VARIATIONS IN SOIL FERTILITY UNDER COTTON CROPS IN THE BÉNOUÉ COTTON-GROWING AREA IN NORTHERN CAMEROON

Herve Guibert
Cirad
Cotonou, France
Corinne Fesneau
Universite de Bourgogne
Dijon, France
Mathurin M'Biandoun
IRAD
Garoua, Cameroon

Abstract

The status of soils under cotton crops must be compared before and after a sufficiently long cropping period in order to detect variations that have occurred. Continuous monitoring of plots in research stations to determine such patterns is, however, long and costly. To overcome this problem, a study was carried out in 2004 on plots that had been monitored previously. Scientists, technicians and farmers who participated in the first assessment were also involved in the present study, so the plots could be accurately located. The second assessment was conducted using the same analytical techniques as those described in the first assessment. A database was compiled with data from 58 plots on ferruginous soils in the Bénoué cotton-growing area, with the interval between two assessments ranging from 4 to 21 years. The results presented here concern 27 plots. The study revealed that: (i) the soil organic matter and available P contents had barely declined, (ii) the soil CEC had sharply decreased along with the N, K, Ca and Mg soil mineral contents, and (iii) this decline in mineral reserves paralleled the mineral budget of the crops. These hypotheses should be confirmed by processing the remaining collected data, but it was found that the characteristics of these especially fragile soils decreased. These results were readily and cost-effectively obtained. The geographical coordinates of the fields in which soil samples were collected were unfortunately not determined, and the soil analysis results were not adequately stored. This calls for the construction of databases to pool raw research results that are accessible to everyone. Research would thus fulfil its role of producing and providing public access to collected information.

Introduction

Alfisols prevail throughout Africa, especially in North Cameroon. Crop yields are directly related to the chemical characteristics of these soils. BERTRAND and GIGOU (2000); GUIBERT (1999); CRETENET *et al.* (1994); FALLAVIER (1995); FELLER (1995) and SANCHEZ (1976) thus documented direct correlations between yields obtained on these soils and their clay content, C, N and exchangeable cation levels (K, Mg, Ca), as well as their available P and pH levels. GUIBERT *et al.* (2001); GUYOTTE *et al.* (1997) and FRITZ and VALLERIE (1971) confirmed these correlations in North Cameroon. Fertility patterns in cultivated Alfisols can be assessed according to variations in their chemical characteristics.

Variations in these soil characteristics can, however, only be documented according to their measurements in the same plot at two different times, i.e. t_0 and t_1, separated by an interval of around 10 years so as to be able to clearly measure significant differences. In order to obtain quick results at low expense, the t_0 data used in the present study were derived from previous studies carried out to analyse soil characteristics in plots in North Cameroon, and then a new analysis was conducted on data collected in the same plots in 2004 (t_1). The procedure implemented to compile these datasets is described and the results are presented. This study highlights the importance of preserving such data from former analyses in a more readily useable format.

Materials and Methods

This study involved three phases: (i) a search of CIRAD's soil analysis laboratory archives to find soil characteristics data recorded previously in North Cameroon; (ii) to pinpoint the plots where the previous soil analysis data had been collected, sample collection, obtaining information on the cropping history of these plots; and (iii) sample analysis.

Archives

CIRAD's soil analysis laboratory stores the results of different requested analyses. These archives were searched to draw up an inventory of studies that involved soil analyses in North Cameroon. A hundred and three files of analyses carried out between 1973 and 1999 were found for Alfisols in North Cameroon. However, only five of these files could be used for the present study as the initial requests clearly indicated the exact plot locations. Hence, there is substantial information loss within these archives.

Field data

When the plots were clearly located, their GPS geographical coordinates were recorded. For each plot, the same horizons as those assessed in the previous study (t_0) were sampled (pooling of six replicate samples). Farmers filled in a questionnaire on the cropping history of the study plots between t_0 and t_1, including the dates of plot clearing and the number of fallow years. In the Bénoué basin, we sampled 63 plots on Alfisols (t_1 = 2004) overlying Cretaceous sandstone bedrock. The results presented here concern 27 of these plots located in the area around Djalingo and Ngong. The t_0 analyses had been carried out by GIGOU (1978), SUZOR (1991), and then again by GUYOTTE (1993, 1994) in farmers' fields, and also by POULAIN (unpublished data) in 1973, 1990 and 1996, respectively. A matched comparison (Statview software) was used to determine statistically significant differences between the t_1 and t_0 data, along with the Student's *t*-test with a 5% type 1 risk.

Soil analyses

In the IRAD laboratories in Garoua (Cameroon), the samples were dried and sieved to 2 mm and then sent to CIRAD for analysis. The choice of analyses performed depended on those that had been carried out in the initial studies. Particle-size was assessed by sedimentation analysis (pipette method) using an automated granulometer. Five fractions were separated according to the Atterberg scale. The cation exchange complex was analysed using the cobaltihexamine method (ORSINI *et al.*, 1976) or the ammonium acetate method (FALLAVIER *et al.*, 1985), depending on the analytical method used to assess the samples collected at t_0. Available P was determined by Olsen's method, modified by Dabin. Total C and N were measured with a Carlo Erba elemental analyzer (measurement error of +/- 0.02 $mg.g^{-1}$ for C and +/- 0.01 $mg.g^{-1}$ for N).

Results

Cropping practices

The main cropping sequences involved maize/groundnut/cotton. Only cotton and maize crops had benefited from chemical fertilizer applications. The recommended dosage for cotton was 200 $kg.ha^{-1}$ NPK (15 /20/15) at emergence and 50 $kg.ha^{-1}$ urea (46% N) at 30 days postemergence. With late sowing (i.e. after 20 June), the NPK dosage was 50% lower. Dosages usually applied by farmers on maize crops were 150 $kg.ha^{-1}$ NPK and 50 $kg.ha^{-1}$ urea. Very often, however, farmers only applied half the recommended dosages. Organic fertilizer (compost) was only applied on one of the studied plots in the last 5 years. Six plots had slight signs of erosion, four of which were located in the Djalingo region. The dates the plots were first cultivated ranged from 1954 to 1989.

Available phosphorus

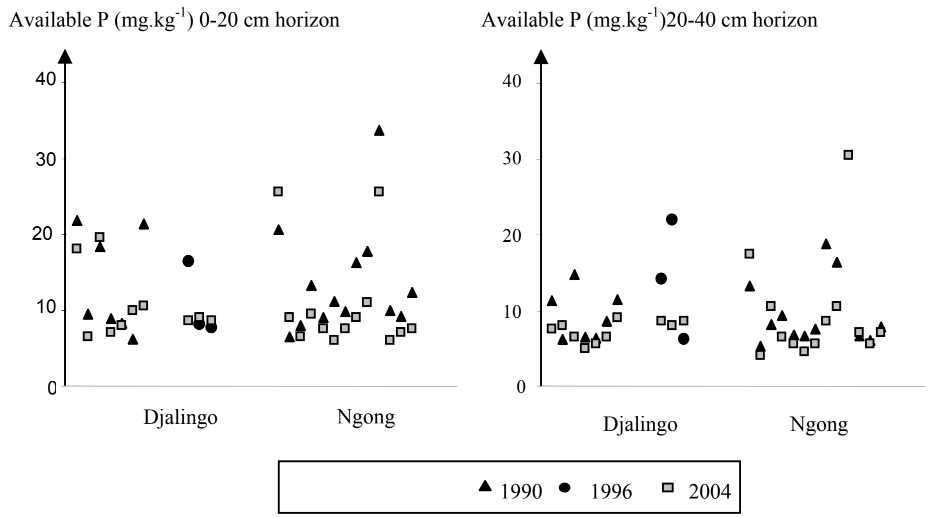

Figure 1: Variations in soil available P in 27 plots between t_0 (1990 or 1996) and t_1 (2004) in North Cameroon

For the two soil horizons (Figure 1), there was a significant difference between the 2004 and 1990 data. The relatively moderate decrease averaged 2.73 mg/kg in 14 years for the 0-20 horizon.

Carbon

As the soils were noncarbonated, we assumed that total C was equivalent to the organic C content. The statistical tests revealed a difference in the results obtained, but this general decrease was relatively moderate for the 2004 carbon levels and those obtained in previous analyses, as shown in Figure 2.

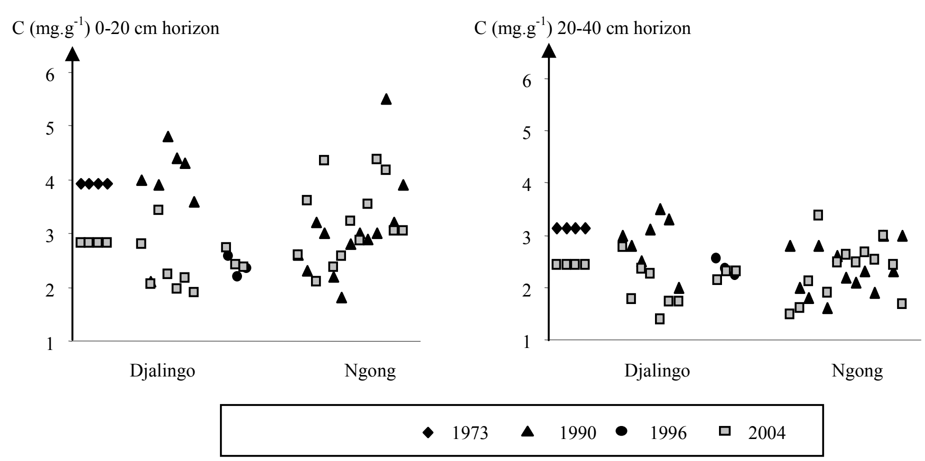

Figure 2: Variations in soil C in 27 plots between t_0 (1973, 1990 or 1996) and t_1 (2004) in North Cameroon

C/N ratio

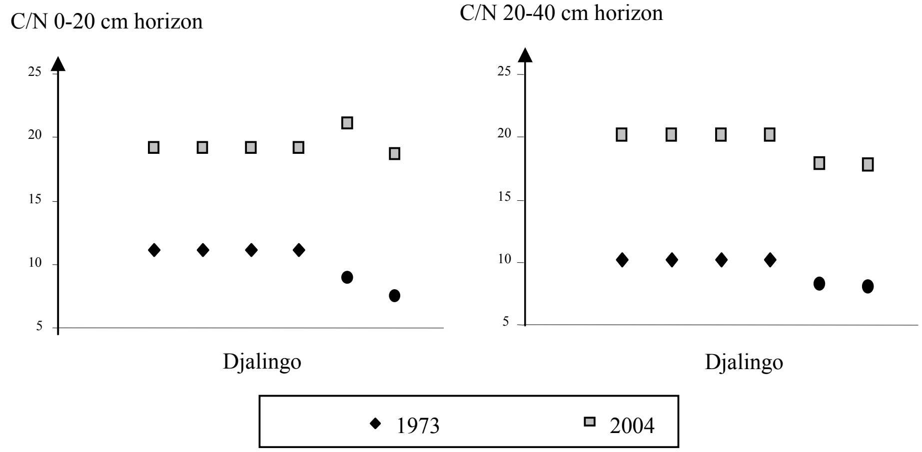

Figure 3: Variations in the soil C/N ratio in 27 plots between t_0 (1973, 1990 or 1996) and t_1 (2004) in North Cameroon

An analysis of soil N had been conducted at t_0 for only six plots. The C/N ratios calculated for these plots at t_0 were around 10, whereas those measured at t_1 were always over 15 (Figure 3). The soil N contents declined more sharply than the soil C levels, but these results should be checked against data from a larger number of plots.

Cation exchange capacity

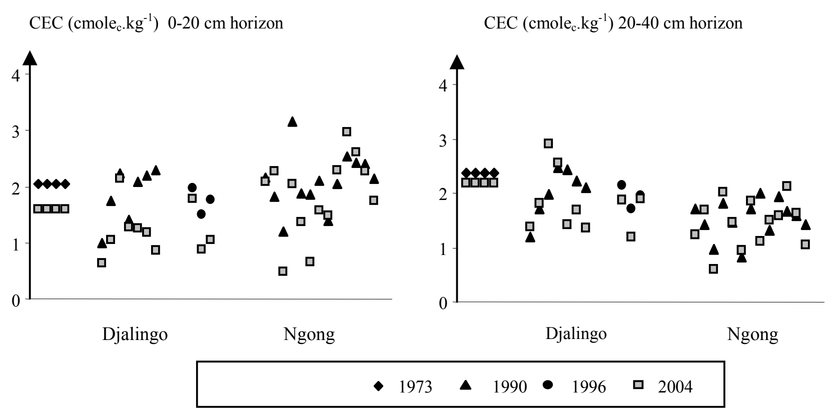

Figure 4: Variations in the soil cation exchange capacity (CEC) in 27 plots between t_0 (1973, 1990 or 1996) and t_1 (2004) in North Cameroon

There was a marked significant decrease in CEC for both soil horizons (Figure 3). A mean annual 1% CEC loss from t_0 was noted.

Exchangeable potassium
For both soil horizons, a substantial overall drop in the exchangeable potassium content was noted (Figure 4), i.e. 56% lower than the levels at t_0 in 14 years for the 0-20 cm horizon, and 36% for the 20-40 cm horizon.

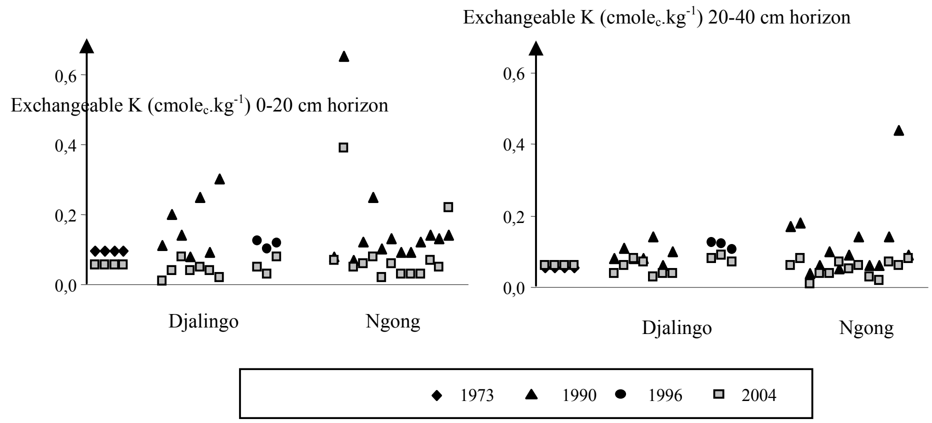

Figure 5: Variations in soil exchangeable K in 27 plots between t_0 (1973, 1990 or 1996) and t_1 (2004) in North Cameroon

Exchangeable calcium and magnesium
The results concerning these two elements were similar to those obtained for potassium, with a decrease of 28% and 35% for calcium and magnesium, respectively, in the 0-20 cm horizon.

Discussion

Soil organic matter patterns
The results obtained for soil C were in agreement with the Hénin-Dupuis soil model (HENIN and DUPUIS, 1945), as shown in Figure 6. On average, for the 0-20 cm horizon, the soil C k_2 mineralization coefficient was 0.06 of the 4.9 mg.g^{-1} A_0 value (C content at the time of plot clearing) and the 2.6 mg.g^{-1} equilibrium soil C content. HIEN (2004) and GUIBERT (1999) obtained soil C k_2 mineralization coefficient values ranging from 0.04 to 00.9 for different tropical soils.

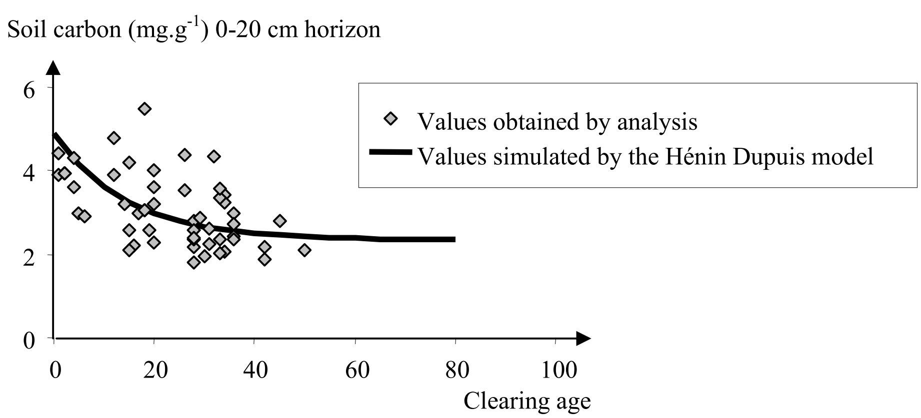

Figure 6: Hénin Dupuis model applied to soils in the Bénoué basin

Variations in levels of elements required by plants
Calculation of crop mineral budgets on the basis of data collected on the cropping history of the plots showed a relatively balanced P budget, but deficit N, K, Ca and Mg budgets (FESNEAU, 2004). These results are in agreement with the results of the present study concerning variations in levels of these elements in the soil, i.e. a slight decrease in P, but a marked decline in N, K, Ca and Mg.

Conclusion

The results highlighted a general degradation in the chemical characteristics of cultivated soils in the Ngong and Djalingo regions in North Cameroon. After 30 years of cropping, the soil CEC and K had especially dropped to critical levels determined by GUIBERT (1999) and GUIBERT *et al.* (2001), i.e. levels under which crop yields would be affected. For the 0-20 cm horizon, the soil potassium, calcium and magnesium contents decreased by 56%, 28% and 35%, respectively, in 14 years.

Several factors were responsible for this pattern: the low fertility potential of Alfisols on sandstone bedrock (BRABANT and GAVAUD, 1985), continuous cropping without organic matter recycling or fallowing, and the low level of mineral recycling.

This study relied on soil analysis data derived from previous studies. It is now essential to set up systems for storage of these initial data on soil characteristics and other environmental components (biocenosis, climate) so as to enhance the efficacy and rapidity of future studies on changes in the cropping environment.

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