



Impact of cattle night corralling on soil properties and vegetation in the semiarid degraded rangeland of Ethiopia

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ABSTRACT

In Ethiopia, rangeland degradation is a severe environmental problem. To improve rangeland vegetation cover and support the rangeland-based livelihoods, it is imperative to repair degraded rangeland using different rehabilitative measures. This study was carried out to evaluate the effects of night cattle corralling impact on soil chemical parameters, herbaceous species compositions and biomass yield of degraded rangeland. To conduct the experiment, severely degraded (SD) and moderately degraded (MD) rangelands with an area size of 30m x10m (300m²) each was identified. Then, each of the selected rangeland types was separated into two paddocks with an area size of 10m x 15m (150 m²). The treatment paddocks of the severely and moderately degraded rangeland were treated by cattle impact tools corralling cattle every night in the paddock for one month (SDT₁ and MDT₁). While the second paddock in both rangeland types was used as a control without cattle impact tools (SDT₂ and MDT₂). A randomized complete block design was used and each treatment was replicated three times. The results showed that soil chemical parameters and herbaceous species compositions in both degraded rangeland paddocks treated with cattle impact tools (SDT₁ and MDT₁) changed significantly ($p < 0.05$) than paddocks without cattle impact tools (SDT₂ and MDT₂). Likewise, there was an increased difference ($p < 0.05$) in biomass yields of 2.98 ton/ha and 5.35ton/ha from severely and moderately degraded rangeland, respectively for paddocks treated with cattle impact tools (SDT₁ and MDT₂), compared to paddocks of biomass yield of 0.98 ton/ha and 2.78 ton/ha without cattle impact tools treatments for SDT₂ and MDT₂ respectively. Thus the result from this study emphasized the advantage of night cattle corralling impact tools for improved soil parameters and herbaceous species compositions of degraded rangeland. Hence, we concluded that employing cattle impact tools to restore degraded rangeland significantly improved soil physico-chemical properties, with ultimate effect on vegetation cover, vegetation compositions and herbaceous biomass yield, attributed from soil seed bank growth.

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Introduction

In Ethiopia, rangeland covers over 61 to 65% of the whole land mass and is mainly utilized as

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source of livestock feed (Tadele and Girma, 2022). This resource has been supporting the dry-land rural communities (Angassa *et al.*, 2014; Melak *et al.*, 2019). However, plant vegetative cover, species compositions, and biomass yield from rangeland are affected by degradation due to rapid population increase, increment in urbanization, overgrazing, the collapse of traditional institutions and rangeland mismanagement (Angassa and Oba, 2010; Tessema *et al.*, 2011; Malatinszky *et al.*, 2013; Melak *et al.*, 2019; Tadele and Girma, 2022). These have induced deleterious impacts on dry land pastoral ecosystems and community livelihoods in general (Vetter, 2005; Kassahun *et al.*, 2008). Similarly, in South Omo, where the project was conducted, rangeland resource depletion is a serious current problem affecting livestock production and as a consequence aggravating the livelihood poverty line of the pastoral and agro-pastoral communities of South Omo (Brehanu *et al.*, 2017; Denbela *et al.*, 2017; Denbela *et al.*, 2020). Thus, restoration of degraded rangeland by employing various restoration methods is imperative to restore degraded rangeland and increase rangeland vegetation cover. One of the innovative method to restore degraded rangeland is using cattle impact tools (trampling, dunging, urinating), which entails cattle concentration in small areas for short periods of time, followed by an appropriate rest periods for the rangeland to allow vegetation to emerge from the soil seed bank (Savory and Butterfield, 1999; Wolf, 2011; Ritchie *et al.*, 2012). The scientific theory behind cattle impact tool was, when cattle are concentrated in small or large areas for short period of time, the cattle do exert physical action on to the soil and break down the hard soil crust formed to ease water retention and infiltration deep into the soil profile, and at the same time soil physio-chemical compositions and productiveness could be improved from manure nutrient flow (Gomez *et al.*, 2006; Stankovičová *et al.*, 2008; Strauch *et al.*, 2009; Shahriary *et al.*, 2012; Jawuoro *et al.*, 2012). As a result, seed sprouting and seedling establishing might enhance on bare land (Amiri *et al.*, 2008; Azarnivand *et al.*, 2010). The use of cattle impact tool was already

being used in a number of countries to restore degraded rangeland like that of Zimbabwe (Abel and Blaikie, 1989), Kenya (Ritchie *et al.*, 2012; Lalampaa *et al.*, 2016), USA (Strauch *et al.*, 2009), South Africa, Botswana, and Namibia (Oba *et al.*, 2001). However, the efficiency of this tool has not been evaluated in Ethiopia. Therefore, this study was conducted in the pastoral area of South Omo with the main objectives of evaluating the effects of cattle impact tools on soil physico-chemical properties, herbaceous species diversity, richness and herbaceous biomass yield.

Materials and Methods

Description of site

This research activity was conducted consecutively for two years, from February 2017 to January 2019, in Bori Kebele (smallest administrative-sub unity) of Bena-Tsemay district of South Omo zone, South-west Ethiopia. The experimental trial site was located between 5° 25'30" and 5° 14'30" North latitude and 36°36'30" and 36°36'30" East longitude. The climate was semiarid to arid, with annual average rainfall of 838 mm and ambient temperatures ranging from 26°C to 35°C. Herbaceous and woody plant species were the most common vegetation categories in the trial site (Admasu *et al.*, 2010; Denbela *et al.*, 2020). Various woody species of *Acacia*, *Grewia* and *Solanum* are the dominant woody species, while *Cynodon dactylon* and *Tetrapogon tennulis* are dominant among the grass species in the communal grazing areas (Admasu *et al.*, 2010).

Experimental treatments and design

We selected one severely degraded and one moderately degraded communal rangelands that make a total of 6 experimental plots. The main plots have an area size of 30 m x 10 m (300m²) each; which were adjacent to each other. Further, both main rangeland plots were each separated into two paddocks having an area size of 15 m x 10 m (150m²) and fenced with locally available native trees to protect cattle movement from one paddock to the other paddock. Then one paddock per each type of rangeland was corralled by total of 20 cattle for overnight for intensive physical actions of the

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cattle (hoof trampling, excreting manure (faces and urine) and allowing them to leave the paddock during the day time to graze for a period of one month. The second paddock which did not receive cattle impact tools in this study was used as control. The experimental treatments used in this study were: severely degraded range land paddock with cattle impact tools (SDT_1) and severely degraded rangeland paddock without cattle impact tools (SDT_2); The other treatments were

moderately degraded rangeland paddock with cattle impact tools (MDT_1) and moderately degraded rangeland paddock without cattle impact tools (MDT_2). A randomized completed block design (RCBD) was used and each paddock was replicated three times with 6 total numbers of plots/paddock. After the cattle impact tool was completed, the trial sites were protected from cattle and human interference until the data collection process was completed.

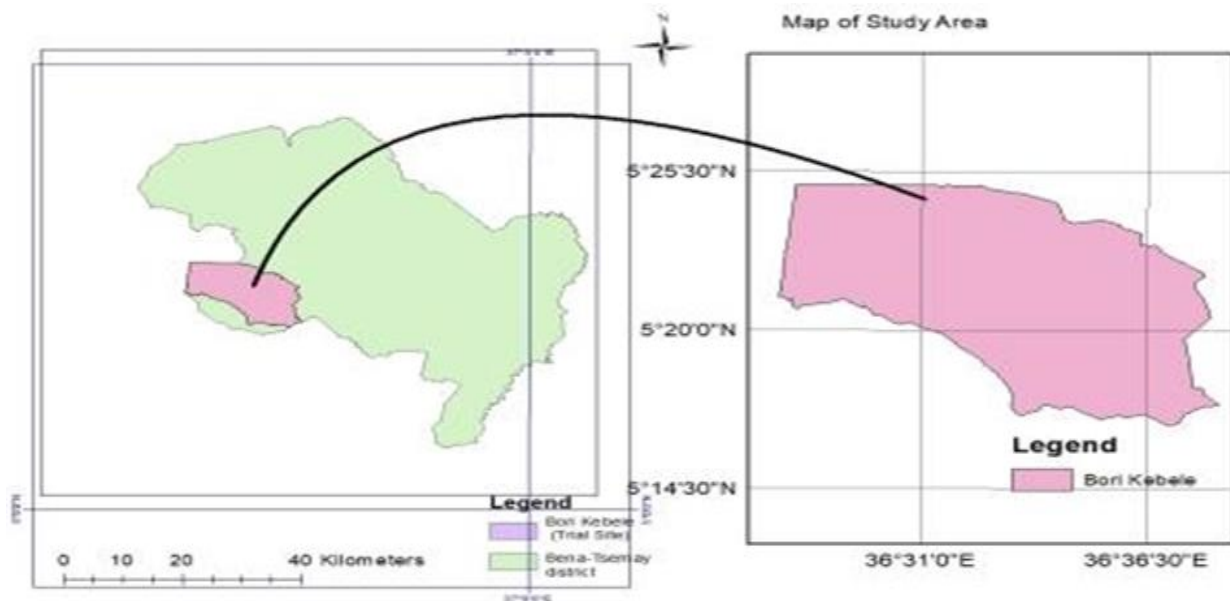


Figure 1: Map of the study area

Soil sample collection and analysis

Soil samples were collected to determine soil chemical compositions after 1, 020 days of cattle evacuation. From each paddock, three 1 m transects were laid out in a Z-shaped orientation, indenting at least 0.5 metre from the boundaries of each paddock. Along each transect of each paddock, three 0.5 m x 0.5 m quadrates were placed at an interval of 1m and soil samples were taken from each quadrate by using soil auger at a depth of 20 cm (2 samples from the center, 2 samples from bottom and 2 samples from the top layer). The six soil samples from each quadrate was mixed thoroughly, and made composite soil sample. The composite samples were sieved through a 2 mm mesh to remove stones, roots and large organic residues, and allowed to air dry, and sealed in plastic bags and stored at room

temperature for further laboratory analyses. For the analysis of soil chemical compositions, about 100g sample per quadrate was analyzed at Debre Birehan Agricultural Research Center, soil laboratory. The Walkley and Black (1934) method was used for analysis of organic carbon (OC), while the soil total nitrogen (N_{tot}) was analyzed by Macro kjeldahal method (Bradstreet, 1965). The analysis of available phosphorus (P) and exchangeable potassium (K) were conducted according to the method of Olsen *et al.* (1954).

Herbaceous species assessment

The herbaceous species composition assessment was undertaken from each treatment plot of the rangeland (cattle impact tools and control) in October, 2019 on termination of the main rainy season. At this time, all forage species appeared in

good growth condition for easy identification of the species in the rangeland. For herbaceous species identification, three (0.5 m × 0.5 m) quadrates were laid out along a transect line of 2 m long at an interval of 1m distance between each quadrate in both treatments. From each replicated plot, about 6 quadrates were sampled and making a total quadrate of 36 samples from both rangeland types (severely and moderately degraded areas). The herbaceous species in the quadrates were clipped, and clipped samples were classified by sorting into three botanical-categories (grasses, legumes and forbs). The species that were easy to identify the scientific nomenclature were properly identified in the field using Ethiopia Flora identification Book (Hedberg and Edwards, 1989), while for those which were difficult to identify their scientific names in the field were labeled in paper bags with representative plants parts (flowering head and other organic parts), and then dried using plant presser. Following drying, the specimens were counted and registered with the local names, and transported to Adami Tule Agricultural Research Center for botanical name identification and were identified by experienced botanist using botanical keys for Flora of Ethiopia (Hedberg *et al.*, 2009). The species diversity (H') was calculated by using equation = $Species\ diversity = -\sum_{i=1}^s p_i \ln p_i$. Where, p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N), \ln is the natural logarithm of whole species. The H' (low, moderate and high) by considering species richness (S) (Spellerberg and Fedor, 2003; Laurila-Pant *et al.*, 2015). The H' has three categories, namely: $H' < 2$ = low, $2 < H' < 3$ = moderate and $H' > 3$ = high (Laurila-Pant *et al.*, 2015).

Forage biomass yield

We randomly laid down four sample quadrates of area sized 0.5 m by 0.5 m (0.25 m²) per treatment and forage sample was harvested at ground level using hand shears. The biomass yield of the collected herbaceous species was determined on dry matter basis by drying in an oven at 105^oc for 24 hrs. (AOAC, 1990). Then the biomass yield (ton/ha) was estimated by method of James *et al.* (2008).

Statistical analysis

The collected data was analyzed by SPSS statistical software. The **two-sample t-test** was used to determine effect of cattle impact tools on soil chemical parameters, herbaceous species diversity and richness, and herbaceous species biomass yield (Bevans, 2022). The variation among the treatment plots were accepted at $p < 0.05$ having the model of $Y_{ijk} = \mu + T_i + e_{ijk}$, where; y_{ijk} = dependent variables; μ = overall mean; T_i = treatment and e_{ijk} = random error).

Results and Discussion

Cattle impact tools on soil chemical parameters

The night cattle corralling impact tools on soil chemical parameters investigated in this study is presented in Table1. The findings showed that the soil OC and N_{tot} were 165 and 150 times higher ($p < 0.05$) in severely degraded paddock treated with SDT_1 , respectively than the SDT_2 . However, the concentration of C/N and available P in the severely degraded rangeland were similar ($p > 0.5$) in both treatments of SDT_1 and SDT_2 . Meanwhile, about 637.5 times higher ($p < 0.05$) K value was obtained in severely degraded paddock treated with SDT_1 than SDT_2 treatment. Similarly, in the moderately degraded paddock about 197, 71.82 and 60.5 times higher ($p < 0.05$) soil OC, C/N and K, were obtained respectively from the paddock treated with MDT_1 than the MDT_2 treatment. Nevertheless, the concentration of the N_{tot} and available P in the moderately degraded paddock was similar ($p > 0.05$) between the experimental plots treated with MDT_1 and MDT_2 . In both severely and moderately degraded paddocks higher soil OC, N, K, and C/N was attained from those treated with SDT_1 and MDT_1 than those treated with SDT_2 and MDT_2 . This is perceived to be attributed due to cattle impact tools during the period of corralling, which was the effect of both hoof trampling and nutrient flow back from the dung and urine despite grazing, which improved valuable soil nutrients for uptake by plants. Cattle convert undigested vegetative plant material into dung or manure, which is rich source of soil-organic-carbon and nitrogen (Harris, 2002; McAndrews *et al.*, 2006). Similarly, owing to the two-year restoration of the paddocks, more forage species grown were transformed into carbon compounds, establishing a tissue of plant biomass that returned carbon to the

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soil via litter falls and dead plant materials. Plant root wastes are the main foundation of soil organic content, and so increased of below ground biomass would improve soil compositions through the biological activities of soil microbes (Lutta, 2015; Reeder *et al.*, 2004). The soil OC content recorded in this study from both rangeland types with and without cattle impact tools was lower than reported values of 2.5% and 0.71%, respectively by Lutta (2015) from the Kenya rangeland. The total N content of the rangeland types with and without cattle impact tools obtained from this study was lower than reported values of 0.40% and 0.15% by Lutta (2015) for those treated with cattle impact tools and without cattle impact tools respectively in Kenya degraded rangeland. The higher value for soil available P content of both rangelands treated

with cattle impact tools was due to addition of manure and urine into the soil from the cattle droppings. Similar study like that of our finding was reported by Fekadu *et al.* (2017) who indicated that application of cattle manure in degraded grazing land has the potential to improve soil available P of natural grassland. The higher exchangeable K content from both rangelands treated with cattle impact tools compared to treatment without cattle impact tool was due to the addition of potassium nutrient by animal excreta (dung and urine) droppings at the period of corralling for overnight stay. The exchangeable potassium content obtained from severely degraded rangeland treated with cattle impact tools was lower on this study than the value of 1.27 Cmol/kg of soil reported by Lutta (2015).

Table 1: Effects of cattle impact tool on soil chemical compositions in Bena-Tsemay district of South Omo, Southern Ethiopia

Soil parameters	Experimental treatments							
	SDT1	SDT2	SEM	P-value	MDT1	MDT2	SEM	P-value
Soil OC (%)	0.85 ^a	0.32 ^b	0.07	<0.00	1.99 ^a	0.67 ^b	0.04	<0.04
Soil N _{tot} (%)	0.15 ^a	0.06 ^b	0.02	<0.02	0.18	0.08	0.06	0.28
Soil C/N	9.75	6.95	1.72	0.17	11.77 ^a	6.85 ^b	1.11	<0.01
Available P (ppm)	4.7	2.08	0.55	0.07	7.96	3.54	0.06	0.11
K (Cmol/kg soil)	1.05 ^a	0.59 ^b	0.08	<0.00	2.68 ^a	1.67 ^b	0.15	<0.00

(**SDT1**= severely degraded range land paddock with cattle impact tools; **SDT2** = severely degraded rangeland paddock without cattle impact tools; **MDT1**= moderately degraded rangeland paddock with cattle impact tools; **MDT2**= moderately degraded rangeland paddock without cattle impact tools; **N_{tot}** = Total nitrogen; **SEM** = Standard error of mean, **OC**= Organic carbon; **C: N** = Carbon and nitrogen ratio; **P** = Phosphorus; **K** = Potassium).

Effects of cattle impact tools on species diversity and richness

The effect of night cattle corralling impact tools on herbaceous species diversity and richness is presented in Figure1 and 2, respectively. The result revealed that higher ($p < 0.05$) grass, legumes and forbs H' and species richness were found in the paddocks that treated with SDT_1 than SDT_2 . However, in the moderately degraded rangeland treated with MDT_1 and MDT_2 revealed that the H' and species richness of grass and forbs were almost similar, but H' and species richness of legumes did vary significantly ($p < 0.05$). The H' of

grass in paddocks of severely and moderately treated with SDT_1 and MDT_1 were 3.25 and 3.39, respectively, which were categorized as indicators of high species diversity. But, the H' of grass in severely and moderately degraded rangeland paddocks that were treated with SDT_2 and MDT_2 recorded to be 0.78 and 1.93, respectively. This was rated on low H' range. The higher H' and richness in both rangelands types; severely and moderately treated with SDT_1 and MDT_1 in this study was attributed due to the physical action of trampling, dunging, urinating, salivating, and rubbing effect, which is very useful in improving

soil fertility and enhancing soil seed bank germination, as result increased herbaceous plant diversity and richness plots than control one. According to Savory (1988), when cattle trample the land with high intensity for a short period of time, the soil is pulverized, irregularities on the soil shallow favor plant material germination, and dung and urine are added to the soil, which improves soil

fertility and water retention, resulting in an escalation in species diversity and richness on degraded areas. Furthermore, Dreber and Esler (2011) report signified that cattle trampling has the ability to increase seedling densities from soil-seed-banks in semiarid rangelands of Southern Africa, where increased species diversity and richness was seen.

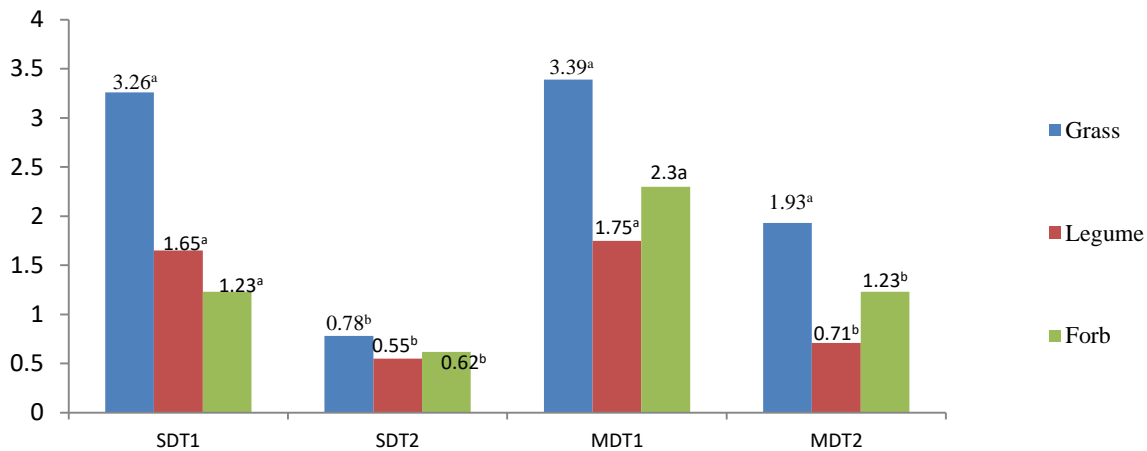


Figure 2: Effect of cattle corralling impact tools on herbaceous species diversity.

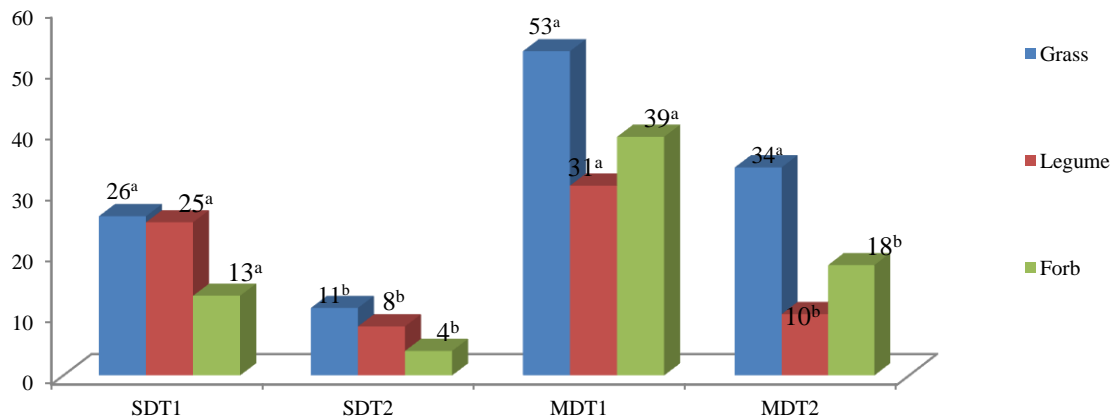


Figure 3: Effect of cattle corralling impact tools on herbaceous species richness

Moreover, similar to result from present findings, Solomon *et al.* (2006) and Scott *et al.* (2010) found that cattle grazed rangelands over short periods of time preferred numerous small-seeded annual species in soil seed banks, resulting in increased H' and richness. The increased H' and richness of

grass species relative to legume species for both rangeland types might be explained by grass species' stronger responsiveness to total N and P than legume species. This finding also agreed to those of Steele (2008) and Nebi *et al.* (2021), who argued that legumes had a lower nitrogen response

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than grass species, resulting in faster grass growth with longer root and shoot development.

Effects of cattle impact tools on biomass yield

The effect of night cattle corralling impact tools on herbaceous biomass yield productivity of degraded rangelands is presented in Table 2.

Table 2: Effects of cattle impact tools on biomass yield (ton/ha) in Bena-Tsemay district of South Omo Zone, South-west Ethiopia

Experimental treatments	Biomass Yields (t ha⁻¹)	SEM	P-value
SDT1	2.98 ^a	0.82	< 0.03
SDT2	0.98 ^b	0.29	< 0.03
MDT1	5.35 ^a	0.80	< 0.04
MDT2	2.78 ^b	0.73	< 0.04

(SDT1= severely degraded range land paddock with cattle impact tools; SDT2 = severely degraded rangeland paddock without cattle impact tools; MDT1= moderately degraded rangeland paddock with cattle impact tools; MDT2= moderately degraded rangeland paddock without cattle impact tools).



Fig 4: SD before cattle impact



Fig 5: SDT1 after one year



Fig 6: SDT1 after two years

Moreover, during trampling time, animals adds-up manure for long periods which causes an increased in soil-organic-carbon and soil-health improvement, which as a consequence has increased species diversity and forage biomass production (Schmidt, 2011). Likewise, Peterson (2010) also reported that trampled plant material and cattle dung after grazing would keep the soil surface cooler, by reducing evaporation and simultaneously would increase water infiltration rate down the soil profile. This retained moisture would support to stimulate nutrient recycling by soil-microorganisms activity and in the return, increased forage biomass production.

Conclusion

The result from this study showed that severely degraded rangeland treated with SDT₁ produced 204 times higher ($p < 0.05$) biomass yield than SDT₂. Similarly, a moderately degraded rangeland paddock treated with MDT₁ yielded 92.5 times higher ($p < 0.05$) biomass yield than MDT₂. The higher biomass yield obtained from severely and moderately degraded rangeland paddocks treated with SDT₁ and MDT₁ in this study was primarily due to cattle trampling effect and excreta droppings which were responsible for improving water holding capacity, nutrient cycling and as a result has favored the coming out of herbaceous plant species from the soil-seed bank. This was in agreement to the finding of Hart *et al.* (1993) and Todd-Brown *et al.* (2014). Similar finding of Peterson and Gerrish (1995) and Redden (2014) disclosed that the addition of dung and urine from cattle in range-land has increased soil-organic-matter and the soil nutrient content, which eventually enhanced more-fertile-soil, providing good favorable environmental condition for the growth of herbaceous species with higher biomass yield.

The study found that severely and moderately degraded rangeland paddocks treated with cattle impact tools had higher soil chemical parameters, vegetation composition and biomass yield than that from untreated cattle impact tools. This clearly signified that using cattle impact tools or taking physical action of cattle greatly promote soil seed bank regeneration by increasing vegetation cover and biomass yield, due to increase in soil fertility and soil moisture retention in the soil plant system. From this finding, we can conclude that degraded rangeland rehabilitated using heavy stock density of cattle to enable them exert maximum impact tools on degraded rangeland for a short duration

and then to be followed by adequate rest periods for the species to come out and the vegetation attain a stage of growth to accommodate the cattle to graze. As a result, attempts to restore degraded rangeland in tropical regions in general, and pastoral regions of Ethiopia in particular, should explore the use of cattle impact tools as a main development options of rehabilitating degraded rangelands.

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Author contributions

Denbela Hidosa prepared proposal from the idea initiated and securing fund executed the research, analyzed the data and transcribed the whole set up of the paper. Last but not least Dr Kidane G/Meskel initiated the idea for proposal development and also contributed to improve the paper quality and the grammatical soundness of the language write-up.

Conflict of interest statement

We declared that there are no competing interests between us for publication of this manuscript.

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Data Availability

All data are available in the main text or in the additional materials. The whole analysis and write-

up was undertaken from the data collected and the data is secured to our reach

Ethical Approval

Not applicable.

Consent for publication

We decided and approved this manuscript for publication in *Bangladesh Journal of Animal Science*.

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