Managing soil fertility to sustain crop production in the watersheds in Senegal

Mateugue Diack[A], Fary Diom[B] and Khady Sow[C]

[A]UFR de Sciences Agronomiques, d'Aquaculture et de Technologie Alimentaire, Université Gaston Berger, Saint-Louis, Sénégal, Email madiackaly@yahoo.com
[B]Institut des Sciences de la Terre, Université Cheikh Anta Diop, Dakar, Sénégal, Email diomfary@ucad.sn
[C]Agence Nationale du Conseil Agricole et Rural, BP 494, Kaolack, Sénégal, Email sowkhady1@yahoo.fr

Abstract
Crop production has been decreasing in the past decades, due to some extent to the rapid population growth, coupled with the increase population of livestock on the rangelands. As a result, there has been pressure on land and cultivation on marginal lands to maintain food production at minimum levels. Land mismanagement, inappropriate soil management and farming practices among others have accentuated soil erosion, nutrient depletion as well as environment degradation. In the fight against land degradation, emphasis needs to be shifted away from the erection of physical structures to a better understanding of the role of watershed as a provider of nutrients for soil quality improvement. This study relates the chemical composition of the geomorphologic units, within the watershed, to the soil fertility and crop production. A ultimate goal of watershed management is to achieve and maintain a balance between resource development to increase the welfare of the population - and resource conservation to safeguard resources for future exploitation and to maintain ecological diversity - both for ethical reasons and as an assumed prerequisite for the survival of mankind, then the objective of this study is to increase/stabilize production of crops and forage.

Key Words
Soil fertility, watershed management, soil degradation, soil chemical properties, farming practices, crop production

Introduction
The rapid population growth which, in the past decade, exceeded growth in agricultural production has resulted in pressure on land and cultivation on marginal lands to maintain food production at minimum level. Coupled with this situation, is the increased population of livestock on the rangelands which are minimally managed and, in most cases, over-stocked, causing serious soil erosion and land degradation. Deforestation, land mismanagement, bush fires and inappropriate soil management and farming practices among others have accentuated land as well as environment degradation (Chopart *et al.* 1979). Nutrient depletion is the most important element in the land degradation equation (Pieri 1989; Ndiaye 1979). Many areas in Senegal have predominant inherently low fertility soils; degraded soils, soils cropped over long periods and removal of nutrients through crops and residues both for domestic and export crops-without replenishing the nutrients lost and use of marginal areas unsuitable for agricultural activities (Diack *et al.* 2000). In addition, non-adoption of improved management practices by the majority of farmers has resulted in accelerated erosion, one of the major causes of land degradation. As a result, arable lands have decreased from 3.8 10^6 to 2.4 10^6 ha with a drastic decrease in the use of upland soils for crop production. As an alternative, the watershed is an area which catches the water from precipitation and is then drained by a river and its tributaries. It is a "resource region" where the eco-system is closely interconnected around a basic resource - water. The watershed or river basin is therefore an ideal management unit (Michel 1973). Micro-watershed planning has been conceived and adopted for holistic development of rainfed farming in recent years. Watershed management is fast becoming a blueprint for agricultural development in most parts of the country today, by introduction of improved soil and moisture conservation measures, better crop and rangeland management practices. The objective of this study is (1) to determine the key-soil chemical properties within two morphological units; (2) to provide guidance for future studies on management strategies of watersheds to improve crop production.

Methods
Watershed site
The watershed is located in the Koutango village, Kaolack, a semiarid agrecological zone in the southern part of the peanut basin. It covers 173.3 km^2 between 13^O 66' and 13^O 82' and 15^O 91' and 16^O 09'. The region is characterized by a north Sudanian climate with an average annual rainfall of 700 mm. Rainfall

events (June-October) are quite aggressive with a degradation index of 1730 t/km^2/an. Temperatures vary between 20^{O}C in December-January and 35^{O}C in April-June. Vegetation is relatively dense and represented by *Cordyla pinnata* associated with *Combretum glutinosa* and *Piliostigma reticulaum*. From its toposequence, the watershed presents four geomorphologic sequences: an upland unit which is 40 m high, naturally established colluvium on a slight slope, a flat terrace and a lowland unit. For the purpose of this study, the last three units were evaluated in terms of soil fertility within the watershed, by analyzing soil chemical properties.

Soil analysis
Soil sampling was done from soil profile, according to the distinct number of layers and soil horizons, in each of the two morphological soil units. Each soil sample was analyzed for total carbon (C) by the Walkley-Black method, total nitrogen (N) by the Kjeldalh method, total phosphorus (P) by the Duval method and cation exchange capacity (CEC) by the Cobaltihexamine Chloride method.

Results and discussion
Total carbon content varies between 3.14 and 25.20 g/kg under lowland condition. In the colluvium, total C varies between 1.29 and 3.14 g/kg whereas under terrace condition, it varies between 1.21 and 3.00 g/kg (Figure 1). Compared to the colluvium and terrace soils, the lowland soil presents the highest values for total C content, at the soil surface, within the watershed. With high soil moisture content from rainfall and the presence of diverse vegetation, the soil carbon content tends to accumulate over time, which contributes to an establishment of a good soil fertility level.

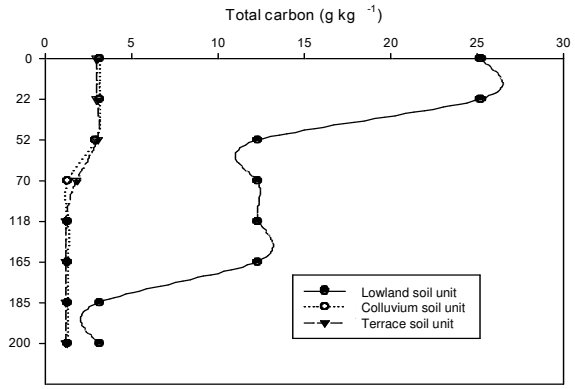

Figure 1. Total soil carbon for soils in the different geomorphologic units within the watershed.

Total soil N content varies between 0.32 and 1.50 g/kg. For the colluvium varies between 0.18 and 0.32 g/kg while under terrace conditions, total N varies between 0.18 and 0.22 g/kg (Figure 2). Similar to the soil carbon, total nitrogen has the highest content under lowland conditions as compared to colluvium and terrace.

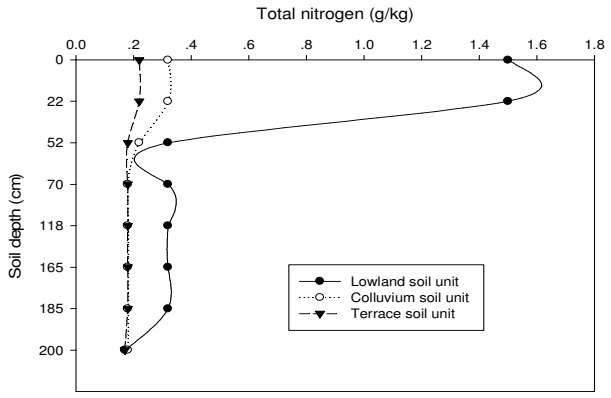

Figure 2. Total soil nitrogen for soils in the different geomorphologic units within the watershed.

Under lowland conditions, the total P content varies between 0.18 and 0.42 g/kg whereas in the colluviums, it varies between 0.21 and 0.41 g/kg and between 0.16 and 19 g/kg for the terrace (Figure 3). It has been noted that total P contents are not different between the lowland and colluviums units in the shallow layers. This could be due to the presence of Fe as Fe is linked to P in general for most tropical soils (Cissé 1981)

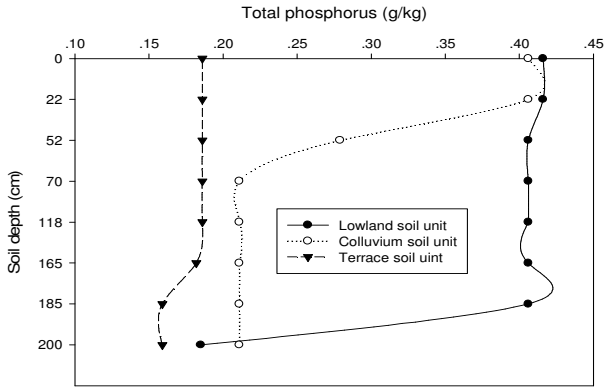

Figure 3. Total soil phosphorus for soils in the different geomorphologic units within the watershed.

Soils from the lowland have CEC contents varying between 1.10 and 11.6 me/100g. In the colluviums CEC content varies from 2.30 to 5.70 me/100 g whereas in the terrace, it varies between 1.50 and 2.10 me/100 g. The highest contents are noted for soils under lowland conditions, particularly in the horizons high in clay and/or organic matter (Figure 4).

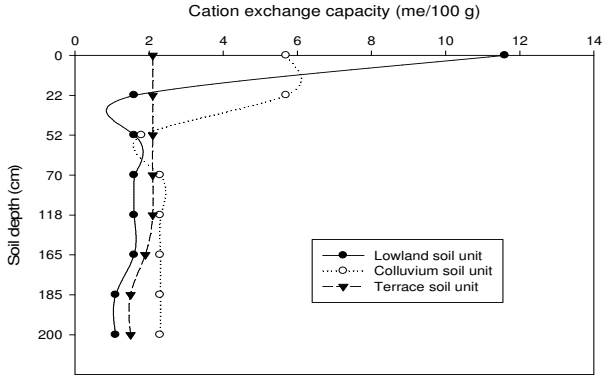

Figure 4. Cation exchange capacity for soils in the different geomorphologic units within the watershed.

Conclusion

Based on an evaluation of the chemical soil properties, through comparison, of the different components of the watershed, soils under lowland conditions seem to be more suitable for sustainable crop productivity. Upland soils are known for not having high enough levels of nutrients for crop production in an environment where pressure on land and cultivation on marginal lands to maintain food production is an issue. Therefore, the management of watersheds throughout the region needs to be undertaken.

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