Applied Soil Ecology 113 (2017) 155–165

Contents lists available at ScienceDirect

Applied Soil Ecology

journal homepage: www.elsevier.com/locate/apsoil

Research Paper

Contrasted effects of annual and perennial grasses on soil chemical and biological characteristics of a grazed Sudanian savanna

Lambiénou Yé[a,b,*], Jean-Christophe Lata[c,d], Dominique Masse[e], Hassan Bismarck Nacro[b], Roger Kissou[f], Ndèye Hélène Diallo[g], Sébastien Barot[h]

[a] Centre Universitaire Polytechnique de Dédougou, Université Ouaga I Pr Joseph KI-ZERBO, Burkina Faso
[b] LERF, IDR, Université Polytechnique de Bobo-Dioulasso, Burkina Faso
[c] Sorbonne Universités, UPMC Univ Paris 06, IEES-Paris, 7 quai Saint Bernard, 75005 Paris, France
[d] Department of Geoecology and Geochemistry, Institute of Natural Resources, Tomsk Polytechnic University, 30, Lenin Street, Tomsk 634050, Russia
[e] IRD, UMR 210 ECO&SOLS (Montpellier SupAgro CIRAD INRA IRD), LMI IESOL (ISRA-UCAD-UT-IO-INERA-IRD),place Viala(Bt. 12), F-34060 Montpellier Cedex 2, France
[f] BUNASSOLS, Burkina Faso
[g] LEMSAT, Centre ISRA-IRD de Bel-Air, Dakar, Senegal
[h] IRD, IEES-Paris, 7 quai Saint Bernard, 75005 Paris, France

ARTICLE INFO

Article history:
Received 19 August 2016
Received in revised form 15 December 2016
Accepted 4 February 2017
Available online 20 February 2017

Keywords:
Annual and perennial tropical grasses
Savanna
Soil chemical and biological characteristics
Burkina Faso

ABSTRACT

Growth and composition of plant communities depends on physico-chemical and biological characteristics of soils. Conversely, plants influence nutrient cycling and soil characteristics. Thus, they affect the long-term availability of nutrients, which feedbacks on their own growth and the primary productivity of ecosystems. This study focuses on the fertility and functioning of soils of a grazed savanna in Burkina Faso. It describes the effects of annual and perennial grasses involved in fallow succession, on chemical and biological (microbial biomass, mineralization and enzymatic activities) characteristics of soils. To do this, soil samples were collected under the four dominant species of grasses (*A. ascinodis*, *A. gayanus*, *A. pseudapricus* and *L. togoensis*) and under bare areas within 48 plots, as well as above- and belowground grass biomass. Results show that root biomass, pH_{KCl}, basal respiration and fluorescein diacetate activities were significantly higher under perennial grasses (*A. gayanus* and *A. ascinodis*) than annual (*A. pseudapricus* and *L. togoensis*) and bare soil. Nitrate levels were higher under *A. gayanus* that had the lowest root biomass. Total carbon, total nitrogen, microbial biomass and acid phosphatase were higher under the perennial grass *A. ascinodis*. pH_{water} was lower under *A. pseudapricus*. Finally, ammonium and β-glucosidase activities weren't significantly different between species. Overall, these results appear complex certainly due to factors of variability that remain to be identified. Nevertheless, they support the general hypothesis that perennial grasses have a greater influence on soil than annuals. Soil biological parameters (Basal respiration, microbial biomass, Beta-glucosidase, fluorescein-diacetate and acid phosphorus) exhibited strong relationship with soil pH, total C and N.

1. Introduction

The composition of plant communities depends on physico-chemical and biological characteristics of soils. Conversely, plants influence nutrient cycling and soil characteristics (Hobbie, 1992; Chapman et al., 2006). Thus, they affect the long-term availability of nutrients, which feedbacks on their own growth and the primary productivity of ecosystems. Many mechanisms are involved (Hobbie, 1992; Knops et al., 2002): for example, plants influence the mineralization of soil organic matter (SOM) through root exudates *via* rhizosphere priming effects (Dijkstra and Cheng, 2007; Shahzad et al., 2012). They also influence the stocks and fluxes of mineral nutrients by direct absorption and the control of various functions such as soil nitrification and denitrification. In particular, some African perennial grasses are known to inhibit nitrification (Lata et al., 2004; Subbarao et al., 2013). Both biological nitrification inhibition (BNI) and the preference for nitrate or ammonium (Kahmen et al., 2008) can be interpreted as strategies evolved by plants to prevent nitrogen (N) losses and to

* Corresponding author at: Centre Universitaire Polytechnique de Dédougou, Université Ouaga I Pr Joseph KI-ZERBO, Burkina Faso.
E-mail address: ylambienou@yahoo.fr (L. Yé).

http://dx.doi.org/10.1016/j.apsoil.2017.02.003

grow under conditions of low N availability such as tropical soils (Boudsocq et al., 2009, 2012). In particular, this could be of crucial importance on tropical ferruginous soils of tropical Sudanian savannas characterized by their low level in mineral nutrients and organic matter (OM).

In this context, Sudanian savanna grasses likely affect the physico-chemical and biological soil parameters through several mechanisms including those mentioned above, and in interaction with cattle grazing. As linked to plant traits, these effects should also differ between grass species and biological types. Indeed, the study of fallows has shown that some perennial grass species, especially Andropogoneae spp., improve the availability of mineral nutrients, soil organic content and some biological properties of tropical ferruginous soils of tropical savannas (Somé et al., 2006). These perennial grasses also improve soil structure compared to annual grasses (De Blic and Somé, 1997). On the contrary, annual grasses are unlikely to influence significantly nutrient cycling and improve soil fertility. As opposed to perennial grasses, they can't build up over years dense root systems that interact with the same small patches of soil (Fournier, 1987, 1994; De Blic and Somé, 1997). Annuals have also lower productions of biomass than perennials.

In Sudanian fallows, successions of grass species (Somé, 1996; Fournier et al., 2001) begin with annual grasses settled within a few years after stopping cultivation. About ten years later, they are replaced by the perennial grass *Andropogon gayanus* which is, in turn, replaced about twenty years after stopping cultivation by perennial grasses such as *Andropogon ascinodis*, *Hyparrhenia* spp., *Schizachyrium sanguineum*, *Monocymbium cerisiiforme*. This succession isn't respected in all cases. It can be blocked at the stage of annual grasses that may prevent the installation of perennial grasses in some conditions where their competitive ability for water or nutrients favor them at the expense of perennials (Fournier and Nignan, 1997). Overgrazing may also lead to the replacement of perennial by annual species (César, 1992). Overall, the succession likely depends on soil type, grazing pressure and climatic conditions allowing in some savannas (as in our study site) perennial and annual grasses to coexist and form patches of a few square meters. In order to evaluate and understand the effects of these two "biological types" of grasses on nutrient cycling, it is necessary to determine soils characteristics under these facies. Knowledge of these effects should help to develop strategies for the sustainable management of grazed savannas where these grasses dominate.

Among the key mechanisms involved in grass competitive abilities, recycling of limiting nutrients is essential in nutrient-poor environments. Generally, perennial tuft grasses of tropical savannas produce an abundant biomass despite a poor availability of mineral nutrients, especially N (Abbadie et al., 1996). This can be explained by a relative independence of these grasses from nutrient cycling of the bulk soil (Abbadie et al., 1992). Indeed, thanks to their spatial organization and their longevity (several decades), these grasses build permanent dense root systems that allow an efficient recycling of mineral nutrients released by root decomposition. This limits N losses and results in the accumulation of N in the rhizosphere (Abbadie et al., 2000).

This study focuses on the impact of annual and perennial grass species on soil and nutrient cycling in a Sudanian savanna of Burkina Faso grazed by livestock. A recent study on this site (Yé et al., 2015) shown that $\delta^{15}N$ values for grasses were similar to those found in efficient recycling savannas (Abbadie et al., 1992) and that $\delta^{15}N$ were lower for perennials than annuals. This suggested that perennials better control N cycling than annuals, which leads to a higher N cycling efficiency (Templer et al., 2007). Our objective is therefore to evaluate the impact of grasses on soil characteristics, besides nitrogen content and ^{15}N signature that could affect soil fertility within patches of the two dominant annual and the two dominant perennials grasses of a grazed savanna. We want here to test further the hypothesis that perennial grasses have a higher capacity than annual to control nutrient cycling in the studied grazed savanna. We more precisely hypothesize that perennial grasses improve soils chemical and biological properties such as enzymatic activities and pH in comparison to annual grasses in grazed savanna.

2. Material and methods

2.1. Study site

The study site is the third management unit of the protected forest of Dindéresso in the West of the town of Bobo-Dioulasso, at the altitude of 390 m (11°12.494′North, 4°24.159′West, altitude 390 m). The climate is South-Sudanian: there is a wet season from May to October and a dry season from November to April. The area is located between the 900 and 1200 mm isohyets. Some 1254 mm of rain fell in 2010, 831 mm in 2011 and 1089 in 2012. The mean annual temperature is 28 °C. The whole forest lies on sedimentary rocks, *i.e.* Bobo-Dioulasso coarse sandstone (BUNASOLS, 1985; FAO, 1994). According to the French soil classification (CPCS, 1967), soils are tropical ferruginous leached modal soils and tropical ferruginous leached indurated soils. Correspondences with the World Reference Base classification (FAO, 2006) were established. These are Lixisols (Rhodic and endopetroplinthique). In general, the soils of this site have low organic matter, N and phosphorus contents (BUNASOLS, 1985).

Vegetation consists in a shrub savanna grazed by cattle. It is characterized by dominant shrub/small tree species: *Vitellaria paradoxa*, *Terminalia laxiflora*, *Detarium microcarpum*, *Parkia biglobosa*, *Guiera senegalensis*, *Combretum nigricans*, *Gardenia ternifolia*. The herbaceous layer is dominated by grasses. The main annual grasses are *Andropogon pseudapricus*, *Loudetia togoensis*, *Microchloa indica.* The main perennial grasses are *Andropogon gayanus*, *Andropogon ascinodis*, *Hyparrhenia subplumosa*, *Schizachyrium sanguineum* and they are all bunch grasses. There are some legumes (*Cassia mimosoides, Indigofera trichopoda*, *Zornia glochidiata*, *Tephrosia pedicellata*, *Tephrosia bracteolata*), Cyperaceae (*Fimbristylis hispidula*) and other forbs (*Waltheria indica*, *Pandiaka heudelotii*, *Spermacoce stachydea*, *Striga hermonthica*). Grass aboveground biomass and necromass are burnt each year by bushfires.

The study site has been divided in four blocs of approximately 1.5 ha according to the dominance of perennial and annual grasses and the frequency of grazing: blocs 1 and 2 are co-dominated by two annual grasses (*A. pseudapricus* and *L. togoensis*) and are more grazed by cattle during the rainy season while blocs 3 and 4 are co-dominated by two perennial grasses (*A. ascinodis* and *A. gayanus*) and are less grazed during the rainy season. Blocs 1 and 2 are indeed next to the main road, so that they are more easily reached by cattle and pastoralist, and blocs 3 and 4 are supposed to host an abundant population of tsetse flies during the rainy season so that they are avoided to limit the risk of cattle infection by trypanosomiasis. Blocs 1 and 2 have shallower soils (at most 55 cm deep, they are indurated ferruginous leached soils). Blocs 3 and 4 have deeper soils (at least 105 cm deep, the indurated layer is deeper, they are modal ferruginous soils). Blocs 1 and 2 are contiguous. Blocs 3 and 4 are contiguous. Blocs 1–2 and blocs 3–4 are separated by a distance of about 2000 m.

2.2. Grasses species

Four grass species including two annual grass species (*Andropogon pseudapricus* and *Loudetia togoensis*) and two perennial grass species (*Andropogon gayanus* and *Andropogon ascinodis*) were selected for this study because they are the