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Population survey of *Milicia excelsa, Pouteria adolfi-fridercii, Antiaris toxicaria* and *Prunus africana* in south and south-western Ethiopia: implications for domesticating and establishing Seed Production Areas

Abstract

The population dynamics and genetic qualities of stem height and dbh of the populations of *Milicia excelsa, Pouteria adolfi-fridercii, Antiaris toxicaria* and *Prunus africana* were assessed and studied in 14 forest ecosystems in south and south-western Ethiopia. A systematic random quadrat sampling technique was employed to identify potential habitat area for selected timber species in south and south-western Ethiopia. So, a total of 10 parallel transect lines were set out across each forest habitat. *Milicia excelsa* was assessed in four forest ecosystems; Bebeka -Duduka natural forest (45 tree stem ha^{-1}) and Yayu coffee mixed forest (40 tree stem ha^{-1}) appeared to have relatively denser population of *M. excelsa* compared to the other pilot forests. Similarly, statistically larger stem height (m) is observed in Bebeka-Duduka natural forest ($\bar{x}$*=29.5, SD=4.2*) and larger dbh size (cm) in Bebeka 1 coffee mixed forest ($\bar{x}$*=48.5, SD=25.2*) at $p<0.05$. Hence, Bebeka-Duduka natural forest and Bebeka 1 coffee mixed forests are identified for *in-situ* SPA establishment project of the target species. *Pouteria adolfi-fridercii* was assessed in eight forest ecosystems; Masha-Gora shewi forest appeared to have dense population of *P. adolfi-fridercii* (150 tree stem ha^{-1}) followed by Bebeka-Kebereta (80 tree stem ha^{-1}) as compared to the remaining pilot forests. However, statistically larger stem height (m) is scored in Bebeka 2 natural forest ($\bar{x}$*=30.6, SD=2.98*) and Bebeka-kebereta forest ($\bar{x}$*=30.0, SD=4.4*) and larger dbh size (cm) in Bebeka 2 natural forest ($\bar{x}$*=96.5, SD=19.9*) at $p<0.05$. So, Bebeka 2 natural forest and Bebeka-kebereta forest are identified for SPA establishment project of the target species. *Antiaris toxicaria* was assessed in two forest ecosystems where both forest habitats appeared to have the same density of *Antiaris toxicaria* in hectare. Moreover, analyses of mean stem height (cm) of Bebeka 1 forest ($\bar{x}$*=21.4, SD=5.2*) and Bebeka-kebereta forest ($\bar{x}$*=22.4, SD=2.7*), and mean dbh size (cm) of Bebeka 1 forest ($\bar{x}$*=48, SD=16.4*) and Bebeka-kebereta forest ($\bar{x}$*=48, SD=8.2*) appeared to have not significantly different at $p<0.05$. *Prunus africana* was assessed in five forest ecosystems; Masha-Gora shewi forest appeared to have dense population of *Prunus africana* (150 tree stem ha^{-1}) followed by Kaho-shemeta forest (130 tree stem ha^{-1}) as compared to the remaining pilot forests. However, statistically larger stem height (m) is scored in Kaho-shemeta natural forest ($\bar{x}$*=31, SD=7.6*) and larger dbh (cm) in Masha-Gora shewi forest ($\bar{x}$*=64.7, SD=28.2*) at $p<0.05$. As the result, Kaho-shemeta natural forest and Bonga-Teja-adela forest are identified for establishment of seed production area of the target species *in-situ*. Hence, while implementing the project of domestication and seed production area establishment in south and south-western Ethiopia, *in-situ* and *ex-situ* areas must be selected and delineated in accordance with this preliminary information of the population dynamics and genetic qualities of stem height and diameter at breast height. The survey data generated in this study would bridge the research gap in relation to the population status of the target tree species in the designated area.

Keywords: indigenous tree species, population, functional traits, density, height, diameter

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Introduction

Ethiopia is becoming dependent on wood products imported, and the demand for sawn wood, paper and ply wood is steadily increasing each year.[1] In spite of there are many indigenous timber species in Ethiopia, species used for domestic timber production are limited to 3 to 4 species namely *Eucalyptus, Cupresuss, Pinus* and to some extent *Grevillea*. However, potential timber species including *Milicia excelsa, Antiaris toxicaria, Pouteria adolfi-fridercii* and *Prunus africana*, restricted within natural forest ecosystems in south and south-western parts of the country, can be used for production of quality timber.[2]

Natural forests in western and south-western Ethiopia are the major sources of livelihood (timber and non-timber forest products) for the communities in the surrounding area.[3] These forests are also the potential sources of economically important timber species such as *Milicia excelsa, Antiaris toxicaria, Pouteria adolfi-fridercii* and

Prunus africana. However, in recent years, conversion of forest ecosystems into agriculture lands (coffee and tea plantations) is becoming increasing. As the result, species such as *Milicia excelsa, Antiaris toxicaria, Pouteria adolfi-fridercii* and *Prunus africana* are under high pressure due to random cuttings and deforestation.[4,5] To the knowledge of the researcher, the population status of these tree species in the designated area is not well documented. So, it is becoming necessary to find innovative ways of maintaining and improving the genetic quality of these species by domesticating them into a wider scale of ecological and social environment and upgrading the seed supply by developing Seed Production Areas (SPA). The survey data generated in this study would help to bridge the research gap in relation to the population status of the target tree species in the designated area. Therefore, the main objective of this study was to assess the population dynamics (density), stem height and dbh size of *Milicia excelsa, Pouteria adolfi-fridercii, Antiaris toxicaria* and *Prunus africana* in south and south-western Ethiopia. The study was specifically designed (1) to conduct a population survey of *Milicia excelsa, Pouteria adolfi-fridercii, Antiaris toxicaria* and *Prunus africana* in selected forest ecosystems in south and south-western Ethiopia, (2) to measure the regeneration status of each species in their habitats, and (3) to measure the stem height and diameter at breast height (dbh) size of the population of the target species thereby domesticating the best populations and establishing Seed Production Area (SPA) for the target species *in-situ* and *ex-situ*.

Materials and methods

Measuring population dynamics and natural regeneration

A Systematic random quadrat sampling technique was employed, i.e. representative forest habitat areas were identified and systematically selected for sampling purpose. A total of 10 parallel transect lines (160m) were measured out across a representative forest habitat area, and 30 quadrats (20m by 20m) were laid randomly at 50m interval along each transect line.[6–8] Hence, matured tree population, with DBH ≥2.5cm and Height ≥1.5m was counted, analyzed and summarized in tables.[9] On the other hand, seedling and sapling counts (*seedlings* are young of tree species with DBH <2.5cm and height 1-50cm and *saplings* are young of tree species with DBH <2.5cm and height between 50-150cm was conducted in each 20m by 20m quadrat.[9] So, at every 50m along the line, 5m by 5m sub-plots were placed to count the seedling and sapling populations.[10–12] Count data of the seedling and sapling population with the corresponding abundance of trees in each forest plot was recorded and summarized in tables. Hence, the regeneration status of target species in each forest habitat was analyzed by comparing the population density of seedling with sapling, and sapling with matured trees as follows[8,13]: 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 (even though saplings may be less than, more than, or equal to mature trees); 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.

Measuring functional traits (stem height and dbh)

A Systematic random quadrat sampling technique was employed, i.e. representative forest habitat areas were identified and systematically selected for sampling purpose. A total of 10 parallel transect lines (160m) were measured out across a representative forest habitat area, and 30 quadrats (20m by 20m) were laid randomly at 50m interval along each transect line (modified from.[6–8] Hence, for trees with DBH ≥2.5cm and Height ≥1.5m, stem height and dbh (at 1.3m above the ground) were recorded,[9] and the data was analyzed, tested and presented in figures and tables. *T-tests* were computed for the purpose of mean comparison and determining the level of mean separations (significance level at p<0.05%) amongst the different forest habitats.

Result and discussion

The population dynamics and regeneration status of *Milicia excelsa, Pouteria adolfi-fridercii, Antiaris toxicaria* and *Prunus africana* were assessed and studied in 13 forest ecosystems (3 sites in Metu zone, 3 sites in Sheka zone, 3 sites in Kaffa zone, and 4 sites in Benchi-Maji zone (Table 1). The survey data generated in this study would bridge the research gap in relation to the population status of the target tree species in the designated area.

Milicia excelsa

Population dynamics and regeneration status

Milicia excelsa (Rock-elm, Iroko) was studied and documented in four forest ecosystem; Yayu coffee mixed forest, Bebeka 1 coffee mixed forest, Bebeka-Duduka natural forest and Yayu-Chach natural forest (Table 2). So, the forest systems are attributed by both natural and mixed forest type. Bebeka -Duduka natural forest (45 tree stem ha^{-1}) and Yayu coffee mixed forest (40 tree stem ha^{-1}) appeared to have relatively denser population of *M. excelsa* compared to the other pilot forests.

The existence of "none regeneration" status in Yayu coffee mixed forest could be due to the presence of frequent clearing-up works in coffee mixed forest that could have possibly hindered the germination of dispersed seeds on the ground. On the other hand, the existence of "none regeneration" status in Yayu-Chach natural forest could be related to presence of unsuitable environmental conditions or may it was not the right phenological calendar for the trees to set and disperses their seeds during our survey period.

Analysis of stem height and dbh

Analysis of t-test for mean stem height of *M. excelsa* population in Yayu coffee mixed forest ($\bar{x}$*=23.31, SD=7.6, SE=4.01*), Bebeka 1 coffee mixed forest ($\bar{x}$*=21.4, SD=3, SE=0.75*), Bebeka-Duduka natural forest ($\bar{x}$*=29.5, SD=4.2, SE=1.0*) and Yayu-Chach natural forest ($\bar{x}$*=21.5, SD=12, SE=4.9*) shows that *M. excelsa* population in Bebeka-Duduka natural forest has significantly larger mean stem size at p<0.05 compared to the remaining pilot forest sites (Figure 1). However, no significant difference of mean stem height is observed amongst the other three sampling sites at p<0.05. On the other hand, it also reported that old trees of *M. excelsa* could reach 21-50meters high, and grows in Moist and Wet Kolla agro-climatic zones of Ilubabor and Kaffa regions in the altitude of 500-1000meter above sea level.[14,15] According to Agroforestry Database, *M. excelsa* is a deciduous tree having 30-50meter stem height.[16]

Analysis of t-test for mean dbh of *M. excelsa* population in Yayu coffee mixed forest ($\bar{x}$*=34.7, SD=27.2, SE=6.8*), Bebeka 1 coffee mixed forest ($\bar{x}$*=48.5, SD=25.2, SE=8.9*), Bebeka-Duduka natural forest ($\bar{x}$*=36.5, SD=8.2, SE=1.9*) and Yayu-Chach natural forest ($\bar{x}$*=37.52, SD=26.3, SE=10.7*) shows that *M. excelsa* population

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in Bebeka 1 coffee mixed forest has significantly larger mean dbh at $p<0.05$ compared to the remaining pilot forest sites (Figure 2). However, no significant difference of mean DBH is observed amongst the other three sampling sites. Similarly[14,15] reported that old trees of *M. excelsa* may reach 2meters in diameter. According to Agroforestry Database, *M. excelsa* is a large deciduous tree reported to have diameter of 2-10meters dbh length.[16] The larger record of DBH size in Bebeka 1 coffee mixed forest might be due to the fact that the coffee estate routinely manage the forest as part of clearing-up management works so that it in turn decrease the competition for nutrients. *M. excelsa* in this forest habitat is managed to attain the larger DBH size possible compared to the remaining untouched and partially disturbed forests piloted. Stem dbh is also related with the age of the tree; the older the tree the wider the diameter it possess if other environmental conditions are constant and favorable. The overall vegetation density of an ecosystem and the level of nutrients competitions would also affect carbon accumulation of a tree and its size of the diameter as well.

Table 1 Summary of the study pilot forest sites; physical and biological components of the ecosystems

Forest name (site)	GPS location	Substrate (soil) type	Humidity / rainfall	Associated biotic community
Yayu forest biosphere	08° 22'35.7" N 036° 01'37.8" E	Loam to clay soil; poor drained reddish to blackish soil, 15-20 cm thick liter and humus	High humidity/ rainfall	Plants: Coffee, Albizia sp., other shrubs and herbs; Animals: Wild mammals , and insects etc.
Bebeka 1- coffee mixed forest	06° 54'13.6" N 035° 26'36.6" E	Sandy loam and moderately drained reddish soil; 15-20 cm thick liter and humus	Intermediate humidity/ rainfall	Plants: Coffee, other trees, shrubs and herbs; Animals: Wild mammals, , and insects etc.
Bebeka 2- natural forest	06° 51'28.1" N 035° 24'03.0" E	Sandy loam and moderately drained reddish soil; 15-20 cm thick liter and humus	Medium humidity/ rainfall	Plants: M. excelsa and other higher plants and climbers; Animals: Hyena, primates, and insects etc..
Shera-Kaffa natural forest	07° 16'39.9" N 036° 10'57.7" E	Sandy loam and moderately drained reddish soil; 15-20 cm thick liter and humus	High humidity/ rainfall	Plants: Coffee, Syzygium guineese, P. africana and other higher plants and climbers; Animals: Primates and other mammals, and insects etc.
Kaho Shemeta natural forest	07° 40'19.9" N 035° 29'34.8" E	Sandy loam and moderately drained reddish soil; >20 cm thick liter and humus	High humidity/ rainfall	Plants: Pouteria sp. (low density and rare) and other higher plants and climbers; Animals: Gureza, other primates , and insects etc.
Bebeka -Duduka natural forest	06° 55'82.5" N 035° 28'10.3" E	Sandy loam and well drained reddish soil; 15-20 cm thick liter and humus	High humidity	Plants: Plants: Pouteria sp., Antiaris sp., etc.; Animals: Wild mammals – pigs, primates, and insects etc.
Yayu - Chach natural forest	08° 22' 22.2" N 036° 02'93."6 E	Loam soil; well drained reddish to blackish soil, 15-20 cm thick liter and humus.	High humidity	Plants: Plants: Albizia sp., Croton macrostachyus; Animals: wild mammals – pigs, primates , and insects etc.
Bebeka -Kebereta forest	06° 55'82.5" N 035° 52'81.0" E	Loam and moderate well drained reddish soil; 10-15 cm thick liter and humus	High humidity	Plants: Plants: M. excelsa, Antiaris sp.; Animals: wild mammals – pigs, primates , and insects etc.
Bonga -Shera forest	07° 16'73.1" N 036° 10'51.8" E	Moderately well drained soil; 15-25 cm thick liter and humus	High humidity	Plants: Plants: P. africana, C. macrostachyus Animals: Wild mammals – pigs, primates , and insects etc.
Masha-Gora shewi forest	07° 37'60.3" N 035° 30'06.0" E	Sandy loam and moderately drained soil; 15-25 cm thick liter and humus	High humidity	Plants: Plants: P. africana, Ficus sp., Syzygium sp., Animals: Wild mammals: pigs, primates , and insects etc.

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Table Continued

Forest name (site)	GPS location	Substrate (soil) type	Humidity / rainfall	Associated biotic community
Masha - Sherach forest	07° 37'45.0" N 035° 52'99.9" E	Sandy loam and moderately drained soil; 15-25 cm thick liter and humus	High humidity	Plants: Plants: P. africana, Ficus sp., Syzygium sp.; Animals: Wild mammals – pigs, primates, and insects etc.
Yayu -Wabu Dureni forest	08° 22'86.5 "N 035° 48'05.5" E	Clay to Loam soil; moderate drained reddish to blackish soil, 15-25 cm thick liter and humus	High humidity	Plants: Plants: M .excelsa, C. macrostachyus; Animals: wild mammals – pigs, primates , and Insects etc.
Bonga-Teja-adela forest	07° 16'41.7" N 036° 12'75."1 E	Moderately well drained soil; 10-15 cm thick liter and humus	High humidity	Plants: Ekebergia spp., Olea sp. , C. macrostaycus; Animals: wild mammals – pigs, primates, and insects etc.

Table 2 Summary descriptions of Yayu and Bebeka 1, Bebeka -Duduka natural forest and Yayu - Chach natural forest pilot survey sites in reference to *M.excelsa*

Forest site	Total counts (N)			Density (per ha)	Distribution/ Dispersion	Reg. status	Overstory shading
	Seedling	Sapling	Trees	($\bar{x}$*10000/ 400 m²)	($S^2/\bar{x}$ ratio)		
Yayu	0	0	16	40	1 = Random distribution and intermediate dispersion	None	Partial
Bebeka 1	34	0	8	20	0.78 = Uniform distribution and high dispersion	Fair	Partial
Bebeka -Duduka natural forest	19	10	18	45	1.53= aggregately distributed, low dispersion	Fair	Partial
Yayu - Chach natural forest	0	0	6	15	2.7= aggregately distributed, low dispersion	None	Partial

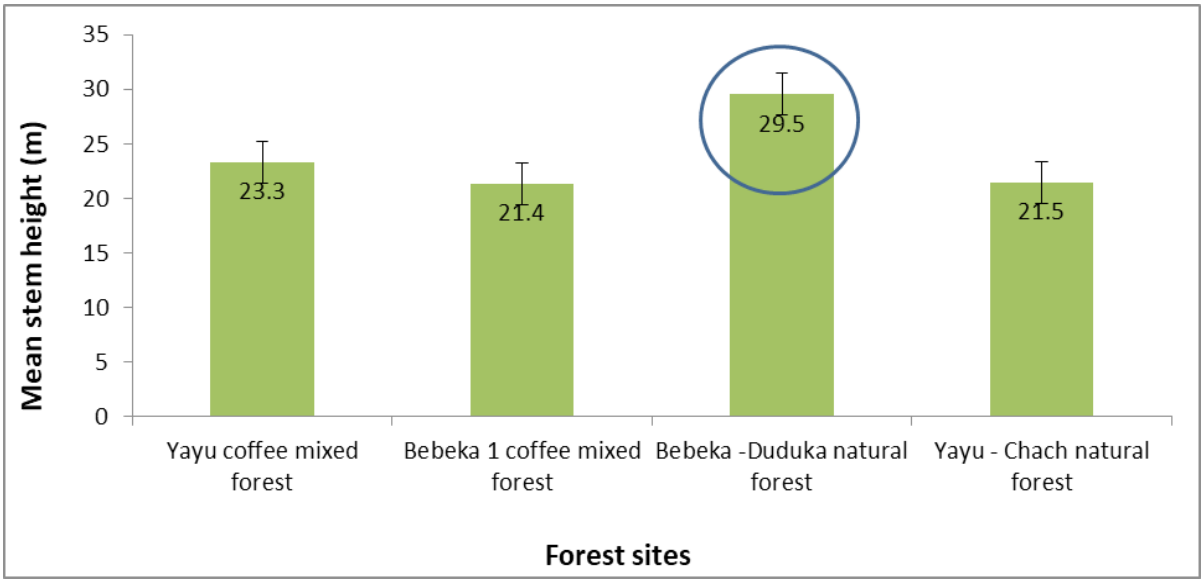

Figure 1 Comparison of mean ($\bar{x}$) and standard error (*SE*) for measurements of stem heights of *M. excelsa* population in Yayu coffee mixed forest, Bebeka 1 coffee mixed forest, Bebeka-Duduka natural forest and Yayu-Chach natural forest. Stem height ranging from 10-36m is recorded in Yayu coffee mixed forest, 17-26m in Bebeka 1 coffee mixed forest, 22-32m in Bebeka-Duduka natural forest and 10-35m in Yayu-Chach natural forest.

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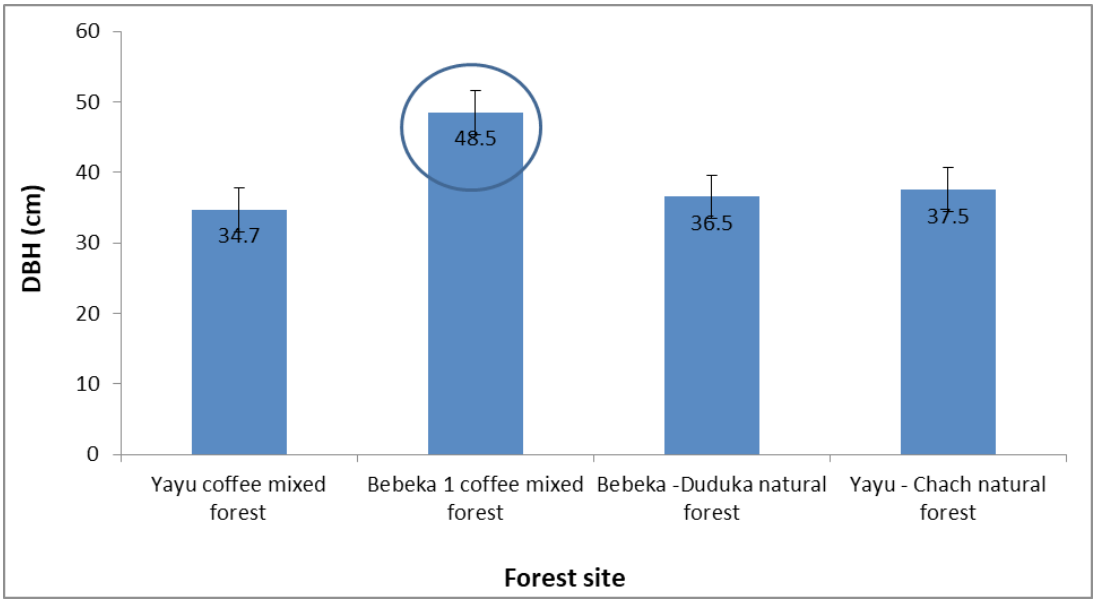

Figure 2 Comparison of mean ($\bar{x}$) and standard error (*SE*) for measurements of dbh of *M. excelsa* population in Yayu coffee mixed forest, Bebeka 1 coffee mixed forest, Bebeka-Duduka natural forest and Yayu-Chach natural forest; dbh size of 10-100cm is recorded in Yayu coffee mixed forest, 20-100cm in Bebeka 1 coffee mixed forest, 24-46.5cm in Bebeka-Duduka natural forest and 13-70cm in Yayu-Chach natural forest.

Pouteria adolfi-fridercii

Population dynamics and regeneration status

Pouteria adolfi-fridercii was surveyed in eight forest ecosystems namely Bebeka 2 natural forest, Yayu coffee mixed forest, Shera-Kaffa natural forest (undisturbed), Bebeka-kebereta forest, Bonga-Shera forest, Masha-Gora shewi forest, Masha-Sherach forest and Yayu-Wabu Dureni forest (Table 3). Masha-Gora shewi forest appeared to have dense population of *P. adolfi-fridercii* (150 tree stem ha^{-1}) followed by Bebeka-Kebereta (80 tree stem ha^{-1}) as compared to the remaining pilot forests.

Table 3 Summary descriptions of Bebeka 2 natural forest, Yayu coffee mixed forest, Shera-Kaffa natural forest (undisturbed), Bebeka-kebereta forest, Bonga-Shera forest, Masha-Gora shewi forest, Masha-Sherach forest and Yayu-Wabu Dureni forest pilot survey sites in reference to *Pouteria adolfi-fridercii*

Forest site	Total counts (N)			Density (per ha)	Distribution/ Dispersion	Reg. status	Overstory shading
	Seedling	Sapling	Trees	($\bar{x}$*10000/ 400m²)	($S^2/\bar{x}$ ratio)		
Yayu	12	0	13	32.5	4.8=aggregately distributed and low dispersion	Fair	Partial
Bebeka 2	13	8	29	72.5	3.02=aggregately distributed, low dispersion	Fair	Partial
Shera-Kaffa	20	7	30	75	0.3=uniform distribution and high dispersion	Fair	Partial
Bebeka -Kebereta forest	86	16	32	80	1.44= aggregately distributed, low dispersion	Fair	Partial
Bonga -Shera forest	14	19	22	55	4.64=aggregately distributed, low dispersion	Poor	Partial
Masha-Gora shewi forest	18	26	60	150	8= aggregately distributed, low dispersion	Poor	Partial
Masha - Sherach forest	3	8	26	65	3.3=aggregately distributed, low dispersion	Poor	Partial
Yayu -Wabu Dureni forest	6	12	21	52.5	1.6= aggregately distributed, low dispersion	Poor	Partial

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Analysis of stem height and dbh

Analysis t-test for mean stem height of the populations of *Pouteria adolfi-fridercii* in Bebeka 2 natural forest ($\bar{x}$*=30.6, SD=2.98, SE=0.55*), Yayu coffee mixed forest ($\bar{x}$*=23.7, SD=6.2, SE=1.7*), Shera-Kaffa natural forest ($\bar{x}$*=25.0, SD=10.7, SE=1.9*), Bebeka-kebereta forest ($\bar{x}$*=30.0, SD=4.4, SE=0.78*), Bonga-Shera forest ($\bar{x}$*=25.4, SD=5.0, SE=1.1*), Masha-Gora shewi forest ($\bar{x}$*=26.1, SD=4.3, SE=0.55*), Masha-Sherach forest ($\bar{x}$*=24.3, SD=5.11, SE=1.2*) and Yayu-Wabu Dureni forest ($\bar{x}$*=24.8, SD=4.1, SE=0.88*) shows that Bebeka 2 natural forest and Bebeka-kebereta forest appeared to have significantly larger mean stem height at $p<0.05$ compared to the other pilot forest sites (Figure 3). However, there is no evidence showing that the mean variations of stem height amongst the other pilot forest sites are significant at $p<0.05$. According to Agroforestry Database, *Pouteria adolfi-fridercii* is reported to have up to 50meter stem height.[16] In this study, the maximum stem height (40m) is observed in Bebeka-kebereta forest and Shera-Kaffa natural forest while the minimum stem height (14m) is recorded in Yayu-Wabu Dureni forest. The height is also affected by the age of the tree. Moreover, the overall vegetation density of an ecosystem and the level of nutrients competitions would also affect carbon accumulation of a tree and its size.

Figure 3 Comparison of mean ($\bar{x}$) and standard error (*SE*) for measurements of stem height of *Pouteria adolfi-fridercii* populations in Bebeka 2 natural forest (undisturbed), Yayu coffee mixed forest (disturbed), Shera-Kaffa natural forest (undisturbed), Bebeka-kebereta forest, Bonga-Shera forest, Masha-Gora shewi forest, Masha-Sherach forest and Yayu-Wabu Dureni forest.

Analysis t-test for mean dbh of the populations of *Pouteria adolfi-fridercii* in Bebeka 2 natural forest ($\bar{x}$*=96.5, SD=19.9, SE=3.7*), Yayu coffee mixed forest ($\bar{x}$*=36.2, SD=30.1, SE=8.3*), Shera-Kaffa natural forest ($\bar{x}$*=42.8, SD=26.5, SE=4.8*), Bebeka-kebereta forest ($\bar{x}$*=44.6, SD=13.0, SE=2.3*), Bonga-Shera forest ($\bar{x}$*=35.2, SD=12.7, SE=2.7*), Masha-Gora shewi forest ($\bar{x}$*=64.8, SD=28.2, SE=3.6*), Masha-Sherach forest ($\bar{x}$*=40.3, SD=13.0, SE=2.7* and Yayu-Wabu Dureni forest ($\bar{x}$*=38.1, SD=8.1, SE=1.7*) shows that Bebeka 2 natural forest appeared to have significantly larger mean dbh at $p<0.05$ compared to the other pilot forest sites (Figure 4). Masha-Gora shewi forest is found to be second most important site with respect to dbh size. However, there is no evidence showing that the mean variations of stem height amongst the other pilot forest sites are significant. According to Agroforestry Database, *Pouteria adolfi-fridercii* is reported to have up to 3 meter dbh size.[16] In this study, the maximum dbh (1.5m) is observed in Bebeka 2 natural forest while the minimum dbh (8cm) is recorded in Yayu coffee mixed forest and Shera-Kaffa natural forest. Stem dbh is also affected by the age of the tree; the older the tree the wider the diameter it will possibly have if other environmental conditions are constant and favorable. Moreover, the overall vegetation density of an ecosystem and the level of nutrients competitions would also affect carbon accumulation of a tree and the size of its diameter as well.

Prunus africana

Population dynamics and regeneration status

The population of *Prunus africana* was assessed in Kaho-shemeta, Bonga-Teja-adela forest, Bonga -Shera forest, Masha-Gora shewi forest and Masha - Sherach forest (Table 4). Masha-Gora shewi forest appeared to have dense population of *Prunus africana* (150 tree stem ha^{-1}) followed by Kaho-shemeta forest (130 tree stem ha^{-1}) as compared to the remaining pilot forests.

Analysis of stem height and dbh

Analysis of t-test for mean stem height of the populations of *Prunus africana* in Kaho-shemeta natural forest ($\bar{x}$*=31, SD=7.6, SE=1.0*), Bonga-Teja-adela forest ($\bar{x}$*=25.6, SD=7.3, SE=1.9*), Bonga-Shera forest ($\bar{x}$*=24, SD=5.2, SE=1.5*), Masha-Gora shewi forest ($\bar{x}$*=26, SD=4.3, SE=0.5*), and Masha - Sherach forest ($\bar{x}$*=25, SD=3.9, SE=0.5*) shows that Kaho-shemeta natural forest is proven to have population with significantly larger stem height at $p<0.05$

compared to the remaining pilot forests (Figure 5). However, there is no evidence showing that the mean variations of stem height amongst other pilot forest sites are significant. Moreover, the SE bars of the sample means ($\bar{x}$) stem height of *Prunus africana* population are apparently overlapped suggesting that variation of mean stem height amongst the population *Prunus africana* Bonga-Teja-adela forest, Bonga -Shera forest, Masha-Gora shewi forest and Masha - Sherach forest are not significant. According to Agroforestry Database, *Prunus africana* is reported to have 10-24 (36 max.) meters stem height.[16] On the other hand,[14,15] also reported that mature trees of can reach up to 40meters, and grows at 1500-2300meters above sea level with high-rainfall areas in Moist and Wet Weyna Dega agroclimatic zones and occurs in montane and riverine forests of Ilubabor, Kefa, Arsi, Wolega, Sidamo, Gonder, Gojam and Shewa regions.

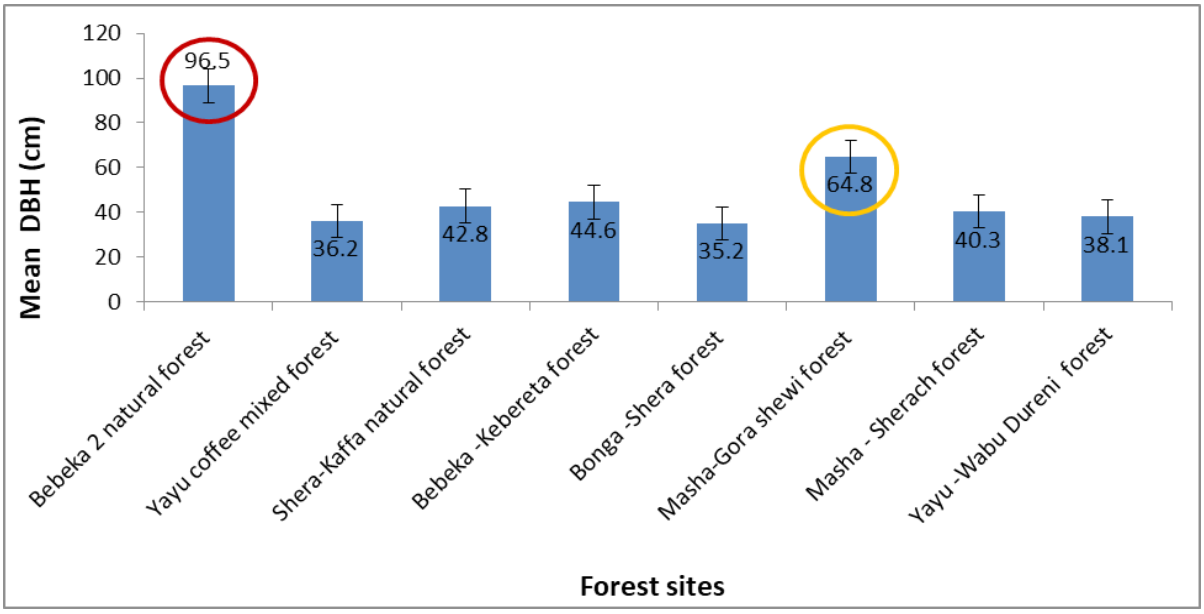

Figure 4 Comparison of mean ($\bar{x}$) and standard error (*SE*) for measurements of dbh of *Pouteria adolfi-fridercii* populations in Bebeka 2 natural forest (undisturbed), Yayu coffee mixed forest (disturbed), Shera-Kaffa natural forest (undisturbed), Bebeka-kebereta forest, Bonga-Shera forest, Masha-Gora shewi forest, Masha-Sherach forest and Yayu-Wabu Dureni forest.

Table 4 Summary descriptions of Kaho-shemeta, Bonga-Teja-adela forest, Bonga -Shera forest, Masha-Gora shewi forest and Masha - Sherach forest

Forest site	Total counts (N)			Density (per ha)	Distribution/ Dispersion	Reg. status	Overstory shading
	Seedling	Sapling	Trees	($\bar{x}$*10000/ 400m²)	($S^2/\bar{x}$ ratio)		
Kaho-shemeta	130	29	52	130	5.3=aggregately distributed	Fair	Partial
Bonga-Teja-adela forest	75	28	14	35	1.4=aggregately distributed	Good	Partial
Bonga -Shera forest	12	3	11	27.5	2.1=aggregately distributed	Fair	Partial
Masha-Gora shewi forest	18	26	60	150	8=aggregately distributed	Poor	Partial
Masha - Sherach forest	76	28	47	117.5	2.8=aggregately distributed	Fair	Partial

Analysis of t-test for mean dbh of populations of *Prunus africana* in Kaho-shemeta natural forest ($\bar{x}$*=50, SD=30, SE=4.1*), Bonga-Teja-adela forest ($\bar{x}$*=50, SD=17.5, SE=4.5*), Bonga-Shera forest ($\bar{x}$*=38, SD=12.9, SE=3.9*), Masha-Gora shewi forest ($\bar{x}$*=64.7, SD=28.2, SE=3.6*), and Masha - Sherach forest ($\bar{x}$*=52, SD=21.4, SE=3.2*) shows that Masha-Gora shewi forest ($\bar{x}$*=64.7, SD=28.2, SE=3.6*) is found to have significantly larger mean dbh at $p<0.05$ compared to the remaining pilot forest sites (Figure 6). However, according to Agroforestry Database, *Prunus africana* have stem diameter of 1meter.[16]

Antiaris toxicaria

Population dynamics and regeneration status

The population of *Antiaris toxicaria* was assessed in Bebeka 1 coffee forest site and Bebeka-kebereta site. Both forest habitats appeared to have the same density of *Antiaris toxicaria* in hectare. Overall, the ecological descriptions of the pilot forest sites are summarized below (Table 5).

Citation: Seid MA, Mulatu Y, Anjulo A, et al. Population survey of *Milicia excelsa, Pouteria adolfi-fridercii, Antiaris toxicaria* and *Prunus africana* in south and south-western Ethiopia: implications for domesticating and establishing Seed Production Areas. *MOJ Eco Environ Sci.* 2020;5(4):153–162.
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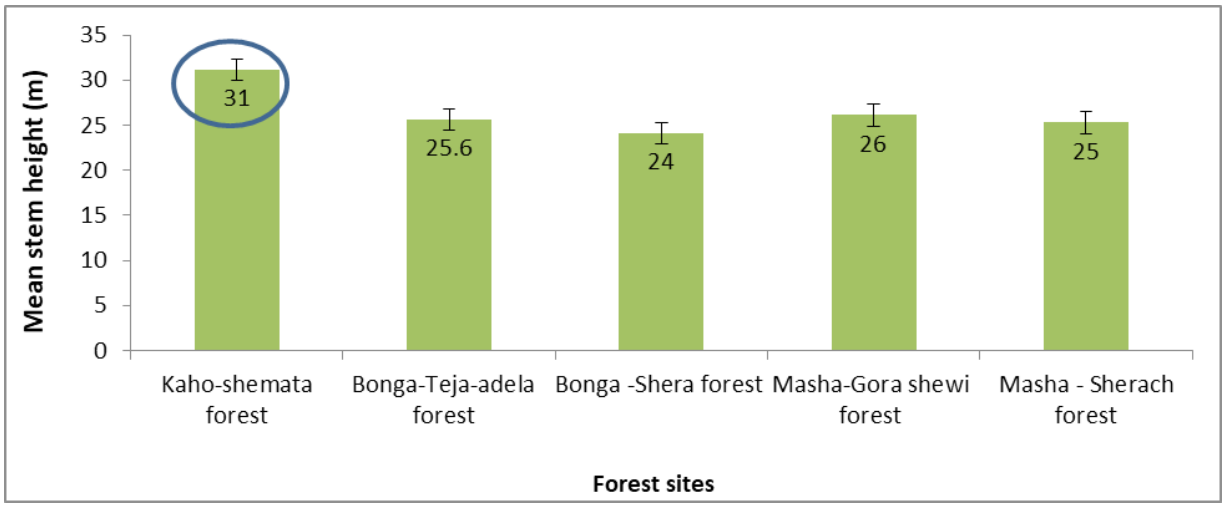

Figure 5 Comparison of mean ($\bar{x}$) and standard error (*SE*) for measurements of stem height of *Prunus africana* population in Kaho-shemeta natural forest, Bonga-Teja-adela forest, Bonga -Shera forest, Masha-Gora shewi forest and Masha - Sherach forest.

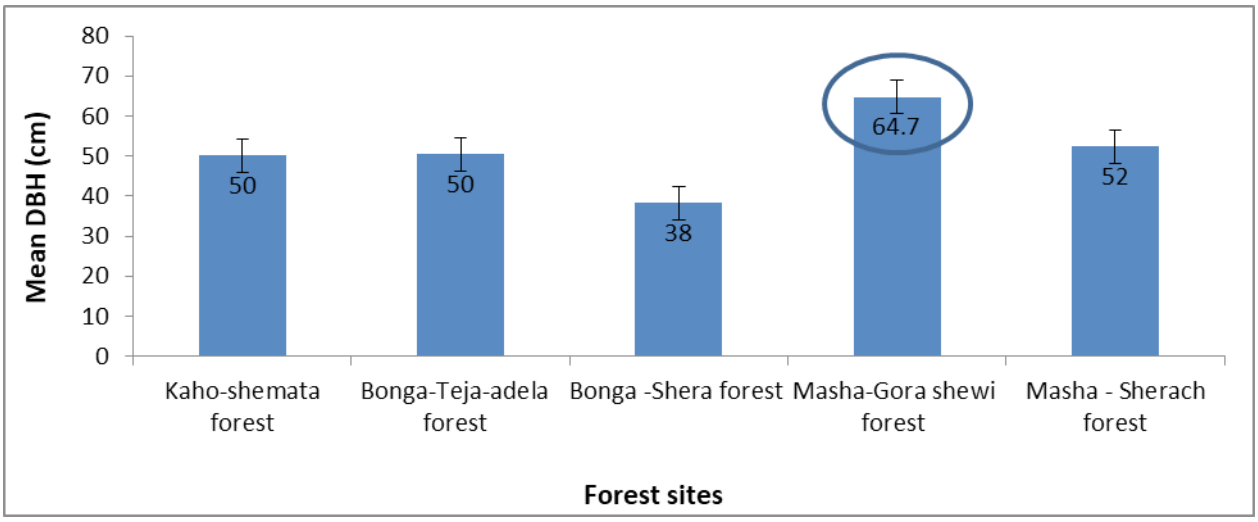

Figure 6 Comparison of mean ($\bar{x}$) and standard error (*SE*) for measurements of dbh of *Prunus africana* population in Kaho-shemeta natural forest, Bonga-Teja-adela forest, Bonga -Shera forest, Masha-Gora shewi forest and Masha - Sherach forest.

Table 5 Summary descriptions of *Bebeka 1 coffee forest* and *Bebeka-kebereta pilot* survey sites in reference to *A. toxicaria*

Forest site	Total counts (N)			Density (per ha)	Distribution/ Dispersion	Reg. status	Overstory shading
	Seedling	Sapling	Trees	($\bar{x}$*10000/ 400m²)	($S^2/\bar{x}$ ratio)		
Bebeka 1	213	0	5	12.5	1=> random distribution	Fair	Partial
Bebeka -Kebereta forest	10	4	5	12.5	1=> random distribution	Fair	Partial

Analysis of stem height and dbh

Analysis of t-test for mean stem height of *A. toxicaria* shows that Bebeka 1 forest ($\bar{x}$=*21.4, SD=5.2, SE=2.3*) have statistically not different population at $p<0.05$ compared to Bebeka-kebereta forest ($\bar{x}$=*22.4, SD=2.7, SE=1.2*) (Figure 7). The maximum height recorded in Bebeka 1 forest is 27m and the minimum is 17m. On the other hand, stem height ranges from 18-25m in Bebeka-kebereta forest. So, both or either of the two forests could be used for domestication work and SPA establishment project. Generally, according to Agroforestry Database, *A. toxicaria* is reported to have 20-40 m stem height.[16]

Analysis of t-test for mean dbh of *A. toxicaria* populations in shows that the mean variation of DBH between *A. toxicaria* populations in Bebeka 1 forest ($\bar{x}$=*48, SD=16.4, SE=7.3*) and Bebeka-kebereta forest ($\bar{x}$=*48, SD=8.2, SE=3.6*) is statistically not significant at $p<0.05$

Citation: Seid MA, Mulatu Y, Anjulo A, et al. Population survey of *Milicia excelsa, Pouteria adolfi-fridercii, Antiaris toxicaria* and *Prunus africana* in south and south-western Ethiopia: implications for domesticating and establishing Seed Production Areas. *MOJ Eco Environ Sci.* 2020;5(4):153–162.
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(Figure 8). The dbh ranges from 30-60cm in Bebeka 1 coffee forest and from 35-55cm in Bebeka-kebereta forest. On the other hand,[16] reported that *A. toxicaria* normally has a diameter ranging from 0.6 to 1.8m.

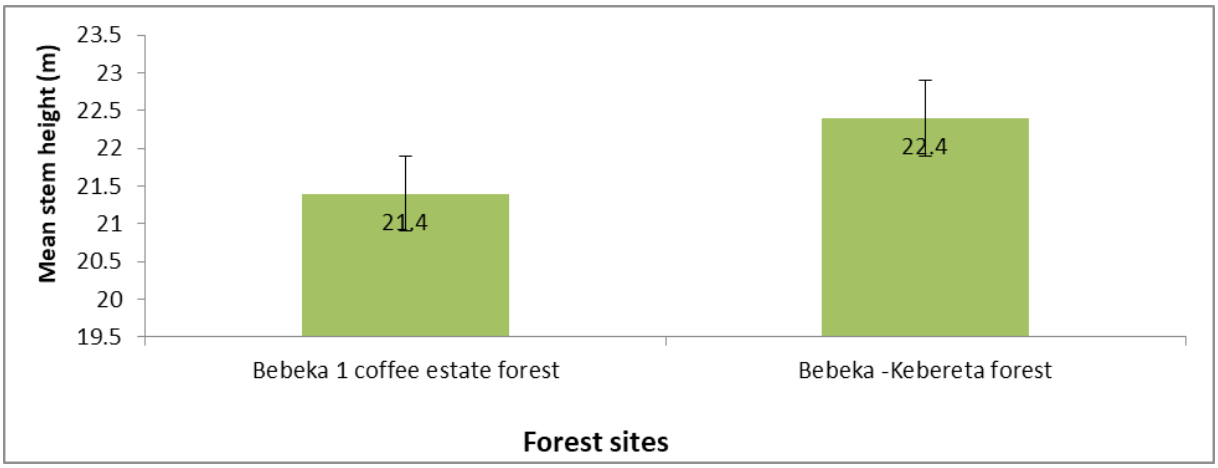

Figure 7 Comparison of mean ($\bar{x}$) and standard error (*SE*) for measurements of stem height of *A. toxicaria* population in Bebeka 1 coffee forest and Bebeka-kebereta pilot survey sites.

Conclusion and recommendations

In this study, natural forest ecosystems in south and south-western Ethiopia were assessed to find out the population dynamics and dendrological parameters such s stem height and dbh for four important indigenous timber trees. As far as *M. excelsa* is concerned, Bebeka -Duduka natural forest and Yayu coffee mixed forest appeared to have relatively denser population compared to the other pilot forests; Masha-Gora shewi forest appeared to have dense population of *P. adolfi-fridercii* and Bebeka-Kebereta as compared to the remaining pilot forests; Masha-Gora shewi and Kaho-shemeta forests appeared to have dense population of *Prunus africana* as compared to the remaining pilot forests; *Antiaris toxicaria* have equal density in Bebeka 1 coffee forest site and Bebeka-kebereta sites.

Generally, Bebeka area forest complex is identified as potential *in-situ* site for domestication and SPA establishment project of *Milicia excelsa, Pouteria adolfi-fridercii* and *Antiaris toxicaria*. On the other hand, Kaho-shemeta natural forest and Bonga-Teja-adela forest are identified as potential *in-situ* site for domestication and SPA establishment project of *Prunus africana*. Therefore, while implementing the project of domestication and SPA establishment in south and south-western Ethiopia, *in-situ* and *ex-situ* areas must be selected and delineated in accordance with this preliminary information of the population dynamics and genetic qualities of stem height and dbh. The survey data generated in this study would bridge the research gap in relation to the population status of the target tree species in the designated area. So, potential users of these findings include biodiversity conservation institutes, forest and environmental institutes, forest and seed enterprise, and other forest-based enterprises such as honey producers, forest extension organizations and others.

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Conflicts of interest

The authors declare there are no conflicts of interest.

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