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REVIEW ARTICLE OPEN ACCESS

EFFECT OF GRAZING EXCLUSION ON CARBON STORAGE ON GRAZING LANDS: A REVIEW

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ABSTRACT

Grazing exclusion is increasingly practiced in most grassland ecosystems of the world and is the key management aspect to restore degraded grasslands. This review is initiated to explore the contribution of grazing exclusion in increasing ecosystem carbon sequestration. This review includes research findings from almost all types of terrestrial grassland ecosystems in the world. It produces conclusion from recently conducted research findings regarding the importance of grazing exclusion on biomass and soil carbon stock. It focuses on impact of grazing on carbon sequestration, effect of grazing exclusion on aboveground, belowground and soil carbon storage. Accordingly, grazing exclusion is an effective ecosystem restoration approach to sequester and store carbon in the living biomass and soil profiles. It is important for climate change mitigation. It has a key role mainly in highly degraded and moisture stress grazing lands. It also reduces the loss of carbon from ecosystem to atmosphere via grazing. Grazing exclusion increases biomass productivity of living vegetation. It is critical to increase aboveground carbon storage. Exclusion of highly degraded areas and application of appropriate grazing is relevant to sequester more carbon in to root and microbial biomass. Grazing exclusion also increase soil carbon sequestration through moisture reserve, increasing soil cover and reducing wind erosion. Moderate grazing is also appropriate after complete restoration to increase rate of carbon sequestration from outside. Therefore, efforts have to be applied to expand exclosures in degraded ecosystem considering benefits of local community. Study findings regarding the influence of grazing exclusion on the remaining open grazing lands are meagerly found which is not sufficient for conclusion.

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INTRODUCTION

Grazing land carbon sequestrations are key component in the global carbon cycle (Speed *et al.*, 2014). But, they also contribute substantially to atmospheric carbon pools through loss of soil organic carbon during extensive grazing and cultivation (Foley *et al.*, 2011). Different studies have examined the impact of grazing and grazing land exclosure on ecosystem carbon storage. Globally livestock grazing is the most extensive rangeland use system. This land use becomes principal factor for ecosystem change (Speed *et al.*, 2014). Awareness is essential on the impact of grazing on aboveground and belowground biomass to predict consequences of land use for carbon sequestration (Klumpp *et al.*, 2009).

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Grazing can generally play a key role in affecting ecosystem function (Holdo *et al.*, 2007; Li *et al.*, 2011; Wu *et al.*, 2009). Grazing has both positive (Hafner *et al.*, 2012; Li *et al.*, 2011) and negative effects on soil organic carbon (Sun *et al.*, 2011). Extended grazing damages primary production and trampling compacts the soil, thereby reducing organic matter and increase sandy dune (Gamoun *et al.*, 2010; Su *et al.*, 2017). Under high grazing photosynthesis is decreased followed by a decline in root biomass (Klumpp *et al.*, 2009) and a change in carbon storage. Hence, grazing may affect ecosystem carbon sequestration (McSherry and Ritchie, 2013) by changing vegetation biomass productivity and soil organic matter through impacting ground litter quality and decomposition rate (Piñeiro *et al.*, 2010; Speed *et al.*, 2014). Changes in land use and management practices to sequester carbon are becoming integral to global efforts that both address climate change and alleviate poverty (Stringer *et al.*, 2012). Sequestration of soil organic carbon, in turn, is also a practical option to decrease soil degradation, increase productivity and mitigate climate change (Shiferaw *et al.*, 2013). Grazing exclusion is an effective ecological management measure that excludes grazing (Lunt *et al.*, 2007; Wang *et al.*, 2015) to reverse the negative effects of overgrazing (Golodets *et al.*, 2010) for grassland restoration (Wang *et al.*, 2014). It has become common grazing land management practice in Ethiopia for the last two decades (Birhane *et al.*, 2017; Yayneshet *et al.*, 2009). It serves as a response to persistent soil, vegetation and water degradation, affecting forest resources, agricultural biodiversity and ecosystem services (Mekuria *et al.*, 2017). Grazing exclosure is type of land management practice implemented with the aim to rehabilitate over grazed land and improve ecological conditions of generally degraded areas (Birhane *et al.*, 2017; Mekuria, 2013). Other author concluded that community exclosures can actively stimulate further carbon stock accumulation in the grazing lands of Northern Ethiopia (Solomon *et al.*, 2017). Study results in Northern Ethiopia indicated that carbon storage was increased as age of exclosure increased (Gebrewahid, 2017). In similar area, other author reported that there was higher carbon stock on exclosures than that of the adjacent communal grazing (Mekuria, 2013). There was also positive response of plant biomass and carbon storage to exclosures in rangelands of Iran (Niknahad *et al.*, 2015). Other authors realized that soil carbon content and plant biomass and diversity were increased after eight years grazing exclusion in Loess Plateau of China (Wang *et al.*, 2014).

On the other hand there is no significant difference in soil carbon content between exclosures and adjacent open grazed rangelands in southern Ethiopian (Aynekulu *et al.*, 2017). This was supported by other authors where, the effects of grazing intensity on soil carbon storage were not much visible in Southern Patagonia (Peri *et al.*, 2016). Whereas soil carbon storage was significantly increased with increase in grazing pressure in alpine meadows of China (Li *et al.*, 2011). This increase was related to increase in belowground biomass accumulation with grazing. However, other authors found a result against to the above argument that grazing exclusion had significant positive effects on soil organic carbon in the same area (Li *et al.*, 2016). The potential of grazing exclusion to sequester carbon has been investigated in different grazing ecosystems by different authors; but the results are inconsistent. The findings showed increased, decreased or remained unchanged with grazing exclusion, which is difficult to design comprehensive conclusion and recommendation. Thus, comparing the findings and organizing interpretations could take us to the concrete conclusion. Therefore, large number of research findings has reviewed to conclude on the effect of grazing exclusion on terrestrial ecosystem carbon storage in grazing lands.

Effects of grazing on carbon sequestration

One of the major human activities in grasslands is grazing by domestic livestock (Gillson and Hoffman, 2007). This can directly affect carbon stock depending on relative magnitude of its effect (Golluscio *et al.*, 2009; Han *et al.*, 2008; Xie and Wu, 2016). It also leads to reduced plant production (Hou *et al.*, 2014; Tanentzap and Coomes, 2012) and increased soil erosion and CO_2 flux. Livestock grazing alters cycles of carbon in rangeland ecosystems by interactions between plants and soil (Li *et al.*, 2011; Wu *et al.*, 2009). Grazing influences the factors that control soil carbon in a complex way (Piñeiro *et al.*, 2010). A study in Desert Steppe of Northern China indicated that grazing had significant negative effects on soil carbon content. The authors revealed as continuous grazing decreased soil organic carbon by 7.9% (Hou *et al.*, 2014). In the other way a review summarized from different studies indicated that soil carbon can increased, decreased, or remained unchanged under contrasting grazing conditions across temperature and precipitation gradients (Piñeiro *et al.*, 2010). As grazing changed from low intensity to high intensity, photosynthesis decreased followed by death of roots and rhizomes and decline in root biomass. This is followed by lower transfer of new carbon to roots and rhizomes and loss of stored carbon. Those changes led to a decrease of soil fungi, a proliferation of Gram+ bacteria and accelerated decomposition of old particulate organic carbon (Klumpp *et al.*, 2009). As the study in western Chaco of Argentina rvealed that soil organic carbon store decreased from the highly restored (7.0 kg m^{-2}) to the overgrazed (1.5 kg m^{-2}) areas (Abril and Bucher, 2001). There were also general decreasing trends for carbon storage with increasing stocking rates in grasslands of Northern China (He *et al.*, 2011). Lower concentrations of soil organic carbon was recorded in the continuous heavy grazing (44.2 g kg^{-1} soil) and exclosures (49.1 g kg^{-1} soil) compared to the lightly grazed (59.8 g kg^{-1} soil) areas (Ingram *et al.*, 2008). This indicates positive effect of moderate grazing on soil carbon input and carbon sequestration. While other author found that less carbon loss in the grazed plots by shoot respiration (17%) and more was translocated belowground (40%) (Hafner *et al.*, 2012). Hence, carbon stock in soil layers was higher under grazed grassland than in the ungrazed area in Tibetan montane pasture. Review of more than 90 studies also revealed that root contents were higher in grazed than in their ungrazed counterparts at the driest and wettest study sites (Piñeiro *et al.*, 2010). But, the root contents were lower at sites with intermediate precipitation. A study conducted in shortgrass steppe of USA indicated that the heavy grazing area was 7.5 Mg ha^{-1} higher in soil organic carbon than the exclosure. These authors also found that heavy grazing affected soil inorganic carbon more than soil organic carbon. The heavy grazed area was 23.8 Mg ha^{-1} higher in total soil carbon than the exclosure treatment (Reeder *et al.*, 2004). This might be because of influences of herbivores on litter decomposition and nitrogen mineralization (Tanentzap and Coomes, 2012).

In contrast, a three-year field study confirmed that carbon storage exhibited a highly positive correlation with residual aboveground and root biomass (Sun *et al.*, 2011). That means grazing-induced reduction in plant productivity and changes in species composition would depress carbon storage. This increase in grazing pressure can lead to a gradual change of grazing lands from being ‘carbon sinks’ to become ‘carbon sources’. Other authors also revealed that soil organic carbon was highest under ungrazed (13.3 kg m^{-2}) and lowest under heavily grazed (9.8 kg m^{-2}) (Xu *et al.*, 2014). The possible explanation is grazing reduce aboveground and belowground biomass. Other author observed an underlying transformation from soil carbon sequestration under light grazing to carbon loss under heavy grazing (He *et al.*, 2011). Generally, continuous grazing is very detrimental to vegetation and soils. It results to less vegetation cover and litter accumulation, and very low organic carbon accumulation (Yong-Zhong *et al.*, 2005). Therefore, appropriate grazing intensity will promote vegetation and soil carbon sequestration and subsequent carbon storage considering precipitation gradient and vegetation type.

Effect of grazing exclusion on aboveground biomass carbon: The aboveground carbon pool consists of each living undergrowth, collective of stem, stump, brushwood, bark, seed and foliage (Worku and Agonafir, 2017). Grazing lands are considered to have great potential for carbon sequestration after adoption of improved management practices (Chang *et al.*, 2014). Grazing land management options like exclosures are among rehabilitation strategies practiced in degraded areas (Mengesha and Denoboba, 2015). Exclosures displayed higher plant species richness, diversity and biomass than the communal grazing lands in grazing lands of northern Ethiopia (Mekuria and Veldkamp, 2012). These vegetation factors are critical indicators of ecosystem carbon store. Aboveground tree carbon was significantly found higher with age of exclosure (41.63 Mg ha^{-1} for eight years exclosure and 28.33 Mg ha^{-1} of open grazing) in Northern Ethiopia (Gebrewahid, 2017). Therefore, suggestion of promotion of area exclosure practices is proved to be potential activity in carbon storing. This is supported by study conducted in Nile basin, Ethiopia (Mekuria *et al.*, 2015); in Northern Ethiopia (Gessesse, 2016; Mekuria, 2013; Shimelse *et al.*, 2017); in grassland of Loess Plateau, China (Wang *et al.*, 2014) and Tibetan montane pasture (Hafner *et al.*, 2012) (Table 1). But, a study in NW Patagonia disagree with the above conclusion and checked that there was no significant difference in carbon store between exclosure and adjacent free grazing areas (Nosetto *et al.*, 2006).

According to the result of study in an alpine ecosystem aboveground carbon stocks are higher in long-term absence of grazers than in continual grazing. They suggested that reduction of herbivore populations can increase aboveground carbon stocks; however, sequestration rate is low (Speed *et al.*, 2014). Lei Deng *et al.* (2014) This is also confirmed that aboveground carbon stock of the grazed grassland was lower than that of the restored grassland, while carbon sequestration rates decreased with vegetation restoration (Lei Deng *et al.*, 2014; Niknahad *et al.*, 2015). Authors critically reviewed findings and summarized that grazing exclusion had significantly increased aboveground carbon stock with mean rate of change 10.64 g m^{-2} yr^{-1} after grazing exclusion. They also observed that the rate of change was declined along with years of grazing exclusion increase (Deng *et al.*, 2017). Others also conducted a meta-analysis from 78 papers studied to analyze the effects of grazing exclusion in grasslands of China (Xiong *et al.*, 2016). The result revealed that grazing exclusion significantly increased carbon stored in aboveground biomass and litter mass by 84.7% and 111.6%, respectively. They suggested that grazing exclusion should be ceased after about six to ten years. Other findings (Wang *et al.*, 2014) also confirmed this finding that the carbon pools in above ground biomass were on average 76.5% higher for grazing exclusion than for free grazing. The reason to increase carbon stock in grazing exclusion is that it reduces output of carbon from the ecosystem to livestock and increase productivity (L. Deng *et al.*, 2014). The above findings are enough to suggest grazing exclusion has the potential to enhance carbon store (on average 192.70%) in aboveground biomass in different grazing ecosystems.

Effect of grazing exclusion on belowground carbon allocation: The belowground carbon consists of the biomass restricted within live ancestry (Worku and Agonafir, 2017). Root system of permanent grasslands is of outstanding importance for biomass acquisition (Gao *et al.*, 2008; Kauffman *et al.*, 2004). Exclosures showed higher belowground carbon stocks than the adjacent free grazing lands in Tigray Region, Norther Ethiopia (Shimelse *et al.*, 2017) (Table 2). This was confirmed by other authors that there is higher belowground carbon stock in every category of exclosure durations than that of the adjacent grazing lands (Mekuria *et al.*, 2009; Yong-Zhong *et al.*, 2005). This indicates the significant potential of exclosures to restore degraded lands and enhance ecosystem carbon content. Other study (Xiong *et al.*, 2016) also revealed that grazing exclusion stored 25.5% higher carbon in belowground biomass compared with the grazed sites in temperate meadow and temperate steppes. Carbon stocks in belowground biomass was 58–157% higher in exclosure than in the grazed grassland in Semi-arid Grassland (Qiu *et al.*, 2013). By contrast, root biomass carbon was 70% lower inside exclosure than outside exclosure due to the lower root to shoot ratios in subtropical pasture (Wilson *et al.*, 2018). This was supported by a study in temperate and subtropical grasslands of South America (Piñeiro *et al.*, 2009) (Table 2) and in semiarid steppes in Inner Mongolia (Cui *et al.*, 2005). and Other studies also observed increasing in belowground net primary production and its carbon storage with grazing; conversely (Derner *et al.*, 2006; Rathjen *et al.*, 2012), other authors reported findings against to this result (Hou *et al.*, 2014; Kauffman *et al.*, 2004). Root carbon showed no significant differences between grazed and non-grazed conditions in NW Patagonia, Argentina (Nosetto *et al.*, 2006). Other study balanced the above contrasting findings that light and moderate grazing grassland showed higher belowground carbon storage potential than exclosures and highly grazed grassland. Therefore, larger number of studies has agreed on negative effect of continuous grazing on belowground (Xu *et al.*, 2014) carbon content. They support application of appropriate grazing and exclosure management to sequester more carbon to the soil profile.

Effect of grazing exclusion on soil organic carbon: The soil is the principal carbon storage in terrestrial ecosystems. It stores much higher than the biotic biomass carbon storage (Lal, 2004; Svejcar *et al.*, 2008; Wang *et al.*, 2011; Yao *et al.*, 2010; Zhang *et al.*, 2013). Soils of grasslands represent a large potential reservoir for storing carbon. This potential depends on how grasslands are managed for grazing and browsing (McSherry and Ritchie, 2013). Livestock grazing intensity is thought to have a major impact on soil carbon storage in grassland ecosystems (Abdalla *et al.*, 2018; McSherry and Ritchie, 2013). Heavy stocking rate could be expected to negatively affect soil carbon because of plant physiological responses to increased grazing pressure. Herbs can respond to grazing by decreasing root elongation and translocation of carbon to new leaves so that decreasing carbon sequestration to roots (Schuman *et al.*, 1999). Soils may potentially act as efficient sinks of carbon under appropriate grazing management like exclosure (Liebig *et al.*, 2013; Shrestha and Stahl, 2008). Grazing exclusion of degraded grazing lands can enhance soil carbon storage (Mekuria *et al.*, 2009; Steffens *et al.*, 2008; Xu *et al.*, 2014; Yong-Zhong *et al.*, 2005) through restoration of plant species richness, diversity and its capacity to sequester carbon (Abebe *et al.*, 2006; Chen *et al.*, 2012; Ibáñez *et al.*, 2007).

Other author also found that there is an improvement of soil carbon stocks in exclosures (Mekuria, 2013). This indicates that exclosures have positive effect on ecosystems carbon stock and enhancement of regulating ecosystem services.

Table 1. Change in aboveground carbon storage (Mg ha^{-1}) between exclosures and adjacent free grazing

Author	Annual rainfall	Annual temperature	AGBCG	AGBCE	Absolute change	Percentage effect of Exclosure	Age of Exclosure
(Mekuria, 2013)	609 mm	17.5 °C	0.58	5.5	4.92	848.3	10 yrs
(Mekuria *et al.*, 2015)	1020 mm	22 °C	2.2	6.0	3.8	172.72	7 yrs
(Gebrewahid, 2017)	525 mm	28.6 °C	28.33	41.63	13.30	47	8 yrs
(Solomon *et al.*, 2017)	529 mm	22.5°C	7.76	22.29	14.5	187	DNA
(Gessesse, 2016)	610 mm	17.4°C	1.49	9.08	7.59	509.4	15 yrs
(Mekuria *et al.*, 2009)	562 mm	22 °C	8.0	15	7.0	87.5	15 yrs
(Mekuria *et al.*, 2011)	609 mm	17.5 °C	1.07	8.90	7.84	732.71	20 yrs
(Yusuf *et al.*, 2015)	550 mm	20°C	0.48	0.75	0.27	56.25	15-25 yrs
(Shimelse *et al.*, 2017)	607 mm	20.25°C	32.96	43.32	10.04	30.5	10 yrs
(Wu *et al.*, 2014)	339 mm	-2.2 °C	0.15	0.43	0.28	187	6 yrs
(Wang *et al.*, 2014)	373.3 mm	7.39 °C	0.29	0.53	0.24	83	8 yrs
(Hafner *et al.*, 2012)	582 mm	5 °C	2.35	7.28	4.93	168	7 yrs
(Ngatia *et al.*, 2015)	550 mm	DNA	0.89	1.57	0.68	76	17 yrs
(Qiu *et al.*, 2013)	425 mm	6.9°C	DNA	DNA	---	86	17-27 yrs
(Nosetto *et al.*, 2006)	424 mm	6°C	7.84	4.86	2.98	-38.01	15 yrs
(Schuman *et al.*, 1999)	384 mm	DNA	0.749	1.6	0.851	113.62	40 yrs
(Yong-Zhong *et al.*, 2005)	366 mm	6.58C	0.43	1.33	0.90	209.3	10 yrs
(Wilson *et al.*, 2018)	1300 mm	24°C	0.48	0.98	0.50	104.17	15 yr
(Xiong *et al.*, 2016)	RDL	RDL	0.71	1.32	0.61	85.92	8 yrs
Number of cases reported							
Increase					18		
Decreased					1		
Average percentage change					192.70%		

*DNA= Data Not Available; AGBCG = Aboveground biomass carbon under free grazed; AGBCE = Aboveground biomass carbon under exclosure; RDL= Review of Different Literatures.

Table 2. Change in belowground carbon storage (Mg ha^{-1}) between exclosures and adjacent free grazing

Authors	Annual rainfall	Annual temperature	BGBCG	BGBCE	Absolute change	Percentage effect of Exclosure	Age of Exclosure
(Yusuf *et al.*, 2015)	550 mm	20°C	0.66	1.56	0.90	136.36	15-25 yrs
(Gessesse, 2016)	610 mm	17.4°C	3.16	3.67	0.51	16.14	15 yrs
(Shimelse *et al.*, 2017)	607 mm	20.25°C	0.16	0.95	0.79	493.75	10 yrs
(Wilson *et al.*, 2018)	1300 mm	24°C	2.74	0.83	1.91	-69.71	15 yrs
(Wu *et al.*, 2014)	339 mm	2.2°C	4.5	5.5	1.00	22.22	6 yrs
(Zhou *et al.*, 2007)	385 mm	1.6°C	5.569	8.682	3.113	55.90	5 yrs
(Schuman *et al.*, 1999)	384 mm	DNA	7.421	8.789	1.368	18.43	40 yrs
(Nosetto *et al.*, 2006)	424 mm	6°C	2.60	1.58	1.02	-39.23	15 yrs
(Yong-Zhong *et al.*, 2005)	366 mm	6.58C	0.55	1.88	1.33	241.82	10 yrs
(Hafner *et al.*, 2012)	582 mm	5 °C	3.49	1.93	1.56	-44.70	7 yrs
(Piñeiro *et al.*, 2009)	1165 mm	16.96°C	4.63	2.702	1.928	-41.64	14 yrs
(Qiu *et al.*, 2013)	425 mm	6.9°C	DNA	DNA	---	157	17-27 yrs
(Xiong *et al.*, 2016)	RDL	RDL	4.19	5.48	1.29	30.79	8 yrs
		Number of cases reported					
Increase					9		
Decreased					4		
Average percentage change					75.13%		

BGBCG = Belowground biomass carbon under free grazed, BGBCE = Belowground biomass carbon under exclosure

Review of results studied in in grasslands of China revealed that grazing exclusion significantly increased carbon stored in soils by 14.4% compared with the grazed sites (Xiong *et al.*, 2016). In contrast, it is found that soil in grazed areas was 6-9 Mg ha^{-1} higher in carbon than in the counter exclosures due to increase in carbon cycling rates (Schuman *et al.*, 1999). Other authors also showed that ungrazed lands exhibited a decline in carbon storage compared with adjacent grazed areas (Hafner *et al.*, 2012; Reeder and Schuman, 2002). Research findings in other areas found no significant change in soil organic carbon in areas with 40, 36 and 12 years grazing exclusion (Aynekulu *et al.*, 2017; Shrestha and Stahl, 2008; Speed *et al.*, 2014). This is countered by other study that compared to grazing exclosure, continuous grazing significantly decreased soil carbon by 7.9%, whereas rotational grazing significantly increased soil carbon by 1.3% (Hou *et al.*, 2014). Soil carbon record under moisture stress was the highest on grazing exclosure compared to the open grazing (Mureithi *et al.*, 2014) and rotational grazing while during the moist year rotational grazing show the highest soil carbon (Hou *et al.*, 2014). More than 82% of research findings reviewed (Deng *et al.*, 2017) shown increase in soil carbon stock with grazing exclusion. Other authors also observed an increase in soil organic carbon concentration across age of exclosures (Chen and Tang, 2016; Mekuria *et al.*, 2009). The significant increase in carbon stocks of exclosures compared to the open grazing lands indicates the potential for restoration of soil quality through land rehabilitation (Mureithi *et al.*, 2014; Qiu *et al.*, 2013). The reason to increase soil carbon stock in grazing exclusion is due to increase in soil moisture through reducing evaporation. This is due to increase in canopy and litter cover resulting in higher carbon input (Wu *et al.*, 2010). A possible reason for recovery of soil carbon in exclosures is due to reduction in quantity of nutrients lost via wind erosion (Zhou *et al.*, 2011). Different studies balanced the above argument that controlled grazing has shown higher carbon accumulation than both free grazed and exclosure sites (Ingram *et al.*, 2008; Xu *et al.*, 2011). This was also confirmed by (Zarekia *et al.*, 2012), where, moderate grazing increases soil organic carbon with the reason of breaking and transferring plant material and litter to the soil.

Table 3. Change in Soil Organic Carbon storage (Mg ha^{-1}) between exclosures and adjacent free grazing

Authors	Annual rainfall	Annual temperature	SOCFG	SOCE	Absolute change	Percentage effect of Exclosure	Age of Exclosure
(Mekuria, 2013)	609 mm	17.5°C	27.93	71.00	43.07	154.21	10 yrs
(Girmay and Singh, 2012)	550 mm	18.25°C	91.00	105.00	14.00	15.39	DNA
(Mekuria *et al.*, 2011)	609 mm	17.5 °C	39.9	93.63	53.73	134.66	20 yrs
(Shimelse *et al.*, 2017)	607 mm	20.25°C	30.6	51.51	20.91	68.33	20 yrs
(Feyisa *et al.*, 2017)	567 mm	24 °C	34.9	40.8	5.9	16.91	20-30 yrs
(Aynekulu *et al.*, 2017)	436 mm	22.5°C	38.74	33.56	-5.18	-13.37	36 yrs
(Yusuf *et al.*, 2015)	550 mm	20°C	39.9	48.33	8.425	21.12	15-25 yrs
(Xu *et al.*, 2014)	400 mm	1.5°C	98.00	133.0	35.00	35.71	20 yrs
(Nosetto *et al.*, 2006)	424 mm	6°C	33.88	35.36	1.48	4.37	15 yrs
(Chen *et al.*, 2012)	366 mm	6.8°C	5.65	19.81	14.16	250.62	25
(Schuman *et al.*, 1999)	384 mm	DNA	101.27	88.15	-13.121	-12.96	40 yrs
(Shrestha and Stahl, 2008)	205 mm	DNA	9.38	9.38	0.00	0.00	40 yrs
(Witt *et al.*, 2011)	300 mm	21°C	13	19	6.00	46.15	13-40 yrs
(Xing *et al.*, 2014)	339 mm	-2.2°C	64.825	75.29	10.465	16.14	7 yrs
(Hafner *et al.*, 2012)	582 mm	5°C	101.7	84.1	-17.6	-17.31	7 yrs
(Xu *et al.*, 2011)	400 mm	1.5°C	83.2 (132.8 CG)	112.3	27.3	32.81	10 yrs
(Niknahad *et al.*, 2015)	343 mm	16.6ºC	52.45	71.78	19.33	36.85	20 yrs
(Piñeiro *et al.*, 2009)	1165 mm	16.96 ºC	93.67	90.33	-3.34	-3.57	14 yrs
(Ingram *et al.*, 2008)	425 mm	DNA	70.50	80.50	10.00	14.18	10 yrs
(Yong-Zhong *et al.*, 2005)	366 mm	6.58C	4.983	5.593	0.61	12.24	10 yrs
(He *et al.*, 2012)	334 mm	0.96ºC	84.6	103.12	18.52	21.89	30 yrs
(Wu *et al.*, 2014)	339 mm	-2.2 °C	66.04	75.29	9.25	14	6 yrs
(Wu *et al.*, 2008)	345 mm	1.1°C	61.33	83.19	21.86	35.64	24
(Reeder *et al.*, 2004)	325 mm	DNA	72.1	64.6	-7.5	-10.40	56 yrs
(Xiong *et al.*, 2016)	RDL	RDL	47.1	55.1	8.00	16.99	8 yrs
(Qiu *et al.*, 2013)	425 mm	6.9°C	DNA	DNA	---	77	17-27 yrs
(Zhou *et al.*, 2007)	385 mm	1.6°C	DNA	DNA	---	56	5 yrs
Number of cases reported							
Increase					21		
Decreased					5		
As it is					1		
Average percentage change					37.91%		

SOCFG = Soil Organic Carbon under free grazed; SOCE= Soil Organic Carbon under exclosure; CG= Controlled Grazing

Summary of the figurative findings of different authors in Table (3) indicates 37.91% increase in soil carbon stock of exclosures.

Conclusion

It is evident from this review that grazing exclusion is an effective ecosystem restoration approach to sequester carbon in the living biomass and soil ground. It is an effective practice to restore degraded grazing lands, since vegetation and soil have shown to improve under long-term grazing exclusion in different agro-ecology. It decrease soil erosion rate and increase the overall species diversity and living biomass. Grazing exclusion reduces loss of carbon from ecosystem to atmosphere via grazing and increase biomass of living vegetation due to the removal of grazing pressure. It is critical to increase aboveground carbon storage. Moderate grazing may be appropriate after complete restoration to increase rate of carbon sequestration from outside. Greater number of studies has agreed on negative effect of continuous grazing on the belowground carbon content. They support the application of appropriate grazing and exclosure management to sequester more carbon in to the root and microbial biomass. Adoption of exclosure management can considerably increase the amount of carbon to be stored in the soil profile through water conservation and reducing evaporation rate. It increases vegetation restoration, canopy and litter cover resulting in higher carbon input. The vegetation restoration also reduces wind erosion which is critical to maintain soil quality including carbon content. Therefore, grazing exclusion with subsequent controlled grazing can increase quantity of ecosystem carbon stock, ultimately to mitigate climate change. Efforts have to be applied to widen exclosures in degraded ecosystems considering the benefit of local community. Study findings regarding the influence of grazing exclusion on the remaining open grazing lands are meagerly found which is not sufficient for conclusion.

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