East African Journal of Forestry & Agroforestry
eajfa.eanso.org
Volume 8, Issue 1, 2025
Print ISSN: 2707-4315 | Online ISSN: 2707-4323
Title DOI: https://doi.org/10.37284/2707-4323

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Influence of Thinning Regime on Woody Species Density and Abundance in Kimondi Forest, Nandi County, Kenya

Emma Anyango[1], Dr. Joyce A. Obuoyo, PhD[1] & Prof. Boniface O. Oindo, PhD[1]*

[1] Maseno University, P. O. Box 333, Maseno, Kenya.
[*] Author for Correspondence Email: emmaanyango36@gmail.com

Article DOI: https://doi.org/10.37284/eajfa.8.1.3330

Date Published:

16 July 2025

Keywords:

Silvicultural Regimes, Thinning Regime, Woody Species Abundance, Woody Species Density.

ABSTRACT

A silvicultural regime refers to the planned sequence of treatments applied to a forest stand, which mainly includes pruning and thinning regimes. The latter is a silvicultural practice that is important for the management of forest growth, composition, structure, and health. Despite the ecological and silvicultural importance of thinning, its limited application in plantation forests has constrained the effective management of woody species density and abundance. Thus, the aim of this research was to assess the influence of the thinning regime on woody species density and abundance. This study focused on *Eucalyptus saligna, Cupressus lusitanica and Pinus patula* as the woody species that are harvested for timber in the Kimondi forest. The study applied a cross-sectional descriptive study design. Systematic sampling was used in collecting primary data. Data were analysed using box plots, Analysis of Variance and Duncan multiple range test. The box plots showed *Eucalyptus saligna* having the highest median density and the widest interquartile range, indicating both a greater abundance and variability across sampling sites. *Cupressus lusitanica and Pinus patula* had a moderate median density with a narrower distribution, indicating lower variability. Analysis of variance revealed a highly significant difference in tree abundance and density across the thinning regime ($p = 0.000$), with an effect size ($Eta^2 = 0.7519$), indicating that 75.19% of the variation of woody species density and abundance can be explained by the thinning regime. Duncan's Multiple Range Test confirmed that mean abundance varied significantly across the thinning regime. The study concluded that a thinning regime can improve the density and abundance of woody species, *Eucalyptus saligna*, *Cupressus lusitanica*, and *Pinus patula.* We recommend that forest managers in plantation forests adopt thinning regimes to improve woody species density and abundance.

APA CITATION

Anyango, E., Obuoyo, J. A. & Oindo, B. O. (2025). Influence of Thinning Regime on Woody Species Density and Abundance in Kimondi Forest, Nandi County, Kenya. *East African Journal of Forestry and Agroforestry*, *8*(1), 324-335. https://doi.org/10.37284/eajfa.8.1.3330

CHICAGO CITATION

Anyango, Emma, Joyce A. Obuoyo and Boniface O. Oindo. 2025. "Influence of Thinning Regime on Woody Species Density and Abundance in Kimondi Forest, Nandi County, Kenya" *East African Journal of Forestry and Agroforestry* 8 (1), 324-335. https://doi.org/10.37284/eajfa.8.1.3330.

Article DOI: https://doi.org/10.37284/eajfa.8.1.3330

HARVARD CITATION

Anyango, E., Obuoyo, J. A. & Oindo, B. O. (2025), "Influence of Thinning Regime on Woody Species Density and Abundance in Kimondi Forest, Nandi County, Kenya", *East African Journal of Forestry and Agroforestry*, 8(1), pp. 324-335. doi: 10.37284/eajfa.8.1.3330.

IEEE CITATION

E., Anyango, J. A., Obuoyo & B. O., Oindo "Influence of Thinning Regime on Woody Species Density and Abundance in Kimondi Forest, Nandi County, Kenya", *EAJFA*, vol. 8, no. 1, pp. 324-335, Jul. 2025.

MLA CITATION

Anyango, Emma, Joyce A. Obuoyo & Boniface O. Oindo. "Influence of Thinning Regime on Woody Species Density and Abundance in Kimondi Forest, Nandi County, Kenya". *East African Journal of Forestry and Agroforestry*, Vol. 8, no. 1, Jul. 2025, pp. 324-335, doi:10.37284/eajfa.8.1.3330

INTRODUCTION

According to a study by Zhou *et al. (*2012), ecological thinning is a silvicultural strategy used in forest management that involves reducing trees to improve the functions of a forest other than timber production. On the *Pinus radiata* and *Pinus patula* plantations in New Zealand, thinning has been widely used (Horáček et al., 2017). These writers also discovered that the use of wood is regarded in New Zealand as a sustainable alternative to lessen environmental effects in the building and construction industry. Producing engineered wood, like laminated veneer lumber (LVL), improves the low-grade hardwood logs from plantation thinning (Horáček *et al.,* 2017). However, the energy and chemical requirements of engineered wood may outweigh its environmental advantages (Velamazán *et al.,* 2017). According to research by Geldenhuys *et al.* (2018), thinning improves canopy penetration of solar radiation and reduces canopy closure in Miombo Woodland, Vila Ulongwe, and Nkantha regions, Tete Province, Mozambique. Thinning increases this energy's photosynthetic efficiency and prolongs needle retention, particularly in the lowest portions of the crown (Geldenhuys *et al.,* 2018). Additionally, following thinning, the root system, crown diameter, length, and crown area all grow, improving the grade of wood that is taken (Grigoreva *et al.,* 2020).

The reaction to thinning in Yemrehane Kirstos Church Forest of Lasta Woreda, North Wollo zone, Amhara region, Ethiopia was also studied by Abunie and Dalle (2019) in Africa. They found that this regime changed the temporal evolution of radial growth at all frequencies in radial growth chronologies. The importance of solar energy then increases within the crown, according to Brancalion *et al.* (2019). The longer needle retention period is influenced by this energy's enhanced photosynthetic efficiency, particularly in the lower portion of the crown (Terefe & Gure, 2019). Furthermore, the length, diameter, and area of the crown of the native woody species require rigorous and frequent maintenance, particularly thinning and pruning, to maintain the diameter growth performance of chosen clones (Bauhus, 2020). This growth can occur quite quickly in the early growth stage (>2.5 cm year−1). According to earlier research, varying thinning intensities appear to support important growth traits in a variety of species stands. Over a 12-year treatment period, mild (10%), moderate (20%), and high (40%) thinning in *Larix kaempferi* stands in Gabon produced considerable changes in diameter and height growth compared to the control (0%) (D'Amato and Palik, 2020).

Studies conducted in Kenya with reference to the Loita forest have primarily demonstrated that foresters can modify stand density to affect the growth, quality, and health of residual trees. This also gives them the chance to capture mortality and remove the less desirable, usually smaller and malformed, trees for commercial purposes (Otuoma *et al.,* 2016). Because removing a tree from a stand affects the other trees above and below ground, thinning has a significant impact on the ecology and micro-meteorology of the stand, lessening the inter-tree competition for water (Resende *et al.,* 2018). According to Wekesa *et al.* (2018), silvicultural thinning is a potent technique that may be utilised to affect the stability and development of stands as well as the qualities of harvestable products. Research clearly

Article DOI: https://doi.org/10.37284/eajfa.8.1.3330

shows that thinnings are not meant to grow a new tree crop or make permanent canopy openings, in contrast to regeneration treatments. Thus, it is appropriate for research on how particular silvicultural regimes affect the density and abundance of woody species, with a focus on species thinning.

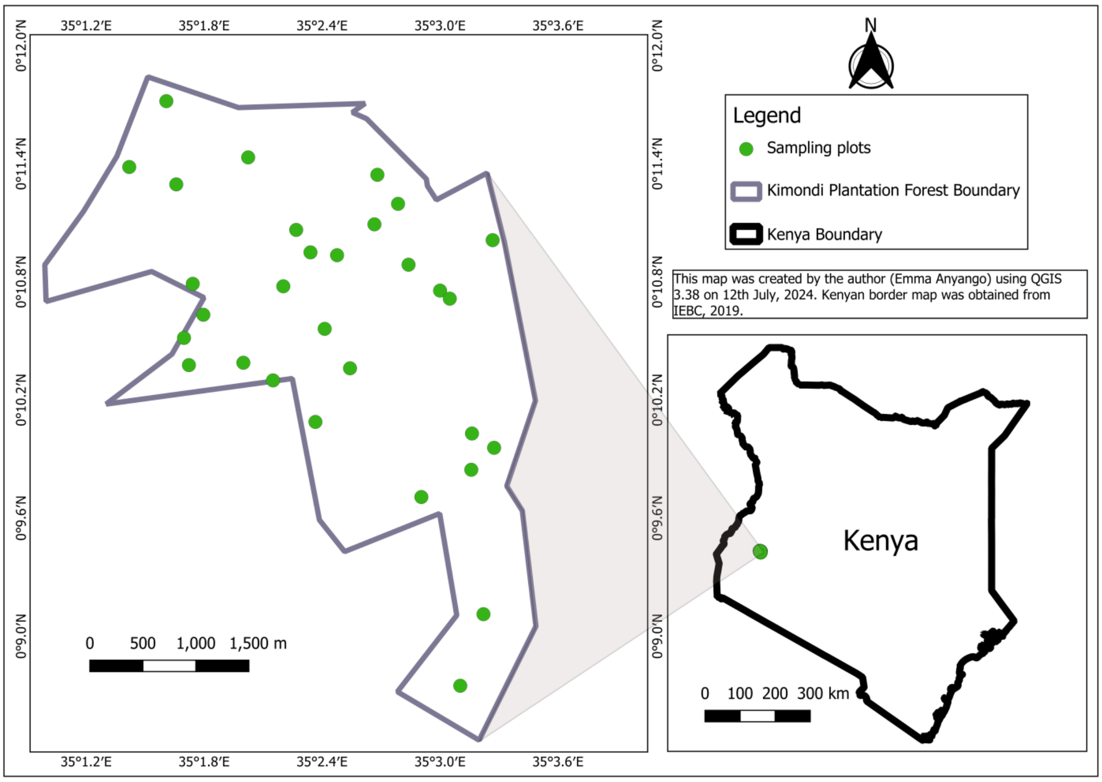
The dominance of small-sized individuals is suggested by the forest's 79.8% woody plants that are less than 15 meters in height in Kimondi Forest. Similar findings were noted by several writers, who conjectured that the cause might be large-sized woody species' high rates of mortality and/or regeneration, which are traits of stable size distribution typical in real forests (Omondi *et al.,* 2020). According to Felix *et al.* (2022), the low tree density in Kimondi Forest may possibly be related to the removal of trees as a result of anthropogenic disturbances such as charcoal burning and illicit logging (pit sawing). Recent studies reviewed, have focused mainly on the effects of anthropogenic activities on the density and abundance of woody species. However, hardly any studies have focused on the influence of silvicultural regimes on woody species density and abundance. Therefore, the objective of this study was to assess the influence of the thinning regime on woody species density and abundance in Kimondi Forest, Kenya.

MATERIALS AND METHODS

Study Area

Nandi County, Emgwen, and Aldai Sub Counties are home to Kimondi Forest Station, which is situated in the South Nandi Forest Reserve. It is surrounded by the counties of Kakamega and Vihiga. It is located in the Rift Valley at latitudes 0018' N and 0032 N and longitudes 37005 E and 37023' E. The elevation is between 1700 and 2000 meters above sea level. It is located 4 km from Kapsabet town along the Kapsabet-Chavakali road, west of Kapsabet town and south of the main Kapsabet-Kaimosi route. It is reachable from Kisumu by the 75-kilometre Chavakali-Kapsabet route. 5,435.5 hectares make up this forest today after 741.8 hectares were cleared for habitation. 1,339.95 ha of plantations and 4,095.55 ha of wild forest make up this area.

Figure 1: Map of Kimondi Forest



Article DOI: https://doi.org/10.37284/eajfa.8.1.3330

Study Site

The topography of Kimondi Forest Station, which is a component of South Nandi Forest, has a significant impact on soils, climate, and biodiversity. This is due to the high abundance of terrain that results from its construction during the Cainozoic era.

The AfriCover classification system divides the forest into three major vegetation categories. There are three types of vegetation: plantations, open forests, and closed forests.

Field Sampling

The study population is the Kimondi Forest. A systematic sampling technique was used to select woody species in the forests. In a total sample of 30 plots, each measuring 20m by 20m were established randomly, which represented a sample of the 5,435.50ha occupied by the closed-canopy forest. This entailed one plot per 180ha of the forest.

In each plot, all woody species with a diameter at breast height (DBH) ≥ 10 cm measured at 1.3 m above the ground were counted and identified. This was done to avoid counting the saplings. The relevance sampled out the targeted woody species likely to be utilised for timber and other wood-related activities. The identification was done with the help of an expert from the Kenya Forest Service.

Data Collection

Information that is gathered directly from first-hand sources is referred to as primary data. The study area's woody species was observed, 30 sample plots were used, each measuring 20m by 20m, and the number of woody species in each plot was counted and recorded as the primary data collection method. A basic count of the woody tree species in the vicinity of the sampled forests is one of the primary data sources that was collected from the field. It also included the size of the forest sampled. Data used in this study were obtained between March 2024 and June 2024. This is because timber is best harvested during spring (March, April, May) and summer (June, July and August) months when the sap is flowing to prevent damage to the tree when leaves have fallen off the hardwood trees. These methods were appropriate for the data collection because the data to be collected could be obtained by measurement (sample plots 20m by 20m each, height of trees to be counted), counting (number of woody species) and observation (the woody species density – closeness or openness). Observation schedules were used to assess the extent of the use of silvicultural regimes in the forest and how they had influenced woody species abundance. Data on woody species abundance was collected by identifying a specific woody species within the sampled area and counting them in the whole of the sampled areas in Kimondi forest to get the abundance of each of the tree species in Kimondi forest. Woody species richness and abundance were used to calculate the quantity of woody species. As the woody species was counted in the plots, the intervening variables such as Soil type, Soil depth, Forest pest, Spacing of woody species and amount of graded timber from the number of coppices were recorded per plot. This is to aid in the analysis of how these variables have influenced the quality and quantity of the woody species.

Independent variable is silvicultural regimes' attributes, e.g. ecological thinning. The dependent variables were woody species density and abundance. The instruments for data collection included a measuring tape for measuring the sampled area in the Kimondi forest. String was used to demarcate the quadrants. Data were collected within the selected 30 study sites within the study site. This approach captures most species that would be considered. Measurements for trees include DBH, which was obtained from previous botanical survey data. The study sites were based on their location in the forests. The plots were established in the forest. To assess the influence of silvicultural regimes on Kimondi Forests, the number of individuals of all woody species was counted and recorded in the sampled areas. Secondary data was appropriate for sourcing the maps of the forests.

Article DOI: https://doi.org/10.37284/eajfa.8.1.3330

Box plots were used to show the distribution of the woody species across the regime. One-way ANOVA test was used to analyse the relationship between the thinning regime and the number of woody species per plot. Duncan's Multiple Range test was also used. Results were presented in tables containing mean and standard deviation of abundance and density, least significant difference, p value<= 0.05, and the superscript letters indicate the significant difference in the means.

RESULTS

This section examines the influence of the thinning regime on Density (trees/m²) and Abundance (individual tree count) of *Cupressus lusitanca*, *Pinus patula*, and *Eucalyptus saligna*.

Figure 2 shows the box plots indicating the woody species density and abundance comparison.

Figure 2: Boxplots Showing the Distributions of Woody Species (*Cupressus lusitanca*, *Pinus patula*, and *Eucalyptus saligna*) Densities and Abundance under the Thinning Regime.

The boxplots (Figure 2) compare the density distribution of *Cupressus lusitanca*, *Pinus patula*, and *Eucalyptus saligna*. Among them, *Eucalyptus saligna* shows the highest median density and the widest interquartile range, indicating both a greater abundance and variability across sampling sites. *Cupressus lusitanica* has a moderate median density with a narrower distribution, suggesting a more consistent presence. In contrast, *Pinus patula* has the lowest median density and a similar

Article DOI: https://doi.org/10.37284/eajfa.8.1.3330

spread to *Cupressus lusitanica*, indicating it is the least dense and possibly less widely distributed in the studied area. This comparison highlights *Eucalyptus saligna* as the dominant species in terms of density.

Table 1: One-way ANOVA Output Table Showing Comparison of Means of Woody Species Density and Abundance under Thinning Regime

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	403.7556	2	403.7556	45.23882	3.4E-14	3.101296
Within Groups	133.2333	87	3.02567			
Total	536.9889	89				

The results (Table 1) show that the interaction between thinning regime and woody species abundance and density is statistically significant at a 95% confidence level. The calculated effect size (Eta^2 =0.7519) shows that about 75.19% of the variation in density and abundance can be explained by the thinning regime. These results show that *Eucalyptus saligna* increases in abundance and density when a thinning regime is applied. When *Eucalyptus saligna* are thinned, they have time to allow stems to straighten and self-prune lower branches off valuable lower bolts. However, the low number of thinned woody species in Kimondi forest is a result of delayed thinning due to a ban on harvesting mature trees, i.e moratorium. Some of the thinned *Pinus patula* and *Cupressus lusitanca* were infected by pests and diseases such as *Oemida gahani,* which deteriorates the timber quality.

There was a highly significant difference at P-value = 0.000***. This implies that the thinning regime has a significant influence on the woody species density and abundance in Kimondi Forest (H_1). The effect size, Eta^{2,} shows that 75.19% of the variation in the abundance and density of woody species can be explained by the thinning regime.

Table 2: Duncan Multiple Range Test of Thinning Regime and Woody Species Density and Abundance

Influence of Thinning Regime on Woody Species Density and Abundance

Duncan[a]

		Subset for alpha = 0.05		
Thinning Regime	N	1	2	3
3	10	244.50		
2	10		272.00	
1	10			317.90
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 10.000.

The Table 2 analysis of the influence of thinning and pruning regimes on woody species density and abundance in the Kimondi Forest plot revealed significant differences among the woody species. Woody species density increases as thinning intensity decreases. Heavy thinning reduces density, while light thinning maintains more woody vegetation. The statistical test confirmed that these differences are significant at the 95% significance level.

Eucalyptus saligna species in the thinning regime were 216, representing 50.12% of the species in the plots, hence the most abundant species. Thinned *Cupressus lusitanicas* was a total of 121, an equivalent of 28.07% of species in this particular regime. The least thinned species was *Pinus patula,* which was 94 in number, equating to 22.76% of the woody species. In comparison to the other regimes, 30.65% of the woody species counted were thinned only in the Kimondi forest. The mean and standard deviation of abundance indicate that there was a significant difference between the species thinned, the L.S.D. was 0.0893.

The mean and standard deviations of density also had a significant difference with an L.S.D. of 0.002. The overall density of the thinned species was approximately 29.51% of all the species counted in the plots. *Eucalyptus saligna* had a density of 0.54, representing 50% of species per M^2 *Cupressus lusitanica* had a density of 0.235 species per $m^{2,}$ equating to 27.78% of the species in this regime. *Pinus patula* recorded the least density of 0.235, which is 22.22% of the woody species in this regime.

DISCUSSION

The forest plot revealed significant differences among the woody species. Woody species density increases as thinning intensity decreases. Heavy thinning reduces density, while light thinning maintains more woody vegetation. The statistical test confirmed that these differences are significant at the 95% significance level.

The findings from Kimondi Forest showing that thinning increases the abundance of *Cupressus lusitanca*, *Pinus patula*, and *Eucalyptus saligna* species are consistent with global patterns. For instance, Prevedello *et al.* (2018) conducted a global meta-analysis that emphasised the biodiversity value of scattered trees in human-modified landscapes. Their results indicated that patches with scattered trees, akin to thinned forest conditions, supported up to 5.3 times higher species richness and abundance. This parallels the Kimondi findings, where thinned plots showed notably higher individual tree counts, suggesting that thinning fosters microhabitats and light availability that benefit woody species. Zeller and Pretzsch (2019) discovered in a related study that the thinning regime enhanced the diameter increment that is 2-2.5 times for large *Eucalyptus saligna* trees with a DBH of >20 cm and even 7to9 times for trees with a DBH of less than 20 cm. On the other hand, despite a higher average increment for the heavily thinned stand, Wanjira and Muriuki (2020) said in their study that the diameter increment did not differ significantly by thinning severity for both large and woody species. Regardless of whether 30 or 50% of the basal area was eliminated, additional research by Tsai *et al*. (2018) revealed a considerably greater increment related to the thinning regime when comparing both thinned stands with unthinned regimes.

Furthermore, Terefe and Gure (2019) asserted in the findings of their research that the rise in increment by thinning is even bigger for trees less than 20 cm DBH, especially after removing 50% of the basal area. The niche-based theory of island biogeography is consistent with the prolonged carbon residence time of large diameter coarse woody debris due to its slower disintegration. Consistent with the results of this investigation, Syampungani *et al.* (2016) suggested that further advantages of larger tree populations include increased adaptability in prospective wood products (e.g., *Eucalyptus saligna*) and a wider variety of habitat (e.g., for organisms that specialise in large dimension wood and cavity dwelling animals). Swaim J.T. *et al*. (2018) showed in their work that internal decay of huge trees must be taken into account in order to prevent applying allometric functions and overestimating biomass and, consequently, carbon stocks. In their research, Smith *et al.* (2018) additionally demonstrate a greater decline in increment for the heavily thinned stands of certain *Cupressus lusitanca* and *Pinus patula* trees, similar to the results presented above.

Regionally, in East Africa, Wahungu *et a*l. (2024) demonstrated that thinning intensities significantly affect regeneration, whereby their study across East African savannas revealed that

Article DOI: https://doi.org/10.37284/eajfa.8.1.3330

moderate to high thinning enhanced woody species recruitment by reducing competition. However, overly intense thinning led to excessive coppicing, potentially undermining canopy structure. In line with the results of this investigation, the SIS Swedish Institute for Standards (2020) stated that the general goal of thinning management is to balance long-term maximum wood production with the preservation of a steady supply of material from thinnings. Inadequate management of the amount removed during thinnings can lead to either under- or overcutting, which lowers profitability and results in a loss of volume production. In relation to these studies, thinning can lead to an unpredictable supply of timber on the market.

This nuanced relationship supports the need for optimal thinning regimes, much like the managed thinning observed in Kimondi, where abundance increased without apparent structural degradation. This specificity mirrors the varied responses in Kimondi, where *Eucalyptus saligna* demonstrated the highest mean abundance under thinning, followed by *Cupressus lusitanca* and *Pinus patula*. Such species-level differentiation affirms the importance of context-specific silvicultural practices. In Kenya, Mutiso *et al.* (2024) found that exotic tree species such as *Cupressus lusitanca* and *Pinus patula* dominated blocks in Londiani Forest, Kenya, with varied regeneration success. This reflects the situation in Kimondi, where exotic species also respond well to thinning, though regeneration success may differ depending on block-specific management. Similarly, Anyango (2020) in Kakamega Forest found that forest edge density influenced tree species richness, echoing Island Biogeography Theory's assertion that habitat configuration and size determine biodiversity outcomes. This theory relates directly to Kimondi, where thinned patches can be likened to better-connected “islands” with higher ecological value. In the Taita Hills, Kariuki *et al.* (2023) linked biomass and biodiversity to tree size and species identity, noting that larger individuals disproportionately contributed to ecosystem function.

Thus, Kimondi forest, being a planted forest, is also expected to have more dense and abundant woody species through the silvicultural regimes best suited for each species. This study has revealed that thinning of the Kimondi forest offers many benefits, such as foot access can be greatly improved and more light can penetrate the canopy, future thinning and harvesting costs are reduced, and economically, it increases the growth of the remaining woody species. When poor quality trees are removed, the remaining trees get more space, nutrients, sunlight and water. Similar to the findings of this study, Pachas *et al.* *(*2019) also found that thinning helps recover wood volume from trees that would normally die from competition for light, nutrients or space. Recovering this wood allows the stand to produce more wood over its rotation. Otuoma, *et al.,* (2016*),* concluded in his research that there will likely be more space covered by *Eucalyptus saligna*, the most popular hardwood species, due to the increased demand for transmission poles to support the ongoing expansion of rural electrification as well as for building, fuelwood, carbon sequestration, and mitigating the effects of climate change. *Eucalyptus saligna* offers a wide range of advantages, including windbreaks, erosion management, buffers to natural forests, flood control, and mitigation of climate change, in addition to industrial wood, poles, lumber, fuelwood, bee fodder, and essential oils. Compared to *Cupressus lusitanca* and *Pinus patula, Eucalyptus saligna* is produced in greater quantities as a result of the thinning regime. *Eucalyptus saligna* is therefore now commonly used in furniture, joinery, and building. Therefore, planting more *Eucalyptus saligna* than *Cupressus lusitanca* and *Pinus patula* is equivalent to commercial tree farming with a thinning strategy.

CONCLUSION

The findings of this study demonstrated that thinning regimes significantly affect the density and abundance of woody species, particularly *Eucalyptus saligna*, *Cupressus lusitanica*, and *Pinus patula*. The box plots showed *Eucalyptus saligna* having the highest median density and the widest interquartile range, indicating both a

Article DOI: https://doi.org/10.37284/eajfa.8.1.3330

greater abundance and variability across sampling sites. *Cupressus lusitanica and Pinus patula* had a moderate median density with a narrower distribution, indicating lower variability. A one-way ANOVA revealed a highly significant difference in tree abundance and density across thinning treatments ($p = 0.000$), with an effect size ($Eta^2 = 0.7519$), indicating that 75.19% of the variation of woody species density and abundance can be explained by thinning practices. Duncan's Multiple Range Test confirmed that mean abundance varied significantly across thinning intensities, suggesting reduced thinning intensity correlates with increased tree density. Furthermore, 30.65% of the woody species sampled were found exclusively in the thinned regime. The Least Significant Difference (LSD) test showed significant differences in both abundance (LSD = 0.0893) and density (LSD = 0.002) among the species. These findings highlight the superior performance of *Eucalyptus saligna* under thinning conditions due to improved access to light, nutrients, and space, reinforcing the value of targeted silvicultural interventions to enhance forest productivity, biodiversity, and ecological sustainability. The study concluded that a thinning regime can improve the density and abundance of woody species, *Eucalyptus saligna*, *Cupressus lusitanica*, and *Pinus patula.*

Recommendations

Prioritise Selective and Moderate Thinning to Improve Forest Stand Structure. Moderate, species-appropriate thinning enhances stand health by reducing competition for essential resources. This allows species like *Pinus patula* and *Eucalyptus saligna* to achieve better growth and form. Over-thinning or no thinning can lead to stagnation or structural weaknesses. Forest managers should use adaptive schedules and intensity levels based on species behaviour and site-specific feedback.

Areas for Further Research

❖ There is a need to evaluate the economic implications of the thinning regime, including input costs, labour, and timber returns, in order to support efficient resource allocation and policy planning.

Competing Interests

Authors have declared that no competing interests exist.

REFERENCES

Abunie A. A. and G. Dalle (2019). "Woody species abundance, structure, and regeneration status Yemrehane Kirstos church forest of Lasta Woreda, North Wollo zone, Amhara region, Ethiopia," *International Journal of Forestry Research*, vol. 2018, Article ID 5302523, 8 pages, 2018.Centre for International Agricultural Research Policy Brief, Research Findings with Policy Implications. Canberra: ACIAR.

Anna L., Johan Ö. And Björn W. (2023), Pruning revisited – effect of pruning season on wood discoloration and occlusion in four temperate broadleaved tree species *Forestry: An International Journal of Forest Research*, Volume 96, Issue 4, October 2023, Pages 605–617,

Anyango, E. (2020). *Effects of forest fragmentation on tree species richness in Kakamega Forest, Kenya*. Maseno University.https://edocs.maseno.ac.ke/handle/123456789/3999

Assèdé, E. S. P., Azihou, F. A., Biaou, S. S. H., Mariki, S. B., Geldenhuys, C. J., Sinsin, B. (2021). Managing woodland development stages in Sudanian dry woodlands to meet local demand in fuelwood. Ener. Sustain. Dev. 61, 129–138. doi: 10.1016/j.esd.2021.01.006

Binglin P., Zhenyu W., Mei Y., Shinan L. (2020). Effects of thinning on tree growth and soil chemical properties of Betula luminifera plantation. *J. Beihua Univ. (Nat. Sci.)* 21 398–404. 10.11713/j.issn.1009-4822.2020.03.024

Brancalion, P.H.S *et al*., (2019). Global restoration opportunities in tropical rainforest landscapes. Sci. Adv.5, essav 3223.

D'Amato AW and Palik B.J. (2020). Building on the last "new" thing: exploring the compatibility of ecological and adaptation silviculture. Canadian Journal of Forest Research 51:172–180. https://doi.org/10.1139/cjfr--0306

Felix L. Mogambi M. and Zipporah L. (2022). The Role of Forest Resource and Resource Users' Boundaries in Improving the Livelihoods of Communities Adjacent to Arabuko-Sokoke Forest Reserve, Kenya. International Journal of Natural Resource Ecology and Management. Vol. 7, No. 1, 2022, pp. 54-58. doi: 10.11648/j.ijnrem,0701.17

Geldenhuys, C. J., Prinsloo, A. J., and Antão, L. V. T. (2018). Monitoring the impact of selective thinning and pruning on recovery of condition, biodiversity and productivity in Miombo woodland development stages: Report 2: Wood harvested through different harvesting intensities, Vila Ulongwe and Nkantha areas, Tete Province, Mozambique. Report FW-07/18. Pretoria: Forest wood cc.

Horáček, P., Fajstavr, M., Stojanović, M., 2017: The variability of wood density and compression strength of Norway spruce (Picea abies /L./ Karst.) within the stem. Beskydy 10(1,2): 17–26

Kariuki, M., Wekesa, C., & Omondi, S. (2023). *Tree species identity and biomass dynamics in the Taita Hills forests*. *Forests*, 14(3), 642. https://doi.org/10.3390/f14030642

Kenya Forest Service (2020) Economic Potential of Popular Commercial Tree Species in Kenya. pp. 2- 3. http://www.kenyaforestservice.org/documents/Brochure commercial forestry.

Kinyanjui, M. J., Langat, D., & Njenga, M. (2023). *Silvicultural practices and forest recovery in Kenya's highland plantations*. *Forest Ecology and Management, 531*, 120785. https://doi.org/10.1016/j.foreco.2023.120785

Koivula M., I.and Vanha-Majamaa (2020), Experimental evidence on biodiversity impacts of variable retention forestry, prescribed burning, and deadwood manipulation in Fennoscandia, Ecological Processes, 9, 11.

Magnus P. (2022). Evaluating thinning practices and assessment methods for improved management in coniferous production forests in southern Sweden, Department of Department of Forestry and Wood Technology, Linnaeus University, Växjö, ISBN: 978-91-89709-54-6 (print), 978-91-89709-55-3.

Mwanzia, R. K., Gitonga, D. K., & Wekesa, J. (2021). *Monitoring biodiversity changes in Nandi Forest ecosystems*. *African Journal of Ecology, 59*(3), 349–358. https://doi.org/10.1111/aje.12798

Mutiso, D., Kamondo, B., & Wambugu, C. (2024). *Woody species composition and regeneration in Londiani Forest, Kenya*. *Forests*, 15(4), 653. https://doi.org/10.3390/f15040653

Otuoma, J., Anyango, B., Ouma, G., Okeyo, D., Muturi, G.M., Oindo, B. (2016). Determinants of above-ground carbon offset additionality in plantation forests in a moist tropical forest in Western Kenya. For. Ecol. Manage. **365**, 61–68.

Pachas A.N.A, Sakanphet S, Soukkhy O, Lao M, Savathvong S, Newby JC, Souliyasack B, Keoboualapha B, Dieters M.J. (2019). Initial spacing of teak (Tectona grandis) in northern Lao PDR: impacts on the growth of teak and companion crops. Forest Ecology and Management. 435:77–88.

Pfister, O. (2009). Influence of spacing and thinning on tree and wood characteristics in planted Norway spruce in southern Sweden. Doctoral thesis No:61. Faculty of Forest

Science, Swedish University of Agricultural Sciences, Alnarp. 54 pp.

Resende C.L, Scarano F.R, Assad E.D, Joly C.A, Metzger J.P, Strassburg B.B.N, (2018).From hotspot to hopespot: An opportunity for the Brazilian Atlantic Forest. Perspect Ecol Conserv. 16, 208–214.

Richard M. (2024), A Model for Spatially Explicit Landscape Configuration and Ecosystem Service Performance, ESMAX: Model Description and Explanation; Sustainability 16(2):876 DOI:10.3390/su16020876.

Rossman A. K., Halpern C. B., Harrod R. J., Urgenson L. S., Peterson D. W., Bakker J. D. (2018). Benefits of thinning and burning for understory diversity vary with spatial scale and time since treatment. *For. Ecol. Manage.* 419 58–78. 10.1016/j.foreco.2018.03.006 .

Royo AA, Pinchot CC, Stanovick JS, Stout SL (2019) Timing is not everything: assessing the efficacy of pre- versus post-harvest herbicide applications in mitigating the burgeoning birch phenomenon in regenerating hardwood stands. Forests 10:324. https://doi.org/10.339 0/f10040324

Sadono R. (2017). Temporary site index for two-invented teak clones with generative regeneration in the state forestland in East Java, Indonesia. Advances in Environmental Biology. 11:6– 12.

SIS-Swedish Institute for Standards (2020).*Tree Care — Processes and Methods for Tree Pruning — Part 2: Requirements for Providers* Swedish Institute for Standard, pp. SS 990001–SS 990002.

Smith, L. L., Cox, J. A., Conner, L. M., McCleery, R. A., and Schlimm, E. M. (2018). Management and restoration of wildlife. Pages 233-251 in L. K. Kirkman, and S.B. Jack (eds.). Ecological Restoration and Management of Longleaf Pinus patula Forests. CRC Press, Boca Raton, Florida.

Stimm, K.; Heym, M.; Uhl, E.; Tretter, S.; Pretzsch, H.(2021). Height growth-related competitiveness of oak (Quercus petraea (Matt.) Liebl. and Quercus robur L.) under climate change in Central Europe. Is silvicultural assistance still required in mixed-species stands? For. Ecol. Manag. 482, 118780.

Swaim J.T, Dey D.C, Saunders M.R, Weigel D.R, Thornton C.D, Kabrick J.M, Jenkins M.A (2018) Overstory species response to clearcut harvest across environmental gradients in hardwood forests. Forest Ecology and Management 428:66–80. 8.

Syampungani, S., Geldenhuys, C. J., and Chirwa, P. W. (2016). Regeneration dynamics of miombo woodland in response to different anthropogenic disturbances: forest characteri sation for sustainable management. Agrofore st. Syst. 90, 563–576. doi: 10.1007/s10457-015-9841-7.

Terefe A.and Gure A.(2019), “Effect of exclosure on woody species abundance and population structure in comparison with adjacent open grazing land: the case of Jabi Tehnan district north western Ethiopia,” Ecosystem Health and Sustainability, vol. 5, no. 1, pp. 98–109.

Tsai H.C, Chiang J.M, McEwan R.W, Lin T.C (2018) Decadal effects of thinning on understory light environments and plant community structure in a subtropical forest. Ecosphere 9:e02464. https://doi.org/10.1002/ ecs2.2464.

Ulvcrona, K.A. (2011). Effects of silvicultural treatments in young Scots Pinus patula-dominated stands on the potential for early biofuel harvest. Doctoral thesis No. 79. Faculty of Forest Science, Swedish University of Agricultural Sciences, Umeå. 64 pp.

Velamazán M, San Miguel A, Escribano R, Perea R (2017) Threatened woody flora as an ecological indicator of large herbivore

Article DOI: https://doi.org/10.37284/eajfa.8.1.3330

introductions. Biodivers Conserv 26:917–930.

Wahungu, G., Chira, R., & Kirui, P. (2024). *Influence of thinning intensities on woody species regeneration in East African savannas*. *Frontiers in Ecology and Evolution*, 12, 1461573. https://doi.org/10.3389/fevo.2024.1461573

Wang, Y., Wang, A.D. delCampo, X. Wei, R. Winkler, W. Liu, Q. (2020). LiResponses of forest carbon and water coupling to thinning treatments from leaf to stand scales in a young montane Pinus patula forest Carbon Balance Manag., 15 (1), p. 24, 10.1186/s13021-020-00159-y.

Wang, J. et al., (2021). Impacts of juniper woody plant encroachment into grasslands on local climate. Agric. For. Meteorol. 307, 108508.

Wanjira, E.O & Muriuki, J. (2020). Review of the Status of Agroforestry Practices in Kenya. Background study for preparation of Kenya National Agroforestry Strategy (2020 – 2030). World Agroforestry, Nairobi.

Wekesa, C., Maranga, E.K., Kirui, B.K., Muturi, G.M., Gathara, M. (2018). Interactions between native tree species and environmental variables along forest edge-interior gradient in fragmented forest patches of Taita Hills, Kenya. For. Ecol. Manage. 409, 789–798.

Zhou J.Y, Li R, Zhang W.H, He J.F (2012) Effects of thinning intensity on structure characteristics and spatial distribution of *Quercus wutaishanica* populations. Sci Silv Sin 48(4):149–155.