Herald Journal of Agriculture and Food Science Research Vol. 2 (6), pp. 171 - 176 December, 2013
Available online http://www.heraldjournals.org/hjafsr/archive.htm

ISSN : 2350 – 2193

Full Length Research Paper

Characteristics of *Tonkpi* Mountain soils and plateaus soils in West Côte d'Ivoire

***Bakayoko S.[1, 2], Soro D.[1, 2], Kouadio K.K.H.[1, 3], Konan-Waidhet A.B.[1], Angui P.[4]**

[1]University Jean Lorougnon Guédé, Department of Soil Science and Geology, BP 150 Daloa, Côte d'Ivoire
[2]Swiss Centre for Scientific Research in Côte d'Ivoire, 01 BP 1303 Abidjan 01, Côte d'Ivoire
[3]University Felix Houphouët Boigny, UFR STRM, Laboratory of Soil Science and Geology, 22 BP 582 Abidjan 22, Côte d'Ivoire
[4]University Nangui Abrogoua, UFR Science and Environment Management, Laboratory of Geoscience, 02 BP 801 Abidjan 02, Côte d'Ivoire

Received October 10, 2013 Accepted November 21, 2013

The evaluation of soil fertility under cassava growing is important in the assessment of soil management options. The first meter of deep and developed ferrallitic soils of West Côte d'Ivoire was analysed under the two very distinct types of contours, namely the mountain and the plateaus, which are in the region. The soils were sampled in order to access their fertility status. The soil was red or dark, with sandy clay loam texture and different levels of degradation. The *tonkpi* Mountain is not highly cultivated because it's difficult to get to the top. Soil in about 10 fields from the plateaus specially grown with cassava (*Manihot esculenta* Crantz) or cassava-based crop mixture were sampled and analysed for determination of their physico-chemical properties. Results showed that organic C decreased from 1.3 to 0.53% at 0-30 cm soil layers and total N decreased from 0.08 and 0.04% in the top 30 cm layer of the soil, respectively with the *Tonkpi* mountain soils and plateaus soils. In the plateaus, soils were impoverished because of the population pressure which has led to soil degradation. On the *tonkpi* Mountain, soils contained significantly higher nutrients compared with those from plateaus. Variations in soil properties may be attributed to climatic differences, altitude and farming systems.

Keywords: *Tonkpi* Mountain, plateau, soil fertility, soil degradation, West of Côte d'Ivoire

INTRODUCTION

A major landscape feature of West Côte d'Ivoire is a series low plateaus with red soils and mountains with dark soils called "*18 mountain-region*". The low plateaus have the highest rural population densities in west Côte d'Ivoire, with many localities of more than 200 inhabitants per square kilometer. The total population of Man is estimated to be 1 584 494 inhabitants (RGPH, 1998).
Plateau soils have been cultivated with cassava (Manihot esculenta Crantz) over the last twenty years. The cultivation is concentred in this zone because it is difficult to locals to accessing Tonkpi mountain for farming.

*Corresponding Author E-mail: sidiky_bakayoko@yahoo.fr Tél: +225 23 47 27 90/07 41 41 83

Cassava is the staple food of people in the West Côte d'Ivoire. In order to realize the maximum benefits which could be obtained from cassava, production systems, processing methods and urban consumptions patterns are required (Asadu et al., 1998). Cassava has been it is often the last crop grown before the land is allowed to revert to bush fallow (Bakayoko et al., 2007) in traditional cropping systems. However, soil constraints that reduce yields of cassava are salinity (above 1 mS/cm), exchangeable aluminium (Al) (above 148 ppm), high pH above 8.0 and exchangeable sodium (Na) percentage of above 2.5% have been outlined by Cock and Howeler (1978). Onwueme and Sinha (1991) also pointed out that cassava does best on light sandy loam soils with high fertility. Severe soil degradation has been commonly observed in west Côte d'Ivoire (MINAGRA, 1999). Therefore, soil fertility in the area became increasingly

Figure 1. Top of *tonkpi* mountain

Figure 2: Cassava growth on plateaus soils

low. Thus, the plateau of Man area is one of the most highly degraded areas of West Côte d'Ivoire whereas the top of *Tonkpi* mountain where cropping is relatively recent possesses less degraded. Decline in yields has been observed in cassava-based systems in plateau soils compared to yields in top *tonkpi* Mountain. The average yield of cassava on plateau plots was 8 t/ha versus 23 t/ha on top *tonkpi* Mountain plots. Howeler (1980) indicated that the harvest of a ton of tubers of manioc is equivalent to a withdrawal of the ground of approximately 2.3 kg of N, 1,2 kg of P_2O_5 4.9 kg of K_2O, 0.6 kg of Ca and 0.3 kg of Mg. Technical soil data for soil fertility evaluation and their influence on yields in cassava growing in this area are not usually available. Hence, the objective of the current study was to obtain relevant soil data to estimate the fertility status of soils specifically cropped to cassava and cassava mixtures on plateaus soils and mountain soils in West of Côte d'Ivoire.

MATERIAL AND METHODS

Site Description

The study was carried out at Man located at 500 km in the northwest of Abidjan (Côte d'Ivoire) on *Tonkpi* Mountain (altitude 1293 m, 07° 33´N, 07° 38´W) (Figure 1) and on plateaus farms (altitude 357 m, 07°25´N, 07°34´W) (Figure 2). The average annual rainfall is 2000 mm unimodally distributed from March to October. The annual average temperature is 24°C, about 80 to 85% relative humidity, and a monthly total solar radiation of 314 MJ m $^{-2}$. The main vegetation types in Man area are gallery forests, grassland often subjected to flooding and savanna. Fallows are mainly composed of *Imperata cylindrica* (Poaceae), *Chromolaena odorata* (Asteraceae). The soils are highly desaturated ferralitic (Avenard et al., 1971)

Soil Sampling

Reserach works were carried out in 2012 and 2013 on ten farmer's fields (more than 20 years old).The experiments were conducted in a split-plot design. The treatments were *tonkpi* mountain or plateaus soil (main factor), cassava and soil type (sub-plot). The sub-plots were contiguous and mesured 10 m X 10 m = 100 m^2 and each farmer represented one replicate. Soil samples were collected from *Tonkpi* mountain top and from all fields of ten selected farmers carrying both sole cassava and cassava intercropped with other crops at 0-30 cm and 30-60 cm depth using a post-hole auger. The major crops intercropped with cassava included maize, banana or beans. 3 pedological pits were excavated in each field to examine the soil profile and ensure the same soil type was present, therefore, 30 samples from tonkpi mountain and 30 samples from plateaus.The sampling was done when the soil was moist during the growing season. Where one auger point was insufficient to represent the field, several points were chosen, some pedological pits were excavated in the field to examine the soil profile and ensure the same soil type was present. Thus, soil samples collected were composited by depth. So, Soil samples were taken from two soil depth: 0-30 cm and 30-60 cm for analysis in laboratory.

Laboratory analysis

The rates of clay, silt and sand were evaluated. Soil particles size distribution was analysed using Robinson pipette method on air dried soil sieved on 2 mm mesh sieve and following the procedure described by Mathieu and Pieltain (1998). Particles size distribution was measured after oxidation of the organic matter with hydrogen peroxide (H_2O_2) of a soil sample sieved through 2 mm mesh, followed by particles dispersion with a sodium hexametaphosphate solution $(NaPO_3)_6$ (Van Reeuwijk, 1993). Soil organic carbon was determined using the Walkley and Black method (1934). The total nitrogen was measured by dried combustion and by Kjeldahl method (Moral *et al.,* 2005). All samples were dried in a forced -air oven at 60 °C during 48 hours and ground to 0.5 mm for analysis. Total organic carbon was determined by oxidation with $K_2Cr_2O_7N$ (bichromate of potassium) in H_2SO_4 (sulfuric acid), according to Yeomans and Bremner (1989). NH_4^+-N was extracted with 2 M KCl and determined calorimetrically by the phenol salt method (Honeycult *et al.,* 1991). NO_3^--N was determined by second-derivative spectroscopy in a 1:30 (w/v) water extract (Sempere *et al.,* 1993). Total nitrogen (N_t) and organic nitrogen (N_{org}) were calculated as the sum of Kjeldahl-N and $NO3^-$-N and as the difference between N_t and the inorganic nitrogen (sum of NH_4^+-N and NO_3^--N), respectively.

Statistical analyses

The data were subjected to the analyses of variance in order to determine the effects of soil depth, altitude and cropping patterns on the soil properties according to the experimental design (split-plot) (linear model with interactions), by the analysis software SAS® (Statistical Analysis System Institute Inc., Cary, NC, USA). The factors used are altitude (2), crop mixture (3), soil depth (2). For the significant effects, the averages were compared using Student-Newman_Keuls method (Dagnelie, 2003) The significant differences between treatments were compared with the least significant difference (L.S.D) at 5% level of probability.

RESULTS

Particle-size distribution

The main morpho-pedological units that characterise the area are soils of loamy texture on plateaus and sandy clay soils on *tonkpi* Mountain. The physical characteristics of these soils are given in the Table. The clay rates were between 25.6 and 28.7% in the *Tonkpi* mountain soils and between 13.9 and 16.9% in plateaus soils. The mean silt rate of the soil ranged from 6.7 to 8% and 4.7 to 5.3% respectively in the *Tonkpi* mountain soils and in plateaus soils. The sand content was relatively high in the plateaus (78.4 to 80.8%) compared to that of*Tonkpi* Mountain (64.6 to 66.4%). It was the opposite for clay and silt which were higher in the *Tonkpi* Mountain than in the plateaus soils ($p<0.05$).

Organic C

The average organic C of the soil which were 1.3 and 0.53% at 0-30 cm soil layers, respectively in the *Tonkpi* mountain soils and in plateaus soils were significantly different at ($p<0.05$). The same trend was observed at

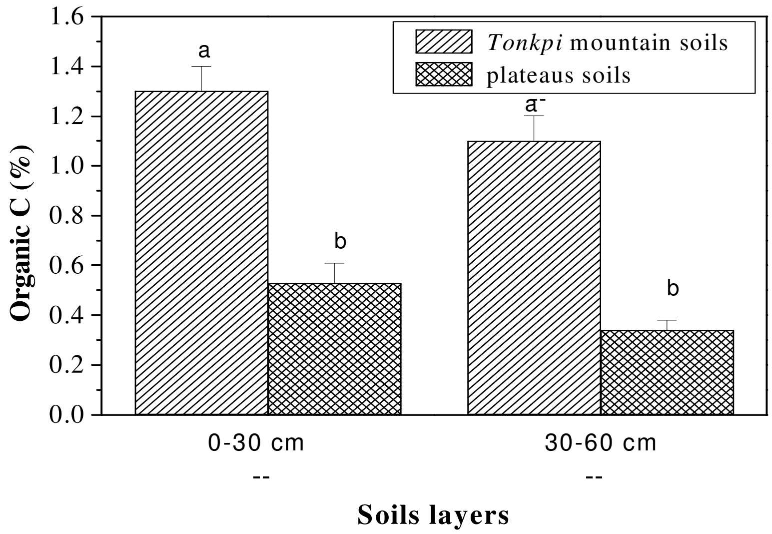

Figure 3. Soil organic C content at 0-30 and 30-60 cm soil layers in *Tonkpi* mountain soils and plateaus soils in the Man area, Côte d'Ivoire.

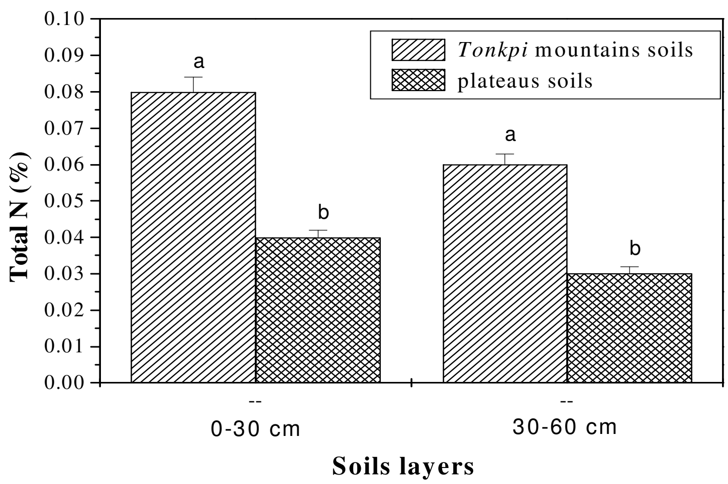

Figure 4. Soil total N content at 0-30 and 30-60 cm soil layers in *Tonkpi* mountain soils and plateaus soils in the Man area, Côte d'Ivoire**.**

30-60 cm soil layers where organic C was 1.1% in the *Tonkpi* mountain soils and 0.34% in plateaus soils (Figure 3).

Total N

The amounts of Total N were 0.08 and 0.04% in the top 30 cm layer of the soil, respectively with the *Tonkpi* mountain soils and plateaus soils. The N total was significantly lower in the plateaus soils (0.03%) than in *Tonkpi* mountain soils (0.06%) ($p<0.05$) (Figure 4).(table 1)

DISCUSSION

The *Tonkpi* mountain soils had higher values of soil clay and silt than the plateaus soils. This is probably due to its finer texture that is prone to gradual consolidation events destroy soil aggregation (Home *et al.,* 1992). Indeed, the sand rate was higher in the plateaus soils than the *Tonkpi* mountain soils. According to Alcazar *et al.* (2002), this difference of the sand content between the two soils types can be seen as a difference in potential risk of runoff and erosion. Therefore, the soil aggregate stability was higher with the *Tonkpi* mountain soils than the plateaus soils (Nyamangara *et al.*, 2001). The decrease

Table 1. Particle-size distribution in the *Tonkpi* Mountain and plateaus soils

Horizon	Clay (%)	Fine silt (%)	Coarse silt (%)	Fine sand (%)	Coarse sand (%)
Tonkpi mountain					
0-30 cm	25.6 ± 1.2b	3.2 ± 0.2a	4.8 ± 0.4a	22.3 ± 1.5c	44.1 ± 2.2cd
30-60 cm	28.7 ± 1.4a	3.1 ± 0.1ab	3.6 ± 0.2b	18.0 ± 1.2d	46.6 ± 2.6c
plateaus					
0-30 cm	13.9 ± 0.5d	2.3 ± 0.1c	3.0 ± 0.3c	29.1 ± 1.6a	51.7 ± 2.7ab
30-60 cm	16.9 ± 0.5c	2.1 ± 0.1d	2.6 ± 0.2cd	25.9 ± 1.1ab	52.5 ± 2.7a

Values in the same column with different letter are significantly different at $p<0.05$.

in soil fine particle (fine silt plus clay) contents on plateaus soils can be explained by the removal of a greater amount of this fraction by runoff and hand hoed plots. This observation is consistent with the finding of Roose (1981) who showed that on ploughed plot, the fine particles content of the runoff was higher than in no-till plot or surface protected plot. Organic C and total N were significantly high in the *Tonkpi* mountain soils than the plateaus soils. Organic C and total N were drastically reduced in plateaus soils compared to *Tonkpi* mountain soils. They were lowest in plateaus soils. This result indicates that long-term growing might reduce organic C and total N in the soil. Indeed, plateaus soils are always used to grow crops. The substantial increase of cassava yield on *tonkpi* mountain soil was probably due to several effects including improved moisture availability, supply of nutrients and biological activity (De Ridder and Van Keulen, 1990). Organic C have been showed to improved water capture and rentention (Lal *et al.*, 1980). This suggests that the plots in plateaus soils are severely degraded. This trend is not surprising because of the usual greater microbial activities associated with the topsoil than the subsoil because of many factors such as decline of soil organic matter (Asadu *et al.,* 1998). That suggests that cassava growing soils of the plateau zone are less fertile than those of the mountain zone. The significant difference between the both soils can be attributed to the differences in the organic C and clay. In term of nutrients content, the soils grown to sole cassava or cassava intercropped with other crops are statistically similar. Soil organic carbon influences a wide range of physical, chemical and biological properties of soil and is considered the most important indicator of soil quality (Carter *et al.*, 1999). The soil organic carbon content is inversely proportional to bulk density as reported by Baur and Black (1994). Several workers have reported positive influence of soil aggregation on soil quality (Six *et al.,* 1998). Like our work, Aïhou *et al.*, (1999) sampled degraded and non-degraded fields on *terre de barre* soils at the Niaouli research station in Southern Benin. They found that total N (0.3 vs 0.9 g/kg) was drastically reduced on the degraded field compared to the non degraded field. Therefore, soil degradation in the case of the plateaus soils appears to be a relatively simple process of depletion of organic C.

CONCLUSION

This study showed that *Tonkpi* Mountain soils are more fertile than plateaus soils in Man area in west of Côte d'Ivoire. The degradation of plateaus soils has been observed because those soils are used to grow cassava since a long time. The nutrient contents of soils from fields where cassava was grown as a sole, major or minor crop were generally similar. The rating of the nutrient levels show that the soils grown to cassava in cassava growing areas are very poor compared to *Tonkpi* Mountain soils. In the plateau area, soil fertility management in cassava growth system should integrate compost application or other organic matter source.

ACKNOWLEDGMENTS

Many thanks are due to the staff of the Regional Direction of National School directed by COULIBALY Emmanuel André Tiémoko for their assistance during my research in Man area. M. COULIBALY is gratefully acknowledged to go with me on the *Tonkpi* mountain.

REFERENCES

Aïhou K, Sanginga N, Vanlauwe B, Lyasse O, Diels J, and Merckx R (1999). Alley cropping in the moist savannah of W. Africa. I. Restoration and maintenance of soil fertility on *terre de barre* soils in benin Republic. Agrof. Syst. 42: 213-227.

Alcazar J, Rothwell RL, and Woodard PM (2002). Soil disturbance and the potential for erosion after machanical site preparation. North. J.

Appl. For. 19: 5-13.

Asadu CLA, Nweke FI, and Ekanayake IJ (1998). Factors affecting the fertility status of soils growing cassava in sub-saharan Africa. Commun. Soil Sci. Plant Anal. 29: 141-159.

Avenard JM, Edlin M, Girard G, Sircoulon J, Touchebeuf P, Guillaumet JL, Adjanohoun E, Perraud A (1971). Le milieu naturel de la Côte d'Ivoire. éd. ORSTOM, Paris, 391 p.

Bakayoko S, Nindjin C, Dao D, Tschannen A, Girardin O, et Assa A (2007). Fumure organique et productivité du manioc (*Manihot esculenta* Crantz) en Côte d'Ivoire. Agronomie Africaine 19 (3): 271–279.

Baur A, and Black AL (1994). Quantification of the effect of soil organic matter content on soil productivity. Soil Sci. Soc. Am. J. 58: 185-193.

Carter MR, Gregorich EG, Angers DA, Beeare MH, Sparling GP, Wardle DA, and Voroney RP (1999). Interpretation of microbial biomass measurements for soil quality assessment in humid regions. Can. J. Soil Sci. 79: 507-520.

Cock JH, and Howeler RH (1978). The ability of cassava to grow on poor soils. Pp. 145-154. In: G.A. Jung (ed.), Crop Tolerance to Suboptimal Land Conditions. Am. Soc. Agron. Spec. Publ. 32: 145-154.

Dagnelie P (2003) Principes d'expérimentation, planification des expériences et analyse de leurs résultats, Les presses agronomiques, Gembloux.

De Ridder N, and Van Keulen H (1990). Some aspects of the role of organic matter in sustainable intensified arable farming systems in West African semi-arid tropics (SAT), Fert. Res. 26: 299-310.

Home DJ, Ross CW, and Hughes KA (1992). Ten years of maize/oats rotation under three tillage systems on a slit loam in New Zealand. 1. A comparison of some soil properties. Soil Till. Res. 22, 131-143.

Honeycult CW, Potar LJ, and Halteman WA (1991). Predicting nitrate formation from soils, fertilizers, crop residue and sludge with thermal units. J. Environ. Qual. 20:850-856.

Howeler R (1996). Mineral nutrition in cassava. Pp. 110-116. In : ET Cranwell, CJ Asher and JN O'Sullivan (eds), Proceedings of Mineral Nutrient Disorders of Root Crops in the Pacific Workshop. Nukrialofa, kingdom of Tonga, 17-20 April 1995.

Howeler RH (1980). Soil-Related Cultural Practices for Cassava. *in*: Weber J. *et al*. (1980). Cassava Cultural Practices. éd. IDRC, Ottawa (Canada), pp. 61-62.

Lal R, De Vleeschauwer D, and Nganje RM (1980). Changes in properties of a newly cleared tropical alfisol as affected by mulching. Soil Sci. Soc. Am. J. 44: 827-833.

Mathieu C, and Pieltain F (1998). Analyse physique des sols: Méthodes choisies. Lavoisier, Paris.

MINAGRA (1999). L'agriculture ivoirienne à l'aube du XXI[ème] siècle. éd. SARA, Ministère de l'Agriculture, Abidjan, Côte d'Ivoire, 31 p.

Moral R, Moreno-Caselles J, Perez-Murcia MD, Perez-Espinosa A, Rufete B, and Paredes C (2005). Characterisation of the organic matter pool in maures. Biores. Technol. 96:153-158.

Nyamangara J, Gotosa J, Mpofu SE (2001). Cattle manure effects on structural stability and water retention capacity of a granitic sandy soil in Zimbabwe. Soil Till. Res. 62:157-162.

Onwueme IC, and Sinha TD (1991). Field crop production in tropical Africa. Technical centre for Agriculture and Rural Corporation (CTA), Ede, The Netherlands.

RGPH. (1998). Recensement Général de la Population et de l'Habitat 1998. éd. Institut National de la Statistique, Abidjan (Côte d'Ivoire).

Roose E (1981). Dynamique actuelle des sols ferrallitiques et ferrugineux tropicaux d'Afrique Occidentale. Etude expérimentale des transferts hydrologiques et biologiques de matières sous végétations naturelles ou cultivées. Collection Travaux et Documents no. 130, vol. 30. Thèse d'Etat Orléans, ORSTOM, Paris, 569 p.

Sempere A, Olivier J, and Ramos C (1993). Simple determination of nitrate in soils by second-derivative spectroscopy. J. Soil Sci. 44: 633-639.

Six J, Elliott ET, Paustain K, And Doran JW (1998). Aggregation and soil organic matter accumulation in cultivated and native grassland soils. Soil Sci. Soc. Am. J. 62: 1367-1377.

Van Reeuwijk LP (1993). Procedures for Soil Analyses. Technological paper No. 9, International Soil Reference and Information Centre (ISRIC).

Walkley A, and Black JA (1934). An examination of the Detjareff method for determining soil organic matter and a proposed modification of the chromatic acid titration method. Soil Sci. 37: 29-38.

Yeomans JC, and Bremner JM (1989). A rapid and precise method for routine determination of organic carbon in soil. Commun. Soil Sci. Plant Anal. 19:1467-1475.