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Effects of traditional soil management practices on the nutrient status in Sahelian sandy soils of Niger, West Africa

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ABSTRACT

In the Fakara region of the Sahel zone, Niger, West Africa, farmers have been implementing traditional soil management practices such as the application of dry farmyard manure (FYM) and household waste (HHW), livestock corralling, and fallows. Previous studies, however, have not accumulated enough data on the effects of these practices on the soil nitrogen (N) pool in the Sahelian sandy soils.

The objectives of this study were to evaluate the effects of these traditional practices on each N pool and on other nutrients. As the indicator of available N, phosphate buffer extractable organic nitrogen (PEON) was employed. Total N was significantly higher in the fields adjacent to houses (H) and suburban fields where FYM had been applied for 10 years (FYM10) or 5 years (FYM5), compared with that in the no-treatment fields (NT) which had received no organic matter (OM) and chemical fertilizer for several decades. FYM10, H, and reserved fallows (RF) showed significantly higher levels of PEON than of NT. The amounts of total N and PEON in soils from all corralling practices, and all normal fallows were at the same level compared with NT. Similarly, the mineral N pool was higher for the soils from H, FYM10, and mixed corralling with sheep and goats.

The principal component analyses (PCA) showed that all eigenvalues of soil pH, exchangeable potassium (K), available phosphorus (P), total N and carbon (C), PEON and mineral N in principal component 1 (PC1) were positive, thus relating strongly to soil management practices which can enhance the essential nutrients: the pool of N, P, and K, and C pool in soil. For PC2, the eigenvalues of mineral N, exchangeable K, and pH were positive, strongly relating to soil management practices which can enhance cations in soil. In comparison with NT the eigenvalues of PC1 of the managements with OM application were higher than in NT while those for the normal fallows without OM application were as low as those in NT. The eigenvalues of PC2 were higher for H and all corralling practices compared with the values for NT. We understood that the practices of transporting manure and corralling are important for the improvement of the fertility of Sahelian soils. Furthermore, the findings suggest that corralling is a more economical and useful practice than the others; livestock are moved around and drop manure directly on the farmland, thus the loss of OM in transportation and the labor requirement are also low.

1. Introduction

In the Sahel zone of West Africa, famers have used traditional fallow practices to restore soil fertility. Recently, however, long-term fallows are less frequently employed, mainly because population increases have had an impact on land use in the region (de Rouw and Rajot, 2004). In the Sahel zone of several West African countries, such as Senegal, Mali, Niger, Burkina Faso, and Chad, the average annual rate of population increase was 3.2% in 1995, 2.8% in 2005, and 2.8% in 2010. These rates are extremely high compared with those of advanced countries (U. S. Census Bureau, 2011). For three villages in the Fakara region of Niger, where this study was conducted, the annual rate of population increase was about 3.2% on average from 1988 to 1996 (Hiernaux and Ayantunde, 2004).

The normal fallow practices used to have duration of more than 15 years (Wezel and Haigis, 2002). In the last 20 years, farmers have started to reduce the length of fallows and to practice continuous cultivation because of population pressure (Achard and Banoin, 2003; Wezel and Haigis, 2002). International Livestock Research Institute (ILRI) reported that the duration of fallows is about 3.0 years (±0.3) and it is extremely short compared with 4.9 years (±0.3), the duration of cultivation (Hiernaux and Ayantunde, 2004). In a previous study conducted in the Chical village (14°25′N, 3°26′E) in the northeast of the Fakara region, 42% of farmers practicing fallows did so for 1 to 3 years, 44% for 4 to 10 years, and only 14% for 10 to 30 years ($n = 50$) (Schlecht and Buerkert, 2004). Wezel and Haigis (2002) suggested

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that the current short-term fallows are not sufficient to restore soil fertility. They advised farmers in Niger to continue fallowing for more than 15 years to increase the organic matter (OM) level. To address this situation, farmers started to cultivate with alternative soil management practices, such as transporting farmyard manure (FYM) and household waste (HHW), and corralling livestock to allow the direct dropping of manure on the farmland. In previous studies, nutrient budgets in the practices of transporting manure and corralling were relatively well understood (Achard and Banoin, 2003; Harris, 1998, 1999; Schlecht et al., 2004). However, the effects of the farmers' traditional soil managements on the chemical properties of the Sahelian sandy soils have been minimally studied. There are only a few reports on the pool size of total nitrogen (N), total carbon (C) or organic C, available phosphorus (P), and exchangeable potassium (K) under the different traditional soil managements (Gandah et al., 2003; Hoffmann et al., 2001). Furthermore, the previous studies have not addressed the available N in these farmlands.

We have reported that phosphate-buffer extractable organic nitrogen (PEON) can be used as a good indicator of the amount of available N in the Sahelian sandy soils (Suzuki et al., 2008). PEON is an intermediate N pool between total N and mineral N, and therefore has important roles as both a storehouse and a source of available N for the crops (Matsumoto et al., 2000a,b; Ogawa et al., 1989; Suzuki et al., 2008). Accordingly we decided to use PEON as the new indicator for available N in this study. The objective of this study was to evaluate the effect of traditional soil management practices on soil N pools, the pool of other nutrients, and pH.

2. Materials and methods

2.1. Study site

Three villages in the Fakara region of Tillabéri prefecture in Niger, West Africa, were selected for this study: Banizoumbou (BZ, 13°31′N, 2°39′E); Kodey (KD, 13°22′N, 2°50′E); and Tchigo Tégui (TT, 13°30′N, 2°46′E) (Fig. 1). A detailed description of these villages is reported by Suzuki et al. (2008). Forty farmlands with various soil management practices were chosen by using village maps, based on the database of International Livestock Research Institute (ILRI). To acquire information on the practices of OM application, field surveys were conducted in 2005 from 21 to 23 June and from 18 to 20 July. Based on the field surveys, 33 farmlands from three villages were selected (Fig. 1).

The traditional soil management methods used in the study sites were transporting manure of FYM and HHW, livestock corralling, and fallow practices (Table 1). In the transporting manure practice, HHW includes crop residues and leftovers from the houses; FYM contains manure from sheep, goats, and chickens which is piled up near the houses (Ooyama, 2005). Farmers carry FYM and HHW to the farmland either by hand or on carts for application during the dry season. When farmers manually apply this OM to their fields, they either spread it uniformly over the fields or place it sporadically on certain parts of the fields (Fig. 2). Farmers were reported to apply OM more intensively to the places where the crop growth was not good in the previous season in order to achieve more homogeneous crop growth over the farmland (Schlecht and Buerkert, 2004).

In this study, we selected pearl millet fields in which FYM and HHW had been applied continuously for 5 years (FYM5) (Table 1) or for more than 10 years (FYM10), based on interviews with farmers and information obtained from the ILRI database (Hiernaux and Ayantunde, 2004). Because OM is not applied uniformly to farmland each year, the sites for soil sampling were selected from places where OM was applied during the previous dry season (December 2004 to May 2005). In addition, we chose the fields adjacent to the houses (H) where a mixture of FYM and HHW was applied almost daily. The frequency and intensity of OM application surrounding the houses were much higher than on those farmlands where it was applied manually (Table 1).

The livestock corralling practice is conducted by enclosing the livestock on farmlands to dung the fields directly. To enclose livestock in a part of the field, farmers construct a temporary fence to hold the animals, or draw cows to parts of the field by enclosing the calves in a certain area. In an additional approach, sheep and goats are tied to stakes. Cows are the primary animals corralled in the field for manuring, but some farmers with a constrained household economy use small ruminants. The corralling practice is relatively common because it does not require carts or human labor to transport manure to the field. In addition, cows and small ruminants trample the manure and mix it with the surface soils, thus reducing losses by wind erosion. Farmers consider that the effects of the manure continue for 3 to 5 years after corralling (Hoffmann et al., 2001). Accordingly, they generally change the corralling site to return to the same place in the farmland after 3 to 5 years (Fig. 3).

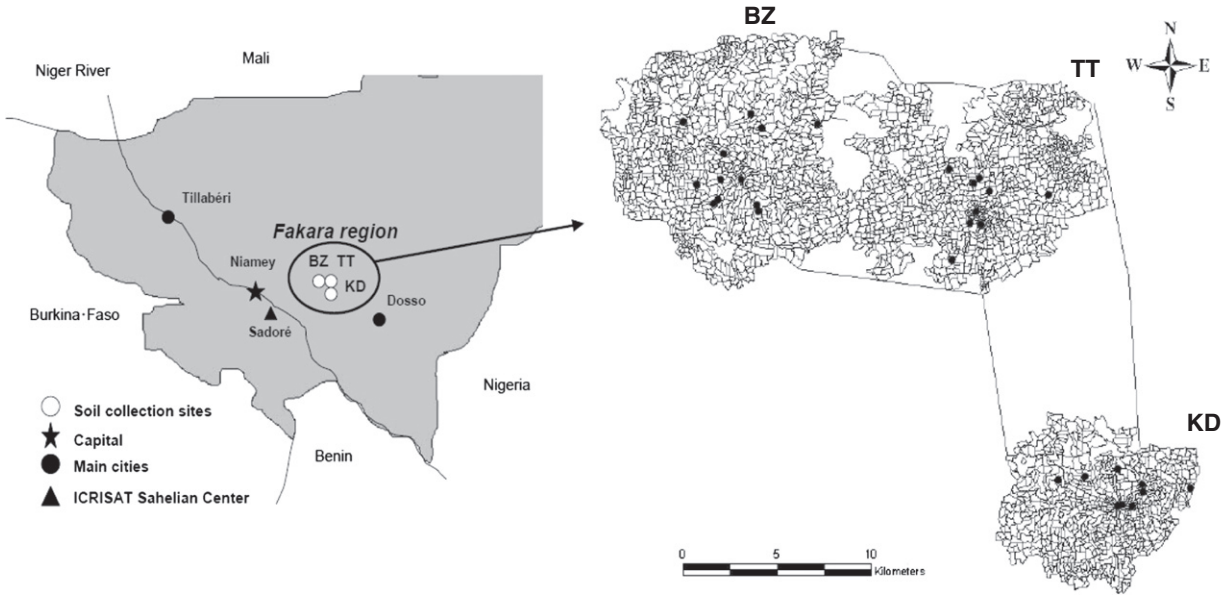

Fig. 1. Location maps of the study site showing three villages in the Fakara region (left) and the fields where soil samples were collected (right). White circles represent three villages: Banizoumbou (BZ), Tchigo Tégui (TT), and Kodey (KD). Black circles on the right of the map represent fields for soil sampling.