Improving the quality of sandy soils of the Batéké plateau (D.R. Congo) by using local geological materials and industrial organic waste products

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In tropical Africa, a productive and sustainable agricultural system is one of the fundamental priorities to the well-being and food safety of the population, and it constitutes a cornerstone of development. The fast growing African population and the continued soil fertility degradation require special management practices for sustaining agricultural productivity over a long period of time. This is of particular importance to the province of Kinshasa (DR Congo), where the sandy soils covering the major part of its hinterlands are very marginal and severely constraining the food supply to the capital. Furthermore, the farmers and local population have only limited capital at their disposal and therefore cannot afford regular applications of conventional chemically processed fertilizers. The use of local geological resources (agrominerals, rock fertilizers or petrofertilizers) and organic industrial wastes in the crop production systems can be an alternative solution to enhance soil productivity.

This study has been conducted within the frame of research for appropriate methods of sustainable management of the sandy soils of Kinshasa's hinterland, in order to ensure and guarantee the food security. It consists of scientific research of the use of greenstone of Gangila, pink dolomite of Kimpese, rock phosphate of Kanzi and coffee waste to improve the quality of the sandy soils on the Batéké plateau, being the eastern part of Kinshasa's hinterland. The study comprises 7 different chapters. The first two chapters are devoted to the physical environment of the Batéké plateau and to a literature review on the use of agrominerals and industrial coffee wastes in agriculture, as well as to the theoretical concepts used to describe surface charges of highly weathered, tropical soils. The 5 last chapters deal, respectively, with the agropedological status of the soils, the impact assessment of *Acacia auriculiformis* forest on the chemical fertility of soils, the characterization of the amendments, the reactions of these amendments with the soils, and their effects on plant growth and mineral nutrition.

The determination of the agropedological status of the soils showed that the Batéké sandy soils, classified as *Rubic Ferralic Arenosols (Dystric)* in WRB (FAO, 2006), and as *Isohyperthermic Ustoxique Quartzipsamments* according to USDA Soil Taxonomy (Soil Survey Staff, 2006), have a clayey mineralogy limited to kaolinite and residual oxides of Al and Ti. These soils are dominated by variable charge colloids; they present an acid reaction with Al and Mn toxicities, and have low organic matter and mineral nutrient contents.

Furthermore, their water and nutrient storage capacity is very limited. The low chemical soil fertility and low water holding capacity are likely to be the major constraints to the agricultural productivity of these soils.

Impact assessment of the *Acacia auriculiformis* forest on the chemical fertility of the Batéké soils revealed that the *Acacia* fallows significantly improve organic carbon and nitrogen contents, sum of base cations and cation exchange capacity. The *Acacia* trees act as a major *source* of organic matter (OM), hence increasing organic carbon and nitrogen content and decreasing the C/N ratio up to the optimal range. The increased OM content suggests that humification processes are the main cause of the significant decrease in pH. The study revealed that the point of zero net proton charge was systematically lower than soil pH and that it decreased with increasing OM content, thereby increasing the cation exchange capacity (CEC), although the concurrent acidification retarded a significant beneficial impact at field pH for *Acacia* fallows of 10 years and older. The study clearly showed that slash-and-burn practices are required to correct soil acidity, and to liberate the nutrients stored in the remaining biomass and litter before each new cropping period.

Physico-chemical and mineralogical characterization of the amendments permitted to highlight their agronomical potential and provided useful information about their ability to release nutrients in an acid environment. The study showed that the greenstone of Gangila is an ultrabasic and peraluminous rock, mainly composed of chlorite, epidote, amphibole (hornblende), feldspars (plagioclases) and quartz. It presents a basic reaction in aqueous solution (pH 8.7), and possesses a calcium carbonate equivalent (CCE) of about 19.5%. Pink dolostone of Kimpese was classified as dolomitic limestone with a mineralogical composition limited to dolomite, calcite and quartz. It is characterized by a basic reaction in aqueous solution (pH 10.5) with a CCE of 85%. Kanzi rock phosphate is a natural sedimentary phosphate classified as medium to high reactive. It contains on average about 22% P_2O_5 with fluoroapatite and wavellite as major potential *sources* of phosphorus. On the other hand, coffee waste presents the excellent properties of organic manure containing about 45% OC, 1.7% N, 3.0% K_2O and 30% cellulose, and has a lignin/N ratio of 17, promoting its mineralization in terrestrial ecosystems. Its aqueous solution has a pH of about 7.9 and it has an acid neutralizing capacity (CCE) of about 18%. Overall, the study indicated that all materials have the required properties to be used as natural amendments of acid tropical soils.

The study of the amendment reactions with the soils gave satisfactory results. All amendments significantly increased the soil pH above 5.5, with a substantial neutralization of exchangeable Al. With respect to soil organic matter status, the study revealed that application of coffee waste to soil, stimulated the highest production of OM, increased significantly the N content, and improved organic matter quality by decreasing the C/N ratio, while Kanzi rock phosphate significantly increased the availability of soil phosphorus. The CEC of the soil significantly improved due to the liming effect and/or the increase in OC content, induced by amendment application. The restoration of the base saturation was improved depending on the type of amendment used; an important Ca and/or Mg saturation was achieved by dolostone, greenstone and Kanzi rock phosphate,

while coffee waste restored the exchange complex with up to 18% of exchangeable K. A study of the charge properties of both the control and amended soils highlighted that the surface charge is largely pH dependent and that it increases with increasing organic matter content. The developed negative charge CECT was very positively correlated with the difference ($pH_o - pH_{soil}$). However, application of coffee waste and Kanzi rock phosphate decreased pH_o, as a result of the increasing OM content or specific phosphate sorption with the production of additional negative charges. The liming effect induced by the amendments resulted in a significant increase of the negative charge component CEC_T, and a concomitant decrease of the positive charge AEC. The study showed that although the dolomitic limestone induced the highest development of negative charge CEC_T, the persistence of this beneficial effect was recorded in coffee waste amended soils.

Application of greenstone of Gangila, Kanzi rock phosphate, dolomictic limestone from Kimpese and coffee waste to soil, increased the water retention by about 3, 6, 7 and 9% respectively. The study showed that all applied agrominerals affected the dynamic of base cations, and the relative loss of monovalent cations was higher than that of bivalent ones.

The study of the effects of amendments on plant growth and mineral nutrition revealed very interesting results. Application of the amendments to the Batéké Arenosols significantly increased the dry matter (DM) of the plants. The highest soybean yield (DM, grains) was recorded for plants harvested from dolostone amended soils, while coffee waste stimulated the highest dry matter production of Italian ray-grass. All amendments increased the absorption of nutrients (N, P, Ca, Mg and K) by plants, although K, P and/or N were limiting factors for plant growth. The results also illustrated that, at the end of the soybean and ray-grass experiment, all amended soils were exempted from Al toxicity, having a pH exceeding 5.5, and still contained nutrients (N, P, K, Ca, Mg) which could be used for the subsequent crops. The study clearly showed that plant productivity can be further increased by mixing agrominerals with coffee waste or other organic manure rich in N, P and K content.