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Soil seed bank characteristics in relation to land use systems and distance from water in a semi-arid rangeland of southern Ethiopia

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Abstract

The size and species composition of the soil seed bank of southern Ethiopia rangelands were examined under three land use systems (communal land, a government ranch and traditional grazing reserves) and along a distance gradient (near, middle and far) from water sources. Soil seed bank sampling was carried out at the end of the growing season from 0.25 m^{-2} quadrates 30 mm deep. The aboveground species composition was also compared. Of the total plant species identified in the soil seed bank in the greenhouse, 25% were grasses and 75% non-grasses. The near, middle and far sites from water was dominated by *Leucas glabrata*, *Verbesina encelioides* and *Lintona nutans*, respectively. *Lepthotrium senegalensis* made up 67% of the total composition of the soil seed bank in the traditional grazing reserve. Graminoid seedling density at the traditional grazing reserve (798.8 seedlings m^{-2}) was higher ($P<0.01$) than that of the ranch and communal sites, but did not vary significantly along the distance gradient from water (average 239.2 seedlings m^{-2}). Non-graminoid seedling density did not vary much ($P>0.05$) between the land use systems (average 128.9 seedlings m^{-2}) and along the distance gradients from water (average 183.7 seedlings m^{-2}). Sorensen's similarity index of the aboveground vegetation and the associated seed bank was low at all the sites. Difference in grazing pressure between the land use systems was one of the most likely causes of variations in the soil seed bank density and botanical composition of graminoids. The non-significant differences in the graminoid seed bank density along the distance gradients from water were due to similar population of grasses and may not explain the levels of grazing impact and disturbance. Regeneration from the soil seed bank may have a profound effect in restoring the composition of the grass layer in the degraded Borana rangelands if sustainable management practices are applied and sufficient rest periods followed. By translocating seed rich topsoil from the grazing reserves to degraded grazing areas, the soil seed bank can be used to develop valuable grass species at small community level.

Keywords: Borana; Degradation; Graminoids; Non-graminoids; Seedling density; Similarity index

1. Introduction

Plants establish themselves by the expansion and subsequent fragmentation of vegetative parts such as tillers, rhizomes or runners, or by the successful establishment of a soil seed bank or bulbils (Freedman et al., 1982). Seeds may have been introduced to the seed bank during the current (i.e. seed rain or transient seeds) or previous years and are removed through germination, predation, senescence and pathogens. It is the balance between these processes that will determine the turnover rate of the seed bank in a particular location (Bekker et al., 1997; Laura and Brenda, 2000; Snyman, 2004a). Plants commonly delay their reproduction by allowing a part of their offspring into a dormant state, thus forming a seed bank (Baskin and Baskin, 1998). Delayed reproduction is an apparent maladaptation since the mean annual number of offspring is reduced (Aikio et al., 2002).

Soil seed banks are important in savanna ecosystems where grasses count as a large part of the vegetation and their role is threefold. Firstly, it is a potential pool of propagules for regeneration of grasses after disturbance (Hodgson and Grime, 1992; Bekker et al., 1997; Snyman, 1998; Laura and Brenda, 2000). Secondly, the seed bank may reduce the probability of population extinction of plants (Venable and Brown, 1988). Thirdly, it is likely to be the

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major source in establishing aboveground plant communities following environmental changes such as rainfall (Du Preez and Snyman, 1993; Wilson et al., 1993; Hayatt, 1999).

Recruitment from the seed bank is restricted to periods with favourable conditions of those soil parameters that may control seed germination. One of the most important variables in this regard is soil water (Reynal and Bazzaz, 1973; Snyman, 1998, 2004a), while other factors include soil pH (Thanos and Skordilis, 1987; Henig-Server et al., 1996), heat exposure (Thanos and Georghiou, 1988; Snyman, 2005) and light (Trabaud and Renard, 1999). Storage of viable seeds in the soil and the subsequent establishment are also functions of disturbance factors (Sousa, 1984; Thompson, 1986). Drought in combination with human activities may adversely affect the seedling recruitment of the seed bank (Skoglund, 1992; Kinloch and Friedel, 2005a). Heavy grazing by livestock introduces a disturbance to grasslands, which can negatively affect the size and composition of grasses in the seed bank, both in space and time (Skoglund, 1992; Bekker et al., 1997; Solomon, 2003; Snyman, 2004a,b).

Gradients of grazing over increasing distances from watering points and under various land use systems have been used extensively in rangeland research, investigating the impact of livestock on rangeland vegetation. Many studies report that variable rainfall had the most influence on plant growth, although persistent changes in species composition occurred at more intensely grazed areas close to watering points (Fusco et al., 1995; Friedel, 1997; Kinloch and Friedel, 2005a) and in the communal rangelands. However, others found that the reasons for the vegetation change along a distance gradient from watering points, and in relation to land use are complex and dependent on the interaction of rainfall, landscape characteristics and grazing (Friedel, 1997; Fernandez-Gimenez and Allin-Dias, 1999; Kinloch and Friedel, 2005a,b; Van Rooyen et al., 1994).

The sustainable use of Ethiopian rangelands for pastoralism depends on understanding how grazing interacts with the underlying environmental variables and ecological processes of these ecosystems. Moreover this depends on understanding the extent and degree of the deterioration of the rangelands and how it can be restored. The evaluation of soil seed banks can therefore give an idea of the recovery potential of degraded rangelands (Bekker et al., 1997; Solomon, 2003; Tongway et al., 2003; Snyman, 2004a). Studies dealing with vegetation in the arid and semi-arid pastoral Africa are restricted to the aboveground vegetation community, and ignore seed bank stored in the soil—a part of the plant diversity the recordings of which require more time and effort. The objectives of this study were to examine seedling density and floristic composition of graminoids and non-graminoids along a distance gradient from water and under three land use systems (communal areas, a government ranch and a traditional grazing reserve) and to assess the similarity of the grass composition between the seed bank and aboveground plant community.

2. Procedure

2.1. Study area

The Borana rangeland is located in the southern parts of Ethiopia, covering approximately 95,000 km^2. The landscape is slightly undulating and ranges in altitude from 1000 m to 1500 m, having peaks up to 2000 m (between 4°3′N to 5°00′N and 37°38′E to 38°23′E) (Coppock, 1994). The area has an arid to semi-arid climate with annual rainfall ranging from an average of 110 mm in the south to 600 mm in the north. The rainfall in general is bimodal with 59% of the total rainfall that occurred from March to May and 27% from September to November. Droughts are common at an average frequency of once every 5–10 years (Coppock, 1994). The mean annual temperature varies from 15 to 24 °C and shows little variations across the seasons (Coppock, 1994). The geology is dominated by 40% quaternary deposits, 38% basement complex formations and 20% volcanic. Four vegetation types were described (Agrotec/crg/sedes associates, 1974) namely (i) evergreen and semi-evergreen bushland and thickets, (ii) rangeland dominated by *Acacia* and *Commiphora*, (iii) rangeland dominated by shrubby *Acacia*, *Commiphora* and allied genera, and (iv) dwarf shrub grassland or shrub grassland.

2.2. Site selection and layout

The first part of the research was conducted in a communal grazing area where three sites along a distance gradient from four water sources were studied. All the study sites have similar soil, landscape and altitude. The selection criteria for the watering points included their water holding capacity and age. Accordingly, water ponds (wells) with either a small capacity or with a very recent age (<10 years old) were excluded. Due to nearly similar vegetation pattern around the watering points, only one transect was established at each of the selected watering points. The length of transects away from the watering points were 12 km. Each transect was divided into three sub-transects (4 km each), simply named near, middle and far from water. Approximately in the middle of each sub-transect a plot of 20 m × 50 m was marked. A total of four quadrates (0.25 m^2 each) soil samples were collected from each plot along each distance site from water.

The second part of the research was conducted on sites subjected to three adjacent land use systems (communal grazing areas, a government ranch and three traditional grazing reserves). In all land use systems the herbaceous layer were dominated by similar species, mainly annual grasses and have also similar soil and landscape. Unfortunately there is a lack of accurate information on the grazing history of these areas. However, it is well known that for the communal grazing area the grazing pressure over an extended period was very high (well above the recommended grazing capacity), resulting in large bare areas. The stocking rate at the government ranch was also higher than the grazing capacity, while that of the traditional grazing reserve was used for comparison purposes. The communal grazing area and government ranch were grazed