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Effect of Forest Restoration on Vegetation Composition and Soil Characteristics in North Wollo and Waghemira Zones, Northeastern Ethiopia

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Abstract: As a counter measure of deforestation and forest degradation, there are many forest restoration practices with area exclosures. However, these restoration interventions are not yet scientifically evaluated weather successes or not. Thus, this study is to evaluate the impacts of forest restoration with area exclosures on vegetation and soil property changing aspects. The method followed concept of forest restoration based on selected indicators and comparing against best practices. For this purpose, three districts in three agro-ecologies were selected. In each district one exclosures, adjacent church forest and adjacent grazing land were selected. Then vegetation data were collected and analyzed by using different diversity indices. Biomass was computed by using allometric equations developed for forests of dryland tropical Africa. The soil sample were collected from the main quadrates at 5 points in three different depth and then composite. Data was analyzed by using one-way ANOVA via vegetation qualities and selected soil parameters in different land uses and agro-ecologies. The soil result was compared with critical values. There was significant difference in vegetation composition, biomass and soil attributes across land uses and agro-ecologies ($p < 0.03$). Exclosures showed intermediate values between Church forest and grazing land in vegetation composition, biomass and some soil attributes. Therefore, forest restoration with area exclosures is the better tool for degraded forest restoration. Further research is required to understand ecosystem services of area exclosures and trajectory of successional changes in vegetation composition and soil parameters of the area exclosures.

Keywords: deforestation; restoration; exclosure; church forest; grazing land; vegetation composition; and soil attributes

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1. Introduction

In the dry land parts of Ethiopia, there are distinctive vegetation adapted to moisture stress climate. These forests are mostly tropical dry forests which are dominated by woody plants, primarily trees, the canopy of which covers more than 10% of the ground surface, occurring in climates with a long dry season (Gumbo, 2010). Among nine forest types in Ethiopia, most are classified under dry forest (IBC, 2007). The dry woodlands in Ethiopia are known for their valuable non-timber forest products (NTFPs). In addition, these dry forests have very crucial role for climate regulation, fodder, non-timber products (gum and resin) and this increases the farmer's adaptive capacity through diversified livelihoods (Alemu *et al.*, 2015).

Despite of this fact, now a day the dry forest are under threat and heavy pressure such as clearance for firewood, expansion of cash crops and new settlements and actually, they are shrinking overtime. According to Gumbo (2010) in dry lands there are high climate variability, frequent drought and occasional floods, thus rain-fed crop production is not sustained. As a result, the population overexploited the dry forests for non-timber products and converts, the dry forestland to agricultural land. This is mainly due to associated with the high population pressure and the increasing needs for new agricultural land and additional sources of biomass energy.

This accelerated deforestation resulted in soil erosion, loss of biodiversity, disruption of the way of life of forest dwellers, shortage of wood (fuelwood, timber), inadequacy of non-timber products, and affects the hydrological regime of an area and the CO_2 balance in the atmosphere. Generally deforestation have far reaching local and global consequences such as, climate change and biophysical changes that in turn have environmental, social and economic impacts with the immediate effects on communities that depend on forests for part or their entire livelihood (Yirdew *et al*., 1996).

This calls urgent intervention by different approaches such as restoration, rehabilitation and reclamation of degraded forest with area exclosures, agroforestry practice and afforestation and reforestation (Yirdew et al., 1996). Habitually, the ecosystem that requires restoration has been degraded, fragmented, transformed or entirely destroyed as the direct or indirect result of human activities (Alemayehu, 2007) and (SER, 2004).

Ecological restoration presents complex and poorly understood implications for the structure and composition of future forests, landscapes, and fauna. The outcomes of a particular restoration are; restoration of soil fertility for agricultural or forestry use; production of timber and non-timber forest products; or recovery of biodiversity and ecosystem services (Chazdon, 2008). Ecological forest restoration is mostly practiced in the form of area exclosures. Danano (2003) explain that, area exclosure and protecting an area of open grazing land from human use is an important practice in Ethiopia to permit natural rehabilitation, enhanced by additional vegetative and structural conservation measures.

Restoration of forest with area exclosure practices should be evaluated with selected indicators that are in line with environmental, social and economic objectives of exclosures. This is important to realize the trajectory of vegetation change from open grazing land to the reference forest mediated by exclosure. The trajectory or the status of area exclosure evaluated by selected indicators may be resemblance to the reference forest or open grazing land. Specific and measurable indicators are needed to help evaluation weather the restoration practices success or fail. After evaluation the outcomes are (increase, decrease, maintain), the magnitude effect (plant cover, diversity, biomass etc.) and the period (time) with related to reference site (SER, 2016). This information is important for development practitioners for further scaling up.

There are many forest restoration practices with area exclosures in the northern degraded lands of Ethiopia. The restoration works through area exclosures in the study area are not seriously evaluated. This is because there is limited synthesis and methodological research to develop indicators and evaluation criteria. Due to this the determinants for successful and fail of forest restoration with area exclosures were not identified in the study areas. Thus, this research was designed to evaluate the impacts of exclosures on vegetation dynamics and some soil attributes after passive restoration intervention and develop the conceptual framework for evaluation of forest restoration practice.

2. Methodology

2.1. Description of the study area

The study was conducted in Waghemira and North Wollo Zones, in Amhara region on three selected districts (Lasta, Sekota and Abergele) (Figure 1). **Lasta** district is one of the administrative districts in north Wollo Zone, which is geographically located between 12035'31'' N Latitude and 39004'30'' E longitudes. **Sekota** is one of the district of Waghemira Zone located in 120 0`22`` north longitudes and 3900`58``east latitudes.

Abergele is one of the district of Waghemira Zone located in 1304`42`` north latitude and 38053`29`` east longitude.

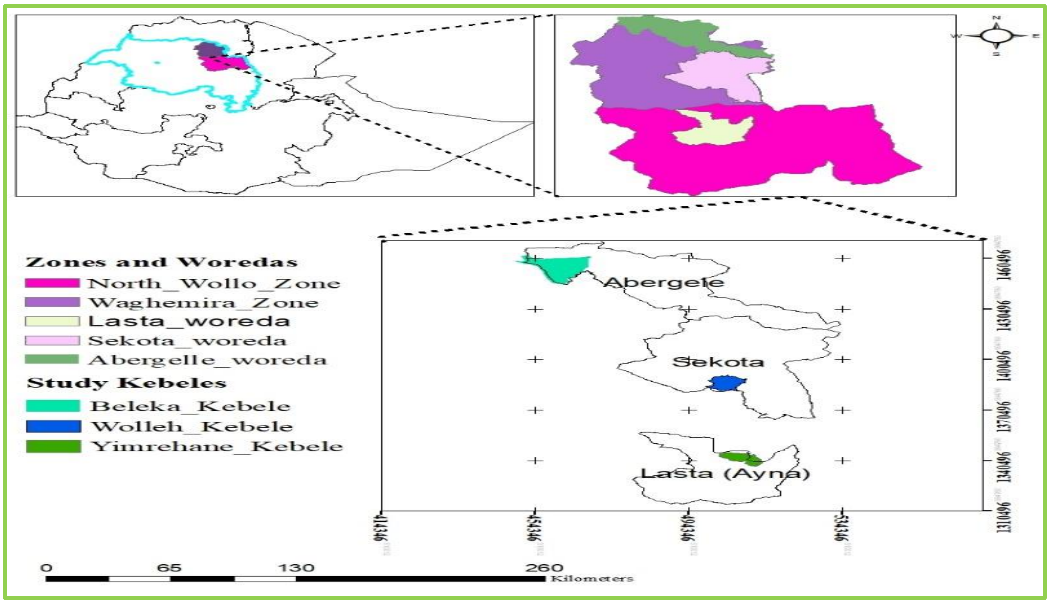

Figure 1. Map of the Study area.

Table 1. characteristics of study area.

Attributes	Highland	Mid-altitude	Lowland
Altitude (m.a.sl.)	2129 to 3600	1340 to 2200	500 to 1300
Rainfall (mm)	500 to 1000	350 to 700	250 to 750
Temperature (^{0}C)	24.5	16 to 27	23 to 43
Soil	Eutric Cambisols (51%)	Umbric Leptosols (52%)	Eutric Leptosols (29%)
Agro-ecology	Dega (52.7%)	Woyena-Dega (65%)	Dry Kolla (55%)
Topography	Chain of mountains, hills ad cliffs		
Vegetation	bushy woodlands and forest only at churches		

2.2. Sampling Size and Procedure

Table 2. Sample size.

S.No	District	Agro-ecology (m.a.s.l)	Area of selected exclosure	Area of selected church	Area of selected grazing	Age of exclosures
1	Lasta	Highland (2129-3600)	9.8 ha	54 ha	8.5 ha	10 years
2	Sekota	Mid-altitude(1340-2200)	3 ha	8.87 ha	2 ha	10 years
3	Abergele	Lowland (500-1300)	3.268 ha	11.35 ha	6.7 ha	10 years

Three districts (Lasta, Sekota and Abergele) at different agro-ecological Zones (Highland, mid-altitude and lowland) respectively were selected purposively. The agro-ecological classification of the study district is based on (Azene, 2007).

Then in each agro-ecology (districts) one area exclosures, one adjacent grazing land and one adjacent church forest (reference) were selected purposively. The criteria for selection was the presence of exclosure intervention and their accessibility at the same age (10 years).

Vegetation data were collected from quadrats, which were placed in systematic random sampling. The size of the quadrats was 20 m by 20 m square for tree inventory, 10 m by 10 m for sapling inventory and 5 m by 5 m for seedling inventory. The distances between the quadrates on transect was 250 m and the distance between parallel transects was 200 m (Kent, 2012).

The soil sample were collected from the main quadrates at four corners and at the middle in three different depth (0-10 cm, 10-20 cm, and 20-40 cm) with auger technique and then composite with plastic bag. Then soil sample were analyzed at the laboratory following appropriate laboratory procedures.

2.3. Methods of Data Collection

For evaluation of woody vegetation species local name, common name and scientific name at each quadrate were recorded. The height of trees are measured with Hypsometer. The diameter of trees was taken at 1.3 m (DBH) and at 0.6m with caliper and diameter tape. Different tree growth stages that, trees with the DBH >2.5 cm and height of >2.5 m, sapling with the DBH <2.5 cm and height of 1m < h< 2 m and seedling: having the DBH < 2.5 cm and height of <1 m were recorded at each quadrates (Kent, 2012).

Soil sample was taken at four corners and at the center of the main quadrate by disturbed sampling technique with auger at different depth. Then composite all soil samples by different land use and different soil depth. After that taken 1 kg soil sample from the composite sample after appropriate mixing for laboratory analysis of texture, pH, soil organic matter, available phosphorus and total nitrogen.

2.4. Data Analysis

The vegetation indicators analyzed by biodiversity indices such as Shannon diversity index (H'), species similarity index and species evenness index (Shannon, 1948). The species similarity was analyzed by Sorenson's Coefficient (Gotelli, 2013). The species evenness was analyzed with Evenness index = H'/ log S. (Pielou, 1966). The Flora of Ethiopia and Eritrea books helps for species identification. The above ground biomass of woody species having the DBH >-5cm calculated by (Chave *et al.,* 2014).Wood specific density of woody species taken from (Ethiopia's forest reference level submission to the UNFCCC, 2016) guideline.

To simplify the process for estimating below-ground biomass, it is recommended that) root-to-shoot ratio value of 1:5 is used; that is, to estimate below-ground biomass as 20% of above-ground tree biomass (Bhishma *et al.*, 2010) and (Bazezew *et al.*, 2015).

For Litter fall, Herb and Grasses (LHG) based on (IPCC, 2006)

The soil attributes were analyzed at Sekota agricultural research Center soil laboratory based on the procedure of soil and plant analysis (Sahlemedhin, 2000). Then the soil sample laboratory result was compared with soil critical values (Abiy, 2008; Alemu and Tekaligni ,2016). Then finally, all vegetation and soil attribute data were summarized and tested by SPSS for one-way ANOVA (at alpha = 0.05).

3. Results and Discussion

3.1. Vegetation Composition

3.1.1. Woody Species Density

High woody species density (1660 – 2265 stem ha^{-1}) was recorded in exclosures followed by church forest (717 – 1440 stem ha^{-1}) and grazing land (152-850 stem ha^{-1}) (Figure 2). The exclosure have better in stem density than church forest and grazing land. This is because of the open space, which gives favorable condition for regeneration of light demander species. That means there is no competition for light due to upper strata vegetation. Thus, scrub vegetation start to grow. As a result, the number of stems increase in exclosures.

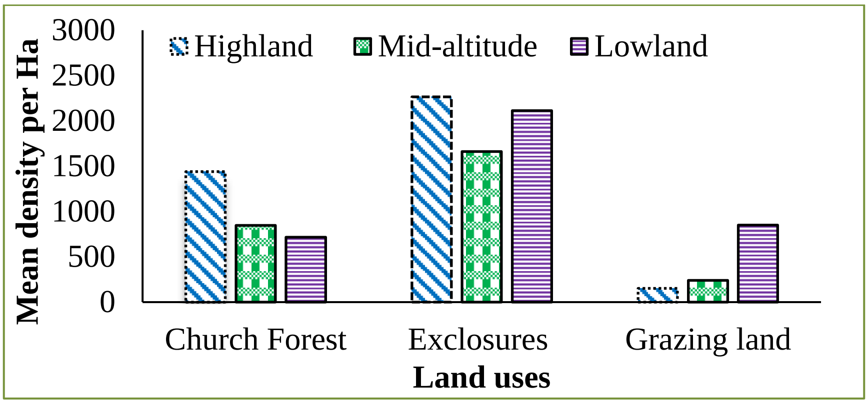

Figure 2. Woody species density.

Therefore, excluding open grazing land from livestock and human interference is a better strategy for natural regeneration. The better the natural regeneration facilitates the forest restoration. This idea is similar with Birhane *et al.* (2007) in Tigray, northern Ethiopia, Mamo (2008) in northeast Ethiopia, South Wollo and Asmamaw (2011) in central Ethiopia north Shoa that, area exclosures increase the vegetation density. All above scholars approved that, excluding livestock from open grazing land as area exclosure increase natural regeneration lead to natural forest restoration. Because, overgrazing (browsing and trampling) destroy the newly emerged seedling and saplings.

3.1.2. Species Composition

High number of species (7-16) was recorded in exclosures forest followed by church forest (11-12) and open grazing land (3-5). Number of species was low at mid-altitude but similar at lowland and highland areas (Figure 3).

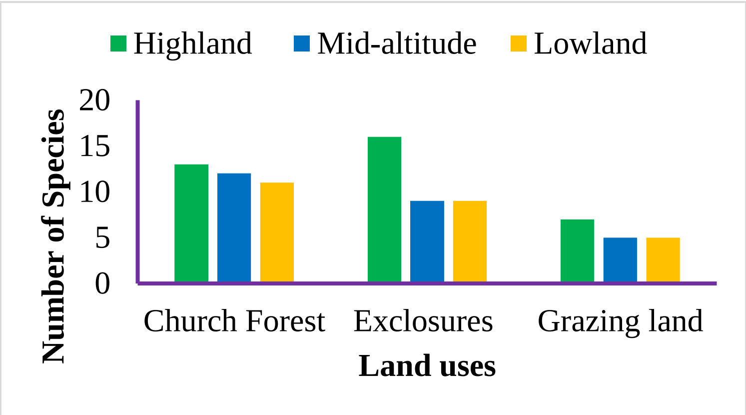

Figure 3. Species richness of different land uses at different sites.

Exclosures have the highest species richness than church forest and grazing land. This is because of in exclosures there is open space. There is low trampling and other disturbances. Therefore, the dormant species from soil seedbank starts to regenerate. In the other hand, there is seed dispersal by wind and wild animals from near natural forest or church forests.

Species diversity was high (0.78 - 2.27) at church forest followed by exclosures (1.1 - 1.73) and open grazing land (0.48 - 0.8). The dominance and evenness index is high in church forest followed by exclosures and open grazing lands (Table 3).

Table 3. Species diversity and evenness in different land use and agro-ecology.

Agro-ecology	Land use	Species diversity (H')	Evenness (E)

Highland	Church forest	2.04	0.3
	Exclosure area	1.2	0.16
	grazing land	0.8	0.15
Mid-altitude	Church forest	2.27	0.9
	Exclosure area	1.73	0.79
	grazing land	0.78	0.48
Low land	Church forest	2.3	0.95
	Exclosure area	1.1	0.5
	grazing land	0.48	0.3

According to Shannon (1948) species diversity index, the church forest was at good range (2 to 2.4) while exclosures have medium range (1 to 1.5) but open grazing land is below the minimum range (< 1) of species diversity index (Table 3). Simpson (1949) evenness index ranged from zero to one, at which close to one means all species evenly distributed, while close to zero means few dominant species control the community. In exclosures and the church forest species evenness is close to one that means the species get the chance to special distribution, however in open grazing lands evenness indexes close to zero at which high stress resistant few species are dominant.

In church forest, light demander species have no chance to germinate because of the close space of upper canopy. In exclosures, there is enough open space; thus, light demanders start to germinate. Therefore, exclosures have optimum species diversity and it may increase with age of exclosures still upper canopy will be closed. In open grazing lands, there are few dominant species presented, which resist the grazing stress. Thus, species diversity is very low. Similarly, Asefa *et al.* (2003) conclude that in northern highlands of Ethiopia, species diversity increases from open grazing land 0.5 to 1.8 after exclosures. This idea also supported by Mengistu *et al*. (2005) in central and northern highlands that, exclosures have species diversity twice the open grazing land. Therefore, the species at dormancy in open grazing land regenerate or due to seed dispersal by wildlife after the area is exclosed. Thus, exclosed the open grazing land increase the species diversity and species richness.

3.131. Species similarity index

The highest species similarity is between exclosures and open grazing land (0.4-0.8) followed by church and exclosures (0.3 - 0.6). High species similarity also recorded at midd-altitude areas (0.6-0.8) followed by highland (0.24 – 0.6) and lowland areas (0.24 – 0.4) (Figure 4).

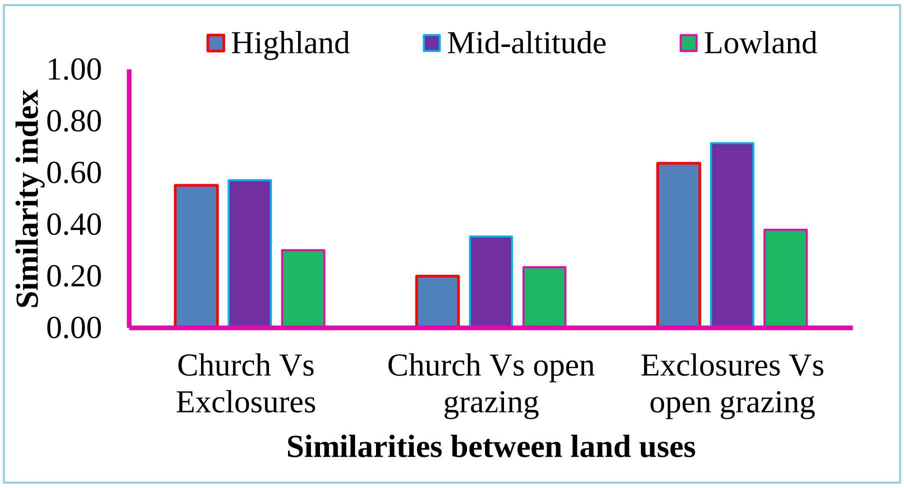

Figure 4. Species similarity index.

The similarity index ranges from 0 to 1 and; close to one means there is high similarity and close to zero means there is low similarity (Gotelli, 2013). The similarity between church forest vs. exclosures and exclosures vs. open grazing land at mid-altitude and highland areas close to one. However, in the lowland areas the similarity between church and exclosures close to zero. The exclosed forest have species similarity midway between church and open grazing land, as a trajectory from degraded grazing land area to reference adjacent church forest in highland and mid-altitude areas but not in lowland areas.

3.2. Population Structure and Regeneration status

3.2.1. Population structure

In highland areas, *Junipers procera* and *Olea europea* are the dominant species in churches having inverted J-shaped population structure, while in exclosure *Dodonia angostifolia* and *Rhus glotinos* are the dominant species having hump-shape (unimodal) population structure. Similarly, over all church forest in the highland area, have inverted J-shaped population structure (Figure 5 A). There is no dominant species in grazing land. However, there overall population structure shows J-shaped structure that only few big trees with no seedling and sapling population.

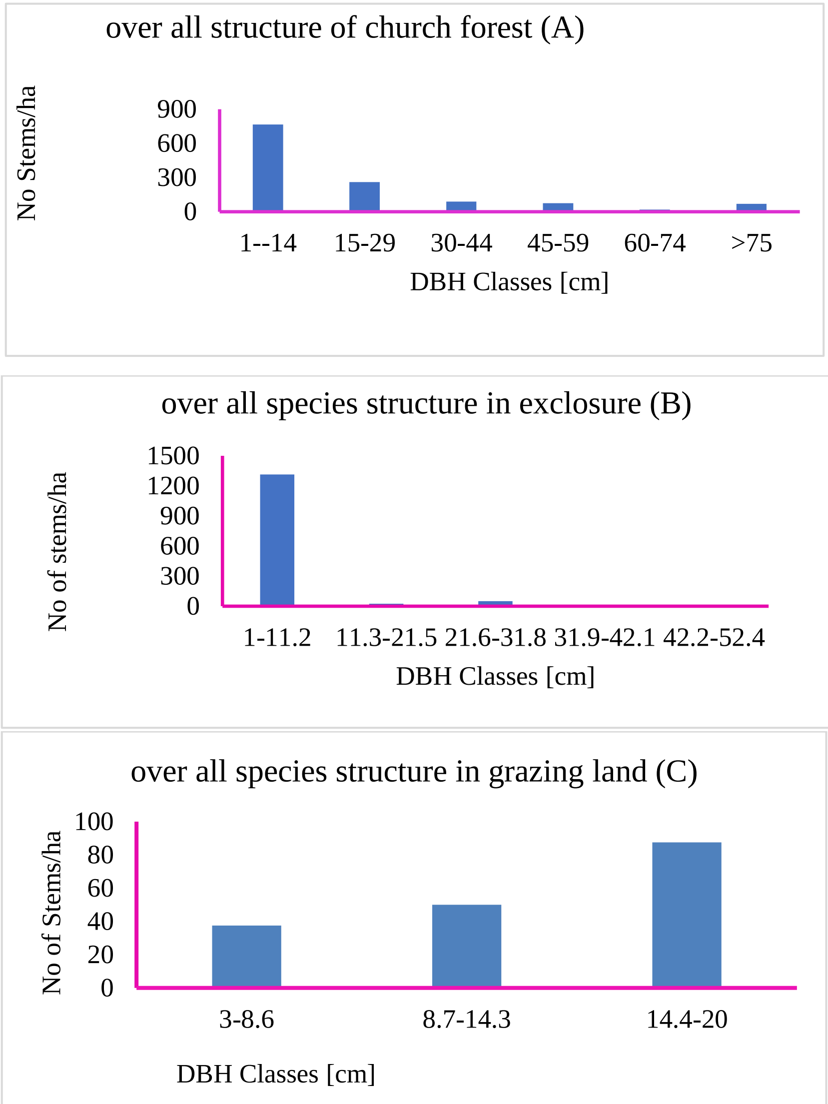

Figure 5. Population Structure of highland areas.

The lower DBH population of the species were found where there is open space, while, at the dense forest inside the church forest there is low regeneration, only big trees are preset. The seedlings and saplings of these species are found at the border where there is open space. These species are light demanders; therefore, the regeneration is only at the border and open space. *Rhus glutinosa* and *Dodonia angostifolia* are dominat species in exclosures at highland areas. *Dodonia angostifolia* is a poineer species that regenerate first in exclosures. This shows that the species are regenerated from soil seedbank or dispersal after the area is exclosed. All species in exclosures at the highland areas have inverted J-shape structure that most populations are at sapling stage (Figure 5 B). this is due to open space and the condition is favorable for ligh demandrs and the exclosures are young. In grazing land at the highland areas there are few stressed tress in DBH range of 14-20 cm. The population structure is J-shape structure indicating low regeneration (Figure 5 C). the regeneration may be affceted by grazing disturbances.

In mid-altitude areas, *Dodonia angostifolia* and *Olea europea* was dominant species in churches having inverted J-shape population structure. Over all, the church forest in mid-altitude areas have inverse J-shape structure. In churches, most population are found in DBH range 3- 20 cm and there is few big trees (Figure 6 A).

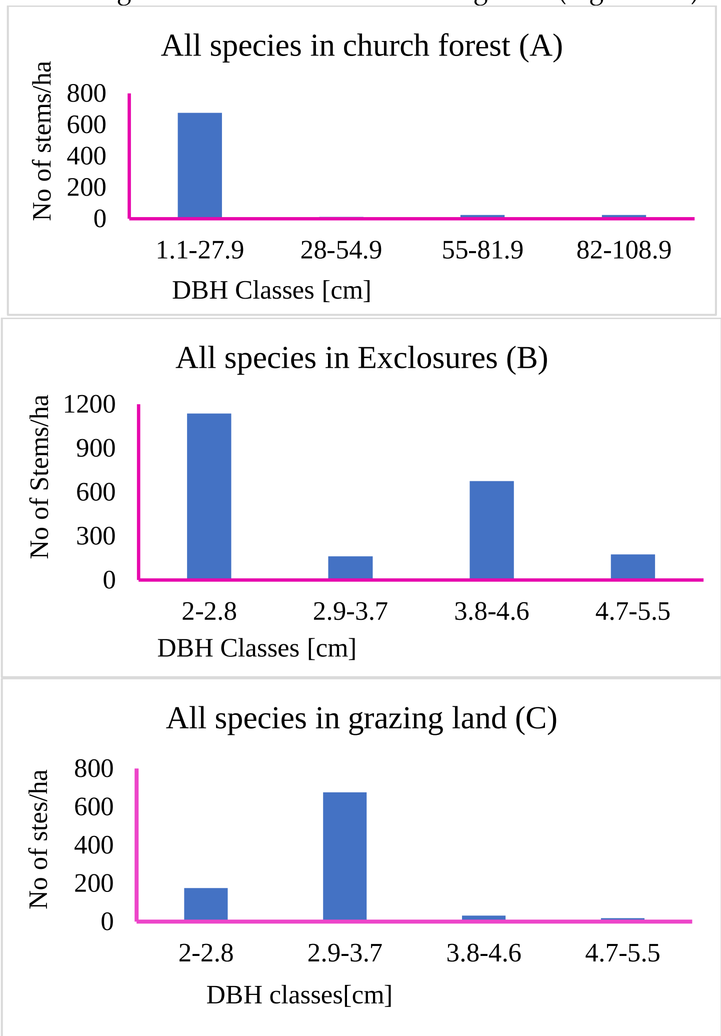

Figure 6. Population structure in mid-altitude areas.

In exclosures, only *Dodonia angostifolia* is the dominant species having J-shaped structure (Figure 6 B). In exclosure, most trees are found at 3-4 cm DBH range that are newly regenerated after area is enclosed. However, there is no dominant species in grazing land. *Acacia etbaica* and *Euclea divinorum* are remnants shrubs in grazing land, which resist the grazing and other disturbance stresses (Figure 6 C).

In lowland areas, *Diospyros mesifiliformis* and *Oncoba spinosa* was dominant species in churches having J-shape population structure. All most all trees have in the church and grazing land have DBH > 10 cm. This shows there is low regeneration in churches and grazing land (Figure 7 A and B). While, in exclosures *Acacia asak and Adansonia digitata* were the dominant species. *Acacia asak* have having inverted J-shaped structure and *Adansonia digitata* have J-shape structure.

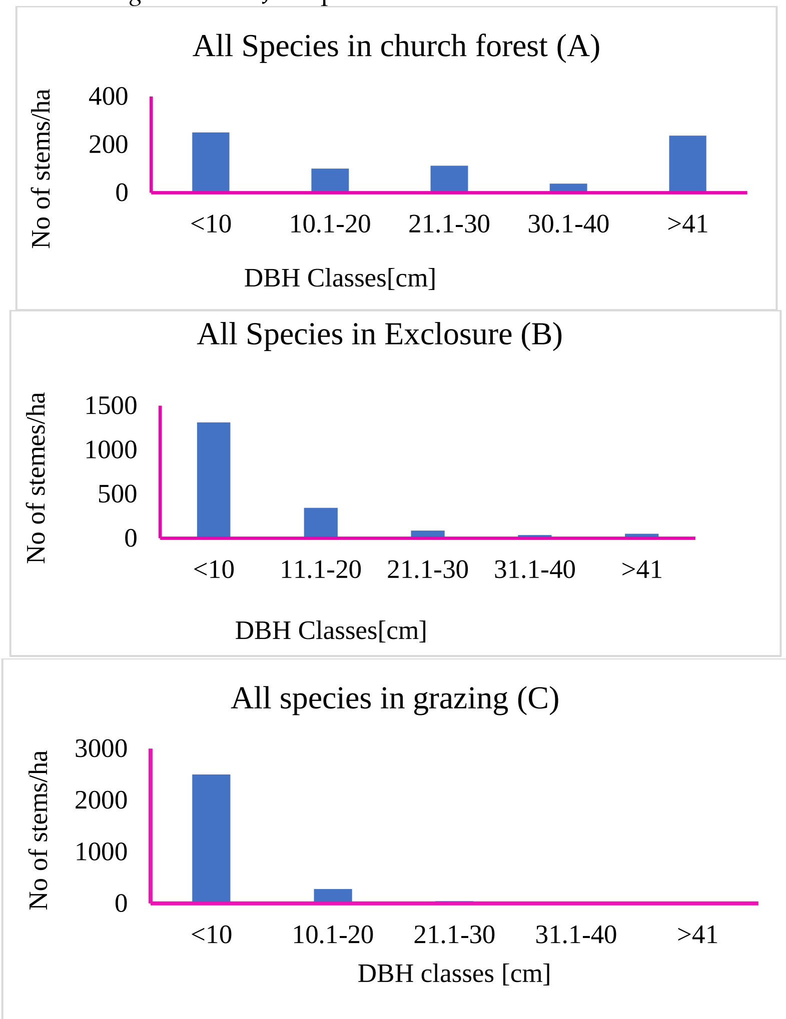

Figure 7. Population structure in lowland areas.

At low land areas, there is low regeneration in exclosures. The lowland grazing have inverted J-shape structure (Figure 7 C). There are only few big trees without seedling and sapling population in grazing lands. That means there is no regeneration in open grazing land.

3.2.2. Regeneration status

In terms of regeneration, exclosures have high seedling and sapling population while church forest and grazing land have low seedling and sapling population. At highland areas, church forest have J-shaped, exclosures forest have inverted J-shaped and open grazing land have J-shape population structure. At midd-altitude areas, same trend to highland areas but at exclosures there is high sapling population. At lowland areas, the regeneration status is very low; that means very low seedling population and thus population structure is J-shaped Figure 8).

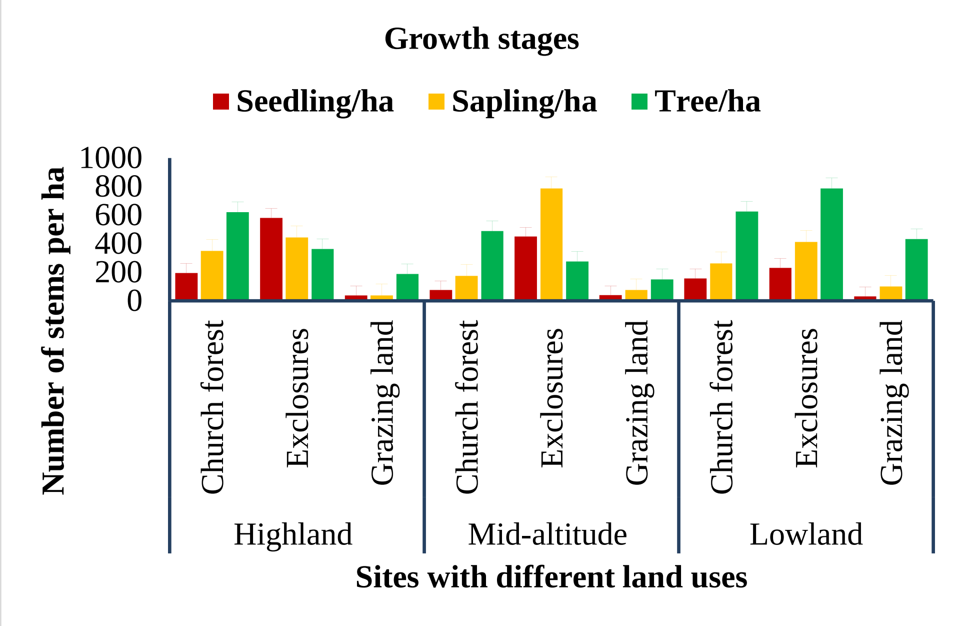

Figure 8. Regeneration status of woody species across different land uses.

At churches, the upper canopy affects the regeneration, so the population are only competent trees. It is an indicator of unbalanced community. *Junipers procera* and *Olea european* are a dominant species in most church forests in the highlands of Ethiopia. However, there is low regeneration because of low open space and high trampling effect of livestock. This idea is similar with Haile (2006) that in highland parts of North Wollo, *Junipers procera* and *Olea european* are common dominant species having J-shaped structure. There is only big trees in dense and there is low seedling and sapling population. While in exclosures the population structure is inverted J-shape structure that means there is high population of seedling and sapling. It is an indicator of healthy community. Exclosure was open grazing land before establishment. After exclosures, the stressed vegetation starts to grow and support natural regeneration as a nurse tree. The space is open helping to regenerate the light demanders. Thus, population of exclosure is in the order of seedling > sapling > tree. This idea is supported by Mengistu *et al*. (2005) in degraded hillsides of central and northern Ethiopia, Birhane *et al*., (2007) in northern Ethiopia, Mamo (2008) in northeast Ethiopia that, the population structures is inverted J-shape if there is no livestock interferences, that means properly protected and managed as area exclosures. Therefore, area exclosure restore the normal and healthy community after the open common grazing land is exclude from livestock and human interference.

3.3. Biomass

3.3.1. Woody species biomass

The highest WBM (613 -2594 ton ha^{-1}) recorded in lowland followed by highland (8.7 - 148.5 ton ha^{-1}) and at mid-altitude 9.9-47.13 ton ha^{-1}). In terms of land uses, the WBM was high at church forest (47.13 - 2594.5 ton ha-1) followed by exclosures (12.3 – 613.4 ton ha^{-1}) and grazing land (8.7 - 821.3 ton ha^{-1}) (Figure 9).

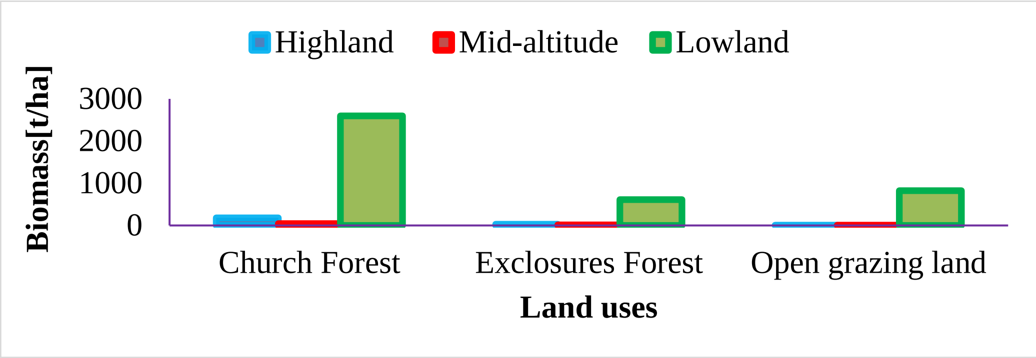

Figure 9. Mean woody biomass of different land uses at different sites.

The highest biomass at lowland area is due to big trees like *Adansonia digitata* L. having high diameter up to 178 cm. This tree increase the basal area and biomass at grazing land and exclosures. Additionally, *Acacia asak* dominantly grown in exclosures and open grazing land having the thorn in the lowland contribute to high biomass in the lowland.

In highland and mid-altitudes, the area is much degraded, that almost no big trees remain at open grazing land; after exclosures *Dodonia angostifolia* as a pioneer species start to grow having less diameter and then low biomass. Even if in this condition, the woody biomass in exclosures is intermediate between church and grazing land. That means exclosing open grazing land contribute for restoration of biomass flow from vegetation to soil. Yaynshet (2009), in northern Ethiopia stated the same findings that, the aboveground biomass measured inside the exclosures was more than twice that of the adjacent grazed areas and more biomass produced from the young than the old exclosures. Mekuria (2013) also stated similar idea that Woody biomass increased with exclosures age while grass biomass carbon slightly decreased because of canopy cover after well-developed community. Mekuria *et al*. (2015) also stated aboveground biomass and carbon increased following the establishment of exclosures on communal grazing land. Qasim *et al*. (2017) explained that aboveground vegetation biomass across sites in the order of area exclosures > open grazing land.

3.3.2. Litter, grass and Herbaceous biomass

The highest litter, grass and herb biomass (1.35 - 2.3 t ha^{-1}) recorded in church forests followed by exclosures (1.42 – 1.96 t ha^{-1}) and grazing land (0.57 - 0.99 t ha^{-1}). In terms of agro-ecology, the highest LHG was recorded in highland (0.57 – 2.3 t ha^{-1}) followed by mid-altitude (0.99 – 2.1t ha^{-1}) and lowland areas (0.75 -1.35 t ha^{-1}) (Figure 10).

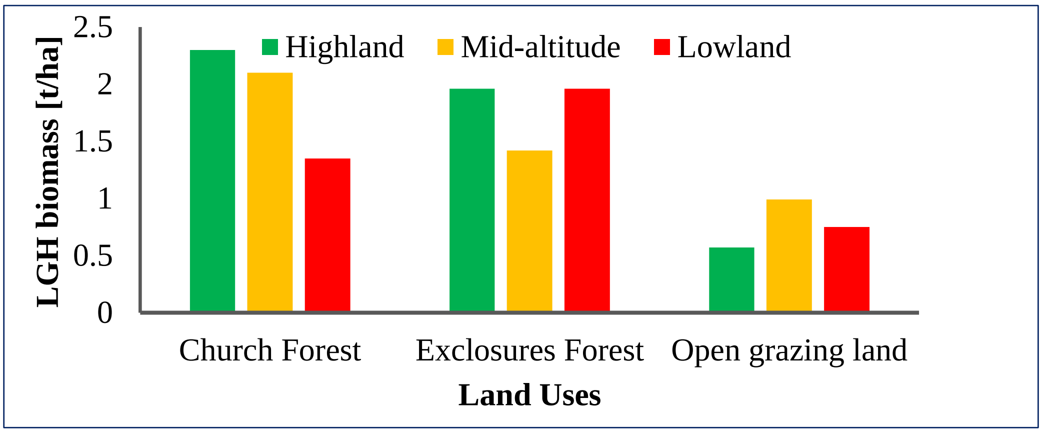

Figure 10. LGH biomass of different land uses at different sites.

In exclosures the grass and herbaceous species contribute for high LHG biomass, while in church forests litter fall contribute to the biomass. However, in open grazing land the grass, litter and herbs browsed by livestock, thus the biomass is less in highland and midd-altitude areas. Descheemaeker *et al*. (2006) get similar findings that litter biomass increase with exclosures age in Northern Ethiopia, Tigray after the open grazing land exclude from livestock and human interferences.

3.4. Soil Attributes of Area Exclosures

3.4.1. Soil particles

There was highly significant difference of sand ($p = 0.008$), clay ($p = 0.000$) and loam ($p = 0.000$) contents between different land uses. However, there was no significant difference of sand, clay and loam contents of soil at different agro-ecologies. The highest mean clay content was record in church forest (6.8 %) followed by exclosures (6 %) and grazing land (4 %). The highest mean sand content was record in grazing land (88.3 %) followed by exclosures (87.4 %) and church forest have the least sand content (79.56 %). The highest mean loam content was record in church forest (13.5 %) followed by grazing land (7.2 %) and exclosures (6.5 %) (Table 4).

Table 4. soil particle content of the study site +- Standard error of the mean n = 9).

Agro-ecology	land use	Sand (%)	Clay (%)	Silt (%)	Texture classes
	church	82.6 ± 1.2^{A}	5.4 ± 0.74^{A}	12.3 ± 1.1^{A}	loamy sand
Highland	exclosures	84.6 ± 1.2^{B}	6 ± 0.74^{AB}	9.4 ± 1.1^{B}	loamy sand
	grazing land	86.3 ± 1.2^{B}	4 ± 0.74^{BC}	9.6 ± 1.1^{B}	loamy sand
	church	74.6 ± 1.2^{A}	7.4 ± 0.74^{A}	18 ± 1.1^{A}	Sandy loam
Mid-altitude	exclosures	91.3 ± 1.2^{B}	4.6 ± 0.74^{AB}	4 ± 1.1^{B}	Sandy
	grazing land	88.3 ± 1.2^{B}	3.3± 0.74^{BC}	8.4 ± 1.1^{B}	Sandy
	church	81.3 ± 1.2^{A}	8 ± 0.74^{A}	10.7 ± 1.1^{A}	loamy sand
Lowland	exclosures	86.4 ± 1.2^{B}	7.3 ± 0.74^{AB}	6.3 ± 1.1^{B}	sand
	grazing land	90.4± 1.2^{B}	5.6 ± 0.74^{BC}	4 ± 1.1^{B}	Sandy

Based on clay, sand and loam content proportion of the soil at highland areas in all land uses have loam sand textural class. Church forests have loamy sand textural class in all agro-ecologies. In mid-altitude and lowland areas, area exclosures and grazing land have sandy textural class. Sand Clay and loam content of the soil increase from grazing land to church forest. However, the sand content of the soil decreased from grazing land to church forest. This tell us the exclosure practices increase the soil clay and loam content from its litter fall and under vegetation decomposition. This is because of organic matter increment in vegetation covered area church and area exclosures. This idea is similar with Prasad & Power (1997) that soil organic matter have a habit of to increase the clay and silt content the soil under vegetation covered area. This is due to two mechanisms. At the first, unions between the surface of clay particles and organic matter delay the decomposition process. Then soils with higher clay content increase the potential for aggregate formation. Under similar climate conditions, the organic matter content in fine textured (clayey) soils is two to four times that of coarse textured (sandy) soils (Prasad & Power, 1997). Based on Mekuria & Aynekulu (2011) findings in northern parts of Ethiopia the sand content was reduced after area exclosure but the clay and silt contents of soil were increased slightly when the age of exclosure increased. Temesgen *et al*. (2014) in Northern Ethiopia also conclude similar idea that sand content of the soil reduced by area exclosures practice while, silt and clay content was increased after the area is enclosed.

3.4.2. Soil pH

There was significant difference in pH across land uses and agro-ecologies ($p > 0.05$) (Appendix Table 2). However, not significant difference between soil depths. The highest pH recorded in lowland areas (6.9 - 8.4) followed by highland areas (6.6 -7.6) and mid-altitude (5.6 -7.6 (Figure 11).

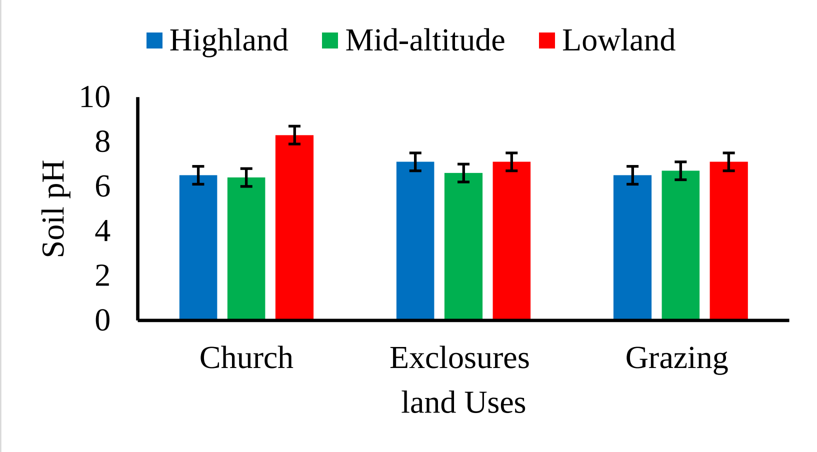

Figure 11. Soil pH in different soil depth and land uses.

Exclosures forest have high pH than others in highland areas. This is supported by Mekuria *et al*. (2017) at which after 7 years exclosures soil pH increases 6 to 7.3. This idea is disproved by Endale (2016) that, closed area have lower pH than open grazing land, this is because vegetation cover. Vegetation cover allows litter decomposition, which will lead to high infiltration because of improved soil organic matter and physical characteristics. These leached bases percolate down deep in to the soil and the top soil remains acidic and the pH become lower. However, high pH up to 8.4 recorded in churches having good vegetation cover at lowland areas. This is because of the presence of buffering compounds such as carbonates. Based on Gomez (2016), at which carbonate compounds increases the soil pH to 8.5. This is why in high vegetation cover areas, there is high organic carbon having negative charges. This negative charges attract the positive cations (basic compounds) like calcium and then make carbonate compound.

Based on Alemu and Tekaligni (2016) soil critical value, the soil pH at church forest, exclosures, and open grazing land is almost neutral at which pH range from 6.8 to 7.3. Therefore, there is no soil pH change with area exclosures in all agro-ecologies. This is may be due to the age of exclosures. May be it needs more time to moderate soil pH. Vogt *et al*. (2015) proven three soil pH ranges. These are a $pH < 4$ indicates the presence of free acids, generally from oxidation of sulfides; a $pH < 5.5$ suggests the likely occurrence of exchangeable Al; and a pH from 7.8 to 8.2 indicates the presence of $CaCO_3$. Based on this our result have on under the third (7.8 to 8.2) range i.e. the soil of the study areas ranged from neutral to slightly alkaline.

3.4.3. Soil Organic Carbon and Organic Matter

Church forests show significant difference ($p = 0.02$) in soil organic carbon and soil organic matter across depth in all agro-ecologies. There was significant difference in SOC between lands uses ($p = 0.003$) in all agro-ecologies (Appendix Table 2). The highest SOC recorded at church forest (0.58 – 2.9%) followed by exclosures (0.13 - 2.27%) and open grazing land (0.5 - 1.1%) (Figure 12).

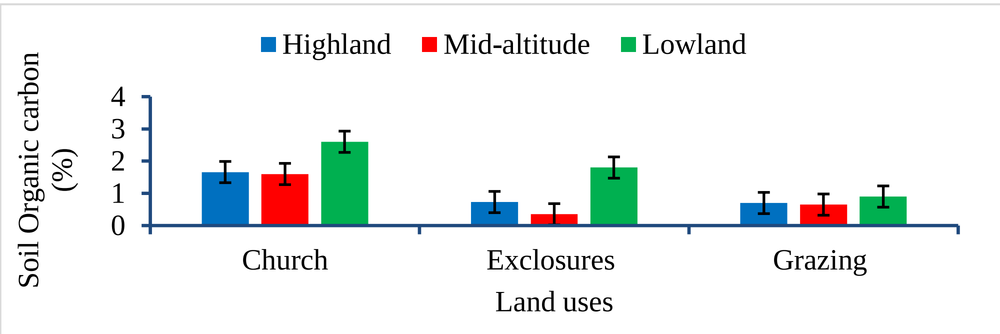

Figure 12. soil organic carbon in different soil depth and land uses.

Based on Abiy (2008) and Alemu and Tekaligni (2016) soil critical values, our SOC and SOM at church forest have medium organic carbon (2.1-4.2 %) at highland and mid-altitude areas but, high at lowland areas (4.3 to 5). Exclosures have low SOC and SOM in all agro-ecologies. Open grazing land have very low SOC and SOM in all agro ecologies. This shows exclosure have SOM and SOC contents, which is a transitional between church forest and open grazing land. Therefore, exclosure contributes for the development of soil organic matter important for soil fertility and soil biology. This idea is alike with Endale (2016) in West Hararghe Zone of Oromia that there is high soil organic carbon in exclosures. Thus, exclosure practice substitute the loss soil by erosion, overexploitation and aboveground biomass deduction by consequent grazing.

As Mekuria *et al*. (2007) soil organic matter increases with age of exclosures after exclosures in Northern Ethiopia. That means vegetation restoration lead biomass production increased and then the soil productivity increases. This idea is showed by Vogt *et al*. (2015) that, many soils specifically those under forest, have good organic soil materials at the surface (defined as containing > 20% organic carbon) called forest floor or litter fall. This why, the most recently deposited, relatively undecomposed foliage, twig, etc. on the surface. In general, SOM is a large and active component of the global carbon cycle, containing three times the carbon that is contained in terrestrial and twice the carbon that is contained in the atmosphere.

3.4.4. Soil Total Nitrogen

There was highly significant difference (p = 0.000) in Total Nitrogen (TN) between land uses and agro-ecologies (Appendix Table 2). Nevertheless, there was no significant difference of TN between soil depths in all agro-ecologies. The highest TN was recorded in highland followed by lowland and mid-altitude. In terms of land uses, church forest have high TN followed by exclosures and open grazing land (Figure 13).

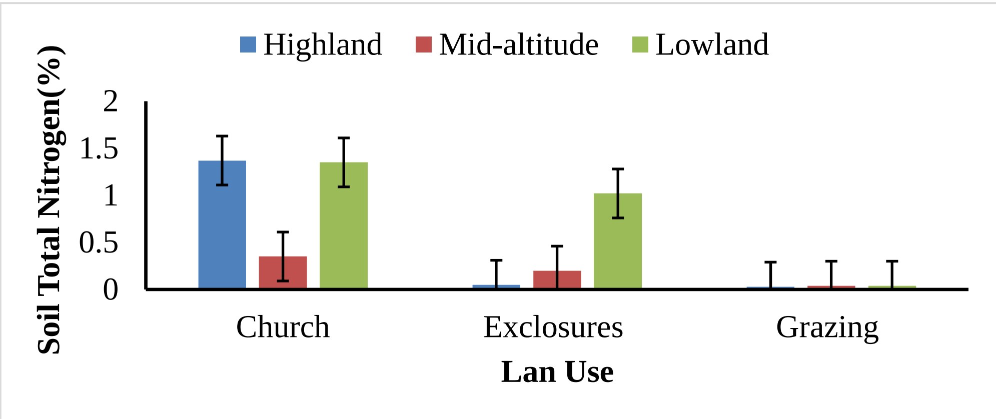

Figure 13. Soil total Nitrogen in different soil depth and land uses.

Based on Alemu and Tekaligni (2016) soil critical value, church forests have very high TN in highland and mid-altitude areas, but very high TN in lowland areas. On the other hand, exclosures have low TN in all agro-ecologies. Compared to church forest and exclosure, open grazing land have very low TN in all agro-ecologies. This shows that after exclosures there was Nitrogen fixation in the soil. This idea is similar with Endale (2016) that TN is increased slightly after exclosures. Thus, enclosed forest have TN in the intermediate of open grazing and church forests.

Mekuria *et al*. (2017) discussed that TN and SOC in the exclosures forest have no difference with open grazing land in 7 years exclosures in northern Ethiopia. This is why, regain of these type of element in the soil needs more time after area exclosure.

3.4.5. Available Phosphorus

There was no significant difference in available phosphorus (AvaP) across land uses and soil depth in all agro-ecologies. Nevertheless, there was significance difference in

AvaP across different agro-ecologies ($p < 0.05$) (Appendix Table 2). The highest AvaP recorded in in church forests (6.3 – 38.81 ppm) followed by exclosures (2.46 – 14.9 ppm) and open grazing lands (3.1 - 14.6 ppm). In terms of ago-ecology, highland areas had highest (4.36 – 38.81 ppm) followed by mid-altitude (3.22 – 24.6 ppm) and lowland areas (2.46 – 21.8 ppm) (Figure 14).

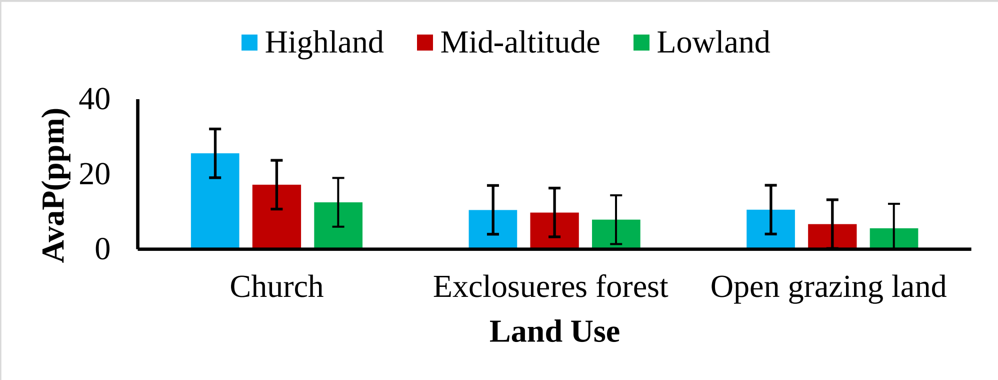

Figure 14. Soil available phosphorus in different soil depth and land uses.

Based on Alemu and Tekaligni (2016) soil critical value, AvaP (ppm) in church forest is low at highland, optimum at mid-altitude and very low in lowland areas. In exclosures, AvaP (ppm) is low in highland areas, very low in mid-altitude and lowland areas. Exclosures exhibited a trajectory of nutrient build from open grazing to church (reference) in soil restoration. This is similar to Descheemaeker *et al*. (2006) in northern highlands of Tigray the AvaP in enclosed forest (2.95 ppm) is increased from open grazing land (1.28 ppm) to church forests (10 ppm). However, according to Mekuria *et al*. (2017) when the area exclosures age increased there is high nutrient cycling then, AvaP decrease with soil and accumulates at the wood growing system.

Finally, the conceptual framework for Evaluation of forest landscape restoration was develop as (Figure 15).

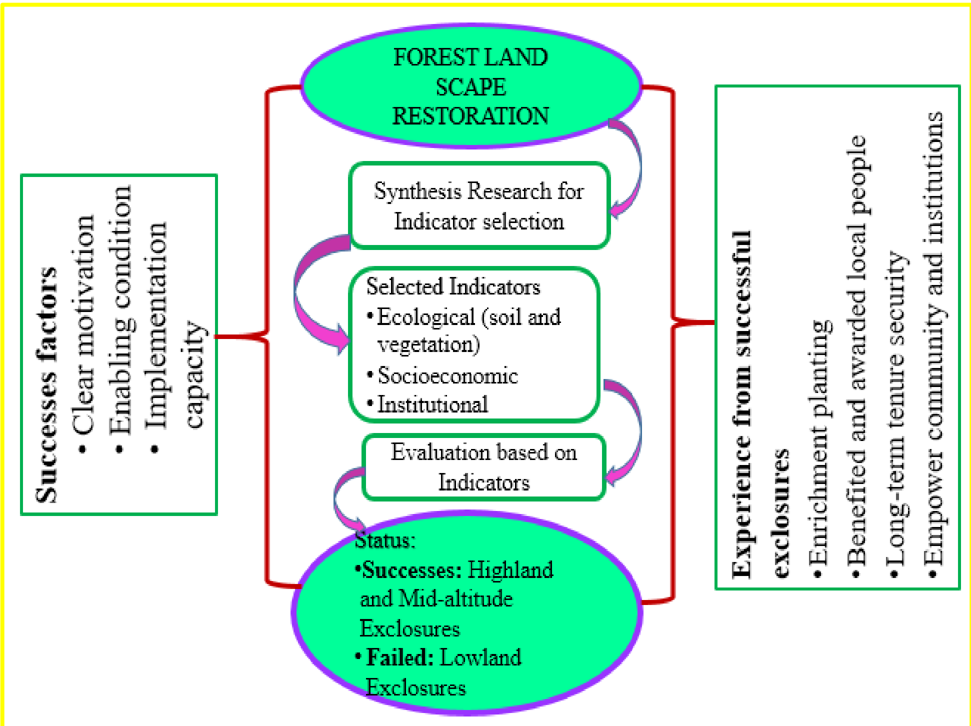

Figure 15. Conceptual framework for Forest Landscape Restoration.

4. Conclusion and Recommendation

Exclosure is a best strategy for increasing species diversity, number of stems, regeneration and biomass of a given degrade forest. This resulted in natural forest restoration. The exclosure also have species similarity in between church and open grazing land, as a trajectory from degraded grazing land to reference adjacent church forest. Thus, degraded and cleared forest starts succession; develop to its climax community and get-up-and-go to its former state after exclosures. This leads to the sustainable ecosystem goods and services for the community those their livelihood is depend on forest.

Exclosure improves soil nutrients after the area is exclude from livestock and human interferences. The soil nutrient improvement is because of litter fall, grass residue and herbaceous vegetation decomposition. This is why in exclosures livestock and fuelwood collectors do not collect and browse litter, grasses residue and herbaceous vegetation. The soil nutrients facilitate the trajectory of degraded and cleared forest to its former state as close as possible. Thus, exclosures practice substitute the loss soil by erosion, overexploitation and aboveground biomass deduction by consequent grazing.

In low land study area the natural regeneration was very low. Therefore, enrichment plantation with indigenous tree and shrub species is required. In all study areas, there is extreme disturbance during harvesting of grass for cut and carry grass at regeneration period. Thus, awareness should be given for user groups to care for regenerated seedlings. In mid-altitude study areas the local by-law have allowed to seasonal cropping. There is high regeneration loss by trampling of livestock enter in to the exclosures for farming practices. Therefore, the local by-law should be revised to limit the number of livestock and awareness should be given for user groups during farming period. Further research is required that for evaluation of restoration trajectory by establishing permanent plots for well understanding of forest succession after restoration intervention.

Area exclosure is the best strategy for soil reclamation and restoration for degraded areas of North Wollo and Waghemira zone degraded areas. It is very essential tool for recovery of soil and sustainable and integrated soil fertility management in degraded hill lands in in the areas where the lad is out of production or farming practices. Thus for sustainable and integrated soil fertility and other natural resources management area exclosure is a vital tool. Further research is required to understand soil dynamics at exclosure and trajectory of changes in soil property dynamics of the area exclosure by establishing permanent plot.

Appendix

Table A1. Vegetation compotation.

Land uses	Sites	Density [ha]	Richness	Woody Biomass [ton/ha]	LHG biomass [t/ha]	Diversity[H’]	Evenness	Dominance
Church forest	Highland	1440	11	184.5	2.3	2.04	0.3	0.8
	Mid-altitude	845	12	47.13	2.1	2.27	0.9	0.87
	Lowland	717	11	2594.8*	1.35	2.3	0.9	0.87
	Mean	**1001**	**11**	**942.14**	**1.9**	**2.2**	**0.7**	**0.84**
Exclosures	Highland	2265	14	31.7	1.96	1.2	0.2	0.43
	Mid-altitude	1660	7	12.3	1.42	1.73	0.8	0.78
	Lowland	2114	16	613.4	1.96	1.1	0.5	0.46
	Mean	**2013**	**12**	**219.1**	**1.76**	**1.34**	**0.5**	**0.55**
Open grazing land	Highland	152	5	8.7	0.57	0.8	0.2	0.45
	Mid-altitude	240	3	9.9	0.99	0.78	0.5	0.38
	Lowland	850	5	821.6	0.75	0.48	0.3	0.2
	Mean	**414**	**4**	**280.07**	**0.77**	**0.68**	**0.33**	**0.34**
Total Mean		1143	9	637.7	1.48	1.48	0.5	0.58
CV		32.3	30	13.8	27.9	26	32.8	41.37
LSD		694.4	5.08	1124	0.77	0.49	0.19	0.29
Significance [0.05]		**	*	*	**	**	*	*

NB: * Significant difference between land uses (p<0.05); ** Significant difference between land uses (p<0.01).

Table A2. soil chemical properties across different agro-ecologies, land uses and soil depth.

Agro-ecologies	Land use type	Depth	pH	OC[%]	OM[%]	TN[%]	AvaP [ppm]
Highland	Church	0-10 cm	6.1	1.28	2.2	1.55	22.4
		10-20 cm	6.6	1.78	3.01	1.39	19.39
		20-40 cm	6.7	1.92	3.31	1.17	21.81
	Exclosures	0-10 cm	6.6	0.84	1.44	0.06	14.9
		10-20 cm	7.1	0.66	1.3	0.05	14.55
		20-40 cm	7.6	0.69	1.2	0.04	10.23
	Grazing	0-10 cm	6.5	0.94	1.61	0.05	12.7
		10-20 cm	6.5	0.61	132	0.03	11.65
		20-40 cm	6.5	0.6	1.03	0.02	10.32
Mid-altitude	Church	0-10 cm	6.6	2.03	3.5	0.18	38.81
		10-20 cm	5.6	2.07	3.46	0.41	24.6
		20-40 cm	7.1	0.78	3.23	0.45	9.39
	Exclosures	0-10 cm	6.7	0.44	0.75	0.04	5.04
		10-20 cm	6.9	0.50	0.56	0.47	4.55
		20-40 cm	6.3	0.13	0.23	0.10	2.46
	Grazing	0-10 cm	5.6	0.50	0.86	0.05	4.36
		10-20 cm	6.8	0.51	0.87	0.04	3.22
		20-40 cm	7.6	0.95	0.83	0.04	3.43
Lowland	Church	0-10 cm	8.2	2.06	3.55	1.01	15.48
		10-20 cm	8.3	2.90	5.00	1.50	7.54
		20-40 cm	8.4	2.83	4.88	1.54	6.33
	Exclosures	0-10 cm	6.9	2.27	3.91	1.44	11.53
		10-20 cm	7.2	1.53	2.64	0.83	10.44
		20-40 cm	7.3	1.73	2.98	0.78	10.92
	Grazing	0-10 cm	6.9	0.85	1.47	0.04	14.59
		10-20 cm	7.2	1.1	1.48	0.05	5.2
		20-40 cm	7.1	0.75	1.46	0.03	3.1
	Mean		6.92	1.23	6.99	0.49	11.813
	CV		8.6	26.2	13.15	32.8	31.7
	LSD		1.04	0.92	1.6	0.52	16.2
	Significance[0.05]		*	*	*	**	*

Table A3. Soil texture across different agro-ecologies, land uses and soil depth.

Agro-ecology	land use	Depth (cm)	Sand (%)	Clay (%)	Silt (%)	Texture classes
Highland	church	0-10	80	6	14	loamy sand
		10-20cm	84	4	12	loamy sand
		20-40	84	6	10	loamy sand
	exclosures	0-10	86	6	8	loamy sand
		10-20cm	84	6	10	loamy sand
		20-40	84	6	10	loamy sand
	grazing land	0-10	87	4	9	loamy sand
		10-20cm	86	4	10	loamy sand
		20-40	86	4	10	loamy sand
Mid-altitude	church	0-10	76	6	18	Sandy loam
		10-20cm	76	6	18	Sandy loam
		20-40	72	10	18	Sandy loam
	exclosures	0-10	90	6	4	sandy
		10-20cm	92	4	4	sand
		20-40	92	4	4	sandy
	grazing land	0-10	89	4	7	Sandy
		10-20cm	87	2	11	sandy
		20-40	89	4	7	loamy sand

Lowland	church	0-10	82	6	12	loamy sand
		10-20cm	82	8	10	loamy sand
		20-40	80	10	10	Sandy loam
	exclosures	0-10	90	8	2	sand
		10-20cm	82	8	10	loamy sand
		20-40	87	6	7	loamy sand
	grazing land	0-10	93	6	1	sandy
		10-20cm	90	5	5	sandy
		20-40	88	6	5	sandy

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