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Review Article

Effects of Exclosures on Vegetative and Soil Fertility Improvement in the Highlands of Ethiopia: Review

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Abstract

Land degradation, which includes all elements that reduce the land's ability to function and generate ecosystem products and services, is the ongoing deterioration of the land's loss of productive capacity. 50% of the Ethiopian highlands had experienced major erosion, posing serious ecological and socioeconomic problems for both the rural populations' way of life and the environment. To reduce these problems locals' experienced different mechanisms from the Exclosures is the one. Exclosures are places that are off-limits to domestic animals and humans in order to encourage plant regeneration naturally and lessen the degradation of formerly deteriorated communal grazing fields. Exclosures have been used extensively and have demonstrated encouraging outcomes in restoring damaged areas through natural regeneration with little financial or input needed. The review paper's overall goal is to examine the effects of exclosures on increases in soil fertility and vegetative growth in Ethiopia's highlands. Exacerbates the degradation of Ethiopia's soil, vegetation cover, and nutrient depletion, land degradation poses a serious challenge to sustainable land use and impacts the livelihood of the country's rural population. In contrast to open land, which had low species richness and evenly dispersed species, exclosures had higher diversity, richer biodiversity, and a less even distribution of species. Scholars found that after 22 years of establishment, exclosures in the Ethiopian highlands had double the plant species richness and diversity value compared to communal grazing pastures. Exclosures are often the best way to improve soil fertility and vegetation diversity and richness in Ethiopia's highlands when compared to open ground, grazing land, crop land, and communal land.

Keywords

Exclosures, Vegetation, Diversity, Richness, Land Degradation, and Soil Fertility

1. Introduction

Land degradation is the ongoing deterioration of the land's loss of productive capacity and includes all elements that reduce the land's ability to provide ecosystem services and goods [1]. Anthropogenic activities such deforestation, over grazing, over cultivation, fertilization, and nutrient depletion [2] are major contributors to this worldwide issue [3]. The environment, ecosystem functioning, and human livelihoods are all negatively impacted by the unsustainable use of land

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resources [4]. Land degradation, which encompasses nutrient depletion, soil degradation, and reduction of plant cover, is a significant ecological and economic issue in Ethiopia [5]. According to [6], it is a major issue in the Ethiopian highlands in particular.

High human and livestock population pressure, rough terrain, and unsuitable farming methods have all been identified as major contributors to the processes of land degradation in the highlands [7, 8] Anticipated that by 2010, the entire area of degraded land in the Ethiopian highlands will have reached 100,000 km^2. Nonetheless, a research by [9] found that, as of 2006, the area covered by degraded land has already doubled to 228,000 km^2. Similar to this, [10] claimed that 50% of the highlands had experienced major erosion, posing serious ecological and socioeconomic problems for both the rural populations' way of life and the environment.

In the past, government and non-government development groups have implemented various forms of sustainable land management techniques (SLM) in the Ethiopian highlands in response to the trend of land degradation that is only becoming worse [2]. Among the various techniques, exclosures have been used extensively and have demonstrated encouraging outcomes in the rehabilitation of degraded lands via natural regeneration with the least amount of investment and inputs [11]. Exclosures are places that are off-limits to domestic animals and humans in order to encourage plant regeneration naturally and lessen the deterioration of formerly degraded communal grazing pastures [12]. Exclosures, according to [13], entail primarily using social fence to keep areas free from farming, tree and shrub chopping, and cattle grazing. Diverse woody and non-woody plant species reappear as a result, increasing the greenness of the landscape, decreasing soil erosion and sediment deposition downstream, and increasing water infiltration and stream discharge [14].

Natural vegetation recovery in exclosures in Ethiopia's northwestern highlands benefits formerly damaged commons, which are green spaces with significant species diversity [15]. Area exclosures have a significant role in the production of biomass, biodiversity enhancement, preservation of plant species diversity, restoration of native vegetation, rehabilitation of degraded forest wood land, shelter of wild animals, supply of animal feed, and extraction of medicinal plants for humans and animals are all greatly impacted [11, 16] Found that after 22 years of establishment, exclosures in the Ethiopian highlands had double the plant species richness and diversity value compared to communal grazing pastures. In contrast to open land, which had equally dispersed species base and low species richness, exclosures had a larger diversity and richer species [17]. In addition [18] studies that exclosures have been found to be one of the most popular interventions for restoring soil fertility, restocking biodiversity, and restoring degraded lands. This paper was aimed to review related literatures and overview the effectiveness of exclosures on vegetative and soil fertility improvements in the highlands of Ethiopia.

1.1. Effects of Land Degradation on Vegetation and Soil Fertility Decline in the Highlands of Ethiopia

Land degradation is the temporary or permanent reduction of the productive capacity of land caused by natural processes or human activity [19]. It is an ongoing deterioration of the land's loss of productive capacity, which includes all elements that reduce the land's ability to function and generate ecosystem products and services [20]. It is an international issue mostly caused by human activities including deforestation, over grazing, over cultivation, fertilizing, and nutrient depletion [2, 3]. The environment, ecosystem functioning, and human livelihoods are all negatively impacted by the unsustainable use of land resources [4]. According to [5], land degradation, which encompasses nutrient depletion, soil degradation, and reduction of plant cover, is a significant ecological and economic issue in Ethiopia.

Figure 1. *Effects of land degradation on the livelihood of the rural population, soil fertility and forest vegetation.*

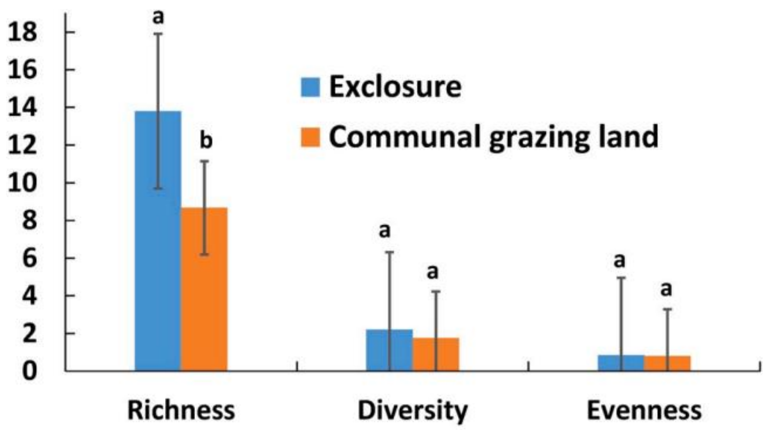
Land degradation is a major issue in the Ethiopian highlands when compared to other regions [6, 21] estimated that land degradation causes a deforestation rate of 1410 km^2 annually; whereas, the [22] found 620 km^2 annually. Ethiopia's entire area covered by forests decreased from 65% to 2.2% [23]. Out of this, the highlands saw 90% of the overall forest decline, or 5.6% of annual deforestation. The physical, chemical, and bioavailability of soil nutrients have all been adversely impacted by these changes [24]. Furthermore, Ethiopia's very early and widespread deforestation has reduced biological variety to the point where some plants may become extinct locally [25]. By aggravating the degradation of plant cover, soil, and nutrient depletion in Ethiopia [5], land degradation impacts the livelihood of the rural population and poses a serious danger to sustainable land use [1].

1.2. Effects of Exclosures on Vegetation Diversity and Richness in the Highlands of Ethiopia

The variety of species in an ecosystem is known as diversity. The age classes of the woody plants in the enclosures showed differences in their species composition and richness [26]. Exclosures, according to [13], entail primarily using social fence to keep areas free from farming, tree and shrub chopping, and cattle grazing. Diverse woody and non-woody plant species reappear as a result, increasing the greenness of the landscape, decreasing soil erosion and sediment deposition downstream, and increasing water infiltration and stream discharge [27].

Natural vegetation recovery in exclosures in Ethiopia's northern highlands benefits formerly degraded commons, which are green spaces with significant species richness [15]. The relevance of exclosures for the preservation of biological diversity is demonstrated by the woody species' significantly higher richness in these areas compared to open spaces [28]. Exclosures practices are important for the conservation of genetic resources of woody species, especially rare and unique species that are highly threatened with extinction, as evidenced by the relatively high diversity values of exclosures compared to open areas [29].

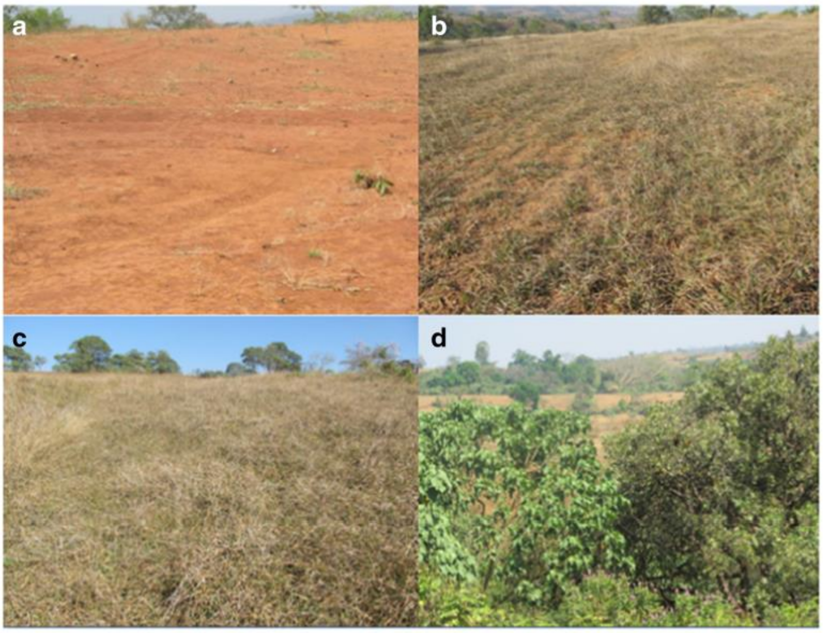
The total number of species in a sample or habitat is known as species richness. The relevance of exclosures for the preservation of biological diversity is demonstrated by the woody species' significantly higher richness in these areas compared to open spaces [28]. In contrast to open land, which had equally dispersed species base and low species richness, exclosures had a larger diversity and richer species [17]. Because anthropogenic disturbance is minimized, species richness is influenced by the age of enclosures [26]. In the exclosures, there were 91.03% more naturally regenerating woody plants than artificially planted ones (8.9%), with no planted seedlings detected in the open grazing areas. Naturally regenerating species made up the majority of the species in the exclosures [29].



Source: adapted from Anwar *et al.* (2020)

Figure 2. *Average species richness, diversity and evenness in exclosures and communal grazing land. Different letters in the same group of bars indicate significant differences between the exclosures and communal grazing land.*

According to [30] exclosures have little influence on species evenness over time, but they have a favorable significant effect on vegetative diversity and richness (Figure 1). This notion was further reinforced by [29], who found that whereas grazing land had low species richness and equally dispersed species, the exclosures had a larger diversity and richer species.



Source: adapted from Shimels *et al*. (2020)

Figure 3. *Sampling sites "a" Degraded land (control). "b" Restoring (Gambela, 4 years old) exclosures with Chomo grass over sowing. "c" Restored (Darge Tobora, 8 years old) exclosures over sown by Chomo grass. "d" Restored (Darge Tobora, 15 years old) exclosures with woody and bush cover.*

According to [31] exclosures throughout time provide important values for species diversity, richness, and improved soil fertility (Figure 2). There are no species on the degraded area, and the soil is infertile, but after four years some diversity species, such as grasses, herbs, shrubs, and trees, emerge. Additionally, after eight years, the reemerging species grow and diversify to a medium extent, and the soil becomes medium fertile. Then, after fifteen years, the area is covered with trees and the tree species exhibit greater diversification and richness also become high. The result of [26] and [32], said that Shannon diversity indices in the exclosures indicate higher species diversity than in the open site (Table 1 and Table 2).

Table 1. *Species diversify, Evenness, and Richness of the exclosures.*

EXclosure			
Shannon Diversity	**Evenness**	**Richness**	**Scholars**
1.41	2.48	15	Tamrat and Dinsa, 2022
2.39	0.64	19	Mastewal *et al*., 2006
1.19	0.77	17	Anwar *et al.*, 2024
1.77	0.78	9.94	Eshetie *et al.*, 2021
2.2	0.84	14	Anwar *et al.*, 2020
3.21	0.84	46	Fikadu and Argaw, 2021

Table 2. *Species diversity, evenness, and Richness of Open site area.*

Open site			
Shannon Diversity	**Evenness**	**Richness**	**Scholars**
1.1	1.48	6	Tamrat and Dinsa, 2022
1.71	0.48	16	Mastewal *et al*. (2006)
0.63	0.5	15	Anwar *et al.*, 2024
1.39	0.77	5.96	Asmare *et al.*, 2019
1.6	0.85	11	Anwar *et al.*, 2020
1.96	0.72	17	Fikadu and Argaw, 2021

Exclosures or area closures are positively correlated with species richness and diversity, but they have little bearing on species uniformity across time [26] (Table 3). These findings demonstrate that species richness is greater in the 29-year exclosures area and lower in the 8-year exclosures area. Additionally, his research reveals that the exclosures area and church woodland differ significantly from one another.

Table 3. *Species richness of the exclosures.*

Enclosures Compared	Sorensen's index
CF vs. 29-years AC	352.9
CF vs. 22-years AC	141.7
CF vs. 10-years AC	17.1
CF vs. eight-years AC	180.0
29-years AC vs. 22-years AC	220.0
29-years AC vs. 10-years AC	27.0
29-years AC vs. eight-years AC	165.2
22-years AC vs. 10-years AC	55.6
22-years AC vs. eight-years AC	120.0
10-years AC vs. eight-years AC	47.1

Note: AC= Area Enclosures and CF= church forest
Source: adapted from Mastewal *et al*. (2006)

1.3. Effects of Exclosures on Soil Fertility Improvement and Conservation in the Highlands of Ethiopia

1.3.1. Effects on Soil Fertility Improvement

Exclosures have been shown to have a beneficial global impact on soil and aboveground carbon sequestration [33], as well as the restoration of soil characteristics and nutrient content [34]. Exclosures have been found to be beneficial in the semi-arid highlands of Ethiopia. They have been shown to reduce runoff, reduce sediment deposition, improve soil nutrient status, restore native vegetation, improve soil nutrient status, improve ecosystem carbon stock, and provide economic benefits. Additionally, farmers in semi-arid regions have generally viewed exclosures favorably [35].

The measurement of exclosures' impact on soil fertility considers the availability of micro- and macronutrients, which are required for plant growth. Among the important nutrients for plant growth are nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), and chlorine (Cl) [36]. According to studies by [37, 38], differences exist in the soil organic carbon stock composition of converted grazing lands (exclosures land) due to variations in soil type, land-use history, land cover, climate, terrain, and vegetation cover.

1.3.2. Effects on Soil Conservation

The primary causes of soil erosion and nutrient loss in Ethiopia are insufficient agricultural practices, such as cultivation on steep slopes, vegetation clearance, and overgrazing [39, 40]. In northern Ethiopia, for example, farming on steep slopes caused an annual loss of 35 tons of soil per hectare of land [41]. But these days, disclosures have lessened the detrimental impact. Because of this, it was developed as a method of land management with an emphasis on space in order to enhance the surrounding environment and reduce soil erosion [40, 42].

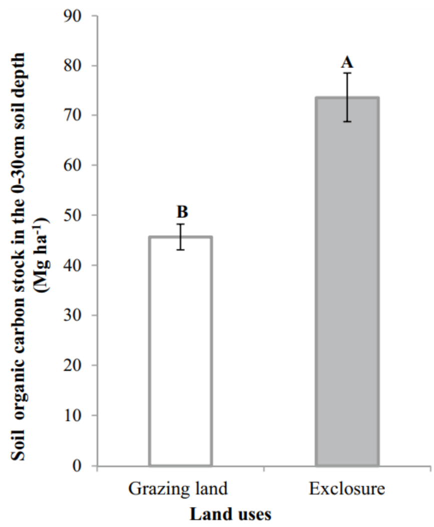
Twenty years following the establishment of an exclosures on communal grazing areas, the amount of carbon in soil organs grew dramatically, according to studies done in the semi-arid Tigray region [27]. Increased length of exclosures led to a minor but non-significant increase in soil carbon content in the semi-arid southern Ethiopian rangelands [37].

1.4. Effects of Exclosures on Soil Fertility Improvement and Conservation on the Highlands of Ethiopia

Exclosures have been found to be beneficial in the semi-arid highlands of Ethiopia due to their ability to reduce runoff, reduce sediment deposition, improve soil nutrient status, restore native vegetation, improve soil nutrient status, improve ecosystem carbon stock, and provide economic benefits. Additionally, farmers in semi-arid regions have generally viewed exclosures as beneficial [35]. Soil pH, P availability, and electric conductivity were not affected, most soil parameters were enhanced when open grazing area was converted into exclosures [43]. Exclosures area has a higher degree of vegetation cover and an enhanced soil structure, which decreases soil erosion more effectively than open grazing land [30]. According to [44], soil depth and exclosures' ages have an impact on the availability of N, P, and cation exchange capacity.

According to [6], after exclosures were established in Ethiopia's northern highlands, soil organic matter rose with the age of the exclosures. This indicates that the restoration of vegetation raises biomass output, which in turn raises soil productivity. This concept is further supported by [45], who found that good organic soil materials, also known as forest floor or litterfall, are present at the surface of many soils, particularly those found beneath forests. These soils are described as having more than 20% organic carbon. Increased soil cover due to better vegetation cover has reduced evapotranspiration losses of soil moisture. Increased litter deposition, carbon sequestration, and improved water infiltration have all been made possible by better soil cover, which has also been essential for improving fertility and raising production [46].

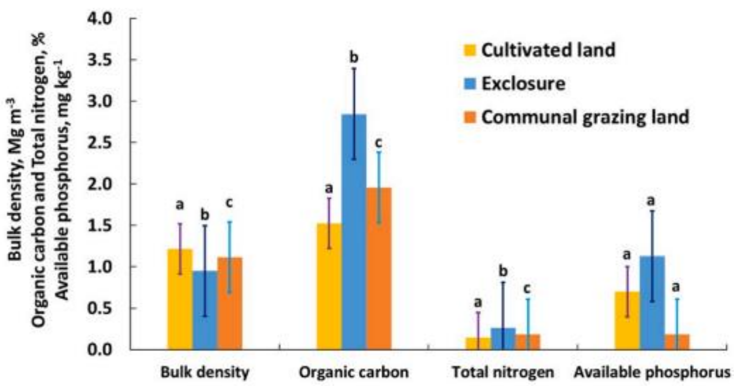
Researchers have found that, in general, exclosures area species improve soil fertility through the decomposition of leaves, dead stems, roots, litters, and by enhancing soil microorganisms; however, the duration of exclosures, vegetation, and soil types all influence the success of restoring soil carbon and fertility on degraded land [47]. As we mentioned in the section above [31], the results further supported such notions.



Source: adapted from Abay *et al.* (2020)

Figure 4. *Effect of conversion of open grazing land to exclosures on soil organic carbon stock (Mg ha^{-1}). Diferent letters represent significant difference between the land uses. Error bars denote standard error.*

Abay *et al.* (2020) results show as Compared to grazing land, exclosures areas have higher soil organic carbon (Figure 3). This indicates that exclosures have a higher potential and are the most effective method of enhancing soil fertility and conserving soil.



Source: adapted from Anwar *et al.* (2020)

Figure 5. *The three land use classifications' mean values for bulk density, organic carbon, total nitrogen, and accessible phosphorus. Substantial variations in land uses across the tested variables are indicated by different letters within the same bar group.*

Compared to cultivation and communal land, exclosures have high organic carbon, nitrogen content, and availability of phosphorus [30] result (Figure 4). The Exclosures site's high levels of organic carbon, nitrogen content, and phosphorus availability were caused by the biomass and woody plant residues that were present [48]. But compared to cultivation and communal land, exclosures have lower level of bulk density (Figure 4). According to [48], the bulk density of the soil was one of the main factors considered when determining the soil's fertility status. Under exclosures and degraded sites, the mean values of the bulk density of soil were 1.20 and 1.53 g/cm3, respectively [16]. It's possible that livestock trampling during grazing is the cause of the high bulk density at the degraded site (grazing land) [42].

2. Conclusion

Land degradation is becoming a more serious issue in our nation, particularly in the highlands. Vegetative and soil fertility drop as a result of land degradation and disturbance is the reason behind the decline in the area's vegetation and soil fertility. Exclosures land management practices play a significant role in improving soil fertility and restoring vegetation in various sections of the nation, particularly in Ethiopia's northern highlands. In Ethiopia's damaged highlands, vegetation richness and diversity have achieved a new level due to the reduction of disturbance impacts. Improvements in soil fertility can also be attained in the exclosures area through the activity of decomposers, which break down fallen leaves, dead stems, roots, and other materials. Because of the minimal disturbance, decomposers break down materials more quickly. Exclosures are often the best way to improve soil fertility and vegetation diversity and richness in Ethiopia's highlands when compared to open ground, grazing land, crop land, and communal land.

Abbreviations

EXs	Exclosure
G. land	Grazing Land
SLM	Sustainable Land Management

Conflicts of Interest

There is no conflict of interest between authors.

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