Comprehensive Research and Reviews in
Biology and Pharmacy
Journal homepage: https://crrjournals.com/crrbp/
ISSN: 2961-3590 (Online)

(RESEARCH ARTICLE)

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Effects of cultivation on soil seed bank flora of Borana Rangeland, Southern Ethiopia

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Comprehensive Research and Reviews in Biology and Pharmacy, 2022, 01(01), 035–041

Publication history: Received on 16 July 2022; revised on 28 August 2022; accepted on 02 September 2022

Article DOI: https://doi.org/10.57219/crrbp.2022.1.1.0036

Abstract

The effects of cultivation on soil seed bank flora of Borana rangeland were examined under three land use systems (Enclosure land, open grazing land, and different ages cultivated land). Soil seed bank sampling was carried out at the end of the growing season from 0.25m2 quadrates at 30 mm deep. Of the total plant species identified in the soil seed bank, 34.6% were grasses and 65.4% were forbs species. From the nine grass species recorded, four were identified as highly desirable, two as desirable and three as less desirable. From the highly desirable group, *Dactyloctenium aegyptium* was found to be common and dominant at the three land use systems of the enclosure, open grazing and cultivated lands for less than five years, while highly desirable species perennial grass like *Cenchrus ciliaris* and *Chlorisrox burghiana* were only found in enclosure lands. The species richness of enclosure, open grazing and cultivated 1-5 years land were higher respectively while cultivated land more than 10 years was the least. There were significant differences ($P < 0.05$) in soil texture between land uses of the study sites. Due to cultivation pressure, more than ten years of cultivated land has more sandy soil than the remaining rangeland of the study areas. Generally long periods of cultivation and grazing pressure have negative impacts on Borana rangeland soil seed bank flora whiles enclosure land has higher values in restoring and sustaining the productivity of rangeland ecosystems. Therefore, a rangeland land use policy is required to sustain the productivity of rangeland through developing appropriate land use plans for each land use type of rangeland that is used to reduce the impact of rangeland ecosystem deterioration. Practices of rangeland management like resting of rangeland through enclosure, and moderate grazing with rotation grazing systems should be developed and strengthened in order to sustain rangeland ecosystem and feed resource productivities.

Keywords: Enclosure; Cultivation; Species composition; Species richness; Soil texture

1. Introduction

n most areas of Ethiopia, where there is unpredictable rainfall, a sustainable cropping system will produce more dry matter of nutritional value for ruminant forage than grazing areas. This factor overcomes the key negative impact of increased cropping with the reduction of available areas for livestock grazing. In arid and semiarid areas, with crop failures to the extent of harvesting little animal feed is available, especially in the face of climate change. In the Borana rangeland, cultivation is a recent phenomenon when compared to livestock production. Cultivated land quickly degrades the productivity of the rangeland. Cultivation can bring the loss of many plants and animals, soil degradation, and other losses. If the rangeland is cultivated for several years, it might affect rangeland biodiversity, resulting in the disappearance of many important species that have paramount importance for pastoralism.

The sustainable use of Ethiopian rangelands by pastoralists depends on understanding the extent and degree of deterioration of rangelands (Teferaet al., 2007). This study aims at complementing previous studies by contributing additional quantitative data for a better understanding of the impact of different land use on rangeland productivity. Besides, these data may give important information to decision-makers and development projects to improve the

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livelihood of Ethiopian pastoral communities. Therefore, the objectives of the study were to examine the seedling density and floristic composition of cultivated and uncultivated land, to study the difference and similarities of grass species in cultivated and uncultivated land, and to examine soil physiochemical characteristics in the cultivated and non-cultivated land.

2. Material and methods

2.1 Study areas

The Borana rangeland was located in the southern part of Ethiopia. The altitude ranges from 1000 to 1500 m.a.s.l. (meters above sea level), with peaks in the mountains reaching above 2000 m.a.s.l. (Helland, 1982). It is dominated by arid and semiarid climates and characterized by a general scarcity of water. The soil samples were collected from three districts of rangeland representatives (Yabello, Teltele, and Dire districts). For each district, the field layout considered was five lands system; open grazing, enclosure land, cultivated land of 1-5 years, 6-10 years, and cultivated land of more than 10 years.

2.2 Soil sampling

Soil samples were carefully spooned from three separate soil depths, each 30 cm thick i.e. 0 – 10 cm, 10 – 20 cm, and 20 – 30 cm using a sharp knife following the method used by Teketay and Granstroem (1995), and within each sample quadrat of 0.5 x 0.5 m. The samples were placed in labeled and tagged cheesecloth bags for immediate transportation to the lath house for germination. The pots were placed at random in the lath house with the assumption that the lath house is uniform.

2.3 Incubate of the soil samples

In the lath house, labeled plastic pots were filled with sterile sand. Before using the sterile sand, it was checked for possible seed contamination by keeping sterile sand moist over a clean flat floor. The soil sample was spread over the sand in each plastic pot to a depth of 100 mm. Each pot was hand-watered daily in the first week. Pots were examined every three to four days for the first two months and then periodically to keep soil moist. Except for the crop, all the germinated seedlings were counted over the experimental period.

2.4 Laboratory analysis

The soil was sampled and analyzed from samples collected and mixed for the lath house experiment. The soil samples were properly labeled and packed in plastic bags for lab analysis. Samples were air-dried ground and sieved with a 2 mm mesh size. Soil parameters were analyzed for soil texture, pH, Available phosphorus, organic matter, and organic carbon following standard procedures. The texture was determined by the hydrometer method, pH by a pH meter in 1:2.5 soil: water ratio, and soil organic carbon by the Walker-black method, the percent soil organic matter was calculated by multiplying the percent organic carbon by a factor of 1.724.

2.5 Data analysis

Plant diversity of germinated species from soil seed bank was analyzed using PAST version 3.10, Paleontological Statistical software (Hammer et al, 2001). The data generated from the soil seed bank in the lath house was analyzed in randomized block design using a general linear model by SAS software version 9,1. LSD (least significant differences) test with $P<0.05$ was used for means comparison.

3. Results and discussion

3.1 Seed bank botanical composition

A total of 26 species representing graminoid flowering plants were identified (Table 1). Of these, 34.6% were grasses and 65.4% were non-grass plant species. The seed bank of botanical composition at the enclosure, open grazing, cultivated <5 years, and cultivated >10 years lands were dominated by Aristida kenyensis species respectively. In the enclosure land, Aristida kenyensis species made up 30% of the total botanical composition. Of the 9 grass species recorded, four were identified as highly desirable, two as desirable and three as less desirable. From the highly desirable group, Dactyloctenium aegyptium was found to be common and dominant at the three land use systems of enclosure, open grazing and cultivated <5 years, while highly desirable species like Cenchrus ciliaris and Chlorisrox burghiana were only found in the enclosure. The less desirable grass species, Aristida kenyensis, was common and dominant in

the enclosure, open grazing, cultivated <5 years and cultivated >10 years land. Among the desirable species, Cyperus species and ergrostis species were found to be common along the enclosure land. The productive types of rangeland grass species like Cenchrus ciliaris and Chlorisrox burghiana occurred only at enclosure land.

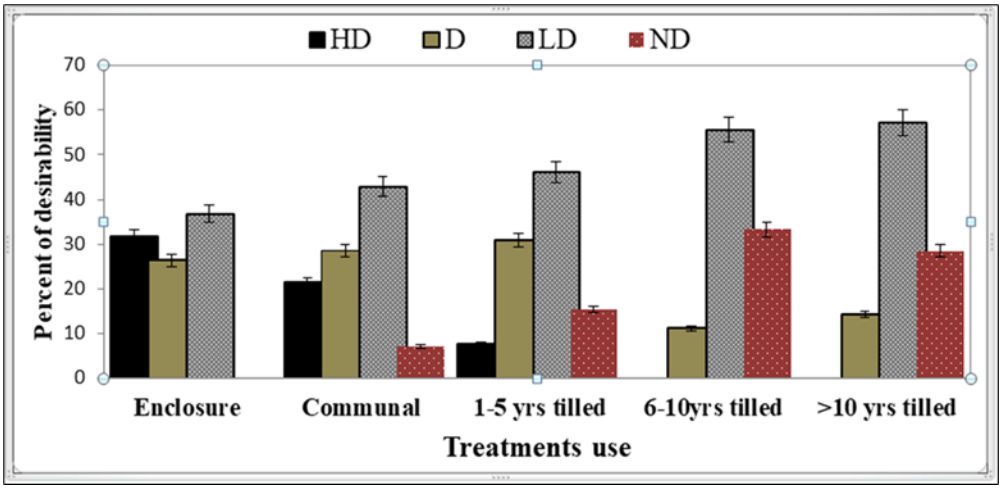
Table 1 Botanical composition of soil seed bank from different land types of semi-arid rangeland of Borana

Scientific name	Local name	Life form	Desirability	Land use type				
				Enclosure areas	Open grazing	Cultivated 1-5 years	Cultivated 5-10 years	Cultivated >10 years
Setariave ticillata	Raphuuphaa	A	LD	2.29	0.00	3.77	0.00	0.00
Aristida kenyensis	Biilaa	A	LD	30.29	26.09	28.30	21.43	6.56
Cyperus species	Saattuu	A	HD	9.71	13.04	3.77	0.00	0.00
Digitaria species		A	LD	5.14	4.35	0.00	0.00	0.00
Commelina africana	Qaayyoo	A	HD	8.57	2.17	0.00	0.00	0.00
Ceratostigma species	Gurbii	A	LD	1.71	2.17	0.00	0.00	0.00
Dactyloctenium aegyptium		P	HD	2.86	4.35	1.89	0.00	0.00
Barleria spinisepala	Qilxiphee	P	D	9.14	8.70	3.77	0.00	0.00
Tagete sminuta	Sunkii	A	ND	1.14	2.17	0.00	0.00	1.64
Cenchrus ciliaris	Mata guddeessa	P	HD	1.14	0.00	0.00	0.00	0.00
Parthenium hysterophorus	Kuubaa	P	ND	0.00	2.17	7.55	25.00	24.59
Chlorisrox burghiana	Hiddooluucolee	P	HD	0.57	0.00	0.00	0.00	0.00
Eragrostis species	Biilaa	P	HD	1.14	0.00	0.00	0.00	0.00
Abutilon hirtum	Gurbii daalatii	P	D	7.43	13.04	9.43	10.71	40.98
Tribulus cistoides	Mogoree	A	LD	0.57	0.00	3.77	14.29	1.64
Lippia carviodora	Urgoo Loonii	P	D	2.29	0.00	0.00	0.00	0.00
Indigofera spinosa	Shaana simpiree	A	LD	0.00	0.00	0.00	0.00	3.28
Amaranthus thunbergii	Raafuu	A	LD	7.43	8.70	11.32	0.00	11.48
Sesamothamnus rivae	Huuraa laafaa	A	D	0.00	4.35	0.00	0.00	3.28
Brachiaria eruciformis	Birachria	P	HD	5.71	2.17	0.00	0.00	0.00
Acantos permum	Keessaa ka'ii	A	ND	0.00	0.00	13.21	10.71	6.56
Forb species	Homoo rafisaa	A	LD	0.00	0.00	5.66	10.71	0.00
Indigofera species		A	D	0.00	0.00	3.77	0.00	0.00
Lantana rhodesiensis	Midhaan durbaa	P	D	1.71	6.52	3.77	0.00	0.00
Bidens biternata		A	LD	0.00	0.00	0.00	7.14	0.00
Hibiscus crassinervius	Bungaala	P	HD	1.14	0.00	0.00	0.00	0.00

Key:- A= annual, P= perennial, D= desirable, HD=High desirable, LD= Less desirable, ND=none desirable or invaders

Of the total non-grass species identified, 65% were herbaceous annuals and 35% were semi-perennials. Parthenium hysterophorus and Acantos permum species are invader species that were commonly found in cultivated land of study sites whereas the highly desirable species of herbaceous species were found in enclosure land. The differences observed in seed bank botanical composition along the five lands were due to the impact of levels of grazing intensity and duration of cultivation pressure. The higher seed bank of botanical composition was graminoids at the enclosure land reserves compared to the open grazing and cultivated areas of land. The enclosure land has lower grazing pressures since it allows grazing only during the dry season of the year and rested in both the growing season and sometimes in the cool dry season. While the open grazing land had high grazing pressure with unlimited stock density in all seasons. Cultivated land had got a higher chance of exposure to heavy erosion, which has been increasing year-round. Low graminoids seed bank compositions were measured on the cultivated land. It can be assumed that with continuous cultivation, the aboveground grass biomass has been removed by root-off and destruction of germinated seed bank by repeatedly ploughing and weeding. Also in densely utilized open grazing areas, the low graminoids seed bank composition was measured because continuous overgrazing causes reduced aboveground biomass and destruction of grassroots by trampling livestock (Brinkmann, 2020). Consequently, the production capacity of grass and their ultimate contribution of seeds to the soil seed bank were reduced. Kinloch and Friedel (2005a) came to the conclusion that the impact of grazing on the standing herbage and seed bank depends on the severity of grazing over preceding decades and the coincidence with drought in that time. One finding also suggests that a decrease in total seed density at very high levels of grazing and an increase in density at intermediate levels due to a decrease in the number of animals (Kinloch and Friedel, 2005a). Therefore, the rangeland may have the capacity to rehabilitate the composition of the highly desirable and desirable species if only a moderate grazing system is applied with a sufficient rest period.

3.2 Desirability of species distribution along land use types



[1]abc Means in the same color without a common letter are different

Figure 2 Proportional species desirability of treatment use

The proportional different groups of species desirability distributions for the study areas of soil seed bank were different across the five land field layouts. The result indicated that at enclosure land, the less desirable species had the highest proportion followed by the highly desirable and desirable species (31.6, 26.3%) respectively, whereas the reverse held true for the 6-10 and more than 10 years cultivated land that dominates by less and none desirable species (less desirable species 55.6% and 57.1%, and also none desirable species 33.3% and 28.6% respectively). At the communal/open grazing land, the less desirable species had the highest percentage (42.9%) followed by the desirable and highly desirable species (28.6 % and 21.4 %) respectively. For 1-5 years of cultivated land, less desirable species had the highest proportion (46.2%) followed by desirable and none desirable species (30.8% and 15.4 %) respectively.

3.3 Species richness and diversity

The individual herbaceous species that germinated from soil collected from the enclosure land(175) was higher ($P<0.001$) by 78.8 % and 76.7 % than germinated herbaceous species recorded from open land and cultivated land respectively (Table 2). The germinated individual species between all lands did show highly marked variation. The herbaceous species that germinated in cultivated for 6-10 years was higher than land cultivated for 1-5 years due to being highly encroached and invaded by weeds species. There were highly significant differences in the germinated

herbaceous richness for all land use types. The species richness of enclosure, open grazing, and cultivated 1-5 years land were higher respectively while cultivated >10 years was the least (Table 2). This indicates that land cultivation decreased the species richness due to disturbed origin soil seed banks and exposed soil to wind and water erosion, the land was dominated by few weed species. Similarly, the species diversity and evenness of collected soil seed banks were highly significant (P<0.001) between all land use types. Therefore enclosure land of rangeland was the better practice of rangeland management which has higher values in restoring and sustaining the productivity of rangeland resources than other the remains land use types.

Table 2 Mean values of species richness and diversity of the soil seed bank sampled from different land use types

Land use type	Numbers of species count	Species richness	Species diversity	Species evenness
Enclosure land	175a	19a	2.40a	0.58e
Open grazing land	47d	15b	2.36b	0.71c
Cultivated 1-5 years	53c	13c	2.27c	0.74b
Cultivated 6-10years	61b	9d	1.68e	0.59d
Cultivated >10 years	28e	7e	1.86d	0.92a
CV	9.1	9.1	9.1	9.1
P-values	0.001	0.001	0.001	0.001

[1]abc Means in the same column without a common letter are different

3.4 Soil physical properties

The soil physical properties of three district rangeland of study areas were presented in Table 3. The soil laboratory analysis result indicated that there were significant differences (P< 0.05) in soil texture between grazing and cultivation pressure. Due to cultivation pressure, ten years of cultivated land has more sandy soil than remain rangeland of the study areas. Enclosure rangeland type was less exposed to erosion by livestock trampling as that of open grazing rangeland (continuous grazing) during rainy season. Followed to enclosure land, cultivated land of 1-5 years has less sandy soil than others land type of study areas. There was no significance difference in soil texture classification among land of study sites. The soil texture of study sites of rangeland classified into sandy, clay, loam while slightly differed in their color within districts. Teltele site was brow color types of soil, while Yabello study site was red and Dire rangeland type was red-brown. This dissimilarity of soil texture and color were determined the soil properties while, they were affected by heavy grazing and cultivation pressure together with climatic factors through reduction of their soil parent materials. Similarly, Pimentel, D. (2006), Filip (2002) reported that environmental factors and anthropogenic activities affect soil living organism those maintain soil health and function.

Table 3 Mean values of soil physical properties of different land use type

Land use type	Sand soil (%)	Clay soil (%)	Silt soil (%)
Cultivated >10 years	61.92a	23.08b	15.00b
Open grazing land	52.77a	24.92ab	22.31ab
Cultivated 1-5 years	49.86a	27.92ab	22.22ab
Cultivated 6-10years	52.41a	33.58a	14.01b
Enclosure land	34.41b	34.15a	31.44a
CV	11.13	11.13	11.13
P-values	0.016	0.016	0.016

[1abc] Means in the same column without a common letter are different

3.5 Soil chemical properties

The result of pH, organic matter, organic carbon and available phosphors of three land use of the study sites are indicated in Table 4. The pH, organic matter and carbon and available phosphors were no significantly different (P >

0.05) between land use types. While enclosure land was higher in soil organic matter and carbon followed by 1-5 years cultivated land than open grazing, 6-10 years and > 10 years cultivated land because enclosure has better management than other land use while the recent rangeland that converted to cultivated land is a potential grazing land. Whereas, the percentage of soil organic matter and carbon were lower than the standard requirement of forage production i.e. medium average content of the soil in their soil organic matter and carbon respectively (Frank, 1990). This is due to the effect of overgrazing on both grazing land and also frequent cultivation that facilitator for degradation rangeland is the main factors complain with recurrent drought. The result agreed with Kumasiet at. (2010) and Zhanet al. (2020) that concluded the removal of vegetation by herbivores reduces ground covers and soil organic matters and nitrogen

Table 4 Mean values of soil chemical properties of different land use type

Land use type	PH	EC	%OC	%OM	AvP
Enclosure land	6.96a	102.48ab	1.49a	2.5a	8.64a
Open grazing land	7.04a	93.66b	1.34a	2.30a	9.55a
Cultivated 1-5 years	7.04a	247.29a	1.17a	2.51a	10.07a
Cultivated 6-10years	6.69a	106.31ab	1.16a	2.02a	8.98a
Cultivated >10 years	7.34a	176.29ab	1.13a	1.94a	9.03a
CV	24.3	13.2	24.3	24.3	24.3
P-values	0.54	0.19	0.54	0.54	0.54

[1]abc Means in the same column without a common letter are different; %OC = percentage of organic carbon, %OM = percentage of organic matter, and AvP = available phosphorous

4. Conclusion

Differences in species composition among the land use type were manifest due to the variance in cultivation and grazing pressure. Long periods of cultivation and heavy grazing pressure have a negative impact in changing the botanical composition of herbaceous species layer towards less desirable and none-desirable species and also size and composition in the soil seed bank. Whereas an enclosure land had higher botanical composition and desirability of species than open grazing and cultivated land of study areas. In Borana pastoralists, the enclosure land has been experienced in their traditional grazing system that ensured the restoration as well as maintenance of seed bank composition of desirable herbaceous species. The species richness of enclosure, open grazing and cultivated1-5 years land were higher while cultivated >10 years were the least. This indicates that land cultivation pressure decreased the species richness due to disturbed origin soil seed banks and exposed soil to wind and water erosion, and the land was dominated by few weed species. The size, species richness and species composition of seed banks of study areas are important indicators for rangeland ecosystem condition whether it deteriorated or not used alarms for developing rangeland ecosystem management. In Borana pastoralists, the enclosure land has been the common practice in their traditional grazing systems that are used for stand hay preservation and they ensured the resilience restoration of rangeland through maintain the seed banks of desirable herbaceous species composition. The soil seed banks have been used to recover threatened palatable plant species.

Therefore, the enclosure of rangeland with light grazing was the better practice for resilience rangeland management which has higher values in restoring and sustaining the productivity of rangeland ecosystems. Now cultivation expanded and is seen as an option for livelihood diversification. So cropping practices shall be applied separately on specific areas of rangeland through appropriate dryland agriculture practices (clustering method, little tillage, crop rotation, use of pure seed that free from weeds and has early age maturity), sowing at the onset of rainfall, and also may use supplement irrigation than full irrigating methods) that used to reduce the disturbance of the rangeland ecosystem.

Compliance with ethical standard

Acknowledgments

The authors would like to acknowledge Oromia Agriculture Research Institute, Yaballo Pastoral, and Dryland Agriculture Research Centre for providing financial support and Borana communities for their time and valuable information during our data collecti9on.

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