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Research Article

Does Selective Logging Have Impact on Abundance and Above Ground Biomass of Woody Species in Yechi Forest? In case Essera District Dawro Zone South West Ethiopia

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ABSTRACT

In the Essera district, selective logging is used to extract wood, particularly in the naturally high forests. Selective logging has been defined as a harvesting method used primarily in native forests and hardwood plantations where a few desired and economically valuable tree species are harvested in accordance with predetermined criteria as opposed to clear cutting, where a whole forest compartment is completely clear-cut in the harvesting process. The purpose of the study was to evaluate the effects of selective logging on woody species' abundance and above-ground biomass in the Yechi Forest, Essera District, and Dawro Zone of south-western Ethiopia. To estimate the above and belowground biomass/carbon, a non-destructive approach which involves the use of allomoteric models was used. The popular allomotric equation of Chave etal. (2014) was used in this study to determine the biomass of tree species having ≥ 5 cm DBH as it fits to biophysical conditions of the study area. The model: AGB= 0.0673 × (ρD^2H) ^0.976. 3.51 Mg ha-1 of harvested above-ground biomass, or 0.83 trees per hectare, was taken from the research forest. In terms of species, Cordia africana was the most heavily harvested species (0.53 tree ha-1, or 68.08% of all trees collected). Additionally, it represented 58.4% of all the aboveground biomass that was harvested per hectare. The second most frequently encountered tree species was Syzygium guineense (18.3% of all trees and 0.14 tree ha-1). The Shannon-Wiener Diversity (H') Index and the average evenness values for the total forest were 2.1 and 0.50, respectively. These results suggest that the study forest has low diversity and a less even representation of all the species found in the analyzed quadrants. Government must support alternative energy and building material sources. Establishing programs, such as participatory forest management, to help local communities feel more ownership over their environment and reduce the negative effects of human activity.

Key word: Above ground biomass, Abundance, Forest, Woody Species

INTRODUCTION

The main causes of carbon emissions from developing nations, which account for 15-20% of global carbon emissions, include deforestation, forest degradation, and land use change (LUC) (Kannaninen *et al.*, 2010; Angelsen, 2008; UNFCCC, 2009). The principal causes of changes in Earth's environmental circumstances and the planet's climate are the rising atmospheric concentrations of carbon dioxide (CO2) and other greenhouse gases (GHG) (IPCC, 1990).

The international community has been working harder since the early 1990s to mitigate and adapt to the effects of climate change. While adaptation efforts are focused on reducing environmental vulnerability or boosting the environment's resilience to deal with future global climatic conditions, mitigation efforts are those that aim to reduce the concentrations of carbon dioxide and other GHGs in the atmosphere (Kanninen, 2012).

The COP15 in Copenhagen in December 2009 recognized the critical importance of reducing emissions from deforestation and forest degradation and the need to strengthen the role of forests in the removal of greenhouse gases from the atmosphere. They called for the immediate establishment of the REDD+ mechanism (Reduced Emissions due to Deforestation and Forest Degradation and the role of Sustainable Management, Conservation, and the Enhancement of C.

The current international REDD+ mechanism global climate change mitigation initiative) , sustainable forest management planning, conservation planning, economic development, improvement of local and global ecological models require the efficient assessment of the causes of deforestation and forest degradation (Carlos Souza *et al.,* 2002, Souza and Roberts, 2005). The effective implementation of any climate change mitigation initiative in developing countries requires that there should be a constant assessment and monitoring of deforestation, forest degradation, and land use change. This entails an understanding of: (i) the aerial extent of deforestation and forest degradation, (ii) the proportion of forest biomass loss in deforestation and forest degradation, (iii) the location where deforestation or forest degradation is occurring, and (iv) the carbon content of each forest type in metric tons of carbon per hectare (Kanninen *et al.*, 2007, Ramankutty *et al.*, 2007, Olander *et al.*, 2008, Baldauf *et al.,* 2009).

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Selective Logging

Wood harvesting in Essera district, especially in natural high forests is carried out through a selective logging process. Selective logging has been described as a harvesting system practiced mainly in native forests and in hardwood plantations where a few desired and commercially valuable trees species are harvested following a predefined criteria as opposed to clear cutting where a whole forest compartment is completely clear-cut in the harvesting process. Selective harvesting is said to remove only a portion of the standing trees leaving a viable forest for natural regeneration and growth.

The management plan defines the species to be harvested, the minimum exploitable diameter for each species which guarantees that at least 50% of the harvested tree species is able to reconstitute during the next rotation cycle, the quantity of wood to be harvested in terms of number of trees and volumes, the logging sequence for a 30 year rotation cycle and many other forest management obligations. Above-ground biomass is the carbon pool that is most affected by selective logging activities and is also one of the six carbon pools that has been recommended for investigation in the IPCC 2006 guidelines. The activities which affect above-ground biomass during selective logging include: (i) the biomass that is taken out through the trees that are harvested (ii) the construction of logging roads and log yards and (iii) residual damage caused to the surrounding vegetation by tree fall and machinery maneuvering (Vincent Medjibe *et al*., 2011, Durrieu de Madron *et al*., 2011).

Research Objectives

The main objective of this study was to assess the Impacts of Selective Logging on Abundance and Above Ground Biomass of Woody Species in Yechi Forest Essera District Dawro Zone South West Ethiopia.

The specific objectives of the study were:

- To quantify above-ground biomass affected by selective logging activities in the study site,
- To investigate woody species that is the most victims to selective logging,
- To investigate the reason why selective logging is undergone in study forest
- To assess the impacts of selective logging on abundance of woody species in study forest

The main research questions were:

1. What quantity of above–ground biomass is affected by the following selective logging activities? (i) Logging for construction, (ii) logging for timber production, (iii) logging for charcoal, (EVI) logging for fuel wood
2. What are the woody species that are strongly affected by selective logging?
3. Why is selective logging undergone in study forest?
4. What are impacts of selective logging on distribution of woods plant species?

METHODOLOGY

Description of Study Area

Dawuro is one of the 13 zones in SNNPR. It is situated 7^o 14' North latitude and 37^o 5' East longitude. The Zone has 5 districts (w*oredas)*: Loma, Mareka, Essera, Gena Bosa and Tocha, its capital, is located about 438 kilometers south West of Addis Ababa. Essera district, which is purposefully selected for study, is rich in forest resource. Essera districts lies in three agro- ecological regions: *Kola* region which is within 500-1500 meters above sea level (masl) and receives 500-1,500milimeters (mm) of rainfall; *Woyina Dega*within 1501-2500 masl and receives 1281501-2500 mm; and *Dega* at above 2500 m.a.s.l and receives more than 2500 mm (Zeleke, 2014).

Figure 1 indicates the map of study forest called Yechi forest found in Dawro zone Essera district of South Western Ethiopia which is natural forest and now being attacked by selective logging of currently valuable tree species.

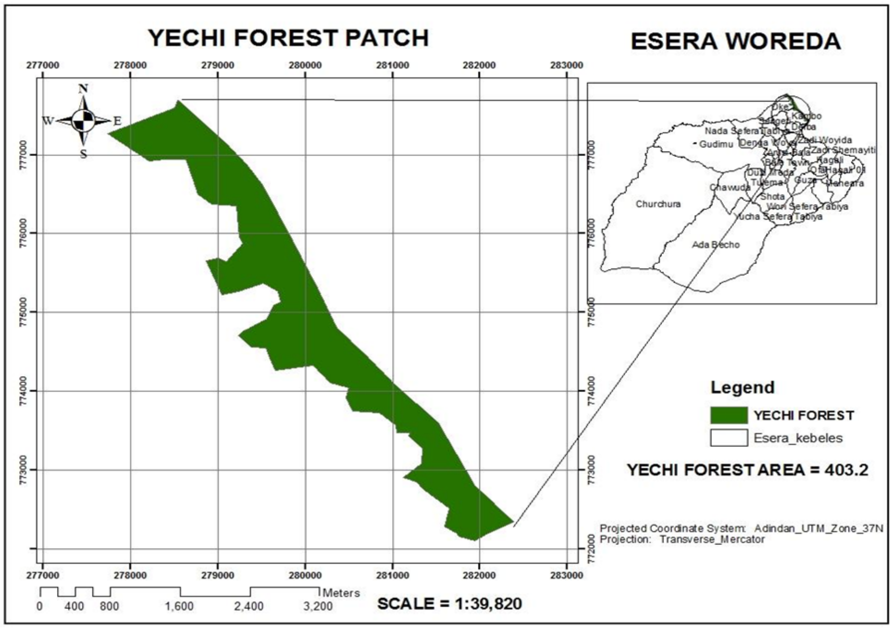

Figure 1. Map of Study Forest

Data collection

The data which was collected in the field include: forest exploitation inventory data which was used for calculating above-ground biomass of the selectively logged trees species, the location and distribution which were used to assess the quantity of above-ground biomass affected by the former and the later.

The forest exploitation inventory data was obtained from the Forest Management sector of Forest and Environmental protection office of Dawro zone and Essera district.

This data comprised two phases of inventory data: an initial inventory of all principal selectively logged tree species at exploitable diameter found in AAC 3-4 and a second inventory comprising only the trees that were effectively logged in AAC 3-4 in 2011. The minimum exploitable diameter is different for different tree species in Dawro.

The average exploitable diameter for the different tree species in this study (based on the forest exploitation inventory data) are summarized on table below. According to forest data sources, the initial inventory was carried out using the services of a consultant and the final inventory was conducted by an internally constituted team.

Both datasets were collected through a systematic inventory of 61 counting blocks of 1000 m x 1000 m. The blocks were further divided into 250 m x 1000m sub plots or counting units. However, due to the irregular form of the study site, some peripheral blocks did not have the standard dimensions, resulting in blocks which had sizes that were smaller than the standard block size. Therefore, the counting block sizes varied from 1-100 ha.

The initial inventory was carried out in December 2021 while the final inventory was conducted between January and July 2022.

The data comprised of a systematic recording of all the selectively tree species based on the minimum exploitable diameter of each species. The information recorded on the field data sheets included the DBH of the trees, the tree identification information (mostly common names of the trees and an assigned inventory code), and the bole quality class. The relative location of the individual trees were positioned on a field sketch maps on which other biophysical characteristics of the forest were also indicated.

Processing of forest inventory data

The forest exploitation inventory data was converted into a digital format dataset by geo-localizing (positioning the trees on their relative field locations) using ArcGIS21 software. Geo-localization of the data was carried out through on-screening digitizing, using the field data sheets and field sketched inventory maps as support documents. The dataset was then attributed based on information presented on the field data sheets.

Quantification of above- ground biomass of the selectively logged tree species

The forest exploitation inventory data as described result section was used to calculate the above-ground biomass of the trees inventoried in the study area.

The parameters found in the datasets that were useful for calculating above-ground biomass were the tree species names and the diameter at breast height (DBH) of the individual trees. Above-ground biomass was estimated through the use of species specific allometric equations. The equations were computed in MS excel and the volumes of the individual trees calculated accordingly. The calculated tree volumes were then used alongside the species specific wood densities of the different tree species to calculate the above-ground biomass of the individual trees. The general biomass equation for moist tropical rainforest developed by Chave et al. (2005) was used for tree species whose species specific allometric equations could not be located.

To estimate the above and belowground biomass/carbon, a non-destructive approach which involves the use of allomoteric models was used. The popular allometric equation of Chave etal. (2014) was used in this study to determine the biomass of tree species having ≥ 5 cm DBH as it fits to biophysical conditions of the study area.

The model:

AGB= 0.0673 × (ρD^2H) ^0.976

Where, AGB – aboveground biomass (kg),
H– Height of tree (m),
D– Diameter (cm) at breast height (1.3m), and
ρ– Wood density (t/m^3), the African trees average wood density values (0.58 ton/m^3) (Brown *et al*., 1997).

The tree biomass was converted into C by multiplying the above ground tree biomass by 0.5 (Brown, 2002).

AGC = AGB X 0.5

Where, AGC – Aboveground carbon

The allometric equations used for volume estimation was extracted from (Henry *et al*., 2011). The equations were selected according to the following criteria: for each species, the first consideration was given to allometric equations that was developed using data collected in study forest.

The third and final option is then to use the general biomass equation for moist tropical rainforest developed by (Chave *et al*., 2005) in the cases the equations were unavailable based on the first two criteria.

The equations selected were also equations that use DBH as the only input parameters since that were the only available parameter in the forest exploitation inventory data that could be used for this purpose.

The species specific wood density values were used in the study were extracted from the databases of FAO and the World Agroforestry Center which are available on the respective web pages of these organizations that were accessed on 23/10/2021 at:
http://www.fao.org/docrep/w4095e/w4095e0c.htm, http://www.worldagroforestry.org/sea/Products/AFDbases/WD/asps/DisplayDetail.

Survey Data

To assess the reason why selective logging taking place and for in-depth data to triangulate information gathered by other sources observation, key informants interview, focus group discussion and semi-structured questionnaires were applied.

Sample size

The original sample size for the study was 61 plots with a plot size range from 1-100 ha. However, from data exploration activities, it was realized that outliers and leverages observed in the datasets were resulting from sample plots that were less than 30 ha in size.

Statistical analysis

Statistical analyses were carried out using IBM SPSS Statistic 20.

The datasets were first explored and checked for any possible abnormalities (outliers and leverages). They were further analyzed to ensure that the data fulfilled the different assumptions for the linear regression analysis.

RESULT AND DISCUSSION

Above-ground biomass logged

The results indicated that 0.83 trees were logged per hectare, representing about 3.51 Mg ha-1of above-ground biomass harvested. Species wise, *Cordia africana* was the species that was highly harvested (68.08% of all the trees harvested and 0.53 tree ha^{-1}). It also accounted for about 58.4% of the total above-ground biomass logged per hectare. *Syzygium guineense* was the second highest tree species logged (18.3% of the trees logged and 0.14 tree ha^{-1}). It accounted for 31.1% of the total above-ground biomass harvested (see table below).As result indicated, 0.83 trees were logged per hectare and the total measured impact of selective logging on above-ground biomass was (3%), indicating that 97% of above-ground biomass is unaffected by selective logging activities. This leads to the conclusion that selective logging activities were observed to have a low impact on above-ground biomass in the study area.

In study forest, the harvesting of above-ground biomass was differ as species desirability (Table 1). For instance *Cordia africana* is highly desired tree species for timber production and its above ground biomass harvesting very high followed by *Syzygium guineense.*

Table 1. The synthesis of above-ground biomass harvested by species

Species	DME average	Tree count	%	Count ha^{-1}	AGB ha^{-1}	% AGB ha $^{-1}$
Prunus africana	108	9	0.26	0.002	0.012	0.3
Cordia africana	120	2346	68.08	0.533	2.049	58.4
Schefflera abyssinica	103	37	1.07	0.008	0.077	2.2
Syzygium guineense	110	632	18.34	0.144	1.092	31.1
Pouteria altissima	79	14	0.41	0.003	0.023	0.7
Erythrina abyssinica	78	92	2.67	0.021	0.089	2.5
Podocarphus falcatus	105	2	0.6	0.00	0.004	0.1
Dracaena steudneri	86	26	0.75	0.006	0.022	0.6
Croton macrostachyus	43	3	0.09	0.001	0.001	0.0
Juniperus procera	115	6	0.17	0.001	0.012	0.3
Hagenia abyssinica	80	109	3.16	0.025	0.029	0.8
Phoenix reclinata	58	106	3.08	0.024	0.051	1.4
Ficus sycomorus	63	3	0.09	0.001	0.002	0.1
Ficus vasta	78	61	1.77	0.014	0.046	1.3
Total	-	3446	100	0.783	3.51	100

AGB= Above-ground biomass (Mg ha^{-1}), DME average = Average diameter exploited per species, # of trees = total number of trees logged.

The Reasons of Selective Logging (Table 2)

Table 2. Reasons of Selective logging

No	Reasons of Selective logging	Response rate										
		Strongly disagree (1)		Disagree (2)		Neutral (3)		Agree (4)		Strongly Agree (5)		Mean
		Fr.	%	Fr.	%	Fr	%	Fr.	%	Fr.	%	
1	For timber production	15	7	29	12	0	0	64	29.7	117	54.3	3.84
2	For construction material	0	0	22	10	13	6	108	50.3	79	36.7	3.52
3	For firewood	15	7	13	6	0	0	97	45.2	90	41.8	3.40
4	For charcoal production	22	10	13	6	0	0	67	32.4	111	51.6	3.38
5	Others	29	12	0	0	0	0	64	29.7	117	54.3	3.21
		Weighted Mean = 3.193										

Source: Own survey, 2021

As the table 2 above shows, in the study area there were various reasons why selective logging is undergone on selected desirable woody plant species of the study forest. As the result indicated of respondents strongly agreed that timber production is for the first cause with the highest mean (3.84), of the respondents agreed that harvesting construction material which was the second influential factor with mean 3.52, followed by fire wood with mean of 3.4, the following factor that respondents strongly agreed was charcoal production with mean value 3.38, the next influential factor was that the respondents strongly agreed that there are other factors like felling tree to harvest fodder, to make local bee hive, for fencing materials whose mean was 3.21.

The Impacts of Selective Logging on Abundance of Woody Species

A total of 62 woody species belonging to 50 genera and 31 families were identified. Among the families, Moraceae is the most abundant with seven species followed by Fabaceae with 6 species, Myrtaceae with 5 species and Ficus was the most widely abundant Genus.

In Essera Forest among the identified species 58 (93.5%) were native and 4 (6.5%) were exotic (*Eucalyptus camaldulensis, Eucalyptus glubulus, Melia azedarach* and *Grevillea robusta)*. The recorded species were composed of 66% trees, 13% shrubs, and 21% lianas. Size of each sample was 20m by 20m which was 400m^2 and the study was conducted a total of 90 sample plots. Therefore, a total area of sample plot was 400m^2*90=36000m^2=3.6 hectare. Figure 2 indicated the proportion of the Vegetation of the Yechi Forest and tree part has lion share which is 66%.

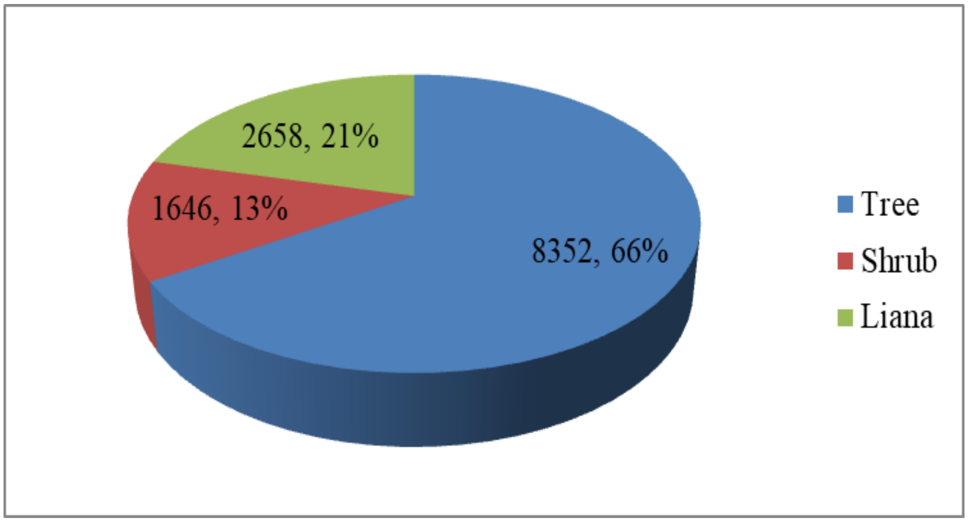

Figure 2. Proportion of the Vegetation of the Yechi Forest

Species Richness and Evenness of Woody Plant Species of Essera Forest

Species richness is the number of different species present in an area. In study forest a total of 59 woody species were recorded. Shannon Diversity Index (H') of Yechi forest was 2.1. Where, EH= Equitability (evenness) index which has values between 0 (a situation in which the abundance of all species are completely disproportional) and 1 (all species are equally abundant) and S = number of species/plot area.

The overall average Shannon-Wiener Diversity (H`) Index and the average evenness values for the entire forest were 2.1 and 0.50, respectively implying that the study forest is with low diversity and less even representation of individuals of all species encountered in the studied quadrants.

CONCLUSION AND RECOMMENDATION

The results indicated that 0.83 trees were logged per hectare, representing about 3.51 Mg ha-1of above-ground biomass harvested. Species wise, *Cordia africana* was the species that was highly harvested (68.08% of all the trees harvested and 0.53 tree ha^{-1}). It also accounted for about 58.4% of the total above-ground biomass logged per hectare. *Syzygium guineense* was the second highest tree species logged (18.3% of the trees logged and 0.14 tree ha^{-1}).

Timber production, constructional materials harvesting, fire wood collection charcoal production, and other activities like tradition bee hive making and materials for fence were very reasons why selective logging is taking place in study forest.

In Yechi forest, 0.83 trees were logged per hectare and the total measured impact of selective logging on above-ground biomass was (3%), indicating that 97% of above-ground biomass is unaffected by selective logging activities. This leads to the conclusion that selective logging activities were observed to have a low impact on above-ground biomass in the study area.

The overall average Shannon-Wiener Diversity (H`) Index and the average evenness values for the entire forest were 2.1 and 0.50, respectively implying that the study forest is with low diversity and less even representation of individuals of all species encountered in the studied quadrants.

The government and its institutions should play their pivotal roles and responsibilities in strengthening as well as in correcting the gaps and in creating integrated mechanisms at national, regional and local levels for conservation and sustainable use of forest resources.

Alternative sources of energy and construction material must be facilitated by government.

Creating mechanisms such as participatory forest management by which human impacts can be minimized through discussion and consultation with the local communities to make the sense of ownership.

Data Availability

The data used are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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