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Corrective Interventions to End-Splitting and Surface Cracking in Kenya Grown *Eucalyptus grandis* Poles

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Abstract

This study determined the effect of three pole pre-drying handling techniques, on end-splitting and surface checking in *Eucalyptus grandis* poles from high-land and low land areas in Kenya. A total of 144 *Eucalyptus grandis* trees were sampled from two sites; Kericho, representing the wet highlands and Londiani representing the drier lowlands regions of Kenya. Pole samples from both sites were subjected to the three pre-drying handling techniques for the first 30 days after felling and allowed to dry to the required moisture level under observations. The number of end splits and surface checks on each sample pole were counted and the length of the worst ones was measured in millimeters after every 15 days until all the poles reached 25% MC. The sap wood and heart wood ratios were determined from selected samples. Results showed that on the overall, poles from high land areas had the highest sap-wood proportions and similarly had the highest number and the longest end splitting and surface checks. On the other hand, pre-drying techniques that allowed felled trees to dry slowly with their foliage intact for the first 30 days of felling produced the best quality poles, with fewer and shallower end splits and surface checks. The study recommended that felling and leaving poles to dry slowly with foliage intact be considered in reducing losses incurred as a result of wood stresses during drying of poles.

Keywords

Eucalyptus grandis, Wood Cracking, Wood Stresses, Wood Drying

1. Introduction

1.1. Background

Eucalyptus species, mainly native to Australia, are widely grown for various uses in many countries world over. These species were introduced to the East African region during the colonial rule and to date they form a significant proportion of the tree species grown in the region. About 100 Eucalyptus species were introduced and tried in Kenya as early as 1900 with the aim of supplying wood fuel for the Kenya-Uganda railway (Oballa, 2009). Of these, four species; *Eucalyptus grandis*, *E. saligna, E. globulus* and *E. regnans* were found to be fast growing, while fourteen (14) others were rated moderate in growth rate, when grown in different ecological regions in the country (Oballa, 2009; KFS, 2009). After introduction and successful establishment of the Eucalyptus species in Kenya, there has been concerted effort to grow them, not only in state forest plantations but also on large-scale farms. The species has also been grown in small-scale farms in a variety of planting architecture. In an effort to increase forest productivity to meet an increasing demand for wood products, research and development initiatives have introduced Eucalyptus hybrids in the recent years. The most popular hybrids and which have shown potential in different climatic zones are those of *E. grandis* and *E. camadulensis*, which are generally referred to as GCs (Oballa, 2009).

The uses of Eucalyptus wood include sawn timber, power and telecommunication transmission poles, pulp, building poles, fencing posts and wind breaks (Zziwa et al., 2017; Oballa, 2009). The species *E. grandis, E. saligna* and *E. camadulensis* are the most commonly used species for power transmission poles. *Eucalyptus saligna* is also prefered for sawn timber, especially for flooring, due to its brown coloured heart wood (Oballa & Langat, 2002; Maua, 1997). The demand for power transmission poles in the East African region has been growing, with a corresponding response by farmers and investors in growing the species. This has positively contributed to increased tree growing (Zziwa et al., 2017). In Kenya, this has been a welcome move towards achieving the Constitutional requirements of at least 10% tree cover by 2030.

In the recent years, Eucalyptus has become the tree of choice for many Kenyan commercial tree farmers due to its fast growth rate, multi-use nature and ready market for its products, with established value chains for majority of the products. With the high demand for sawn timber being experienced in the construction sector, Eucalyptus has found market as sawn timber particularly in regions where first line timber species; cypress and pines are not easily available. Similarly, rising demand for power transmission poles, as a result of the government's sustained effort to connect more citizens with electricity has been pushing high the utility potential for the species. Eucalyptus has also recently become an alternative material for reconstituted wood products, particularly during the periods when Kenya experienced moratoriums restricting harvesting of wood from state managed forest plantations. It has also been tried for peeler logs. Young Eucalyptus trees have constantly supplied the building and construction industry with scaffolding poles.

The utility of wood is influenced by the inherent anatomical, physical and mechanical properties among other factors (Forest Products Laboratory, 1987). Unlike steel and other materials, whose structure and strength can be manipulated to homogeneous state (Saleem et al., 2020), wood in general, in addition to being porous is non homogeneous, hygroscopic and anisotropic. When a living tree is felled, the wood begins to release moisture to the atmosphere. The rate of moisture loss from the wood cells influences the quality of wood in all the species but is more pronounced in some than others, depending on the anatomical properties (Desch & Dinwoodie, 1981). Drying of wood can therefore cause losses, if the process is not done in consideration of the wood species and the corresponding properties (Panshin & Carl de Zeeuw, 1980). Defects such as end splits, cell collapsing, warping and surface cracks or checks among others can develop in drying wood, rendering it less useful for many purposes. These phenomena are influenced by the rate of moisture loss in the wood, in form of both free and bound water.

Further, growth related stresses develop in trees as a result of normal wood tissue development during growth. These stresses arise due to polymerization of lignin within the secondary cell walls (Malan, 1988; Forest Products Laboratory, 1987). The stresses cause lateral expansion of the cross section of the fibres and a corresponding reduction in length during maturation of the cells, according to the Poisson's ratio (Panshin & de Zeeuw, 1980). While these stresses are minimal in some species like soft woods, they can be large, particularly in some hard woods, becoming the primary cause of a variety of seasoning defects. In standing trees, these stresses may not have significant effects, probably due to the moisture equilibrium in the living wood cells. However, once the tree is cut, cracks begin to develop at the log ends, especially in trees with moderate to severe growth stresses (Panshin & de Zeeuw, 1980). Eucalyptuses are some of the most challenging species due to these stresses (Malan, 1988).

Eucalyptus wood is highly prone to seasoning defects caused by deformation of the wood cells due to loss of moisture at different rates (Forest Products Laboratory, 2010). Due to high initial moisture content and inherent growth stresses, Eucalyptus wood tend to release moisture faster than most other species. In addition to wood-water relationships, other factors, such as the density and log diameter, sap wood and heart wood contents have been shown to influence wood drying behavior and development of seasoning defects, particularly in Eucalyptus species. Studies have provided technical insights on the drying behavior of Eucalyptus wood, such as the effects of drying logs with or without the bark on, effect of log diameter (Forrester et al., 2013), and the correlation between the drying and anatomical characteristics of wood including sap wood and heart wood ratios (Travan et al., 2010), among others.

Site conditions like rainfall and temperature as well as silvicultural treatment also have been reported as having great impacts on growth stress development in trees. According to Malan (1995), a good quality site has twice as much effect on splitting of wood as compared to a poor-quality site. This is because trees grow much faster without compaction of cells, developing fuzzy or weak grains that split easily when exposed to any external forces. A good site also influences moisture content in the wood cells. Shrinkage is also greatly affected by temperature during drying. High temperatures result into rapid drying, increasing the rate of wood cell shrinkage. Rapid shrinkage results into stress formations that are released through wood check and split formations (Kettula, 2015). Low humidity and exposure to direct sunlight favor the development of surface checks and end-splits, which can be experienced in uncontrolled air drying conditions (Forest Products Laboratory, 2010; Shore, Clubs, & Meeting, 1960).

Eucalyptus wood is considered complex and is known to develop serious end splits soon after felling, probably due to accumulated growth stresses. Minimizing these and other seasoning defects is a major challenge to wood material scientists world over. Several studies have looked at a variety of factors that influence these behaviors and ways of minimizing their effects. Studies in the early years (Panshin & de Zeeuw, 1980) suggested that steel strapping at each end of the log effectively minimizes end splitting. Keeping logs under water spray for several months was also reported as being able to reduce splitting during timber sawing. While Malan (1988) suggested that environmental factors, which affect tree crown and wood development and by extension wood quality, do not significantly affect growth stress generated in the tree, Forrester et al. (2013) observed that growth strain was lower in trees subjected to common silvicultural treatment than in untreated trees. These studies tended to contradict each other in regard to the effect of silvicultural treatment as an effective tool for reducing growth stresses. This could be explained by looking at other factors involved in tree growth, particularly related to the environmental conditions.

1.2. Problem Statement

Splitting and cracking of wooden power transmission poles have been reported in Kenya and other countries, leading to financial losses and risks if it happens while the pole is in service (Muthike & Ali, 2021; Mugabi & Thembo, 2018). Splitting and surface checking lower the suitability of the poles, particularly due to reduced strength. Some poles develop end splits and surface cracks after felling, during drying and at times after preservative treatment (Forest Products Laboratory, 2010). Cracks could also become openings for pathogens to access untreated inner heart wood while the pole is in service, exposing it to earlier damage than anticipated.

In Kenya, the Standard Specification for Power Transmission Poles ((Kenya Bureau of Standards, 2008) KS 516: 2008), requires that poles should be graded to minimize among other defects, excessive end-splitting and surface cracking before use. In the recent years, pole treatment firms have reported excessive end-splitting and surface cracking of poles, during harvesting, handling, seasoning and even after preservative treatment, affecting particularly poles from the highland areas. This study determined the effect of pole pre-treatment handling, on end-zsplitting and surface cracking in *Eucalyptus grandis* poles from wetter highlands and drier low land areas of Kenya. The study was aimed at identifying the climatic condition that produce more stable poles under the current industrial practices. It also targeted to propose some post felling procedures to minimize end-splitting and surface cracking in *Eucalyptus grandis* wood to improve pole quality.

2. Materials and Methods

2.1. Study Sites

The Mau Complex in Kenya is the largest closed-canopy montane ecosystem in Eastern Africa, spanning over at least three climatic zones. It generally falls in climatic zones I and II, on the high altitude regions, with a mean annual rainfall of about 1300 mm. The lower attitude areas fall in zone III, with rainfall ranging between 600 to 800 mm in a normal year. Mean monthly rainfall ranging from as low as 30 mm in lower areas to as high as over 120 mm in higher altitude areas are common. The complex is classified as trimodal, with the long rainy season predominant between the months of May and June and the short rainy season between September and November and sometimes extending to December. With the high altitude areas receiving high rainfall and moderate temperatures, tree growth rates are higher compared to lower altitude areas. Mau region is one of the major sources of wooden poles, mainly from Eucalyptus, traded for power transmission (Muthike & Ali, 2021). Majority of poles are sourced from large scale tea estates and small-scale private wood lots around Kericho, Bomet and parts of Koibatek counties. Due to the wide climatic zone where Eucalyptus species are grown, poles are also sourced from drier areas like Londiani.

2.2. Sampling Sites and Procedure

Two sites were selected from Mau regions; Kericho, representing the wet highlands and Londiani, representing the drier lowlands. Due to the site differences in terms of rainfall, Eucalyptus trees grow at different rates. In the highland areas, 10-meter poles attain the required diameter for poles ((Kenya Bureau of Standards, 2008) KS 516: 2008), at between 8 and 10 years while in the drier lowland areas, the same species attain similar dimensions at between 13 and 15 years. The two chosen sites therefore represented the common climatic conditions in most of the regions from where poles are sourced. From each site, poles were sampled following guide lines provided by the Kenya Standards Specification ((Kenya Bureau of Standards, 2008) KS 516: 2008) for power transmission poles. The plantations from which sample trees were obtained in both sites belonged to the same company and therefore had been subjected to the similar silvicultural treatment.

From the highland site, 72 *Eucalyptus grandis* trees were sampled at the age of 9 years, with a similar number sampled from a plantation in Londiani site at the age of 14 years, giving a total of 144 poles. To minimize presence of reaction wood and obtain poles with pith well centered, sample trees were selected from relatively flat areas within the plantations. Also, to avoid the plantation edge effects, sample trees were selected from at least two lines away from the plantation edges.

2.3. Pre-Seasoning Treatments and Data Collection

The selected 72 trees from each site were sub-divided into three (3) sets of 24 poles each. Each set of poles was subjected to one of the following post-felling treatments A, B and C as shown in Table 1 and described below. After the treatment, all poles were finally assembled in a common yard in Njoro for final drying to at least 25% moisture content (MC).

- **Treatment A:** Trees were felled and left with branches and tops (full foliage) as well as bark intact for 30 days. After the 30 days, branches and tops were removed and poles transported for further seasoning at Njoro. The bark was removed after attaining 25% moisture content.
- **Treatment B:** Trees were felled, branches removed but left with tops and the bark intact for 30 days. After 30 days, the tops were cut and bark removed then poles transport for further seasoning at Njoro.
- **Treatment C:** Trees were felled and branches and tops removed. The trees were cut to pole size, debarked and transport to Njoro for seasoning.

Njoro was chosen for the final pole drying place because it is fairly dry and hot, providing representative conditions of most of the areas were pole treatment plants are situated.

Observations were made on each set of poles and moisture content measured after every 15 days from the felling time until the poles attained moisture content (MC) ≥ 25%. No plates were fixed on the pole ends. At the end of the drying time, each pole was subjected to pole grading based on the specifications provided by the Kenyan standard ((Kenya Bureau of Standards, 2008) KS 516: 2008), focusing on end splitting and surface checks. The number of end splits on each pole end pole was recorded and the length of the longest one measured in millimeters. Surface checks were also numbered and the deepest (>25 mm deep) identified and length measured and recorded.

Table 1. Pole selection, felling and handling treatments.

Site	Pole Set	No. of poles	Treatment
Kericho	KA	24	A
	KB	24	B
	KC	24	C
Londiani	LA	24	A
	LB	24	B
	LC	24	C
Total		**144**	

From each site, five (5) poles were sampled and crosscut at one meter from the bottom, at the middle and one meter from the top. The cut sections were used to measure the total pole under bark diameter at each section. By colour observation, the sapwood and heartwood portions were demarcated and the diameter of the heartwood measured at each cut section. The data obtained was used to compute the heartwood and sapwood proportions in each pole. Data was analyzed for parameter mean values. Significance of differences was tested using t-tests for each corresponding pre-seasoning treatments applied. Other tests done included laboratory based moisture content analysis as well as wood density of the sample poles. These tests aimed at confirming whether there were any significant differences in initial moisture content and wood density of poles from the two areas during felling.

3. Results and Discussions

3.1. Sapwood and Heartwood Proportions

Results of Sapwood/Heartwood proportions for samples of *Eucalyptus grandis* that were collected from Kericho at 9 years and Londiani at 14 years are shown in **Table 2**.

Results indicate that 9 year old *Eucalyptus grandis* poles from high altitude area, contained higher proportions of sapwood than heartwood (67% and 33%) with a standard deviation of 2.73 against similar size poles harvested at 14 year from the lower altitude areas, which had a sapwood to heartwood ratio of 48 and 52% with a lower standard deviation of 1.02 (**Table 2**). These values were significant at 95% confidence level ($p = 0.004$). In terms of distribution of sapwood and heartwood along the tree height, sapwood increased from the bottom of the tree to the top while heartwood decreases in the same direction in both sites. However, in poles from lower altitude area, sapwood was less at all heights than in poles from the higher altitude areas. Similarly, poles from the high altitude areas had significantly higher mean initial moisture content (147.8%) than that of poles from lower altitude areas (114.3%) ($p = 0.000$). The standard deviations were equally higher in poles from high altitude areas (13.6) than lower altitude areas (9.3).

The differences in heartwood and sapwood proportions were highly associated

Table 2. Heart/Sapwood ratio.

Site	Parameter	Proportion (%)				
		But log	Mid log	Top log	Mean	Initial MC (%)
Kericho (Highland)	Heartwood	40	33	27	33.33	
	Sapwood	60	67	73	66.67 (2.73)	147.8 (13.6)
Londiani (Lowland)	Heartwood	58	52	47	52.33	
	Sapwood	42	48	53	47.67 (1.02)	114.3 (9.3)

*SD is the standard deviation computed for each region.

with the differences in tree growth rates in the two sites. Due to a fast growth rate, attributed to wet conditions in much of the year in high altitude areas, Eucalyptus trees accumulate sapwood cells at a faster rate than the heartwood cells. Sapwood, by nature contains higher moisture in the wood than in poles with higher percentage of heartwood. In these poles, the heartwood cells are also partially alive (still forming) and therefore contain moisture as free water in their cell lumen. When cut, wood lose free water fast, prompting rapid collapse of the cell walls and therefore separation (cracking and splitting).

In the drier lowland site, low rainfall is responsible for the slow growth rate even when trees were exposed to silvicultural treatment similar to those from highlands. The slow growth rate is responsible for the longer time (14 years) it takes for trees to acquire the optimum size for power transmission poles against trees from wetter highland areas taking 9 years. Trees accumulate sapwood cells during the wet period of the year. During dry period, few or no new cells are formed and instead, the sapwood cells are converted into heartwood cells with extractives being deposited. Morais & Pereira (2007) reported lower heart wood ratio in *Eucalyptus grandis* grown in areas with high rainfall than those from areas with low rainfall.

3.2. Pole End-Splitting and Surface Checks

End-split and surface check count and length in the samples of *Eucalyptus grandis* from the two sites are presented in **Table 3**. Results showed that pole end-splitting and surface cracking was influenced by both region and type of treatment given to the poles prior to drying. Poles from high lands higher mean number of end splits (3.4 (1.2)) and surface checks (2.8 (0.7)) than poles from low lands, whose mean number of end splits and surface checks were 2.4 (0.7) and 2.5 (0.3) respectively.

The mean length of the worst end splits and surface checks followed a similar phenomenon with values of 284 (83.3) and 309 (50.1) respectively, for poles

Table 3. Summarized analysis of end splits and surface checks in *Eucalyptus grandis* poles under different pre-drying treatments.

Site	Treatment	Mean Number of End Splits	Mean Length of Worst End Split (mm)	Mean Number of Surface Checks	Mean Length of Worst Surface Checks (>12.5) (mm)	Rejected Poles (%)
High lands	A	2.8 (1.8)	261.6 (80.2)	2.3 (0.7)	238.4 (42.9)	21
	B	3.4 (1.1)	248.9 (81.6)	2.7 (0.7)	309.1 (65.2)	29
	C	3.9 (0.87)	342.3 (88.2)	3.4 (0.8)	380.6 (78.4)	42
	Mean	**3.4 (1.2)**	**284.27 (83.3)**	**2.8 (0.7)**	**309.4 (50.1)**	**31**
Low lands	A	1.8 (0.4)	183.8 (31.5)	1.9 (0.2)	149.9 (26.9)	8
	B	2.4 (0.9)	228.5 (20.9)	2.1 (0.2)	235.7 (36.7)	13
	C	2.9 (0.9)	247.3 (16.2)	3.4 (0.4)	241.3 (41.3)	21
	Mean	**2.4 (0.7)**	**219.9 (22.9)**	**2.5 (0.3)**	**209.0 (35.0)**	**14**

from high lands, against 219 (22.9) and 209.0 (35.0) respectively for poles from low lands. The differences in both cases were significant at 95% confidence level ($p = 0.006$). Similarly, the higher standard deviations (SD) for both number and length of end splits and surface cracks in poles from high lands was an indication of higher influence of region on the quality of poles. In both sites, felling trees and leaving them with folliage intact for 30 days (Treatment A) produced poles with fewer and shorter end-splits and surface cracks than the other two treatments (**Table 3**). The quality of poles subjected to treatment B was better than that of poles subjected to treatment C, which incidentally is the common practice in the pole treatment industry in Kenya. However, poles from highlands recorded consistently higher defects than those from lowlands for all the three treatments.

The differences in quality of dried poles could be partly attributed to differences in tree rate of growth between the wetter high lands and the drier low lands. In a study, Turinawe et al. (2014) reported higher splitting in fast growing than in slow growing Eucalyptus trees. The rate of growth of Eucalyptus trees used in the current study was higher in trees from high lands, attaining the required top diameter for 10 m poles at 8 - 10 years while those from low lands attained the same dimensions at 13 - 15 years. The results also agree with another study by Nankya (2019) involving Eucalyptus grandis and hybrid clones in Uganda. In that study, high end splitting and surface checking was associated with younger trees and by extension high propotions of sapwood than in older trees. Nankya argued that trees with high sapwood proportion had higher moisture to drive out during drying whereas those with a low sapwood proportion had less moisture making them less prone to deep surface checks and end splits.

The overall percentage of pole rejection was higher in poles from high lands (mean = 31%), than in those from low lands (mean = 14%). In both sites, the percentage of rejected poles increased in pre-seasoning treatments that reduced the amount of foliage from the tree within the first 30 days after felling and in poles that were moved from the area of growth immediately after felling.

Studies have reported that end-splitting and surface checking in Eucalyptus is mainly caused by drying stresses that develop due to loss of moisture during drying (Anthony & Destefano, 2018). These stresses develop due to a variety of factors; differential shrinkage in the radial and tangential planes, faster drying of the outer wood surface while the inner part is still green, faster drying of the stem ends while the mid wood is still green. According to Travan, Allegretti, & Negri (2010), it is these growth stresses which induce gradient stresses causing extensive splitting in younger poles. With more foliage on the felled tree, the wood loose the initial moisture much slowly, resulting in less end splitting and surface checking hence increase the quality of poles.

Wood cracking was observed to begin when the trees were cut down. This is associated with the sapwood cells releasing free water and collapsing hence separating. Eucalyptus species are known for absorbing more water from the soil and converting the same to biomass than many other species (Senelwa et al., 2009). This explains the faster growth rate in trees growing in wetter areas like the highlands, than those in drier lowland areas. Fast growth is usually accompanied by in-built stresses within the wood cells. Similarly, faster growths attains larger tree diameter with large sapwood and small and immature heartwood portions. Sapwood cells contain more spaces in their lumen, hence hold more free water than the heartwood cells, which are in most cases either collapsed or filled with extractives. This explains why poles from wetter highland areas developed more and longer end-splits and surface checks than those from drier lowland areas. This phenomenon was consistently demonstrated by the current results, though at varying magnitudes as influenced by different pre-drying treatments. Due to slow growth and conversion of sapwood cells to heart wood cells over more years in trees from drier lowland areas, the wood cells become more stable and less prone to separation when the tree is cut. This is responsible for the reduced end splitting and surface checking of the poles from this site.

During the seasoning process, the rate of moisture lose decreases slowly and maintains the wood cells in stable condition, if the wood is retained in the area of harvest until most of the free water is released and wood cells dry to Fiber Saturation Point (FSP). This reduces splitting and cracking of the wood. Moisture loss continues until the wood dries to a point of balance between the atmospheric moisture and that of the wood cell walls, referred to as the Equilibrium Moisture Content (EMC). In drier areas, this point shifts downwards. As wood dries to this point, it is likely that further cracking can occur particularly if the wood is exposed to direct sunlight. Moving poles from the point of harvest immediately after felling to a hotter/drier area is likely to increase the rate of moisture loss. Worse still, defects could be expected if the poles are debarked immediately as the bark covers the wood cells beneath it.

4. Conclusion and Recommendations

Some of the key conclusions drawn from this study are that, end-splitting and surface cracking is higher in wood from younger trees from highland areas than older ones from the lowlands. Eucalyptus trees from drier lowland areas take longer to attain the required pole dimensions for power transmission. The slow growth rate however helps the trees to increase heartwood cells, reduce free water in the wood cells and hence minimize seasoning defects after felling. Further still, felling and removing all the foliage from trees increase the rate of moisture loss in wood from both lowland and highland areas, although at different scales.

The study recommends that, Eucalyptus wood requires a number of pre-drying treatments, which singly and/or in combination, can minimize seasoning defects, particularly end-splitting and surface checks. In both highland and lowland areas, felling and leaving trees with foliage intact was demonstrated to be helpful in reducing end cracks and surface checks. Leaving felled trees at harvesting site with the folliage intact for at least 30 days was the best treatment in this study. The choice of any one or a combination of these treatments is however influenced by other factors like the availability of space on which the trees can be secure after felling. Some of the other possible treatments include:

- Poles can be felled and just remove the top but leave them with the bark on for at least 30 days before cutting them to size and debarking. This helps to reduce moisture loss through the stem due to the presence of the bark cover. Again, being in the same area, wood cells would not experience excessive stress and therefore cracking and splitting would be minimized as the poles dry.
- Poles can be allowed to completely dry to the required moisture content with the bark on and at the area of felling. This helps to bring the wood cells to the required moisture level with minimal cell stress. This however takes a longer time for the wood to lose moisture, hence may interfere with the supply time lines if this is not adjusted accordingly to allow for such intervention.
- When the poles are transported to the point of seasoning and further processing, a shaded storage facility could cushion them from adverse direct sun rays as they continue to dry.

More importantly, the quality of poles can be enhanced by proper planning and harmonizing of power distribution projects with wooden pole procurement procedures. Pole consumers can plan their procurement to allow suppliers adequate time to dry poles to acceptable moisture levels before preservative treatment. Quick to supply projects can only be expected to deliver quality poles if the suppliers are able to keep ready stocks of treated poles or seasoned poles ready to treat and supply. This, in most cases, is not very practical due to shortage of poles and the elaborate processes that poles must be put through for stable drying and preservative treatment before the poles become a product for quality power line construction.

Authors' Contributions

The following authors contributed to this study: conceptualization, G.M.; methodology, G.M, N.O and G.A; data analysis, all authors; original draft preparation, G.M; writing review and editing, G.M, N.O, G.A, J.G and P.M; all authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

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

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