Applied Soil Ecology 81 (2014) 37–44

Contents lists available at ScienceDirect

Applied Soil Ecology

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

Effects of burning on soil macrofauna in a savanna-woodland under different experimental fuel load treatments

Sabine W.M.F. Doamba [a,*], Patrice Savadogo [b,c], Hassan Bismarck Nacro [a]

[a] Université Polytechnique de Bobo-Dioulasso, Institut du Développement Rural, Laboratoire d'Etude et de Recherche sur la Fertilité du Sol, 01 BP 1091 Bobo-Dioulasso, Burkina Faso

[b] Centre National de Recherche Scientifique et Technologique, Institut de l'Environnement et de Recherches Agricoles, Département Productions Forestières, 03 BP 7047 Ouagadougou 03, Burkina Faso

[c] World Agroforestry Centre (ICRAF)/International Crop Research Institute for the Semi-Arid Tropics (ICRISAT), West and Central Africa Region-Sahel Node, BP 12404 Niamey, Niger

ARTICLE INFO

Article history:
Received 14 June 2013
Received in revised form 9 April 2014
Accepted 10 April 2014
Available online 16 May 2014

Keywords:
Disturbance
Fire severity
Soil biodiversity
Invertebrates
Community changes
Burning impacts

ABSTRACT

In West African savanna-woodland, the use of prescribed burning as a management tool has ecological implications for the soil biota. Yet, the effects of fire on soil inhabiting organisms are poorly understood. The aim of this study was to examine the responses of soil macro-invertebrates to early fires in a Sudanian savanna-woodland on a set of experimental plots subject to different fuel load treatments. The abundance of major macro-invertebrate taxa and functional groups, and taxon richness were quantified in soil cores collected from three different soil layers before and immediately after burning. The results indicated that, overall, there was substantial spatial and temporal variation in the composition of macro-invertebrate assemblages. The immediate effects of fire were to reduce total invertebrate numbers and numbers of many invertebrate groups dramatically. This is probably due to the fact that many of the surface-dwelling macrofauna perished as a result of less favorable microclimate due to fire, diminished resources, or migrate to safer environments. Fuel load treatment did not affect the community taxonomic richness or abundance of the soil-dwelling fauna. Furthermore, annual changes in community composition were more pronounced at the burnt site than in the control. This could be related to the inter-annual difference in precipitation pattern recorded during the two-year study period at our site. Since soil macrofauna population declines in fire-disturbed areas, increasing fire prevalence may jeopardize the long-term conservation of fire sensitive macrofauna groups. Special fire management attention is therefore recommended with due consideration to the type of burning and fuel properties to avoid the detrimental effects of intense fire affecting the resilience of savanna soil macrofauna species.

1. Introduction

Fires are considered the most important natural disturbance agent in various ecosystems, including savannas (Goldammer, 1990; Swaine et al., 1992), grasslands (Briggs and Knapp, 1995; Pyne et al., 1996) and forests (Theresa et al., 2008). Frequent fires are a product of the annual cycle of massive wet season vegetative production that provides dry fuel loads, after seasoning, through the ensuing dry season (Cheney and Sullivan, 1997; Dawes-Gromadzki, 2007). Fire produces a wide spectrum of responses in the affected ecosystems depending on the interaction between many factors, including fire severity, fire intensity, duration of temperatures, fuel loading, degree of combustion, vegetation type, climate, slope, topography, soil characteristics, time since the last fire and area burned (Neary et al., 1999).

Soil is an important component of ecosystems that are likely to be affected by fire (Savadogo et al., 2007; Badía-Villas et al., 2014), and the soil biota is one of the first soil components to respond to fire exposure (Bezkorovainaya et al., 2007; Vasconcelos et al., 2009). Fires affect many of the soil organisms that interact with the below-ground environment either directly or indirectly. Direct effects cause short-term changes, which are reflected in altered species composition and changes in the abundance of some taxonomic groups (Wikars and Schimmel, 2001). Heat penetration into the soil during a fire affects the survival of organisms; either the animals or their eggs are directly killed or injured by the flames or by the heat of the fire or by smoldering material. Indirect effects are usually associated with long-term changes in the environment

* Corresponding author. Tel.: +226 70133571; fax: +226 20 98 25 77.
E-mail address: doambaflore@yahoo.fr (S.W.M.F. Doamba).

http://dx.doi.org/10.1016/j.apsoil.2014.04.005
0929-1393/

that affect the welfare of organisms located below the soil surface (DeBano et al., 1998). These indirect effects can involve competition for habitat, food supply and other more subtle changes in microclimate (destruction of soil organic matter status, increased surface insolation, temperature or pH) that affect the reestablishment and succession of plants and animals (DeBano et al., 1998; Debouzie et al., 2002). There is great variation in the way the soil fauna (in terms of composition and abundance) respond to fire, depending on the intensity, frequency and season of burning, as well as pre- and post-fire conditions (DeBano et al., 1998). Low-severity, rapidly moving fires do not have a major effect, whereas high-severity fires that last a long time have the greatest impact. Moreover, macrofauna species may react in various ways to fire; for instance while some invertebrates can burrow, migrate downward or fly to escape a fire, species with immobile life stages (larvae, pupae) that occur in the surface litter or on above-ground plant tissue are more vulnerable (Malmström et al., 2009; Gongalskya et al., 2012).

In the Sudanian savanna-woodland, fire is widely used as a conservation management tool (Bellefontaine et al., 2000; Sawadogo et al., 2005). Prescribed early fire (burning taking place between October and December–January when the fuel moisture content is at a minimum of 40%) is recommended by managers as the only practical alternative to, often unavoidable, late fires (set from February and just before the next rainy season in May) in the season which are reported to be detrimental to biodiversity and maintenance of the ecosystem's structure and function (Laris and Wardell, 2006). Most studies focusing on how biodiversity is affected by fires have considered plant species which had site specific response to fire (Zida, 2007; Savadogo et al., 2008). Knowledge about the effect of fire on soil biota is limited especially in relation to west Africa (Louppe et al., 1998). In this continent, most research has been conducted in South Africa and has involved studying the impact of repeated fires on fauna (Foord et al., 2003; Uys and Hamer, 2007; Oluwole et al., 2008). Frequent burning may affect soil organic resource quality and quantity thereby leading to increase or decrease in soil macrofaunal population depending on time of burning occurrence and intensity. The results of other previous studies have revealed the adverse effects of increasing fire frequency and intensity on soil fauna communities (Decaëns et al., 1994; Castano-Meneses and Palacios-Vargas, 2003). Some studies have reported that late fire has a much greater destructive impact on soil fauna population density and diversity than early fires (Louppe et al., 1998). In contrast, other studies in South Africa have recorded a significant increase in the soil macrofauna population (Oluwole et al., 2008). An increase of 31.4% in the population density was noted in an annually burned stand against a reduction of the population in stands burned every six years.

Understanding the effect of fire on macrofauna is of value to both conservationists and ecologists (Uys and Hamer, 2007) because this component of the biota performs critical ecosystem functions in soil nutrient cycles, pest control, pollination and waste disposal. Therefore, this study was designed to fill the knowledge gap by contributing to our understanding of the factors that regulate the structure of soil faunal communities in fire-adapted ecosystems (Frost and Robertson, 1987) like savanna-woodland and elucidating the consequences of this for ecosystem function. Specifically we quantified soil macrofauna taxonomic richness and density under different fuel loads and pre–post fire changes for an informed management that will enhance soil macrofauna resilience to facilitate effective ecosystem functioning. We hypothesize that the survival of soil-living macrofauna depends on both the fuel load quantity and the pre–post fire environment; that in high fuel loaded plots and post fire conditions soil macrofauna do not recover to pre-burn levels in short term. In addition, we hypothesize that there is vertical stratification of the fire effect, with large proportions of individuals being affected in the top soil layer.

2. Material and method

2.1. Study site description

The study was conducted in Burkina Faso (West Africa) in the Dindéresso State Forest Reserve (11°13′59.88″N and 4°25′59.59″W). The forest was delimited by the colonial French administration on July 4, 1935 and today covers 8 500 ha. The climate at this location is south-Sudanian with two main seasons: the rainy season extends from May to October and the dry season from October to April (Fontès and Guinko, 1995). Rainfall and temperature data were collected at the synoptic station within the airport (11°09′36″N and 4°19′51″W) located about 20 km from the study site (ASECNA-Agence pour la Sécurité de la Navigation Aérienne en Afrique et à Madagascar). The mean annual rainfall for the study period, 2009–2011, was 1010 ± 145 mm (mean ± standard error). The lowest rainfall (831 mm) was recorded in 2011 and the highest (1290 mm) in 2010. Besides the yearly variation, some monthly variations are also observed; most rain falls between June and September with the maximum in August. Mean daily minimum and maximum temperatures ranged from 16 to 32 °C in January (the coldest month) and from 26 to 40 °C in April (the hottest month). Soils at the reserve are derived from sedimentary substrates and classified as Lixisols according to Driessen et al. (2001). The soil characterization across the entire reserve indicated that they are mainly deep (>85 cm) and dominated by a sandy loam texture (57.5%) followed by sandy textures (17.5%), loamy sand (15%) and loamy silty clay textures (10%). They have poor fertility status (pH 5.95; N: 0.058%; P: 1.77 ppm; C: 0.33%) and low organic matter content (OM: 0.57%) (BUNASOLs, 1985). Phyto-geographically, the study site is located in the Sudanian regional center of endemism in the south Sudanian Zone (Fontès and Guinko, 1995). The Sudanian savanna is an area stretching across the African continent from Senegal in the west to the Ethiopian highlands in the east and is characterized by a dry season lasting 6–7 months and a mean annual rainfall between 700 and 1200 mm (Menaut et al., 1995). The vegetation type at the site is a tree/bush savanna with a grass layer dominated by the annual grasses *Andropogon pseudapricus* Stapf. and *Loudetia simplex* (Pilger) C.E. Hubbard as well as the perennial grasses *Andropogon gayanus* Kunth. and *Andropogon ascinodis* C.B.Cl. Species in the families Combretaceae, Mimosaceae and Cesalpiniaceae dominate the woody vegetation component. In terms of cover, the main woody species are *Combretum nigricans* Lepr. ex Guill. & Perr., *Acacia macrostachya* Reichenb. Ex Benth., *Anogeissus leiocarpus* (DC.) Guill. & Perr. and *Vitellaria paradoxa* C.F. Gaertn.

2.2. Burning experiment and fuel load treatments

The investigation of soil physical and chemical properties was performed at an experimental site which was established in August 2009. The plots were located on flat ground to eliminate the influence of slope on fire behavior (Trollope et al., 2002). The experimental area (11.16 ha) comprised three non-contiguous blocks (3.72 ha) (Fig. 1). The blocks were located to as to minimize variation in aspect, slope, and soil type after a preliminary reconnaissance survey. Each block was further divided into seven plots of 0.24 ha (80 × 30 m). The plots were separated from each other by 10 m fire-breaks and each block was surrounded by a 20 m wide fire-break. All the blocks were similar and have been subject to moderate grazing, mainly by livestock (a mixed herd of cattle, sheep and goats) all year round. The woody vegetation covers an average of 44% in each plot.

The fuel load treatment procedure was as follow: first, except on the control plot, the herbaceous vegetation was harvested manually by cutting at the base, approximately 10 cm above the ground.