# International Journal of Agricultural Research

ISSN 1816-4897

Academic
Journals Inc.

www.academicjournals.com

International Journal of Agricultural Research, 4 (4): 146-152, 2009
ISSN 1816-4897

# Soil Degradation under Culture of Palm Oil Tree in the South of Ivory Cost

[1]K. Ballo, [2]A. Yao-Kouamé, [2]K.A. Alui, [1]A. Kouassi,
[1]D. Boa and [3]Krogba Yves Nangah
[1]National Center for Agricultural Research, 01 Bp 1740 Abidjan 01, RCI
[2]Department of Earth Sciences and Mining Resources, University of Cocody,
22 Bp 582 Abidjan 22, RCI
[3]Department of Science and Environmental Management, University of Abobo-Adjame,
01 Bp 802 Abidjan 01, RCI

**Abstract:** In order to measure the impact of planting on the ground, the present study was undertaken to evaluate the evolution of particle size, chemical and physicochemical properties of soil during two consecutive cycles of cultivation of palm oil trees. The condition of soil under palm grove was compared to a control taken under natural forest. After 25 years of growing in the second generation, soil samples were collected in two areas. Samples were taken: one in the 0-20 cm layer and the other in the in the 40-60 cm layer. All samples were analyzed in a soil science laboratory. The results revealed a degradation of the physical, chemical and physicochemical characteristics of the soil. Planting palm oil trees resulted in the impoverishment of the soil in fine elements and a decline of the content in easily absorbed phosphorous. The cation exchange capacity and the content in organic matter was reduced while the content of exchangeable aluminum quadrupled.

**Key words:** Palm oil tree, tertiary sands, degradation, potassium

## INTRODUCTION

Land degradation is a global and complex issue. Many forms of soil degradation are recognized: the decline of soil organic matter and its biological activity and the destruction of soil structure, soil and training and crusts; declining chemical fertility; soil acidity; reduction in the area (Lahmar and Ruellan, 2007).

The physical (structure and particle size) and chemical characteristics of the soil can degrade under the effect of natural or human factors, particularly by the type of culture. The particle size and the content of the soil in nourishing elements are subjected to unfavorable evolutions as a result of the types of culture (Roose, 2004; Hamado *et al*., 2008).

Sivakumar and Stefanski (2007) challenging considerations who claimed that the erosion under palm grove was not very different from the one who takes place under natural forest and that the plantations of palm trees were similar to the natural forest. Therefore, it has been admitted that the replacement of the forest by the palm grove did not modify the equilibrium of the environment. As a result the expression conversion of the natural tropical forests in artificial forests has often been used to describe the fact that planting palm oil trees does not disrupt the environment.

Afterward, other researchers reported phenomena which prove that planting degrades the characteristics of the soil. Boyer (1982) and Roose (2004) revealed a phenomenon of collapse of the soil under palm grove at Dabou, in Ivory Coast. Similarly, the degradation of the superficial layer of a soil ploughed for annual cultures in Cameroon.

---

**Corresponding Author:** Albert Yao-Kouamé, Department of Earth Science and Mining Resources, University of Cocody, 06 Bp 688 Abidjan 06, RCI Tel: 2250792015

However, all the earlier research under palm grove concerned only the structure of the soil. Those conducted under subsistence crops took into account the particle size, the chemical and physicochemical parameters, but unfortunately concerned only the superficial layer. As a result, the evolution of the parameters of the soil after planting remains badly known.

The present study aims at estimating the impact of the culture of palm oil tree on the particle size, the chemical and physicochemical parameters of the soil, at 0-60 cm dip.

## MATERIALS AND METHODS

### Site of Study

The study was conducted on the experimental search station Mé, located at 24 km from Abidjan in the Northest, with the following geographical coordinates: 5°26' latitude the north and 3°50' longitude west. The climate is of attiéen type with a littoral facies. The experimental site is a continental shelf covering a surface of 4.54 ha. The ground, developed from tertiary sands is of type ferrallitic. The natural vegetation is constituted of *Turreaeanthus africanus* and *Heisteria parvifoli*.

### Biological Material

The biological material used in the study is a (Dura×Pisifera) Tenera hybrid of palm oil tree, derived from the first cycle of selection and having an annual potential production of 100 kg of regime per year, which represent a total annual yield of 14 t of regimes per hectare. The elementary experimental plot of land is constituted of sixteen (4×4) nearby palm trees.

### Preparation of the Ground and the Driving of the Culture

The palm oil trees were cultivated during two consecutive cycles. The first cycle was established after manual clearing of the natural forest. The forest flaps were put in Andean and underwent a light burning. For the second farming cycle, the palm trees of the first generation were shot down at the age of 21 and the new plantation was started one year later. The planting of the second generation lasted 25 years (1976-2001). A covering legume (*Pueraria javanica*) was seeded as a pre-culture, to preserve the risks of soil erosion, direct sunshine and diving rain the early years of planting.

### Fertilization

Trees of the first generation received each 2 kg per year of potassium chloride (KCl) from the age of five years. This fertilization ceased two years before the slaughter. The trees of the second generation were subjected to the fertilization schedule shown in Table 1, up to seven years. Starting from the eighth year of cultivation, only potassium chloride (KCl) was provided to the trees. The annual dose was determined by the content of potassium in leaves (Table 2).

### Experimental Design

The effect of growing on the soil was determined. Measurements were made on the soil layers where the root system of palm oil trees is the most active. Two layers of soil (0-20 and 40-60 cm) were considered. The neighboring natural forest serves as control.

### Soil Sampling

After 25 years of growing in the second generation, soil samples were collected in two areas: the palm grove and the neighboring natural forest. In both settings and on each site, two soil samples

Table 1: Fertilization schedule from the 4th to the 7th after plantation

| Concentration | N (Urea) | $K_2O$ (KCl) | $P_2O_5$ (Super single) | MgO (Kieserite) | $BO_3$ (Borax) |
|---|---|---|---|---|---|
| g/tree/year | 100 | 400 | 400 | 50 | 10 |
| UF/tree/year | 0.05 | 0.24 | 0.07 | 0.017 | 0.004 |

Table 2 : Schedule of fertilization in adulthood based on the levels foliar $K^+$

| $K^+$ content in year $N^{-1}$ (p.c. ms) | Recommended doses of fertilizers in year N (kg/a/year) |
|---|---|
| >0.9 | 0.5 |
| 0.8<K<0.9 | 1 |
| <0.8 | 2 |

were taken: one in the 0-20 cm layer and the other in the in the 40-60 cm layer where the root system is most active. Each elementary plot on land covered an area of 648 $m^2$ (27×24 m) and has four sampling sites.

### Laboratory Analysis

All soil samples were analyzed in soil science laboratory of the Institute National Polytechnique Felix Houphouet Boigny, Yamoussoukro. The particle size was determined by the Robinson's pipette method. The chemical parameters were measured by atomic absorption spectrometry and the cationic exchange capacity was determined by the method using $CO(NH_3)_6Cl_3$. The Oslen's method modified by Dabin was used to determine phosphorus content.

### Statistical Analysis

The results were analyzed with the analysis of variance procedure of the statistical analysis software STATISTICA 7.1. The Turkey test was used to determine whether the means of the different treatments were significantly different at the probability level of $p \leq 0.05$ or 0.01. A Principal Component Analysis (PCA) was applied to different variables and from the original matrix of variables; a small number of combinations correlated with each other were extracted. The projection of all individuals at the axis of the main components allows to assess the dispersion of individuals and to better compare their variability according to the approach developed by Manly (1994). To admit that the phenomenon is sufficiently expressed the cumulative sum of the contributions of its key factors should be about 70% (Thomassone *et al*., 1993).

## RESULTS AND DISCUSSION

The planting impoverished the soil in fine elements (Table 3, 4). In the surface layer (0-20 cm), 35% of clay was lost and the content of coarse sand rose by 8%. In the deep layer (40-60 cm), the clay content was reduced by 35%, the fine silt by 61% and the coarse silt by 26%.

The soil content in easily absorbed phosphorus decreased with the planting. The level of labile phosphorus fell by 75% in the surface layer and by 14% in the 40-60 cm layer.

Planting palm oil trees also affected the level of exchangeable bases. In the surface layer, exchangeable potassium dropped by 46%, calcium and magnesium decreased by 77 and 88%, respectively.

### Content in Exchangeable Potassium Tripled in the 40-60 cm Layer

The planting also resulted in 70 and 24% reduction of the Cation Exchange Capacity (CEC) in the surface layer and the deep layer, respectively. The Sum of Exchangeable Bases (SEB) fell from 76 to 87% in the 0-20 cm layer and was improved by 48% in the deep layer. In the surface layer the saturation level of the (SBE/CEC) complex decreased by 64% while an improvement of 50% was observed in the deep layer.

The soil exchangeable acidity due to aluminum increased when moving from forest to the palm grove. This increase was function of the depth. In the surface layer, the content of exchangeable aluminum quadrupled. The level of organic matter in the soil decreases with the planting. In the surface layer, 70% of total carbon and 64% of total nitrogen were lost. The C/N ratio declined by 17%. In

Table 3: Physical and chemical characteristics of lands under forest or palm grove

| | | Forest | | Palm grove | |
|---|---|---|---|---|---|
| Variables | Sources of variation | 0-20 cm | 40-60 cm | 0-20 cm | 40-60 cm |
| Particle size | A (%) | 11.33b | 19.000a | 7.40c | 12.320b |
| | Lf (%) | 4.00a | 5.620a | 3.72b | 2.180c |
| | Lg (%) | 2.30a | 2.420a | 1.88b | 1.720b |
| | Sf (%) | 20.40a | 17.520c | 19.92b | 20.200a |
| | Sg (%) | 62.12b | 55.720c | 67.08a | 63.720b |
| Bases | $K^+$(meq/100 g) | 0.81a | 0.120c | 0.05b | 0.020b |
| | $Ca^{2+}$(meq/100 g) | 2.65a | 0.150c | 0.30b | 0.150c |
| | $Mg^{2+}$(meq/100 g) | 0.59a | 0.048c | 0.13b | 0.060c |
| | CEC (meq/100 g) | 9.28a | 5.290b | 3.28c | 4.036c |
| | SBE (meq/100 g) | 4.06a | 0.210c | 0.51b | 0.260c |
| | SBE/CEC | 43.76a | 4.010c | 15.57b | 6.450c |
| | P (ppm) | 60.20a | 29.200b | 14.60c | 24.600b |
| Organic matter and acidity | C (%) | 1.66c | 0.380b | 0.50a | 0.280b |
| | N (%) | 0.13a | 0.046b | 0.05b | 0.041b |
| | C/N | 12.29a | 9.160a | 10.34a | 6.310b |
| | PH | 4.99a | 5.720a | 5.08a | 5.320a |
| | $Al^{3+}$ total | 0.51b | 1.160a | 051.00b | 0.510b |
| | $Al^{3+}$ éxch | 11.16c | 84.700a | 50.68b | 76.980a |

Means followed by similar letters are not significantly different *:Significant; **: Highly significant; cal: Calculated; Theor: Theorical; t: Total; exch: Exchangeable

Table 4: Correlation between physicochemical parameters of different soils collected under forest and palm grove

| Sources of variation | Correlation coefficient (r) | Level of significance |
|---|---|---|
| **G1** | | |
| $Ca^{2+}$-SEB | 0.98 | ** |
| $Ca^{2+}$-SEB/CEC | 0.98 | ** |
| SBE-P | 0.64 | * |
| SEC/CEC-pH | 0.64 | * |
| $Ca^{2+}$-pH | 0.54 | * |
| $Ca^{2+}$-C | -0.94 | ** |
| SBE-C | -0.94 | ** |
| SBE/CEC-C | -0.95 | ** |
| **G2** | | |
| A-CEC | 0.99 | ** |
| A-pH | 0.94 | ** |
| CEC-pH | 0.93 | ** |
| Exch Al-A | 0.92 | ** |
| Alt-A | 0.92 | ** |
| pH-Ech Al | 0.84 | ** |
| A-P | 0.84 | ** |
| P-pH | 0.72 | * |
| **G3** | | |
| $Ca^{2+}$-SEB/CEC | 0.98 | ** |
| $Ca^{2+}$-SEB | 0.98 | ** |
| K+-$Ca^{2+}$ | 0.85 | ** |
| K+-$Mg^{2+}$ | 0.85 | ** |
| K+-CEC | -0.91 | ** |

Level of significance at p<0.05 or p<0.01; * is significant and ** is highly significant

the deep layer, 40% of total nitrogen were lost and the C/N ratio decreased by 46%. The decline in cation exchange capacity was greater in the surface layer because of the reduced level of colloidal form of organic matter and lower contents in fine elements.

## Interactions Between Different Physicochemical Properties of the Soil

The Standardized Principal Component Analysis (PCA) applied to physical and chemical parameters of soil allowed to highlight the dynamics of soils components and their interactions before and after exploitation. The first two factors F1 (45.65%) and F2 (34.15%) expressed more than 70% of the total variance and were selected for the interpretation of results in lands under forest (Fig. 1). Thus, group (G1) consisted of pH, $Ca^{2+}$ and SEB and SEB/CEC. The analysis of the correlation matrix

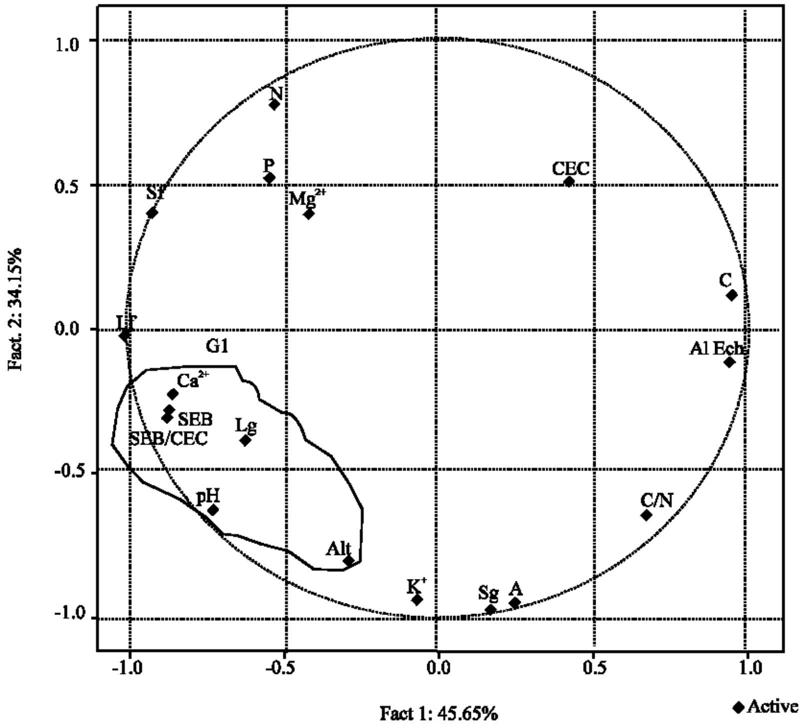

Fig. 1: Community Circles of the experimental design F1-F2 of the soil under forest

shown in Table 4, showed strong correlations between $Ca^{2+}$ and SBE (0.98), $Ca^{2+}$ and SEB/CEC (0.98), fine silt and pH (0.94), fine silt and SEB/CEC (0.90), fine silt and exchangeable aluminum (-0.89); coarse silt and CEC (-0.95), $Ca^{2+}$ and carbon (-0.94), SEB and carbon (-0.94), SEB/CEC and carbon (-0.95) and a correlation between $Ca^{2+}$ and pH (0.54), SEB and pH (0.64), SEB/CEC and pH (0.64).

For lands under plantation, the first two factors F1 (43.48%) and F2 (37.09%) expressed over 70% of the total variance and were selected for the interpretation of results. Thus, the first group (G2) consisted of exchangeable aluminum, total aluminum, clay, CEC, phosphorus and pH. The second group of parameters (G3) consisted of $Mg^{2+}$, SEB /CEC and $Ca^{2+}$ (Fig. 2). The analysis of the correlation matrix, shown in Table 4, also showed strong correlations between the parameters. As a result, the following associations were observed: clay and CEC (0.99), clay and pH (0.94), pH and CEC (0.93), pH and exchangeable aluminum (0.84), exchangeable aluminum and clay (0.92), total aluminum and clay (0.92), clay and phosphorus (0.84) and pH and phosphorus (0.72). The group (G3), exhibited a strong correlation between $K^+$ and $Mg^{2+}$ (0.85) $K^+$ and CEC (-0.91); $K^+$ and $C_a^{2+}$ (0.85); $Ca^{2+}$ and SEB / CEC (0.98) and $Ca^{2+}$ and SEB (0.98).

The impoverishment of the soil surface layer in fine elements is a result of leaching caused by the movement of water in the soil, which is more virulent under palm grove than in natural forest. This can be explained by the fact that the vegetal covering of the soil under palm grove is less abundant than in natural tropical forest. Indeed, the soil under the palm grove is poorly protected because *Pueraria javanica* which served as a covering crop is heliophilic and disappears as soon as the palm trees become adults and produces enough shade (El-Swaify *et al.*, 1988; Hauser *et al.*, 2006). The higher C/N ratio observed under palm grove reflects a more rapid evolution of the soil organic matter.

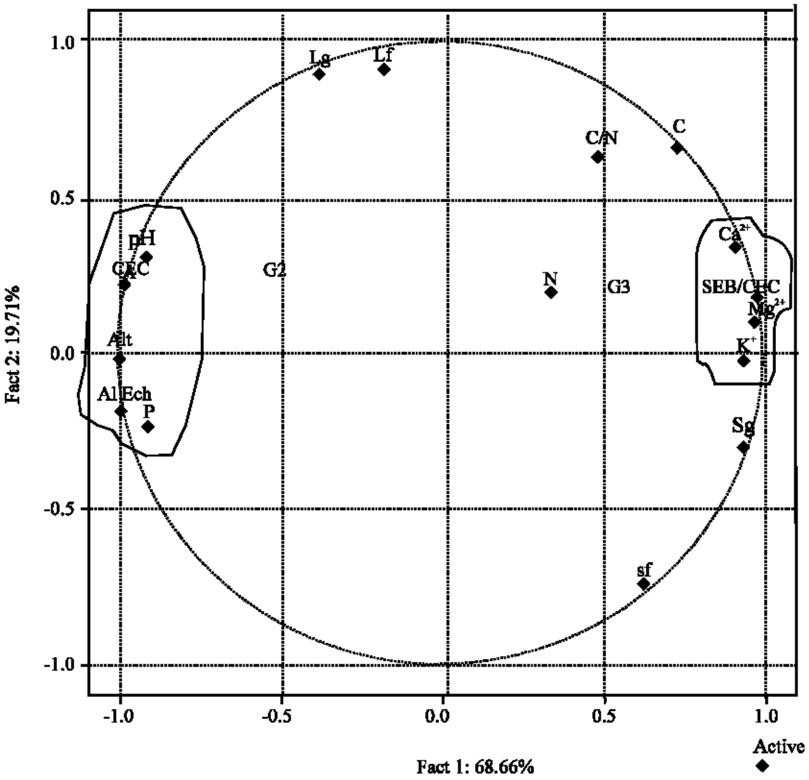

Fig. 2: Community circles of the experimental design F1-F2 of the soil under palm grove

The planting impoverished the soil in fines elements and organic matter. This impoverishment induced low content in exchangeable bases. In the palm oil tree, 90% of roots that ensure the absorption of nutrients are concentrated in the first sixty centimeters of soil (Jourdan and Rey, 1997). Therefore, the movement of fine elements and organic matter outside this layer makes them unavailable for the plant absorption system and are lost. It also appears that a significant proportion of potassium in potash fertilizers applied to the field is certainly lost by leaching. This suggests splitting the annual dose of potassium in several inputs in the soil and climate conditions. This loss of the ability of the soil is due to a deep leaching of fine particles.

The activities of the soil adsorbent complex are insured by the fines elements (clay minerals and organic colloids). The weakness of the cation exchange capacity of the soil under palm grove is a consequence of its low content in fine elements. The original weakness in cations is accentuated by the leaching of the adsorbent complex (Kanmegne *et al*., 2006). The management of potassium fertilization only on the basis of foliar diagnosis, without any monitoring of soil characteristics leads, in fact, to unsustainable exploitation of soil (Mafongoya *et al*., 2006).

The protected monoculture of palm oil tree has caused soil acidification by the release of exchangeable aluminum ions which combine with phosphorus to form non absorbed phospho-aluminic complexes responsible for slowing the development of the root system.

Present results are consistent with those of Haynes and Hamilton (1999), which points, 3 years after planting of crops in Central Cameroon, the loss of 51% of total carbon, 43% of total nitrogen, 20% labile phosphorus and 30% of sand for the 0-10 cm layer of soil.

Soil degradation under palm grove can be prevented or reduced by the culture of persistent covering crops, in order to provide a sustainable protection of the soil against driving rain (El-Swaify *et al*., 1988; Hauser *et al*., 2006; Roose, 2004), as well as the adequate arrangement of palm trees, in order to split water runoff and to reduce erosion strength.

## CONCLUSION

This study showed that long monoculture of palm oil tree degrades the soil in terms of its physical, chemical and physicochemical characteristics. Under palm grove, there was a decline of soil stock in nutrients, a decrease of its ability to store them and an aluminum acidification. This soil degradation was mostly related to a deep leaching of fine particles. In addition, this study led to the suggestion that annual doses of potassium fertilizers should be split, in order to obtain a better economic benefit and sustainable management of the ground heritage.

## REFERENCES

Boyer, J., 1982. Ferrallitic Soils. Volume X. Fertility Factors and Land Use. Initiations-Documents Techniques No. 52, ORSTOM, Paris, ISBN: 2709906376, pp: 384.

El-Swaify, S.A., A. Lo, R. Joy, L. Shinshiro and R.S. Yost, 1988. Achieving conservation-effectiveness in the tropics using legumes. Soil Technol., 1: 1-12.

Hamado, S., B. Laurent, L. Daniel and P.Z. Nabsanna, 2008. Restoring potentialities using zai and compost in Yatenga (Burkina Faso). Biotechnol. Agron. Soc. Environ., 12: 279-290.

Hauser, S., C. Nolte and R.J. Carsky, 2006. What role can planted fallows play in the humid and sub-humid zone of West and Central Africa? Nutr. Cycl. Agroecosyst., 76: 297-318.

Haynes, R.J. and C.S. Hamilton, 1999. Effects of sugarcane production on soil quality: A synthesis of world literature. Proc. S. Afr. Sug. Technol. Assoc., 73: 45-51.

Jourdan, C. and H. Rey, 1997. Architecture and development of the oil-palm (*Elaeis guineensis* Jacq.) root system. Plant Soil, 189: 33-48.

Kanmegne, J., E.M.A. Smaling, L. Brussaard, A. Gansop-Kouomegne and A. Boukong, 2006. Nutrient flows in smallholder production systems in the humid forest zone of Southern Cameroon. Nutr. Cycl. Agroecosyst., 76: 233-248.

Lahmar, R. and A. Ruellan, 2007. Degradation des sols et strategies cooperatives en Mediterranee: La pression sur les resources naturales et les strategies de development durable. Cahiers Agric., 16: 318-323.

Mafongoya, P.L., A. Bationo J. Kihara and B.S. Waswa, 2006. Appropriate technologies to replenish soil fertility in Southern Africa. Nutr. Cycl. Agroecosyst., 76: 137-151.

Manly, B.F.J., 1994. Multivariate Statistical Methods: A Primer. Chapman and Hall, UK.

Roose, E., 2004. The management of water conservation and soil fertility: A new strategy of anti-erosion for sustainable development. Secheresse, 15: 5-7.

Sivakumar, M.V.K. and R. Stefanski, 2007. Climate and Land Degradation-an Overview. In: Climate and Land Degradation, Sivakumar, M.V.K. and N. Ndiangui (Eds.). Springer Berlin Heidelberg, UK., ISBN: 978-3-540-72437-7, pp: 105-135.

Thomassone, R., C. Dervin and J.P. Masson, 1993. Biometrie: Modelisation des Phenomenes Biologiques. Masson, Paris, France, ISBN: 2-225-84074-1, pp: 553.