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EFFECT OF SOME BIOLOGICAL FACTORS ON SOIL VARIABILITY IN THE TROPICS

I. EFFECT OF PRE-CLEARING VEGETATION

by B. T. KANG and F. R. MOORMANN

International Institute of Tropical Agriculture, Ibadan, Nigeria

SUMMARY

Field observations were carried out on an Egbeda soil series in western Nigeria to study the degree of soil-nutrient variability within and between plots due to pre-clearing vegetation. The soil showed lower soil pH, organic C, exchangeable K and Ca contents following cassava grown by traditional methods than following secondary forest vegetation or thicket regrowth. Except for exchangeable K, the degree of variability of the above parameters was observed to be in the following order: secondary forest vegetation > thicket regrowth > cassava plots. The available P status was generally low and showed little relation to pre-clearing vegetation. The implications of soil variability due to pre-clearing vegetation on soil sampling and in field experimentation are discussed.

INTRODUCTION

One of the major problems in conducting field experiments in the tropics, particularly on recently cleared land, is the high degree of soil variability which results in uneven crop growth[5].

Although the problems of soil heterogeneity have been widely studied, as reviewed by Beckett and Webster[2], they have received little attention in the tropics. Several geological, pedological and biological factors are reported to contribute to lateral soil variability[2 6]. Under tropical conditions, some biological factors are observed to have a major influence on the soil variability[3 4].

In various parts of West Africa where shifting cultivation is practiced, farmers usually clear only small parcels of land each year, crop them for three to four years, then abandon them and allow the natural vegetation to regenerate. In the humid lowland areas where root and tuber crops predominate, the common practice is to cultivate maize or yam during the first two years after clearing and fallow with cassava as the last crop in the cycle. As a result of this practice, a mosaic of adjacent small plots either under cultivation or under natural vegetation is observed in many farmers' plots. To assess the degree of soil variability between and within the plots due to this practice and its influence on cropping, a study was conducted in western Nigeria. Some of the results obtained are reported in this paper.

MATERIALS AND METHODS

The investigation was carried out during 1970 and 1971 on an Oxic Paleustalf (clayey, kaolinitic isohyperthermic family) in the forest zone of western Nigeria. The upland soil of the observation plots belongs to the Egbeda series[7 9] and is developed on colluvium and residium derived from Pre-Cambrian banded biotite-muscovite gneiss. The surface soil has a sandy clay loam texture. The subsoil is clayey, containing varying amounts of quartz gravel concentrated mainly in a stone line in the upper part of the Bt horizon (20–40 cm).

Based on aerial photographs and field observations, three adjacent plots under secondary forest, thicket regrowth and cassava respectively were selected for study during 1970. These plots will be referred to respectively, as secondary forest, thicket and cassava plots.

The secondary forest plot consisted of a mixture of oil palm trees (*Elaeis guineensis* Jacq.), akoko trees (*Newbouldia laevis* P. Beauvi), kola trees (*Cola nitida* (Vent.) Schott & Endl) and a few other tree species and shrub regrowth. The plot had been last cropped with yam, and had been abandoned for more than nine years. The thicket regrowth plot consisted of a dense regrowth of small trees (5–6 m) and shrubs. The plot had been last cropped with cassava, and had been abandoned for more than four years. The cassava plot vegetation consisted mainly of tall *Hyparrhenia* species mixed with poor cassava stand. The plots were hand cleared at the beginning of 1970 and the plant debris was removed carefully. Before clearing, marking stones were placed at the plot corners to delineate the plots.

Soil sampling

After clearing, surface (0–15 cm) soil samples were collected from each of the three plots to determine the degree of soil variability within each plot. Soil samples were taken at 1 m interval within rows spaced 2 m apart (Fig. 1). Seventy-seven samples were collected from both the secondary forest and the thicket regrowth plots; eighty-eight samples, from the cassava plot. The soil samples were air dried, sieved ($\leqslant$ 2 mm) and analyzed.

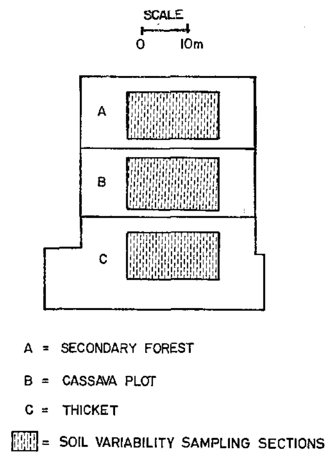

Fig. 1. Location of observation plots and soil variability sampling sections.

Soil analysis

Soil pH was determined with glass electrodes from a 1:1 soil-water paste. Organic-mater content of the soil was determined by wet digestion. Available P was extracted with Bray I extractant and measured colorimetrically. Exchangeable K and Ca were extracted with 1 *N* ammonium acetate at pH 7 and measured with a flame photometer.

Cropping

The plots were cropped with maize cultivar NS-5 during the first season of 1970 and with cowpea cultivar Westbred during the second season. No fertilizer was applied. The plant populations were 53.000 plants/ha for the maize crop and 214.000 plants/ha for the cowpea crop.

Each of the plots was subdivided into four blocks during the first season 1971. Fertilizer was applied on two blocks of each plot at the following rates: 120 kg/ha N; 40 kg/ha P; 50 kg/ha K. The remaining blocks were not fertilized. Maize cultivar NS-5 was planted in all plots at the same population as during 1970. Maize grain yield is reported at 12 per cent moisture content; cowpea seed yield, at 14 per cent moisture content.

RESULTS AND DISCUSSION

Soil analysis

Data on pH measurement are shown in Fig. 2. The average pH value of the secondary forest plot was significantly higher than those of the thicket and cassava plots. The secondary forest and thicket plots also showed greater variability among soil pH values

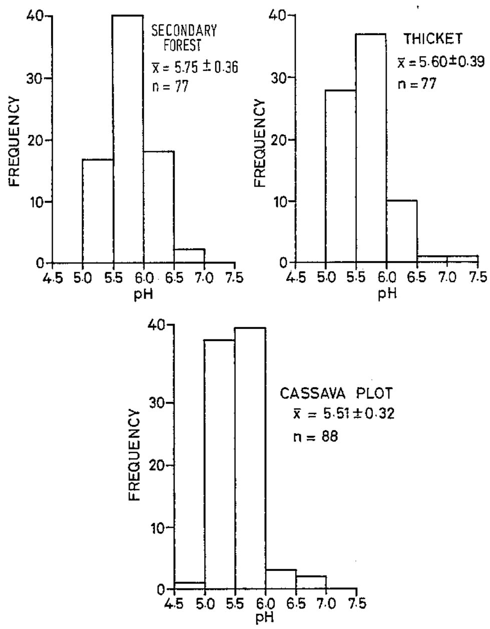

Fig. 2. Variability in soil pH in secondary forest, thicket regrowth and cassava plots.

than the cassava plot. The high degree of variability among soil pH values under fallow vegetation, confirms the results of observations reported by Ahn from a secondary forest in Ghana[1].

The average organic C contents of the three plots were significantly different (Fig. 3). The highest value was observed after secondary forest and the lowest value after cassava. The degree of variability among the organic C values in the three plots showed the same trend as the average values.

The high degree of variability in the organic C content after secondary forest vegetation, and in some extent also after thicket regrowth, was due primarily to the presence of oil-palm tree sites in the plots. The oil palm tree sites showed higher organic C contents in the order of 2–3 per cent; significantly higher than the plot average. After cassava, usually the last crop in the local shifting cultivation cropping sequence, organic C content was quite uniform and distinctly lower.

The available P contents in the soil of all three plots were low (Fig. 4). The low available P values in the three plots are not un-

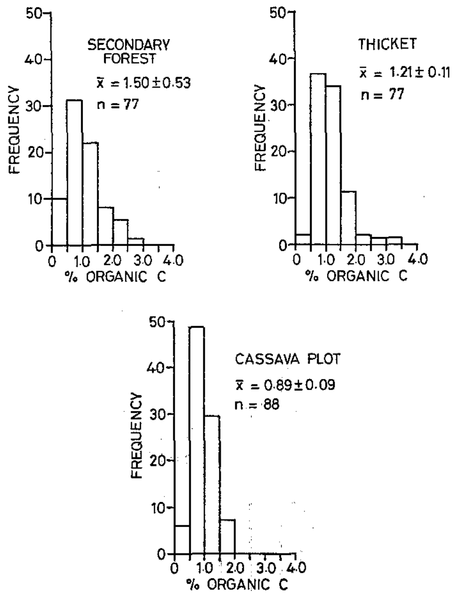

Fig. 3. Variability in soil organic C in secondary forest, thicket regrowth and cassava plots.

expected because under tropical conditions most of the P is tied up in the vegetation[8]. Removal of the vegetation, as was done on these plots also removes the major source of P available to the soil. Despite the low available P values, the secondary forest plot showed a significantly higher P value than the cassava and thicket plots. As expected, the secondary forest plot also showed the highest degree of variability among available P values, followed by the cassava and thicket plots. The thicket plot, with the lowest P content indicating more P depletion by the regrowth vegetation, also showed the least variation among P values.

The secondary forest plot contained a significantly higher amount of exchangeable K than the thicket and cassava plots (Fig. 5). The amount of exchangeable Ca was significantly higher in the secondary forest and thicket plots than in the cassava plot (Fig. 6). The high degree of variability among amounts of exchangeable K and Ca after secondary forest vegetation was primarily due to the presence of palm oil tree sites, where considerably higher values of exchangeable K ($\geqslant$ 150 ppm K) and exchangeable Ca ($\geqslant$ 1000 ppm Ca) were recorded.

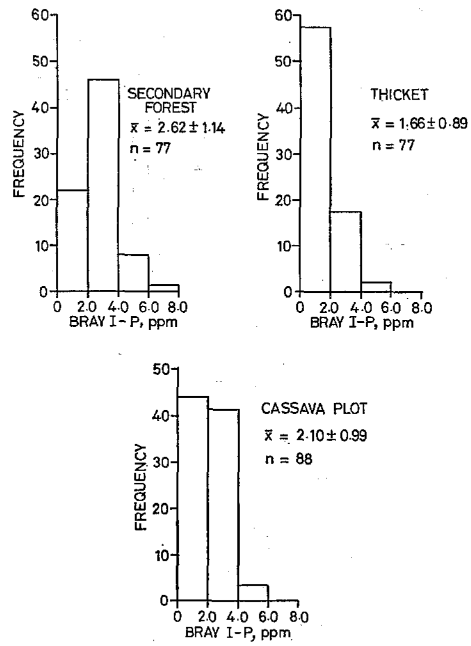

Fig. 4. Variability in soil available (Bray No. 1) P in secondary forest, thicket regrowth and cassava plots.

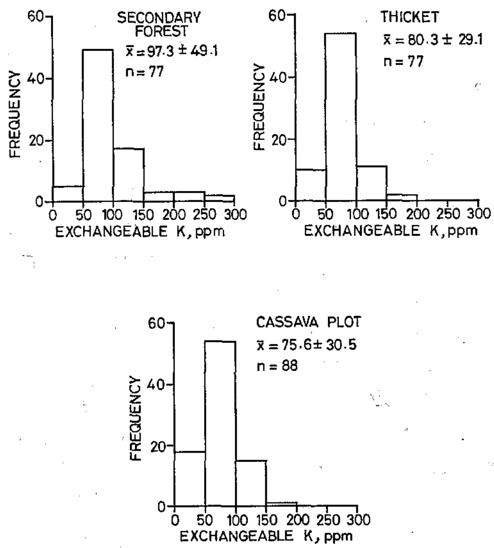

Fig. 5. Variability in soil exchangeable K in secondary forest, thicket regrowth and cassava plots.

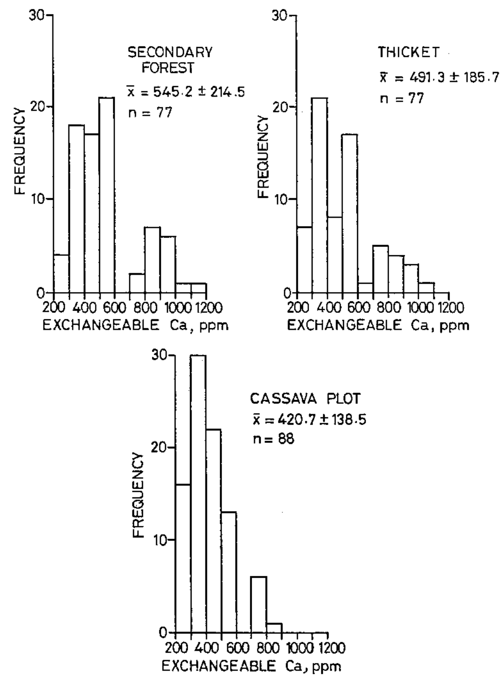

Fig. 6. Variability in soil exchangeable Ca in secondary forest, thicket regrowth and cassava plots.

Crop yields

Yields of maize (first season crop) and cowpea (second season crop), planted during the first year after clearing are shown in Table 1.

The secondary forest > thicket > cassava maize yield sequence was clear. This sequence is in line with the better nutritional status of soils under fallow vegetation. In this respect, the higher organic C content and, consequently, the higher N content appear to be the main contributing factors to the higher yields after fallow. After clearing, considerable N becomes available to crops by mineralization of the organic matter. In the cassava plot at the end of a cropping cycle, the organic C content and, consequently, the N contents are low. The lower soil pH also indicates lower amounts of exchangeable K and Ca. Although four years of thicket regrowth distinctly improved soil conditions, it was not sufficient to completely regenerate the nutritional status of the soil; hence, the intermediate yield.

TABLE 1

Effect of pre-clearing vegetation on maize grain yield and cowpea seed yield during the first year after clearing

Pre-clearing vegetation	Maize yield* kg ha	Cowpea yield** kg ha
Secondary forest	2460	1080
Thicket regrowth	1695	1070
Cassava	1482	910

* First season crop
** Second season crop

These results demonstrate clearly the danger of shortening the fallow period in traditional shifting cultivation systems without adding additional plant nutrients. Although the second season cowpea crop grew slightly better on the secondary forest plot than on the other two plots, there was no difference between the yields of the secondary forest and thicket plots. The yield on the cassava plot was slightly lower. Apparently, for this low-nutrient-requiring legume crop, the importance of N as a differentiating factor in yields is negligible, while other factors, *e.g.* the poorer physical condition of the cassava plot surface soil, became relatively more important.

Maize yields, with and without fertilizer application during the second year after clearing are given in Table 2. The yield trend: secondary forest > thicket > cassava for the no fertilizer plots was even more clear during the second year, which was climatically a better crop year. A carry-over of available nutrients during the second year was apparent in the two fallow plots, which showed relatively higher yields for the no-fertilizer treatments. The cassava plot showed a slight decrease in yield despite more favorable crop weather.

Fertilizer application increased maize yields on all three plots with, as might be expected, the highest response to fertilizer on the low nutrients tatus cassava plot. The yield sequence was maintained in spite of fertilizer application, which may be due to other factors rather than nutrient status.

Soil variability and experimentation

The large differences observed in the degree of variability of some soil chemical properties resulting from the pre-clearing vegetation have significant implications for (1) soil sampling and (2) field ex-

TABLE 2

Effect of pre-clearing vegetation and fertilizer application on maize grain yield during the second year after clearing

Pre-clearing vegetation	Treatment	Grain yield kg ha
Secondary forest	0	3640
	NPK*	4220
Thicket regrowth	0	2160
	NPK	4094
Cassava	0	1340
	NPK	3334

* 120 N– 40 P– 50 K in kg ha

perimentation. To get a meaningful estimate of the nutrient status of the soil under secondary forest vegetation, more samples per unit area are needed than under a traditionally grown cassava crop where the soil is uniformly poor in nutrients. The fact that even with fertilizer application yield differences related pre-clearing to vegetation were not erased (Table 2) indicates the importance of studying the pre-clearing vegetation in conducting field experimentation on traditional farmers' plots.

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