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Population Structure and Ecological Attributes of *Prunus africana* in Selected Sites of Southwestern Ethiopia

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Abstract: Understanding the reproduction and recruitment potential of tree species is very important for establishing *in-situ* seed production area. The main objective of this study was, to assess the population structure and regeneration status of *Prunus africana* tree species in three sampled natural forests such as Yayu, Bonga, and Masha, South western Ethiopia for establishing seed production area. The systematic sampling method was used to collect the data. Ten transects line running parallel to each other's at 100m interval were laid out along the gradient and plots 400 m^2 (size: 20 m x 20 m each) were laid at 50 m interval along each transect line. A total of 90 plots were used for data collection. For natural regeneration data collection sub sample plots 25 m^2 (size: 5 m × 5m) were established at the center and at four corners of each of the main plots. From each plot, total height and DBH of the target tree species were measured using a clinometer and diameter tape respectively. The results of the distribution of the population structure of *P. africana* showed broken J-shape and irregular patterns across the forests. The regeneration status of *P. africana* is "good" in Bonga and Masha and "fair" in Yayu sampled natural forest. The population structure of *P. africana* tree species vary across the study sites. The variation in population structure among the sites highlights the importance of site-specific parameters in selecting seed provenances for conservation and sustainable utilization.

Key words: Population structure, *Prunus africana*, regeneration, seed production.

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Ethiopia has the fifth largest heterogeneous flora in tropical Africa (Motuma *et al.*, 2010). Distributions and types of vegetation in Ethiopia are determined by edaphic, topographic (altitude, slope, aspect) and climatic factors. Accordingly, the south western part of Ethiopia is covered by the moist evergreen montane forests. These moist evergreen montane forests constitute high concentrations of native species and they are major sources of livelihood in the area by providing timber and non-timber forest products (wild coffee, honey, spices) (Chilalo and Wiersum, 2011).

One of the most important tree species found in moist evergreen montane forest is *Prunus africana*. It is an evergreen tree up to 40 m height in forests. *Prunus africana* listed as vulnerable by International Union for Conservation of Nature due to unsustainable levels of harvesting of its bark across Africa (IUCN, 2002). Studying population structure of the forests plays a significant role in determining the dominant status, impact of disturbance and forest successional trends. It provide the overall regeneration profile of the area based on the tree density, frequency, and diameter at breast height, height, basal area (Tesfaye *et al*., 2002; Shibru and Balcha, 2004).

Investigation of the regeneration status plays a vital role to understand the growth performance of three target tree species in the study area. Study of regeneration status is one of the key parameters to determine ecosystem stability (Kadavul and Parthasarathy, 2001). In forest management regeneration study is important to know the current status and the possible changes in forest composition in the future (Malik and Bhatt, 2016).

Materials and Methods

The study was conducted in Bonga, Masha and Yayu sampled natural forest of south western Ethiopia. Bonga forest found in Kafa zone and Masha Forest is found in Sheka zone of Southern Nations, Nationalities and Peoples Regional States (SNNPRS) while, Yayu Forest is found in Illubabor zone of Oromia National Regional State (Fig. 1). Geographically, Bonga Forest is located between 7°00′-7°25′N latitude and 35°55′-36°37′E longitude (Nune, 2008). Masha Forest lies between 7°24′-7°52′N latitude and 35°13′-35°35′E longitude (Fig. 1). Meanwhile, Yayu Forest is situated within the range of 8°21′-8°26′N latitude and 35°45′-36°03′E longitude (Woldegeorgis and Wube, 2012). The altitudinal range of Bonga forest is 1520 to 1780 AMSL, while, Masha and Yayu natural forests altitudinal range is 1700 to 3000 and 1200 to 2000 AMSL, respectively.

The mean annual rainfall of Bonga forests is 794 mm with maximum and minimum temperature of 26.4°C and 11.9°C respectively (**Assefa**, 2010). The mean annual rainfall of Yayu forest is 1900 mm with a minimum of 7.6°C and 34.7°C maximum temperature(Woldemariam, 2003). According to the data taken from the National Meteorological Service Agency of Ethiopia, the mean annual rainfall of Masha natural forest is 2192 mm and its temperature is about 16.7°C (**Assefa** *et al*., 2014). Bonga soils are characterized as deep red to brown

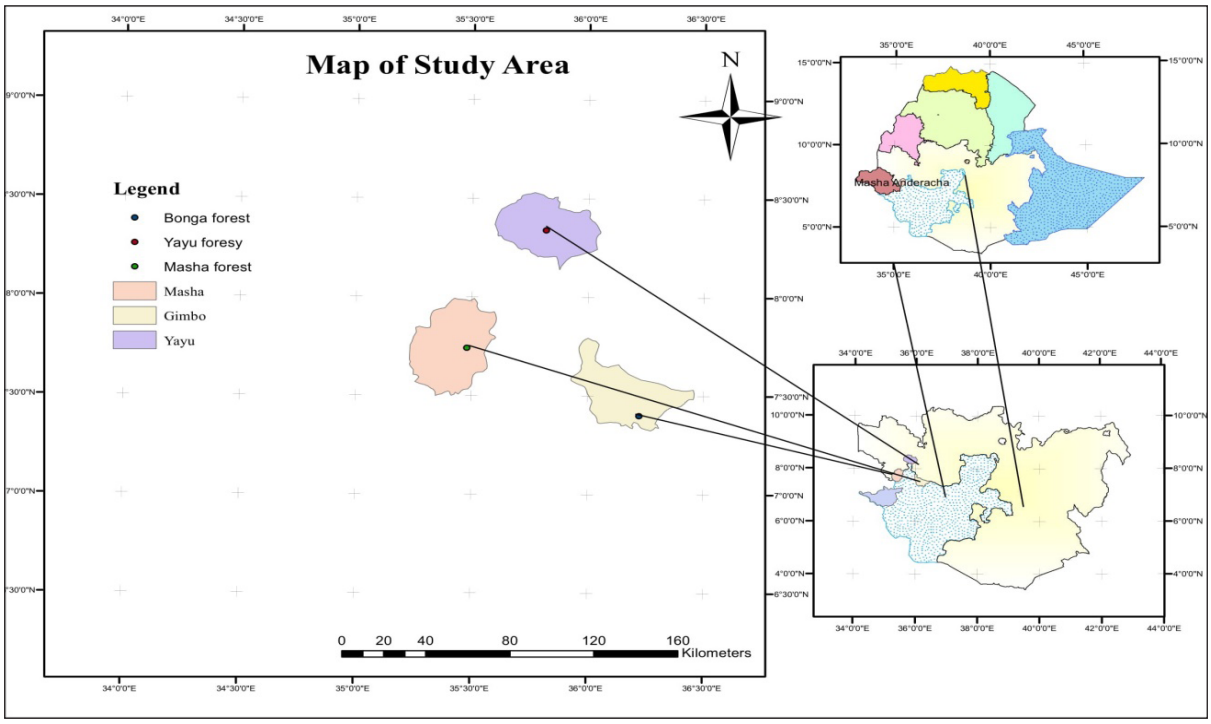

Fig. 1. Map of the study area.

red, lateritic loams or clay loams of volcanic origin with high or medium fertility (Schmitt, 2006). The dominant soil type of Yayu forest is Nitosols. These types of soils are deep, reddish-brown and clayey soil with relatively high organic matter content.

The moist evergreen montane forest consists of high forests of the country mainly the south west forests. The moist forest ecosystem is the most diverse ecosystem in composition, structure and habitat types (NBSAP, 2005), consequently it is rich in biodiversity with a number of endemic species. Some of the characteristic plant species of the forests include; *Pouteria adolfi-friederici, Prunus africana, Albizia gummifera, A. schimperina, A. grandibracteata, Blighia unijugata, Cassipourea malosana, Celtis africana, Croton macrostachyus, Ekebergia capensis, Euphorbia ampliphylla, Ficus sur, F. ovata, F. thonningii, Hallea rubrostipulata, Ilex mitis, Macaranga capensis, Olea capensis* ssp. *welwitschii, Polyscias fulva, Schefflera abyssinica, Sapium ellipticum, and Syzygium guineense ssp. Afromontanum* (Woldemariam, 2003).

The study areas were selected by conducting reconnaissance survey. Systematic sampling method was used to collect the data, based on reconnaissance survey (in the area where the target species potentially found), ten line transects running parallel to each other were laid down along the gradient at each 100 m interval. Sample plot each measuring 20 m x 20 m (400 m^2) for trees and saplings of target species and sub plot of 5 m × 5 m (25 m^2) for seedlings at the four corners and center were laid at each 50 m interval along each transect line. A total of 90 plots were sampled in Adela, Sherah, and Dogii sites.

Data collection for population structure of *Prunus africana* was conducted during January to February, 2020. The wildlings (seedlings) were recorded from sub sample plots for the sizes root collar diameter <3.5 cm and height <0.5m; saplings diameter of 3.5-10 cm and height 0.5 m -2 m. DBH and total height were measured in plots for trees with minimum sizes DBH >10 cm and height >2 m (Bharali *et al*., 2012 ; Dhaulkhandi *et al*., 2008; Gebrehiwot and Hundera, 2014). DBH and Height were measured with diameter tape and clinometer respectively.

In order to provide the high level of species classification accuracy required for reliable ecological assessments, tree species were identified through systematic approach that combined field guides and expert talks. A range of field guides were utilized to help identify tree species based on characteristics like leaf form, bark texture, and flowering patterns in order to differentiate between similar species. These resources provide helpful illustrations and descriptions. Additionally, collaborating with ecologists and botanists allowed for cross-verification of species identifications, particularly for rare or complex species that would be difficult to classify using field guides alone.

The density of tree individuals for measurements was calculated using the number of trees per hectare, which is crucial for understanding population dynamics and the abundance of various species within the forest ecosystem the number of trees per hectare was counted. and the abundance of various species within the forest ecosystem the number of trees per hectare was counted. The trunk's diameter at breast height (DBH) was measured with a diameter tape, enabling an accurate determination of the trunk's diameter at 1.3 meters above the ground. Each tree's height was measured using either a clinometer or a measuring tape; the clinometer provides precise measurements through trigonometric computations, while the measuring tape is helpful for smaller trees or easier access.

Calculating volume and basal area, as well as comprehending tree growth patterns and ecological responsibilities, all depend on precise height measurements. When taken as a whole, these phytosociological characteristics offer a thorough picture of tree communities, enabling a more profound comprehension of their dynamics, structure, and ecological significance all of which are critical for efficient forest management and conservation tactics.

All data of the target species was analyzed and summarized in Microsoft Excel spread sheets and SPSS software based on the DBH size nine classes which measured (i.e., <10 cm, 10.1 to 20 cm, 20.1 to 30 cm, 30.1 to 40 cm, 40.1 to 50 cm, 50.1 to 60 cm, 60.1 to 70 cm, 70.1 to 80 cm, >80 cm) were established. Individual trees having height greater than or equal to 2

m and DBH ≥10 cm within plots were collected and analyzed by classifying into seven classes (2-10 m, 11-19 m, 20-28 m, 29-37 m, 38-46 m, 47-55 m, >55 m). The diameter size classes' population structure was summarized by using histograms. ANOVA was also used to test for difference in DBH, basal area, and height of *Prunus africana* among different natural forest. Finally, all sampled sites were compared in terms of their population structure and then the best site was recommended for seed production area establishment.

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

Results and Discussion

Population Structure of Prunus Africana

DBH, Density and Basal area: A total of 71 individuals of *P. africana* were recorded in 33 plots out of 90 plots sampled in Adela site (Bonga), Sherah site (Masha) and Dogii site (Yayu) natural forests. In Adela site a total of 14 trees of *P. africana* were recorded in 10 plots out of 30, in Sherah site a total of 46 trees were recorded in 16 plots out of 30 plots and in Dogii site a total of 11 trees were recorded in 7 plots out of 30 plots. The sampled forests represent mean densities per ha of 72, 39 and 35 in Sherah site, Dogii site and Adela site natural forest respectively (Table 1).

The highest number of individuals of overall distribution of *P.africana* by diameter class in Adela site natural forest was in the lower (at <10 cm) DBH class (Fig. 2), the highest number of individuals of *P.africana* in Sherah site natural forest was also at the lower (<10 cm) and middle (at 30.1 to 40 cm) diameter class (Fig. 2), while in Dogii site natural forest, the highest frequency was at >80 cm (Fig. 2). The density of *P. africana* was significantly higher in Sherah site natural forest than Dogii and Adela site.

Among the species under study, the Sherah site has the greatest Importance Value Index (IVI), according to the values, underscoring its important ecological importance. This high IVI indicates that Sherah not only has a sizable population but also makes a significant contribution to the community's overall biomass and resource availability. Because of this, it is essential to preserving ecological balance and supporting a number of processes, including the supply of habitat, the cycling of nutrients, and the provision of food for other organisms. Researchers can learn a great deal about the health and biodiversity of natural forests by giving the IVI top priority in their evaluations. They can determine which species have the most impact on maintaining the resilience and stability of ecosystems using this parameter. Effective conservation and management efforts require an understanding of these interactions.

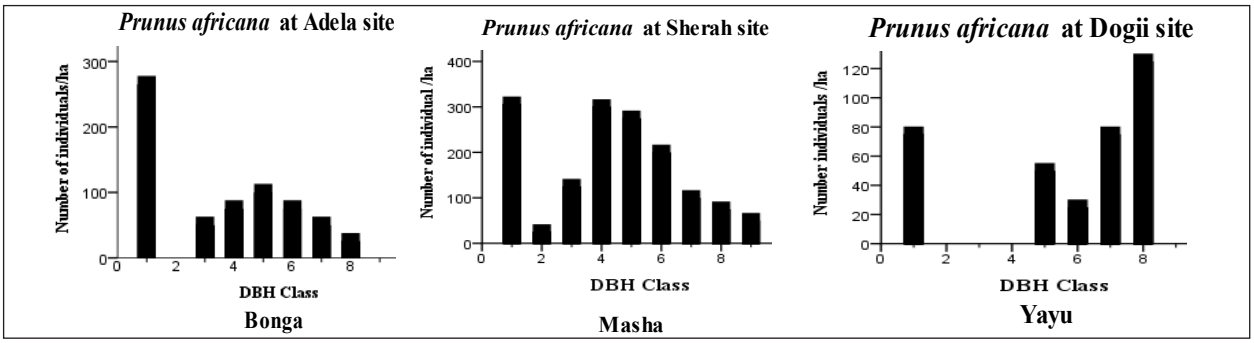

Fig. 2. Population structure of P. africana in Adela, Sherah and Dogii sites natural forests.

Table 1: Density, DBH, Height, and Basal area of Prunus africana tree among sampled natural forests

Natural forests	Density trees/ha) (Mean ± SD)	DBH (cm) (Mean ± SD)	Height (m) (Mean ± SD)	Basal area(m^2/ha)	Relative density (RD)	Relative dominance (RDo)	Importance value index (IVI)
Adela(n=30)	34.97±1.066	50.35±0.911	25.57±0.721	73.71 ±1.247	23.95%	17.59%	141.54%
Sherah(n=30)	71.85 ±0.406	52.3 ±0.952	25.3 ±1.322	244.25 ±1.103	49.10%	58.19%	207.29%
Dogii(n=30)	39.27 ±0.713	62 ±0.946	27.26 ±1.39	101.48 ±0.853	26.95%	24.22%	151.17%
P. value	0.01	0.022	0.048	0.01	0.005	0.001	0.02

SD = Standard deviation.

DBH class versus number of individuals of *Prunus africana* pattern in Adela site natural forest was formed Irregular shape (Fig. 2), in which they are distributed differently in almost all classes. Some DBH classes had large number of individuals while, other DBH classes had small number of individuals. In higher DBH classes the low number of individuals is due to past harvesting which targets mature trees and only left few reproducing individuals leading to a decline in the overall density. The population structure of *Prunus africana* tree graph in Sherah site also shows that Irregular pattern. Different literature also stated that the irregular pattern distribution might be due to selective cutting by the local people for construction and firewood (Gebrehiwot and Hundera, 2014).

The DBH class distribution patterns of *Prunus africana* in Dogii natural forest form broken J-shape pattern; which shows a type of frequency distribution in which there is a low number of individuals and even nothing in the lower diameter classes but increases towards the higher classes. It indicates a poor reproduction and recruitment of species which may be associated with intense competition from the surrounding trees. According to Feyera *et al*. (2007) low number of individuals in the lower diameter class shows that a poor reproduction and recruitment of species due to intense competition from the surrounding trees and capacity of this species indicates the management and conservation problems.

Mean density, mean DBH, and basal area of *Prunus africana* of the three sites were found to be significantly difference (P<0.05). Stem/ha and basal area of *Prunus africana* tree species in Sherah site (Masha) was greater than Adela (Bonga), and Dogii (Yayu) site (P<0.05). The mean DBH of *Prunus africana* tree species in Dogii site (Yayu) was greater than Adela (Bonga), and Sherah site (Masha).

Height of Prunus africana: In Adela site natural forest the highest number of individuals of *P. africana* by height class distribution was at (<2 m) followed by the fourth height class (20-28 m) (Fig. 3). The least number of individuals corresponds to the highest height class (>37 m) and even absence of large individuals in the forest might be associated with the selective cutting of species for various purposes.

The highest height distribution of *P. africana* in Sherah site natural forest was at the fourth height class (20-28 m) followed by the first height class (<2 m) (Fig. 3). The least number of individuals corresponds to the lowest height class (11-19 m) and even absence of large individuals in the forest might be associated

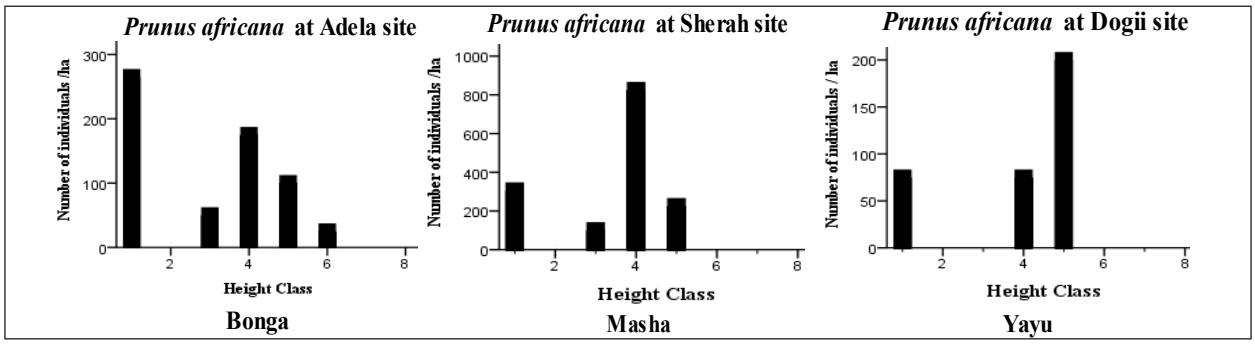

Fig. 3. Population structure of P. africana in Adela, Sherah, and Dogii sites natural forests.

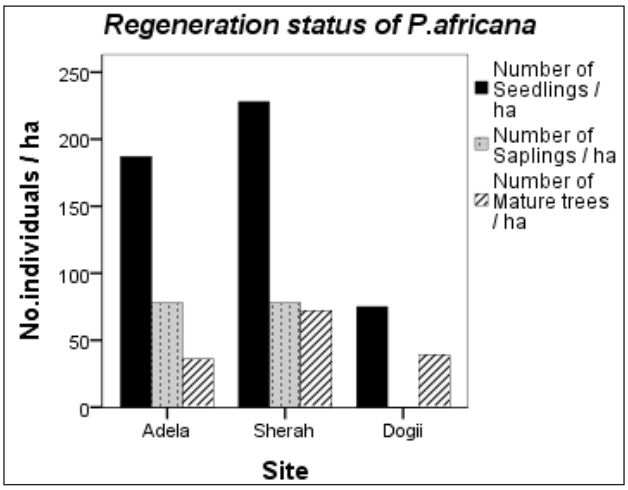

Fig. 4. Regeneration status of P. africana in Adela, Sherah and Dogii site natural forests.

with the selective cutting of species for various purposes.

The height distribution patterns of *P. africana* in Dogii natural forest form broken J-shape; which shows a type of frequency distribution in which there is a low number of individuals and even nothing in the lower diameter classes but increases towards the higher classes. It indicates a poor reproduction and recruitment of species which may be associated with intense competition from the surrounding trees.

Regeneration status of Prunus africana: The density of mature trees, saplings and seedlings of *P. africana* varied among all sampled natural forests. Density of all age classes was higher in Sherah site natural forest than in Adela and Dogii site natural forests. Saplings were missing in Dogii site natural forests (Fig. 4).

These Representative figures showed that the seedling, sapling and mature tree of *P. africana* tree species in different samples natural forests. In Adela and Sherah site natural forests the regeneration status represents good regeneration and recruitment (which seedling > sapling > mature tree stage). While, in Dogii site natural forests the graph showed fair regeneration. The population structure and regeneration status of *P. africana* was significantly higher and good in Sherah site natural forest than others. So, Sherah site natural forest is good and favorable for seed production area than the others selected sampled natural forests.

Conclusions

According to Tomar (2018) when natural stands chosen for its conversion to SPA, it's important to consider tree species with sufficient size and sufficient number of good phenotypes and sufficient seed production. Natural forests with healthy, big in diameter and good looking tall trees are preferable for seed production area. The population structure of *P. africana* tree species vary across the study sites.

The result shows that the population structures and regeneration status of *Prunus africana are* vary across all sampled natural forests. The density of mature trees, saplings and seedlings of *P. africana* varied among all sampled natural forests. Density of all age classes was higher in Sherah site natural forest than in Adela and Dogii site natural forests. The population structure and regeneration status of *P. africana* was significantly higher and good in Sherah site natural forest than others. So, Sherah site natural forest is good and favorable for seed production area than the others selected sampled natural forests.

Management, conservation and monitoring practices of natural forests are crucial because, the edges of sampled natural forests are easily accessible for destruction, the people disturbing and reducing the size of the forest for agricultural expansion and coffee plantation at the study sites.

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