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Original Article

Influence of Pruning Regime on Woody Species Density and Abundance in Kimondi Forest, Kenya

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ABSTRACT

Globally, silviculture is concerned with the establishment, development, upkeep, and propagation of timber stands to increase the shock resistance of forests and the global adaptability and resilience of ecosystems. While silvicultural regimes are widely recognised for enhancing timber quality and stand structure, their long-term ecological impacts on woody species density and abundance remain underexplored. Existing studies have primarily focused on species selection, leaving a significant knowledge gap regarding the effectiveness and optimisation of pruning regime intensity. The research aimed to assess the influence of the pruning regime on woody species density and abundance. This study focused on *Cupressus lusitanica and Pinus patula.* The study adopted a cross-sectional descriptive study design, using systematic sampling. Analysis was done using Box plots, Analysis of Variance and Duncan's multiple range test. Box plots showed that *Cupressus lusitanica* exhibited higher performance with greater variability, while *Pinus patula* showed more consistent but slightly lower outcomes. A one-way ANOVA revealed a highly significant difference in tree abundance and density across pruning treatments ($p = 0.028$), with an effect size (Eta^2) of 0.61139, indicating that 61.39% of the variation is attributable to pruning practices. Duncan's test further confirms that higher pruning intensity reduces woody species density, while moderate pruning enhances regeneration. The findings revealed the importance of the pruning regime on woody species density and abundance and recommended that tailored silvicultural practices are key in advocating for formative pruning as a sustainable and cost-effective method in early tree development stages.

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INTRODUCTION

Woody species are an important part of global forest landscape restoration (FLR) programs, which aim to systematically increase the number of trees in degraded or deforested landscapes by silvicultural regimes. According to Puettmann *et al.* (2009), silviculture has been hailed as a "win-win" strategy that offers rural landowners a means of generating revenue while simultaneously protecting the ecosystem benefits provided by natural forest cover. The integration of native woody species into FLR and the general adoption of enrichment planting are hampered by significant information gaps identified by O'Hara and Ramage (2013). The performance of different species under a pruning regime is poorly understood, particularly with regard to woody species that utilise this regime (Kerketta *et al.,* 2018), as well as optimal techniques for fertilisation and overstory management. More precisely, as Piispanen *et al.* (2014) explain, there is a lack of information about how much a particular woody species' performance depends on the surrounding environment in which it grows.

Regionally, Agroforestry parklands in West Africa rely heavily on Multi-purpose *Faidherbia albida* trees, which are studied in Senegal, where these trees serve as firewood, fruits, and cattle fodder in addition to supporting crop nutrient recycling and water lifting. Pietzarka *et al*. (2016). The site's qualities, the tending technique, and genetics all affect the bare stem's length. (SAIEA, 2016). Dry pruning, or the removal of dead branches, is the pruning method used on coniferous species, whereas green pruning is used on broadleaved species (Sadono R., 2017). In forests containing coniferous species, dry pruning should be used during the thinning operation on trees larger than 15 cm in diameter in order to give a minimum stopping sight distance as revealed by Swaim *et al.* (2018). Broadleaved species have a higher pruning rate than coniferous species due to their growth morphology, which includes a wide crown and open angles between branches (Stere ́nczak *et al.,* 2019). Because the crowns of coppice and seed crop species are too broad, it is important to stop the growth of their saplings (SIS, 2020).

Numerous recent studies highlight the potential of mixed-species silviculture for managing ecosystems sustainably in the face of uncertain and unstable environmental conditions in the future, as evidenced in a study by Schmitt *et al.* (2020). However, the understanding of mixed stands is still incomplete compared to monoculture (Schmitt *et al.*, 2020). The inverse phenology of *Faidherbia albida* trees allows them to produce leaves, flowers, and pods during the dry season, giving fodder, and shed leaves during the wet season, reducing competition for resources with pastures and crops (FAO & UNEP, 2020). Additionally, new computational techniques and multi-spectral and multi-temporal satellite systems provide new opportunities for species identification and single tree classification FAO & UNEP, 2020. When it comes to artificial forest regeneration, tree provenance is crucial (Regolin, 2020). For planted or seeded trees in a forest stand, excellent provenance considers appropriate tree genetics and a good environmental fit (Anna *et al.,* 2023). The incorrect genotype might result in poor trees that are vulnerable to diseases and undesirable consequences, or in unsuccessful regeneration.

Furthermore, as demonstrated by Terefe and Gure (2019), the appropriate application of pruning treatments shortens the cutting cycle and speeds up development. According to Terefe and Gure (2019), pruning is one of the silvicultural

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treatments that encourages wood that is knot-free and has increased strength, durability, and aesthetic value. According to research by Niemistö *et al.* (2019), pruning management lowers and concentrates the occurrence of knots in the wood, which results in higher added-value goods. According to Palik *et al.* (2020), pruning management is important, particularly in plantations where the species do not naturally prune. However, as studied by Gebeyehu *et al.* (2021), pruning can restrict a plant's growth in diameter and height since it reduces the photosynthetically active area of the plant. In hybrids of *Eucalyptus saligna urophylla* and *Eucalyptus saligna grandis,* this impact was noted by (Stimm *et al.,* 2021), who noted a correlation between an increase in pruning intensity and a decrease in plant diameter and height growth. Depending on the species and crown architecture, different pruning responses may occur. Thus, it is imperative to do research to determine the impact of pruning intensity, particularly in native species.

Several methodologies have been used to analyse woody species in tropical rainforests in East Africa, notably in Kenya, Uganda, Tanzania, and Malawi (Rance and Monteuuis, 2011). Research has shown that active planting forest restoration projects should give priority to species that benefit local communities while also taking into account the threat status of the species and their resilience to local stressors (Omoro *et al.,* 2011). However, there is a lack of scientific information on these factors, particularly in tropical ecosystems that have not received much attention (Otuoma et al., 2016). According to Kiruki *et al.* (2018), representatives of the species *Eucalyptus saligna* are common on small farms throughout the region in Turbo, Kenya. Despite their rapid growth and ability to thrive on marginal terrain, these trees have been introduced as part of the species chosen for the pruning regimes and are linked to adverse environmental effects in Africa and other regions (Feyisa *et. al.,* 2018). According to Omondi *et al.* (2020), a variety of exotic conifer species have been successfully introduced in Kenya since 1910 with the aim of supplying wood, mostly for the timber, pulp, and plywood industries. According to research by Onyango *et al.* (2020), of the conifers that were imported, *Cupressus lusitanica and Pinus patula* have flourished in the local growing environment and are now two of the major species that are extensively planted in commercial plantations in Kenya. The focus of these studies has primarily been on the use of tree improvement technologies to scale up conifer plantations. These technologies are derived from a strategy that includes the application of better germplasm, silviculture, tree breeding principles, and pest and disease control. Domesticating this species is essential to prevent its extinction. Unfortunately, because the germination and growth performances of potential provenances are still mainly unknown, no provenances can be offered to farmers with confidence as suitable seed sources. Therefore, in order to maintain the pruning regime, it is necessary to evaluate each species' profitability.

In Kakamega forest, a study was done by Otuoma (2016), within the spatial dimensions of Isecheno forest station
of Kakamega south forest, where *P. africana, O. capensis and C. megalocarpus* are abundant, using the ANOVA test. This study analyzed regeneration potential of the African cherry, identified the appropriate pruning techniques and suitable sowing media that gives optimum germination and sought to identify other tree species with potential commercial uses which could be used as alternative to *P. africana* and hence ease the exploitation pressure that it presently faces due to its medicinal value and valuable multipurpose timber, Wekesa *et al.,* (2018). Due to a shortage of funding to support regime management, the government banned thinning regimes in the Kimondi Forest in 2018. This also led to the forest's prohibition on logging (Odhiambo *et al.,* 2020). According to Odhiambo *et al.* (2020), this was also brought about by the belief that intensive forest management results in extended rotation durations of woody species that are economically viable and that species are managed for volume rather than value. The limitation on thinning had a negative impact on the *Eucalyptus saligna* crop between 2018 and

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2021, since very few logs were graded during that period. Thus, a need to study the influence of pruning regime on woody species density and abundance.

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

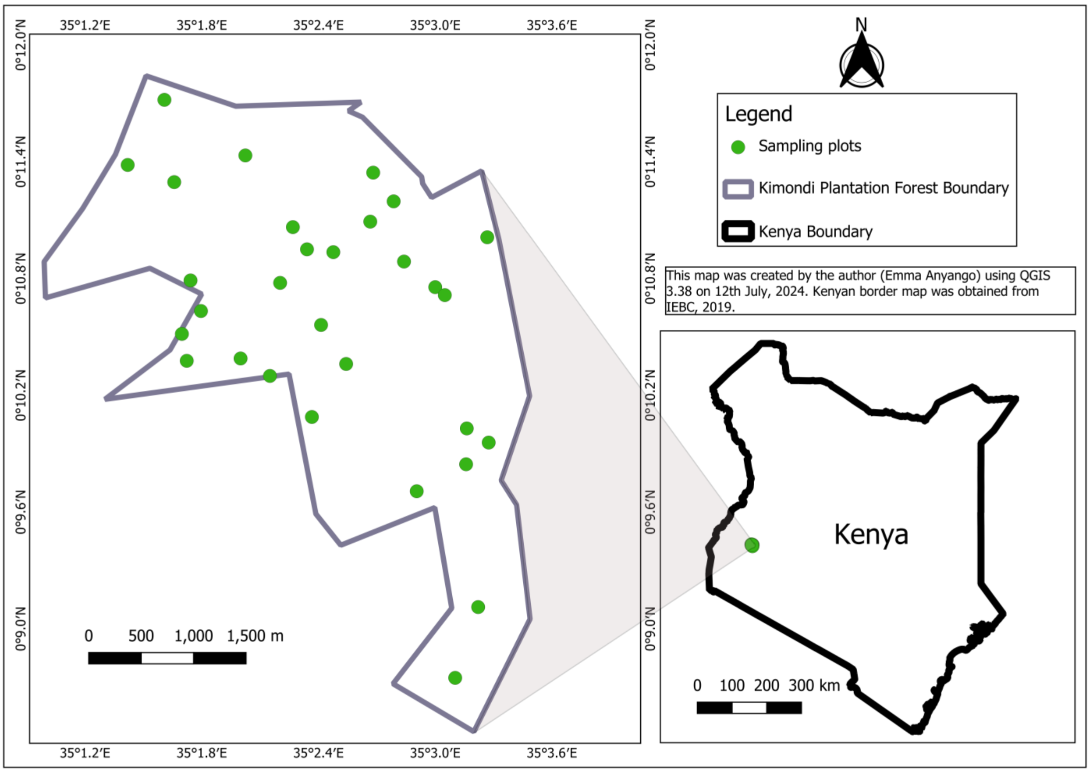

Table 1: Dominant Woody Tree Species in the Kimondi Forest.

Botanical Name	Uses
Cupressusus lusitanica	Timber
Pinus patula	Timber
Eucalyptus saligna	Timber, charcoal production

Field Sampling

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

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

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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 were collected from the field. It also includes the size of the forest sampled. 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 it was have 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 area to get the abundance of each of the tree species in Kimondi forest.

Measures of the Influence of the Pruning Regime on Woody Species Density and Abundance.

One-way ANOVA test was used to analyse the relationship between the pruning regime and the number of woody species per plot. Box Plots were used to show the distribution of woody species. 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.

Ethical Considerations.

This section includes a description of the study's objectives, participant requirements, informed consent procedures, and confidentiality guarantees. Maseno University's Ethics Review Committee issued an ethical clearance letter. The research permit was sought from NACOSTI. In order to conduct the study, we sought permission from the Nandi and Kakamega Counties' local government. The research was conducted according to professional research ethics in order to prevent needless confusion, disputes, and moral conundrums.

RESULTS

Distributions of Woody Species Density in Kimondi Forest

The box plots are used to show distributions of numerical data sets for pruned and unthinned woody species density in order to compare them. They provide general information about groups of data's symmetry, skewness and variance as shown in Figure 2.

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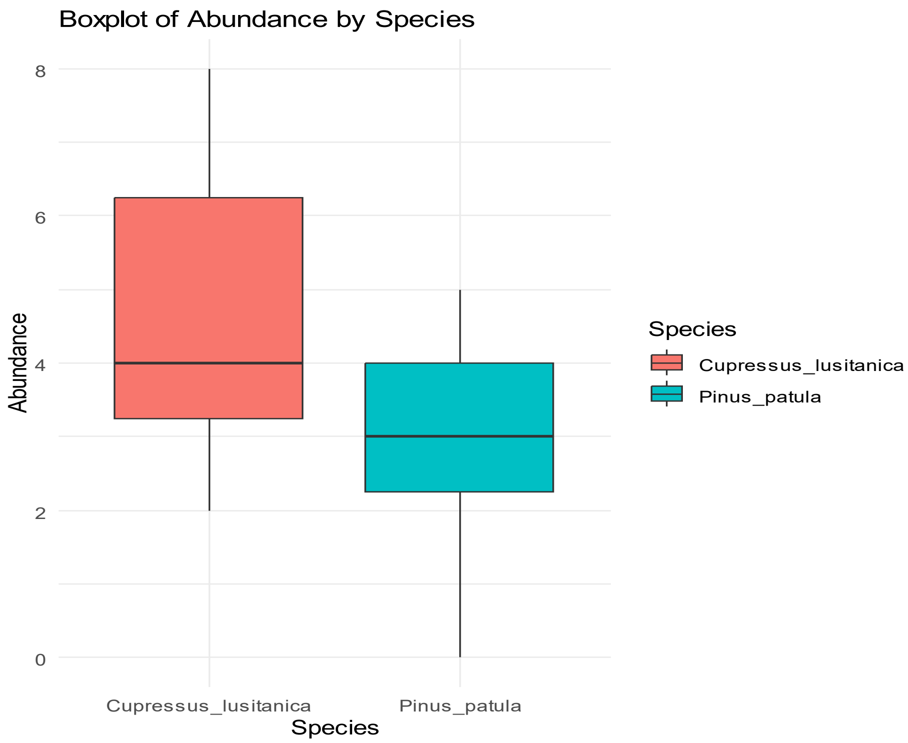
Figure 2: Boxplots Showing the Distributions of Woody Species (*Cupressus lusitanica and Pinus patula*) Densities under Different Thinning Regimes.



The boxplot illustrates a comparative analysis between *Cupressus lusitanica* and *Pinus patula*, highlighting notable differences in their performance for the measured variable. *Cupressus lusitanica* exhibits a higher median value, indicating superior overall performance, while also displaying greater variability, as reflected in its wider interquartile range. The distribution for *Cupressus lusitanica* appears slightly positively skewed, suggesting that while most values are concentrated below the upper quartile, there are a few higher values pulling the distribution upward. On the other hand, *Pinus patula* demonstrates more consistent performance with a narrower interquartile range and a slightly negative skew, indicating that a few lower values may be influencing its distribution. These patterns suggest that while *Cupressus lusitanica* may have greater growth potential, it is also more variable, whereas *Pinus patula* offers more uniform results. This reinforces the importance of integrating both species selection and silvicultural regime design to achieve optimal forest productivity and resilience.

Table 2: One-way ANOVA Showing Comparison of Means of Woody Species Density and Abundance under the Pruning Regime

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	138.5330	1	138.5330	5.050536	0.028437	4.006873
Within Groups	88.0503	58	3.593678			
Total	226.5833	59				

The results indicate that the effect size is 61.139%. The variation of the abundance and density of woody species can be explained by the thinning regime. The Anova results from quantitative data resulting from the summary of the abundance and density of the woody species pruned indicate that *Cupressus lusitanica* had the highest quantity and quality from this regime as

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compared to *Pinus patula*. *Cupressus lusitanica* is easy to regenerate when pruned, as compared to *Pinus patula*, hence the most planted species because it is cheap to maintain.

P value = 0.028* is less than the common alpha level of 0.05, the null hypothesis would basically be rejected. An indicator of enough evidence to conclude that there's a real effect of pruning on woody species density and abundance in the forest. This implies that the pruning regime has a significant influence on the woody species density and abundance in Kimondi Forest (H_1).

In Kimondi forest, it was evident that *Cupressus lusitanica* was denser than *Pinus patula,* especially those grown in areas that were gently sloping, because it is more long-lasting, because they have posts with natural oils and resins that make the timber resistant to rot, decay and insect attack, including termites. The *Cupressus lusitanica* were less in plots that were on steep slopes and water-logged areas, hence isolated. It is evident that the pruning regime results in increased production of *Cupressus lusitanica*. Despite the threat by the local community to harvest the woody species before maturity, there is proper maintenance of the species in the Kimondi forest. In the pruning regime, there is a need to utilise formative pruning, which is relatively cheap and can be carried out during other operations such as weeding or tree shelter maintenance or removal, making financial sense to formatively prune the *Pinus patula* and *Cupressus lusitanica* species on an annual or biennial cycle for the first ten years or so.

Table 3: Duncan's Multiple Range Test of the Interaction between Pruning Regime and Woody Species Density and Abundance

Influence of pruning regime on woody species density and abundance

Duncan[a]

		Subset for alpha = 0.05	
Pruning regime	N	1	2
2	10	241.20	
1	10		287.40
Sig.		1.000	1.000

The analysis using Duncan's Multiple Range Test reveals that pruning intensity significantly affects woody species density in the forest plots studied. High Pruning (Mean = 241.20) resulted in the lowest woody species density. Intense pruning likely removed a significant portion of woody vegetation, reducing the number of woody stems per plot. Moderate Pruning (Mean = 287.40 resulted in an intermediate density. Pruning alters the structure and composition of forest vegetation by reducing canopy cover and stem count and altering microhabitat conditions (light, moisture, competition). Less intensive pruning may promote natural regeneration and biodiversity, while heavier pruning can degrade forest structure and reduce habitat quality.

DISCUSSION

Globally, Turner (2021) found that coniferous species such as *Pinus radiata* in New Zealand responded positively to pruning, with significantly higher growth rates and stand density, attributed to reduced competition and increased light availability. Similarly, *Zhang et al.* (2022) in China showed that selective pruning in plantation forests improved stem form and increased site productivity for *Pinus patula* species more than for other genera like *Cupressaceae*.

Consistent with the current study's findings, Onyango *et al.* (2020) claimed that, in comparison to knotty lumber from unpruned trees, pruning is seen as an investment to improve wood quality that should fetch a higher market value, sufficient to pay pruning expenditures. *Pinus patula* was

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extensively studied in South Africa in the 2000s (Wanjira and Muriuki, 2020). Many African nations, most notably Kenya, Madagascar, Nigeria, and Tanzania, have adopted or used South African and Indian thinning techniques to create indigenous regimes with delayed response pruning as the regime since the 2000s (Wekesa *et al.,* 2018). Regionally in East Africa, Oduor and Githiomi (2021) examined plantation performance under silvicultural manipulation in Uganda and noted that *Pinus patula* plantations responded more favorably to pruning in terms of basal area and tree count compared to *Cupressus lusitanica* and *Eucalyptus saligna.* According to research by Omoro *et al*. (2013), who used the ANOVA test, *Cupressus lusitanica* is more liked since it lasts longer and is denser than *Pinus patula*. Odhiambo *et al.* (2020) went on to say that since *Eucalyptus saligna* trees self-prune, pruning is not required in plantations. This is further demonstrated in the Kimondi Forest, where the *Eucalyptus saligna* tree, to which the trimming regime was performed, was absent.

To improve security and accessibility, however, some mild trimming may be done (Mensah 2016). According to the study's findings, *Pinus patula* has the lowest density and abundance. This is a result of the *Pinus patula* trees' low resilience to heavy pruning; new growth does not originate from latent buds in the bark that is still there, nor do new buds form in the wound wood that grows around pruning wounds. Niemistö *et al.* (2020) concluded that pruning is necessary if knot-free wood is wanted for increased *Pinus patula* abundance and density. This is because plantations developed for saw logs and veneer necessitate the production of high-grade, Clearwood. Furthermore, Lencinas *et al*. (2011) build on previous studies by pointing out that sufficient work has been done on pruning and that, because pruning has been done over time, data on pruning is more extensive compared to thinning. Nonetheless, additional study is still being done in the field of pruning, particularly because of the short rotation that the plantations are subjected to as the forest plantation gets smaller every day (Niemistö *et al*., 2020).

In Kenya, Kinyanjui *et al.* (2023) reported in their study on forest restoration in Mau Forest Complex that Pinus species exhibited better recovery and density responses under controlled pruning than *Cupressus lusitanica*. The findings from Kimondi Forest are consistent with this pattern, highlighting the strategic value of species-specific silviculture. Specifically, for Kimondi Forest, Kiptoo and Korir (2020) had earlier emphasised the need for differentiated forest management strategies, suggesting that *Pinus patula* stands could benefit from pruning while *Cupressus lusitanica* required less intensive intervention. This present analysis validates that suggestion with empirical evidence showing enhanced *Pinus patula* density post-pruning. Further, Mwanzia *et al.* (2021), in their biodiversity monitoring study across Nandi Forests (including Kimondi), noted that species like *Pinus patula* displayed more competitive regeneration traits under semi-managed plots compared to *Cupressus lusitanica*, particularly where pruning was applied as a management strategy. Lastly, Odhiambo and Cherono (2024) in their comparative analysis of forest stand structures in Western Kenya found that silvicultural treatments significantly favoured *Pinus patula* density and structure over *Cupressus lusitanica*, reiterating that silvicultural responses are not uniform across species.

The current regimes proposed thinning regimes, which are exceedingly costly to perform in the field, in accordance with the study's findings. The amount of unthinned and unpruned species in the forest indicates that this has caused enormous backlogs to build up in the field. In contrast, Ladrach (2009) found in his research findings that some of the regimes, as they are currently implemented, are unjustified. For instance, he recommended that there be no more than two early prunings in these stands, one at two and one at four years, due to the spacing between pruning periods in the pulpwood crop of *Cupressus lusitanica*. In the Kimondi forest, there are 1st to 5th pruning sessions in woody species, whereby the 1st and 2nd are done to all *Pinus patula* and *Cupressus lusitanica,* then a selected few stands have other sessions of pruning.

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These regimes' effects on species density and abundance were influenced by intervening circumstances in the Kimondi forest. The distribution of tree species in the Kimondi forest was significantly influenced by a number of regional and local environmental parameters, such as rainfall and altitude, as well as plantation size and other factors related to the environment. Consistent with these results, Kiruki *et al.* (2020) observed that the primary classification of forests into groups was based on soil type, and that discontinuous forest variation indicated the existence of two major soil units that differed in Nigerian forests. Tree species richness and density are therefore influenced by geographical position, Kremer and Bauhus (2020), soil depth and composition, length and frequency of rainfall (or dry season), successional stage, and management history. These studies are confirming the results of this study, which align with the theoretical framework of the study that is adapted from the Island biogeography theory (I.B.T.) by R. MacArthur and Wilson (1967) on the species-area relationship. It illustrates how an island's geographical area and level of isolation affect the richness and variety of creatures that call it home. Hence, the areas in the plantation forest that have steep slopes and are waterlogged have few numbers of species as compared to the species in a proper geographical position. Furthermore, due to the insufficient support that very shallow soil provides, very few woody species can grow in poor, infertile soil locations (Keyser and Loftis 2015). This is because soil depth may be a limiting factor.

Kuuluvainen and Gauthier (2018) found that, as indicated by the linear regression models used in their study, soil variables explained 8.9% of the variation in the distribution of tree species. As such, a high abundance and density of woody species is equated to a forest’s geographical area, whereby when there is adequate area for planting *Cupressus lusitanica and Pinus patula*, it results in inadequate space for a pruning regime, hence greater quantity and quality as advanced in I.BT. The requirement to eliminate several stems and a decrease in the likelihood of knots and faults in future wood (high pruning) also contributed to *Cupressus lusitanica's* increased density and abundance. In a similar vein, Keyser (2012) came to the conclusion in his research that pruning is advantageous since it delays the emergence of significant structural flaws and guarantees that most trees have the capacity to yield higher quality lumber, such as the consistently denser *Cupressus lusitanica*. In Kimondi Forest, stands of *Pinus patula* and *Cupressus lusitanica* that are less than five or ten years old undergo formative pruning and singling in order to produce a single straight stem.

According to research by Kremer and Bauhus (2020), it's critical to "train" trees that exhibit undesired forms. Later, as shown in, high pruning of *Pinus patula* and *Cupressus lusitanica* is performed to produce a straight stem free from external knots to boost the density. According to D’Amato *et al.* (2018), a mature tree with big diameter knots, a forked stem, or neither would be worth significantly more than a tree with a single large diameter, straight stem devoid of knots. Large diameter, long, straight logs with a good percentage of heartwood from *Pinus patula, Cupressus lusitanica, and Eucalyptus saligna* were specifically needed by hardwood sawmills from this research region. In summary, integrating Island Biogeography Theory helps explain why pruned *Pinus patula* stands in Kimondi Forest show higher density and abundance compared to *Cupressus lusitanica*. Pruned plots create semi-isolated microhabitats that favour coloniser-type species like *Pinus patula* due to increased resource availability and reduced competition, supporting the theory’s prediction that species richness and dominance are influenced by disturbance and patch dynamics. This conceptual framework, when integrated with empirical data, enriches our understanding of forest management impacts on species dynamics.

Pruning has advantages, as this study has shown; however, D'Amato and Palik (2020) observed in their research that one drawback is that rot may develop in the stem behind the incision. Cuts must be modest in some species, such as poplar, birch, and horse chestnut, because they have a weakened

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defence mechanism. Compared to *Cupressus lusitanica* and *Pinus patula*, other species such as plane, oak, and lime have a better defensive system and can therefore withstand slightly greater cuts (Lencinas *et al*., 2011). Bekele (2015) further suggested that in order to increase the quantity and quality of woody species, the diameter of the resulting pruning wound should not exceed one-third of the diameter of the limb or bole that was pruned. As a result, this ratio should decrease as the pruning wound becomes larger. This indicates that the Kimondi Forest pruning regime has to be improved, as the sampled plots only include 16.71% of *Pinus patula and Cupressus lusitanica.* After conducting ANOVA tests in the Gatamaiyu forest, Kiruki *et al.* (2018) found that while the pruning treatment did not influence the increment of tree height, it dramatically decreased the increment of DBH and influenced other confounding factors such as soil type and soil pH. Additionally, he concluded that pruning can greatly reduce the total water volume consumed for transpiration at the tree level, effectively raise the leaf net photosynthetic rate, and result in a decrease in stem sap flow rate. Similar to the results of this study, Kremer and Bauhus (2020) discovered that formative pruning is reasonably inexpensive and can be done in conjunction with other tasks like weeding or maintaining or removing tree shelters. For the first ten years or so, it makes financial sense to formatively prune the crop on an annual or biennial cycle.

When comparing *Pinus patula* to *Cupressus lusitanica*, there was a great deal of variation seen in each species. Knot checks were a significant flaw in every species, and they could be addressed technologically in Kimondi Forest's woody species dressing process. The sample size was chosen to avoid repetition of similar data collection in the planted forest. Pruning branch stub holes, which result from a lack of intergrowth around dead branch wood, were the most common flaws in Leyland; so, pruning technique modifications may be helpful in this regard (Koivula and Vanha-Majamaa, 2020). The findings presented here demonstrate that the wood tissues of old and senile individuals are more mechanically robust and rigid than those of juvenile individuals. This is partly due to the gradual increase in cell-wall thickness that occurs with wood tissue ageing, a process that is more pronounced in *Cupressus lusitanica* species. In fact, because of a sophisticated porous vascular system that gets stronger as the tissue microstructure ages, *Eucalyptus saligna, Pinus patula,* and *Cupressus lusitanica* were discovered to have greater mechanical resistance to the progression of stresses (Abunie *et al.,* 2019). These findings emphasise the need for carefully planned pruning regimes. Low to moderate pruning might be ideal for balancing forest use (e.g., access, fuelwood collection) with ecological conservation. Over-pruning could lead to biodiversity loss, soil degradation, and reduced forest resilience. Therefore, a new realisation in this study is that *Cupressus lusitanica* is the most pruned woody species because it lasts longer and is denser than P*inus patula,* hence the need to utilise a pruning regime to improve the quantity and quality of these woody species.

CONCLUSION

In the Formative pruning, when done early and moderately, improved tree form and regeneration, especially in adaptable species like *Cupressus lusitanica*. Box plots showed that *Cupressus lusitanica* exhibited higher performance with greater variability, while *Pinus patula* showed more consistent but slightly lower outcomes. A one-way ANOVA revealed a highly significant difference in tree abundance and density across pruning treatments ($p = 0.028$), with an effect size (Eta^2) of 0.61139, indicating that 61.39% of the variation is attributable to pruning practices. Duncan's test further confirms that higher pruning intensity reduces woody species density, while moderate pruning enhances regeneration. The findings revealed the importance of the pruning regime on woody species density and abundance. These results provide actionable guidance for forest managers seeking to increase timber quality, promote biodiversity, and support climate-resilient forest systems. The implication of this research is its demonstration of how

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silvicultural practices can be tailored to species characteristics and site conditions, offering a more sustainable and cost-effective approach to plantation management. Further research incorporating a wider range of species, including natives and cost-benefit evaluations, will be essential to refine the pruning regime for broader, evidence-based forest management.

Recommendations

Integrate Formative Pruning with Routine Plantation Activities

Formative pruning should be carried out during routine operations like weeding or shelter removal to reduce labour costs. This is especially effective for species such as *Cupressus lusitanica* and *Pinus patula* when implemented annually or biennially in the first ten years. Pruning improves stem straightness and timber quality, but should remain moderate to avoid damaging sensitive species.

Areas for Further Research

- The differences and interrelatedness of the pruning regime on the knots and lumber recovery
- *Long-term effects of pruning regime on forest succession.This entails investigating* ***how pruning influences forest regeneration, species diversity, carbon storage, and ecological stability over time to ensure sustainable forest development.***

Competing Interests

Authors have declared that no competing interests exist.

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