The Contribution of Grazing Enclosures for Sustainable Management and Enhancing Restoration of Degraded Range Lands in Ethiopia: Lessons and Forward

Tesfay Atsbha Hailu
Tigray Agricultural Research Institution, Alamata Agricultural Research Center.

Abstract

From the reviewing of several papers Enclosures showed higher soil organic matter, total soil nitrogen, available phosphorus and cation exchange capacity than the open grazing lands. The higher values of soil properties and nutrient content in enclosures indicate that enclosures are one of the viable options to restore degraded soils. Soil properties in enclosures and open grazing lands showed significant correlations with biomass and vegetation cover indicating that vegetation restoration is a key to restore degraded soils through enclosure establishment. The sizeable differences in soil properties between the enclosures and adjacent grazing lands could be a logical consequence of aboveground biomass and vegetation cover improvements resulting from enclosure land management. In addition, the results demonstrated the positive influence of enclosure age on the restoration of the soils of degraded communal grazing lands. The establishment of enclosures assists to improve the overall ecological conditions of degraded areas so that they can provide better products and services for the people. The vegetation in the enclosure has a significantly higher woody vegetation density than the corresponding open area. The ground cover is much better in the enclosure than in the open area, thus supporting further regeneration because of better soil conditions and micro-climate. The significant increase of absolute stocks of carbon, nitrogen and microbial biomass compared to the degraded open rangeland indicates the potential for the restoration of soil quality through range rehabilitation. The increase in the number and biomass of perennial and annual grass species was significant at enclosure and open area, and the local communities benefit from using these species, through the ‘‘cut-and-carry’’ enclosure management system, for feeding their animals, constructing their grass-thatched huts or both. Establishing enclosures on communal grazing lands can be effective in restoring the degraded soils in the semi-arid lowlands and highlands of Ethiopia. We suggest that enclosures are potential options for future Sustainable Management and Enhancing Restoration of Degraded Range.

Keywords: Area enclosures, Area enclosures, Communal grazing land, Rangeland degradation rehabilitation

Introduction

Overview of Rangelands

According to Teague *et al.* (2009) rangelands are defined as those areas around the world with arid, semi-arid and dry sub humid climates, and where topography and soils are unsuitable for large scale farming, and these areas are traditionally used for pastoralist. In developing countries, pastoralists are more dependent on rangelands than in other countries because other employment opportunities, such as industry, are seldom available. Rangelands in many developing countries are being stress as animal numbers expand to meet a growing human population dependent on a shrinking resource base (Brown, 2008 cited in Holechek, J (2011)).

Many of communal rangelands in Africa are considered as overstocked, degraded and unproductive (Vetter, 2005; Tefera *et al.*, 2007). Causes of these degradations are generally attributed to combination of factors of which most of them are associated to human activities. The consequences of human based activities lead to climate change; that subsequently affects rangeland condition (Harris, 2010). East African countries have a vast area of rangeland, among which Ethiopian rangelands cover about 64% of the total area below 1,500 m.a.s.l that mainly include the Eastern, South, South Western and Western peripheries (Dawit, 2000). Rangelands (including grasslands, shrub lands, deserts, and tundra) occupy about half of the world's land area and contain more than 33% of the above and below-ground carbon reserves (Vashun and Jayakumar, 2012).

The world's agro-ecosystems (rangelands, croplands, and grazing lands), soil biota and non-soil biosphere are not effectively managed and they are very important carbon dioxide reservoirs that could off-set fossil fuel emission and mitigate climate change through carbon sequestration (McDermot *et al.*, 2014). The agro-ecosystems have the capacity to sequester 1.2- 3.1 billion tons of C/yr, and achieve cumulative potential of 30-60 Pg (Pg= petagram =1015 g) over a 50 year period that could off-set up to a third of the yearly increase in atmospheric carbon dioxide that is estimated at 3.3 pg C/year(Lal, 2004 and Lal,2011). This means minimal changes with respect to management in soil carbon sequestration across rangeland ecosystems could have a great impact on offsetting GHG emissions (McDermot *et al.*, 2014). Rangeland soil accounts for approximately 90% of the carbon in comparison to the aboveground biomass (Schuman *et al.*, 2001). Clay and iron greatly impact the soil organic carbon and reduce the bulky density of soils. SOM influences fertility, productivity and stability of the soil. Also, the water holding capacity, pH and soil temperature are buffered by SOM and SOC (Pattanayak *et* *al*., 2005). SOM increases the air spaces of soil pores and surface area, impacting positively on water and nutrients retention which is especially very important on rangelands which experience less than 600 mm precipitation yearly (Fynn *et al*., 2009).

Soil affects the vegetation of rangelands since it influences water availability, soil temperature regime, elemental balance, microbial biomass carbon and the activity and species diversity of soil flora and fauna (Lal, 2004 and Lal, 2011). Enhancing the SOC concentration is very important to improving the soil physical, chemical and biological qualities. The size, shape, arrangement of solids and voids, porosity, fluid holding and retention capacity, organic and inorganic substances and ability to accommodate vigorous root growth and development describe the soil structure (Lal *et al*., 2004). Pastoral communities living in the Ethiopian rangelands constitute roughly 10-12% of the Ethiopian populations (Hogg, 1997). The main pastoral communities are the Somali (53%), Afar (29%) and Borana (10%) living in the Southeast, North Eastern and Southern parts of Ethiopia respectively and the balance (8%) are found in Southern, Gambella and Benshangul regions (Hogg, 1997; Blench, 2001). Because of the low and erratic rainfall, their survival depends on surface and groundwater resources. Access to water during the dry season ultimately determines access to and control of grazing areas. On the Other hand, rangeland resources are threatened by increases in human and livestock populations, resulting in soil loss, deforestation, bush encroachment, and reduced bio-diversity (Blench, 2001). In order to reverse the problems of deforestation and land degradation, the establishment of area enclosures has been promoted to as strategy control land degradation and restores the natural vegetation. The general objective of this review is to review the Contribution of grazing Enclosures for sustainable management and enhancing restoration of degraded range lands.

Objective

General objective

- To review the Contribution of Grazing Enclosures for Sustainable Management and Enhancing Restoration of Degraded Range Lands

Specific objective

- To review the contribution of grazing enclosure of range lands in improving **range land condition**
- To review the contribution of grazing enclosure of range lands in **enhancing soil restoration**
- To appraisal the contribution of grazing enclosure of range lands in **carbon sequestration** in range lend
- To review the contribution of grazing enclosure of range lands in **improving pastoralist livelihood**
- To appraisal the **challenges and opportunities** of grazing enclosure communal range lands.

Methodology followed

This review paper analyzed related studies from 1990 to 2016. All the articles were searched through Google Scholar search engines. The key-words used to complete the search for relevant papers were *"enhancing soil restoration", "range land condition", "Range land degradation", "rehabilitation'', "ecological restoration''* and "*area enclosure*". The focused of the paper searched was on the Contribution of Grazing Enclosures for Sustainable Management and Enhancing Restoration of Degraded Range Lands in Ethiopia.

Over view of literature review

Rangelands degradation

Rangeland degradation is defined by Han *et al.* (2008) as the reduction or loss of the biological or economic productivity of rangelands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitat patterns; such as soil erosion, deterioration of the physical, chemical and biological properties of soil, and long-term loss of natural vegetation. Moreover, different studies showed that rangeland degradation is one of the major challenges in the pastoral and agro-pastoral areas of Ethiopia (Belaynesh, 2006; Samuel, 2009). Based on different studies on different rangelands of Ethiopia, the possible causes of rangeland degradation are heavy grazing, recurrent drought, rangeland cultivation, bush encroachment, human population pressures, shortage of rainfall, inappropriate uses of land resources and soil erosion (Mannetje, 2002; Belaynesh, 2006).

Rangeland Degradation Causes

Various environmental factors such as weather, soil, plant competition and grazing can influence the nutritive value of range plants directly or indirectly (Archer and Stokes, 2000).The proximate causes of rangeland degradation include overgrazing, unsustainable fuel wood use, mining, and plowing of rangelands with subsequent loss of soil productivity. The ultimate drivers, however, are typically associated with policies, socio-economic changes, or interactions of socio-economic and governance factors with climatic stressors such as drought (Donald J., and Jay P.2012). Teshome *et al*. (2009) and Solomon (2015) pointed out that expansion of cultivation, overgrazing, population pressure, re-settlement, establishment of National Park, lack of management and erratic distribution of rainfall were the major causes of rangeland degradation in Ethiopia. Mekuria *et al*. (2007)

highlighted that overgrazing, deforestation and poor land management as the main causes of range land degradation, and also notified that fragmentation of agricultural and grazing lands; decline of soil fertility and decline of yield are the main consequences of soil erosion due to rangeland degradation.

Rangelands Management Practices

Area Enclosure/ Exclosures

Enclosures in Africa were associated with the expansion processes of European overseas missions and its effect in expanding the productive role of capitalism (Makki and Geisler, 2011).

The objective of enclosing communal lands is to improve sustainable natural resource management, ensure access to dry season grazing, and reduces competition for resources and encroachment of conservation areas. This is achieved through the enclosures ability in supporting the regeneration of grasses through controlled livestock access into the land (Makki and Geisler, 2011).

Enclosures are "areas surrounded by walls, objects or other structures" and serve to keep objects, usually animals, inside a given area (Manor and Saltz, 2008). Traditional range enclosures involving semi-private grazing lands are widely used by pastoralists in the Horn of Africa for seasonal grazing by calves and sick or weak animals (Oba *et al,* 2000). Oppositely, Exclosures are ″areas from which unwanted animals are excluded″ and their main purpose is to keep things (animals) out of a given area. Typical examples of Exclosures feature fences that prevent animals from entering and to increase experimental control, it is possible to only exclude targeted species from the fenced area while allowing other animals to move freely (Vercauteren *et al*., 2007).

According to Ayana (2007), range enclosures of different ages may reflect different vegetation states that can be spatially arranged along age chronosequence within the landscape matrix. Enclosures are sources of wood for construction, farm implements, and non-timber forest products. They also play an important role in conserving remaining soil resources and improving soil fertility by augmenting soil nutrients from decomposed plant remains and also limit nutrient loss from a site by controlling runoff (vegetation acting as a physical barrier to soil erosion) (Mengistu *et al*.,2005). Enclosures can be viable systems if they have clearly defined users, clearly defined resource boundaries, and realistic rules established locally. Indeed, laws and legislation should support community management systems to avoid the “tragedy of the commons.” Enclosures with locality-specific and community-based co-management systems are crucial and can be regarded as alternative approaches to managing degraded lands (Maikhuri and Rao 2002).

Contribution of Grazing Enclosures for Sustainable Management and Enhancing Restoration of Degraded Range Lands: Review

The Effects of grazing enclosure of range lands in improving range land condition

According to Ibrahim (2016) enclosure areas have been effective in restoring plant species composition, biomass and cover of herbaceous species and the enclosure areas were in a better condition than the communal grazing areas. He is notified that the low values for basal cover, litter cover, number of seedlings, perennial and undesirable of dominant grasses in the open grazed sites could reflect the impact of continuous grazing and recurrent drought. Similarly, Van der Westhizen *et al*. (2001) argued that in arid and semi-arid rangelands, these parameters are greatly influenced by the effects of gazing pressure, drought and rainfall variability.

Repeated grazing and prolonged drought might lead to a reduction in herbaceous species composition and diversity, which might accelerate decline in rangeland condition. As reported by Angassa (2014) heavy grazing pressure may reduce plant species composition and basal cover. On the other hand, the highest scores for basal cover, age distribution of dominant grasses and number of seedlings were recorded in enclosed sites reflecting the benefits of reduced disturbance such as the effects of heavy grazing, trampling and inappropriate management interventions (Amaha, 2006). In addition, continuous grazing affects the amount of plant litter at the soil surface and exerts indirect pressures on the germination and seedling establishment patterns (Teshome, 2007; Lishan, 2007; Desalew, 2008). The biomass production in the enclosure grazing areas better than the communal grazing areas this might be due to better rangeland management practices in the enclosure areas but the communal grazing areas have deteriorate through continuous overgrazing and mismanagement system of the community (Ahmed, 2006; Ibrahim,2016) (Table1).

Table **1:** Biomass production (LSM and SE) of the two grazing land management practice (Ibrahim, 2016)

Parameters	Enclosure	Communal
Tgb	61.99 ± 1.81^{a}	30.50 ± 1.28^{b}
Tngb	8.62 ± 1.16^{a}	7.57 ± 0.82^{a}
Thb	70.61 ± 2.05^{a}	38.08 ± 1.45^{b}

Tgb=Total grass biomass, Tngb=Total non-grass biomass, Thb=Total herbaceous Biomass; Means with different letters in a row are significantly different at ($P \leq 0.05$).

Amsalu (2000) has reported that increased grazing pressure aggravates the hoof effect, which increases the soil bulk density resulting in reduced infiltration. Teshome (2007) has found low values for basal cover, litter cover, number of grass seedlings and age distribution in heavily grazed sites. This implies that decline in the rangeland condition in the open grazed areas have a direct negative influence on livestock production and livelihood of inhabitants (Mengistu *et al*., 2015) (Table 2).

Table 2: Range condition scores (Mean ± SE) of enclosure and open-grazed areas (Mengistu *et al*., 2015)

Parameter	Enclosure	Open
Grass composition	6.95 ±0.60[a]	5.70±0.65[a]
Basal cover	6.35±0.48[a]	2.70±0.21[b]
Litter cover	4.20±0.68[a]	0.00±0.00[b]
Soil erosion	3.25±0.16[a]	2.20±0.15[b]
Soil compaction	3.60±0.11[a]	2.80±0.12[b]

Mean in the same site and row for each parameter with different superscripts are significantly different (P<0.05)

The Effect of Enclosure on Herbaceous and Woody Species Composition

Open grazed area had less herbaceous species abundance, which probably reflects the impact of increased grazing pressure on most herbaceous species as reported by (Amsalu, 2000; Teshome, 2007; Dereje *et al*., 2002; Desalew, 2008; Angassa, 2014). Herbaceous species composition in the enclosure area was in a better condition than those in the open grazing sites. Moreover, the observed higher species abundance in the enclosure areas is probably related to fewer disturbances by livestock grazing (Angassa and Oba, 2008). Similarly Angassa and Oba (2010) and Angassa (2014) have shown the connection between herbaceous species and grazing intensity, suggesting that more species abundance under light to moderate-grazed areas reflect the effect of heavy grazing on individual species. The decline in the proportion of herbaceous species abundance due to the effect of grazing pressure is consistent with other studies (Oba *et al*., 2000; Amsalu, 2000; Teshoma, 2007). Amaha (2006); Admasu (2006); Desalew (2008) highlighted that the species composition orderly change of from highly palatable to less palatable with the increase of grazing pressure. Under continuous and increased grazing pressure, palatable plants (decreasers) would die and with the death of decreasers less palatable plants (increasers) become dominant (Mengistu *et al*., 2015).

Table 3: Mean values of vegetation characteristics in paired enclosures and adjacent grazing lands

Variables	Enclosure	Open grazing land	Citation
Plant species richness (number)	31.3±4.2*	11.7±4.8*	Mekuria and Aynekulu, 2011
	27	14	Emiru *et al*.,2007
	15.58 ± 1.96	9.38 ± 1.96	Muluberhan *et al*.,2006
Diversity (Shannon– Wiener index)	2.1± 0.1*	1.4± 0.2*	Mekuria and Aynekulu, 2011
	3.72 ± 0.25	2.31 ± 0.25	Muluberhan *et al*.,2006
Canopy cover (%)	43.1± 4.1*	15.1± 2.7*	Mekuria and Aynekulu, 2011

*Differences between enclosures age and the adjacent grazing lands are significant at P<0.05 after paired t-test.

Herbaceous species and woody species diversity was higher in the enclosure than the adjacent grazing area (yayneshet, 2011). The higher diversity measured in the enclosure might be explained by increased litter accumulation, improved soil organic matter and other nutrients inside the enclosures that eventually lead to increased species richness (Hiernaux,1998). Enclosures improved vegetation status with respect to species richness, cover and height (Zhou *et al*., 2011) and community structure (Slimani *et al*., 2010). Gebrewahd (2014) pointed out that were grass species composition significant difference in to range land management. The result shows that very few grass species dominated the open grazing land whereas a relatively good proportion of important grass species were present in enclosed area. And also he reported that the species composition of grasses was significantly lower than the mean in the open grazing land. The same result was reported by Emiru (2002). Similarly, Amsalu (2000) suggested that heavy grazing might cause reduction of plant species composition and diversity over time. Angassa and G. Oba (2010) show that herbaceous biomass and diversity index and evenness of herbaceous species was significantly greater in enclosures than in the open grazed areas.

Table 4: Response of diversity of plant life forms in terms of abundance, species richness and diversity index comparing area enclosures and open-grazed area managements (Dereje *et al*., 2002)

Diversity of life forms	Area enclosure	Open-grazed
Abundance		
Herbs	161.47	114.3
Shrubs	14.6	15.4
Trees	68.6	37.05
Species richness		
Herbs	9.8	7.7
Shrubs	2.9	2.3
Trees	4.8	2.6
Diversity index		
Herbs	1.7	1.62
Shrubs	0.88	0.58
Trees	1.05	0.49

Woody species appearance in enclosures indicates a long period of protection, allowing regeneration of shrubs and trees (Kebrom, 2001; Tefera, 2001). The vegetation composed by the woody species and the ground cover of herbaceous species was denser in the enclosure than in the open area. The difference in density was significantly greater for the herbaceous than for the woody species. This indicates that the disturbance in the open area was mainly due to the high grazing intensity throughout the year (Emiru *et al.,* 2007). The density of woody vegetation was significantly affected by grazing types, i.e. a higher density and canopy cover of woody species was observed in enclosure site than in the communal grazing sites (Augustine, D.J. and S.J. McNaughton, 2004; Teshome *et al*., 2009). Protection influenced the height class distribution of the three woody vegetation attributes, i.e., stem height, canopy height and canopy cover. Average stem height was higher in the enclosures than in the open grazed areas (Butler, L.G. and K. Kielland, 2008; Yayneshet, 2011).

The Effect of area Enclosure on Dry-matter Yield of Herbaceous Species

The total dry matter yield and dry matter of individual grass species were higher in enclosures than in the open grazed areas. The impact of management factors may be the main reasons for the significant difference in terms of herbaceous biomass between the enclosure and open grazed areas (Mengistu *et al*., 2015). The low dry matter yields of forage in the open grazed area as compared to enclosure areas corresponded with the reports of Teshome (2007), suggesting that rangelands in poor condition had low forage production with less desirable forage than those rangeland in good conditions. Similarly, the results of this review is in agreement with other reports (Amsalu, 2000; Amaha, 2006; Gemedo *et al*., 2006; Teklu *et al*., 2010; Shankute *et al*., 2011). Gemedo *et al*. (2006), suggesting that rangelands in poor condition had low forage production with less desirable than rangelands in good condition.

Table 5: Dry matter yield (g/m^2) (Mean ± SE) of herbaceous species rangeland practices (Mengistu *et al*., 2015)

Parameter	Enclosure	Open
Highly desirable grass	43.69±10.59^a	4.96±1.23^b
Intermediate desirable grass	27.05±8.49^a	0.09±0.06^b
Less desirable grass	67.37±13.84^a	2.22±0.82^b
Total grass	117.90±9.13^a	7.27±1.04^b
Legumes	1.97±0.84	0.84±0.32
Forbs	6.99±1.12^a	3.29±0.74^b
Total biomass	126.85±9.23^a	11.40±1.31^b

Mean in the same row for each parameter with different superscripts are significantly different (P<0.05)

Some reports (Amsalu and Baars, 2002; Gemedo *et al*., 2006) have suggested that poor range condition had low forage production with less desirable forage than good range condition. On the other hand, the increase in the DM biomass of forbs and DM of less desirable grasses in the communal grazing lands might be an evidence for poor range condition. This might point out that such low DM herbaceous biomass in the communal grazing area could directly affect livestock production and sustainability of the rangeland over time (Ahmed, 2006). Teshome *et al*. (2009) highlighted that total above ground DM biomass, DM biomass of grass, DM biomass of highly, DM biomass of intermediate and DM biomass of less desirable grasses was significantly highest in the enclosure grazing sites while the lowest was recorded in the communal grazing sites.

Chemical Composition of Herbaceous Species

According to Teka *et al.* (2012); Mittal *et al.* (2012) who studied the nutritional quality of grass species in Borana rangeland and India, respectively showed that differences in grazing land management can greatly influence the nutritive value of herbaceous plants in arid and semi- arid environments. The possible explanations for the observed variation among open grazing land and enclosure area may be due to differences in soil nutrient status and intensity of grazing, where most palatable species may be affected by excessive grazing. Open grazing rangeland sites had higher content of CP than enclosed sites (Teka *et al*., 2012; Mengistu *et al*., 2015). Thus, the low accumulation of CP and increased level of fibers are an indication of poor quality of forage (Teka *et al*., 2012). However, higher NDF and ADF were recorded within area enclosures than open grazed rangeland areas. The possible explanation for the highest content of fibers could be due to lack of proper time of harvesting or utilization by grazing animals at the proper stage of maturity of the forage plant (Shankute *et al*., 2011; Teka *et al*., 2012).

Table 6: Chemical composition (Mean ± SE) and DM (%) of herbaceous species rangeland practices (Mengistu *et al*., 2015)

Parameter	Enclosure	Open
DM (%)	42.00 ± 1.00^{a}	33.50 ± 1.50^{b}
Ash	$17.78\pm0.1.05^{a}$	10.81 ± 0.60^{b}
NDF	67.13 ± 0.65^{a}	61.04 ± 0.49^{b}
ADF	35.45 ± 0.12^{a}	31.68 ± 0.19^{b}
ADL	9.81 ± 0.60^{a}	6.58 ± 0.05^{b}
CP	6.08 ± 0.08^{b}	7.32 ± 0.26^{a}

Mean in the same row for each parameter with different superscripts are significantly different ($P<0.05$)

The Effects of grazing enclosure of range lands in improving Soil condition

Open grazing land had a high degree of erosion, due to reduction of vegetation cover by overgrazing and cutting of fuel wood. The rate of soil erosion can be accelerated when grazing intensively exceeds the threshold and plant cover is reduced below critical level in the open grazing land (Gebrewahd, 2014). This might be due to the reduced animal and human interference in the enclosures, the re-vegetating plants reduced raindrop intensity and hindered detachment of soil particles that cause soil erosion. Soil was more eroded and compacted in the communal grazing sites than in enclosure area (Teshome *et al*., 2009). Soil C, N and P contents could probably be increased by enclosures (Wu *et al*., 2011).

Table 7: Average values of soil chemical properties in exclosures and adjacent communal grazing lands

Soil properties	Open	Enclosed	Citation
SOM (%)	2.26±0.24	4.4±0.69	Mekuria, 2013
	1.5	2.8	Mekuria *et al*.,2009
N (%)	0.31±0.05	0.48±0.08	Mekuria, 2013
P (ppm)	25.29±0.91	44.91±2.58	Mekuria, 2013
CEC (cmolc kg^{-1})	45.57±2.08	54.58±1.59	Mekuria, 2013
	186.21(mmhos)	207.79(mmhos)	Yousefian *et al*.,2011
	39.8±34	46.3±3.4	Stephen *et al*.,2014
PH (1:5 H2O)	6.1±0.1	6.2±0.1	Mekuria and Aynekulu,2011
	8.29	8.38	Yousefian *et al*.,2011
	8.4±0.4	8.3±0.2	Stephen *et al.,*2014

Change in SOC content was closely related to soil texture change under long-term enclosure (Slimani *et al*., 2010). Pei *et al*. (2008) and Zhou *et al*. (2011) suggested that very long-term enclosure could have a significant impact on soil C, N and P in enclosures areas. Mekuria (2013) pointed out that soil organic matter, total soil nitrogen, available phosphorus, and CEC in enclosures were positively and significantly correlated with woody biomass, vegetation canopy cover, silt content, stone cover, and enclosure age, and were inversely and significantly correlated with bulk density and sand content. Stephen *et al*. (2014) highlighted that the bulk density of topsoil significantly higher in the open rangeland than in the enclosures. Similar results were reported by Descheemaecker *et al*. (2006). The average topsoil moisture content was 21% to 22% (w/w) in enclosure systems and 16 % in the open rangeland (Stephen *et al*., 2014).

The removal of organic matter from the enclosures by grazing and grass harvesting activities has the greatest influence on soil restoration. Since most of the tropical rangelands are on degraded soils, the potential for sequestering C through rangeland rehabilitation is substantial (FAO, 2001). Stephen *et al*. (2014) reported that the average N contents were 0.41 mg N/g soil in the open rangeland, increasing to and 0.75 mg N/g in the enclosures. He had also shown that enclosures range land has increase in C stocks compared to open rangeland (8.42% greater than). The pH measurements inside the enclosures showed that its level was lower than that in the grazed area outside the enclosures (Zhanhuan *et al*., 2014).

Table 8: Soil physical properties of the communal enclosures and open rangeland

Soil properties	Open	Enclosed	Citation
Sand (%)	13±3[a]	9±3[a]	Stephen *et al*.,2014
	55.1±2.7	60.4±3.4	Mekuria and Aynekulu,2011
	62.3	62.3	Mekuria *et al.,* 2009
Silt (%)	59±5[a]	56±8[a]	Stephen *et al*.,2014
	28.0±2.6	23.8±1.9	Mekuria and Aynekulu,2011
	21.3	22.4	Mekuria *et al*., 2009
Clay (%)	28±7[a]	35±10[a]	Stephen *et al*.,2014
	16.9±3.4	15.8±2.8	Mekuria and Aynekulu,2011
	15.8	15.3	Mekuria *et al*.,2009
Bulk density (g/cm3)	1.48±0.08[a]	1.19±0.06[c]	Stephen *et al*.,2014
	1.2±0.1	1.1±0.1	Mekuria and Aynekulu,2011
Soil moisture (%)	16±2[a]	22±2[b]	Stephen *et al*.,2014

The herbaceous biomass production and cover are the means of soil restoration (Mekuria *et al*., 2011). Significant increases in the soil organic carbon, total nitrogen and microbial biomass contents and stocks were found in the enclosures as compared with the degraded open rangeland. The significant increase of absolute stocks of carbon, nitrogen and microbial biomass compared to the degraded open rangeland indicates the potential for the restoration of soil quality through range rehabilitation (Stephen *et al*., 2014).

Changes in Ecosystem Carbon Stock in Relation to Enclosure

Rangelands can be large carbon sinks since they are one of the most widely distributed landscapes in the world. Approximately 30% of the ice-free global land surface is in rangelands that have up to 30% terrestrial carbon stocks (Schuman *et al.,* 2002; Neely *et al*., 2009). The process of carbon sequestration on rangeland soils can increase the SOC concentration, enhance the SOC pool and off- set anthropogenic GHGs emissions. Climate change, particularly drought, may impact greatly on rangelands SOC pools, changing them from sinks to emission sources due to the xeric nature of the soils which directly affect the photosynthetic rates than total respiration rates (Balogh, 2005).

In the communal grazing lands, the positive correlation of soil C with vegetation canopy cover suggests that restoring the vegetation canopy cover is vital to restoring soil C stocks (Nosetto *et al*.,2006). An increase in vegetation canopy cover would not only increase litter input into the soil but would also reduce the erosive impact of raindrops, resulting in less soil erosion and consequently less soil C loss (Mekuria *et al*., 2009). A similar mechanism was reported from a study of four different land uses in two ecological regions of Ethiopia, showing that soil organic matter concentration was influenced by the amount and type of vegetation and grasses as well as the intensity of grazing (Bewket and Stroosnijder, 2003).

Restoration of badly degraded rangelands soils and ecosystems that were formerly under cultivation, mining, depletion of woody vegetation and restoring soil stability with permanent vegetation is a high potential to sequestrating soil carbon (McDermot *et al*., 2014). Enclosures showed higher soil C concentrations, soil C stocks, and aboveground C stocks than the adjacent grazing lands. Soil C stock increases of 41 to 60% and to aboveground C stock increases of 83 to 87% following conversion of degraded grazing lands to enclosures. Soil C stocks contributed most of the increase in ECS (range 83–90%) compared with aboveground C in enclosures (Mekuria *et al*., 2011). Booker *et al*. (2013) reported that rangeland management will achieve very little for carbon sequestration. Climate change greatly impact the soil structure and vegetation on agro-ecosystems, particularly at the arid and semi-arid regions where soil water is limited.

Table 9: Total aboveground, belowground carbon stocks and total carbon (t C ha–[1]) across the two rangeland management practices (Bikila *et al*., 2016).

Range management practices	ROC	SOC	Total belowground carbon	Total aboveground carbon	TC
Communal	0.53[a]	127.86[b]	128.39[b]	13.11[b]	141.5[b]
Enclosure	1.53[a]	237.36[a]	238.89[a]	61.49[a]	300.38[a]

Means with the same letter superscripts along columns are not significantly different at a = 0.05 or 0.01 level of significance, ROC = root organic carbon; SOC = soil organic carbon; TC = total carbon; t C ha_1 = ton of carbon per hectare.

Carbon sequestration on rangelands is environmentally friendly, inexpensive and natural process of mitigating climate change when compared to other methods, unlike others, the co-benefits of increasing the SOC pool includes improving biodiversity, enhance agronomic productivity, reduce erosional losses, restore degraded lands, improve the quantity and quality of water resources and advance global food security (Lal , 2011). The literature explains grazing to be one of the management practices that aid in the physical break down, increase rate of residual plant material decomposition and soil incorporation, hence, restoration of badly degraded rangeland soils (Derner *et al*., 2007). Several other studies have shown that grazing intensity and frequency may impact greatly on carbon storage in some areas on rangelands. Schuman *et al*. (2005) reported that severe drought and heavy grazing can close significant deficits in SOC that was previously stored, and also shift the microbial community resulting in further losses in soil C.

Effects of enclosure age on different parameter

In Tunisia, Jeddi and Chaieb (2010) documented that 12-year enclosures enhance the total plant cover, dry matter yield, species richness, and contents of soil organic matter, total nitrogen, and water infiltration rate compared with continually grazed area. Analysis of 115 pastures and other grazing-land studies worldwide by Conant *et al*. (2001) indicates that soil C levels increase with improved management (i.e., fertilization, grazing management, and conversion from cultivation or native vegetation) and that the greatest C sequestration occurs during the first 40 year of implementation of the management practice. Similarly, Cheng *et al.* (2011) indicated that 20 year exclusion of livestock grazing significantly increased aboveground and belowground biomass and species richness. Similar trends were also reported from case studies conducted on enclosures in the central and northern highlands of Ethiopia: enclosures had twice the plant species richness and diversity value compared with communal grazing lands after 22 years of enclosure establishment (Tefera *et al*., 2005), an increase in woody species richness of 13 after 8 years of enclosure establishment (Emiru *et al*., 2006), and an increase in soil organic matter , total N , and available P after 10 years of enclosure establishment (Mekuria *et al*., 2007). 15–25 years enclosure accumulated relatively more herbaceous biomass than <15 years and >25 years enclosures (Angassa and G. Oba, 2010). Gebrewahd (2014) also reported that the five years enclosed land had significant lower mean of grass species composition compared to the ten years enclosed land and pointed out that the age had a significant effect on the increment of grass species composition and diversity. The herbaceous species richness declined with increase in age of the enclosures (i.e. <15 years enclosures had more species richness than enclosures of >25 years old (Angassa and G. Oba, 2010).

Zerihun and Back!eus (1991) pointed out that the composition, diversity and density of woody species of the above-ground vegetation were higher in the enclosures suggesting rehabilitation of the degraded areas in relatively short periods of time by simply avoiding or minimizing interference of people and domestic animals in the degraded areas, i.e. establishing enclosures. Woody species richness was significantly greater in the age of<15 years enclosures than in the >25 years enclosures. Overall, woody plant density was greater in the age of <15 year enclosures than in the >25years. The diversity and evenness of woody species were greater in the age of <15 years enclosures than in the 15-25 years and >25 years enclosures (Angassa and G. Oba, 2010). Mekuria (2013) explain that the large grass and herbaceous species biomass are the outcomes of a management practice that restricts grass harvesting for 3–5 years after enclosure establishment.

Angassa and G. Oba (2010) explain that the highest mean value of species diversity was recorded in the ten years enclosed land; five years enclosure scored intermediate value, whereas the least diversity average was recorded in the open grazing land. This report is in agreement with Oba *et al.* (2001) and Mulbrhan *et al.* (2006). Besides, decline in species diversity in the grazing land could be a result of the loss of seedling of some species unable to establish at early stage of development, and selective defoliation and trampling by grazing herbivores (Belaynesh, 2006).

Table 10: Mean comparison of vegetation attributes in enclosure and open range land (Angassa and Oba, 2010)

Vegetation variables	Age of enclosures			Management	
	<15 years	15-25 years	>25 years	Enclosure	Open
Biomass (g/ m²)	164[a]	176.8[a]	168.1[a]	211.2[a]	128.1[b]
Herbaceous cover (%)	44.1[a]	44.8[a]	43.8[a]	44.2[a]	44.2[a]
Tree cover (%)	56.6[a]	56.7[a]	57.1[a]	56.8[a]	56.8[a]
Basal cover of grasses (%)	13.8[a]	14.1[a]	15.2[a]	17.2[a]	11[b]
Density of herbaceous species / m²	44[ab]	47.8[a]	41.8	44.6[a]	44.5[a]
Herbaceous Richness/ m²	4.6[a]	4.9[a]	4.8[a]	5.1[a]	4.4[b]
Woody richness(m²)	4.3[a]	3.3[b]	3.7[b]	3.9[a]	3.7[a]

a,b Different superscripts within the row show significant difference ($P < 0.05$).

Emiru *et al*, (2007) reported that the vegetation in the enclosure has a significantly higher woody vegetation density than the corresponding open area and also indicted that enclosures show a positive impact on density. The ground cover is much better in the enclosure than in the open area, thus supporting further regeneration because of better soil conditions and microclimate. The mean aboveground biomass yield measured in enclosures was more than twice that of the adjacent grazed areas/uncontrolled grazing land (yayneshet, 2011). The enclosures have marginally higher diversity index than open areas (Macdonald, 2003).The high diversity values of enclosures indicate the technologies' significance in conservation of genetic resources of woody species which are under heavy threat of local extermination (John N. and Gabriel M. 2013).

Changes in Soil Properties, carbon stock Vs Enclosure Age

Range rehabilitation promotes litter and organic matter supply by reducing soil disturbance, restoring herbaceous vegetation and increasing biomass production (Mekuria and Aynekulu, 2011). Enclosure age also plays a role in conditioning the rehabilitation impact on soil properties (Mekuria and Aynekulu, 2011). In particular, the removal of organic matter from the enclosures by grazing and grass harvesting activities has the greatest influence on soil restoration. Since most of the tropical rangelands are on degraded soils, the potential for sequestering C through rangeland rehabilitation is substantial (FAO, 2001). Successful restoration of vegetation cover improves soil water balance and soil fertility, reduces soil erosion and restores the soil biodiversity and ecosystem services (Tongway and Ludwig, 2011). The ten years enclosure had very slight erosion, this could be due to long year rest that increased plant cover and in turn decreased soil erosion (Dereje, 2001; Valckx *et al.* 2002; Emiru 2002; Dereje *et al.,* 2003; Gebrewahd.2014). Range rehabilitation through enclosures resulted in higher microbial biomass, organic carbon and nitrogen stocks within less than 10 years of establishment compared to the degraded open rangeland (Stephen *et al*., 2014).

The higher SOM, TN, and AP contents in enclosures compared to free grazing lands is related to the restoration of natural vegetation, which has increased above-ground and below-ground litter inputs and maybe litter quality and nutrient cycling. A direct impact of grazing on the rangeland ecosystems is the removal of a major part of above-ground biomass, consequently the input of above-ground litter to the soil decreases, which may have important consequences for soil nutrient conservation and cycling (Solomon *et al*., 2000). According to Mekuria *et al*. (2007) higher SOM in enclosure areas potentially improve soil physical properties such as soil structure and total porosity. This in turn increases water infiltration rates into the soil and decreases runoff. In enclosure areas where the canopy of shrubs and understory vegetation has been restored, the soil surface is protected from the erosive energy of falling raindrops, which prevents splash erosion (Mekuria *et al*., 2007). A maximum value of soil in the topsoil was recorded in the oldest enclosure (23 years). This shows a slow but effective restoration of the organic carbon under the tropical semi-arid conditions, factored by the adopted enclosure management (Stephen *et al*., 2014).

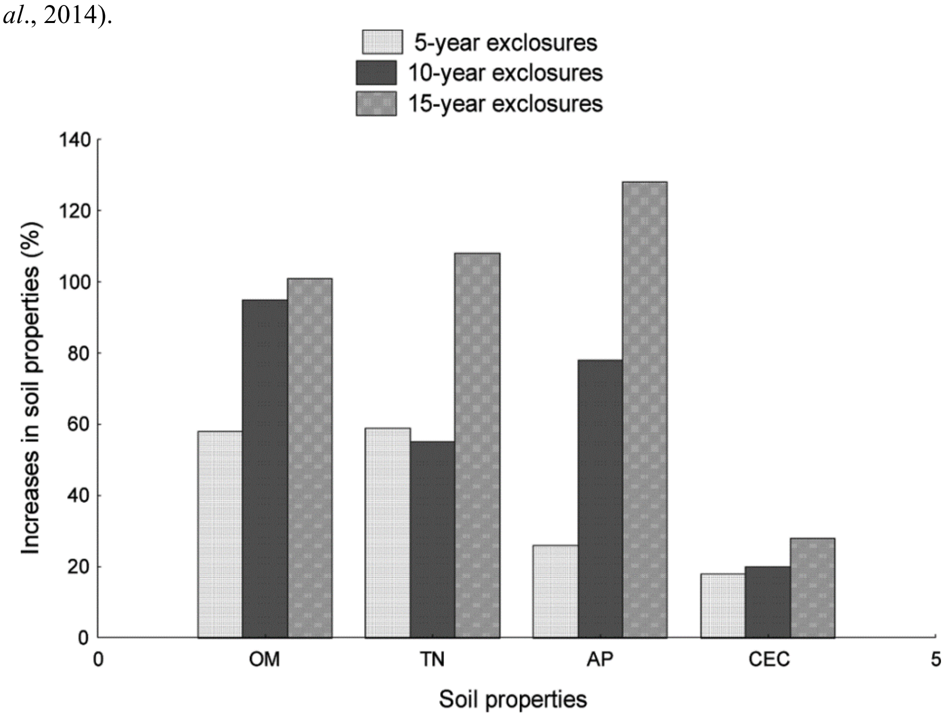

Figure 1: Increases in soil properties following the conversion of communal grazing lands into exclosures. OM refers soil organic matter, TN refers total soil nitrogen, AP refers available phosphorous, and CEC refers cation exchange capacity (Mekuria, 2013).

The lack of difference in soil properties between the 5- and 10-year-old enclosures may have different explanations. For the first 3–5 years after enclosure establishment, all utilization including fodder harvesting is abandoned. This helps to increase litter input into the soil. Furthermore, grass litter is more easily decomposed than tree and shrub leaves. Alternatively, in the 'natural' succession after enclosure, grasses and herbs dominate for the first 5 years followed by evergreen shrubs and trees in later years (Dereje *et al*., 2002). If grasses and herbs produce a better quality litter than shrubs and trees this may explain that the increase in SOM is fast in the beginning and slow after shrubs and trees dominate (Mekuria *et al*. 2007) .The study by Dereje *et al*. (2002) also exposed that restoration of tree species would require longer periods of enclosure, while restoration of herbaceous species richness requires shorter periods. To increase SOM content also beyond the first 5 years after enclosure, it seems important to change grass and herb management after the first 3–5 years. Soil properties increase significant from 5-year to 15-year enclosures was signified that enclosure age strongly influenced the restoration of degraded soils. The relatively large increase in soil properties in the first five years compared to the relative increases in 10 and 15 years period may have resulted from the large carbon inputs derived from grasses and herbaceous biomass (Mekuria, 2013) (figure 1).

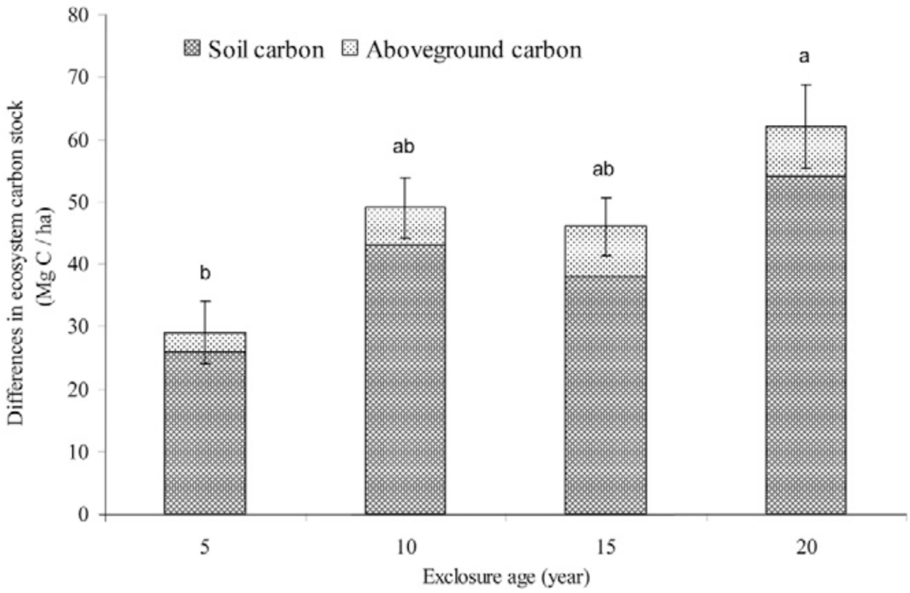

Fig 2: Differences in ecosystem C stocks between paired enclosures and adjacent communal grazing lands in relation to enclosure age (Mekuria *et al*., 2011)

Gebrewahd (2014) notified that the basal cover demonstrated that there was significant variation between the area enclosure and open range land. The mean score exposed that the open grazing land use type scored least mean basal cover and five years enclosure land use type scored intermediate value, while the ten years enclosure land use type attained the highest mean basal cover. It seems that grazing by livestock has a major influence in determining herbaceous biomass and grass basal cover in the open grazed areas compared to the enclosures (Angassa and G. Oba .2010). Many findings (Tadesse *et al*., 2002; Oba *et al*. 2001; Mwalyosi, 2000; Mengistu *et al*., 2005) has exposed that the increase in herbaceous biomass in enclosures could be linked with reduced grazing disturbance by livestock.

The higher soil and vegetation C stocks in enclosures indicate that enclosures have a significant positive effect on the restoration of ECS, even in highly degraded communal grazing lands (Nosetto *et al*., 2006). Similar trends were reported from case studies conducted on enclosures in the central and northern highlands of Ethiopia: an increase in soil organic C in the 0- to 0.15-m depth after 8 years of enclosure establishment (Girmay *et al*., 2009), increase in the 0- to 0.3m depth after 20 years (Descheemaeker *et al*., 2006b) and increase in the 0- to 0.15m depth after 20 years (Tsetargachew, 2008). In semiarid Kenya, Verdoodt *et al*. (2009) also reported increases of in the 0- to 0.15m depth after 15, 18, and 23 years of enclosure establishment, respectively.

Improving pastoralist Livelihood

Rangelands account between 40-70% of the world's land area (Ravi *et al*., 2010) and these rangelands play a critical role in providing humankind with the goods and services needed for survival (Meinzen-Dick *et al*., 2005). Rangelands provide wild ruminants with over 95% of their feed requirements worldwide and it is also a natural habitat for all terrestrial wild animals (Holechek *et al*., 2000). About 80 - 90% of the food energy consumed by nomadic African herders comes from meat, milk, and blood supplied by their livestock. The livestock also act as cash that can be used to buy other food and related necessities (Holechek *et al*., 2000). Rangelands also generate intangible benefits such as the pleasure that people take in observing plants and wildlife, the sense of wonder and spiritual connection that many people feel when immersed in rangeland landscapes, and studying natural systems (Teague *et al*., 2009).

As an estimated 70 % of the world's poorest rely on income from pastoralism and agro-pastoralism, changes in vegetation and its associated ecosystem functions through the use of enclosures will have an immediate effect on their livelihoods (Thomas, 2012). The practice of enclosures in East Africa covers a wide range of management techniques from the physical fencing off of smaller parcels of land for private or communal (Yaynshet *et al*., 2009; Damene *et al*., 2013; Mureithi *et al*., 2015) purposes to more implicit social contracts regarding the use of larger areas of communal land (Monela *et al*., 2005; Barrow 2014). In some areas, enclosures constitute a traditional management tool, and in other areas, enclosures were introduced in order to rehabilitate degraded rangelands. What is new, however, is the increasingly common use of enclosures as a way of privatizing communal land, driven by a combination of increasing restrictions on livestock mobility due to population increase, emerging and expanding markets for livestock and agricultural products, and conflicts around resources in arid and semi-arid areas (Beyene 2009; Catley *et al*., 2013; Napier and Desta 2011).

An increasingly common feature of land use change in dryland Sub-Saharan Africa is the enclosing of land in order to, for example, increase productivity of livestock and alleviate poverty (Mureithi *et al.,* 2015), protect crops and arrest land degradation (Mekuria *et al*., 2011). The livelihood implications of enclosures have been a topic for a number of recent case studies across East Africa and indicate negative social impacts in terms of erosion of traditional, collective property rights, emergence of conflicting interests over land and water resources and a gradual transfer of assets from poor to wealthier households (Angassa and Oba, 2008; Beyene, 2009; Beyene 2010; Lesorogol, 2008; Napier and Desta, 2011).

Enclosures are seen as instrumental in order for households to use land for agribusinesses that includes commercial livestock and agricultural production and in some cases also the buying, selling and/or renting of land (Nyberg *et al*., 2015). Although, Mekuria (2004) supported the idea that farmers benefit from the protective effect of closed areas (closed areas reduce runoff and soil erosion in farmlands located below the closed areas) this is an effect that does not directly affect their income while harvesting of grass and herbs does. The practice of enclosing communal land can be seen as an important management tool for sustainable intensification of drylands within the general framework of a market-driven livestock revolution (Angassa and Oba 2010; Catley *et al*., 2013; Verdoodt *et al*., 2010). Local communities view enclosures as an integral part of the afforestation of degraded lands that demonstrates a sacrifice of short-term benefits in favor of long-term visions and benefits. Local communities have also developed a sense of ownership as they gain experience in authority over direct use, participation in decision-making, and establishing their own by-laws (Tefera *et al*., 2005).

Challenges related to enclosure range land

Establishment of communal enclosures in most African rangelands has been an important coping strategy in response to declining grazing lands and diminishing patterns of livestock mobility due to human population increase (Beyene, 2009). Selemani *et al.* (2013) and Verdoodt *et al.* (2010) indicate that enclosing communal rangelands may result in social conflicts and cause range degradation rather than contributing to rehabilitation. The consequences of establishment of enclosures may result in allocation of poor pasture to some groups and better pasture to others, creating inequality and social tension (Beyene, 2010).

Poor management of common resources pool has often resulted into negative effects on sustainability of communal rangelands. Centralized and local control over resources is believed to have detrimental consequences on the sustainability of communal rangeland resources (Schafer and Bell, 2002). Schafer and Bell (2002) argued that if communities are allowed to control their own resources, they should have strong incentives to manage resources sustainably. In most of common property resources, the right to land has been granted to clan leaders and enforced by community elders (Selemani *et al*., 2013). The gradual dismantling of communal rangelands is therefore attributed to poor organization of institutions managing communal rangelands and shift in land tenure policies (Beyene, 2009).

CONCLUSION AND RECOMMENDATION

In order to reverse the problems of deforestation and land degradation, the establishment of area enclosures has been promoted to as strategy control land degradation and restores the natural vegetation. The overall finding showed that the status of rangeland in the open-grazed areas was in poor condition due to increased grazing pressure while the status of enclosure areas was in a good condition as a result of reduced disturbances. The results of this review showed that enclosures are effective in restoring the nutrient status and quality of degraded soils. Restoration of the soil quality in communal enclosures was rated successful when compared to the open grazing area. Enclosures showed significantly higher soil organic matter (OM), total soil nitrogen content (N), available P content (P), and CEC than the open grazing lands. The higher values of soil properties and nutrient content in enclosures indicate that enclosures are one of the viable options to restore degraded soils. The findings of the reviewing analysis indicated that a consistent positive improvement in vegetation regeneration was observed in the enclosure area. Successful restoration of vegetation cover improves soil water balance and soil fertility, reduces soil erosion and restores the soil biodiversity and ecosystem services.

Rangelands are a large repository of soil C because of their high C density and the vast land area they occupy. Throughout the world, improved rangeland management strategies and practices could greatly increase soil C sequestration, while greatly improving their production potential and other environmental benefits. Area enclosures not only play potential role in enhancing the recovery of vegetation diversity of degraded areas but also contributes to household income. Although, farmers also benefit from the protective effect of closed areas (closed areas reduce runoff and soil erosion in farmlands located below the closed areas) this is an effect that does not directly affect their income while harvesting of grass and herbs does. This indicates the role of area enclosure (exclusion of livestock grazing and human interference from selected areas) as an important policy instrument to allow the recovery degraded vegetation provided that they are properly protected and managed. From a reviewing point of view, it is therefore a good idea to convert grazing areas into closed areas. From the result of this review, we suggest that enclosures are potential options for future Sustainable Management and Enhancing Restoration of Degraded Range

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