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RESEARCH ARTICLE

IMPACT OF AREA CLOSURE ON VEGETATION COVER, WOODY SPECIES STRUCTURE AND SOIL CHEMICAL PROPERTIES IN KELALA DALACHA MOUNTAIN, OROMIA, ETHIOPIA

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ABSTRACT: This study was undertaken in Kelala Dalacha Mountain in Oromia, Ethiopia to determine the impacts of ecosystem rehabilitation on vegetation cover, woody species structure and soil chemical properties. A random sampling method was used to collect vegetation data from a total of 31 quadrats of 400 m^2 each. Four satellite images of the study area, distributed between 1988 and 2018 were analyzed using Arc GIS software to assess the Land Use Land Cover (LULC) changes of the area. Composite sampling was used for soil sample collection and soil was analyzed for selected chemical properties. Data were analyzed using both descriptive and inferential statistics. Result indicated that the vegetation cover was 58.1% in 1988, 64.47% in 1998, 80.32% in 2008 and 88.43% in 2018, showing the positive contribution of area closure in ecosystem rehabilitation. The bare land in 1988 was changed to either woody species or grasses nowadays. Similarly, area closure had a positive impact on vegetation structure. Woody species in the study area displayed an inverted J-shaped pattern of distribution. The lower DBH classes were found to have relatively higher number of individuals than that of the middle and the top classes indicating the importance of area closure. Mean values of soil pH, EC, CEC, OC, TN, P and K were 6.64, 0.082, 30.92, 2.44, 0.213, 3.91 and 219.38, respectively. Area closure is a viable strategy for restoring degraded ecosystems as it had positive impact on vegetation cover, woody species structure and soil chemical properties. Therefore, it was recommended to ensure wide scale applications of area closure on all mountains for restoration of ecosystem function and biodiversity conservation.

Key words/phrases: Area closure, Land cover, Land use, Soil, Vegetation structure.

INTRODUCTION

Ethiopia is one of the top twenty-five richest countries in the world in terms of biodiversity (WCMC, 1994). It is estimated to have around 6,000 species

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of higher plants, of which about 10% are endemic (Ensermu Kelbessa and Sebsebe Demissew, 2014). The flora is very heterogeneous and has a rich endemic species owing to the diversity in climate, vegetation and terrain. Based on studies such as Friis and Sebsebe Demissew (2001), the vegetation types in Ethiopia are highly diverse, varying from Afroalpine and sub-Afroalpine to riparian and swamp vegetation. Although Ethiopia is rich in biodiversity, land degradation and unsustainable utilization of natural resources in mountain ecosystems such as in Kelala Dalacha Mountain have been among the major factors contributing to loss of biodiversity in the country.

Land degradation can be defined as a decline in land quality or reduction in its productivity (FAO, 1995; Hurni *et al*., 2010). It is a loss of actual or potential productivity or utility of land. Reduction in the vegetation cover negatively affects plants, animal production and productivity resulting in loss of biodiversity, increases soil erosion, reduces the amount of soil organic carbon and finally has clear negative impact on food security and quality of the environment. Humans have disturbed, preempted, or damaged much of the earth`s terrestrial ecosystems. Some of this damage is permanent and degradation thresholds have been crossed in many habitats that natural succession alone cannot restore viable and desirable ecosystems without intervention.

Furthermore, dispute of reversing the degradation of natural environments while meeting increasing demand for the natural resources has been dominating the development agenda of most developing nations, and necessitate significant changes in policies, institutions and practices (UNEP, 1992). The problem of land degradation has become even more severe and interlinked in sub-Saharan Africa (SSA), where the prevailing climate change accelerates the expansion of desertification, exacerbates land degradation which will consequently lead to lose of biodiversity (Uitto and Manshard, 1993).

Deforestation and forest degradation include not only conversion to non-forest land but also degradation that reduces forest quality, density and structure of the trees, the ecological services supplied, the biomass of plants and animals, the species diversity and the genetic diversity (FAO, 2005). It is also used to describe forest clearing for annual crops and forest loss from overgrazing. Unregulated agricultural expansions, urban sprawl, unsustainable forestry practices and mining all contribute to human caused deforestation. According to Williams (2002), the causes of deforestation are complex and often differ in each forest and country. The main causes of deforestation in Ethiopia include shifting cultivation, agricultural land expansion into forest ecosystems, logging, overgrazing and fuel wood extraction (EBI, 2015; FAO, 2010). Animal grazing changes the land cover by decreasing soil organic matter and soil aggregate, promoting surface crusting and inhibiting water infiltration (Mwendera *et al*., 1997).

Kelala Dalacha mountainous area was among the most degraded places as a result of high population pressure for agricultural activities, grazing land and demand for wood. Deforestation of the mountain, overgrazing and agricultural expansion were among the major factors that contributed to land degradation in the study area.

To combat this deteriorating situation, the then Institute of Biodiversity Conservation (Now Ethiopian Biodiversity Institute) in collaboration with Regional Program for Sustainable Use of Dryland Biodiversity in East Africa (RPSUD) started conservation activities in 2002 using the area closure approach. The soil seed flora/Regional Program for Sustainable Use of Dryland Biodiversity in East Africa (RPSUD) project was implemented from 2002 to 2005 and then the Ethiopian Biodiversity Institute continued managing the conservation site in collaboration with local authorities and communities. Following the area closure over years, data on vegetation structure, land use/land cover change and changes in soil chemical properties were not documented from this conservation and research site and therefore, this study aimed at filling these data gaps. There were limited data on land use/land cover changes for this study area. Therefore, this study aimed at filling the existing gap in land use land cover change data from 1988 to 2018. As a result, the objectives of this study were to determine impacts of ecosystem rehabilitation on vegetation cover, woody species structure and soil chemical properties in Kelala Dalacha.

MATERIALS AND METHODS

Description of study area

Geographical location of the study area

The study area is located at 62 km South of Addis Ababa and 15 km far from Bishoftu along the old road to Modjo town in Gubasayi “kebele”, the first local administrative unit in Ada’a district, East Shoa Zone, Oromia Regional National State, Ethiopia (Fig. 1). The geo-referenced location is between 08° 38′ 06.3″ up to 08° 38′ 50.0N and 039° 0.2′ 45.8″ up to 039° 03′ 28.2″ E, the altitude ranges between 1,870 and 1,993 m a.s.l.

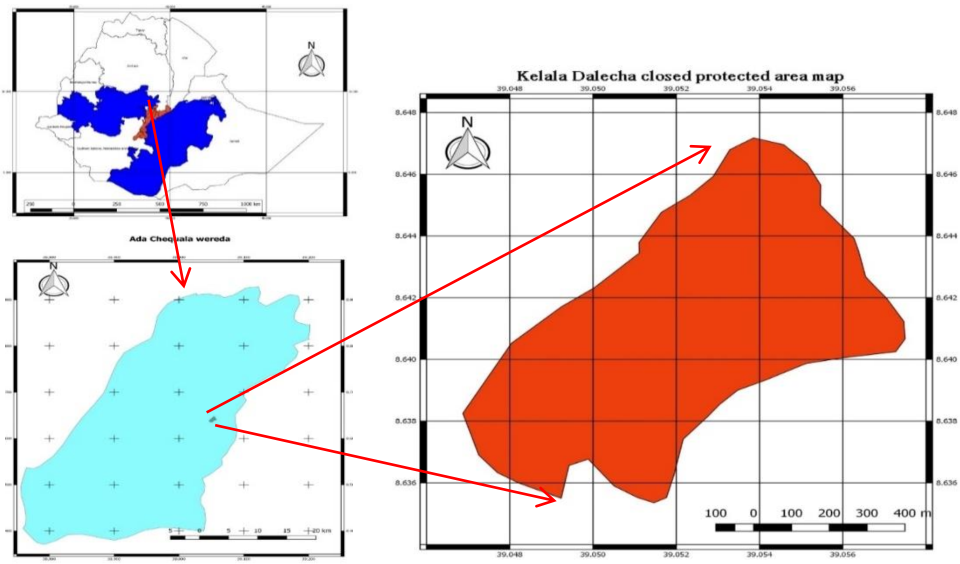

Fig. 1. Map of the study area in eastern Shoa Zone, Oromia, Ethiopia.

Gubasayi kebele surrounding Kelala Dalacha Mountain had 800 household members in scattered villages and also had 540 hectares of agricultural land. Farmers living in the surrounding area of the Kelala Dalacha site were all engaged in agriculture. The agroecology was *woinadega* (mid-altitudinal range) suitable for cereal farming including teff and wheat cultivation. The kebele had a population of around 3,000 cattle and 2,500 goat (ADAO, 2015).

Climate

Based on the data gathered from National Meteorology Service Agency, long term rainfall records showed a bimodal pattern with the annual average rainfall of 862 mm occurred near Debrezeit Air Force Meteorology Station. The main rainy season starts in early June and lasts in September with maximum rainfall in July. The mean annual maximum and minimum temperatures are 28.9 and 6.9°C, respectively. The short rainy season was from March to April with annual average rainfall of 862 mm (Fig. 2).

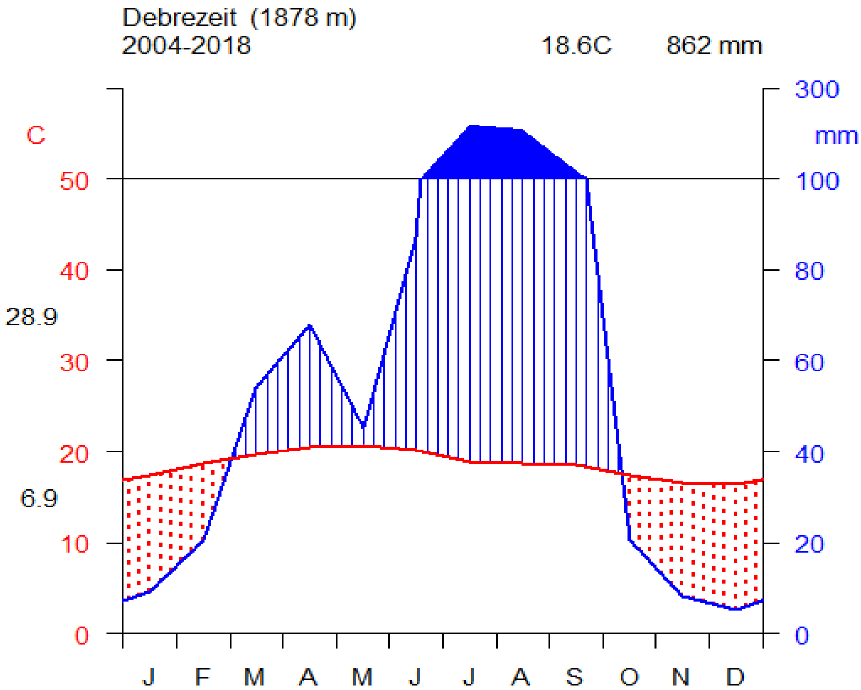

Fig. 2. Climate diagram of Ada'a district, Oromia, Ethiopia.

Land use/land cover

The cultivated land and its surrounding were mainly dominated by agroforestry tree species such as *Fhaiderbia albida* and *Vachellia tortilis*. The major crops grown in Bishoftu (Debrezeit) area included teff (*Eragrotis teff*), maize (*Zea mays*), wheat (*Triticum durum*), chickpea (*Cicer aritinium*.), and grasses such as *Digitaria diagonalis*.

Soil characteristics of the study area

The study sites categorized under three types of parent rock such as: (a) the granites of the crystalline basement which tend to form shallow, sandy soils; (b) the volcanic rocks, such as basalts, which tend to produce fertile loams, generally red in colour, but sometimes black; and (c) the limestone and sandstones which form shallow, poor, sandy soils (Last, 1962). Review of studies showed that the study area falls in the Rift Valley physiographic region, formed by quaternary of the rift floor and recasting deposits and soil type is vertisol (Abiy Tsetargachew, 2008).

Data collection

Land use/land cover change data collection

The land use/land cover change classes were mapped for each year by using ArcGIS. Arc GIS software was used to map and determine the coordinates and geographical location of the study area. It also helped in identifying the different types of vegetation present and determined the land use and land cover change (LULCC) from 1988 to 2018.

Vegetation data collection

A random sampling design was employed for vegetation data collection (Fig. 3). With the help of a Global Positioning System (GPS), each sample plot was located at the exact location given on the device. Vegetation data were collected from a total of 31 plots of 20 m x 20 m (400 m^2). In each plot, all woody species encountered were recorded. Diameter at breast height (DBH) was measured using steel metal graduated caliper and height of the trees/shrubs were measured by Hypsometer.

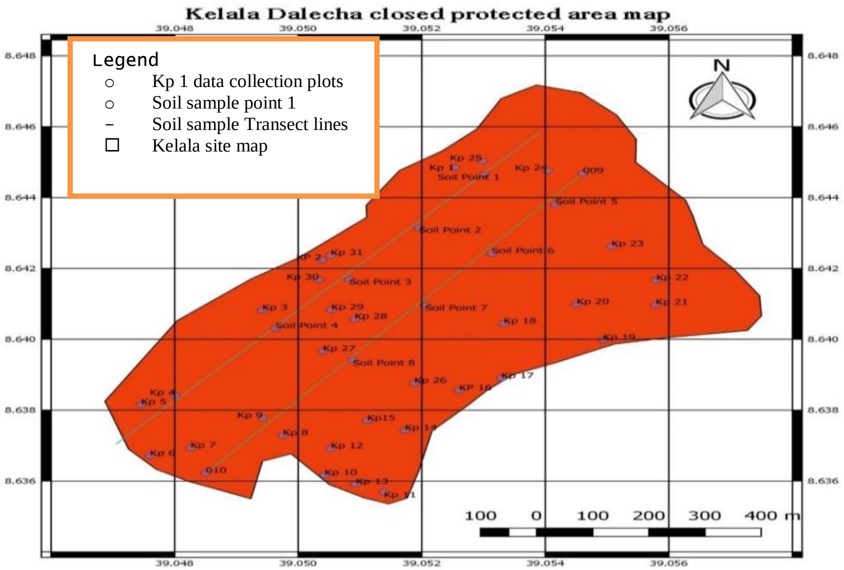

Fig. 1. Sample plot distribution in the Kelala Dalacha study area, Ada’a district, Oromia, Ethiopia.

Within each main plot, five subplots of 1 m x 1 m (1 m^2) were established at the four corners and the centre of the 400 m^2 quadrat and data on seedling/saplings and soil samples were taken from these subquadrats. Following the field manual for vegetation inventory of the Ethiopian

Biodiversity Institute (unpublished), seedlings were defined as young plants having DBH < 2.5 cm and height ≤ 1 m; whereas, saplings were defined as young plants having DBH < 2.5 cm with height > 1 m but < 3 m. The seedlings and saplings were counted to estimate the regeneration status of the forest (Getachew Tesfaye *et al*., 2002). One of the limitations of this study was that data on grass and forbs were not collected from each sample plot.

Collected plant specimens were taken to the National Herbarium of the Addis Ababa University, College of Natural Sciences, Department of Plant Biology and Biodiversity Management and identified using published volumes of the Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989; 1995; Edwards *et al*., 1995; 2000; Hedberg *et al*., 2004). Voucher specimens were deposited in the National Herbarium of Addis Ababa University.

Soil data collection

In determining the impact of ecosystem rehabilitation on soil chemical properties of the study area, soil quality assessment was carried out using a random sampling method and data was collected from the five subplots of 1 m x 1 m (1 m^2) that were established at the four corners and centre of the main quadrat and then pooled. Auger sampler was used for taking individual samples to a depth of 15 cm. Composite sampling was used in soil sample collection. Accordingly, eight composite samples from the Kelala Dalacha sampling site were taken and analyzed for the selected chemical soil attributes such as soil pH, organic matter content, cation exchange capacity, electrical conductivity, essential nutrients (mainly total nitrogen, available phosphorus and available potassium).

Soil chemical properties such as cation exchange capacity, soil pH, organic matter content, electrical conductivity, essential nutrient mainly total nitrogen, available phosphorus and potassium were measured at the National Soil Test Laboratory, Addis Ababa.

Data analysis

Data were analyzed using descriptive statistics.

Land use/land cover change detection analysis

Image selection from the Cloud free Land sat images were downloaded for the years (1988, 1998, 2008, and 2018).

Layer stacking and band selection for Landsat5 (2, 3, 4) and Landsat 8 (3, 4, 5) bands were used (Table 1).

Table 1. Summary for the image's acquisition date, path, senor and resolutions.

Acquisition date (Year/mm/DD)	Path/Row	Sensor	Resolution
1988/12/28	168/054	Landsat5 TM	30 m
1998/12/24	168/054	Landsat5 TM	30 m
2008/12/27	168/054	Landsat7 ETM+	30 m
2018/12/15	168/054	Landsat8 OLI	30 m

Land use/land cover change classifications

Mainly two major classes were identified namely vegetation and barren land from the images by using ENVI5.0 image analysis software as the focus of this study was to evaluate the change brought by area closure.

By collecting training points from the images supervised classification was done for the different years (1988, 1998, 2008 and 2018) in order to determine land use/land cover change classes. After having land use/land cover change classes of each year i.e., four periods: 1988 to 1998, 1998 to 2008, 2008 to 2018 and 1988 to 2018 change detection statistics were calculated in INVI5.0.

Land use/land cover change (LULCC) statistics were computed using the formula employed by Fasika Alemayehu *et al*. (2019):

1. Total LULCC per hectare

$$\text{Total LULCC} = \text{Area}_{\text{final year}} - \text{Area}_{\text{initial year}}$$

Where, area is extent of each LU/LC type.

2. Percent of LULCC

$$\text{Percentage of LULCC} = \frac{(\text{Area}_{\text{final year}} - \text{Area}_{\text{initial year}})}{\text{Area}_{\text{initial year}}} \times 100$$

Where, area is extent of each LULC type.

3. Rate of LULCC

$$R = \frac{(Q2 - Q1)}{t}$$

Where, R, Q2, Q1 and t indicates rate of change, recent year LU/LC in ha, initial year.

Vegetation structure

The vertical structure of tree species was described following the International Union of Forestry Research Organization (IUFRO) scheme

(Feyera Abdena, 2010). The percentages of various plant families, DBH and height classes of woody plants in the study area were summarized bar graphs and tables.

The species population structure of Kelala Dalacha Mountain was computed by classifying the DBH values of the woody species into five DBH class intervals. Based on intensity of disturbance species show variation in population structure pattern reflected through difference in the abundance of different size classes (Tamrat Bekele, 1994). Size class distribution or population structure, therefore, gives a good indication of the impact of disturbance and forest successional trends. As a result, matured woody species recorded in the study quadrats were used in the analysis of population structure. The diameter at breast height (DBH) was classified into five DBH classes and the percentage distribution of trees and shrubs in each class were computed.

All individuals of woody species with a diameter at breast height (DBH) greater than 2.5 cm, and height greater than 2 m were measured to analyze the DBH class distribution. The DBH values of each species in a plot was averaged and classified into the five (5) DBH Classes: Class 1 = 2.5− 10 cm; 2 = 10.1−20 cm; 3 = 20.1−30 cm; 4 = 30.1−40 cm; and class 5 = >40 cm.

Regeneration status of the recorded woody species was determined by computing density ratios between seedling, sapling and mature individuals (Mwavu and Witkowski, 2009).

Soil data analysis

Soil properties were analyzed according to the standard soil analysis procedures provided. Soil pH in a 1:2.5 soil-water suspension, organic carbon by oxidation with potassium dichromate ($K_2Cr_2O_7$) in a sulphuric acid medium (Walkley and Black, 1934), total nitrogen by semi-micro Kjeldahl and available phosphorus by sodium bicarbonate ($NaHCO_3$) extraction (Olsen) procedures. Hence from the Kelala Dalacha, 8 topsoil samples to depth of 0−15 cm were collected and analyzed at the laboratory for determination of soil pH, electrical conductivity, cation exchange capacity, organic carbon, total nitrogen, available phosphorus, and available potassium. Available potassium was extracted by sodium acetate (1N NH_4OAc) extraction while exchangeable calcium and magnesium by ammonium acetate extraction and measured by the atomic absorption spectrometry (AAS) method (Page *et al*., 1982).

The data from the soil laboratory were subjected to a one-way analysis of variance (ANOVA). The multiple comparison test using least significance difference (LSD) was employed for mean separation for those properties that were found significantly different. The level of significance used was 0.05. Data were analyzed using the Statistical Package for Social Sciences (SPSS) release 11 (Bryman and Cramer, 2001).

RESULTS

Change in vegetation cover

Result from the satellite image analysis showed that there was an increase in vegetation cover and decrease in the proportion of bare ground (Fig. 4 and Table 2).

Land use/land cover change detection matrix from 1988 to 2018

Area Coverage of each Land use/land cover change classes and their percentage share for different years are summarized in Table 2. The major land use/land cover classes were barren lands and vegetation (both woody and herbaceous species).

The result showed that barren land has decreased since 1988 in all periods to the final year 2018. As indicated in Table 2, in 1988 barren land was 41.90% with area coverage of 32.58 ha while in 1998 it was at a percentage of 35.53% covering an area of 27.63 ha. In 2008, barren land covered an area of 15.30 ha with a percentage of 19.68% and in 2018, it decreased to 11.57% with an area coverage of 9.0 ha. On the other hand, vegetation cover increased from 58.1% (45.18 ha) in 1988 to 88.4.8% (68.8 ha) in 2018 (Table 2 and Fig. 4).

Table 2. Land use/land cover change class in years (1988, 1998, 2008 and 2018) per hectare in Kelala Dalacha, Oromia, Ethiopia.

Year	1988		1998		2008		2018	
Class name	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
Barren land	32.58	41.9	27.63	35.53	15.3	19.68	9	11.57
Vegetation	45.18	58.1	50.13	64.47	62.46	80.32	68.76	88.43

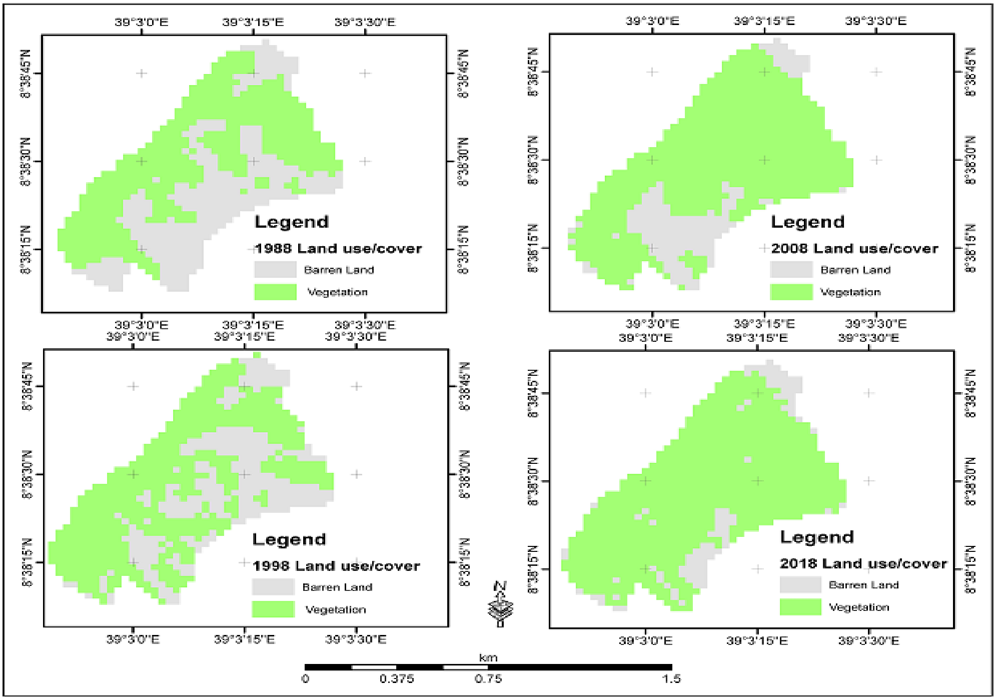

Fig. 4. Land use/land cover change in Kelala Dalacha Mountain Ada'a district, East Shoa Zone, Oromia, Ethiopia.

Change detection matrix between 1988 to 2018

Table 3 summarizes change detection matrix for the period between 1988 to 2018. Column class total is the class of initial year while the row total is class of final year. For the period 1988 to 2018, vegetation cover increased from 451,800 m^2 in 1988 to 687,600 m^2 in 2018. The analysis showed that about 235,800 m^2 barren lands were converted into vegetation within the 30 years period. Image difference (the difference between row total and column class total) was -235800 (90000-325800). In other words, based on the negative image difference (-235,800 m^2), barren land in 1988 were rehabilitated or covered by vegetation (woody and herbaceous species).

Table 3. Change detection statistics for the period 1988 to 2018.

		Initial state 1988			
		Vegetation	**Barren land**	**Row total**	**Class total**
Final state 2018	Vegetation	443700	243900	687600	687600
	Barren land	8100	81900	90000	90000
	Class total	451800	325800	0	0
	Class changes	8100	243900	0	0
	Image difference	235800	-235800	0	0

Change detection matrix between 1988 to 1998

Over a ten-year period (1988 to 1998) of change detection statistics, the initial state of vegetation in 1988 had a row total of 501300 while that of the final state in 1998 had a class total of 451800 (Table 4) producing an image difference of 49500 (501300-451800) showing increase in vegetation cover over years. The initial state of barren land in 1998 had a row total of 276300 with a class total of 325800 in the final state of 1998 giving an image difference of -49500 showing barren land had been transformed into land covered with vegetation.

Table 4. Change detection statistics for the period 1988 to 1998.

Final state 1998	Initial state 1988				
		Vegetation	**Barren land**	**Row total**	**Class total**
	Vegetation	385200	116100	501300	501300
	Barren land	66600	209700	276300	276300
	Class total	451800	325800		
	Class changes	66600	116100		
	Image difference	49500	-49500		

Change detection matrix between the 1998 to 2008

Results (Table 5) indicated that the initial state of vegetation in the year 1998 had a row total of 624600 with a class total of 501300 in the initial state of 2008 thereby giving an image difference of 123300 showing increase in vegetation cover. On the other hand, barren land in the initial state of 1998 had a row total of 153000 and a class total of 191700 at the final state in 2008, resulting in an image difference of -123300 which showed conversion of barren land into more trees, shrubs and grasses.

Table 5. Change detection statistics for the period 1998 to 2008.

Final state 2008	Initial state 1998				
		Vegetation	**Barren land**	**Row total**	**Class total**
	Vegetation	432900	191700	624600	624600
	Barren land	68400	84600	153000	153000
	Class total	501300	276300		
	Class changes	68400	191700		
	Image difference	123300	-123300		

Change detection matrix between 2008 to 2018

Vegetation in the initial state of 2008 had a row total of 687600 and a class total of 624600 in the final state of 2018 producing an image difference of 63000 (Table 6) demonstrating a wide change of an increase in woody species and grasses. In relation to barren land as at initial state in 2008, row total was 90000 and final state in 2018 had a class total of 91800 hereby creating an image difference of -63000 affirming change of barren land to more woody species or grasses.

Table 6. Change detection statistics for the period 2008 to 2018.

Final state 2018	Initial state 2008			
	Vegetation	**Barren land**	**Row total**	**Class total**
Vegetation	595800	91800	687600	687600
Barren land	28800	61200	90000	90000
Class total	624600	153000		
Class changes	28800	91800		
Image difference	63000	-63000		

Structure of woody species

Distribution of diameter at breast height (DBH) of woody species

The general pattern of distributions of tree individuals across the DBH classes displayed inverted J-shaped pattern of distribution (Fig. 5). The lower DBH classes were found to have relatively higher number of individuals than that of the middle and the top classes. Less percentage of individuals was recorded for the highest DBH classes.

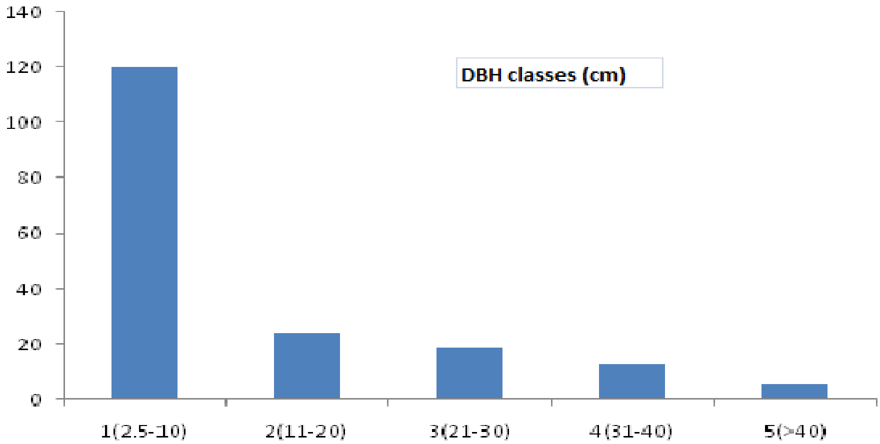

Fig. 5. Overall DBH class distribution patterns of woody species in Kelala Dalacha, Ada'a district, Oromia, Ethiopia.

Population structure of some selected woody species

For the analysis of population structure, six woody species (*Faidherbia albida*, *Vachellia seyal*, *Vachellia tortillis*, *Combretum molle*, *Croton macrostachyus* and *Dodonea angustifolia*) were selected. The studied species showed four different patterns of distributions along their respective DBH classes: bell-shaped, irregular, inverted J-shaped and J-shaped patterns of distribution.

The first pattern showed a bell-shaped distribution. The number of individuals increased with increasing DBH up to certain point then decreased with increase in DBH. For example, *Faidherbia albida* showed such type of distribution pattern (Fig. 6).

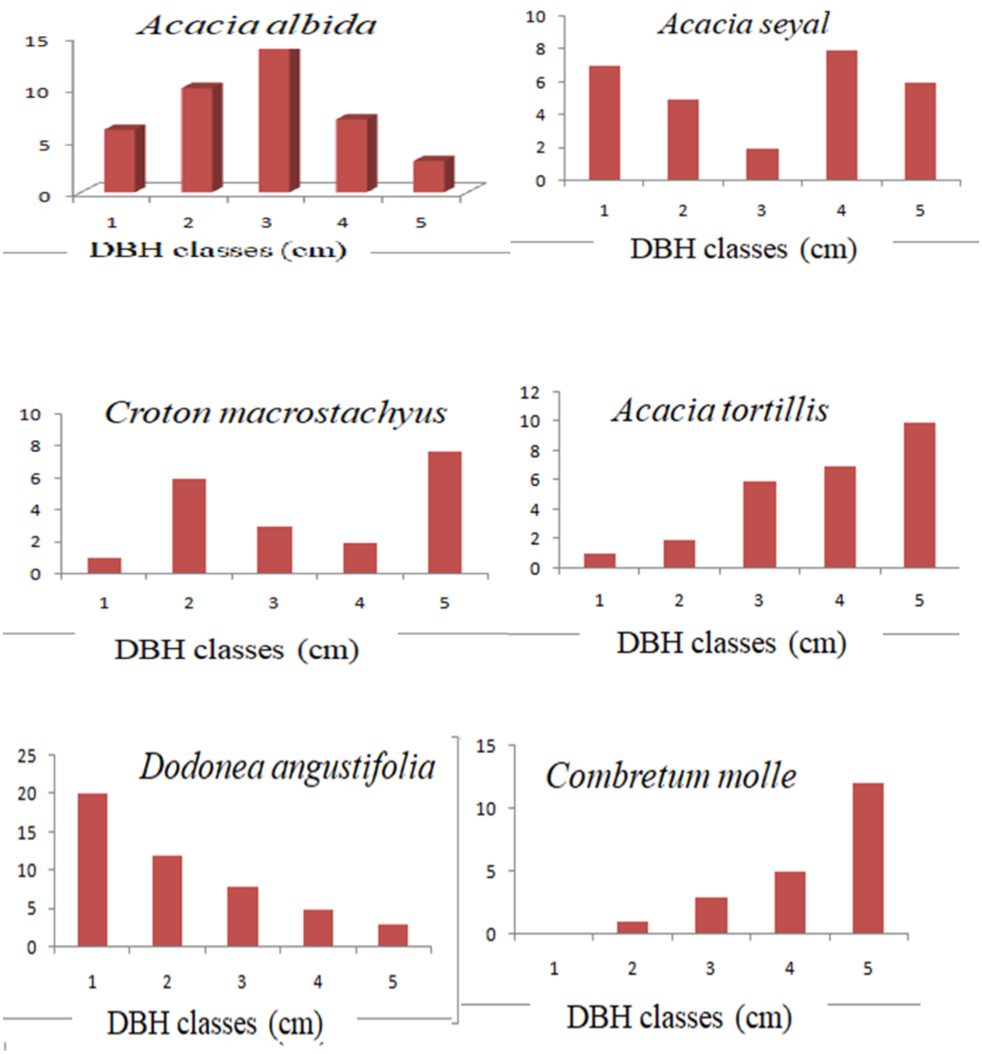

Fig. 6. Population structure of some woody species in Kelala Dalacha Mountain, Oromia, Ethiopia.

The second pattern was described as irregular where no defined pattern was observed across the DBH classes. *Vachellia seyal* and *Croton macrostachyus* displayed such pattern of population structure (Fig. 6).

The third pattern of population structure exhibited the inverted J-shaped distribution (Fig. 6). *Dodonea angustifolia* was seen to be one of the best examples for this distribution pattern.

The fourth pattern was found to be a 'J'-shaped pattern of distribution. This pattern is characterized by having a smaller number or the total absence of individuals in the lower DBH class and higher or gradually increasing to the higher DBH class. *Vachellia tortillis* and *Combretum molle* had this pattern of distribution (Fig. 6).

Soil chemical properties

The chemical properties of soil in Kelala Dalacha were shown in Table 7. Soil pH values of Kelala Dalacha closed area ranged from 6.2 to 7.9 and had average value of 6.64. EC values of the study area ranged from 0.054 to 0.164 with average of 0.082. CEC of Kelala Dalacha ranged from 27.09 to 34.89 with average of 30.92.

Table 7. Mean values of soil chemical properties of Kelala Dalacha, Oromia, Ethiopia. Values are mean ± standard deviation (n=8) at the depth of 15 cm.

Parameters	**Unit**	**Mean ±SD**
pH	pH metre	6.64±0.915
EC	ds/m	0.082±0.036
CEC	meq/100 g	30.92±2.816
OC	%	2.44±0.869
TN	%	0.213±0.095
Av. P	ppm	3.91±1.487
Av. K	ppm	219.38±67.951

DISCUSSION

Contributions of area closure to vegetative cover

The result of this study showed that area closure had significantly contributed to vegetation cover in Kelala Dalacha Mountain in agreement with previous studies. For example, vegetation cover increased from 58.1% (45.18 ha) in 1988 to 88.4.8% (68.8 ha) in 2018. On the contrary, barren land decreased from 41.90% (32.58 ha) in 1988 to 11.57% (9.0 ha) in 2018. Area closures are areas in either forest or any other vegetation area selected for natural regeneration of the native flora as a means of reclaiming the land through protection of the areas from human and animal interference (Alemneh Dejene, 1992). In as much as the purpose of the closure is for the reclamation of degraded vegetation, it is normally done in areas that been used for mining purposes or overgrazed (Bendz, 1986). In Ethiopia, area closure could be traced back to protecting church surroundings from being deforested and increasing plant and animal diversities (Alemayehu Wasie, 2002). Thus, the establishment of closures in Ethiopia and elsewhere has been recognized as a forward-looking environmental method in the rehabilitation of degraded ecosystems or overgrazed areas, especially, in northern Ethiopia where degradation of natural resources has been considerably higher than other parts of the country (Bendz, 1986). Similarly, area closure has contributed to recovery of woody vegetation in degraded dryland hillsides of central and northern Ethiopia (Mengistu Tekalign *et al.*, 2005).

Vegetation structure and implications

A relatively higher number of lower DBH classes and lower numbers in that of the middle and the top classes indicate that small sized individuals were very common in the Kelala Dalacha Mountain and the larger sized were rare. Hence, this distribution depicts that the Mountain was on the status of good regeneration. The general distribution of the species in the forest exhibited inverted 'J' shape distribution. According to Leak (1965) and Peters (1996), this type of population structure is characteristic of shade-tolerant canopy trees that maintain a more or less constant rate of recruitment. There is a large probability that the death of an adult tree will be replaced by the growth of individuals from the smaller size classes. It is considered by many authors as the ideal, stable and self-maintaining plant population (Leak, 1965). However, the analysis of six woody species in the study site revealed four different patterns of distribution in the forest. A bell-shaped pattern of distribution suggested that the lower regeneration and recruitment capacity of these species and indicated the management and conservation problems. *Faidherbia albida* had few individuals in both lower and higher DBH classes with more individuals in the intermediate DBH classes. The Gauss-type distribution pattern showed by this species indicates a poor reproduction and recruitment that might be due to overharvesting of seed-bearing individual (Tamrat Bekele, 1993; Feyera Senbeta and Denich, 2006; Tesfaye Burju *et al*., 2013).

Vachellia seyal and *Croton macrostachyus* displayed irregular patterns of population structure. The irregular distribution pattern could be the result of selective cutting of individual woody species for different purposes (e.g., for construction and firewood) by the local people (Tesfaye Burju *et al*., 2013).

Vachellia tortillis and *Combretum molle* had a 'J'-shaped patterns of population distribution indicating there was poor reproduction patterns and hampered regeneration due to the fact that either most trees are not producing seeds or there are losses due to predators after reproduction (Tamrat Bekele, 1993; Feyera Senbeta and Denich, 2006).

In contrast to the poor recruitment potential of species due to seedling mortality and recruitment limitation as a result of anthropogenic effect of the community findings of the study by Haileab Zegeye *et al*. (2011), the third pattern (inverted J-shaped) distribution exhibited a good reproduction and recruitment capacity of the species that a higher number of individuals in the lower DBH classes and decreases with increase in DBH.

Contributions of area closure to soil chemical properties

The chemical property of soil is extremely important to correct balance of the available plant nutrients in the soil. The availability of nutrients is largely determined by the organic-matter content and its humus percentage in any farm or protected area. Since the objective of establishing closures was to rehabilitate the potential of the land, improvement in soil chemical properties are key indicator parameters.

This study showed that all values of the soil chemical properties were in the class of Salt free (Landon, 1991). The soil pH values of study site fall in the category of slightly acidic (6.2). Soil pH is a measure of soil acidity or alkalinity which influences not only crop yields, crop suitability but also activity of soil microorganism and availability of micronutrient. With low pH there is phosphate deficiency and aluminum and manganese toxicity.

Potassium is taken up through plant roots from soil solution to enhance crop growth. A result from the laboratory analysis for the parameter available potassium also falls under a very high class value ranging from 70 to 275% with an average of 219.38%. Followed by total nitrogen, it is one of the major nutrients required for the nutrition of plants, nearly 95–99% in the organic form and 1–5% in the inorganic form as ammonium or nitrate (Buruah and Barthakur, 1997). Total Nitrogen of study site varied from 0.09 to 0.41%. It is simply an indicator of the soil potential for the element but not the measure in which it becomes available to the plant, therefore result obtained shows that the total nitrogen content had a percentage value of 0.21% indicating soil chemical to be at a high class (>0.06).

Cation exchange capacity having a high class value with an average of 30.92%. It is the total amount of exchangeable cations that can be held by a given soil mass/colloids. Organic matter content was one of the soil attributes selected to evaluate the fertility level of the soil chemical properties.

As soil organic matter is derived mainly from plant residues, it contains the essential plant nutrients. Therefore, accumulated organic matter is a storehouse of plant nutrients. The mean value of organic matter content was at a percentage of 2.44% rating it to be at the medium level (2.1–4.2). Where the rate of addition is less than the rate of decomposition, soil organic matter declines. Equally, where the rate of addition is higher than the rate of decomposition, soil organic matter increases. This can be referred to as a steady state which describes a condition where the rate of addition is equal to the rate of decomposition.

Another parameter used to determine the soil chemical properties at Kelala Dalacha was available Phosphorus which had an average value of 3.91 ppm falling within the low to medium classes. Phosphorus like in the case of Potassium is also taken up through plant roots from the soil solution to enhance plant growth.

According to Grisso *et al.* (2009), electrical conductivity is strongly correlated with soil particle size and texture and therefore, sands, silts and clay have low, medium and high conductivity, respectively. As the electrical conductivity (EC) is the ability of a material to transmit (conduct) an electrical current, electrical conductivity of 0.08% of this study showed that the value of soil at Kelala Dalacha was in the class of salt free.

Area closure contributed not only to vegetation cover but also to improved soil chemical properties (Abiy Tsetargachew, 2008). Skarpe (1991) stated that the presence of good vegetation cover in the area closure reduced erosion through the addition of organic matter and surface litter. Studies showed that under condition of low vegetation cover clay fractions are likely to be lost through the process of selective erosion and migration down the soil profile which ultimately increases the proportion of sand and silt contents in the surface soil (Woldeamlak Bewket, 2003).

CONCLUSION AND RECOMMENDATION

The aim of the research was to assess the impact of area closure on the cover and structure of woody species and soil chemical properties in Kelala Dalacha Mountain. As a result of area closure vegetation cover increased from 58.1% in 1988 to 88.43% in 2018 with increasing trend over the 40 years. The barren land in 1988 was changed to either trees, shrubs and grasses showing significant improvements over time. The general pattern of distributions of woody species across the DBH classes displayed inverted J-shaped pattern of distribution indicating good regeneration status which confirms the fact that area closure had positive impact on the conservation of species and rehabilitation of degraded lands.

Introduction and continuous practice of area closure in the Kelala Dalacha site have brought about an increase in the soil chemical nutrients/properties and vegetation cover. Gradual development within these soil nutrients has also contributed to the rapid growth of plant species.

In summary, area closure contributed to significant improvement in vegetation cover and chemical properties of soil clearly showing the fact that area closure is a viable strategy for restoring/rehabilitating degraded ecosystems. It has been already practiced in many parts of Ethiopia but needs to be widely applied for better management of natural resources and biodiversity conservation. The introduction of area closures is a very advantageous method as it is a fast, cheap and sustainable method for the rehabilitation of degraded lands.

Based on the findings of this study, the following recommendations are drawn to conserve and assure the sustainability of ecosystem services derived from the Kelala Dalacha mountain resources:

- Area closure has positively contributed to vegetation cover, vegetation structure and soil chemical properties. Therefore, there is a need to strengthen applications of area closure for natural resources management by putting in place strategy and management plan.
- Establish a system of community-based conservation areas for already closed sites and ensure conservation and sustainable use of resources.

Limitations of the study

The authors would like to point out that this study has the following limitations:

- Using random sampling for vegetation data collection
- Lack of soil data prior to area closure.

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