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Can Small-Holder Trees Supplement the Public Plantations in the Wood Market? The Case of Kenya's Logging Moratorium

David Kipkirui Langat[1*], Abdalla Kiteo Kisiwa[1], Nereoh Chelimo Leley[1,2], Joram Kimenju Kagombe[1], Joshua Kiplongei Cheboiwo[1]

[1]Kenya Forestry Research Institute, Nairobi, Kenya
[2]Egerton University, Njoro Campus, Egerton, Kenya
Email: *dkipkiruilangat@gmail.com, dlangat@kefri.org

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Abstract

Kenya's public forest sector plantations have been the main source of roundwood for wood-based industries but several factors have reduced its capacity to meet increasing demands, resulting in huge deficits. The growth of smallholder forestry over the last three decades has demonstrated the potential to supplement the deficits. The imposed logging moratorium in public and community forests in 2002-2012 and 2018 not only opened markets for smallholder tree growers but also increased demand pressure from various wood consumers. This paper presents an assessment of the status of farm-based wood resources three years within the latest moratorium period and the potential of farm tree resources to complement wood from public forest plantations. Data were collected from 56 households using semi-structured interviews, key informants interviews, and a rapid assessment of standing and harvested trees from 146 on-farm plots. The main commercial tree species found on the farms were; *Cupressus lusitanica*, *Eucalyptus sp.*, *Grevillea robusta*, *Pinus patula*, and *Acacia mearnsii*. Eucalypts were the most planted trees with an average land size of 1.08 ha. The farm tree resources have sustained some level of wood demand since the moratorium, as indicated by the high volume of wood harvested. The study found that about 40% of current wood resources consisted of trees less than 5 years, and most harvests were of small diameter classes which are essentially juvenile wood and are unsuitable for structural and furniture use. Furthermore, most small-scale farmers lack appropriate silvicultural and management knowledge, preferring smaller growing spacing as shown by the high planting density of 1659 stems·ha^{-1} and also use of inferior germ-plasm, with implications on the quality of wood from farms. It is recommended that rigorous capacity building on tree growing and management techniques be undertaken and a progressive and supportive policy framework on harvesting and trade of trees on-farm be developed.

Keywords

Small-Holder, Farm Forestry, Logging Moratorium, Plantation Management, Wood Supply

1. Introduction

Public forest plantations have been the main source of industrial wood raw material for commercial enterprises in Kenya since 1986 (Cheboiwo et al., 2018). These plantations are managed by the Kenya Forest Service (KFS) and cover about 135,000 ha. Public forest plantations supply about 1 million m^3 of sawn wood, which is less than the country's aggregate demand for wood products, for example, there is a projected future wood deficit increase of 26.5% (GoK, 2013; Cheboiwo, 2016). The current deficit is met by the large-scale private plantations, community forests, and small-holder private farms. Moreover, the Kenyan public forests are faced with threats that have depleted the forest resources by about 5000 hectares per annum, which is expected to hinder the attainment of the country's strategy of achieving and maintaining over 10% tree cover, the country's development blueprint -vision 2030 and the Big Four Agenda (GoK, 2018). This is partly attributed to poor forest sector governance and a widening gap in demand and supply of round wood. To allow for reassessment, rationalization, and streamlining of the sector, the government of Kenya imposed moratoriums on logging activities in public and community forests in 2002-2012 and from February 2018 (Kagombe et al., 2020), which is still on at the moment (2022).

The harvesting moratorium resulted in an artificial shortage of wood materials in the country immediately forcing most commercial enterprises to resort to exclusive harvesting of wood from private farms to stay in business. However, many actors are concerned about the feasibility of farm forestry materials to meet growing forest products demand and have criticized the government directive as an instantaneous pronouncement lacking clear implementation strategies (Kagombe et al., 2020). Previous studies projected the growth of farm forestry since the 1990s from a meagre few hectares to occupying 10% of prime agricultural land by 2020 (FAO, 2010; GoK, 2013; Cheboiwo et al., 2018). The massive growth in farm forestry is demonstrated by an increase of about 48% between 1990 and 2010 indicating the potential role of farm forestry to meet the rising demand for wood products. However, the effects of the moratorium on-farm tree resources have not been documented. This paper presents the effects of the moratorium on farm-based tree resources by evaluating the trends of wood harvesting and tree establishment before and after the proclamation of the moratorium. In addition, it assesses the quality of tree resources available on farms in terms of quantity and quality. This is expected to appraise the potential of smallholder farm forests to complement the wood supply from public plantations in the future and identify suitable intervention strategies.

2. Research Methodology

2.1. Study Design

The study was conducted in the western part of Kenya, targeting major production and outlet sites. Nakuru and Uasin-Gishu Counties were selected as the sample study sites considering the number of actors and volume of active wood-based businesses. A sampling of the production areas within the sites was identified with the support of the Kenya Forest Service (KFS) offices because of their mandate in issuing tree harvesting permits both on public and private farms. Moreover, they are conversant with locations of the most on-farm tree resources. The sampled production areas represented in Uasin-Gishu outlets were Kapseret, Flux, and Turbo, while, in the Nakuru, Kuresoi South and North were the sampled sites. Field data were collected in March 2020. Purposive sampling was applied, which targeted tree growers who had sold trees before the harvest moratorium in the year 2017 and the entire period following the ban including the years 2018, 2019, and 2020. Target farms were selected from movement permit register records obtained from the Kenya Forest Service.

2.2. Data Collection

Data on the area of land under trees, plantation systems, preferred and planted tree species and tree harvesting trends (pre and post-moratorium) were collected from 56 representative farmers using a semi-structured interview. Inventory of standing trees on the farm and harvested biomass was undertaken from the interviewee's farms to understand the status of existing tree resources and the trend of harvesting. A total of 146 sample plots of 0.01 ha were established randomly within the area of farmland under trees across different plantation systems (woodlots and boundary planting). The number of sampled plots from each farm was proportional to the area under trees. To ensure the equivalent area was assessed for boundary planting, the spacing used for each planting configuration was considered. The Diameter at Breast Height (DBH) and height of all standing trees was measured using diameter tape, and a Suunto clinometer respectively. For the harvested trees, stump diameter was measured at 20 cm above the ground for those with stump diameter above 20 cm, while for those which had been harvested below the 20 cm mark, stump diameter was measured at the cut level (Mwakalukwa et al., 2014). Data was also collected on the age of standing and harvested trees and existing silvicultural management. Observations on the general status of trees on the farm (tree stem form and health) were also recorded. Key informant interview and secondary data from Kenya Forest Service was also collected. This included the records on movement permits used for sampling purposes.

2.2. Data Analysis

Data was analyzed qualitatively and quantitatively to infer the potential and challenges of smallholder farm plantations to supply wood products. Descriptive statistics were used to analyze data from farm interviews. Correlation analysis was used to test the relationship between total land owned and land allocated to the tree growing. The data and information from key informant interviews and movement permits were used to triangulate farm data. Farm tree inventory data was used to compute the tree density (stems·ha^{-1}), basal area (m^2·ha^{-1}), and volumes (m^3·ha^{-1}) of both standing and harvested trees. The volumes of standing trees were computed using appropriate local tree species-specific models (**Table 1**). The volume of stumps was determined as vertical closed cylinder volume using the Huber volume formula as described in Equation (1) (Arney, 1968).

$$V = \frac{\pi * (\mathrm{BD})^2}{40,000} * h \tag{1}$$

3. Results and Discussion

3.1. Farm Characteristics

The size of land owned by farmers sampled in Nakuru tree production areas was large, with an average of 6.29 (SD = 5.22) ha compared to Uasin-Gishu 3.08 (SD = 2.42) ha. The mean land holding in Uasin Gishu County was comparable with the documented mean land size for small-scale farming in the rural areas of the county of about 3 ha (Uasin-Gishu CIDP, 2018). However, the official record at Nakuru County is smaller at about 0.77 ha (Nakuru CIDP, 2018) contrary to the results from the study. This disparity could be because the assessment was undertaken in rural areas not affected by urban development and farmers still hold large inherited land sizes. Nonetheless, the size of farms under trees was nearly similar in both Nakuru and Uasin Gishu tree production areas at 1.57 (SD = 1.65) and 1.41 (SD = 1.58) ha, respectively. This suggests that farmers in Uasin Gishu allocate more land to tree planting (46%) compared to only 25% of the land owned dedicated to farm forestry in Nakuru. However, the total land size showed a positive influence on farmers' allocation of land to tree growing ($F(1, 52) = 47.62$, $p < 0.05$, $R^2 = 0.48$). The findings are contrary to other studies which have reported increased farm forestry trends as land size declines due to intra-household

Table 1. Species-specific models applied in computing tree volumes.

Species	Model	Reference
Cupressus lusitanica	$V = C_0 + C_1D^2 + C_2DH + C_3D^2H$	Wanene & Wachiuri (1975)
Eucalyptus sp.	$V = C_0 + C_1(D^2 * H)$	Kiriinya (2004)
Pinus patula	$V = C_0D^2HC_1 - C_1D^2 + C_2DH$	Gor-Kesiah (1978)

Note: V—Total volume over bark (m^3); D—Diameter at breast height (cm); H—total height of standing tree (m); BD is the stump basal diameter (cm) while h is the height of the stump (m), C_O, C_1, C_2 and C_3 are constants and π is the pie.

product demand and the need for increased productivity (Cheboiwo et al., 2017).

The main tree species found on farms were *Cupressus lusitanica* (43%), *Eucalyptus sp*. (40%), *Gravellia robusta* (13%), *Pinus patula* (3%), and *Acacia mearnsii* (1%), as also reported by various other studies (Sikuku et al., 2014; Nyaga et al., 2015; Cheboiwo et al., 2018). *Juniperus procera, Hagenia abbysinica,* and *Olea africana* were some of the indigenous tree species found on a few farms. The dominance of *C. lusitanica* and *Eucalyptus sp*. on farms is an indication of their preference and relatively low species diversity for commercial on-farm tree species, hence the need to promote diverse fast-growing and multipurpose trees among the smallholder farmers. In Nakuru, *C. lusitanica* was the most common tree species (49%), followed by *Eucalyptus sp*. (36%). Contrary, *Eucalyptus sp*. was mostly planted by farmers in Uasin Gishu (46%) followed by Cypress (35%). This variation may be due to farmers' preferences, species-site suitability in the two areas, and market availability.

The plantation species were established in three main agroforestry systems; woodlots covering 60% of farms with a mean area coverage of 0.73 ± 0.22 ha, while boundary planting was observed in 38% of farms covering a mean area of 0.17 ± 0.04 ha. Some farms (2%) in Nakuru in recently degazetted public forest practiced management of scattered naturally regenerating *C. lusitanica* trees. In both study sites, woodlot was the most common agroforestry system; Nakuru (62%) and Uasin Gishu (54%). Generally, C*. lusitanica* was mostly planted in boundaries (52%) while, *Eucalyptus sp*. was mostly planted in woodlots (88%). This trend in the establishment of trees under woodlots is similar to observations reported by other studies, that trees are planted in woodlots to maximize benefits by responding to market demand for wood products and to minimize the negative tree-crop interactions (Nyaga et al., 2015). The establishment of *C.lusitanica* on-farm boundary could be due to the preference of the species for live fencing and boundary demarcation.

Generally, land under trees was dominated by *Eucalyptus sp*. with an average area of 1.08 ± 0.34 ha while *C. lusitanica* occupied an average area of 0.17 ± 0.03 ha. The preference of *Eucalyptus sp*. on-farm could be attributed to the short rotation period from 5 to 17 years while *C. lusitanica* has a rotation age of 25 to 30 years (Cheboiwo, 2016). Moreover, Eucalypts are suitable for growing in most agro-ecological zones and are versatile in utilization (Langat et al., 2015). *Eucalyptus sp*. tree growing has also demonstrated viability with ready markets making it attractive to most farmers (Oballa et al., 2010; Langat et al., 2015). Furthermore, discussions with key informant interviews, found that most farmers planted trees as safety nets during stress-related sales to cope with increased demand for cash to purchase off-farm goods and meet basic needs as also reported by Nyaga et al. (2015) and Cheboiwo et al. (2017).

3.2. Stand Structure of Standing Tree Resources On-Farm

The overall mean stem density of trees on-farm was about 1659 ± 107 stems·ha^{-1}, while the basal area and volumes were 29.48 ± 2.94 $m^2 \cdot ha^{-1}$ and 192 ± 17.56 $m^3 \cdot ha^{-1}$ respectively. Analysis of priority plantation species showed that *C. lusitanica* trees were planted on boundaries at close spacing hence high stem density per unit area (1774 ± 151 $stems \cdot ha^{-1}$) compared to *Eucalyptus sp.* which existed mostly as woodlots with a mean density of 1676 ± 198 $stems \cdot ha^{-1}$.

The yield per unit area reported in the study was high compared to the assumed yield of 17.58 $m^3 \cdot ha^{-1}$ from other estimates (GoK, 2013). Accordingly, this demonstrates the capability of on-farm trees to supply a substantial amount of wood. The mean standing volume was 28% higher for *C. lusitanica* (220.35 ± 29.92 $m^3 \cdot ha^{-1}$) than for *Eucalyptus sp*. (158.73 ± 18.75 $m^3 \cdot ha^{-1}$). The high standing stock volume for *C. lusitanica* in the farms may be due to high density and mean DBH since the species is rarely harvested at a young age because it is mostly utilized for timber, while the low volumes of *Eucalyptus sp*. may be due to the harvesting of the species at a young age.

Most of the existing tree resources on-farm were characterized by trees of ages below 5 years (37%), while 86% were below 15 years. Triangulation of age class distribution with DBH classification exhibited similar trends, with most existing tree resources on-farm characterized by DBH below 19.9 cm (82%) with a mean DBH of 14.17 ± 1.06 cm. This suggests that big mature trees were affected by the rapid harvesting following the logging ban leaving mostly immature small-diameter trees. This result conforms with previous studies which estimated the rotation age of tree species on-farm to only 8 years, and those used for household fuelwood use are as low as 3 years (GoK, 2013). In Nakuru, most of the on-farm trees were below 5 years (42%), unlike, Uasin-Gishu, where the majority (41%) of tree resources were from 10 to14.9 years. This showed most trees in Nakuru were young and most supplies will have to be sourced from other places in the immediate future.

The age-class distribution varied across the species. The majority of the *C. lusitanica* plantation ranged from 1 to 14.9 years with mean DBH and basal area of 13.40 ± 1.15 cm and 31.05 ± 4.65 $m^2 \cdot ha^{-1}$ respectively, with the majority of the farms dominated by trees with DBH range of 10 and 19.9 (57%). The *Eucalyptus sp*. on-farm were dominated by trees below 5 years of age, with dominating DBH class below 9.9 cm (58%) and mean DBH and basal area of 12.20 ± 1.94 cm and 20.49 ± 3.75 $m^2 \cdot ha^{-1}$ respectively (**Figure 1**). The available Eucalyptus resource is much suitable for domestic fuelwood use and small diameter markets such as scaffolding poles, but may not qualify for poles and pulp which requires trees material ranging from (6 to 8) years, transmission poles (10 to 12) years, timber (15 to 20) years and plywood 20 to 25 years (Oballa et al., 2010). The age distribution of *C. lusitanica* in Nakuru showed a high frequency of the species in the lower age distribution range of between 5 and 9.9 years (39%). The trend suggests that the tree resources available on-farm presently are not ready for harvesting. Nonetheless, due to increasing demand for wood, farmers are selling immature wood, which fetches less than at maturity. *Pinus patula* tree resources

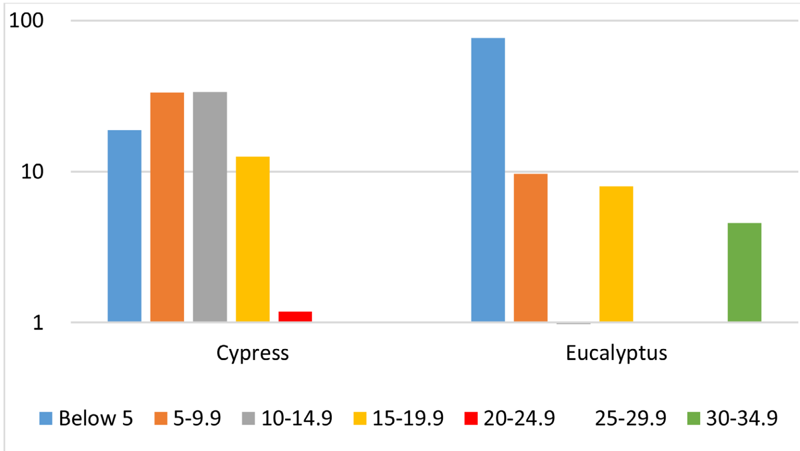


Figure 1. Age class distribution of key on-farm tree species in Nakuru and Uasin Gishu.

ranged from 5 to 14.9 years with most trees ranging between 5 to 9.9 years. This indicates that there are negligible new establishments of the species on farms and future resources from the species are uncertain. Farmers attributed the lack of new establishment of the species to the unavailability of seeds and planting materials. The unavailability of *Pinus patula* germplasm has been attributed to the prolonged extraction period of the seeds resulting in delayed availability (Onyango et al., 2020). Also, Kenya Forestry Research Institute has reported poor seeding of the species in the established seed stands and orchards.

Continuous establishment of new plantations by the small-holder farmers was observed in both study sites. The majority of new planting by households was observed in the year 2018 immediately after the ban with a mean of 604 ± 250 trees compared to 260 ± 185 trees planted in 2017. Although Eucalyptus is the most planted species on the farm, its rates of establishment have declined while that of Cypress continues to rise. This could be due to negative publicity on Eucalypts and new policies and regulations against planting in wetlands and riparian areas by most local governments.

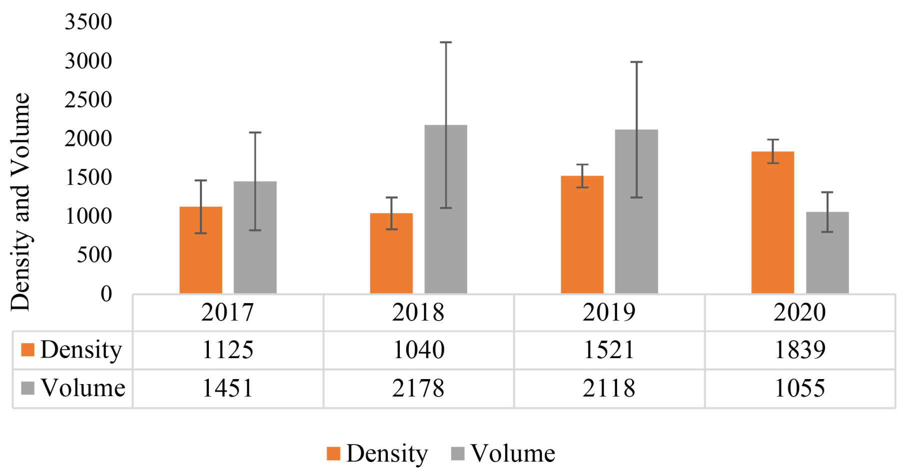
3.3. Silvicultural Management of Trees on the Farm

Generally, most farmers planted trees at a spacing of 2 m by 2 m (36%) and closely at 1 m by 1 m (24%), as opposed to the current prescript spacing regime of between 2 m by 2 m and 3m by 3m depending on the species, purpose, and end uses of materials (Oballa et al., 2010; KFS, 2009). The farmer's spacing decision is in most cases driven by the desire to maximize the number of trees, but this inadvertently, affects the growth of trees, wood quality, and tree maturity, leading to delayed and low returns. The spacing adopted was also linked to the adoption of agroforestry regimes with results showing that most of the boundary plantings were established at a spacing of 1 m by 1 m (33%) while woodlots were mostly spaced at 2 m by 2 m (42%). The varied spacing adopted could be attributed to the desired final product or service. Boundary plantings are established in close spacings because, the primary purpose is live fencing, demarcation, and windbreaks, and the timber or other products use are secondary to the farmer's decisions. Boundary plantings of *C. lusitanica* were established mostly at a spacing of 1 m by 1 m and 2 m by 2 m each with a relative frequency of 36%, while in woodlots, most of the farmers spaced at 2 m by 2 m (50%). For Eucalyptus, boundary plantings were mostly in 1 m by 1 m spacing (67%) while those in woodlots were mostly spaced at 2 m by 2 m (39%). Appropriate silvicultural management at the establishment and different growth levels are necessary to ensure the survival of planted trees, health, and optimal productivity. Poor management including pruning and thinning was observed on the farms.

3.4. Trend on Tree Harvesting from Farms

The rate of tree harvesting on-farm gradually increased since 2017 as portrayed by the density of trees harvested per year. In 2017, 2018, and 2019, the harvested densities were commensurate to the stump volumes, with densities yielding higher stump volumes per unit area. However, in 2020, extracted densities increased rapidly whereas, stump volumes declined (**Figure 2**).

This is also exhibited by the relatively small stump diameter of trees harvested with 33% of 2020 harvested material falling between 10.0 and 19.9 cm stump diameter and mostly lower than 10 years. Correspondingly, only 4% of material in this diameter size was being harvested before the ban in 2017. Mature trees harvested above 30cm stump diameter consisted of about 70% of harvested materials in 2017 but only contributed to 28% of harvested materials in the year 2020. This suggests increased harvesting of juvenile wood as a result of the exhaustion of large mature trees, as depicted by the gradual decline of trees harvested on-farm of an age class of more than 30 years (**Figure 3**). Juvenile trees were mostly harvested as "*kata saba*", meaning they could only be used to produce 7 feet of timber. This novel product from juvenile wood is mostly used to produce door frames. The harvest of juvenile wood from farms has been reported all times after a harvesting ban was imposed on Kenyan public forests



	2017	2018	2019	2020
Density	1125	1040	1521	1839
Volume	1451	2178	2118	1055

Figure 2. Densities and respective volumes of tree extractions between 2017 and 2020.

(Kagombe et al., 2005; Kagombe et al., 2020). This indicates great demand for wood products that the farm tree resources cannot sustain. Harvesting juvenile wood makes the farmer lose out as the tree is harvested when it is at its highest mean annual increment. It would be useful if trees are thinned to leave the remaining trees that would grow to maturity with reduced competition.

Trends of harvest and demand on the two most preferred plantation species (*C. lusitanica* and *Eucalyptus sp.*) show the harvest occurred in all age classes during the year 2020 (**Figure 3**). This implies indiscriminate harvesting of trees from farmlands due to scarcity of the preferred wood. Analysis of this trend best describes the developments in timber production from the key actors. Scarcity of the preferred timber from *C. lusitanica* had led to market demands for immature cypress wood harvesting from trees below 14 years in 2019 and 2020 previously not harvested and also shifted to selective harvesting of less preferred *Eucalyptus sp.* for timber production (**Figure 3**). According to the forests normalization principle where allowable offtake is equivalent to the age of the oldest trees in the plantations, farmland tree resources are being harvested at a very young age. Ideally, the recommended rotation age of public plantations is 28 years with the

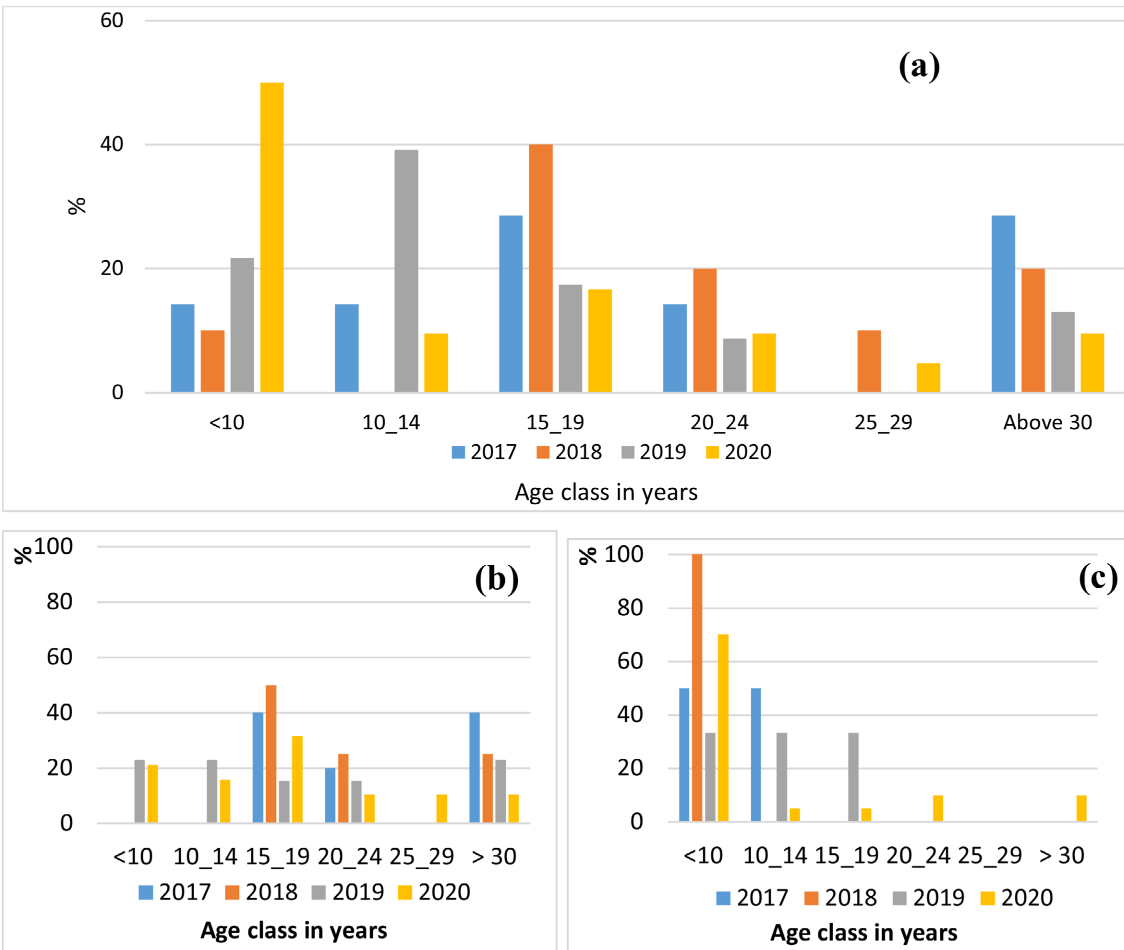


Figure 3. (a) Overall age class of harvested trees per year; (b) *C. lusitanica* harvest age class distribution per year; (c) *Eucalyptus sp.* harvest age class distribution per year.

potential yields of 407.5 $m^3 \cdot ha^{-1}$ (GoK, 2013). The ongoing rampant harvesting of immature trees on-farm compromises the wood quality and will likely affect the sustainable wood supply. This is especially so due to low timber recovery rates resulting from inadequate and inappropriate harvesting and processing equipment (Chain saws and circular saws) thus, high waste for small diameter logs. Farmers end up losing because they do not achieve the optimum potential for their trees. On the other hand, the farmer is motivated by the short-term gain from harvested trees.

4. Conclusion and Recommendations

4.1. Conclusion

The feasibility of trees on-farm to complement wood from public plantations will depend on concerted efforts by key players in the forestry sector namely farmers, government agencies, and the private sector. Most farmers were willing to invest in tree growing as part of their on-farm income diversification and risk management. The preferred commercial trees grown on farms were mostly *Cupressus lusitanica*, *Eucalyptus sp*, *Pinus patula*, *Gravellia robusta*, and *Acacia mearnsii*. *Eucalyptus sp*ecies is the most preferred because of the short rotation period, suitability in most ecological zones, versatility in utilization, and readily available market. *Pinus patula* is the least grown but has a good prospect for timber production. The study demonstrated the capability of on-farm trees to supply a substantial amount of industrial wood with a standing volume of 192 $m^3 \cdot ha^{-1}$ contrary to previous estimates. However, the sector is faced with many challenges that include poor silvicultural practices such as spacing, pruning, thinning, and general stand management. This is attributed mostly to inadequate training and a lack of information on best tree management practices. Intensive and continuous on-farm tree harvesting during the logging ban has resulted in the depletion of mature trees, leaving mostly small diameter immature trees. The scarcity of wood has forced farmers to sell the available immature trees as short-dimension and poor-quality timber, fuelwood, and scaffolding poles that attract low values. Generally, the existing tree resources on the farm cannot sustain rapid harvesting hence the massive wood materials harvested during the moratorium have put a lot of pressure on trees on farms. Early harvesting results in an overall loss in growth where the farmer does not realize real value for the crop. The positive aspects include enhanced tree growing by farmers, attested by accelerated planting observed during the logging moratorium period, however, farmers lack capacity in tree spacing, management, and valuation of their crop leading to overall losses.

4.2. Recommendation

To enhance the capacity and potential of trees growing on-farm, various actions need to be considered. First, to ensure improved access to information, there is a need for coordinated extension services by the state and other actors in the forestry sector. This can be through multi-stakeholder support to County governments which are mandated to provide extension services. The counties can focus and prioritize targeted specialized services to areas that have the potential for industrial wood production. Tree growers are also encouraged to work closely with extension agents in the forestry and agricultural sector to enhance their knowledge on tree production. Additionally, there is a need to promote the registration and certification of tree nurseries in devolved units of administration, support the production of quality seedlings, and act as dissemination points of technical information on tree establishment and management. Moreover, information on site-species matching and silvicultural management for various species should be readily available.

Thirdly, the variation in ages and diversity of tree resources on the farm provides an opportunity for innovations in processing technology. The small diameter logs from farms need appropriate wood processing technology to convert young wood to high-value products without compromising on quality and recovery. This could be realized by promoting various processing models where medium/small enterprises get involved in primary processing at the farm level, targeting alternative reconstituted wood products like medium-density fibreboards (MDF) through wood chipping on sites. The small diameter poles provide an immense opportunity to the farmers to enter the huge post and fencing poles market through appropriate adoption of wood treatment techniques. This is possible when farmers pool together to form tree growers cooperatives that can share equipment in processing, value addition, and marketing.

In addition, there is a need for diversification and the introduction of fast-growing high-value tree species to promote the uptake of tree growing as an enterprise. Accordingly, information on the viability of various forest enterprises should be produced and disseminated, currently, only information on financial returns for a few commercial species is available. For species that have long rotation ages, some form of contract farming or intermediate financial advance with regular payments during the gestation period of the investment can be explored to keep trees to the optimum rotation period. This is currently practiced by the DL Koisagat Tea Company and Better Globe Forestry where farmers are paid periodically. Other Financing options include; green financing where government and international organizations provide credit facilities to support farmers who cannot afford inputs and management operations.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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