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Contribution of Exclosures for Restoration of Woody Species Diversity and Regulating Ecosystem Services in Ethiopia

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Abstract
In Ethiopia Exclosures has been recognized as promising practice in the restoration of degraded land and regulating the environmental services. Though, study on the role of exclosures on rehabilitating of degraded land is very little, fragmented and doesn't often integrate the regulating environmental services. To scale up this practices insight to the Ethiopian level, I carry out reviewing different research articles on the role of exclosure to biodiversity of woody species and regulating ecosystem services. The review of this study showed that exclosure significantly enhanced woody species diversity; reducing soil erosion, improve Soil nutrient contents and the ecosystem carbon stock potential over the adjacent communal grazing lands. In addition to this establishing exclosures has a high contribution to the livelihood of local communities. As a result the local communities have a positive attitude towards the establishment of exclosures in the degraded lands. Overall review from this study strongly indicates that establishment of exclosures in the degraded lands of Ethiopia are a win-win situation since it is advantageous over the people, natural and climate of the country. However, by involving the key stakeholders the governmental and nongovernmental organizations (NGOs') should have to expand this practice to whole degraded lands of the country.
Keywords: Climate change mitigation, Enclosure, Degradation, Rehabilitations, Restoration

1. Introduction

Land degradation has negative impacts on productivity of land, biodiversity, soil fertility and other ecosystem services. Globally, an estimated 25% of the land has been degraded (FAO, 2011). Land degradation is a severe problem across sub-Saharan Africa, and Ethiopia is among the most affected countries. In Sub-Saharan Africa the lives of millions of people was threatening because of land degradation (Blay et al., 2004). On year 1980s, land degradation especially in the Ethiopian highlands has been identified as the most severe environmental problem (Aune et. al., 2001, Hagos and Holden, 2002). For instance the dry land vegetations of Ethiopia are facing to sever degradation as the result of deforestation, agricultural land expansion and over-grazing (Lemenih et al., 2005; Mengistu et al., 2005). This is triggered by population expansion and over-exploitation of the natural resources (Mekuria et al., 2009, Hurni et al., 2005). Therefore, there is an urgent need for their restoration, proper management, sustainable utilization and conservation, which, in turn, require a good understanding of their stand structures as well as diversity and status of regeneration of woody species (Neelo et al., 2015).

Recently, several international efforts are directed toward restoring degraded ecosystems and have set goals, such as restoring 15% of degraded ecosystems (CBD, 1992) and 150 million ha of deforested and degraded forests by 2020 (Lamb, 2011). Ethiopia initiated a number of projects including soil and water conservation works and the establishment of exclosures to stop further land degradation (Nedessa, 2003). About three decades ago the communities in the highlands of Ethiopia started to establish exclosures as part of effort to restore biodiversities and regulating environmental services (Mekuria and Yami, 2013; Mekuria and Aynekulu, 2011). Recently, the government of Ethiopia also initiated climate resilience of green economy (CRGE) strategies identified forestry as the main pillars. At the same time Ethiopian government was also pledged to restore 15 million ha of degraded land which is about one-sixth of the country total area which can sequester 1.42 Gt CO_2 by 2025.

Exclosures are a type of land management, implemented on degraded land for environmental restoration (Tucker and Murphy, 1997). Exclosures play significant roles in carbon sequestration and mitigation of climate change, soil and water conservation, watershed protection, nutrient recycling, nitrogen fixation, amenity and recreation, creation of microclimate and biodiversity conservation (Neelo et al., 2015). Exclosures are usually established in steep, eroded and degraded areas that have been used for grazing in the past (Mekuria, 2013). It is effective system because of involving the local communities in the establishment of exclosures and the responsibility of local authorities for management and control of the area (Descheemaeker et al, 2006).

Though they are small in number and fragmented, several studies have been investigated on the interaction between establishment of exclosures, woody species diversity and regulating ecosystem services. For instance, different studies showed that exclosure of degraded communal lands has a great role to improve woody species diversity (Mengistu et al., 2005; Yami et al., 2006; Yayneshet, 2011; Getseselassie, 2012; Mekuria, 2013), improving soil nutrient content and properties (Mekuria and Aynekulu, 2011), regulate total amount of woody species biomass (Mekuria, 2007; Mekuria and yami, 2013), soil and water erosion control (Mekuria et al., 2009), generating of animal feed and human food (Getseselassie, 2012) and sequestering and storing of C

(Yayneshet *et al*., 2008; Wolde Mekuria et al., 2009, Yimer et al., 2015).

Currently the government of Ethiopia, incorporates exclosure as a strategies which supports to address reducing of deforestation and forest degradation plus (REDD+) with the existing legal and policy framework (R_PP, 2011). However, this review on establishment of exclosures in Ethiopia is required for further expansion and to support polices on restoration of degraded land. The aim of this reviewing paper is to discuss on how establishing exclosure contributes to restore woody species diversity and regulating environmental services.

2. Methods

Several published and unpublished research articles related to exclosures were collected and selected for this review. These research articles are collected directly from the author as well as downloading from the web pages using "Exclosures", "Enclosures", and "Rehabilitation of degraded lands" and "Restorations "as key words. A review of research articles were done by grouping similar articles to each sub titles and then trying to summarize.

3. Exclosure enhanced woody species composition, diversity and structure

Establishing exclosures are the cheapest and convenient methods employed to restore, manage and conserve woody species in the degraded areas (Birhane et al., 2004, 2006; Mengistu et al., 2005; Hailu et al., 2006; Mekuria, 2007; Teketay et al., 2010). Several studies indicated that establishment of exclosure in a degraded land enhances the floristic diversity, composition, structure and density. For instance, in Ethiopia the number of woody species found in Exclosure are more than the adjacent open grazing lands (Mengistu et al., 2005 Birhane et al., 2007; Yayneshet, 2011; Mekuria and Yami, 2013; Kasim et al., 2015). The composition of woody vegetation in exclosures depends largely on age of the exclosure establishment (Pielou, 1975; Yami et al., 2006; Birhane et al., 2007; Mekuria and Yami, 2013). For example Birhane et al., (2006), reported increase in woody species richness of 13 after 8 years of exclosure establishment. The reason for high species richness appearance in exclosure indicates that a long period of protection from livestock and human interface, which can allowing regeneration of tree and shrubs, exemplified in Ethiopia (Tekle, 2001; Mengistu, 2001), in Eritrea (Medaine,1997) and in Northeastern Botswana (Neelo et al., 2015). Similarly, the abundance of woody species was larger in exclosure than adjacent open grazing land (Birhane et al., 2007).

In exclosures higher diversity values were recorded as compared to adjacent open grazing land (Kasim et al., 2015; Mekuria and Yami, 2013; Yayneshet, 2011*;* Mengistu et al., 2005). Mengistu et al., (2005), Study shows that, the value of wood plant diversity found in exclosure is two times more than the value of diversity recorded in open grazing land after 22 years of exclosure establishment. This is simply as a result of excluding human and livestock interface from the degraded areas (Mengistu et al., 2005; Zerihun and Backeus, 1991). Whereas, study conducted in Eastern Tigray Ethiopia by Birhane et al., (2007), in Eritrea by Medanie (1997) and in Tanzania by Mwalayosi (2000) shows that the species diversity of the open areas was recorded to be higher than the closed areas. According to these authors, this is because of the Shannon diversity index is highly influenced by the number of dominant and rare species presence.

Relatively, the diameter class distribution of the most abundant woody species in exclosure showed an inverted J_ shaped (continuous recruitment of tree species), which suggested a normal population structure as compared to adjacent open grazing lands (Kasim et al., 2015; Birhane et al., 2007); Similarly, other studies on Northeastern Botswana by Neelo et al., (2015), indicates that exclosure contributes on protecting the woody species from disturbance and exploitation. In open sites, human disturbance, particularly grazing, is usually the major reason for hampered or poor regeneration (Zegeye et al., 2011). High browsing pressure can lead to the absence of seedlings or juveniles as a result of high seedling mortality (Tremblay et al., 2007; Negussie et al., 2008). As the exclosure age increases, the density of woody species rises and canopy cover expands (Lemenih and Kassa, 2014). The diversity of all woody species soil seed bank including grass and herbs was greater in the exclosure than adjacent open grazing lands (Birhane et al., 2007; Mengistu et al., 2005). this suggesting that the effect of disturbance by human and livestock interface on the soil seed banks is more pronounced in the open areas.

4. Exclosures for regulating Ecosystem services

4.1. Exclosures to Control Soil Erosion

Land degradation in the form of soil erosion and loss of soil fertility caused by the loss of vegetation cover (Fitsum et al., 1999). In Ethiopia, inappropriate agricultural practices such as over-cultivation and overgrazing are most important factors resulting in soil erosion and nutrient losses (Hurni, 1993; Abebe et al., 2014; Mekuria et al., 2009; Bishaw, 2009; Nedass et al., 2005; Lemenih et al., 2005; Mengistu et al., 2005). In the highlands of Ethiopia, the cultivation on steep slopes and clearing of vegetation has accelerated erosion (Bhan, 1988). In the northern Ethiopia report on soil loss shows 35 t ha^{-1} $year^{-1}$ from cultivated steep slopes (30-50%) (Brhane and Mekonen, 2009; Keyser and Sonneveld, 2001). Exclosures are established as a type of land management with spatial emphasis to improve environmental conditions and controlling soil erosion in degraded and generally

open access lands (Yimer ea al., 2015, Abebe et al., 2014; Mekuria and aynekulu, 2011; Mekuria et al., 2006; Mekuria et al., 2009, Descheemaeker et al., 2006; Medhanie, 1997; Nedass et al., 2005). Study conducted in Tigray regional state, Ethiopia by Mekuria et al., (2009) shows that, 10 years old exclosure, reduced estimated soil erosion by 77% (from 52 to 12 Mg $ha^{-1}y^{-1}$). This can be because of exclosures has been restored the canopy of trees, shrubs and understory vegetation which can defense against soil erosion (Gidey et al., 2013; Mekuria et al., 2009). Similarly, earlier studies have been showed that vegetation can play an important role to control soil erosion (Cerda, 1999; Descroix et al., 2001; Lopez et al., 1998; Sanchez et al., 2002).

4.2. Exclosures to enhance soil nutrients and organic carbon stock

Land degradation is one of the critical problems in Sub-Saharan Africa which threaten the lives of millions of peoples (Blay et al., 2004). The major consequences of land degradations are the decreased land productivity, gradual decline of soil nutrients and vegetation cover (Abebe et al., 2014). However, exclosures are established to promote natural regenerations and reduce land degradations of previously degraded communal grazing lands (Mekuria et al., 2014 and 2011; Mengistu et al., 2005; Birhane et al., 2007). Few case studies conducted in the highlands of Ethiopia have shown that exclosures can be effective in restoring degraded soils and increase soil carbon (Mekuria 2013; Mekuria et al., 2014 & 2006; Yimer et al., 2015). Though, study conducted on soil properties and soil organic carbon stocks are not consistent. For instance Reid et al., (2004); Yimer et al., (2015); Abebe et al., (2014) and Mekuria et al., (2009), reported that an increase in organic soil carbon following the establishment of exclosures on grazing lands, whereas (Mekuria et al., 2014) Soil organic carbon and Nutrient contents are not influenced by establishing of exclosures in communal Grazing Land in Nile Basin, Northern Ethiopia.

Study conducted in southern Ethiopia by Abebe et al., (2014), Katrien (2007) and Mekuria et al., (2006), in Northern Ethiopia, shows that in the exclosure there is significantly higher Soil Organic carbon (SOC), total nitrogen (TN) and available phosphors than adjacent un protected lands. Similarly Yimer et al., (2015), in central rift valley areas of Ethiopia, also found exclosure has a significantly higher soil organic carbon than open grazing land and Mekuria and Aynekulu (2011), in Tigray regional state, Northern Ethiopia, showed that there is higher total soil nitrogen (N), available phosphorus (P) than adjacent communal grazing lands. Whereas, study conducted by Mekuria et al., (2014), in Nile Basin, Northern Ethiopia shows that communal grazing land displayed significantly higher soil total nitrogen, phosphorus and potassium compared to exclosures; while, there were not significant differences in soil organic carbon.

The reason for increasing TN, availability of phosphors and soil organic carbon in exclosures than open grazing land was due to the accumulation of soil organic matter and the presence of this organic matter also affects both the chemical and physical properties of the soil and overall health (Abebe et al., 2014). 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). As a result, the TN and availability of phosphors becomes high since there is directly and significantly correlated with the availability of woody species as they improve the soil organic matter and properties (Abebe et al., 2014; Mekuria and Aynekulu, 2011; Johannes and David, 2000; Loreau et al., 2001). Similarly, Mekuria et al, (2014), also agreed that exclosure enhances soil properties but the nutrient content becomes low as a result of higher nutrient uptake by vegetations and on the other hand, the existence of cow dung manure in communal grazing land may improve SOM in communal grazing lands. In addition to this my third assumption is also since the maximum age of exclosures was short (7years) the variation becomes insignificant. Though, study conducted in China (Chen et al., 2012) and Ethiopia (Mekuria et al., 2011), indicated that exclosures have the capacity to increase soil C sequestration. Other studies also reported increasing soil nutrient retention in ecosystem along with the number of plant species and aboveground biomass (e.g., Johannes and David, 2000; Loreau et al., 2001).

Study conducted in the exclosures and adjacent grazing land of highland Tigray, Northern Ethiopia showed that the Average difference in soil organic carbon stock (0-20 cm depth) ranged from 26.0 to 53.7MgC ha^{-1} at the age of five (5) and twenty (20) years (Mekuria, 2013). With the same depth, study conducted by Mekuria et al., (2009), showed that the soil organic carbon stock ranges from 15.9 to 40.1 Mg C ha^{-1}.

4.3. Exclosures to enhance Biomass carbon stock

Deforestation and land degradation are reducing the ability of the land to support delivery of vital ecosystem services (Bishaw, 2005; Chazdon 2008; Guariguata and Balvanera 2009; Butchart et al. 2010; Hector et al. 2011, Mekuria et al., 2015). In Ethiopia, several studies are reported on the role of exclosure to improving ecosystem services and reversing biodiversity losses. In terms of ecosystem service, exclosure contributes to provisioning ecosystem services through regulating services by aboveground and belowground carbon sequestration (McIntosh, and Allen, 1998, Cheng et al., 2011; Mekuria and Aynekulu, 2011; Mekuria, 2013; Mekuria et al., 2009 & 2015; Ubuy et al., 2014).

Several studies were reported that the above ground (AGB) carbon stock of exclosure were significantly higher than the adjacent open grazing land (Mekuria, 2007; Mekuria et al., 2009; Chengi et al., 2011; Witt et al., 2011). Study conducted by Mekuria et al., (2009), in the lowlands of Tigray Regional state, the average

difference in AGB carbon stock of exclosures and adjacent open grazing land ranges between 2.3 and 5.6 Mg C ha^{-1}, in the highlands of Tigray, Northern Ethiopia (age 20) also varied between 2.0 and 7.0MgCha^{-1} (Mekuria, 2013) and in Nile Basin Ethiopia ranges 0.6 to 4.2 t C ha^{-1} (Mekuria et al., 2015). According to the Berhe (2015), in Highlands of Tigray the total dry AGB and BGB ranges between 28.01 and 48.7. Study on total annual litter production in Highlands of Tigray regional state also showed that 30 to 425 g m^{-2}. These studs are promising as compared with the study conducted in exclosures of semi arid Mulga lands of Australia which records about 5.8 t C ha^{-1} over 30 years. Some studies also indicated that the conversion of open grazing lands to exclosures have led to a significant increment (3-4 fold) in carbon sequestration through storing of carbon in the below and aboveground component of forests (Witt *et al*., 2011; Cheng *et al*., 2011).

The aboveground biomass and carbon were influenced by the age of exclosure (Mekuria, 2013; Mekuria et al., 2015, 2009). This influence of exclosure age was supported by increased number of tree species with exclosure duration when compared to shrub species. Exclosure enhances the biomass carbon stock as a result of the protection of exclosures from human and livestock interference, and the positive consequences of increased soil moisture content due to the construction of SWC structures would improve the vegetation coverage, diversity and structures (McIntosh, and Allen, 1998; Mengistu et al., 2005; Birhane et al., 2007, Cheng et al., 2011; Witt et al., 2011; Mekuria et al., 2015).

5. Socio-economic role of exclosures

Forests are a vital source of livelihoods of millions of peoples to national economic development as well as source and sink of carbon and contribute to the rate of climate change mitigation. It is impossible to think of individuals that do not depend on forest and forest products. In the northern highlands of Ethiopia, forest accounting for 27 % of total household income (Babulo et al. 2009), in the Bale mountains, southern Ethiopia 34 % of household per capita income and in Dendi district contributes of the average household income (Mamo et al. 2007). Though, the challenge is on sustainable management of this resource. In Ethiopia deforestation is severe and has a long history, especially in the central and northern highlands (Lemenih and Kassa, 2014).

Recently, Ethiopia has begun taking measures to rehabilitate degraded forests and forest lands (Mengistu et al., 2005; Lemenih and Kassa, 2014). Establishing Exclosure is a promising practice for rehabilitation of degraded lands stared in different parts of Ethiopia. Beyond the rehabilitating of degraded lands and regulating ecosystem service, exclosure has also socio-economic benefits to the livelihoods of the community (Muys et al., 2006; Tilahun et al. 2007; Babulo et al., 2009; Tekalign, 2010; Mekuria et al. 2011; Mulugeta and Achenef, 2015). Most of local peoples are optimistic to establish exclosures than various community plantations programs since this practice is chipper and needs lower labour (Gebrehiwot, 1997, Birhane, 2002). A few have negative attitude towards establishing of exclosures (Birhane, 2002; Mulugeta and Achenef, 2015, Tekalign, 2010), The positive attitude of local communities is crucial for the sustainability of enclosures (Heitschmidt *et al*., 2004) and also for future rehabilitation projects (Mekuria *et al.,* 2009).

The economic role of establishing exclosure can be shown in two ways which is directly as well as indirectly. Exclosure improves the livelihood of community directly by providing animal feed, bee foder, fuel and other non-timber forest product (Muys et al., 2006; Mamo, 2008). Study conducted in Biyo-Kelala Area Exclosures, Ada`a wereda East Shewa Zone of Oromoia shows that the income from exclosure accounts about 3.07 % of the total annual income to the household (Tekalign,2010). Indirectly also benefited by improving the productivity of land and regulating the environmental services (Mekuria, 2013). Over 30 years, the net present value (NPV) of the ecological services of exclosure amount to 3071 US $ ha^{-1} which is by far exceeds the economic outcome of alternative crop production, such as wheat, barley, and teff (Mekuria, 2013). According Mekuria et al., (2015), from aboveground carbon storage of the relatively older exclosures (i.e., 4- to 7-year-old) ranged from US$117 to US$118.5 per hectare, which is higher than the net revenues from teff production.

6. Challenges

Though, Exclosures have crucial social, economical and environmental values to the livelihood of the local community. Most of the exclosures was not initiated either by community or state involvement driven mainly by aid agencies and NGOs (Lemenih and Kassa, 2014). In addition, there are some challenges on the existing and expansion practices (Mulugeta and Achenef, 2015). The most challenging aspect of exclosure practices was illegal grazing of animals, illegal cutting of trees for different purpose, conflicts between adjacent peasant associations (Mulugeta and Achenef, 2015; Berhe, 2014), improper benefit sharing (Tekalign, 2010; Asmamaw, 2011), shortage of grazing land and lack of awareness (Mulugeta and Achenef, 2015), no management plan and also as the canopy cover increases the amount of grass harvested from the exclosure decreases (Lemenih and Kassa, 2014). These are some of the challenges on the exclosure practice on different parts of Ethiopia.

7. Conclusions

This review paper confirms that establishment of Exclosure on the degraded communal grazing land is a vital

option to restore indigenous woody species by enhancing the natural regeneration rates, potential to reduce water erosion, improving soil nutrient content and properties, improve soil organic and Biomass carbon stock and also improve the socio-economic benefits of the local communities. Establishing Exclosure in a degraded land is a win-win situation which can support the social, economical and environmental values. The restoration capacity of the exclosure depends on the years of establishment. As the age of exclosure increased the ability to restore woody species, improving soil nutrients and ecosystem carbon stock potential becomes higher. Establishing exclosure was a win win situation since this supports the local community as well as restoring the degraded lands. Exclosure improves the livelihood of the local community by providing animal feed, bee fodder, fuel, timber and other non-wood forest products.

Majority of the local communities are supported the establishment of exclosures on the degraded communal grazing land because it is easy to establish, cheap and support their livelihoods. Despite of the ecological and socioeconomic roles there are also some challenges for exclosure practices lack of awareness, improper benefit sharing, ownership and lack of grazing lands are some of the challenges listed by different Ethiopian local communities lived nearby exclosures.

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