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Effect of Post Bush Clearing Management Practice on Herbaceous Species Productivity and Soil Status of Rangelands in Hammer District of South Omo Zone

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Abstract

Bush encroachment is one of the factors that cause rangeland degradation in most pastoral areas of east Africa. A study on effects of post bush clearing management practice on rangeland productivity and soil status was conducted in Hammer district of South Omo zone, Southern Ethiopia with the objective of assessing effect post bush clearing management practice on the vegetation composition and soil status. A hectare of rangeland encroached by different acacia species was fenced and replicated/divided into three plots, and each plot was subdivided into four sub-plots to receive four treatments: un cleared woody vegetation (control) T1, cutting at above ground and leave as it is in the field (T2), cutting above ground and remove from field (T3), cutting above ground and burn right in the field (T4). Data on species composition indicated that almost all species present in all treatment groups with exception of two grass species *Cenchrus ciliaris* and *Chloris pycnotrix* dominated in plots which has received T2. Data on total herbaceous biomass, total grass biomass, total non-grass biomass, soil erosion and soil compaction were collected after treatment applications. The applied treatments significantly influenced at ($p<0.05$) total herbaceous biomass, total grass biomass, total non-grass biomass production, soil erosion and soil compaction. The results of this study showed that better biomass yield was harvested from treatment T2 which is highly significant at ($p<0.05$) followed by T3. There was no significant difference at ($p<0.05$) between T1 and T4 in all parameters. On top that pastoralists perceived T2 in terms of lesser labor cost relative to T3 to remove cut materials from the field, even though it was in accessible to harvest and utilize at final stage. Therefore, controlling encroaching tree/shrub species through mechanical control and leaving the cleared material as it had increased the total herbaceous biomass for the livestock. The management of bush encroachment in such a way if sustained will contribute in stabilizing rangelands productivity and help to minimize the shortage of feed.

Keywords: Biomass yield; Bush clearing; Herbaceous layer; Soil compaction

Introduction

Rangelands are lands on which the indigenous vegetation is predominantly grasses, grass like plants, forbs or shrubs and is managed as a natural ecosystem [1]. It consists of native and/or naturalized species, on which management is usually limited to grazing, burning and control of woody species [2]. Purdon and Anderson indicate that in the developing countries of Africa, rangelands comprise over half the land area and support a large human population dependent on grazing livestock [3].

Bush encroachment is the process of open grassland savannah being transformed into thick bushes/shrubs and is commonly seen as an indicator of rangeland degradation in semi-arid savannah [4]. It involves indigenous woody species occurring in their natural environment, and is widespread phenomenon occurring in many parts of the world. The encroachment of inedible shrubs and trees into semi-arid rangelands represents a community change that may be viewed either as a change in the botanical composition or as separate vegetation attribute; the herbaceous-woody species balance [5]. The driving factors behind the shift in vegetation in grass land and savannah in Ethiopia rangeland is associated with anthropogenic activities especially high cattle densities in communal grazing areas, and climatic changes [6].

A study conducted indicated that the rangelands of study district are being encroached by different species of acacia [7]. Hence, he recommended that bush clearing as major solution to improve productivity of rangelands. On the other hand, different studies conducted on effect of bush clearing has reported that its positive impact on growth of herbaceous layer and soil condition of the rangelands [8,9]. Even though, these studies have confirmed that better improvement on rangelands, they failed to describe the management aspect of cleared bush. Hence, this study is designed with following objective as:

1. To identify effective method of post bush clearing management on growth of herbaceous layer and soil status of the rangeland
2. To introduce bush clearing practice to the study district.

Materials and Methods

Description of study area

The study was conducted in the hot dry season of 2013 in Hammer district of south Omo zone, southern Ethiopia, which is about 710 km south of the capital Addis Ababa. The district located 4°27'-5°39' north

and 35°23'-37°49' east, bordering Kenya to south; Bako gazer district to the north; Borana zone and Konso district to the east, and Kuraze and Selamago districts to the west. Land use in the Hammer rangelands is largely communal, but crop cultivation and private enclosures appear to be increasing in recent decades. In this extensive communal semi-arid rangeland of Hammer, herbaceous plants are the major feed sources of grazers. The area has a bimodal pattern of rainfall, with the long rainy season between March and May and the short rainy season between September and November with mean annual rainfall increasing from the extreme south lower part, with some 350 mm, to the upper part where it ranges to 838 mm. The average temperature varies from 26°C-35°C per annum [7].

Sampling procedure

Local community leaders and elders (pastoralists' representatives) who have a deep knowledge about the encroached site were purposefully selected to take part in site selection. Meetings and discussions were held with government officials, local community leaders and elders to raise awareness on the objectives of the study. Through discussion, the community leaders and elders identified the encroached land for treatment. Finally, based upon the consensus reached by the community, a land encroached by different woody species was delineated for the planned activity. A hectare of land which was encroached by different woody species which suppress growth of herbaceous species was divided into three plots. Each replication (plot) with an area of 33.33 m by 100 m was divided into four sub-plots and fenced properly to protect entry of livestock and human beings. Each sub plot 25 m by 33.33 m was ready to accommodate four treatments, namely un cut woody vegetation (control) T1, cutting at above ground and leave as it is T2, cutting above ground and remove the cleared bush from the field T3, cutting above ground and burn right in the field T4.

Herbaceous layer

Total biomass, grass biomass, non-grass biomass, soil erosion and compaction were carried out on the second year after treatment application from 10 plots of 1 m x 1 m quadrats laid in each sub plot. The herbaceous vegetation within 1 m x 1 m sample quadrat was harvested at ground level using hand shears. Vegetation samples from each site were classified into total herbaceous, total grass and total non-grass species. The dry weights of each species were determined by using an electronic digital balance. Dry matter of each species was determined on dry weight basis dried in an oven at 105°C for 24 hours at Jinka agricultural research center.

Soil erosion

Soil erosion assessment was made by visual observation and five readings per sample site were taken. A scale of 0-5 points was considered. Soil erosion was rated based on the amount of pedestals (high parts of soil held together by plant roots with eroded soil around tuft), and in severe cases pavements (terraces of flat soil normally without basal cover with a line of tufts between pavement). The highest score 5 point was given for no sign of erosion, (4 points=slight sand mulch; 3 points=weak pedestals; 2 points=steep sided pedestal; 1=pavement, 0=gullies).

Soil compaction

Soil compaction (1 to 5 points) was evaluated based on the level of capping or crust formation of the surface soil. Soil compaction was assessed based on the amount of capping (crust forming). Five readings per sample site was taken and a range of points (1-5) was given as 5, 4, 3, 2 and 1 points for soil surface with no capping, isolated or scattered capping, >50% capping, >75% capping and almost 100% capping, respectively.

Data analysis

Data were analyzed using SPSS software ver. 20, and Tukey's student zed range (HSD) tests were used for posting hoc multiple comparisons of means [8].

Results and Discussion

Effect of bush clearing on grass species composition

Response of different bush encroachment-controlled method demonstrated promoted herbaceous species richness in terms of plant biomass and restoration of plant biodiversity [9]. Similarly, Thurrow also reported that overall woody vegetation reduces grass cover through increasing the competition for available water and nutrients and reducing the light reaching the grass layer [10,11]. The same result was found in the current study that there was decrease in non-palatable species in different treatment applied areas (Table 1). Therefore, the current study revealed that increasing problem of bush densities adversely impacted diversity, relative abundance and occurrence of grass species. Similarly, Smit also indicated that trees and shrubs are known to concentrate nutrients in soil beneath the canopy because of litter decomposition. This increases soil fertility, and provides an additional mechanism whereby grass production may be stimulated after woody vegetation is cleared [12].

Grass species	Category	Composition of species			
		T1	T2	T3	T4
Digitaria abyssinica	DS	P	P	P	P
Chloris roxburghiana	HD	P	P	P	P
Cenchrus ciliaris	HD	P	D	P	P
Chloris pycnotrix	DS	P	D	P	P
Eragrostis hebrantha	DS	P	P	P	P
Tetrapogon tenellus	HD	P	P	P	P
Bothriochola inscupta	HD	P	P	P	P
Digitaria abyssinica	DS	P	P	P	P
Eragrostis clianensis	DS	P	P	P	P
Panicum maximum	HD	P	P	P	P
Aristida adscensionsis	LD	P	-	P	P

Table 1: Herbaceous species identified in different treatment categories. Cate.=Categories; HD=Highly desirable (Decreaser); DS=Desirable (Increaser); LD=Less desirable (Invader), P=Present (<10% of density), C=Common (>10% and <20% of density), D=Dominant (>20% of density.

Effect of different post bush clearing management on total herbaceous yield

There was significant difference at ($p<0.05$) on total biomass production in bush cleared and left as it is than the other three treatment groups (Table 2). This is attached with mulching effect of woody vegetation through leaf shedding. This study investigated that thinning methods such as mastication reduce woody plant material into small wood chips leaving them as mulch on the ground, and this mulch has been shown to reduce invasive species. The reduced dominance of invasive species may be the result of increased soil carbon from the mulch which leads to reduced soil nitrogen levels that inhibits growth of invasive plants. Alternatively, the mulch may significantly shade the soil surface and inhibit seed germination and seedling growth. Regardless of the mechanism, reduced dominance of invasive plants can lead to increased density, cover, and diversity of native species, which could provide an additional benefit of tree thinning treatments. Fire has a negative effect on aboveground biomass in semiarid rangelands because removal of litter by fire allows the loss of mechanical barriers, toxic allele chemicals, soil temperature, soil moisture, light quantity, and light quality for growth and development of plants [13]. Because of this adverse effect of fire, plant production decreases in the season following the fire in semiarid rangelands. Increase in woody vegetation density suppresses the growth of herbaceous species. Woody plant encroachment is a threat to sustainable livestock production in commercial enterprises and pastoral societies because of its adverse effects on herbaceous production [14]. This study is in line with findings he stated that response of different bush encroachment-controlled method demonstrated by promoted herbaceous species richness in terms of herbaceous plant biomass and restoration of plant biodiversity. Adisu et al. reported the same result that there was a decrease of Shannon Species diversity index (H'), relative number of species present and total number of species present (richness) of grass species with increment of woody plant density in the Borana rangelands. Similarly, several studies have also shown a strong negative association between the level of woody plant encroachment and productivity of the herbaceous vegetation [15-18].

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	83.7 c	4.096	75.393	92.007
Cut and left	148.6 a	4.096	140.293	156.907
Cut and Clear	116.8 b	4.096	108.493	125.107
Cut and Burn	88.3 b	4.096	79.993	96.607

Table 2: Effect of different post bush clearing management on total herbaceous biomass yield.

Effect of different post bush clearing management on total grass yield

There was significant difference at ($p<0.05$) on total biomass production in bush cleared and left as it is than the other three treatment groups. This is attached with mulching effect of woody vegetation through leaf shedding. Increase in woody vegetation density suppresses the growth of herbaceous species. This study investigated that thinning methods such as mastication reduce woody plant material into small wood chips leaving them as mulch on the ground, and this mulch has been shown to reduce invasive species. The reduced dominance of invasive species may be the result of increased soil carbon from the mulch which leads to reduced soil nitrogen levels that inhibits growth of invasive plants. Alternatively, the mulch may significantly shade the soil surface and inhibit seed germination and seedling growth. Regardless of the mechanism, reduced dominance of invasive plants can lead to increased density, cover, and diversity of native species, which could provide an additional benefit of tree thinning treatments. Bellows reported that grazing led to trampling of the surface soil and a decrease in plant density and herbage cover associated with more intense soil erosion and a decrease in plant production and establishment [19] (Table 3).

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	83.7 c	4.096	75.393	92.007
Cut and left	148.6 a	4.096	140.293	156.907
Cut and Clear	116.8 b	4.096	108.493	125.107
Cut and Burn	88.3 b	4.096	79.993	96.607

Table 3: Effect of different post bush clearing management on total herbaceous biomass yield.

Effect of different post bush clearing management on total non-grass herbaceous yield

There was significant difference at ($p<0.05$) on total biomass production in bush cleared and left as it is than the other three treatment groups (Table 4). This is attached with mulching effect of woody vegetation through leaf shedding. Some thinning methods such as mastication reduce woody plant material into small wood chips leaving them as mulch on the ground, and this mulch has been shown to reduce the dominance. This reduced dominance of invasive species may be the result of increased soil carbon from the mulch which leads to reduced soil nitrogen levels that inhibits growth of invasive plants. Alternatively, the mulch may significantly shade the soil surface and inhibit seed germination and seedling growth. Regardless of the mechanism, reduced dominance of invasive plants such as cheat grass can lead to increased density, cover, and diversity of native species, which could provide an additional benefit of tree thinning treatments. In general, gaseous nutrient content (C, N, S, etc.) decreases while mineral nutrient content increases, and the microbial population also changes after a fire [20]. Consequently, these changes affect productivity and botanical composition.

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	26.2	3.028	20.059	Control
Cut and left	36.5	3.028	30.359	Cut and left
Cut and clear	32.2	3.028	26.059	Cut and clear

Cut and burn	22.5	3.028	16.359	Cut and burn

Table 4: Effect of different post bush clearing management on total non-grass biomass yield.

Effect of different post bush clearing management on soil erosion

The soil condition of the rangeland is highly dependent on stocking rate and density. Heavy grazing pressure in rangelands, result in compaction of soil and removal of mulched material. Current study indicated higher soil erosion in burned after bush clearing than in left as it is after bush clearing (Table 5). This might be due to wind erosion of burnt ash material which minimized mulch material that covers soil ground. Fire has a negative effect on plant productivity in arid and semiarid rangelands [21]. Changes in soils after fires produce different responses in the hydrology, soil moisture, organic matter, mineral content, and microbial population because of their complex interactions [22,23]. After a fire, soil chemical and physical properties change depending on combustion processes, the amount of fuel, air temperature, wind speed, topography, and humidity [23]. Removal of aboveground biomass, litter biomass, and organic matter cause nutrient loss, decreasing infiltration and increasing runoff and erosion [24]. After a fire, soil nutrient content changes significantly.

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	26.2	3.028	20.059	32.341
Cut and left	36.5	3.028	30.359	42.641
Cut and clear	32.2	3.028	26.059	38.341
Cut and burn	22.5	3.028	16.359	28.641

Table 5: Effect of different post bush clearing management on soil erosion.

Effect of different post bush clearing management on soil compaction

The soil condition of the rangeland is highly dependent on stocking rate and density. Heavy grazing pressure in rangelands, result in compaction of soil and removal of mulched material. There was significant difference among treatments at ($p<0.05$) in soil compaction (Table 6). In control and burned after clearing has higher soil compaction score than the mulched area. This might be high grazing pressure in the study area. Different studies support current study. The results highlighted that the compaction from livestock trampling likely contributed soil surface and botanical composition and vegetation impacts on the decreasing soil infiltration rate. These results are compatible with the findings of Mapfurno [25]. Chaichi et al. reported that soil infiltration rate in stock grazing region in the first grazing season decreased from 12 to 4 mm min^{-1} (decreasing 67%) [26]. Also, Faizul et al. identified that grazing results in a decrease in water infiltration into the soil and a compaction of the soil surface layer along with a decrease in the soil organic material [27]. Naeth with survey of grazing impact on vegetation and soil infiltration rate clarified that the disturbed topsoil structure because of the effects from trampling by grazing animals is a primary reason for lower water infiltration. Warren reported that the rate of infiltration of water through the profile of rangeland soils declines under grazing along with an increase in soil compaction and increasing soil erosion [28,29].

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Control	2.8 c	0.232	2.3	3.3
Cut and left	4.4 a	0.232	3.9	4.9
Cut and clear	3.4 b	0.232	2.9	3.9
Cut and burn	2.9 c	0.232	2.4	3.4

Table 6: Effect of different post bush clearing management on soil compaction.

Conclusions and Recommendations

- It can be concluded that there is high productivity of herbaceous layer in bush cleared and left as it is in the field. This is mainly due to mulching effect of cleared material in the area.
- Burning or removing cleared material will minimize litter cover of the soil and which result in soil erosion and compaction. This adversely affects plant species composition and density.
- Therefore, it is recommended that bush clearing has positive effect on productivity of rangelands when the cleared material is left right in the field rather removing or burning it to secure feed shortage in the area.

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