POPULATION STRUCTURE AND REGENERATION OF *POUTERIA ADOLFI-FRIEDERICII* TREE SPECIES IN MOIST EVERGREEN AFROMONTANE FORESTS OF SOUTH WEST ETHIOPIA

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ABSTRACT: Knowledge of tree population structure and regeneration status is very important to understand the reproductive and recruitment potential of selected indigenous tree species. The aim of this study was to investigate the population structure and regeneration status of *Pouteria adolfi-friedericii*. The study was conducted in four natural forests of Yayu, Bonga, Bebeka, and Masha, in south western Ethiopia. A systematic sampling method was used to collect vegetation data. Ten transects of 160 m length were laid out in each forest at 100 m interval along the slope gradient and quadrats (size: 20 m×20 m each) were laid at 50 m interval along each transect line. A total 120 quadrats were used for vegetation data collection. Sub quadrats (size: 5 m×5 m each) were established at four corners and in the center of each main quadrat to collect data on regeneration. From each main quadrat, the DBH and total height of the species were measured by using a diameter tape and clinometer, respectively. The size class distribution of the species showed irregular patterns across the forests. The regeneration status of *P. adolfi-friedericii* is "good" in Masha and Bebeka, and "fair" in Bonga and Yayu forests. The population structure of the species varied across the inventoried forest sites.

Keywords*:* Population structure, *Pouteria adolfi-friedericii*, Regeneration, Seed production

INTRODUCTION

Native trees in tropical forests, are severely affected by a complex set of causes. Anthropogenic activities have been modifying tropical forest land cover for food and energy production (Takahashi et al., 2017). Indigenous tree species population are declining from their natural ranges, especially for non-industrial plantations, and there has been little attention devoted to the practice and domestication of such tree species (Nichols et al., 2006).

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Ethiopia has a wide variety of natural conditions that resulted in the existence of heterogeneous flora and fauna, which made the country one of the major centers for biodiversity (Woldemariam, 2003; Alemayehu et al., 2005). The southwestern part of Ethiopia is covered by moist, evergreen montane forests and has a high concentration of native tree species important in providing timber and non-timber products of the forest (Chilalo and Wiersum, 2011; Senbeta, 2014). The moist forest ecosystem is the most diverse ecosystem in composition, structure and habitat types consequently it is rich in biodiversity with a number of endemic species. Some of the characteristic plant species of the forests include; *Pouteria adolfi-friedericii, Albizia gummifera, Prunus africana, A. schimperina, Blighia unijugata, Cassipourea malosana, Celtis africana, Croton macrostachyus, Ekebergia capensis, Euphorbia ampliphylla, Ficus sur, Ilex mitis, Macaranga capensis, Olea capensis ssp. welwitschii, Polyscias fulva, Schefflera abyssinica, Sapium ellipticum, and Syzygium guineense ssp. Afromontanum* (Friis, 2010).

The existing knowledge on the extent of the montane moist forest ecosystem is limited though there are studies on the composition and structure some forest vegetation that exist in this ecosystem (Woldu et al., 1989; Yeshitila, 1997). The moist evergreen montane forest consists of high forests of the country mainly the south west forests. At any site, the plant diversity is influenced by species abundance and distribution patterns (Palit et al., 2012). Species wise, some studies have been conducted to investigate the population dynamics of the montane moist forest of Ethiopia (Hadera, 2000; Tesfaye et al., 2019, Tadesse et al., 2023). *Pouteria adolfi-friedericii* is among the timber tree species found in moist evergreen Afromontane forests within altitudinal range of 1350 – 2450 m.a.s.l in Ethiopia (Hedberg et al., 2003). It is usually found in areas of high-rainfall and commonly found in the Illubabor, Kafa, and Bench-Maji zones (Bekele, 2007). For this study, *P. adolfi-friedericii* was selected because of its high wood quality and economical importance. In the selected study sites, the species is highly exploited by farmers' and loggers for domestic use and trade, without any consideration of its future sustainability. Hence, due to heavy exploitation, this tree species is at risk in Ethiopia. The objectives of this research were to compare the population of *P. adolfi-friedericii*

based on their abundance, regeneration status and reproductive phenology in the selected study sites to establish seed production area and investigate the population structure and natural regeneration status of *P. adolfi-friedericii* in southwestern forests.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Bonga, Bebeka, Masha and Yayu natural forests of south western Ethiopia. Bonga forest is located in the in Kafa zone; Masha Forest is situated Sheka zone and Bebeka forest in the Bench Maji zone of the Southern Nations, Nationalities and Peoples Regional State (SNNPRS). Yayu forest, on the other hand, is located in the Illubabor zone of the Oromia National Regional State (Figure 1).

Bonga forest lies between 7º00' –7º25'N latitude and 35º55'-36º37' E, at altitudes between 1000 - 3400 m.a.s.l. The average annual temperature in Bonga is around 19°C, with the warmest month being March (average temperature of 21.3°C) and the coldest month being August (average temperature of 16.5°C). The average annual rainfall in Bonga is about 1,400 mm, with the rainy season occurring from March to September.

Masha forest is located in the geographic range of 7°24′–7°52′N latitude and 35°13′–35°35′E longitude with altitudinal range between 1700 -3000 m.a.s.l. The average annual temperature in Masha is around 14°C, with the warmest month being March (mean temperature of 15.9°C) and the coolest month being August (average temperature of 12.3°C). The average annual rainfall in Masha is about 2,400 mm, with the rainy season lasting from March to October.

The Bebeka forest is located within 07°16' N and 36°15' E longitude with an altitudinal range of 1000 - 1350 m.a.s.l. The average annual temperature in Bebeka is around 25°C, with the warmest month being March (average temperature of 26.8°C) and the coolest month being August (average temperature of 23°C).

Yayu forest is lies between 8°21'–8° 26' N latitude and 35°45'–36°3' E longitude with an altitudinal range of 1200 -2000 m. a.s.l. The average annual temperature in Yayu is around 16°C, with the warmest month

being March (average temperature of 18.1°C) and the coolest month being August (average temperature of 14.1°C). The average annual rainfall in Yayu is about 2,100 mm, with the rainy season occurring from March to October.

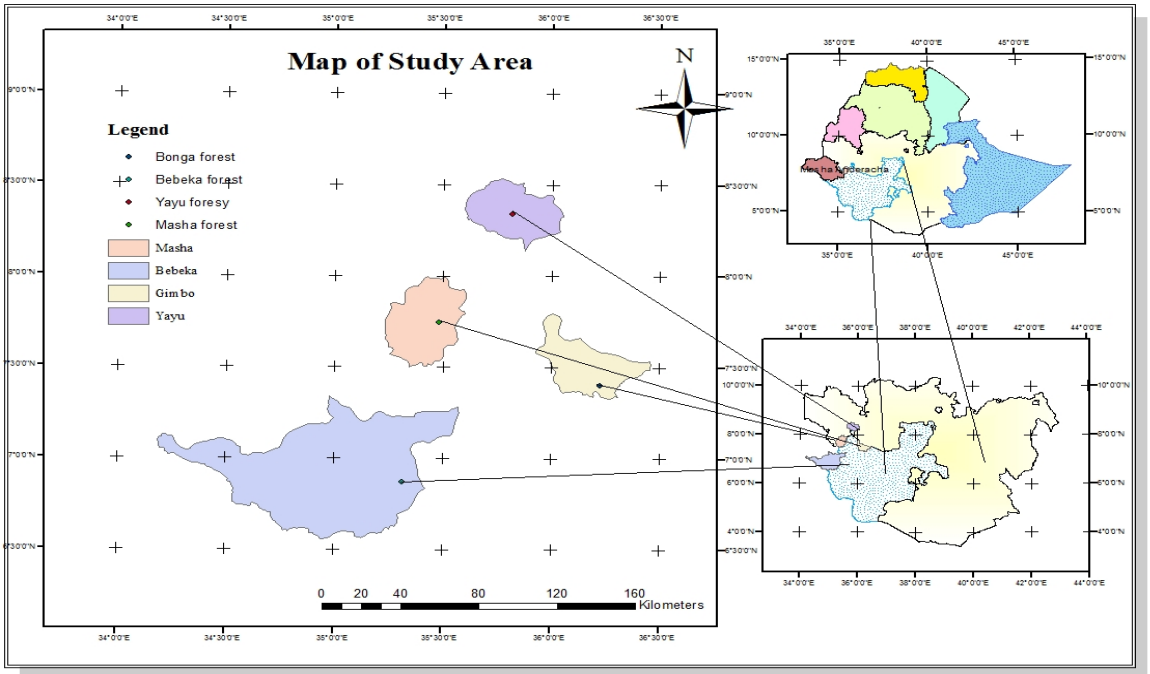

Figure 1. Map of the study area

Soil property

The soils of the study area vary in color and type depending on the topography and types of the parent materials. Most parts of the southwestern Ethiopia is dominated by Cenozoic and Proterozoic volcanic sediments (Schlüter, 2008). In Bonga, the soil is characterized as deep red to brown red, lateritic loams or clay loams of volcanic origin with high or medium fertility (Schmitt, 2006). Whereas the commonly observed soils in Masha vary in color from black to red. Nitisols, Vertisols, Fluvisols and Cambisols are the dominant soils types in the area. The dominant soil type in Yayu Forest is Nitisols. These types of soils are deep, reddish-brown and clayey with relatively high organic matter content. Nitisols have a crumb and/or sub-angular structure and well drained. The soils of Bebeka forest are sandy loam, moderately drained and reddish soil with 15-20 cm thick litter and humus.

Sampling Design

Population structure

The selection of the natural forests of the study was made after considering the potential of the populations of the species studied and taking into account previous field research experience, relevant literature reviews and input from experts and community leaders in the relevant woredas and farmer associations. In addition, a reconnaissance survey was conducted to determine the representative habitats of the research area, the spacing between transect lines, and the location of plots along each line. Ten transect lines were constructed every 100 m along the slope using a systematic sampling technique to collect vegetation data.

Sample quadrats of 400 m^2 (20 m×20 m) each for tree and sapling were laid out at each 50 m interval in each transect line. In each main quadrat, sub quadrat of 25 m^2 (5 m×5 m) for seedling of the target tree species were laid out at four corners and in the center. A total of 120 (30 quadrats for each site) were sampled for *P. adolfi-friedericii* at the Bonga (Adela site), Masha (Gorashewi site), Yayu (Durani site), and Bebeka (Duduka site). The target species was not found in all surveyed areas, possibly due to altitude and other ecological conditions.

Data Analysis

Population structure

Both height and DBH data of the species were entered, cleaned, organized and summarized in Microsoft Excel and SPSS software. Nine DBH classes (i.e., <10cm, 10.1 - 20 cm, 20.1 - 30 cm, 30.1 - 40 cm, 40.1 - 50 cm, 50.1 - 60 cm, 60.1 - 70 cm, 70.1 - 80 cm, >80 cm) were established based on the DBH size ranges measured for the species.

Basal area (BA) was calculated using the formula:

Basal area = $(A) = \pi r^2$; where, π=3.14

Density estimates obtained from transects were used to calculate the number of individuals of the species in the study area. It was a count of the number of individuals of the species within the quadrat on hectare

basis (Kent and Coker, 1992). Afterwards, the sum of individuals of the species was calculated and analyzed in terms of species density per hectare.

$$\text{D (density)} = \frac{\text{number of stems of species counted}}{\text{sample area}}$$

Individual trees having height ≥ 2 m and DBH ≥10 cm within sampling quadrats were collected and analyzed by classifying into seven height classes (2 -10 m, 10.1 - 19 m, 19.1 - 28 m, 28.1 - 37 m, 37.1 - 46 m, 46.1 - 55 m, >55 m). Population structure was summarized using histograms of diameter size classes. ANOVA was used to test for difference in basal area, DBH, height and number of individuals per hectare among forests.

Regeneration

The regeneration status of *P. adolfi-friedericii* in each forest habitat was analyzed by comparing the population density of seedling, sapling and matured trees (Dhaulkhandi et al., 2008 ; Gebrehiwot and Hundera, 2014) as follows: 1)"good" regeneration, if density of seedling > sapling > mature tree; 2)"fair" regeneration, if density of seedling > sapling < mature tree; 3)"poor" regeneration, if a species survives only in the sapling stage, but not as seedlings; 4)"none", if a species is absent both in sapling and seedling stages, but present as mature; and 5)"new", if a species has no mature, but only sapling and/or seedling stages. All forests were compared in terms of their regeneration status and the best forest habitat was recommended for seed production.

RESULTS

Population Structure

DBH, Density and Basal area

A total of 142 individuals of *P. adolfi-friedericii* were recorded in 56 plots out of 120 plots in sampled forests. Out of 30 plots in each site, in Adela site (Bonga), 27 trees were recorded in 11 plots; in Gorashewi

site (Masha), 61 trees were recorded in 17 plots; in Durani (Yayu), 22 trees were recorded in 14 plots and in Duduka site (Bebeka), 32 trees were recorded in 14 plots.

The density, DBH and height of *P. adolfi-friedericii* were significantly higher in Gorashewi site natural forest than Adela, Duduka and Durani sampled natural forests (Table 1). The highest number of individuals by diameter class was recorded in 20.1-30 cm, >80.1 cm, 30.1-40 cm and <10 cm for Bonga, Masha, Yayu and Bebeka forests, respectively (Figure 2).

Table 1. Density, DBH, Height, and Basal area of *P. adolfi-friedericii* among sampled natural forests.

Natural Forests	Density (trees/ha) (Mean ±SD)	DBH (cm) (Mean± SD)	Height (m) (Mean ±SD)	Basal area (m^2/ha)
Adela (n=30)	61.29 ± 0.59	29.00 ± 1.11	25.48 ± 1.49	62.53 ± 1.126
Gorashewi (n=30)	95.24 ± 0.58	64.73 ± 1.46	26.12 ± 0.91	589.00 ± 1.126
Durani (n=30)	78.51 ± 0.72	38.02 ± 0.7	24.72 ± 0.71	65.21 ± 0.548
Duduka (n=30)	57.09 ± 1.00	44.64 ± 1.70	29.9 ± 1.38	134.99 ± 1.100
P value	<0.05	<0.05	<0.05	<0.05

SD=standard deviation; n=number of plots

The DBH class distribution patterns of *P. adolfi-friedericii* in Duduka was characterized by higher individuals at middle stage than mature aged population, in which the density of individuals in the lower and middle DBH class is very high but becoming lower in the highest DBH classes. The height class distribution showed that large number of individuals exhibit middle size classes (between size classes 4 and 6 or from 29 m to 55 m with some individuals characterized by lower height class and very few individuals by large size classes (Figure 2). The maximum height value was recorded for Masha forest.

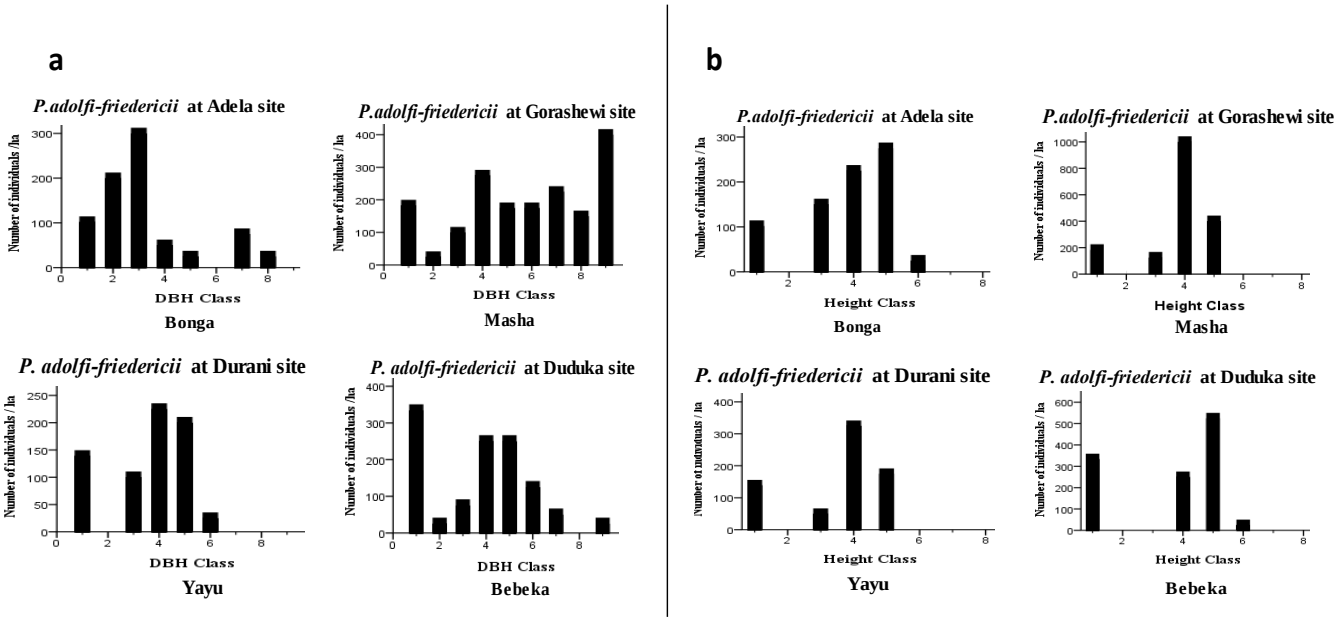

Figure 2. Population structure of *P. adolfi-friedericii* in the four studied sites

Regeneration status

Seedling density was higher for Duduka forest while sapling and mature trees density was higher for Gorashewi forest (Figure 3). This implies that regeneration status of the species can be taken as good status in Gorashewi and Duduka forests as seedling > sapling >mature tree.

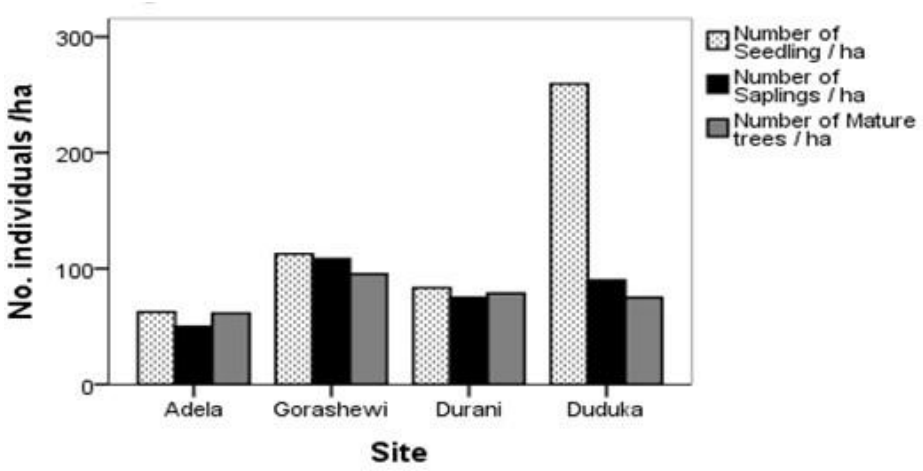

Figure 3. Regeneration status of *P. adolfi-friedericii* in the studied sites.

On the other hand, it is fair regeneration for Adela and Durani forests with seedling > sapling < mature trees. These representative figures show that the seedling, sapling and mature tree of *P. adolfi-friedericii* in

different samples natural forests. In Duduka and Gorashewi site the natural regeneration status represents good regeneration and recruitment which seedling > sapling > mature tree. While, in Adela and Durani site natural forests fair regeneration was observed.

Thus, the present study showed that population structure and regeneration status of *P. adolfi-friedericii* are good in Gorashewi forest which makes it suitable for seed production primarily. Following Gorashewi, Duduka forest is also suitable for seed production as observed from the population structure and regeneration status of the species. On the contrary, the population structure and regeneration status at Adela and Durani forests indicated insufficient number of individuals and absence in some diameter and height classes hence the regeneration status is these forests was ranked as fair.

DISCUSSION

This study showed that *P. adolfi-friedericii* has a clustered distribution pattern in the forest. A total of 142 individuals of *P. adolfi-friedericii* were recorded in 56 plots out of 120 plots in the sampled forests. The distribution of this tree species was influenced by slope and elevation. This result is in consistent with an earlier study which reported that elevation and slope influence the distribution of *P. adolfi-friedericii*, the species being more abundant at higher elevations and on north- and east-facing slopes (Asefa et al., 2017).

DBH class distribution of individuals showed an irregular pattern in Adela and Gorashewi forests in which they were distributed differently in almost all classes. The reason for such irregularities could be anthropogenic impacts.

The DBH class distribution patterns of *P. adolfi-friedericii* in Duduka site natural forest was characterized by higher individuals at middle stage than mature aged population, in which the density of individuals in the lower and middle DBH class is very high but becoming lower in the highest DBH classes even nothing in some DBH classes. According to Gebrehiwot and Hundera (2014) this pattern showed that there is selective cutting of the species for different purposes like for construction and fuel. Mean density, DBH, and basal area significantly varied among forests ($P<0.05$). This result is consistent with the findings of

Teshome et al. (2019) who reported that the species is distributed in clusters, with higher densities in some areas than others.

Similar to the DBH class distribution, there are missing individuals at some height classes across all forests. The absence of large individuals or their presence in few numbers in a forest might be associated with the selective cutting of species for various purposes such as construction, firewood etc. (Gebrehiwot and Hundera, 2014).

The height distribution patterns of *P. adolfi-friedericii* in Gorashewi natural forest was characterized by higher individuals at middle stage than young and mature aged population. This result is consistent with the outcome of Ngomanda et al. (2019), which examined the tree species composition and structure of a forest in Gabon, including *P. adolfi-friedericii*.

The regeneration status of the *P. adolfi-friedericii* tree species at the study sites is satisfactory, indicating good regeneration status, but the target tree species falls below reasonable regeneration status at the Adela site. Prior studies on the regeneration of *P. adolfi-friedericii* indicated that it normally exhibits low rate of regeneration. In two forest reserves in Côte d'Ivoire, Kouamé et al. (2014) investigated the regeneration status of *P. adolfi-friedericii* and discovered that the species rarely regenerates. Koffi et al. (2016) also reported that the species had a very poor rate of regeneration, with only a few seedlings being seen in their study area. The restricted recovery, according to these studies, was caused by habitat fragmentation and overexploitation. Overall, these studies suggest that *P. adolfi-friedericii* is experiencing limited regeneration in its native range, likely due to habitat fragmentation, overexploitation, and other human activities.

CONCLUSIONS AND RECOMMENDATION

The population structure and regeneration status of *Pouteria adolfi-friedericii* in different natural forests in south-western Ethiopia showed that the occurrence of the species is relatively low in all the selected natural forests. The sites, characterized by fair regeneration of *P. adolfi-friedericii* (Adela and Durani), showed that the growth, survival and reproductive potential of the species is at risk. Therefore, urgent priority needs to

be given to conservation and management. The presence of good regeneration potential in Gorashewi and Duduka forests indicated the species' suitability for the environment. In general, due to the population structure and regeneration status of *P. adolfi-friedericii*, the Masha Forest is more suitable for the establishment of seed production areas.

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Declaration

The manuscript is part of an MSc thesis of the first author.

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