepium	7.0[d]	76.5[a]	6.5[c]	17.0[d]	1.14[e]	56.0[c]
C. odoratum	5.5[e]	74.0[b]	4.5[d]	21.5[a]	1.15[e]	52.5[d]
P. maximum	6.0[e]	66.0[d]	12.5[a]	21.5[a]	1.29[c]	60.0[b]
CC – WF	16.5[c]	77.0[a]	6.5[c]	16.5[d]	1.56[b]	42.7[e]
CC - WTF	19.5[b]	74.5[b]	8.5[b]	17.0[d]	1.58[a]	40.8[f]

Means in the same column followed by the same alphabet are not statistically different at 0.05 level of significance.
CC-WF = Continuous cultivation with fertilizer application
CC-WTF = Continuous cultivation without fertilizer application

years standing (Fig. 1). Total porosity was significantly lower in soils that are continuously cultivated than those under fallow. This observation was further strengthened by the significantly higher (P>0.05) bulk density (1.56 - 1.58 g/cc) of the continuously cultivated compared to soils under fallow (0.94 – 1.29 g/cc). Bulk density of 1.5 - 1.6 g/cc is considered a severe limitation to sustainable use of light-textured soils (Lal, 1994) such as Iwo series under study.

Chemical properties of the soils under the different land - use types are presented in Table 2. *G. sepium* and *P. maximum* significantly increased the soil pH over secondary forest, *L. leucocephala* and *C. odoratum*. The lowest soil pH and highest exchangeable – Al were observed in soils under continuous cultivation without fertilizer application. Soils under the secondary forest have organic matter (OM) that is significantly higher than in all other soils. Next in potential to enrich the soils with OM is *C. odoratum*, while continuous cultivation without fertilizer application resulted in the return of very little OM to the soils. Although significantly lower OM were added to soils under *L. leucocephala* when compared to Secondary Forest, nevertheless, the available-P content in soils (25.55 ppm) under the former, *L. leucocephala*, was significantly higher than in the latter (24.45 ppm), Secondary Forest. The ability of *L. leucocephala* to enrich the soils with avail-P, exchangeable Ca and K was superior to that of the secondary forest and other plant species. Although *C. odoratum* was observed to be effective in erosion control, its contributions to increase soil pH, and improve the soil avail-P and exchangeable Ca & K were significantly lower than those of *L. leucocephala* and *G. sepium*. Similarly *P. maximum's* ability for soil chemical properties' regeneration was signi-ficantly lower than for the two shrubs and the herbaceous species evaluated.

Socio-economic Impact of the Study on Man

From this study, it was observed that rather than the usual practice of bush fallow, *L. leucocephala*, *G. sepium* and *C. odoratum* could be cultivated as fallow species. This will accelerate the rate of soil physical and chemical properties' regeneration and thereby shorten the length of fallow period. Adediran et al. (2003) similarly reported that Siam weed (i.e. *C. odoratum)* played a positive role in shortening period of traditional fallow system and improved soil physical and chemical properties. If the period of fallow is significantly shortened, this will enhance more intensive, better and greater utilization of the limited soil resources available. Tenant farmers living on leased agricultural lands will tend to begin to settle for longer period in an area and this will give more opportunities for their children to attend schools and or learn a trade wherever they settle. Thus a better, more sustainable and prosperous future can be achieved by the peasant farmers and their families that constitute more than 70% of Nigerians. Further more, once the farmers' continuous search for farmland is reduced, they will be more willing to adopt technological innovations introduced to them by the agricultural extension agents, and these in turn, will most likely lead to better soil management and conservation by the farmers

Table 2: Soil chemical properties under the different land-use types.

Landuse type	*Soil chemical properties*					
	pH	*O.M. (%)*	*Avail-P (ppm)*	*Exchangeable*		
				Ca	*K (Cmol kg^{-1})*	*Al*
Secondary forest	5.6^{b}	3.06^{a}	24.45^{b}	8.7^{c}	1.10^{c}	0.20^{e}
L. leucocephala	5.6^{b}	2.37^{c}	25.55^{a}	9.15^{a}	1.30^{a}	0.20^{e}
G. sepium	5.7^{a}	1.41^{f}	24.55^{b}	8.83^{b}	1.22^{b}	0.18^{f}
C. odoratum	5.3^{c}	2.43^{b}	8.45^{c}	7.63^{d}	0.30^{e}	0.40^{c}
P. maximum	5.7^{a}	1.57^{e}	8.25^{c}	3.50^{e}	0.40^{d}	0.30^{d}
CC - WF	5.2^{d}	2.09^{d}	24.45^{b}	1.80^{f}	0.18^{f}	1.80^{b}
CC - WTF	5.0^{e}	1.03^{g}	6.0^{d}	1.50^{g}	0.09^{g}	2.50^{a}

Means in the same column followed by the same alphabet are not statistically different at 0.05 level of significance.
CC-WF = Continuous cultivation with fertilizer application
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themselves. The result will be significant increase in crop yield and this will translate into increased income to farmers and at the same time ensure sustainable environment.

SUMMARY AND CONCLUSION

A paleustult in SW-Nigeria was continuously cultivated for about 15 years and this resulted in physical and chemical degradation of the soil. The potentials of two shrub species, *Leucaena leucocephala* and *Gliricidia sepium;* a herb, *Chromolaena odoratum* and a grass, *Panicum maximum*, in the regeneration of the soil's physical and chemical properties were assessed. Results showed that the ultisol under C. *odoratum* and P. *maximum* has significantly lower ($p < 0.05$) gravel content (5.5%), and higher clay content (21.5%) than in other plots. Similarly, the erodibility indices for the soils under *C. odoratum* and *P. maximum* were significantly lower ($P < 0.05$) than in other plots. Total porosity was significantly lower

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