Restorative Capacity of *Tectona Grandis* and *Gmelina Arborea* on Degraded Soil

***[1]Popoola, Olateju Ebenezer and Mgbonu, Kelechi**

Department of Agricultural Education, Federal College of Education, Kontagora, Niger State.

**Corresponding author:* olatejueb@gmail.com

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Abstract

Tectona grandis and *Gmelina arborea,* as fast growing agro forestry species were used to restore the quality of a deliberately degraded Utisol at Onne. The soil was deliberately degraded by bulldozing the vegetation and the surface soil was scrapped off. Properties of the soil were evaluated before and twenty-two years after the establishment of *Tectona grandis* and *Gmelina arborea* fallows. *Tectona grandis* had a cumulative restorative capacity of 4953.60 kg soil materials on one hectare of land in one year with 3343, 60, 5.20, 1336, 200 and 9.4 kg as organic matter, N, P, Ca, Mg and K respectively, whereas *Gmelina arborea* had cumulative restorative capacity of 2830.65kg soil materials / ha/ yr with 1570, 30.1, 1.95, 1071, 147 and 10.6 kg as organic matter N, P, Ca, Mg and K respectively. The relatively better effect of *Tectona grandis* over *Gmelina arborea* was attributed to the slow decomposition of its lower quality litter which resulted to production of more stable organic matter in the long run. The use of the species for soil fertility restoration increased maize yield with *Tectona* having maize grain yield of 17.8% over that of *Gmelina* and 27.8% over natural fallow.

Keywords: Agro-Forestry Species, Restorative Capacity, Soil Quality, Ultisol

Introduction

The extent at which soils degrade depends on the soil quality which is defined as the capacity of a soil to function within land use and ecosystems boundaries, to sustain biological productivity, maintain environmental quality and promote plants, animals and human health (Doran and Parkin, 1994; 1996). Soil degradation is often associated with human activities in using the soil but not adopting any means of ensuring its sustainability and abandoning such for another goldmine (Beets, 1989). The use of any soil for agriculture has often showed a decline in the fertility of the soil. Soil losses from cropped land in Nigeria exceed the soil loss tolerance values beyond which sustainable crop productivity cannot be maintained (Lal, 1986).

The adverse environmental conditions in the tropics usually result in high rate of decomposition of soil organic matter and limit soil micro-faunal and microbial activities (Lal, 1987). The importance of soil organic matter in relation to sustainable agriculture cannot be over emphasized. Sustaining soil organic matter is stressed as the only solution to sustainable crop production in the tropics (Mulongoy and Merckx, 1993). Traditionally, soil organic matter and fertility have been restored by bush fallowing. This method of restoration is no longer sustainable however, it is important that some alternative means of restoring soil quality and productivity be adopted in our agricultural practices.

Akobundu (1984) stated that fallowing to replenish soil nutrients is necessary for sustained crop yield in the tropics. The interdependence of forestry and agriculture has today been acknowledged as the ecological basis for food production in the tropics (UNESCO, 1978). Netting (1993) therefore suggested the use of legumes and agro-forestry species as fallow intensive techniques to reproduce soil fertility and conserve natural resources. Thus, this research was carried out to determine the restorative capacity of *Tectona grandis* and *Gmelina arborea* on soil quality of a degraded Ultisol by evaluating the dynamics in the physico-chemical properties of the soil and examining the litter yield under the different fallows.

Materials and Methods

Description of Experimental Site

The research was carried out in the Rivers Institute of Agricultural Research and Training (RIART) at Onne, south-eastern Nigeria which lies between longitudes $4^0$and 5^0N, and latitudes $7^0$and 8^0E. The climate at Onne is characteristic of the humid tropics with high rainfall of annual mean of 2400mm and high temperatures all year round with small diurnal and annual ranges. Notably, there is no month without rainfall. The vegetation is the rainforest type that has been altered by man’s activities. The soils are the ‘acid sands’ Ultisol with the characteristic poor chemical properties and classified as loamy, siliceous, isohyperthermic, Typic Paleuldult (Hulugalle *et al*., 1989).

Research Procedure

The natural vegetation at the site was bulldozed and the surface soil scraped, leaving the soil as a deliberately degraded one. Then, soil samples were randomly collected from the 0-15 cm depth, bulked and used for the determination of some soil chemical properties (Ikpe *et al*., 2007). Then, planted fallows of *Tectona grandis* and *Gmelina arborea* were established at spacing of 100 cm along hedgerows and 150 cm between hedgerows. By September, 2017 (that is, twenty-two years after the establishment of the fallows), soil samples were similarly collected from the fallows and used for the determination of soil physico-chemical properties. Eventually, the fallows were cleared and use for maize production and soil physio-chemical properties determined afterward.

Litter yield associated with the fallows were determined before the fallows were cleared for maize production. This was done by the 'quadrat method' in which a 1x1 m quadrat was marked out in the fallows and the entire vegetative parts (including decomposing and fresh litters, twigs and branches) of the plant species within the quadrat were collected, dried in the oven for 48 hrs at 60^0C and weighed. Four of such measurements were taken for each fallow type and an average value was calculated. Also, the total Nitrogen (N) and organic Carbon (C) content in the litter were determined, and these were used to evaluate the litter quality of fallow species.

Analytical Methods for Soil Physicochemical Properties

The Organic matter content of the soil was evaluated by determining the soil organic C using the wet oxidation method of Walkley and Black (1934) and multiplying the value by a factor of 1.724. The total N content of the soil was evaluated by employing the micro-Kjeldahl technique as modified by Jones (2001). In the determination of available P, the Bray P 1 extraction method was employed (Bray and Kurtz, 1945a). The exchangeable bases were extracted by the neutral normal ammonium acetate extraction method and the contents of Na and K were determined with the flame photometer whereas Ca and Mg contents were determined by EDTA titration. The soil pH was determined electrometrically with a pH meter.

Plant Tissues Analytical Methods

Total N content in plant tissues was determined by a modified method of the Kjeldahl technique (duPreez and Bale, 1989) while the determination of the organic C content in plant tissues employed the wet oxidation techniques modification of Anderson and Henderson (1986).

Determination of the Restoration Capacity of the Species

The restorative capacity of the species was evaluated by determining the difference in the values of the parameters at establishment of the fallow and after twenty-two years when the research was carried out. The value obtained for each parameter is the contribution of the species for the period of 22 years during the fallowing.Then, with the understanding that a furrow sliced – one hectare of land contains 6.625 x 10^6kg soil materials, the amount of each parameter added for the 22years can be determined.

Parameters Expressed in Percentages

For *Tectona grandis* which contributed (2.97 – 1.86) % organic matter to one hectare in 22 years. This will be equivalent to:

$= \frac{1.11}{100}$ X 6.626 X 10^6 kg organic matter to one hectare in 22 years

= 7.354 x 10^4kg organic matter to one hectare in 22 years

= 0.3343 x 10^4kg organic matter per hectare per year

= 3343kg organic matter per hectare per year

Again, *Tectona* contributed (0.07 – 0.05) % nitrogen to one hectare in 22 years. This is equivalent to:

$= \frac{0.02}{100}$ X 6.626 X 10^6 kg N to one hectare in 22 years

= 1.325 x 10^3kg N to one hectare in 22 years

= 0.0602 x 10^3kg N per hectare in per year

= 60.2 N per hectare per year

Similar calculations were done for the organic matter and the total N contents for *Gmelina arborea*

Parameters Expressed in mgkg^{-1} and cmolkg^{-1}

Available P

(31.00 – 13.75) mgkg^{-1} was contributed by *Tectona* in 22 years

= 17.25mgkg^{-1}P in 22 years

$= 17.25 \times 10^{-3}$ gkg^{-1}P in 22 years

$= 17.25 \times 10^{-6}$ $kgkg^{-1}$P in 22 years

= 17.25 x 6.625kg P per hectare in 22 years

= 114.282kgP per hectare in 22 years

= 5.20kgP per hectare per year

Exchangeable Ca

(11.44 – 0.35) $cmolkg^{-1}$ Ca was contributed by *Tectona* in 22 years

= 11.09$cmolkg^{-1}$Ca in 22 years

$=\frac{11.09}{100}$ X 40 gkg^{-1}Ca in 22 years – (molar mass of Ca = 40$gmol^{-1}$)

$= 0.4436 \times 10^{-3}$ $kgkg^{-1}$Ca in 22 years

$= 0.4436 \times 10^{-3} \times 6.625 \times 10^{6}$kg Ca per hectare in 22 years

$= 29.389 \times 10^{3}$kg Ca per hectare in 22 years

= 29389kg Ca per hectare in 22 years

= 1336kg Ca per hectare per year

Similar calculations were done for the other parameters expressed in $cmolkg^{-1}$ using the molar mass of the elements and for *Gmelina arborea.*

The cumulative restorative capacity of each species was calculated by summing up the contributions in the various forms (organic matter, total N, P, Ca, Mg and K).

Results and Discussion

Litter yield and litter quality

Tectona grandis had a higher litter yield than *Gmelina arborea*. In the *Tectona* fallow, a litter yield of 4.82 tha^{-1} was recorded, the *Gmelina* fallow had a litter yield of 1.89 tha^{-1} (Table 1). The C:N ratios of the litter of the species suggest that *Gmelina arborea* litter was of a higher quality because the C:N ratio of the litter was lower. Higher quality of the litter of *Gmelina arborea* over other agro-forestry species such as *Macaranga grandis* and

Inga edulis had been reported by Ikpe (2003), adding that the *Gmelina arborea* litter decomposed faster and releasing nitrogen to the soil.

The higher quality of the litter from the *Gmelina* fallow allowed for the fast decomposition of the litter by microbes. And this would have led to the lower litter deposit under the *Gmelina* fallow in the long run.

Table 1 Litter yield, C, N contents and C:N ratio of the litter under the fallows

Fallow Type	Litter Yield tha^{-1}	C, %	N, %	C: N Ratio
Tectona grandis	4.82	44.65	1.82	24.53
Gmelina arborea	1.89	27.07	1.61	16.81

Soil physico-chemical properties of the site

Table2 shows the properties of the site after deliberate degradation by bulldozing and at twenty-two years under restoration by the agro-forestry species. Allowing the fallows for this long period gave room to the establishment of a climax vegetation of the species which must have contributed to the restoration of the soil at varying rates during various ages and stages in the life cycle of the fallow species. It is therefore believed that the estimates of the restoration capacity of the species are, approximately, average values of the long run effect of the fallow species.

From Table 2, it is obvious that the properties of the soil were tremendously improved by the agro-forestry species from a degraded status. The increases were between 20 and 3900 % for the various soil properties with *Tectona grandis* fallow having a relatively better effect on the properties, possibly, due to higher resistance of its lower quality litter to microbial decomposition. It is inferentially supposed that the faster decomposition of the higher quality litter of the *Gmelina arborea* fallow would have resulted in the ease of deterioration of the soil organic matter contributed by it, which is considered as primary to the assessment of sustainability of soil system (Swift and Woomer, 1993) and described as the nerve centre of soil fertility sustenance in Nigeria as well as similar tropical environments. This could have led to the lower soil organic matter under the *Gmelina* fallow than under the *Tectona* fallow.

Table 2 Soil physico-chemical properties of the site during the experiment

	Org. mat %	Total N %	Ava. P $mgkg^{-1}$	Exchangeable Bases ($cmol\ kg^{-1}$) Ca	Mg	K	pH (H_2O)	BD gcm^{-1}
	At Establishment of Fallows							
Initial	1.86	0.05	13.75	0.35	0.07	0.06	4.57	
	Under Fallow Species for 22 Years							
Tect. Gran.	2.97	0.07	31.00	11.44	2.80	0.14	6.30	1.31
Gmel. Arbo.	2.38	0.06	20.22	9.24	2.10	0.15	6.70	1.33
	At Maize Harvest							
Tect. Gran.	2.97	0.05	40.7	11.79	2.95	0.22	6.80	
Gmel. Arbo.	2.20	0.06	22.3	12.72	2.89	0.23	6.70	

BD: Bulk Density

Restorative capacity of the agro-forestry species on soil quality

The agro-forestry species (*Tectona grandis* and *Gmelina arborea*) improved the quality of the degraded soil. *Tectona grandis* restorative capacity was estimated at 3343 kg organic matter, 60 kg N, 5.20 kg P, 1336 kg Ca, 200 kg Mg and 9.4 kg K/ha/yr whereas *Gmelina arborea* restorative capacity was estimated at 1570 kg organic matter/ ha/yr, 30.1 kg N, 195 kg P, 1071 kg Ca, 147 kg Mg and 10.6kg K/ha/yr. Thus, the cumulative restorative capacity of the species on the degraded soil was 4953.60 and 2830.65 kg / ha/ yr for *Tectona grandis* and *Gmelina arborea* respectively. The implication of this is that 4953.60 and 2683.65 kg of soil materials can be added to one hectare of land in one year by *Tectona* and *Gmelina* respectively.

Therefore, *Tectona grandis* had a relatively higher restorative capacity on soil quality than *Gmelina arborea*. This could be attributed to the litter quality of the species. Since *Gmelina* litter has higher quality and decomposed faster, the resulting organic matter is likely to deteriorate faster in the long run and lower organic matter content under the *Gmelina* fallow was maintained. This deterioration was accompanied with lower concentration of the soil nutrients whereas in the *Tectona* fallow, the accumulation of stable organic matter in the long run helped in retaining the soil nutrients and making the soil under it better restored than the soil under the *Gmelina* fallow.

Performance of the system for maize production

Grain yield of maize which is the common reason for maize production in the area was enhanced, recording 2.41 and 1.98 tha^{-1} for *Tectona* and *Gmelina* respectively against values of 1.32 and 1.65 tha^{-1} reported by Gbaraneh *et al*. (2006) for maize that did not receive manure and maize that was manured respectively during comparable growing season at Onne. Also, the soil quality did not deteriorate much after using the fallows for maize production (Table 2). Thus, the system was adjudged sustainable in accordance with Driessen (2007) assertion that a land use system is biophysically sustainable if the compounded sufficiency of relevant land attributes does not deteriorate under the applied land use.

Conclusion

The research evaluated the restorative capacity (that is, the amount of soil components added) of *Tectona grandis* and *Gmelina arborea* on soil quality of a degraded Utilisol at Onne. *Tectona grandis* could have added a cumulative of 4953.60 kg soil materials to one hectare of land in one year with 3343, 60, 5.20, 1336, 200 and 9.4kg as organic matter, nitrogen, phosphorus, calcium, magnesium and potassium respectively whereas *Gmelina arborea* added a cumulative of 2830.65kg soil materials to one hectare of land in one year with 1570, 30.1, 1.95, 1071, 147 and 10.6 kg as organic matter, nitrogen, phosphorus, calcium, magnesium and potassium respectively. The use of the fallow for maize production showed increase maize grain yield without deteriorative effect on soil quality. However, diverse mechanisms/factors at play may contribute to observed effects on soil composition. Thus, *Tectona grandis* and *Gmelina arborea* have the capacity of restoring soil quality of degraded Ultisol, in particular and soils in general.

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