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Herbaceous vegetation restoration potential and soil physical condition in a mountain grazing land of Eastern Tigray, Ethiopia

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Abstract: Full knowledge of grazing land vegetation and soil is essential to understand environmental trends and for management decisions. This study was conducted in *Kilte -Awlaelo,* eastern Tigray, Ethiopia. The study aimed to investigate species composition and diversity of the herbaceous vegetation, and examine the physical soil condition of the grazing lands. A total of 45 quadrats measuring 20 m × 20 m (400 m^2) were laid out in 15 sample sites from three corresponding land use types (i.e. ten years enclosure, five years enclosure and open grazing land). From each land use type, five sites with three quadrats each were investigated. Each quadrat was laid out at an interval of 400 m in five parallel transects each 200 m apart from other. To collect data of herbaceous vegetation and soil five randomly located samples of 1 m^2 area each, was selected and marked, within each 400 m^2 sample quadrat located along the main transect. There was significant ($P<0.05$) difference for soil erosion and compaction between the land use types, high degree of soil erosion and compaction exhibited in the open grazing land use. The study has shown also significant ($P<0.05$) variation between land use type in grass species composition, basal cover, age category, and herbaceous diversity. More or less relatively higher mean value for all these parameters were recorded in the ten years enclosure land use type and intermediate value scored by five years enclosure followed by the open grazing land use. A total of 23 species of grasses and 53 non-grass species were recorded and very few grasses occurred in open grazing land use type. Whereas in the two enclosure land use types important grasses such as *Brachiaria sp*., *Bromus pectinatus, Chloris gayana, Cenchrus ciliaris, Chloris radiata, Cynodon dactylon, Dactyloctenium aegyptium, Digitaria velutina, Eragrostis tenuifolia, Lintonia nutans, Setaria pumila, Setaria verticillata* and *Tragus racemosus* all occurred frequently forming the major constituents of the sites. Therefore, regeneration from area enclosure can be an advocated practice for grazing lands rehabilitation.

Keywords: Herbaceous, Area enclosure, Open grazing land, Restoration/Rehabilitation

Introduction

Ethiopia is a mountainous country with topographic features dominated by rugged landscapes. The country consists of two major high plateau regions separated by the Rift Valley and bounded on all sides by lowlands (Tamrat, 1993). The highlands, which are defined as land areas above 1500 m, with the associated valleys, constitute about 44% of the country (EFAP 1993). The Ethiopian highlands are the largest mountain complex in Africa and comprise over 50% of the African land area covered by afromontane vegetation (Tamrat, 1993). Mountain areas have a special role in the conservation of biodiversity and their climatic conditions are favorable for the sustenance of unique mountain ecosystem that supports endemic species (FAO, 2002).

Land degradation is a severe problem across sub-Saharan Africa, and Ethiopia is among the most affected countries. Land degradation in Ethiopia is especially severe in the highlands (Fistum, 2003). To curb further land degradation the government of Ethiopia has initiated a number of projects including soil and water conservation works and establishment of area enclosures with the financial assistance of international donors, mainly the World Food Program (Betru, 2003). Establishment of area enclosures has been an important intervention for rehabilitating hillsides. This practice has become very common especially in the northern highlands of the country due to impressive improvement of productivity and reduction in soil erosion in the areas enclosed in 1980s (WFP/MoA, 2002).

Tigray, one of the regions in Ethiopia belongs to the African dry lands often called the Sudano-Sahelian region (Warren and Khogali, 1992). The region is characterized by undulating and hilly escarpments sparse, highly uneven distribution of rainfall, and by frequent occurrence of drought. The main animal feed resources in the region are crop residues, native pasture, shrubs, and aftermath which account for 47%, 35%, 10%, and 8%, respectively (BoANR, 1996) and about 40% of the total land area is used for grazing (BoANR, 1995). Despite the fact that forage shortage is the major livestock production problem in the region, a total of 262, 000 hectares have been put under enclosure in Tigray to overcome forage shortage and rehabilitate degraded mountain grazing land (Betru *et al.,* 2005). Still, similar actions are underway to recover vegetation of the region in line with the need to get livestock fodder and tree products. Enclosed areas have been useful to achieve conservation based sustainable agriculture (Kindeya, 2004).

Livestock feed in Ethiopian highland is derived mainly from grazing and browsing in permanent grazing land and fallow land, which account 60.18% of the total feed (CSA, 2003). As consequences of these feed deficits, uncontrolled overgrazing has resulted in severe degradation of natural vegetation and soil fertility in communal grazing lands and fallow lands particularly in upland and sloping areas (Alemayehu, 1998). Thus highlands are characterized by high stocking rates, forage scarcity, poor forage quality below livestock needs. In this area mixed livestock species are herded together and graze in communal pasture, private land or stubble depending on time and season of the year. On the other hand, farmers are cultivating more land permanently and the size of grazing land is reduced and pushed to marginal and ecological fragile lands (Mwendera *et al.*, 1997).

Establishing enclosure areas is considered advantageous since it is a quick, cheap and effective method for the rehabilitation of degraded land (Bendz, 1986). Despite the fact that enclosures have proved useful to re-vegetating and rehabilitating degraded lands, knowledge on the diversity, sources of propagates and regeneration status of the developing flora as well as the potential socio-economic benefit that can be derived from such enclosure is lacking (Emiru, 2002). Since restoration of vegetation is possible through natural regeneration, knowledge on the species composition, density and diversity of the vegetation is very important.

The following objectives were addressed in the mountain lands in both enclosed area and open grazing land:

- to study species composition and diversity of the herbaceous vegetation,
- to investigate the physical soil condition of the grazing lands.

Materials and methods

Description of study area

Location and area coverage

Tigray is the most northern part of Ethiopia located on the Sudano-Sahelian dry land zone (Warren and Khogali, 1992). It covers an approximate area of 50 thousand square kilometers. The study was conducted in a mountain grazing land of *Kilte-Awlaelo Woreda,* eastern Tigray. The *Woreda* (district) is divided in to 16 *Tabias* (the smallest administrative units) excluding the town of *Wukro;* the study was conducted in *Arbaha-Atsbaha Tabia* situated 60 km north of Mekelle. The site is geographically located at 12°15' to 14°50' N, 36°27' to 39°59' E and covers a total area of 6,764.0 ha, which is 879.75 cultivated land, 206.00 ha grazing land, 664.50 ha area enclosure and 5,013.00 ha miscellaneous land (BoANR, 2004).

Topography, climate and soils

The agro-ecology of *Kilte-Awlaelo Woreda (District)* experiences semi-arid climate.

The altitude of *Woreda* ranges from 1,500 to 2,500 m a.s.l. The topography of the area generally varies from flat in the Southern and Western to undulating and hilly escarpment in the Northern and Eastern parts of the area. The length of the growing period varies from 75 to 90 days and rainfall of the area ranges from 400 to 550 mm. The mean annual rainfall is about 450 mm and the main rainy season is June to September. The soils in the hilly areas are developed on sedimentary rocks and are mostly lithosols. Luvisols are dominant in flat lands. Soils are shallow and poor on hillsides and relatively deeper and fertile in flat areas (BoANRD, 1999).

Human and livestock population

A recent demographic study in the area estimated the population of *Kilte-Awlaelo Woreda* to be 106,168. On the total population, 51172 (48.2%) were males and 54,996 (51.8%) were females. The total number of farm households was estimated to be 21,667 of which 7152 (33%) were women (BoPED, 2003). According to CSA (2003) in the *woreda* 53,452 cattle, 13,594 sheep, 10, 207 goats, 11,450 donkeys, 828 mules, and 629 camels were inventoried.

Vegetation and soil sampling

The field study of species composition, diversity of the vegetation and changes in vegetation cover was undertaken between February to September 2006. Transect survey method (Moore and Chapman, 1986) was used in three areas with different land uses: ten years enclosure called *Arato*, five years enclosure called *Akeb-tsaeda* open grazing land called *Hina-nebri* located in *Arba-Atsbaha Tabia, Kilte-Awlaelo woreda* of eastern Tigray. Five parallel transect lines in each land use were established each 200 m apart from the other in order to assess vegetation cover and soil condition in the three land use type; 15 sampling sites were selected fallowed the transect, five site from each land use. A total of 45 quadrat each measuring 20m x 20m (400 m^2) were laid out using measuring tape and Silva compass (Type 15T, made in Sweden) at an interval of 400 m along the transect. Sites are here after assigned with numbers: sites 1-5 in the ten years enclosure, 5-10 in the five years enclosure, and 11-15 in open grazing land. Three quadrats were placed in each site. The quadrats delineated using polyethylene strings at four wooden pegs imbedded into the soil at the four corners. The aspect, altitude and slope for each sample site were measured and recorded using Silvia compass, altimeter and clinometers, respectively. In addition, GPS reading (altitude, latitude and longitude) for each sample site was taken using GPS 12 channel readers. Some of the species collected from each quadrat were straight identified, whilst species difficult to be identified were indicated with local names and samples were collected for herbarium, pressed and dried properly using plant presses and transported to the Haramaya University for botanical identification on the base of the Flora of Ethiopia (Hedberg and Edwards, 1989; 1995) and the Flora of East Africa (Cufodontis, 1953-1972). The details of the factors considered and criteria which have been employed for rating the vegetation and soil conditions in each quadrat of the study area are summarized in Appendix Table 1.

Herbaceous vegetation layer

Species composition

The herbaceous vegetation layer was investigated for species composition, diversity, basal cover, seedling number and age categories in each sub-quadrat of 1 m^2. The herbaceous species were classified as in Barrs *et al.*, 1997: decreasers (very desirable/palatable herbaceous species whose presence decreases with gazing), increaser (undesirable herbaceous species that increase with grazing), according to the succession theory of Dyksterhuis (1949). The adaptation of Dyksterhuis (1949) comprised the shift of herbaceous species into another class of decreaser, increaser or pioneer, and was based on the vigor as well as the opinion of the farmers and other experienced people on the palatability of the species. Visual estimates were made to determine the proportion of each herbaceous species (cover-abundance) of the herbaceous layer in another sample an imaginary circle within a radius of 10 m of the sample quadrat. A range of 1-10 points was assigned to the abundance of the herbaceous species; As described in Appendix table 1 where the herbaceous species cover-abundance greater than 90-100% decreasers scored 10 points; and with less than 50% increaser and 10% decreasers 1 point**,** and with the rest falling in between these ranges.

Basal cover and litter

In each quadrat the basal cover or area (the area occupied at the intersections of the plant-soil interface) of the living plant parts were estimated in a randomly laid out plot of 1 m^2 area split into halves, and each further divided in quarters and eighths. Basal estimation has done by clipping for clear observation, accordingly plants basal covers in the plot were cut, transferred and kept together, and drawn in the eighth segment to facilitate visual estimation of basal cover of living plant parts**.** The basal cover rating of tufted species was considered 'excellent' when the eighth is completely filled (12.5%), or very poor less than 3%. In assumption of that, classes of <3%, 3-6%, 6-9%, and 9-12% were categorized (as described in Appendix table 1 in detailed). A score of 0 (zero) was assigned for no basal cover (0% covered area). Creeping grasses were counted twice. Although no system was developed for creepers, both were given the maximum score, 'excellent', because of the abundance of the cover.

Number of seedlings and age distribution

The number of seedlings and age categories of the herbaceous species were recorded from three randomly identified plots, each the size of an A4 paper (30 cm x 21 cm), in each quadrat. The paper was dropped from a height of approximately 2 m above the ground. As explained in detail in Appendix table 1, the category with no 'seedlings' were given 0 point and the more than 4 'seedlings' was given the maximum score of 5 points with the rest falling with in this range of classes (i.e. 0-5 points). Through visual observation all grasses before flowering stage was considered young age, grasses in flowering and seed production were assumed as medium age and perennial grasses post seed production were considered as old plants. Accordingly, the maximum score of 5 was given when all age categories (young, medium aged, old plants) of the dominant species were present. Young age plant was defined as possess 20% old and mature plants of the dominate species and medium when it possess 50% of the biomass of old and mature plants of the dominant species. When there are only young plants a minimum score of 1 point was given (Appendix table 1).

Soil condition assessment

The extent of soil erosion and compaction in each quadrat of the study area was evaluated subjectively by visual observations and as in detail explained in Appendix table 1 a corresponding score ranging 1-5 was assigned in each case. Soil erosion was based up on the amount of pedestals (higher parts of the soils, held together by plant roots, with eroded soil around the tuft), the presence of pavements (terraces of flat soil, normally without basal cover, with a line of tufts between pavements). The maximum score (5 point) was given for no sign of erosion, 4 for slight sand mulch, 3 for weak pedestals (soil hold by plant roots and stone from erosion), 2 for steep sided pedestal, 1 for pavements (surficial concentration of pebbles and rock fragments tending to protect the underlying soil from further erosion) and 0 for gullies. Following the suggestions of Barrs *et al.* (1997), soil compaction was assessed by the amount of capping (crust forming). Thus, a range of 1-5 points were given for soil surface with no capping, isolated or scattered capping, >50% capping, >75% capping and almost 100% capping, respectively.

Statistical analysis of the data

The grazing land vegetation and soil data that were gathered from the field samplings were summarized and analyzed in SPSS (Statistical Package for the Social Sciences) (1996). A total of 15 sample sites each having three quadrats (400 m^2) were used for vegetation and soil. One-way analysis of variance (ANOVA) was used for variables of the vegetation and soil characterizing the study area. One-way ANOVA and Duncan multiple range tests (DMRT) with $P< 0.05$ was employed to investigate if significant differences occurred for each of the considered vegetation and soil parameters. The sum of all species encountered in the quadrat of all sample sites of the two enclosures and open grazing area were used to calculate the species richness.

Indices based on species number and numbers of individuals for species: richness (1), diversity (2) and evenness (3) were calculated using the following formulas.

Margalefs (Dmg) index (Magurran, 1996) of species was calculated by:

$$D_{mg} = \frac{(S-1)}{\ln(N)} \quad (1)$$

Shannon diversity index (Magurran, 1996) was calculated by

$$H = -\sum (pi \ln pi) \quad (2)$$

Where p_i is the proportional abundance of the i[th] species $= \frac{N}{\sum N}$

The Shannon evenness (Hill, 1973) was calculated by

$$E = \frac{H}{\ln S} \quad (3)$$

Where, S: is the total number of species recorded
N: number of individuals for a given species

Results and discussions

Soil and vegetation condition assessment

Soil condition assessment of the study area

The soil erosion and compaction varied significantly (P< 0 .05) (Appendix Table 2, 3 and Table 1) and the extent of soil erosion was ranged from simple sand mulch to gullies over the sample sites. Similarly the extent of soil compaction was ranged from no compaction to 100% capping. Soil erosion and compaction depends on number of factors including the land use type, the geology, the landscape, the vegetation type prevailed in the area, the slope of the area, the intensity and pattern of rainfall (Oba *et al.*, 2001).

The mean values of soil erosion and compaction have shown significant difference between the three land use types (Table 1). Open grazing land had a high degree of erosion, due to reduction of vegetation cover by overgrazing and cutting of fuel wood. The rate of soil erosion can be accelerated when grazing intensively exceeds the threshold and plant cover is reduced below critical level in the open grazing land. Hence, the steepy slopes of mountain grazing land enhances fast runoff which together with overgrazing expose soil particles to easier detachment (Valckx *et al.,* 2002).

Differently, the ten years enclosure and the five years enclosure faced only slight erosion (Table 1). This might be due to the reduced animal and human interference in the enclosures, the re-vegetating plants reduced raindrop intensity and hindered detachment of soil particles that cause soil erosion. The ten years enclosure had very

Table 1 - LSM ± SE of soil erosion and compaction assessed on the sample sites.

Land use type	Site	Soil erosion	Soil compaction
Ten years enclosure	1	$4.67 \pm .33^{f}$	$4.00 \pm .58^{cd}$
	2	$4.00 \pm .58^{def}$	$3.67 \pm .33^{cd}$
	3	$4.33 \pm .33^{f}$	$4.00 \pm .58^{cd}$
	4	$1.33 \pm .33^{abc}$	$4.00 \pm .00^{cd}$
	5	$3.67 \pm .88^{def}$	$4.33 \pm .33$
Five years enclosure	6	$4.00 \pm .58^{ef}$	$4.00 \pm .58^{d}$
	7	$3.67 \pm .33^{def}$	$3.67 \pm .33^{cd}$
	8	$3.67 \pm .88^{def}$	$3.00 \pm .58^{cd}$
	9	$2.33 \pm .33^{bcd}$	$2.00 \pm .58^{ab}$
	10	$2.67 \pm .67^{cde}$	$3.00 \pm .00^{bc}$
Open grazing land	11	$1.67 \pm .33^{abc}$	$1.67 \pm .33^{ab}$
	12	$1.00 \pm .00^{ab}$	$1.00 \pm .00^{a}$
	13	$0.67 \pm .33^{a}$	$1.00 \pm .00^{a}$
	14	$0.67 \pm .33^{a}$	$2.00 \pm .00^{ab}$
	15	$1.67 \pm .33^{abc}$	$1.00 \pm .00^{a}$
	P in ANOVA	0.000	0.000

[abcd] Means within a row with different superscript are significantly different at P £ 0.05

slight erosion, this could be due to long year rest that increased plant cover and in turn decreased soil erosion. The erosion in the open grazing land could be also attributed to sloppy and stony nature of the mountain grazing land. As it was demonstrated by Valckx *et al.* (2002) slope and stones did worsen soil erosion in central Tigray and their data analysis revealed that slope and stony landscape was directly correlated with soil erosion.

The soil erosion and compaction result of the present study confirms previous findings of Emiru (2002), Dereje (2001) and Dereje *et al.* (2003), who conducted studies in enclosure areas of eastern Tigray. They reported that enclosures resulted in a reduction of soil erosion and biodiversity increasing in mountain areas. On the other hand, open grazing land had higher erosion as a consequence of livestock overgrazing, which also affected watershed properties by altering plant cover (Lang and McCaffrey, 1984; Bari *et al.* 1993) and by the physical action of animals hooves (Blackburn, 1983). Reductions in vegetation cover may increase the impact of rain drops (Busby and Gifford, 1981), decrease soil organic matter (Johnston, 1962) and soil aggregates (Warren *et al.*, 1986; Proffit *et al.*, 1995); increase surface crust and decrease water infiltration rates (Mwendra et *al.*, 1997). The effect might also increase runoff, reduce soil water content, and increase erosion (McIvor *et al.*, 1995). Moreover, soil compaction has been shown to reduce root growth of several plant species (Lull, 1954). This could lead to severe degradation of the open grazing land.

Herbaceous vegetation cover

Herbaceous species composition and diversity

A total of 23 grass species and 53 non-grass species from 32 families were recorded (Appendix Table 9). The graminoids identified and categorized into decreaser, and increaser accounted for 34.7 and 63.3 %, respectively (Table 2). There was significant difference ($P<0.05$) in grass species composition according to land use types (Appendix Table 4). The study revealed that very few grass species dominated the open grazing land whereas a relatively good proportion of important grass species were present in both enclosed areas (Table 3). The species were *Brachiaria sp., Bromus pectinatus, Chloris gayana, Cenchrus ciliaris, Chloris radiata, Cynodon dactylon, Dactyloctenium aegyptium, Digitaria velutina, Eragrostis tenuifolia, Lintonia nutans, Setaria pumila, Setaria verticillata* and *Tragus racemosus,* all occurred frequently in the herbaceous layer in the enclosed sites than the sampled sites from the open grazing land (Appendix Table 10, 11).

The species composition of grasses was significantly ($P<0.05$) lower than the mean in the open grazing land, followed by five year enclosure (Table 3). The present result suggests that the main reason for low number of grass species in open grazing land is the high grazing intensity throughout the year. Hence, heavy grazing tends to reduce the presence of palatable species and consequently become dominated by other herbaceous plant or bush (De Haan *et al.,* 1997). The same result was reported in eastern Tigray in an open grazing land and enclosure by Emiru (2002). He reported that there was an increment of herbaceous species in the enclosure due to absence of grazing animals. Ayana (1999) reported that species composition, age distribution, and basal cover could depend on grazing management, rainfall and livestock population

Similarly, Barrs, *et al. (*1997) and Amsalu (2000) suggested that heavy grazing might cause reduction of plant species composition and diversity over time. Moreover,

Table 2 - Classes of indicator species according to the succession theory of grasses documented from the sample sites.

Site	Species name	Life form	Decreasers	Increasers
1	*Avena sterilis*	*A*		x
2	*Brachiaria sp.*	*P*	x	
3	*Bromus pectinatus*	*P*		x
4	*Cenchrus ciliaris*	*P*	x	
5	*Chloris gayana*	*P*	x	
6	*Chloris radiata*	*P*	x	
7	*Cynodon dactylon*	*P*	x	
8	*Dactyloctenium aegyptium*	*A*	x	
9	*Digitaria abyssinica*	*A*		x
10	*Digitaria velutina*	*A*		x
11	*Digitaria sp.*	*A*		x
12	*Eleusine jaegeri*	*P*		x
13	*Eragrostis brownei*	*A*		x
14	*Eragrostis schweinfurthii*	*A*		x
15	*Eragrostis tenuifolia*	*A*		x
16	*Hyparrhenia hirta*	*P*		x
17	*Hyparrhenia rufa*	*P*		x
18	*Lintonia nutans*	*P*	x	
19	*Pennisetum petiolar*	*A*		x
20	*Sporobolus discosporus*	*A*		x
21	*Setaria pumila*	*A*		x
22	*Setaria verticillata.*	*A*	X	
23	*Tragus racemosus*	*A*		x

A = annuals P = perennials

Ahmed (2003) and Admasu (2006) have confirmed that species compositions could be negatively correlated with increased rangeland deterioration. At the end, wherever grazing is followed by drought there is further reduction of herbaceous species diversity and worsened mountain land degradation particularly in the open rangeland.

The five years enclosed land had significant ($P<0.05$) lower mean of grass species composition compared to the ten years enclosed land and pointed out that the age had a significant effect on the increment of grass species composition and diversity. However, it was reported that after long year protection herbaceous species composition enclosures might decline as was seen in eastern Tigray (Dereje, 2003).

Herbaceous species diversity, which was calculated based on Magurran's, (1996) method, showed that there was a significant difference ($P<0.05$) between land use types (Appendix Table 5). The highest mean value of species diversity was recorded in the ten years enclosed land; five years enclosure scored intermediate value, whereas the least diversity average was recorded in the open grazing land. This result is in agreement with Mulbrhan *et al.* (2005). It was also suggested by Oba *et al.* (2001) that species richness declines in heavy grazing grassland, hence species diversity is positively correlated with biomass. Besides, decline in species diversity in the grazing land could be a result of the loss of seedling of some species unable to establish at early stage of development, and selective defoliation and trampling by grazing herbivores (Belaynesh, 2006). Contrary to the present findings, Green and Boone (1995) reported 8 years enclosure had significantly lower (P<0.01) species diversity compared to grazed parts. They suggested that this can be due to the reduced disturbances caused by livestock that would otherwise favor the establishment of pioneer species.

Table 3 - LSM ± SE of herbaceous (grass) species composition, species diversity, basal cover, age distribution, and seedling number.

Land use type	Site	Species composition	Basal cover M^2	Age distribution M^2	Species diversity	Seedling number/ A4
Ten years enclosure	1	$8.33\pm.33^{d}$	$7.67\pm.88^{f}$	$4.67\pm.33^{d}$	$6.50\pm.46^{g}$	$5.00\pm.00^{a}$
	2	$8.00\pm.58^{d}$	$7.33\pm.33^{df}$	$4.00\pm.58^{cd}$	$5.58\pm.73^{gh}$	$5.00\pm.00^{a}$
	3	$6.00\pm.58^{bcd}$	$6.33\pm.67^{df}$	$4.67\pm.33^{d}$	$4.63\pm.55^{fg}$	$4.67\pm.33^{a}$
	4	7.00 ± 1.5^{cd}	$7.00\pm.57^{df}$	$1.33\pm.33^{ab}$	$4.52\pm.50^{def}$	$4.33\pm.33^{a}$
	5	$6.67\pm.88^{bcd}$	$7.00\pm.00^{df}$	$3.33\pm.67^{cd}$	$4.46\pm.14^{cdef}$	$4.67\pm.33^{a}$
Five years enclosure	6	$5.67\pm.88^{bcd}$	$5.67\pm.88^{def}$	$4.67\pm.33^{d}$	$4.11\pm.45^{bcdef}$	$5.00\pm.00^{a}$
	7	$4.67\pm.88^{abc}$	$3.33\pm.67^{abc}$	$4.00\pm.57^{d}$	$3.68\pm.08^{bcd}$	$5.00\pm.00^{a}$
	8	6.00 ± 1.5^{bcd}	$5.33\pm.88^{cde}$	$1.67\pm.33^{ab}$	$3.75\pm.34^{bcdef}$	$5.00\pm.00^{a}$
	9	$4.00\pm.58^{abc}$	$3.67\pm.88^{bcd}$	$2.00\pm.58^{abc}$	$3.30\pm.27^{bcd}$	$5.00\pm.00^{a}$
	10	$4.67\pm.67^{abc}$	$3.67\pm.88^{bcd}$	$2.33\pm.33^{bc}$	$2.82\pm.24^{bc}$	$4.67\pm.33^{a}$
Open grazing land	11	$4.00\pm.58^{abc}$	$2.33\pm.88^{ab}$	1.00±.00ab	$2.45\pm.52^{ab}$	$4.67\pm.33^{a}$
	12	$2.67\pm.89^{a}$	$1.33\pm.33^{a}$	$.67\pm.33^{a}$	$2.86\pm.31^{bc}$	$5.00\pm.00^{a}$
	13	$2.33\pm.88^{a}$	$1.33\pm.33^{a}$	$1.33\pm.33^{ab}$	$2.90\pm.26^{ba}$	$4.67\pm.33^{a}$
	14	2.00±.58	$1.67\pm.33^{ab}$	$1.00\pm.58^{ab}$	$3.20\pm.35^{bc}$	$4.33\pm.33^{a}$
	15	$2.33\pm.33^{a}$	$1.67\pm.33^{ab}$	$2.00\pm.58^{abc}$	$1.5833.29^{a}$	$4.67\pm.33^{a}$
	P in ANOVA	0.000	0.000	0.000	0.000	NS

[abcd] Means within a row with different superscript are significantly different at P ≤ 0.05 NS= none significant

Basal cover, age distribution, and seedling number

The basal cover data demonstrated that there was significant variation ($P < 0.05$) between the land use types (Appendix Table 6). The result showed that the basal cover difference was in relation to variation in species composition between the land use types (Table 3). The mean score exposed that the open grazing land use type scored least mean basal cover and five years enclosure land use type scored intermediate value, while the ten years enclosure land use type attained the highest mean basal cover. Therefore, the present study confirmed that longer enclosure periods would promote re-vegetation of various herbaceous species that might lead to higher soil cover. However, Dereje, et al. (2003) has reported that herbaceous species presence decreased after three years enclosure in eastern Tigray. The result of basal cover in the present study reflected a good score for soil condition (Table 1).

One-way ANOVA evidenced that there was no significant difference in grass seedling number ($P > 0.05$) between three land use types (Appendix Table 7). The mean scores were slightly lower in the open grazing land compared to the enclosed areas. This might indicate that there was heavy grazing during the data collection on the open grazing land. The present result is in agreement with Ahmed (2003) and Belaynesh (2006). The age distribution of grass species demonstrated that there was significant variation ($P<0.05$) between land use types (Appendix Table 8). The overall mean score of age distribution of grass species showed that sites sampled from the ten years and five years enclosures included species of the 2 and 3 age groups. Instead the sites from open rangeland have most species in the 1 age group. This variation might be attributed to land use factor, due to the occurrence of heavy grazing in the open grazing land and restoration of some grasses in the enclosure sites.

Conclusions and recommendations

The present study revealed that the enclosed mountain grazing land had better conditions than open grazing sites. The enclosure sites had significantly higher grass species composition and living plant basal cover. As a result, soil erosion and compaction has been reduced in the enclosure sites. Besides, the regeneration of herbaceous plants was increasing in the enclosures. Though the information given in this research is useful to understanding botanical composition and diversity, more data is still required to ensure that conclusions have sure environmental validity. Therefore, based on the present results, the author recommends the following points: Area enclosure is an advisable and cheap strategy of natural rehabilitation, and it should be widely practiced with full involvements of local community. Therefore consideration should be given for the expansion of enclosures as a land rehabilitation practice.

Dedication

I dedicated this work to my father who passed while I am developing this manuscript for publication.

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Appendices

Appendix Table 1 - Criteria for the scoring of the different factors determining the grazing lands condition.

Score	Grass Composition (%)	Basal cover (%)	No. of seedlings	Age distribution	Soil erosion	Soil compacting
10	91-100 decreasers	>12 no bare areas				
9	81-90 decreasers	-				
8	71-80 decreasers	>9 evenly distributed				
7	61-70 decreasers	>9 occasional bare spots				
6	51-60 decreasers	>6 evenly distributed				
5	41-50 decreasers	>6 bare spots	>4 seedling on A4 paper	Young, medium and old	No soil movement	No compaction
4	10-40 decreasers >30 increasers	>3 mainly perennials	4 seedling on A4 paper	Two size categories present	Slight sand mulch	Isolated capping
3	10-40 decreasers <30 increasers	>3 mainly annuals	3 Seedling on A4 paper	Only old	Slope sided pedestals	>50% capping
2	<10 decreasers >50 increasers	1-3	2 seedling on A4 paper	Only medium	Steep sided pedestals	>75% capping
1	<10 decreasers <50 increasers	<1	1 seedling on A4 paper	Only young	Pavements	Almost 100% Capping
0		0	No seedling		Gullies	

Adopted from: Barrs *et al.* (1997)

Appendix Table 2 - ANOVA for soil erosion of the sample sites

Source of variation	Sum of Squares	Degree of freedom	Mean Square	F	Sig.
Sites	84.00	14	6	8.182	0.000
Error	22.00	30	0.733		
Total	106.00	44			

Appendix Table 3 - ANOVA for soil compaction of the sample sites

Source of variation	Sum of Squares	Degree of freedom	Mean Square	F	Sig.
Sites	65.911	14	4.708	11.15	0.000
Error	12.67	30	0422		
Total	78.58	44			

Appendix Table 4 - ANOVA for grass species composition of the sample sites

Source of variation	Sum of Squares	Degree of freedom	Mean Square	F	Sig.
Sites	180.58	14	12.89	5.92	0.00
Error	65.33	30	2.18		
Total	245.91	44			

Appendix Table 5 - ANOVA for species richness of grasses of the sample sites

Source of variation	Sum of Squares	Degree of freedom	Mean Square	F	Sig.
Sites	66.68	14	4.76	9.884	0.00
Error	14.45	30	0.482		
Total	81.13	44			

Appendix Table 6 - ANOVA for basal cover of the sample sites

Source of variation	Sum of Squares	Degree of freedom	Mean Square	F	Sig.
Sites	237.64	14	16.98	13.17	0.000
Error	38.67	30	1.29		
Total	276.31	44			

Appendix Table 7 - ANOVA for grass seedling number of the sample sites

Source of variation	Sum of Squares	Degree of freedom	Mean Square	F	Sig.
Sites	2.44	14	0.18	0.982	0.493
Error	5.33	30	0.78		
Total	7.77	44			

Appendix Table 8 - ANOVA for age condition of the sample sites

Source of variation	Sum of Squares	Degree of freedom	Mean Square	F	Sig.
Sites	92.78	14	6.64	11.069	0.00
Error	18.00	30	0.60		
Total	110.978	44			

Appendix Table 9 - List of herbaceous species collected in field sample sites.

No.	Botanical Name	Family	Life form
1	*Abutilon sp.*	*Malvaceae*	*F*
2	*Achyranthes aspera*	*Amaranthaceae*	*F*
3	*Ajuga integrifolia*	*Lamiaceae*	*F*
4	*Alium cepa*	*Amryllidaceae*	*F*
5.	*Amaranthus dubius*	*Amaranthaceae*	*F*
6	*Anagallis arvensis*	*Primulaceae*	*F*
7	*Andrachne sp.*	*Euphorbiaceae*	*F*
8	*Anthriscus sylvestris*	*Umbelliferrae*	*F*
9	*Asystasia mysorensis*	*Acanthaceae*	*F*
10	*Asystasia schimperi*	*Asteraceae*	*F*
11	*Avena sterillis*	*Poaceae*	*G*
12	*Bidens pilosa*	*Asteraceae*	F
13	*Brachiaria sp.*	*Poaceae*	*G*
14	*Bromus pectinatus*	*Poaceae*	*G*
15	*Cenchrus ciliaris*	*Poaceae*	*G*
16	*Centella asiatica*	*Umbelliferae*	*F*
17	*Celtis sp.*	*Ulmaceae*	F
18	*Chloris gayana*	*Poaceae*	*G*
19	*Chloris radiata*	*Poaceae*	*G*
20	*Cissus petiolata*	*Vitaceae*	*F*
21	*Commelina africana*	*Commelinaceae*	F
22	*Commicarpus africanus*	*Nyctaginaceae*	*C*
23	*Crepis capillaris*	*Asteraceae*	*F*
24	*Cynodon dactylon*	*Poaceae*	*G*
25	*Cyphostemma adenocaula*	*Vitaceae*	*F*
26	*Dactyloctenium aegyptium*	*Poaceae*	*G*
27	*Digitaria abyssinica*	*Poaceae*	*G*
28	*Digitaria velutina*	*Poaceae*	*G*
29	*Digitaria sp.*	*Poaceae*	*G*
30	*Echinops pappi*	*Papindaceae*	F
31	*Eleusine jaegeri*	*Poaceae*	*G*
32	*Eragrostis brownei*	*Poaceae*	*G*
33	*Eragrostis schweinfurthii*	*Poaceae*	*G*
34	*Eragrostis tenuifolia*	*Poaceae*	*G*
35	*Erucastrum arabicum*	*Crucifereae*	*F*
36	*Euphorbia hirta*	*Euphorbiaceae*	F
37	*Euphorbia schimperiana*	*Euphorbiaceae*	F
38	*Fimbristylis dichotoma*	*Cyperaceae*	*S*
39	*Galinsoga parviflora*	*Asteraceae*	*F*
40	*Galium spurium*	*Rubiaceae*	*F*
41	*Geranium sinense*	*Geraniaceae*	F
42	*Gloriosa superba*	*Liliaceae*	*F*
43	*Guizotia scabra*	*Asteraceae*	*F*
44	*Heliotropium cineraceus*	*Boracinaceae*	*F*
45	*Hyparrhenia hirta*	*Poaceae*	*G*
46	*Hyparrhenia rufa*	*Poaceae*	G
47	*Indigofera articulata*	*Papilionoideae*	*L*
48	*Indigofera hochstetteri*	*Papilionoideae*	*L*
49	*Ipomoea sp.*	*Canvolvulaceae*	*C*
50	*Kalanchoe petitiana*	*Crassulaceae*	*F*
51	*Kohautia aspera*	*Rubiaceae*	*F*

Appendix Table 9 - continued

NO.	BOTANICAL NAME	FAMILY	LIFE FORM
52	*Leucas martinicensis*	*Lamiaceae*	*F*
53	*Lindenbergia sp.* .	*Scrophulariaceae*	*F*
54	*Lintonia nutans*	*Poaceae*	*G*
55	*Medicago polymorpha*	*Papilionoideae*	L
56	*Mollugo nudicaulis*	*Aizoaceae*	*F*
57	*Monothecium glandulosum*	*Acanthaceae*	*F*
58	*Ocimum basilicum*	*Lamiaceae*	F
59	*Ocimum lamiifolium*	*Lamiaceae*	*F*
60	*Oxalis corniculata*	*Oxalidaceae*	*F*
61	*Oxygonum sinuatum*	*Polygonaceae*	*F*
62	*Oxygonum sp.*	*Polygonaceae*	*F*
63	*Pennisetum petiolar*	*Poaceae*	*G*
64	*Plantago lanceolata*	*Plantaginaceae*	*F*
65	*Scorpiurus subvillosus*	*Papilionoideae*	*F*
66	*Senecio vulgaris*	*Asteraceae*	*F*
67	*Setaria pumila*	*Poaceae*	*G*
68	*Sonchus oleraceus*	*Asteraceae*	*F*
69	*Solanum nigrum*	*Solanaceae*	*F*
70	*Sporobolus discosporus*	*Poaceae*	*G*
71	*Setaria verticillata*	*Poaceae*	*G*
72	*Tagetes minuta*	*Asteraceae*	F
73	*Tragus racemosus*	*Poaceae*	G
74	*Tribulus terrestris*	*Zygophyllaceae*	F
75	*Urtica sinensis*	*Urticaceae*	F
76	*Vicia sativa*	*Papilionoideae*	*L*

Where : F=forb G=grass S=sedge C= climbers and L= legume

Appendix Table 10 - Herbaceous species count in each quadrat of the sampled site 1-8.

		site																							
		1			2			3			4			5			6			7			8		
		Quadrat																							
No.	Scientific name	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1	*Abutilon sp.*	0											5					1		8		3		3	
2	*Achyranthes aspera*	0						4					4												
3	*Ajuga integrifolia*	6					1	5			2											1	1		
4	*Alium cepa*										4	4								4					1
5	*Amaranthus dubius*	6			7			2	4	6	4	3			7	6			6		4				5
6	*Anagallis arvensis*			3			4																		
7	*Anderachne sp.*																								
8	*Anthriscus sylvestris*																								
9	*Asystasia mysorensis*																								
10	*Asystasia schimperi*	1						2		2													1		
11	*Avena sterilis*		8	5	5	5	6	5		6	7			8	5		4	4	4				7		
12	*Bidens pilosa*																								
13	*Brachiaria sp.*																								
14	*Bromus pectinatus*																								
15	*Cenchrus ciliaris*	7	4	3	7	8	2	7	8	4				4	7			3			4		4	9	
16	*Centella asiatica*	5			6	4						3	2												
17	*Celtis sp.*																								
18	*Chloris gayana*	4	7	8	9	9	9	7		7			8	7	9	4	6		4	9		4	6	7	
19	*Chloris radiata*																								
20	*Cissus petiolota*	6	6	4	6	4	3		7	9	5	2	9	6	6	8	10	5	5	6	6		5		
21	*Commelina africana*	3				2			4		3			5					3	4	4		4	1	1
22	*Commicarpus africanus*		5	3					3		2														
23	*Crepis capillaris*											2						1					2		3
24	*Cynodon dactylon*																								
25	*Cyphostemma adenocaula*							8				5	5							9				4	
26	*Dactyloctenium aegyptium*							3			8														
27	*Digitaria abyssinica*							10																2	

Appendix Table 10 - continued

28	*Digitaria velutina*																								
29	*Digitaria sp.*																								
30	*Echinops pappi*																								
31	*Eleusine jaegeri*					8				2		2								5					
32	*Eragrostis brownei*																								
33	*Eragrostis schweinfurthii*																								
34	*Eragrostis tenuifolia*							5			3	8					3				3	9	4		
35	*Erucastrum arabicum*	9		4							7									7					
36	*Euphorbia hirta*																								
37	*Euphorbia schimperiana*							4																	
38	*Fimbristylis dichotoma*								3							5				3					
39	*Galinsoga parviflora*																								
40	*Galium spurium*																								
41	*Geranium sinense*			2	2	2	3		1	2		2	4		2		8	4	3		5	4	2	2	3
42	*Gloriosa superba*							6																	
43	*Guizotia scabra*		5				6				9	9		5					7		8			4	4
44	*Heliotropium cineraceus*																								
45	*Hyparrhenia hirta*	2		2					6												3				2
46	*Hyparrhenia rufa*								5		10	8					7	9			7	7			
47	*Indigofera articulata*	4		9		6	7		3								9	3	9	5	10		10	8	8
48	*Indigofera hochstetteri*								4																
49	*Ipomoea sp.*																								
50	*Kalanchoe petitiana*																								
51	*Kohautia aspera*												6				3					1			
52	*Leucas martinicensis*																								
53	*Lindenbergia sp.*										1	2													
54	*Lintonia nutans*																								
55	*Medicago polymorpha*																								
56	*Mollugo nudicaulis*																								
57	*Monothecium glandulosum*																								

Appendix Table 10 - continued

58	*Ocimum basilicum*			2																					
59	*Ocimum lamiifolium*	3					2		2		5						3	2	2			3		3	2
60	*Oxalis corniculata*																								
61	*Oxygonum sinuatum*																								
62	*Oxygonum sp.*								3																2
63	*Pennisetum petiolar*	2			5						3	3			3									2	
64	*Plantago lanceolata*																								
65	*Scorpiurus subvillosus*																								
66	*Senecio vulgaris*																								
67	*Setaria pumila*																								
68	*Sonchus oleraceus*				6	5	3								1			3	5			8		2	
69	*Solanum nigrum*			10	4	7	6		5	5		6			2		5	6	8		5	2	4		7
70	*Sporobolus discosporus*						2						3			5								2	
71	*Setaria verticillata*				1	3		2																	
72	*Tagetes minuta*							2																	
73	*Tragus racemosus*			2														2		2					
74	*Tribulus terrestris*																								
75	*Urtica sinensis*			2																					
76	*Vicia sativa*							2			3		2	3											
	Total	58	35	59	58	63	54	74	58	43	76	59	48	38	42	28	58	43	56	62	59	42	50	49	38

Appendix Table 11 - Herbaceous species count in each quadrat of the sampled site 9-15 and frequency per quadrat.

		site																					Total	
		9			10			11			12			13			14			15				
		Quadrat																						
No.	*Scientfic name*	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	count	%
1	*Abutilon sp.*	1	2	3																			5	1
2	*Achyranthes aspera*									2			3						3				6	1.2
3	*Ajuga integrifolia*			2																		2	7	1.4
4	*Allium cepa*																						5	1
5	*Amaranthus dubius*							2	4				4	6	3	5		8	2	6	2	7	25	5
6	*Anagallis arvensis*			2																			2	0.4
7	*Andrachne sp.*																		5		4		2	0.4
8	*Anthriscus sylvestris*								5			7			8								3	0.6
9	*Asystasia mysorensis*																						0	0
10	*Asystasia schimperi*					2	5																7	1.4
11	*Avena sterilis*		4				8	6	4	5	2				4			6	3		6		25	5
12	*Bidens pilosa*	2		4																			0	0
13	*Brachiaria sp.*																						0	0
14	*Bromus pectinatus*																						0	0
15	*Cenchrus ciliaris*					3	2	4	4		3	6	4	4	8		5		4	4	4	3	31	6.2
16	*Centella asiatica*	6	7		3														2				7	1.4
17	*Celtis sp.*																						0	0
18	*Chloris gayana*				9	8	9	5	6	3	7		3	4	6	10	7	6	8	4	5		36	7.1
19	*Chloris radiata*		7	9																			1	0.2
20	*Cissus petiolota*			3		9		4		4	4	7	4	5	5	5	5	5	2	5	4	5	37	7.3
21	*Commelina africana.*	2	4																				12	2.4
22	*Commicarpus africanus*	1			5				3	3	2		2			5			2				11	2.2
23	*Crepis capillaris*										2			7		6	2	3		7			11	2.2
24	*Cynodon dactylon*			1																			0	0
25	*Cyphostemma adenocaula*					4	7	5		9	4			7		7	4			7	5		17	3.4
26	*Dactyloctenium aegyptium*	6	6			1	3			2													5	1
27	*Digitaria abyssinica*				5																		3	0.6

Appendix Table 11 - continued

28	*Digitaria velutina*						4																1	0.2
29	*Digtaria sp.*					7																	1	0.2
30	*Echinops pappi*	8	5																				0	0
31	*Eleusine jaegeri*							1	2		2										1		8	1.6
32	*Eragrostis brownei*																						0	0
33	*Eragrostis schweinfurthii*																						0	0
34	*Eragrostis tenuifolia*							4								5			3		4		12	2.4
35	*Erucastrum arabicum*			4	4																		5	1
36	*Euphorbia hirta*																						0	0
37	*Euphorbia schimperiana*																						1	0.2
38	*Fimbristylis dichotoma*																2						6	1.2
39	*Galinsoga parviflora*	2	2		4	4					1											4	4	0.8
40	*Galium spurium*																						0	0
41	*Geranium sinense*						1	2	3	1	1	2	2	3			3		2	3	2		30	6
42	*Gloriosa superba*			2																			1	0.2
43	*Guizotia scabra*					3		5	5	4	8	10	4	4	4		4		7	4	5		24	4.8
44	*Heliotropium cineraceus*	5		4		2																	1	0.2
45	*Hyparrhenia hirta*				4		3																7	1.4
46	*Hyparrhenia rufa*							8	8			9	9	8				9	10	8	8		16	3.2
47	*Indigofera articulata*							9	2									5			9		18	3.6
48	*Indigofera hochstetteri*	4																					1	0.2
49	*Ipomoea Sp.*																						0	0
50	*Kalanchoe petitiana*																						0	0
51	*Kohautia aspera*																						4	0.8
52	*Leucas martinicensis*			1																			0	0
53	*Lindenbergia sp.* .																						2	0.4
54	*Lintonia nutans*																						0	0
55	*Medicago polymorpha*																						0	0
56	*Mollugo nudicaulis*																						0	0
57	*Monothecium glandulosum*																						0	0
58	*Ocimum basilicum*												4										2	0.4
59	*Ocimum lamiifolium*						4	3	1	1	1		5	4	3	4	3		3	4	3		26	5.2
60	*Oxalis corniculata*	1	1	3																			0	0
61	*Oxygonum sinuatum*																						0	0
62	*Oxygonum sp.*				6	3										5							5	1

Appendix Table 11 - continued

63	*Pennisetum petiolar*																					4	8	1.6
64	*Plantago lanceolata*			3																			0	0
65	*Scorpiurus subvillosus*																						0	0
66	*Senecio vulgaris*																						0	0
67	*Setaria pumila*																						0	0
68	*Sonchus oleraceus*							1		3									3		1	2	13	2.6
69	*Solanum nigrum*								3	3	2				5			4					22	4.4
70	*Sporobolus discosporus*	5	6			2																	5	1
71	*Setaria verticillata*																						3	0.6
72	*Tagetes minuta*				3																		2	0.4
73	*Tragus racemosus*									2	2		2	2					1	2			10	2
74	*Tribulus terrestris*		3																				0	0
75	*Urtica sinensis*																						1	0.2
76	*Vicia sativa*							2											3		2		7	1.4
	Total	42	45	38	43	48	46	61	50	42	41	41	46	54	46	52	35	46	63	54	65	27	504	100