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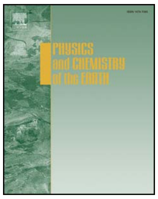

Fertility status of cultivated floodplain soils in the Zambezi Valley, northern Zimbabwe

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ABSTRACT

Flood–recession cropping improves smallholder farmers' household food security. The objective of this study was to determine the fertility status of cultivated Zambezi Valley floodplain soils, in northern Zimbabwe. The study was conducted at three sites, along tributaries of Musengezi River. Soil samples were taken at 0.20 m depth increments to 0.60 m from hydromorphologically stratified fields, during the cropping season. Sampling points were replicated twice in each stratum at points equidistant from river edges. Relative elevations of sampling points were measured using levelling equipment. Soil was analysed using: core method for bulk density, hydrometer method for texture, loss on ignition for soil organic carbon (SOC), Kjeldahl procedure for total nitrogen (N), 0.01 M $CaCl_2$ for pH, and Inductively Coupled Plasma (ICP) for Mehlich 3 extractable elements. Data from soil analyses were subjected to One Way Analysis of Variance and Pearson's correlation analysis. Bulk density ranged from 1.2 to 1.4 $g\,cm^{-3}$ and it was negatively related to distance from river; and positively related to elevation at two sites. Highest values for SOC and total N were 2.04% and 0.36% respectively. Soil pH ranged from 7.70 to 8.60. Soil organic carbon and N were positively related to distance from river but negatively related to elevation. Threshold concentrations for deficiency: < 12 ppm for K, and < 39 ppm for Mg, were exceeded. Calcium, Na, and micronutrients in most cases exceeded concentrations reported for floodplains. Practices that slow down flowing water and fertilizer microdosing are among possible fertility management options.

1. Introduction

Floodplains are among the most productive ecosystems in the world, usually endowed with fertile alluvial soils and water resources (Adams, 1993; Koschorreck and Darwich, 2003; Lynch and Brown, 2000; Pwiti, 1996; Rinklebe et al., 2007). Flood–recession cropping, planting crops after a river's seasonal flood recedes, provides multifaceted adaptation to extreme weather conditions namely droughts and floods; poor rainfall distribution and poor soil fertility that often limit crop productivity in semi–arid Sub–Saharan Africa (Motsumi et al., 2012; Postel, 2000). In addition, floodplains provide a unique setting that is able to support more crop production intensification than the adjacent upland areas. Flood–recession cropping is so lucrative that in some cases, smallholder farmers continue to live in areas where regular flood–related disasters that include drowning of people and livestock, disease outbreaks, attack of people and livestock by wildlife, and loss of property occur regularly (Mavhura et al., 2013). Efficient management and sustainable utilisation of floodplains reduces food import costs through improved crop productivity. The economic value of flood–recession cropping in the Zambezi basin was estimated at US$50 million (Schuyt, 2005).

According to Postel (2000), the majority of water–stressed populations in 2025 will be in Sub–Saharan Africa and Asia. Therefore, ability to thrive despite local extreme weather events that are associated with climate change implies that flood–recession cropping will increase in importance as climate change intensifies. In addition, the need to meet the food requirements of an ever–growing population (Mathews et al., 2013; Schuyt, 2005) and to support sustainable rural livelihoods (Andriesse et al., 2007) will contribute to pressure on floodplains. Low crop yields obtained in upland fields caused by extreme weather events will force more and more people to practise flood–recession cropping in the fertile but environmentally fragile floodplains. Under these conditions, best management practices need to be developed in order to optimise crop productivity and environmental protection. In fact, opening up new areas in floodplains should be minimized in order to strike a balance between agriculture and nature. Therefore, as Nyamangara et al. (2000) asserts, with respect to communal areas, increases in crop production must be achieved by increasing the productivity of currently cultivated land rather than opening up virgin

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land. Although floodplains share some common attributes; differences exists regularly and this necessitates development of site–specific 'best fit' technologies and policies.

The ability of farmers to maintain soil fertility over time has been a major challenge in upland smallholder farming areas in Sub–Saharan Africa (Nyamangara et al., 2000; Tittonell and Giller, 2013). In these areas, a decrease in soil organic matter content has led to prevalence of degraded non–responsive soils (Mapfumo and Giller, 2001; Tittonell and Giller, 2013). The single most important nutrient element that limits crop production in Sub–Saharan Africa is nitrogen (N). Although N enrichment in wetlands has been reported (Hefting et al., 2005; Isermann, 1990; Meybeck and Helmer, 1989), the problem of excess N may not exist in Sub–Saharan Africa as often reported in temperate zones. Low N fertilizer use in the catchment areas may result in limited N deposition; thus N management may require a different management route from that reported in temperate areas. In Zimbabwe's communal areas, nutrient deficiencies are common for N, phosphorus (P), and sulphur (S) (Nyamangara et al., 2000). In addition, deficiencies of magnesium (Mg), potassium (K) and zinc (Zn) and copper (Cu) have been reported in degraded soils (Grant, 1981; Mugwira and Nyamangara, 1988; Zingore et al., 2007).

There is paucity of published literature on soil fertility status under flood–recession cropping in the Zambezi Valley. Replacement of natural vegetation by annual crops during the terrestrial phase alters the carbon content and distribution in the soil profile. The magnitude of change in C distribution is likely to be influenced by crop residue and weed management methods employed by the farmers. It is important to determine to what extent annual deposition of silt by retreating floods serve as natural mechanisms for soil fertility renewal under continuous cropping. Therefore, the objective of this study was to determine the fertility status of the Zambezi Valley floodplain soils in Muzarabani communal areas. It is envisaged that information on soil fertility status would provide a basis for selection of options for sustainable management of the floodplain. Maize (*Zea mays* L.), the staple and most cultivated food crop in the floodplains was chosen as a reference crop for determination of fertilizer recommendations in order to relate the fertility status of the soils to crop nutrient requirements.

2. Materials and methods

2.1. Study area

The study was conducted in Muzarabani Communal Area (16.12°S; 031.15°E, altitude 334 m a.s.l.) in Centenary district, northern Zimbabwe (Fig. 1). The major river in the area is Musengezi, a tributary of the Zambezi River. The area receives most of its rainfall between December and March and the mean annual rainfall is 650 mm. The mean annual temperature is 25 °C and the area is frost free (Pwiti, 1996). Soil type ranges from fine–grained loamy sands to sandy clays (Anderson et al., 1993). According to the FAO/UNESCO soil classification, the soils are classified as Calcaric Cambisols, Eutric Vertisols, Vertic Cambisols, Chromic Cambisols, Calcic/Chromic Luvisols (Anderson et al., 1993). The soils generally have high agricultural potential. Maize, cotton (*Gossypium hirsutum* L.) sorghum (*Sorghum bicolor* L. Moench), and pearl millet (*Pennisetum glaucum* L. R. Br.) are the major upland rainfed crops. The vegetation is typically of dry savanna type, dominated by *Colophospermum mopane* Kirk ex Benth. and species of *Combretum*, *Sterculia* and *Vachellia* (previously *Acacia*). The naturalised *Ziziphus mauritiana* Lam., is also common. Dominant grass species include spear grass *Heteropogon contortus* (L.) Beauv. ex Roem. & Schult and some *Digitaria* species.

Seasonal floods, which mostly occur between January and February, are a frequent phenomenon in this area. In addition to the low–lying nature of the area, its location between the Kariba dam, upstream and Cahora Bassa dam, downstream, predisposes the area to human–engineered flooding (Mavhura et al., 2013) and farmers use the residual moisture and the alluvial soils for crop production.

2.2. Experimental design

2.2.1. Site selection and description

Three research sites, two along Zhoubvunda River, and one on Mukumbura River, tributaries of Musengezi River were selected (Fig. 1). Fields that experience flooding, where flood–recession cropping was practised almost yearly were selected after consultation with the owners. Five farmers' fields were chosen, but for the purposes of this study, these were considered as three sites because fields that were a continuum on the same side of the river were regarded as one. The three sites are herein identified as Zhoubvunda 1 (16.18S; 031.19E, altitude 363 m a.s.l.), Zhoubvunda 2 (16.17S; 031.18E, altitude 352 m a.s.l.) and Mukumbura (16.01S; 031.19E, altitude 328 m a.s.l.)

According to the farmers, flood–recession cropping at Zhoubvunda sites dates back to the 1960s. Land area under cropping was smaller than the current field boundaries, which have been in existence since early 1980s. At Mukumbura, flood–recession cropping reportedly began in the year 2000.

The major crop grown at all the sites is maize and the other crops include cowpeas (*Vigna unguiculata* (L.) Walp.), sugar beans (*Phaseolus vulgaris* L.), watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai, pumpkins (*Curcubita* spp.) and sweet potatoes (*Ipomoea batatas* L.). Farmers maintain *Z. mauritiana* trees in their fields. Field edges are bound by live fences. Land is cleared using slashes and axes followed by burning of the vegetative material.

2.2.2. Soil sampling

Soil samples were collected between June and July 2015, during the flooding–recession cropping season. In order to capture the full range of soil types and hydrological conditions (Rinklebe et al., 2007), the selected fields were stratified according to hydromorphological regimes, resulting in sampling points at distances: 30, 64, 123, 186, and 225 m from the river edge at Mukumbura; 36, 107, and 161 m, from the edge of the river at Zhoubvunda 1; and 42, 93, 120 and 170 m, from the edge of river at Zhoubvunda 2. Sampling points were replicated twice in each stratum. The replicates were approximately equidistant from the edge of the river and are hereafter referred to as measuring positions.

Soil samples for chemical analysis and textural determination were taken from profile pits at 0.20 m depth increments up to 0.60 m. Separate soil samples were taken using 100 cm^3 cores at the same depths for bulk density determination. Although differences in the topography of floodplains are usually slight, they result in important hydrological and pedological differences (Pinay et al., 2002; Rinklebe et al., 2007); therefore, relative elevations of measuring positions were measured using Leica Runner 20 Automatic level (Leica Geosystems, Switzerland).

2.2.3. Laboratory analyses

Soil bulk density was determined for 72 samples that were oven-–dried for 48 h at 105 °C. Soil texture was analysed using the hydrometer method (Bouyoucos, 1962). Organic matter content was estimated by the loss on ignition (LOI) method at 550 °C for 12 h in a muffle furnace (Ziadi and Tran, 2008). Prior to ignition and chemical analyses, soil samples were crushed to pass through 0.425 mm sieve and mixed to ensure homogeneity. Soil organic carbon (SOC) was estimated by dividing organic matter content by a factor of 1.724 (Jiménez and García, 1982).

Potassium, Calcium (Ca), Mg, Sodium (Na), Cu, Zn, Manganese (Mn), Boron (B), Molybdenum (Mo), Nickel (Ni), Cobalt (Co) and Iron (Fe) were extracted using the Mehlich 3 method (Ziadi and Tran, 2008); and analysed using the Inductively Coupled Plasma (ICP– SPECTRO ARCOS CETAC AUTO SAMPLER ASX52–AMETEK, Germany).

Nitrogen was analysed using the Kjeldahl procedure (Rutherford et al., 2008). Digestion was done in the Foss Tecator Desiccator at