Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture

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An analysis of vegetation as a resource in south-eastern Nigeria

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Summary

A long-term study was initiated in 1988 in two fallow systems: a planted *Dactyladenia* (*Acioa*) *barteri* system at Mbaise and a natural bush fallow at Umuahia in south-eastern Nigeria. The planted fallow systems consisted of rows of *D. barteri* spaced 2 m apart and lengths of fallow periods ranged from 1 to 3 years. The natural bush fallow periods ranged from 1 to 5 years old. Analysis of the natural bush fallow showed that *Dactyladenia barteri*, *Anthonotha macrophylla* and *Dialium guineense* dominated the vegetation. Stems with a girth of over 20 cm contributed most to the stem basal area in the natural bush fallow in all fallow periods. In the planted fallow, a stem basal area of 20 m^2/ha was observed only in the 3-year-old fallow. Girth class distribution in the planted *D. barteri* field after the second year of fallow was more uniform than in the natural fallow, indicating less interference with the vegetation in the former. For the same fallow length, the amount of litter produced and the nutrient composition, were identical in the two systems. Soil analysis showed that pH, soil organic carbon, total nitrogen and extractable phosphorus tended to increase with fallow length in the natural fallow. Organic C and total N content in the soil under planted fallow did not change, but extractable P increased with fallow length. The authors concluded that the two fallow systems are potential means of restoring soil fertility through litterfall and pruning application.

Natural bush is a storehouse of abundant and readily available resources for crop production. Vegetation management is an important component of farming practices for sustained crop production in the humid and sub-humid tropics. Where there is no pressure on arable land, farmers in tropical Africa have practised shifting cultivation, with long fallow periods and crop rotation. These practices improve soil structure, return organic matter to the soil and restore soil fertility (Greenland, 1975; Lal, 1987). However, the population growth in some areas of the humid rainforest ecologies of West Africa has resulted in a reduction in the length of the fallow period, to the extent that the soil restoration advantages of the bush fallow system have been almost totally lost (Uzozie, 1971). For example, in Mbaise in south-eastern Nigeria the shortage of arable land as a result of population pressures has reduced the fallow period from 10 to 3 years.

Yield decline and growing weed pressure are common in parts of the tropics where bush fallow periods been reduced. Peasant farmers faced with the prospect of shorter fallow periods in Mbaise have, for many decades, practised a traditional alley cropping system using *Dactyladenia (Acioa) barteri* as the hedgerow species. An important economic aspect of this system is that the stems of *Dactyladenia barteri* are used for staking yam (*Dialium* sp.), a major food crop in the region. At Umuahia, also in south-eastern Nigeria, *Dactyladenia barteri*, *Anthonotha macrophylla* and *Dialium guineense* are selectively protected duing land clearing. In this system and in the more common bush fallow systems, improvement in soil physical, chemical and biological characteristics can be realised through the supply of adequate amounts of organic matter to the surface soil as mulch. Little is nown about the resource profile of these fallow systems, the extent of their contribution to soil improvement and the processes involved in the regeneration or degradation of resources in these systems.

The objective of the study reported here was to characterize the two fallow systems and to assess their potential contribution to soil improvement.

MATERIALS AND METHODS

Site selection and vegetation analysis

Two sites were selected in the humid forest region of south-eastern Nigeria: a planted *Dactyladenia barteri* fallow system at Mbaise (7°03'E, 05°32'N) and a natural bush fallow system at Umuahia (7°03'E, 05°29'N). In Mbaise, each of the four participating farmers had planted *Dactyladenia barteri* fields with fallow lengths ranging from 1 to 3 years; in Umuahia, the four participating farmers each had five fields, with fallow periods ranging from 1 to 5 years.

An analysis of the vegetation was carried out during the dry season (December) before bush clearing. Using 3 x 3 m quadrats along selected transect points as sample units, all woody species were identified and recorded. Records were also made of the number of woody stumps and their basal diameter, the number of stems per stump, the girth of each stem at the base, and the height of the vegetation at the sampling point. Canopy cover was assessed directly under the stump and expressed as a percentage of the samples taken. Herbaceous plants were assessed in 1 x 1 m quadrats within each transect.

Litter production and nutrient composition

Studies on litter production were restricted to three species, *Dactyladenia barteri*, *A. macrophylla* and *Dialium guineense*. In each farm, three stumps of each species were randomly selected and tagged. Tagged stumps were then monitored for as long as the bush fallow lasted. Litter was collected once a year (in December) from three randomly selected locations under each tagged stump, using 25 x 50 cm quadrats. The samples were bulked an a subsample was then taken for dyring and analysis.

In Mbaise, where *Dactyladenia barteri* is planted directly in the rows, spaced 2 m apart, litter was collected from the area between the hedgerow using the same number and quadrat size as in Umuahia. In the laboratory the soil was sieved and the litter was then floated in the water to eliminate any remaining soil particles. Floating litter debris was collected and added to the other more bulky litter before drying at 105°C for 12 hours. The dried litter was then ground in a mill and a weighed sample was used for analysis of nitrogen, phosphorus, potassium, calcium and magnesium (IITA, 1979).

Soil analysis

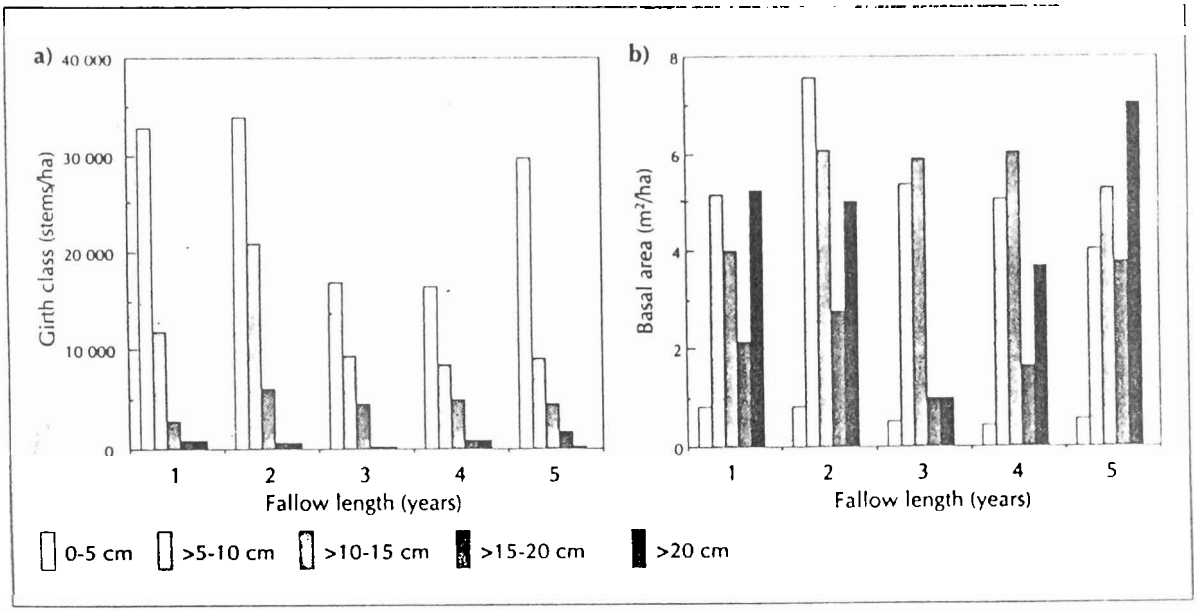
Surface soil from the various systems was collected to a depth of 10 cm (3 cm diameter) on diagonals in the transects used to collect litter. A randomized block design was used, with each farm as a replication and fallow lengths ranging from 1 to 3 (Mbaise) or 5 (Umuahia) years. A soil sample (1 kg) was passed through a 2 mm mesh sieve and fractionated using the method recommended by the Tropical Soil Biology and Fertility Programme (TSBF) (Anderson and Ingram, 1989). The floating materials consisted mainly of plant particles that float in water, the light (0.25-2 mm) fraction (the active fraction, presumed to have a short turnover time of less that 5 years) and the fine fraction (0.15-0.25 mm) which consists mainly of minerals. These fractions were then analysed for organic C using the method described by Amato (1983). The soil samples were also analysed for pH, organic C, total N and extractable Bray-I P (IITA, 1979)

RESULTS AND DISCUSSION

Vegetation analysis

In the natural bush fallow at Umuahia, the most abundant species were *Dactyladenia barteri*, *A. macrophylla* and *Dialium guineense*. These species appeared mainly as regrowths from old stumps randomly disributed on the farms. On most stumps there were several stems. The species featured in all the girth classes throughout the sampled fields and, together, accounted for over 80% of the total stem density in each field. The decline in the number of stems in the 0-5 cm girth class with an increase in fallow length up to 4-year fallow periods was expected (*see* Figure 1) but the sudden increase in the number of 0-5 cm stems in the 5-year fallow suggests

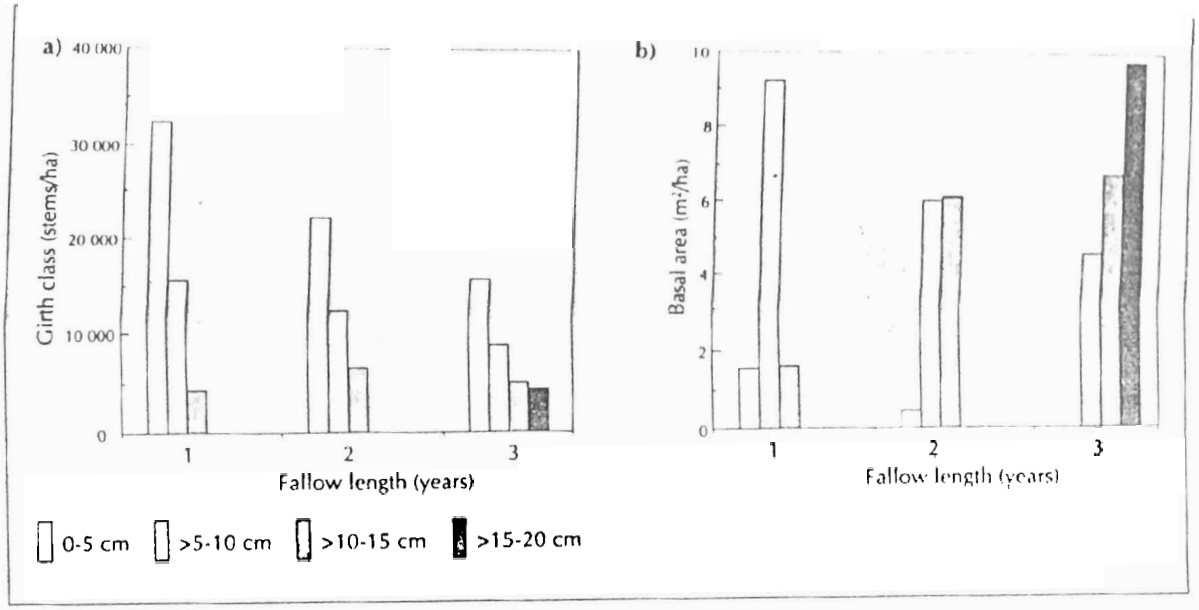
Figure 1 **Effect of length of bush fallow on a) girth class and b) basal area of trees, Umuahia, Abia State, Nigeria**



a return to the juvenile stage). This is an indication of high human activity or greater capacity of the larger stumps at Umuahia to generate new shoots. The extended juvenile state of bush fallow in this area will certainly have an adverse effect on the conservation of the resources needed for crop production. Stems of greater girth decreased in density in the 3-year-old fallow. The reasons for this decrease need futher investigation. For example, if any of the fallow species is of economic value (as firewood, for instance) to the farmer prior to bush clearing, this might explain its selective thinning.

Stems of over 20 cm girth accounted for most of the stem basal area at Umuahia. Girth class distribution at Mbaise after the second year of fallow was more uniform than at Umuahia, indicating less interference with the vegetation (*see* Figure 2). In the 3-year fallow stems with girths of over 5 cm were dominant. The minimal basal area was over 4 m^2/ha. As the fallow matured, stems with a basal area of less than 2 m^2/ha declined sharply.

Figure 2 Effect of length of bush fallow on a) girth class and b) basal area of *Dactyladenia barteri*, Mbaise, Imo State, Nigeria



Litter production

The amount of litter produced by the two systems is given in Figure 3. Although the litter in the bush fallow at Umuahia was from three tree species, the amount from the *Dactyladenia barteri* fallow at Umuahia was higher in the first year of fallow, equal to the other species in the second year (some plants may have been removed for use as staking materials) and higher in the third year. The amount of *Dactyladenia barteri* litter almost doubled between the first and third year. By the third year, the canopy was generally about 70%, to the nearly uniform distribution of litter. The canopy cover and the litterfall play an important role protecting the soil surface from erosion and reducing weed density and weed seed populations in the soil.

The analysis of the litter for content of major nutrients showed that the two systems had similar amounts of litter for each given fallow length (*see* Figure 4).

Figure 3 **Litter dry weight in natural bush fallow and planted fallow**

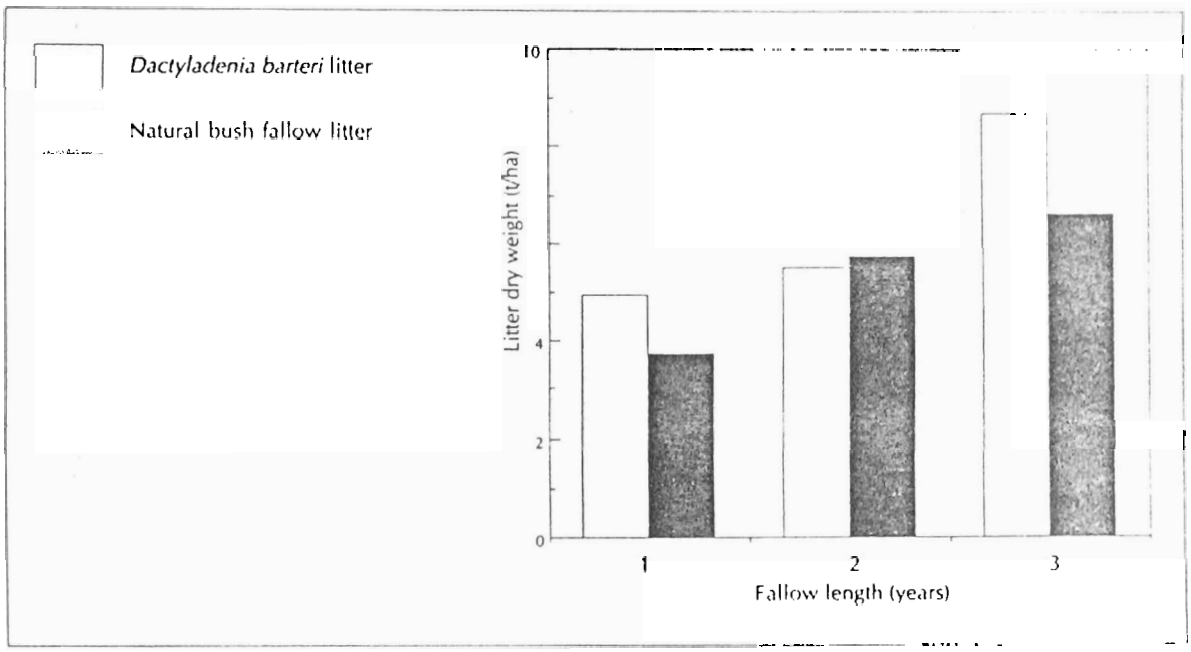
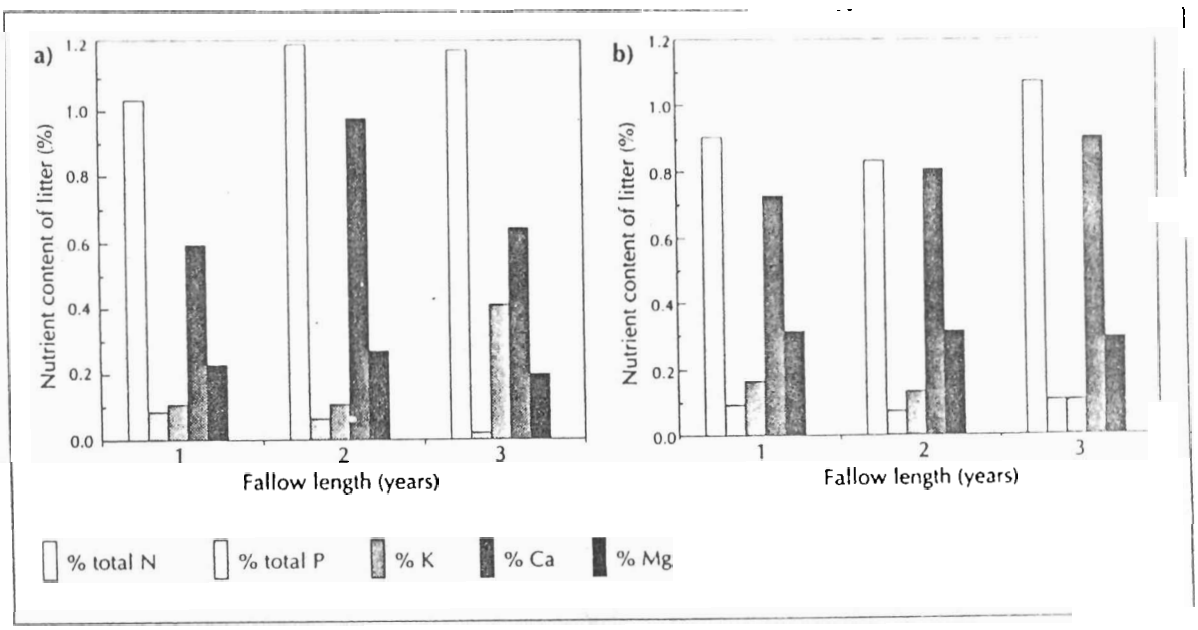


Figure 4 **Percentage nutrient content of litter from a) planted *Dactyladenia barteri* fallow and b) natural bush fallow**



Soil analysis

Data from the soil chemical analysis are presented in Tables 1 and 2. At Mbaise, fallow length did not significantly influence the parameters studied (*see* Table 1). The floating, light and fine materials in the 1-year fallow were equivalent to 1.33, 0.51 and 0.70 g C/kg, respectively. Their respective C content increased by 21, 53 and 51% in the 2- and 3- year fallows. This could be explained partly by the differences in organic input measured as litterfall. *Dactyladenia barteri* contained 67% C (Mulongoy and Gasser unpubl.) and 31% lignin (Mulongoy et al., *see* Paper 1.3 *these proceedings*). Unexpectedly, soil pH and organic C tended to decrease with increased fallow length, although the values were not significantly different. Extractable P content, however, increased by 63% with fallow length. This increase represented an addition of 5.9 kg P/ha and could be explained partly by the amount of litter.

At Umuahia it was possible to compare three farms for 2-, 3- and 4-year fallow lengths (*see* Table 2). The amount of each fraction was not significantly influenced by fallow length. In general, pH, soil organic C, total N and extractable P increased in 4-year fallow plots.

These data show that woody species, either planted or selectively protected, have the potential to restore fertility to the soil within a short span of time. However, food crop growth and yield must be estimated to correlate changes in soil chemical properties with soil fertility.

CONCLUSION

The stems of *Dactyladenia barteri* at Mbaise contributed more to the basal area in 3-year fallows than the stems in fallows of the same length at Umuahia, where bush fallow species are not planted. The high concentration of a single species (*Dactyladenia barteri*) at Mbaise may have been responsible for the greater impact of this fallow species on soil fertility maintenance than that observed in the natural bush fallow system at Umuahia.

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