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Site Suitability, Early Survival, and Growth Performance of Five Indigenous Tree Species to Integrate in Urban Green Space of Addis Ababa, Ethiopia

By Eyob Tenkir, Tamrat Bekele, Sebsebe Demissew, and Ermias Aynekulu

Abstract. Background: We evaluated site suitability, early survival, and growth performance for *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, *Vachellia abyssinica*, *Hagenia abyssinica*, and *Afrocarpus falcatus* in the urban landscape of Addis Ababa, Ethiopia. Methods: The MaxEnt model was used to evaluate site suitability for the 5 indigenous species. For the early survival study, experimental plots were established and 500 seedlings, 100 seedlings for each species, were planted on 2021 July 15 and monitored until 2022 February 30 for a total of 225 days. Silvicultural activities such as mulching, weeding, and watering were conducted. Every 45 days, measurements of height, root collar diameter (RCD), death, damage, wilting, and defoliation were recorded. Results: The result of the study indicated that the Addis Ababa area is well to moderately suitable to grow the 5 species. Mean survival rates marginally declined over the course of 225 days, from 99.6% at 45 days after planting to 90.4% at 225 days after planting. Eighteen *V. abyssinica* seedlings were found to be dead. Wild animals browsed and damaged 45% of *O. europaea* seedlings. *H. abyssinica* had the highest growth performance. The study shows that, relative to the other 4 species, *V. abyssinica* had a greater number of wilted, defoliated, and dead seedlings. Conclusion: Each of the 5 species had a high rate of early survival and found the urban environment to be suitable. This result will assist in the shift away from planting only exotic tree species in green spaces and encourage the presence of indigenous tree species.

Keywords. Early Survival; Indigenous Species; Restoration; Suitability; Tree Planting.

INTRODUCTION

In accordance with the Global Forest Resource Assessment, global forests cover an estimated 4.06 billion hectares (31%) of the Earth's surface. Almost 1.6 billion people rely directly on the forest for food, fuel, timber, shelter, and work (FAO 2016). Ninety-three percent of forests are thought to be naturally regenerating, whereas only seven percent (290 million hectares) are planted. Nevertheless, from 1990 to 2020 naturally regenerating forests have been diminishing and the extent of planted forests have been steadily growing.

Since 1990, 178 million hectares of forests have been lost from the earth (FAO 2020). In the tropics, deforestation continues at a rate of 13 million hectares per year with negative impacts on biological diversity (Bremer and Farley 2010). About 17.35 million ha (15.4%) of Ethiopia is forested. However, due to increasing pressure, Ethiopia has been losing about 92,000 ha (0.54%) of forest annually between 2000 and 2013 (FDRE 2018). Ecologically and commercially high valuable indigenous species in Ethiopia are being negatively impacted by forest degradation. The demand for wood furniture made from indigenous species—such as *Hagenia abyssinica*, *Cordia africana*, *Afrocarpus falcatus*, and others—has increased over time (Furo et al. 2019). Commonly utilized and deteriorated species, including *Hagenia abyssinica, Afrocarpus falcatus,* and *Juniperus procera*, were protected by the legal system (FAO 1994). In Ethiopia, deforestation coupled with planting mostly exotic species are threats for indigenous plants (Negash 2002).

Projections indicate the potential for 9 million ha to be deforested between 2010 and 2030 unless action is taken (FDRE 2011). To mitigate deforestation and forest degradation and enhance the forest cover, 3 million ha reforestation targets have been set by the government to be implemented by regions and city administrations (FDRE 2021). To re-establish the fundamental link that indigenous trees provide for both people and other forms of life, landscape restoration using indigenous trees is crucial (Negash 1995).

In Ethiopia, most tree planting programs, including the recent national-level Green Legacy Initiative, planted largely exotic tree species (Gemechu and Jiru 2021). Ethiopian forest plantations largely use exotic species, with a few recent attempts being the exception. The reliance on exotic species for reforestation or restoration ignores the long-adapted indigenous species with their variety of benefits (Wassie 2020).

Remnant trees found in church compounds, recreational parks, northern hills, and other green spaces of Addis Ababa indicate that Addis Ababa was once covered with indigenous species such as *J. procera*, *A. falcatus*, *O. europaea* subsp. *cuspidata*, *H. abyssinica*, and *V. abyssinica*. However, natural vegetation was reduced significantly due to anthropogenic effects (Tenkir Shikur 2011; Argaw et al. 2017). Integrating indigenous tree species in urban regreening is important both to get the services provided by the indigenous tree species and to conserve the species. It is suggested that all plantation sites use both indigenous and exotic species to make the plantation ecologically sound and sustainable (Kassa et al. 2009). One of the justifications attributed for the planting of exotic species was the better growth performance of exotic species than indigenous tree species (Gemechu and Jiru 2021). Enhanced biodiversity outcomes are expected with plantations that utilize indigenous tree species (Stephens and Wagner 2007). Poor site suitability analysis is a significant contributor to the low rate of seedling survival (Kodikara et al. 2017). Various models were used to produce site suitability maps including maximum entropy model (MaxEnt)(Phillips et al. 2002). MaxEnt is a correlative machine-learning model with several applications in ecology and suitability studies (Phillips et al. 2006). Knowledge of site suitability is important to predict the appropriate conditions for cultivating plants (Wei et al. 2018).

The survival rate of planted seedlings has proven to be the most important key indicator of the success of forestry activities (Sullivan et al. 2009). In addition, inappropriate species selection in afforestation or restoration is the cause of the low survival rate of seedlings (Abrha et al. 2020). Information on suitability and patterns of species distribution is crucial for developing future conservation plans (Elith et al. 2011).

Santamour (1990) outlines how planting a mix of species protects urban forests against pests. The reforestation techniques in different landscapes of Addis Ababa involve planting potted seedlings of largely monoculture exotic species. Since seedling survival was low, it was noted that seedlings were repeatedly planted on the same site (Tenkir Shikur 2011). Many restoration attempts fail to considerthe variables that affect survival (Sullivan et al. 2009). Plantations were established by various implementers; however, the methods used to identify site suitability have gaps (Nyebenge et al. 2009; Wendimu 2013). This study was initiated to generate scientific information on the suitability of Addis Ababa and analyze site suitability, survival, and growth performance of highly economically and ecologically important indigenous tree species (i.e., *J. procera*, *H. abyssinica*, *O. europaea* subsp. cuspidata, *V. abyssinica*, and *A. falcatus.* The knowledge gathered from such studies can be applied to enhance the integration of indigenous species in urban areas, including a 22,000-ha potential green space in Addis Ababa (Zeleke et al. 2018).

METHODS

Study Area

This study was carried out at the Gullele Botanic Garden (GBG), which is situated in the Gullele district of Addis Ababa, Ethiopia (Figure 1), where the mean minimum temperature ranges from 8.56 to 9.82 °C, the mean maximum temperature ranges from 18.25 to 23.52 °C, and the mean average temperature ranges from 13.4 to 16.67 °C. The mean minimum annual rainfall is 817.5 mm, the mean maximum annual rainfall is 1,466.8 mm, and the mean annual rainfall is 1,037.52 mm (Alemu and Dioha 2020). The elevation of the site is about 2,638 m above sea level. The GBG was chosen for the study following a direct visual assessment of the grounds. The site where the experimental plot was established had enough permanent river water to water the planted seedlings and was fenced to restrict access of domestic animals and the free movement of humans.

Soil Characteristics

The experimental plot was established in the forest mountain range within the GBG, which was formerly dominated by *Eucalyptus* trees. Within the mountain range containing the experimental site at 2,038 m above sea level, exhibits specific physical and chemical properties in the soil. These properties consist of an

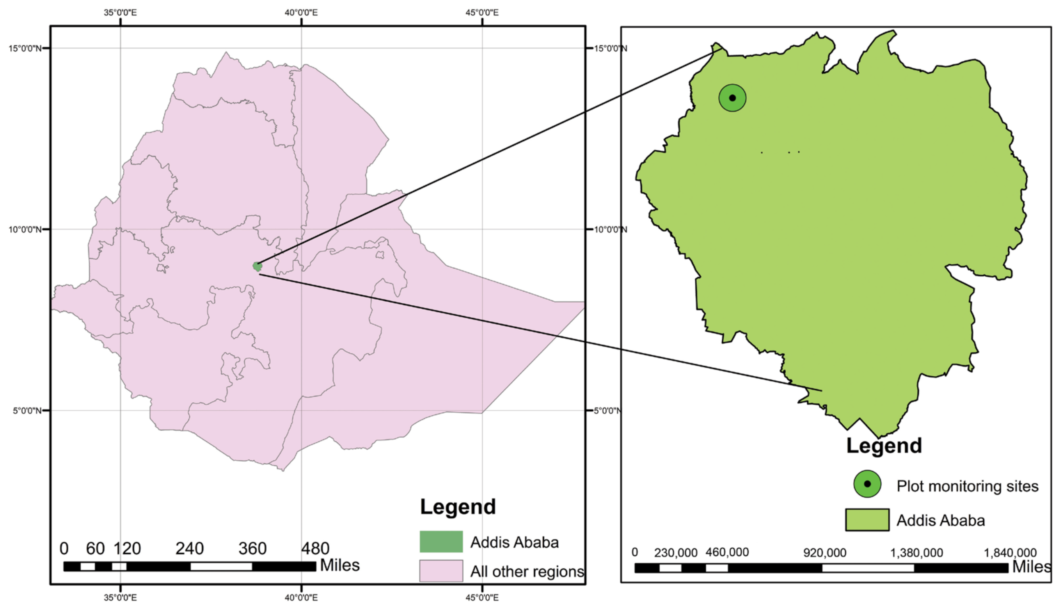

Figure 1. Study area.

average electrical conductivity of 0.003 ms/cm, a mean pH of 4.13, 1.1% organic carbon content, 1.09% total nitrogen content, and a bulk density of 1.68 g/mL. The soil texture is composed of 34% sand, 11% clay, and 55% silt, categorizing it as salt loam. Additionally, it has a creation exchange capacity of 8 moles/kg. A soil pH below 5.5 signifies a low pH, indicating acidic soil properties, while a soil bulk density above 1.46 g/cm^3 suggests compact soil (Landon 1984). Consequently, the study site soil exhibits potentially acidic properties, and its bulk density indicates that it is compacted.

Selected Species

The 5 selected species for this experiment were the indigenous species frequently planted in mountain landscape of Addis Ababa. The selected species are *Afrocarpus falcatus*, *Hagenia abyssinica*, *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, and *Vachellia abyssinica*. These species are characteristic species of dry Afromontane vegetation and were once largely found in and around Addis Ababa.

Experimental Design

Seedling Production and Field Planting

Viable seeds of *Afrocarpus falcatus*, *Hagenia abyssinica*, *Juniperus procera*, *Olea europaea* subsp. *cuspidata*, and *Vachellia abyssinica* were obtained from the seed center at the Forestry Research Center in Addis Ababa and Amhara. Each seed was sown directly on 15 cm (height) by 8 cm (diameter) polyethylene tubes filled with mixed substrates of 4:2:1 (local soil:forest soil:sand soil, respectively). Seedlings of 5 species (100 seedlings per species) were raised at Yeka Ankorcha government nursery site. The raised seedlings have green and healthy leaves, strong and upright stems, and are free from any visible disease symptoms.

Five plots, each 400^2 m in size, were used to study the early development, survival, and perfomance of five indigenous species. Five hundreds seedlings in five replicates of one hundred seedlings each were designed at the field using a completely randomized deisgn (CRD). These seedlings were separated by 2 m on each side. From the day of planting on 2021 July 15, during the rainy season, until 2022 February 30, the seedlings were monitored for a total of 225 days in the field.

All individuals were tagged and numbered to enable the identification of each seedling. All the required seedling treatments (watering, shading, weeding, and hardening) were conducted.

Data Collection

Site Suitability

The MaxEnt can be effectively used to model species distribution based on presence-only data. It has been used in the field of conservation biology and ecology

(Elith et al. 2011). The MaxEnt model was used to identify suitable sites for the selected 5 species. The mapping process utilized occurrence and environmental data (topographic and climatic data). Occurrence data, including longitude and latitude, were collected primarily from field surveys using a hand-held Global Positioning System (GPS) device and national herbarium collections. Topographic environmental data, factors including slope, aspect, and elevation were generated from Advanced Space-borne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM 2009; Gebrewahid et al. 2020). To acquire climate-related environmental data, 19 bioclimatic variables were used (Fick and Hijmans 2017). The specifics of these bioclimatic and topographic variables are presented in Table 1.

Early Survival and Growth Performance

Seedling survival data was collected to identify the extent and causes of mortality. To estimate seedling survival and growth, the numbers of living seedlings were counted every 45 days thereafter until the end of 225 days (Tafesse 2007). Plants with no live parts were recorded as 'missing' and considered dead, and the remaining plants were considered alive. Variables affecting survival were recorded at each site (Holzwarth et al. 2013). Growth performance parameters, seedling height and root collar diameter (RCD) were measured every 45 days for each seedling. Seedling height was measured in centimeters using a ruler, while RCD was measured using a diameter caliper in millimeters (mm) near soil surface (Bahru et al. 2018).

To evaluate the effect of tree canopy closure on the performance of planted seedlings, we used Canopy-Capture (Patel 2018). Canopy Capture offers a quick and repeatable proxy for comparisons of average canopy cover and understory illumination (Lusk 2022).

Statistical Data Analysis

MaxEnt species distribution modeling was used to predict the climatically suitable habitats for the selected

Table 1. Bioclimatic and topographic variables used in the species suitability mapping.

Code	Name of variable and description	Unit
Bio 1	Annual mean temperature (CV)	°C
Bio 2	Mean diurnal range precipitation of wettest quarter	°C
Bio 3	Isothermality (Bio2/Bio7)(× 100)	%
Bio 4	Temperature seasonality (Sd × 100)	°C
Bio 5	Max. temperature of warmest month	°C
Bio 6	Min. temperature of coldest month	°C
Bio 7	Temperature annual range	°C
Bio 8	Mean temperature of wettest quarter	°C
Bio 9	Mean temperature of driest quarter	°C
Bio 10	Mean temperature of warmest quarter	°C
Bio 11	Mean temperature of coldest quarter	°C
Bio 12	Annual precipitation	mm
Bio 13	Precipitation of wettest month	mm
Bio 14	Precipitation of driest month	mm
Bio 15	Precipitation seasonality (CV)	%
Bio 16	Precipitation of wettest quarter	mm
Bio 17	Precipitation of driest quarter	mm
Bio 18	Precipitation of warmest quarter	mm
Bio 19	Precipitation of coldest quarter	mm
Elevation	Elevation	m
Slope	Slope	%

species using occurrence localities and bioclimatic variables. MaxEnt is currently one of the most frequently applied environmental niche models (Merow et al. 2013). ArcGIS 10.2 (Esri, Redlands, California, USA)(ArcGIS 2013) was used to extract suitability for the selected species based on occurrence localities from the maps of climate suitability generated by our MaxEnt models. Site suitability levels for the 5 species in Addis Ababa were mapped and categorized into high suitable (red), suitable (yellow), mid suitable (green), and low suitable (blue)(Figure 2).

Survival and damage of seedlings were analyzed for each tree species planted in the experimental plot using the following formula (Megan 2013):

$$\text{Mortality rate} = \text{number of seedlings dead during study period} / \text{total number of seedlings planted} \times 100$$
$$\text{Survival Rate} = 100 - \text{mortality rate}$$

The difference between 2 consultative samplings was considered corresponding mean height or RCD increment over a period of 225 days.

Using SPSS software, statistical analyses such as mean, variance, and standard error (SE) were calculated to estimate mean survival, damage impacts on seedlings, plant height, and RCD and were used to see the variability across species.

$$SE = s / \sqrt{n}$$

where s = the standard deviation between means; n = the sample size; SE = Standard Error.

RESULTS

Site Suitability

Addis Ababa is suitable for all 5 species. A large part of the middle- and lower-elevation sites is highly suitable for *A. falcatus*, *O. europaea* subsp. *cuspidata*, and *V. abyssinica* while the high-elevation sites are highly and moderately suitable for *H. abyssinica*. Higher, middle, and lower parts of the city are highly suitable for *A. falcatus* (Figure 2).

Seedlings Survival Rate

The average survival rates of the 5 species marginally declined over the course of 225 days, from 99.6% at 45 days after planting to 90.4% at 225 days after planting. *Juniperus procera* and *Olea europaea* exhibited high survival rates, ranging from 94% to 100% across the various days after planting, with a total standard deviation of 2.775 and 2.191, respectively, signifying relatively low variation in survival rates. *Afrocarpus falcatus* had survival rates ranging from 89% to 100%

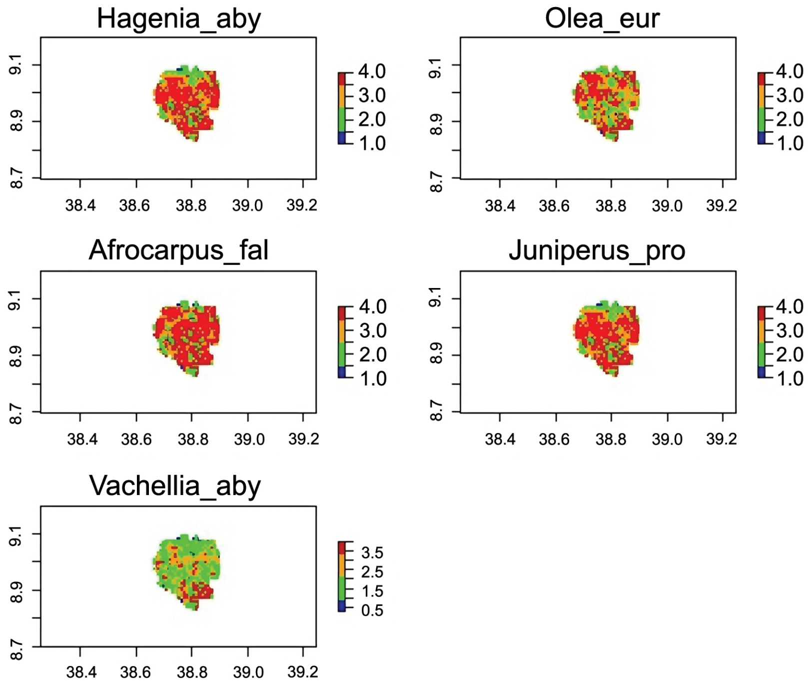

Figure 2. Site suitability for 5 indigenous species: Juniperus_ pro = *Juniperus procera*; Olea_eur = *Olea europaea* subsp. *cuspidata*; Hagenia_aby = *Hagenia abyssinica*; Afrocarpus_ fal = *Afrocarpus falcatus*; Vachellia_aby = *Vachellia abyssinica*.

with a total standard deviation of 3.813, indicating higher variability in survival rates compared to *Juniperus procera* and *Olea europaea. Hagenia abyssinica* survival rates were the least variable, ranging from 93% to 98%, with a total standard variation of 1.924. With a total standard deviation of 7.563 and the broadest range of survival rates (82% to 100%), *Vachellia abyssinica* suggests increased variability and lower survival rates (Table 2). At 7 months and 15 days post planting, there were recorded deaths or missing seedlings for 18 *V. abyssinica*, 9 *A. falcatus*, 6 *H. abyssinica*, and 4 *O. europaea* (Figure 3). For all species the mortality rates increased between mid-February and April, 180 days after the seedlings were planted (Figure 4).

Factors for Seedlings Damage

Olea europaea has the highest mean browsing score (0.45), followed by *Vachellia abyssinica* (0.07), *Hagenia abyssinica* (0.01), *Juniperus procera* (0.02),

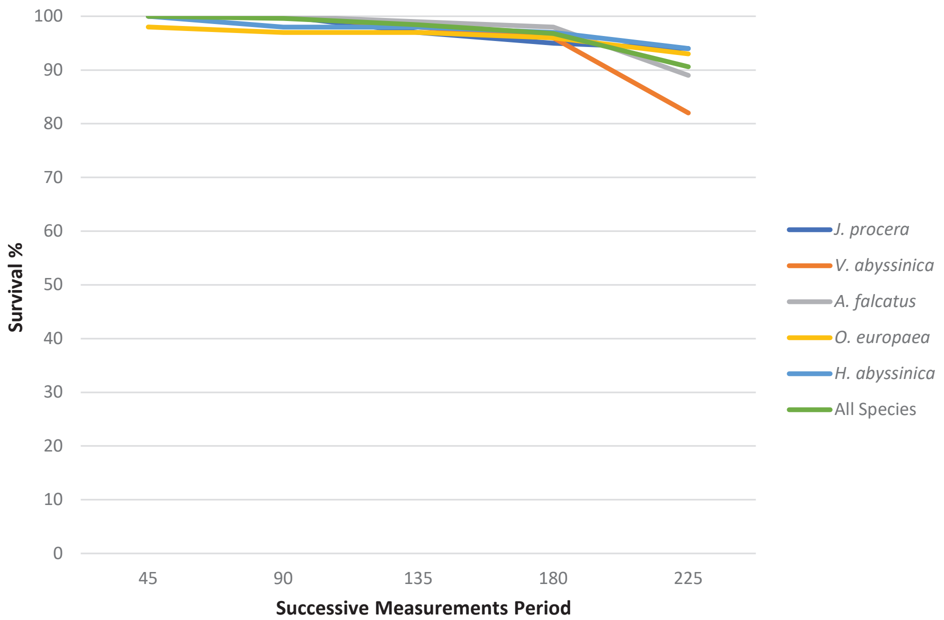

Figure 3. Early survival of 5 indigenous species seedlings.

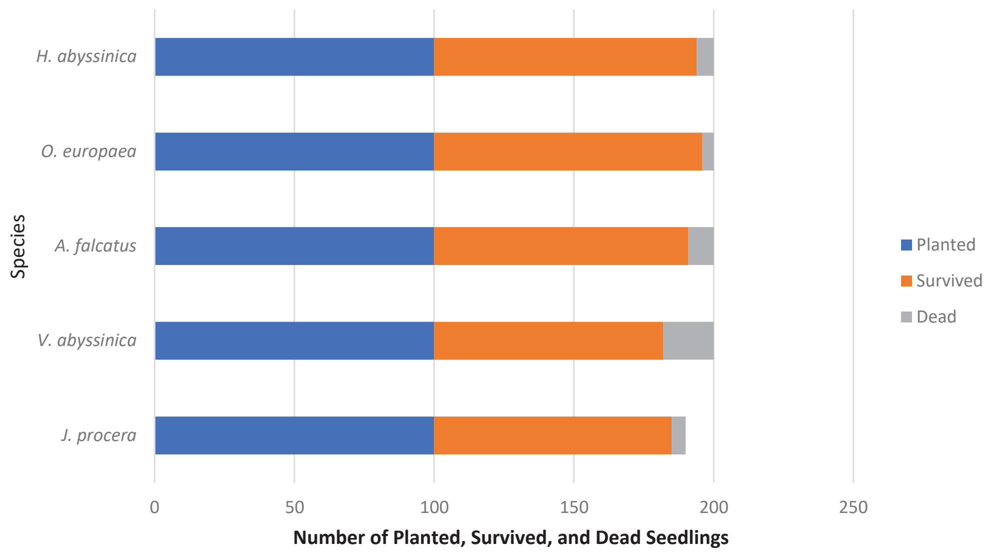

Figure 4. Seedling survival rate of the 5 tree species.

and *Afrocarpus falcatus* (0.02). *Olea europaea* is the most browsed species among the 5 (Table 3).

Olea europaea was browsed by wild animals even though the Gullele Botanic Garden was fenced and restricted from domestic animals. Less herbivore damage was recorded for *V. abyssinica*, *J. procera, A. falcatus,* and *H. abyssinica*. Young shoots of *O. europaea* subsp. *cuspidata* were visited and repeatedly browsed even after the seedling resprouted young shoots, but unlike the other studied species, it is hardy to damage and resprouted again. *V. abyssinica* (40%) and *A. falcatus* (31%) exhibited wilting and partial defoliation (Figure 5).

The results indicate that there are differences in the degree of wilting and defoliation among the different species. *Vachellia abyssinica*, for example, has a much higher mean value of 0.43 and a standard error of 0.05 for wilting and defoliation compared to the other species (Table 3). Wilting and defoliation rates of the 5 species was associated with the shading effect of nearby trees. The amount of wilting and defoliation in *V. abyssinica, A. falcatus*, and *H abyssinica* seedlings increased in sites when canopy cover was lower than 25% (Figure 6).

Height Growth of the 5 Indigenous Seedlings

The mean growth in height pattern revealed that the 5 species show overall mean height increment between 0 to 225 days. *H. abyssinica* showed a comparatively significant mean height change, with an initial mean height of 21.4 + 0.7 cm at 0 days increasing to 28 ± 1.0 cm at 225 days, with a total height growth change of 7.1 cm. *O. europaea* had relatively slow height

Table 2. Average survival percentage (%) of each species and all the species in the monitoring period.

No	Species	Average survival/days after planting					Total standard deviation of survival
		45	90	135	180	225	
1	*Juniperus procera*	100.00	100.00	97.00	95.00	94.00	2.775
2	*Olea europaea*	100.00	98.00	98.00	97.00	94.00	2.191
3	*Afrocarpus falcatus*	100.00	100.00	97.43	98.00	89.00	3.813
4	*Vachillea abyssinica*	100.00	100.00	98.00	96.00	82.00	7.563
5	*Hagenia abyssinica*	98.00	97.00	97.00	96.00	93.00	1.924
		99.60	**99.00**	**97.47**	**96.40**	**90.40**	3.911

Table 3. Mean and standard error of seedlings of wilted-defoliated and browsed species.

Species	Wilted, defoliated, and browsed	x̄± SE
Vachillea abyssinica	Wilted and defoliated	0.43 ± 0.050
	Browsed	0.07 ± 0.026
Hagenia abyssinica	Wilted and defoliated	0.1400 ± 0.03487
	Browsed	0.0100 ± 0.01000
Juniperus procera	Wilted and defoliated	0.2400 ± 0.04292
	Browsed	0.0200 ± 0.01407
Olea europaea	Wilted and defoliated	0.0400 ± 0.01969
	Browsed	0.4500 ± 0.05000
Afrocarpus falcatus	Wilted and defoliated	0.3100 ± 0.04648
	Browsed	0.0200 ± 0.01407

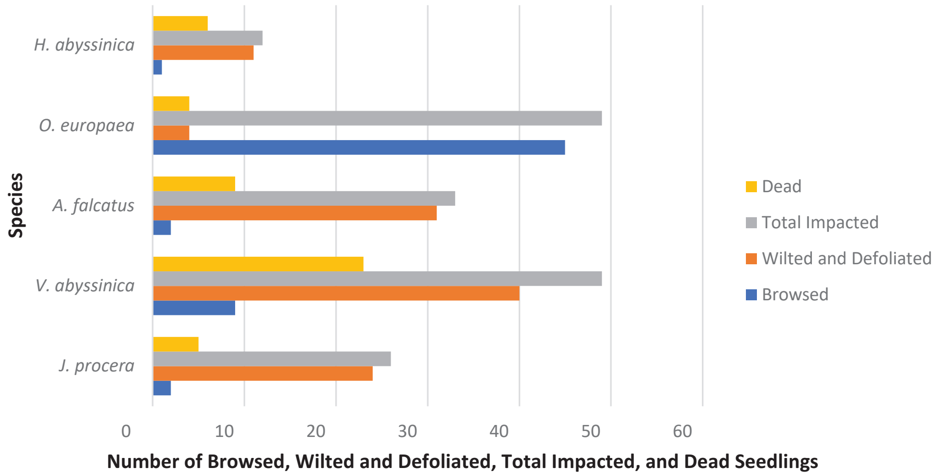

Figure 5. Indigenous tree seedlings damage.

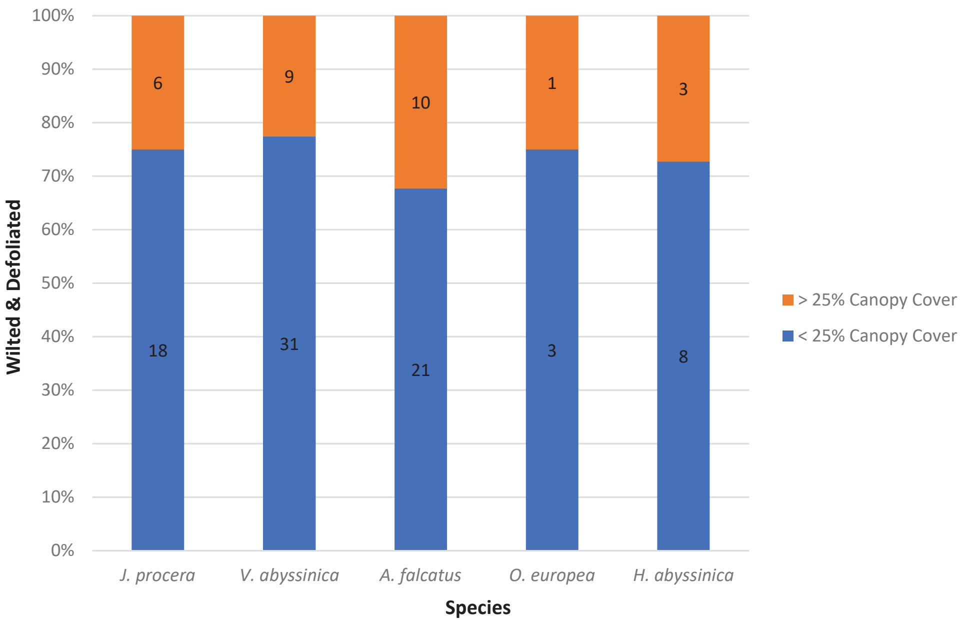

Figure 6. Wilted and defoliated seedlings.

growth with an initial mean height of 30.9 ± 1.0 cm at 0 days, which increases to 31.9 ± 1.2 cm at 225 days. *A. falcatus* height growth dropped from 19.2 ± 0.6 to 18.6 ± 0.8 between 180 and 225 days. *J. procera* showed consistent growth with no drop in height (Table 4).

Root Collar Diameter (RCD)

The growth rates for different species of trees vary and can have periods of rapid increase and slow growth. Specifically, the RCD growth of *V. abyssinica* appears slow initially (0.28 to 0.39 cm from 0 to 90 days) but increases significantly between 90 to 180 days (0.39 to 0.65 cm). There is no change in the mean value from 180 to 225 days (0.65 to 0.65 cm), which might indicate a slowing down of growth. *H. abyssinica* show a more consistent growth rate over time, steadily increasing from 0.3 cm to 0.84 cm over 225 days. The growth rate appears to be higher in comparison to *V. abyssinica*. The growth rate of *J.*

Table 4. Mean height growth in centimeters (cm) of the monitored species.

Species	Mean height growth in cm after planting (days)					
	0	45	90	135	180	225
	x̄ ± SE	x̄ ± SE	x̄ ± SE	x̄ ± SE	x̄ ± SE	x̄ ± SE
V. abyssinica	42.2 ± 1.5	44 ± 1.5	44.2 ± 1.6	45.9 ± 1.5	45.9 ± 1.6	45.37 ± 1.6
H. abyssinica	21.4 ± 0.7	23.4 ± 0.7	25.1 ± 0.8	26.3 ± 0.9	27.6 ± 0.9	28.5 ± 1.0
J. procera	13.2 ± 0.3	14.4 ± 0.3	15.1 ± 0.3	16.0 ± 0.3	17.1 ± 0.4	18.9 ± 0.5
O. europaea	30.9 ± 1.0	29.8 ± 1.0	30.6 ± 1.1	31.3 ± 1.0	31.6 ± 1.1	31.9 ± 1.2
A. falcatus	15.4 ± 0.4	17.4 ± 0.5	18.1 ± 0.5	18.7 ± 0.5	19.2 ± 0.6	18.6 ± 0.8

Table 5. Mean root collar diameter growth in millimeter at different time interval.

Species	Time after planting (days)					
	0	45	90	135	180	225
	x̄ ± SE	x̄ ± SE	x̄ ± SE	x̄ ± SE	x̄ ± SE	x̄ ± SE
V. abyssinica	0.28 ± 0.01	0.35 ± 0.01	0.39 ± 0.10	0.46 ± 0.01	0.65 ± 0.22	0.65 ± 0.02
H. abyssinica	0.3 ± 0.10	0.43 ± 0.01	0.53 ± 0.02	0.70 ± 0.02	0.77 ± 0.02	0.84 ± 0.03
J. procera	0.11 ± 0.03	0.13 ± 0.01	0.16 ± 0.01	0.25 ± 0.01	0.25 ± 0.01	0.43 ± 0.16
O. europaea	0.16 ± 0.01	0.21 ± 0.01	0.30 ± 0.01	0.4 ± 0.01	0.41 ± 0.01	0.45 ± 0.02
A. falcatus	0.13 ± 0.01	0.17 ± 0.01	0.26 ± 0.01	0.30 ± 0.01	0.37 ± 0.01	0.46 ± 0.05

procera appears to be slow, ranging from 0.11 cm to 0.25 cm between 0 to 180 days. However, there is a significant increase between 180 to 225 days (0.25 to 0.43 cm), which indicates a period of rapid growth. *O. europaea*, similar to *H. abyssinica*, shows consistent growth over time, increasing from 0.16 cm to 0.45 cm over 225 days; the overall growth rate appears slower in comparison to both *V. abyssinica* and *H. abyssinica*. *A. falcatus* demonstrates a consistent growth rate, increasing from 0.13 cm at day 0 to 0.46 cm at day 225. The growth rate appears to be slower than *H. abyssinica* and *V. abyssinica* but similar to *O. europaea* (Table 5).

RCD growth and seedling height exhibited a linear connection, excluding species that did not display height changes due to browsing. For instance, *H. abyssinica* demonstrated an increase in height and RCD with measurements of 9.13 cm and 53 mm, respectively. Similarly, *A. falcatus* (5.9 cm in height and 36 mm RCD) and *J. procera* (5.56 cm in height and 35 mm RCD) both revealed corresponding growth in RCD and height (Figure 7 and Figure 8).

DISCUSSION

Site Suitability

Site suitability maps showed that Addis Ababa has a high suitable environment for the 5 indigenous tree species. High suitable sites indicate the site has favorable biophysical and climatic conditions for the successful establishment of the indigenous seedlings. Moderate suitable sites indicate a second priority for the species to be planted, which must be allotted for planting only after critical assessment of various factors. On the other hand, not suitable sites represent sites that are not appropriate for growing the candidate species. Studies indicated that the survival of seedlings might be higher in suitable sites than in unsuitable sites (Huang et al. 2022). The result showed the high, middle, and lower elevation part of Addis Ababa are highly suitable to grow *V. abyssinica, J. procera, P. falcatus*, and *O. europaea* subsp. *cuspidata* species. Whereas, for *H. abyssinica*, the higher part of the city is more suitable than the middle and lower parts. Ayele et al. (2009) found that *Hagenia abyssinica* populations throughout Ethiopia are situated at higher altitudes.

The examination on the survival of 5 species, which indicated that the minimum survival rate was 82%, validated the suitability of Addis Ababa for

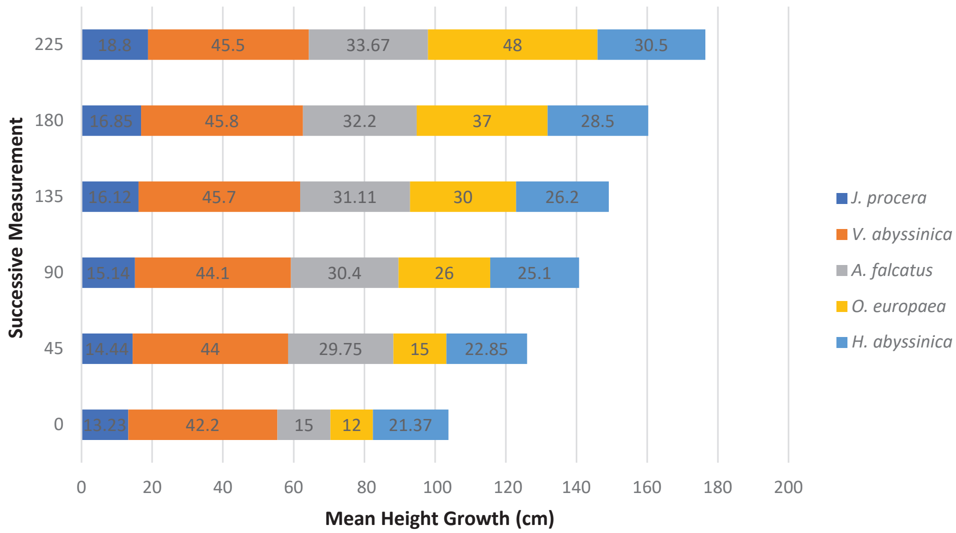

Figure 7. Mean growth in height of the 5 indigenous tree seedlings.

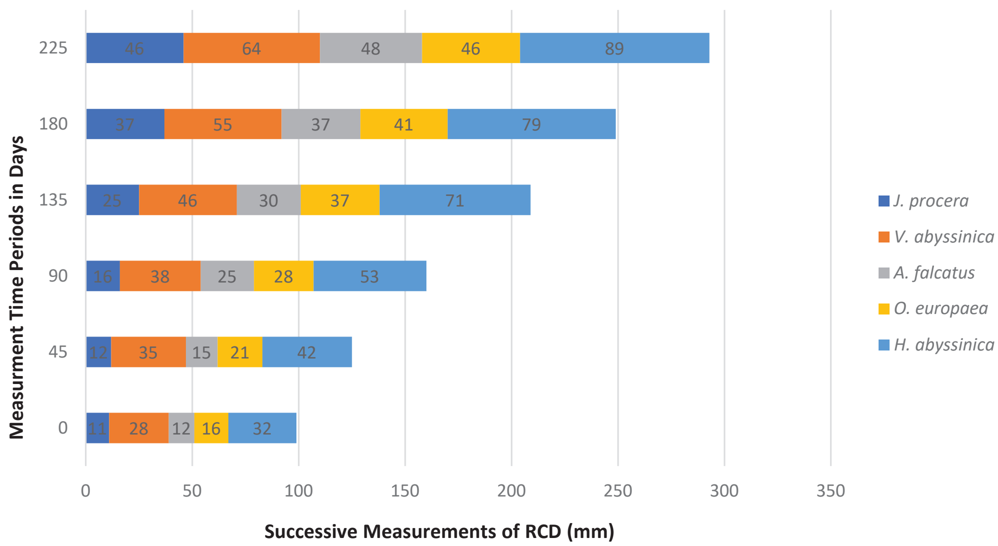

Figure 8. Mean Root Collar Diameter (RCD) of 5 indigenous species.

widely planting of the 5 species (Figure 3). The vegetation atlas of Ethiopia categorized and mapped the vegetation type based on altitude, climate, and soil criteria. The result showed that Addis Ababa falls in dry Afromontane vegetation type where the 5 indigenous species that were being monitored are considered as characteristics species (Friis et al. 2010).

Scientific information on suitability of the city is crucial for urban landscape designers and urban foresters integrating these species in the city landscape. Numerous studies have also shown that selection of indigenous species and suitable site identification for planting are the key question for urban landscape designers (Gotoh and Yokota 2009; Gilroy et al. 2017; Backstrom et al. 2018). Studies also indicated that selecting and cultivating threatened plants in urban environments contribute towards conservation and help to restore the decline of indigenous species in urban landscapes (DeCandido et al. 2007; Pan et al. 2019).

A significant portion of Addis Ababa is suitable for planting the 5 indigenous species, hence, planting these species will have a good influence on the city's biodiversity. Even while increasing biodiversity is not the primary goal of urban greening, planting indigenous species helps to reduce landscape degradation brought on by urban growth and can act as a refuge for regionally or globally endangered species (Jones and Leather 2013; Aronson et al. 2017; Blackmore 2019; Soanes and Lentini 2019).

Seedling Survival

H. abyssinica had the least varying survival rates among the 5 species with a range of 93% to 98% and a total standard deviation of 1.94. *Vachellia abyssinica* had the widest range of survival rates (82% to 100%), with a total standard deviation of 7.563, and predicted higher variability and poor survival rates (Table 2). The 5 monitored indigenous species showed high survival rates between 82% and 96% (Figure 3). This may be due to silvicultural management practices used in the experimental plot, specifically watering, weeding, mulching, and restriction of domestic animals and people, which have all contributed to the high survival rate. Studies have revealed that early seedling survival of planted seedlings hampered by environmental stress particularly water stress (Kolb and Robberecht 1996; Mihertu et al. 2006; Eshetie et al. 2020). The study made by Cole and Newton (2009) indicated that weeding practices significantly reduce mortality and/or help for the growth of seedlings.

Seedling Damage

Olea europeae and *Hagenia abyssinica* had the greatest and lowest mean browsing values with mean value of (0.45) and (0.01)(Table 3). *Olea europaea* (45%) selected and repeatedly browsed by wild animals (Figure 5). Even though, the repeated browsing of the seedlings hampered height growth of *Olea europaea*, this species was able to recover from repeated browsing. Aerts et al. (2008) and Tesfaye et al. (2010) reported that *Olea europaea* can survive repetitive cutting and browsing by increasing the shoot and leaf density, decreasing leaf size, and transforming shoots to spines. *O. europaea* subsp. *sylvestris* in the Mediterranean maquis survived frequent disturbance (Massei and Hartley 2000).

Studies also indicated that seedlings could tolerate a certain level of damage using compensatory growth (i.e., an encouraging growth response to injury), and thus resume height growth (Guillet and Bergstrom 2006). Studies indicated that *Olea europaea* leaves used as fodder have high nutrient value (Garcia et al. 2003; Xie et al. 2013). Similar studies indicated that animals select and browse young shoots of seedlings and negatively impact seedling growth rates (Kuijper et al. 2010; Ohse et al. 2017). Another study also indicated that animals select young shoots of seedlings because of their easy palatability and richer nutrient contents (Swaine 1996).

A. falcatus and H. abyssinica remain unaffected by herbivory (Figure 5). *A. falcatus* is unaffected by herbivory likely due to their characteristic tough leaves that deter animals from browsing (Tesfaye et al. 2010). Wilting and defoliation of the 5 species seedlings are directly correlated with the presence of shade. The amount of wilting and defoliation in *V. abyssinica*, *A. falcatus*, and *H. abyssinica* seedlings increased in sites with canopy cover percentages lower than 25% (Figure 6). Direct sunlight or less canopy cover (< 25% canopy cover) showed significant inversely correlated with growth and healthiness of the *V. abyssinica* and *A. falcatus* seedlings or which led to increased mortality rate (Figure 6 and 7). Open field where the cloud cover was minimal and the intensity of light was high the survival of *A. falcatus* seedlings can be affected (Negash 1995). Studies also indicated that partially shaded conditions can increase seedling survival when compared with full-sun conditions (Ashton et al. 1997; Cole et al. 2011). Ballal (1996) found that a 50% light intensity in the form of overhead shade caused significant increases in initial height of *Acacia senegal* seedlings. Bazzaz and Miao (1993) reported that good growth of *Quercus semiserrata* seedlings was recorded in medium light conditions. Various studies on *A. falcatus* recorded the impact of photoinhibition on the juvenile stage in open fields (Negash 1995; Fetene and Feleke 2001).

Seedling Growth Performance

The mean height growth pattern showed that during the first 90 days after planting, there was a general growth increase which then slowed down (Table 2). This may be because the first 2 months were rainy. Mekonnen et al (2006) found that greater height increments were observed at an earlier stage. *Hagenia abyssinica*, *A. falcatus*, and *J. procera* exhibited maximum mean height growth changes of 9.13 cm, 5.9 cm, and 5.56 respectively (Figure 8). The performance of these 3 species is important for Addis Ababa to integrate in greening urban landscape. However, growth of *O. europaea* is limited by browsing pressure.

Although all 5 species' RCD increased, the rates of growth varied between them and across the various subsequent times of measurements. Particularly, *V. abyssinica* appears to grow slowly at first (0.28 to 0.39 cm from 0 to 90 days), then dramatically between 90 and 180 days (0.39 to 0.65 cm)(Table 5). The difference in average values between the various species indicates that they each have distinct growth patterns or rates of change for the RCD. This offers insights into the species' growth dynamics. The results showed that there was a relationship between height and RCD growth, particularly with species where their height was not affected by browsers. *H. abyssinica* showed higher height (9.13 cm) and RCD (53 mm) change. The second and third highest change in height and RCD was observed on *A. falcatus* (5.9 cm height and 36 mm RCD) and *J. procera* (5.56 cm height and 35 mm RCD) respectively. A study conducted on early survival of seedlings showed that higher height and RCD values are crucial for seedling growth (Bahru et al. 2018).

CONCLUSION

Integrating indigenous species in urban and other landscapes depends critically on scientific information generated on survival and suitability of indigenous species. The results generated by this study help Ethiopia to fulfill its 2016 commitment to restore up to 15 million hectares of forest cover by 2030, which is the most ambitious commitment made by all nations that have joined the African Forest Landscape Restoration Initiative. The study showed that Addis Ababa is a suitable site for the successful growth of 5 indigenous species. Urban green planners have a reasonable candidate for future urban re-greening initiatives. Each of the indigenous species seedlings had a high early survival rate between 82% and 96%. This is closely linked to the site suitability and the silvicultural practices used, including mulching, watering, weeding, and protection from domestic animals and people. Therefore, putting those silvicultural practices into operation is crucial for the high survival of the indigenous species seedlings.

Wild animals choose and frequently browse young shoots of *O. europaea*, which created stunted growth on the species' overall growth performance. Therefore, the species needs to be protected during the early stages of planting or it may be necessary to move the species to the planting location once their leaves have become hardy or unpalatable. Wilting of the seedlings in open field or under canopy cover during the early planting seasons is one of the indicators that it is essential to plant *A. falcatus* species under shade or provide shade during the early planting stage.

LITERATURE CITED

Abrha G, Hintsa S, Gebremedhin G. 2020. Screening of tree seedling survival rate under field condition in Tanqua Abergele and Weri-Leke Wereda, Tigray, Ethiopia. *Journal of Horticulture and Forestry*. 12(1):20-26. https://doi.org/10.5897/JHF2019.0618

Advanced Space-Borne Thermal Emission and Reflection Radiometer Global Digital Elevation Model [ASTER GDEM] [software]. 2009. Tokyo (Japan): Ministry of Economy, Trade, and Industry (METI) and Washington (DC, USA): National Aeronautics and Space Administration (NASA). [Accessed on 2021 May 24]. www.gscoud.cn

Aerts R, November E, Maes W, Van der Borght I, Negussie A, Aynekulu E, Hermy M, Muys B. 2008. In situ persistence of African wild olive and forest restoration in degraded semiarid savanna. *Journal of Arid Environm*ents. 72(6):1131-1136. https://doi.org/10.1016/j.jaridenv.2007.11.009

Alemu ZA, Dioha MO. 2020. Climate change and trend analysis of temperature: The case of Addis Ababa, Ethiopia. *Environmental Systems Research*. 9:27. https://doi.org/10.1186/s40068-020-00190-5

ArcGIS. 2013. ArcGIS 10.2. Redlands (CA, USA): Esri. https://www.esri.com/en-us/arcgis

Argaw M, Nedaw D, Kelbessa E, Yeshitla K, Biru M, Beyene A, Sahle M, Sormessa T, Hussen A, Tsegaye D, Desalegn W, Biru D. 2017. Catchments and vegetation management study for Addis Ababa rivers and riversides development plan

project. Addis Ababa (Ethiopia): Addis Ababa University, Center for Environmental Science.
Aronson MF, Lepczyk CA, Evans KL, Goddard MA, Lerman SB, MacIvor JS, Nilon CH, Vargo T. 2017. Biodiversity in the city: Key challenges for urban green space management. *Frontiers in Ecology and Environment.* 15(4):189-196. https://doi.org/10.1002/fee.1480
Ashton PMS, Gamage S, Gunathilake IAUN, Gunathilake CVS. 1997. Restoration of a Sri Lankan rainforest: Using Caribbean pine *Pinus caribana* as a nurse for establishing late-successional tree species. *Journal of Applied Ecology*. 34(4):915-925. https://doi.org/10.2307/2405282
Ayele TB, Gailing O, Umer M, Finkeldey R. 2009. Chloroplast DNA haplotype diversity and postglacial recolonization of *Hagenia abyssinica* (Bruce) J.F Gmel. in Ethiopia. *Plant Systematics and Evolution.* 280(3-4):175-185. https://doi.org/10.1007/s00606-009-0177-5
Backstrom AC, Garrard GE, Hobbs RJ, Bekessy SA. 2018. Grappling with social dimension of novel ecosystems. *Frontiers in Ecology and the Environment*. 16(2):109-117. https://doi.org/10.1002/fee.1769
Bahru T, Kidane B, Mulatu Y. 2018. Provenance variation on early survival rate and growth performance of Oxytenanthera abyssinica (A. Rich.) munro seedlings at green house: An indigenous lowland bamboo species in Ethiopia. *International Journal of Forestry Research*. 2018:5713456. https://doi.org/10.1155/2018/5713456
Ballal ME.1996. Effect of some nursery practices on quality and field performance of Acacia Senegal seedlings in western Sudan. *University of Khartoum Journal of Agricultural Sciences*. 4(2):128-138.
Bazzaz FA, Miao SL. 1993. Successional status, seed size and responses of tree seedlings to CO_2, light and nutrients. *Ecology.* 74(1):104-112. https://doi.org/10.2307/1939505
Blackmore S. 2019. Cities: The final frontier for endangered plants? *Sibbaldia: The Journal of Botanic Garden Horticulture*. (17):3-10. https://doi.org/10.24823/Sibbaldia.2019.264
Bremer LL, Farley KA. 2010. Does plantation forestry restore biodiversity or create green deserts? A synthesis of the effects of land-use transitions on plant species richness. *Biodiversity and Conservation.* 19:3893-3915. https://doi.org/10.1007/s10531-010-9936-4
Cole EC, Newton M. 2009. Tenth-year survival and size of under planted seedlings in the Oregon Coast Range. *Canadian Journal of Forest Research*. 39(3):580-595. https://doi.org/10.1139/X08-198
Cole RJ, Holl KD, Keene CL, Zahawi RA. 2011. Direct seedling of late successional trees to restore tropical montane forest. *Forest Ecology and Management*. 261(10):1590-1597. https://doi.org/10.1016/j.foreco.2010.06.038
DeCandido R, Calvanese N, Alvarez RV, Brown MI, Nelson TM. 2007. The naturally occurring historical and extant flora of Central Park, New York City, New York 1857-2007. *Journal of the Torrey Botanical Society.* 134(4):552-569. https://doi.org/10.3159/07-RA-002.1
Elith J, Phillips SJ, Hastie T, Dudik M, En Chee Y, Yates CJ. 2011. A statistical explanation of MaxEnt for ecologists. *Diversity and Distributions*. 17(1):43-57. https://doi.org/10.1111/j.1472-4642.2010.00725.x
Eshetie M, Kassaye M, Abebe G, Belete Y, Ngusie G, Asmare S. 2020. Factors hindering seedling survival in Sekota District, North Eastern Amhara, Ethiopia. *Journal of Forest Research: Open Access.* 9(4):241. https://doi.org/10.35248/2168-9776.20.9.242
Food and Agriculture Organization of the United Nations (FAO). 1994. Proclamation for the conservation, development, protection and utilization of forest resource. Addis Ababa (Ethiopia): Negarit Gazeta of the Transitional Government of Ethiopia. Proclamation No.94/1994. 7 p. http://faolex.fao.org/docs/pdf/eth8954.pdf
Food and Agriculture Organization of the United Nations (FAO). 2016. State of the world's forests 2016. Forest and agriculture: Land-use challenges and opportunities. Rome (Italy): FAO. 107 p. https://www.fao.org/3/i5588e/i5588e.pdf
Food and Agriculture Organization of the United Nations (FAO). 2020. Global forest resource assessment 2020: Main report. Rome (Italy): FAO. p. 167. https://doi.org/10.4060/ca9825en
Federal Democratic Republic of Ethiopia (FDRE). 2011. Ethiopia's Climate-Resilient Green Economy Strategy. p. 188. https://www.preventionweb.net/files/61504_ethiopiacrge.pdf
Federal Democratic Republic of Ethiopia (FDRE). 2018. National REDD+ Strategy. Ministry of Environment, Forest and Climate Change. p. 74. https://faolex.fao.org/docs/pdf/eth178847.pdf
Federal Democratic Republic of Ethiopia (FDRE). 2021. Updated nationally determined contribution. p. 39. https://unfccc.int/sites/default/files/NDC/2022-06/Ethiopia%27s%20updated%20NDC%20JULY%202021%20Submission_.pdf
Fetene M, Feleke Y. 2001. Growth and photosynthesis of seedlings of four tree species from a dry tropical afromontane forest. *Journal of Tropical Ecology*. 17(2):269-283. https://www.jstor.org/stable/3068646
Fick SE, Hijmans RJ. 2017. WorldClim 2: New 1km spatial resolution climate surfaces for global land areas. *International Journal of Climatology*. 37(12):4302-4315. https://doi.org/10.1002/joc.5086
Friis I, Demissew S, Van Breugel P. 2010. *Atlas of the potential vegetation of Ethiopia*. Atlas Over Danmark Series. Copenhagen (Denmark): Royal Danish Academy of Sciences and Letters. p. 307.
Furo G, Jiao G, Feng M. 2019. Ecological performance of economically prioritized indigenous tree species in Munessa-Shashemene Natural Forest, Ethiopia. *Journal of Biodiversity & Endangered Species*. 7(2):231. https://www.hilarispublisher.com/open-access/ecological-performance-of-economically-prioritized-indigenous-tree-species-in-munessashashemene-natural-forest-ethiopia.pdf
Garcia AIM, Moumen A, Ruiz DRY, Alcaide EM. 2003. Chemical composition and nutrients availability for goats and sheep of two stage olive cake and olive leaves. *Animal Feed Science and Technology*. 107(1-4):61-74. https://doi.org/10.1016/S0377-8401(03)00066-X
Gebrewahid Y, Abrehe S, Mersesa E, Eyasu G, Abay K, Gebreab G, Kidanemariam K, Adissu G, Abreha G, Darcha G. 2020. Current and future predicting potential areas of *Oxytenanthera abyssinica* (A. Richard) using MaxEnt model under climate Northern Ethiopia. *Ecological Processes*. 9:1-15. https://doi.org/10.1186/s13717-019-0210-8

Gemechu HW, Jiru DB. 2021. Review on factors affecting regeneration of indigenous tree species in Ethiopia. *European Journal of Biophysics*. 9(1):24-29. https://doi.org/10.11648/j.ejb.20210901.14

Gilroy JJ, Avery JD, Lockwood JL. 2017. Seeking international agreement on what it means to be "native". *Conservation Letters*. 10(2):238-247. https://doi.org/10.1111/conl.12246

Gotoh T, Yokota Y. 2009. Development of agroforestry technology for the rehabilitation of tropical forests. Ibaraki (Japan): Japan International Research Center for Agricultural Sciences (JIRCAS). Working Report No. 60. 107 p. https://www.jircas.go.jp/en/publication/jircas_working_report/60

Guillet C, Bergstrom R. 2006. Compensatory growth of fast-growing willow (*Salix*) coppice in response to simulated large herbivore browsing. *Oikos*. 113(1):33-42. https://doi.org/10.1111/j.0030-1299.2006.13545.x

Holzwarth F, Kahl A, Bauhus J, Wirth C. 2013. Many ways to die-partitioning tree mortality dynamics in a near-natural mixed deciduous forest. *Journal of Ecology*. 101(1):220-230. https://doi.org/10.1111/1365-2745.12015

Huang TH, Huang CL, Lin YC, Sun IF. 2022. Seedling survival simultaneously determined by conspecific, heterospecific, and phylogenetically related neighbors and habitat heterogeneity in a subtropical forest in Taiwan. *Ecology and Evolution*. 12(1):e8525. https://doi.org/10.1002/ece3.8525

Jones EL, Leather SR. 2013. Invertebrates in urban areas: A review. *European Journal of Entomology*. 109(4):463-478. https://doi.org/10.14411/eje.2012.060

Kassa H, Campbell B, Sadewall M, Kebede M, Tesfaye Y, Dessie G, Seifu A, Tadesse M, Gardew E, Sandewall K. 2009. Building future scenarios and uncovering persisting challenges of participatory forest management in Chilimo Forest, Central Ethiopia. *Journal of Environmental Management*. 90(2):1004-1013. https://doi.org/10.1016/j.jenvman.2008.03.009

Kodikara KAS, Mukherjee N, Jayatissa LP, Dahdouh-Guebas F, Koedam N. 2017. Have Mangrove restoration projects worked? An in-depth study in Sri Lanka. *Restoration Ecology*. 25(5):705-716. https://doi.org/10.1111/rec.12492

Kolb PF, Robberecht R. 1996. High temperature and drought stress effects on survival of *Pinus ponderosa* seedlings. *Tree Physiology*. 16(8):665-672. https://doi.org/10.1093/treephys/16.8.665

Kuijper DPJ, Cromsigt JPM, Jedrzejewska B, Micicki M, Jedrzejew-ski W, Kweczlich I. 2010. Bottom-up versus top-down control of tree regeneration in the Bialowieza Primeval Forest, Poland. *Journal of Ecology.* 98(4):888-899. https://doi.org/10.1111/j.1365-2745.2010.01656.x

Landon JR. 1984. Booker tropical soil manual: A handbook for soil survey and agriculture evaluation in the tropics and subtropics. Harlow (United Kingdom): Longman. p. 530. https://doi.org/10.4324/9781315846842

Lusk CH. 2022. A field test of forest canopy structure measurements with the CanopyCapture smartphone application. *Peer J.* 10:e13450. https://doi.org/10.7717/peerj.13450

Massei G, Hartley S. 2000. Disarmed by domestication? Include responses to browsing in wild and cultivated olive. *Oecologia*. 122(2):225-231. https://doi.org/10.1007/PL00008850

Megan K. 2013. Assessing the plant species, mortality rate and water availability under the canopies in the MillionTreesNYC plots [research paper]. 19 p. https://www.nybg.org/files/forest/MeganSummer2013ResearchPaper.pdf

Mekonnen K, Glatzel G, Yohannes Y, Amha Y. 2006. Performance of eight tree species in the highland Vertisols of central Ethiopia: Growth, foliage nutrient concentration and effect on soil chemical properties. *New Forests*. 32(3):285-298. https://doi.org/10 .1007/s11056-006-9003-x

Merow C, Smith MJ, Silander JA. 2013. A practical guide to MaxEnt for modeling species' distributions: What it does, and why inputs and settings matter. *Ecography*. 36(10):1058-1069. https://doi.org/10.1111/j.1600-0587.2013.07872.x

Mihertu M, Hunde T, Gebere B. 2006. Species selection for degraded lands with particular reference to site preparation. Addis Ababa (Ethiopia): Forestry Research Center.

Negash L. 1995. Indigenous trees of Ethiopia: Biology, uses and propagation techniques. Addis Ababa (Ethiopia): Addis Ababa University. p. 11-38.

Negash L. 2002. *Erythrina brucei*: Propagation attributes, leaf nutrient concentration and impact on barely grain yield. *Agroforestry System*. 56(1):39-46. https://doi.org/10.1023/A:1021182428083

Nyebenge M, Wanjara J, Owuor J, Theuri W. 2009. Geographical Information Systems (GIS) production and spatial analysis of suitability maps for biofuel feedstock for Ethiopia, Rwanda, Tanzania, Uganda, and Kenya. Nairobi (Kenya): World Agro-forestry Centre. Final Report. ICRAF-GTZ Project. https://www.worldagroforestry.org/publication/geographical-information-systems-gis-production-and-spatial-analysis-suitability-maps-0

Ohse B, Seele C, Holzwarth F, Wirth C. 2017. Different facets of tree sapling diversity influence browsing intensity by deer dependent on spatial scale. *Ecology and Evolution*. 7(17):6779-6789. https://doi.org/10.1002/ece3.3217

Pan K, Lu Y, He S, Yang G, Chen Y, Fan X, Ren Y, Wang M, Zhu K, Shen Q, Jiang Y, Shi Y, Meng O, Tang Y, Chang J, Ge Y. 2019. Urban green space as potential habitats for introducing a native endangered plant, *Calycanthus chiensis*. *Urban Forestry & Urban Greening*. 46:126444. https://doi.org/10.1016/j.ufug.2019.126444

Patel N. 2018. CanopyCapture. https://nikp29.github.io/CanopyCapture

Phillips SJ, Anderson RP, Schapire RE. 2006. Maximum entropy modeling of species geographic distributions. *Ecological Modeling*. 190:231-259. https://doi.org/10.1016/j.ecolmodel.2005.03.026

Phillips SJ, Dudik M, Schapire RA. 2002. Maxent software for modeling species niches and distributions [software]. Version 3.4.1. http://biodiversityinformatics.amnh.org/open_source/maxent

Santamour FS. 1990. Trees for urban planting: Diversity, uniformity and common sense. In: *Proceedings of the 7th Conference of the Metropolitan Tree Improvement Alliance (METRIA)*. METRIA 7: Trees for the Nineties; 1990 June 11–12; Lisle, Illinois, United States. Minneapolis (MN, USA): University of Minnesota. p. 57-65.

Soanes K, Lentini PE. 2019. When cities are the last chance for saving species. *Frontiers in Ecology and the Environment*. 17(4):225-231. https://doi.org/10.1002/fee.2032

Stephens SS, Wagner MR. 2007. Forest plantations and biodiversity: A fresh perspective. *Journal of Forestry*. 105:307-313. https://doi.org/10.1093/JOF/105.6.307

Sullivan JJ, Meurk C, Whaley KJ, Simcock R. 2009. Restoring native ecosystems in urban Auckland: Urban soils, isolation, and weeds as impediments to forest establishment. *New Zealand Journal of Ecology* 33(1):60-71. https://newzealandecology.org/nzje/2892

Swaine M. 1996. *The ecology of tropical forest tree seedlings*. Man and the Biosphere Series Vol. 18. Carnforth (United Kingdom): The Parthenon Publishing Group and Paris (France): UNESCO. p. 340.

Tafesse M. 2007. Growth performance of three indigenous and one endemic tree species of Ethiopia on a degraded site in Central-West Ethiopia [thesis]. Addis Ababa (Ethiopia): Addis Ababa University. 90 p. http://etd.aau.edu.et/handle/123456789/6860

Tenkir Shikur E. 2011. Challenges, problems and intervention made to develop urban forest of Addis Ababa, Ethiopia. In: Johnston M, Percival G, editors. *Tree, people and the built environment: Proceedings of the Urban Trees Research Conference*. Urban Trees Research Conference; 2011 April 13–14; Edgbaston, Birmingham, United Kingdom. Edinburgh (Scotland): Forestry Commission. p. 130-140. https://doi.org/10.13140/2.1.2755.4888

Tesfaye G, Teketay D, Fetene M, Beck E. 2010. Regeneration of seven indigenous tree species in a dry Afromontane forest, southern Ethiopia. *Flora – Morphology, Distribution, Functional Ecology of Plants*. 205(2):135-143. https://doi.org/10.1016/j.flora.2008.12.006

Wassie SB. 2020. Natural resource degradation tendencies in Ethiopia: A review. *Journal of Environmental Systems Research*. 9:33. https://doi.org/10.1186/s40068-020-00194-1

Wei B, Wang R, Hou K, Wang X, Wu W. 2018. Predicting the current and future cultivation regions of *Carthamus tinctorius* L. using MaxEnt model under climate change in China. *Global Ecology and Conservation*. 16:e00477. https://doi.org/10.1016/j.gecco.2018.e00477

Wendimu MA. 2013. Jatropha potential on marginal land in Ethiopia: Reality or myth? Frederiksberg (Denmark): University of Copenhagen, Department of Food and Resource Economics. IFRO working paper 2013/17. p. 17. https://ideas.repec.org/p/foi/wpaper/2013_17.html

Xie PJ, Huang LX, Zhang CH, You F, Zhang YL. 2013. Reduced pressure extraction of oleuropein from olive leaves (*Olea europaea* L.) with ultrasound assistance. *Food and Bioproducts Processing*. 93:29-38. https://doi.org/10.1016/j.fbp.2013.10.004

Zeleke AW, Woldie TM, Landsberg F, Yimer BA, Ayane TG. 2018. National potential and priority maps for tree-based landscape restoration in Ethiopia. Addis Ababa (Ethiopia): Ministry of Environment, Forest and Climate Change (MEFCC). Technical Report version 0.0. 78 p. https://assets.forest-atlas.org/eth/documentation/MEFCC-Ethiopia-National-Landscape-Restoration_high-res.pdf

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Eyob Tenkir (corresponding author)
Department of Plant Biology and Biodiversity Management
Addis Ababa University
Addis Ababa, Ethiopia
+251-91-215-9425
eyobtenkir1@yahoo.com

Tamrat Bekele
Department of Plant Systematics and Biodiversity Management
College of Natural Sciences
Addis Ababa University
Addis Ababa, Ethiopia

Sebsebe Demissew
Department of Plant Systematics and Biodiversity Management
College of Natural Sciences
Addis Ababa University
Addis Ababa, Ethiopia

Ermias Aynekulu
Centre for International Forestry Research and World Agroforestry (CIFOR-ICRAF)
Nairobi, Kenya

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