*Ethiopian Journal of Science and Sustainable Development*

*e-ISSN 2663-3205* *Volume 8 (2), 2021*

Journal Home Page: www.ejssd.astu.edu.et

Review Paper

# Ecosystem Services of Exclosures in Ethiopia: A Review

Meseret Habtamu*, Eyasu Elias

*Centre for Environmental Science, College of Natural and Computational Science, Addis Ababa University, P.O. Box 80119, Addis Ababa, Ethiopia*

**Article Info**

**Article History**:
*Received 04 May 2021*
*Received in revised form 20 August 2021*
*Accepted 03 Sept. 2021*

**Keywords:**
*Economic benefits*
*Ecosystem services*
*Exclosures*

**Abstract**

Exclosures are areas that are closed-off from human and domestic animal disturbances to allow regenerating vegetation to reduce further land degradation and enhance rehabilitation. Exclosures have different ecosystem and economic benefits. The objectives of this systematic review were to appraise research findings and to summarize the most important literatures on the role of area exclosures for ecosystem services in Ethiopia. After several screening steps using inclusion and exclusion criteria, only 33 studies qualified for qualitative analysis. Different studies indicated that exclosures have ecological and economic importances for the area and local communities. The practice of area exclosures is becoming popular and about 7 Mha of degraded area has been rehabilitated between the years 2011 and 2014. Moreover, a total of 15,404.6 ha of land have been established as area exclosure in different regions of the country from the year 2015-2019. A total of 1.4 Mha degraded lands were rehabilitated using area exclosures until 2019. Exclosures play vital role to restore native vegetation composition, richness, diversity, rehabilitation of degraded lands, reducing soil erosion, recharging ground water, increase soil and above ground biomass. In addition it provides considerable fodder access for livestocks and efficient to increase financial income for households.

## 1. Introduction

Natural resources are getting depleted at a faster rate in different regions of Ethiopia. There are various driving forces for natural resource loss. Deforestation has been a major problem for quite a long time. Some of the consequences are decline or loss of biodiversity, degradation of land and water bodies, possible negative effects on the local, regional and global climatic conditions as well as negative impacts on the welfare of human beings (Berry, 2003; Gashaw et al., 2015). The drivers of deforestation and forest degradation include population growth, agricultural expansion, resettlement, land tenure, free grazing, forest fires, pests and diseases, and unwise utilization (Yigremachew et al., 2015). The forest degradation in Ethiopia is closely linked to the ongoing population growth (Reusing, 2000; Zeleke and Hurni, 2001; Dessie, 2007; Mulugeta and Habtemariam, 2014).

Forest and land degradation is a serious problem worldwide, particularly in developing countries. Approximately one billion people live in degraded areas, which represent 15% of the Earth's population, and one third of the world's population is considered to be affected by land degradation (Sabogal et al., 2015). Deforestation over the period 1980-1990 reached 8.2% of total forest area in Asia, 6.1% in Latin America and 4.8% in Africa (Contreras- Hermosilla, 2000). Despite a

*Corresponding author, e-mail: meseret.habtamu@aau.edu.et

https://doi.org/10.20372/ejssdastu:v8.i2.2021.375

number of initiatives to stop forest decline, the world continues to lose some million hectares of forests every year at a regional level. South America suffered the largest net loss of forests between 2000 and 2010 about 4.0 million hectares per year followed by Africa, which lost 3.4 million hectares annually (FAO, 2010). Deforestation, soil erosion, and land degradation are serious problems in Ethiopia. The clearing of forests has been a long historical process in Ethiopia and it continues at a conservatively estimated rate of 62,000 ha per year (Berry, 2003). This is mostly converted into cropland with greatly reduced vegetative cover, accelerated soil erosion, also change the hydrological pattern of run off, reducing infiltration and increasing stream flow during and after rain (Berry, 2003). In addition to deforestation, population growth has led to a number of problems related to inappropriate cultivation, overgrazing, soil erosion, soil fertility decline, water scarcity, lack of pasture, and a fuel wood crisis.

Betru (2003) cited in Abera et al. (2016) stated that sustainable conservation and utilization of the remaining forest resources and rehabilitation of the degraded would provide economic, social and ecological benefits. This requires designing economically feasible, socially acceptable and ecologically viable management and conservation strategies. In this regard, the government of Ethiopia has initiated a number of projects including soil and water conservation and the establishment of area exclosures to stop further land degradation. The main actors include governmental and non-governmental agencies and the private sector. Recent approaches attempt to combine participatory and decentralized approaches that include engagement of NGOs and the private sector (Eshetu, 2006).

Seven million hectares of degraded area has been rehabilitated using area exclosure until 2014 in the country (EBI, 2014). A report by Tigray Regional Bureau of Agriculture and Rural Development (2013) indicates that approximately 1,288,445 ha of land in the region is managed through area exclosures as stated in Yigremachew et al. (2015). Establishing exclosure is a promising practice for rehabilitation of degraded lands started in different parts of Ethiopia (Emiru et al., 2006; Yayneshet et al., 2009). It has been widely promoted, especially in the northern and central highlands of Ethiopia. Thus, general objective of this review is to assess research findings and to summarize the most important literatures on the role of exclosures for ecosystem services, economic benefits and the challenges in Ethiopia.

## 2. Methodology

In order to achieve the aim of the review paper on the role of exclosures for ecosystem services, the collected data were extracted and total of 33 secondary data were used. Additional data were collected from different reports of Food and Agriculture Organization (FAO), Ministry of Agriculture (MoA), and Ministry of Environment, Forest and Climate Change (MEFCC).

The first step was defining key terms by reviewing the final verified title and this was in turn, used to choose appropriate databases. Terms were then combined in relevant categories using Boolean logic operators ("OR" and "AND").

The search procedure was tested by the chosen database: Science Direct; and then the final algorithm that retrieved the highest proportion of all known relevant articles were selected: The search was done from October 10 to 30, 2020.

## 3. Results and Discussion

### 3.1. Exclosures in Ethiopia

Exclosures are areas that are enclosed to allow restoration and rehabilitation of degraded lands by natural means. The context and definition of area exclosures vary from country to country (Abera et al., 2016). In the Ethiopian context, it can be defined as the degraded land that has been closed-off or otherwise protected from human and domestic animal disturbances to allow regenerating native vegetation (Emiru et al., 2017; Wolde et al., 2017). Most parts of Ethiopia are generally regarded as heavily deforested, natural forest has been decreasing at an alarming rate (Cheng et al., 1998). To ameliorate this situation, different initiatives and strategies have been implemented to increase the forest area in Ethiopia. In response to the 2011 Bonn Challenge, Ethiopia has committed to restoring 15 million ha of degraded forest. In the climate resilient green economy (CRGE) document, the government has set afforestation and re-forestation targets to cover 3 million ha of land by 2030 (FDRE, 2011).

## 3.2. Ecosystem Services of Exclosures in Ethiopia

Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth (Millennium Ecosystem Assessment, 2005). Exclosures are ecologically and economically advantageous (Wolde et al., 2007). It could contribute to both peoples' livelihood and environmental quality (Temesgen, 2018). In addition, area exclosures have contribution to the 3 pillars of sustainable development; environmental benefits (increased vegetation cover, decreased downstream soil erosion, increased biodiversity and improved microclimate), economic benefits (sustainable fire wood from fallen branch, grass harvesting through cut and carry, and bee hiving) and social benefits (land users right secured, increased community institution rights, awareness creation and knowledge transfer). Some of the major ecosystem services of area exclosures in Ethiopia are discussed below.

## 3.3. Biodiversity Conservation

The practice of exclosures has become popular in most regions of Ethiopia. For example in Tigray region (Emiru et al;, 2006; Haile, 2012; Mastewal et al., 2006; Aynekulu et al., 2009; Wolde et al., 2009; Wolde and Masetewal, 2013; Samson et al., 2017; Mekuria et al., 2018), Oromia region (Meron 2010), Amhara region (Kibret, 2008; Getachew and Malke, 2015; Abera et al., 2016; Belay and Eyasu, 2017; Wolde et al., 2017), SNNP region (Ango et al., 2014; Yirdaw et al., 2017) and central rift valley (Mohammed et al., 2015) have shown that exclosures are becoming a common conservation practice in different regions of the country.

Different studies indicated that establishment of area exclosures enhanced biodiversity, floristic composition, structure and density in different regions of Ethiopia. A research conducted in Southern Wello by Kebrom (1998) cited in Kibret (2008) pointed out that establishment of exclosures improved composition, density, richness, and diversity of woody species in comparison to open adjacent sites. Similarly Wolde et al. (2018) in Aba-Gerima watershed of Amhara region demonstrated that after four years of establishment, the exclosure displayed higher plant species richness and diversity compared to the adjacent grazing land. This is known that increased vegetation density in exclosures results in increased infiltration and higher transpiration, which in its turn triggers vegetation restoration through increased biomass production (Nyssen et al., 2007). Different studies confirmed that exclosures have great contribution for biodiversity conservation (Table 1).

A study by Meron (2010) showed that the stand density of all woody plants in the old and young exclosures was 1022 $ha^{-1}$ and 587 $ha^{-1}$ respectively, however, in the respective open grazing area the density was 180 $ha^{-1}$. Similarly, Emiru et al. (2006) reported that 27 woody species representing 18 families were observed in exclosures and 14 woody species representing 12 families were recorded in open area. In addition, Angassa et al. (2010) reported that herbaceous biomass was more than twice as high compared to areas outside of exclosures.

Biophysical comparison of exclosures and adjacent free-access lands by (Tefera et al., 2005) showed that above-ground woody species composition increased by 50%, whereas soil seed banks increased by 43% after

**Table 1**: Diversity indices of woody species for enclosures and non-exclosures

| Exclosure age | No. of species in Exclosure | No. of species in open grazing land | Reference |
|---|---|---|---|
| - | 2659 (Individual trees) | 746 (Individual trees) | (Emiru et a l., 2007) |
| | 1022[1] | 180 | (Meron, 2010) |
| | 585 | 332 | (Ermias et al., 2009) |
| 20 | 85 (Woody species) | 25 (woody species) | (Wolde, 2013) |
| - | 93 | 41 | (Haile, 2012) |
| | 47 | 37 | (Kibret, 2008) |
| | 42 | 35 | (Mastewal et al., 2006) |
| 7 | 20 | 13 | (Mamo, 2015) |

exclosure. It has become a common phenomenon to observe acceleration of plant and animal diversity with time after the establishment of exclosures (Eshetu, 2006).

The success of exclosure depends largely on the time since closure, the original vegetation and past disturbance history (Emiru et al., 2006). For instance the study by Mastewal et al. (2007) indicated that the density of large wild mammals varied as of exclosures age. The composition of woody vegetation also depends largely on age of the exclosures establishment (Tefera, 2001). Similarly, Mastewal et al. (2006) reported that the older exclosures had higher woody species density and diversity than the younger ones. For instance, the 29-year-old exclosure had 42 woody species and there were 35, 23, 21 woody species in the 22, 8 and 10-year old exclosures, respectively.

There are evidences that suggest area exclosures are becoming promising alternatives to combat desertification and conserve biodiversity in completely degraded lands. Species which had long disappeared from the exclosures in eastern Tigray (e.g. *Olea europaea* subsp. cuspidata and *Juniperus procera*) re-appeared, densities and diversities of the flora (particularly grasses) and fauna increased, the level of soil erosion decreased, and even springs started to flow after exclosures were established (Emiru et al., 2007). Exclosures establishment is currently used as means to maintain biodiversity. Kassa et al. (2017) reported that most northern highlands of Ethiopia have more trees and woody biomass than 100 years ago, and this positive trend has also been observed in other parts of the country during the past three decades.

## 3.4. Rehabilitation of Degraded Land

Establishing exclosures is considered advantageous since it is cheap, fast and productive method for the rehabilitation of degraded lands (Tucker & Murphy, 1997; Emiru et al., 2006,). Some of the degraded areas have become re-vegetated within just a few years, and it is strongly hoped that the current momentum of restoration of the vegetation would continue leading to rehabilitation of the degraded lands, which would in turn offer the desired socio-economic benefits as well as environmental services (Wolde et al., 2009). Area exclosures has become very common, especially in the highlands, due to the impressive improvement of productivity and reduction in soil erosion (MoA, 2000). According to Betru et al. (2005) as cited in Meron (2010) in Tigray region alone, a total of 262,000 ha have been closed until 2010. A Study by Wolde et al. (2018) at Aba Gerima watershed in North-Western Ethiopia which confirmed that exclosures could be one option for restoring degraded landscapes within short period of time. In Tigray highlands, the establishment of exclosures has become an important measure to combat land degradation and restore vegetative cover. Because of their high sediment trapping capacity, exclosures are a very efficient soil and water conservation measure. They accelerate fertile soil buildup and prevent important sediment loads from leaving the catchment or silting up water reservoirs (Descheemaeker et al., 2006). Vegetation rehabilitation through exclosures is competent measures for soil and water conservation, and alternative forms of land use to overcome erosion and deposition (FAO, 2001).

Exclosures are supplemented with enrichment plantings of native and/or exotic species as well as soil and water conservation measures to speed up the recovery processes (Eshetu, 2006). About seven million hectares of degraded area has been rehabilitated using exclosures between the years 2011 and 2014 (EBI, 2014) in Ethiopia. According to MoA (2019) report, starting from 2015 till 2019, a total area of 15404.6 ha rehabilitated in Different regions of the country.

## 3.5. Soil Conservation and Restoration

Exclosures have a significant positive effect on the restoration of degraded soils. It has effective role in improving soil nutrient content and properties. A study in northern highlands of Ethiopia proved that exclosures showed higher total soil nitrogen (N), available phosphorus (P), and cation exchange capacity than the communal grazing lands (Wolde and Ermias, 2011). A similar study by Gebregergs et al. (2019) illustrated that highest Organic Carbon, and total Nitrogen were recorded in the 10 years of exclosures than open grazing lands.

The higher soil organic matter content in exclosure can potentially improve the soil physical properties such as soil structure and total porosity (Yimer et al., 2015). Similar results were reported from exclosures established within the last two decades in the central Highlands of Ethiopia: an increase of 0.67% organic

matter, 8.85 mg $kg^{-1}$ increase in available P, and 9.18 cmolc $kg^{-1}$ increases in CEC after 9 years of exclosure establishment (Mamo, 2008) and 2.33%, 0.08%, 7.89 cmolc $kg^{-1}$ increases in organic matter, total soil N, and CEC, respectively, after 20 years of exclosure establishment (Tsetargachew, 2008) cited in Wolde and Ermias (2011).

Establishment of exclosures is required to detect significant improvements in most of the investigated soil properties. A study that was conducted in Douga Tmbein Woreda in Tigray region indicated that soil loss from free grazing lands was 47% higher than the soil loss from exclosures (Wolde et al., 2009). In addition a study by Kibret (2008) in Kallu woreda in southern Wello confirmed that soil moisture percentage is higher in exclosure than in the open site, this could also be attributed to the higher organic matter accumulation. Exclosures were effective in soil conservation, restoring degraded soils and increasing soil carbon in the highlands of Tigray. The higher soil nutrients content and properties in all exclosures indicate the positive effect on the restoration of degraded soil (Mekuria et al., 2011).

### 3.6. Exclosures Enhance Biomass Carbon Stock

Area exclosures have great role to enhance biomass carbon stock. Establishing exclosure on degraded lands leads to increased carbon absorption or sequestration (Wolde, 2005; Wolde et al., 2009). A study by Gebregergs et al. (2019) in the semi-arid areas of Tselemti district (northwestern Tigray region) confirmed that higher aboveground carbon stock was recorded in 10 years exclosure and lowest on open grazing land. Another study by Samson et al. (2017) in Tigray region demonstrated that exclosures showed higher soil carbon concentration, soil carbon stocks, and aboveground carbon stocks than the adjacent free grazing lands (Figure 1).

Plant species diversity and aboveground biomass increased with exclosure age (Wolde and Mastewal, 2013). Different studies proved this; for instance a study in Tigray region of semi- arid grazing systems showed that the mean aboveground biomass measured inside the exclosures was more than twice that of the adjacent grazed areas and more biomass was produced from the young than the old exclosures (Tesfay, 2011). A similar study by Yayneshet (2011) reported a two- fold increase in aboveground biomass after eight years of exclosure establishment. The improvement in soil properties and nutrients is a key factor for the enhancement of biomass production in exclosures (Wolde, 2005). The establishment of exclosures is a viable option to restore native vegetation composition and aboveground biomass (Wolde and Mastewal, 2013).

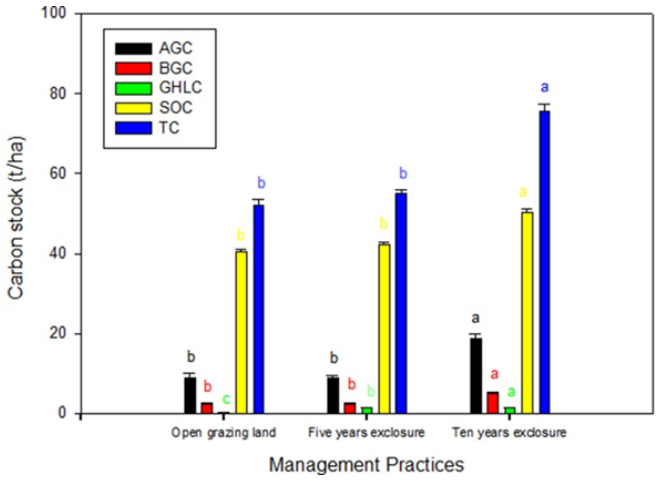


**Figure 1:** Carbon stock (ton/ha; mean ± SE) under the 5 and 10 years of grazing exclosures and open grazing lands (Extracted from: Gebregergs et al., 2019) (AGC = aboveground carbon stock, BGC = belowground carbon stock, GHLC = grass, herb, and litter carbon stock and SOC = soil organic carbon, and TC= Total Carbon).

### 3.7. Socio-economic Benefit of Area Exclosures

Exclosure land management can support to diversify the livelihood options of local communities, as most of the regenerated woody species are economically important, and once vegetation is restored, income generating activities can be integrated (Mekuria et al., 2018). Exclosures are boosting annual household income of local people (Tefera et al., 2005).

The existing wider implementation of exclosures in Ethiopia especially in the high lands is related to the multifaceted benefits of exclosures (Wolde et al., 2018).

Several previously degraded areas have regained forest vegetation via natural succession through exclosures (Emiru et al., 2017). Forest resources of Ethiopia serve for economic, ecological and social purposes. Forests contribute an estimated 4% to GDP through the production of honey, forest coffee, and timber. Recent estimates indicate that about 26-30% of the total coffee production of the country originates

from wild and semi-managed coffee forests. The value of wild coffee is estimated 130 million USD/annum (Mulugeta, 2012). The economic value of closed areas could be categorized as use and non- use values (Bedru et al., 2006). Area exclosures directly or indirectly contributes to the increase of crop yields, fodder production and improvement of farm income (Nyssen et al., 2007).

A study by Meron (2010) showed that on average a household share of thatching grass sells for 104 Ethiopian Birr annually in Biyo Kelala exclosure and 38 Ethiopian Birr in Tiya exclosure (Tefera et al., 2005). A similar study by Asmamaw (2011) in Kewot District (North Shewa region) showed that enclosures provide considerable fodder access for livestocks and are efficient to increase financial income for households. The Net Present Value of exclosures ecosystem services under consideration was about 28% (837 US$) higher than alternative wheat production indicating that exclosures are competitive to alternative land uses (Wolde, 2013).

For exclosures to continue playing their environmental conservation role, socioeconomic needs of local people is very important. A sustainable and socially fair harvesting system of the wood resources or a rotational grazing system initiates local people to have positive attitude towards exclosures (Descheemaeker et al., 2009). The linking of exclosures with other natural resource management, soil and water conservation and livelihood diversification practices has been the biggest innovation that has contributed to the sustainability, acceptability and broader impact of the practice in terms of environmental, social and economic aspects in addition to climate change adaptation and mitigation benefits. For example, beekeeping has been linked to exclosures as the practice does not result in damage to it, while beekeeping provides an alternate income and contributes to resilience to climate change through livelihood diversification. This ensures that the practice of exclosures contributes to both climate change adaptation and mitigation (Abenet et al., 2016).

### 3.8. Challenges of Area Exclosures

Exclosure has been one of the strategies for rehabilitating the degraded hillsides and for soil and water conservation programs (Betru et al., 2005). Though area exclosures have multiple benefits, there are also challenges that hinder not to access their benefits effectively. The challenges differed from regions to regions. It has often been criticized for not offering communities with enough revenue to get out of poverty, as it is usually designed with the main purpose of protecting forests. The major challenges of area exclosures in most areas are conflicts among peasant associations for land, shortage of grazing land, uncontrolled grazing, weak bylaws and absence of exclosures guards/keepers (Getachew and Malke, 2015).

In addition lack of national land use plan, poverty, landlessness and tenure insecurity are also challenges of area exclosures (Kassa et al., 2017), lack of clear and negotiated benefit sharing mechanism, slow process of rehabilitation, poor soil, seed and seedling bank, moisture stress due to rainfall scarcity and erratic natural phenomena limit the survival of seedlings (Emiru et al., 2017), and increased expectations of the community about economic benefits on exclosures became challenges (Gebremedhin et al., 2000). Conducting enrichment plantation of economically important plant species such as fruit trees and trees that can be used for fuel wood (e.g., *Acacia decurrens*) could help improve the short-term benefits of the exclosure. Allowing communities to harvest fruits and fuel wood can contribute to increasing their incomes and diversifying their livelihoods (Abenet et al., 2016).

## 4. Conclusion

The major focus of the review paper was to investigate the different ecosystem and economic benefits of area exclosures in different regions of Ethiopia and identify the major challenges. All the review articles indicated that exclosures have various ecosystem and economic benefits. It is a very suitable and in most cases a very essential practice for areas that are highly degraded and not very productive. Exclosures are sources of wood for construction, and non-timber forest products. They also play an important role in conserving remaining soil resources and improving soil fertility. It improves soil fertility by augmenting soil nutrients from decomposed plant remains. It also limits nutrient loss from a site by controlling runoff (vegetation acting as a physical barrier to soil erosion). This eventually improves the capability of the land to support other vegetation types including exotic plantations.

Area exclosures integrated with other natural resource and income generating activities such as soil and water conservation, promotion of wood saving and solar stoves, crop land management, grazing land management plans, agro-forestry, apiculture, fodder production and community capacity building show greatest success and sustainability. Moreover, the studies showed that area exclosure is an intervention measure that boosts land productivity, biodiversity conservation and plays a key role in carbon sequestration.

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