Potential Growth, Yields and Socioeconomic Benefits of Four Indigenous Species for Restoration in Moist Forests, Mau Kenya

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Abstract
Natural forests in Kenyan are important national assets that play critical roles in the economy while offering a range of ecological services. The natural forests ecosystems have experienced massive degradation over the last three decades. The early assault on natural forests involved clearing thousands of hectares to create farms and room for establishment of exotic plantation species known for their superior growth performance and economic returns since 1920s. The recent prominence placed environmental conservation and provisioning of environmental service such as water and biodiversity has enhanced investment in rehabilitation of degraded natural forests since 1990s. The development of multiple uses of natural forests for production of timber and environmental services is one strategy that is being discussed by policy makers and forest users. However, the strategy is hindered by limited information on potential yields and economic gains from use of indigenous species in forest restoration activities. The study was aimed at bridging the knowledge gap by assessing the growth, yield potentials and financial returns of four indigenous species namely *P. africana*, *X.gilletti*, *J. procera*, and *P. fulva* was initiated in 2006. The study is important because of the increasing focus on biodiversity and forest conservation and their contribution to socioeconomic development in developing countries. The study involved collection of growth data from old plantation stands in Kakamega, Nandi and Mt Elgon and derivation of individual tree volumes and yields using volume equation tables developed by Wachiori eta al (1996). The generated costs of establishing and maintaining plantations and prevailing stumpage prices were used in the financial cost-benefit analysis for study species. The study revealed a strong correlation between growth in yield per tree and age as the coefficient of determination of all the species was over 50%. The mean annual increment in volume were 10.09 m^3/ha for *P. africana*, 9.57 m^3/ha for *X. gilleti* 7.46 m^3/*ha P. fulva*, and 3.73 m^3/ha for *J. procera* that is relatively low as compared competing exotic species that ranged between 15 to 60 m^3/ha/yr. The optimal financial rotation for *X. gilleti*, *P. fulva* and *J. procera* was 38 years while that for *P.africana* was 48 years. The study revealed that at an interest rate of ten percent the four species was found to be financially viable for use in forest restoration activities. However, the yields and returns are low as compared to competing exotic species. It is recommended that more experimental plots need to be established for collection of accurate data for better growth and yield assessments.
Keywords: Indigenous species, growth, yield modeling, financial returns

1.0 Introduction

Forests in Kenya are important resources that play a pivotal role in the local and national economies. It is estimated that over 70% of the rural population relies on forests for provision of a wide range of goods and services and the sector contributes 19% of the Gross Domestic Product (Senelwa, 2005; Gachanja, 2003). Forests also supply over 70% and 90% of the total national and domestic energy requirements respectively (Mbugua, 2005; Senelwa, 2005). Several industries including pulp and paper, building and construction, and tea that employ a large workforce are dependent on forest and tree resources for raw materials and other inputs (KFMP, 1994). Forests also form the backbone of sawmilling, which together with dependent downstream small and medium enterprises such as furniture-making and wood carving are estimated to employ over 150,000 people (Kagombe et al., 2006). Further, forests provide non-wood products used in pharmaceutical, tannery and related industries that as well earns the country over US$ 40 million annually (KAFU, 2000; Oduor et al., 2002). Apart from these consumptive benefits, forests also provide a range of ecological services including stream-flow regulation, biodiversity conservation and climate regulation among others.

However, natural forests are threatened by several human related activities mostly excisions and degazettement for agriculture and other land uses that claim 5,000 ha of forest land every year (KFMP, 1994; Wanjiku et al., 2005; Ogweno and Ototo, 2005). High demand for charcoal in urban areas is a key driver of deforestation that lead to clearing of 50,000 ha of forests annually (Hankins, 2002). Other management malpractices such as poor management, unsound practices and over-harvesting by licensees have left about 20,000 ha of plantations in establishment backlog (Ogweno et al., 2005; Kagombe et al., 2005). Forest fires destroy on average 3,000 ha of forests every year (Kagombe et al., 2005). Though logging of indigenous forests was banned in 1986 (Ogweno and Ngutai, 1996), illegal harvesting of high value indigenous species such as camphor, Meru oak, Cedar and Sandal wood is still rampant in most forests. These factor contributed to the loss of 186,000 hectares between 1990 and 2005 (Kagombe et al., 2005). Though the current annual deforestation rate, estimated at 0.34%, is lower than the average for Africa (0.78%), it is significantly higher than the world average of 0.24 % (Ogweno and Ototo, 2005).

The continued loss forest cover across all forest types in the country is projected to widen the annual wood deficit to over one million m^3 2015 (KFMP, 1994; Odwori and Ogweno, 2001). These developments poses serious threats to the survival of wood industries, employment opportunities and livelihoods of thousands forest-dependent communities and conservation efforts. The high demand for timber for various purposes has necessitated development of complimentary sources of roundwood for industry including regeneration and exploitation of high value indigenous species.

To meet the new challenges stakeholders in forestry sector has pursuit two pronged developments that include the expansion of commercial plantations and farm forests. The new frontier to expand forests includes reforestation and restoring the natural forests targeting the degraded forests (Newmark, 1998). The restored natural forests are expected to yield multiple benefits including flow of forest products and services to local communities, urban households and forestry based industries and downstream enterprises dependent on forest materials. Past afforestation and reforestation schemes targeted mainly use of exotic species in plantations but indigenous species have lately been emphasized due to growing environmental concerns and awareness in the country. However, growth and yield potential and economic gains that can accrue from cultivation of these species are not well developed to inform decision makes and investors in the forest sector. The information is critical in planning natural forest restoration and community forestry initiatives that is expected to contribute to socioeconomic development while restoring the forest to its ecological functioning. Therefore the study was aimed at bridging this knowledge gap by assessing the growth and yield potential of four indigenous species namely *Prunus africana*, *Xanthoxylum gilletti*, *Juniperus procera*, and *Polycsias fulva*; and to undertake a financial analysis to inform growing of these species in plantations and farm woodlots.

The species were purposely selected for several reasons specific to each of them. *Prunus africanum* is well known for its medicinal value mostly use of its bark extracts in the treatment of Benign Prostatic Hyperlasia (BPH), which is a disease afflicting older males worldwide (O'Brien et al., 2000; Cunnighum et al., 2002). It timber is highly valued in local markets due to durability and toughness under harsh conditions including wet environments. *Juniperus procera* is on high demand because it produces fine-textured, straight-grained wood of medium hardness with the heartwood highly resistant to termites and rot (Wanyondu et al., 2005). *Xanthoxylum gillettii* timber is widely used in furniture making. The use of its bark in treatment of various ailments has further made it a popular species among many farmers and forestry specialists. *Polyscias fulva* is desired because, aside from the desirability of its timber, it is thought to be fast growing and hence a potential substitute for exotic species under plantation landscapes.

1.1 Problem statement

Deforestation and degradation of forests leads to loss floral species diversity and only a few of the species lost can recover unaided (Lamb, 1998), hence the need to aid recovery of degraded forest lands. The past attempts to reforest and restore degraded forests relied exotic tree species that met only the timber needs but did not restore the species diversity of degraded lands and the fact that most of them were not compatible with biodiversity conservation objectives (Noss and Cooperrider, 1994; Lamb, 1998; Heilman et al., 2003). Because of this, many stakeholders view afforestation, reforestation and enrichment planting with indigenous species as the surest options for restoring biodiversity and ecological functioning of degraded lands while offering a range of economic benefits (Pimmentel et al., 2000; Ricketts et al., 1999; Lamb, 1998).

Though conceptually the indigenous species may restore the original diversity of the forest, the performance of such species has not been evaluated technically in terms of wood volume production and financial returns. This is because such studies have largely focused on exotic plantation species grown for sawn wood and pulp. However, successful use of any tree species in afforestation and reforestation scheme largely depends on its ability to yield revenues for the government and farmers as economic consideration remain the overriding reason for investors' involvement in tree growing initiatives (Franzel and Scherr, 2002). This brings to the fore a number of questions regarding the cultivation of indigenous tree species: What are the growth and yield potential of these species and what products can be generated from them? How does the quantity and value of wood from indigenous species compare to those from exotic species? At what age should these species be harvested for sawn wood to ensure optimal economic returns? These questions need to be addressed if indigenous species are to be promoted for reforestation and restoration of degraded forests for production purposes. Therefore the current study was aimed at providing answers to some of the questions. The results of the study are also expected to inform decisions on the cultivation of indigenous tree species on farms and private lands.

1.2 Objectives

The general objective of this study is to assess the economic viability of growing selected indigenous species in plantations and farm woodlots.

The specific objectives were:

1. To assess the growth and yield of the selected indigenous species and determine the merchantable volume of sawn wood that can be generated from them;
2. To undertake a financial analysis of growing these species in plantations and compare their financial returns with that of exotic species
3. To determine the optimal rotation period for the species for sawn wood production using scenario analysis
4. To make recommendations on the suitability of selected species for commercial purposes

2.0 Methods and Materials

2.1 Growth Modelling

Growth in biological organisms refers to the increase in the size of an organism over a period of time. In the case of trees, growth is usually two-fold vertically the apical growth and laterally the lateral growth (Weiskittel, et al; 2011). Apical growth is usually expressed by increase in height of the tree while lateral growth is expressed by increase in diameter of the stem. In forestry, diameter at breast height (over bark) and total height of the trees are the most common measurements of growth. Another often used measure of growth is the basal area, which is usually calculated from the DBH.

The use of DBH and height to measure growth is usually at the individual tree level. In forestry, however, interest is on the growth of the stock as a stand and this is expressed normally by volume (M^3) per unit area (Ha). Volume is a function of the dbh and height. Special formulas have been developed for the computation of tree volumes. These formulas are normally referred to as volume equations and are developed for each tree species particularly in the case of well-studied exotic ones. These equations generally use dbh and height in their computations and are often designed to incorporate both stem form and taper. Examples of these include:

$$V = 0.01722 + 0.0001937d^2 + 0.00005069dh + 0.00002296d^2h \quad \text{.................................} 1$$

For *Cupressus lusitanica* (Wanene and Wachiori, 1975)

While for exotics these equations have been there for quite some time and have been evaluated and refined overtime but equations have been developed for only a few of the indigenous species. These include:

$$LogV = -3.6321 + 2.2542\log d \text{, Or } LogV = -4.2224 + 0.9673\log d^2h \quad \text{..............................}2$$

For *J. procera* (Wachiori et al., 1996)

$$LogV = -3.8645 + 0.9049\log d^2 \quad \text{.. ....}3$$

For *Podocarpus latifolia* (Wachiori et al., 1996).

$$LogV = -3.4920 + 2.1875\log d,$$

$$\text{Or } LogV = -3.9596 + 1.9274\log d + 0.9788\log h \quad \text{.................}4$$

Combined volume equation for indigenous species (Wachiori et al., 1996).

In this study, the combined volume equation (Equation 4) was used in computing individual tree volumes for *Xanthoxylum gillettii*, *Prunus africanum* and *Polyscias fulva*, while equation 2 was used to compute individual tree volume for *J. procera*.

Yield tables are another tools for estimating yield of forest stands and generally give the volume (M^3/ha) per given age or age class of a stand. These tables are the tools most commonly used to determine the amount of wood that can be generated from a given stand of timber. The tables are developed by plotting mean annual increment (M^3/ha) against age of the stand for any given species. Mean annual increment commonly abbreviated as MAI is calculated by first getting the average annual increment of a single stem in a stand and them multiplying this by the average number of stems in one hectare of the stand. This is done for various ages or age classes of the species under consideration. The essence of yield tables is to help determine the amount of wood material that can be obtained from a given stand of timber. From the yield table we can then determine the value of material by simply multiplying the volume of wood by its royalty.

2.1 Study Sites

This section gives details of the compartments from which data were collected and describes the methodology used in collecting and analyzing data.

Tree inventory data were collected from Nandi, Kakamega, Mount Elgon and Kapcherop forests. Nandi and Kakamega forests are the remnants of the once flamboyant Guino-Congolian rain forests while Mount Elgon and Kapcherop forests are Afromontane forests. Detailed information on these forest blocks are given in Tables 1.1 and 1.2 give details of the compartments from which the data were obtained.

Table 1: Description of the forest blocks

Parameter	**Nandi**	**Kakamega**	**Mt. Elgon**
Location	0.0° and 0.34° N, 34.45° and 35.25° E	0.15° and 1.0° N, 34.20° and 35° E	0.52° and 1.18° N, 34.38° and 35.23° E
Rainfall	1,200 to 2,000mm per yr	1,000 to 2,400mm per yr	970 to 1,400mm per yr
Mean annual temp.	12°C to 26°C	11°C to 32 °C	10.3°C to 18.6°C
Altitude	1,300 to 2,000m a.s.l	1,250 to 2000m a.s.l	Over 1,800m a.s.l
Topography	Hills, plateau	Hills, peneplain	Hills, flat plains
Soil type	Dark to red brown friable clay	Dark brown to reddish brown friable clay	Well drained fertile volcanic soil
Ownership	State	State	State
Area	54,487.4 Ha	28,199.7 Ha	50,292.4 Ha

Source: Compartmental records of the respective forests and ground surveys in Kakamega, Nandi and Mt Elgon

Table 3.2: Details of compartments from which data were collected

Forest block	**Subcompartment**	**Species**	**Age (Yrs)**	**Spacing (sq. m)**	**Area (Ha)**	**No. trees sampled**
Suam	1 (A)	J. procera	30	2.5X2.5	10	60
Suam	1 (U)	J. procera	35	2.5X2.5	10	50
Suam	*	P. fulva	71	2.5X2.5	*	43
Kapcherop	*	J. procera	16	3.0X3.0	*	43
Kobujoi	1 (F)	P. africanum	25	3.0X3.0	9.8	50
Kobujoi	1 (F)	P. fulva	25	3.0X3.0	9.8	37
Kobujoi	1 (F)	X. gillettii	25	3.0X3.0	9.8	41
Kobujoi	1 (M)	P. africanum	20	2.5X2.5	18.4	40
Kimondi	*	P. fulva	11	3.0X3.0	2	40
Kimondi	*	P. africanum	33	3.0X3.0	3	47
Malava	1(D)	P. africanum	45	3.0X3.0	2	30
Malava	1(D)	X. gillettii	31	3.0X3.0	2	40
Malava	1(D)	P. africanum	57	3.0X3.0	3	22
Malava	1(D)	X. gillettii	33	2.5X2.5	3	30
Kakamega	ICARF Site	P. africanum	9	4.0X4.0	2	83
Jubert	Jubert 5	J. procera	84	3.0X3.0	4	43

Source: Compartmental records of the respective forests and ground surveys in Kakamega, Nandi and Mt Elgon

2.3 Data Collection and Analysis

2.3.1 Growth and Yield Data Collection

Field data were collected between March and April 2011 in compartments and beats. Compartments were selected based on the occurrence of plantations or experimental plots of the selected species in the compartment. Beats were selected based on the occurrence of enrichment plantings of the selected species. The design of study comprised circular plots of 200m^2 for plantations and experimental plots and a 20-meter wide transect running across the entire beat for beats. In Each plot (or transect), the following data were collected:

- Diameter at breast height (DBH)
- Height of the tree (H)
- Stem form (scored on a scale of 1-3 where 1=poor (crooked), 2=good (fairly straight), and 3=very good (straight cylindrical bole))

Date of planting (age), spacing and area covered were obtained from compartment registers at the respective forest station or district forest offices. Information on spacing was validated by actual field measurements.

2.4 Modeling Growth and Yield of the Species

From the data collected individual tree volumes were calculated using tree volume equations (Equations 2 and 4) developed for indigenous species by Wachiori et al. (1996). Based on the tree volumes computed for each tree were transformed using average plot volumes to obtain per hectare volumes for each species and age. Similarly, average DBH and dominant height per plot were calculated and expressed on per ha basis based on the number tree on an hectare of land for each age and species. Based on these calculations, mean annual increments in DBH, height and volume at individual tree level and stand (per ha) level were computed. The volume per hectare for each species was computed based on the number of stems that could have been removed through thinning and death. DBH-age, height-age and volume-age curves were generated for each species at the various ages. These were assessed on the strength of their correlation coefficient.

2.5 Costs and Revenue Data and financial analysis

Costs of establishing and maintaining plantations of these species were adapted from Okelo and Partners (1990). A market survey of selected wood dealers was conducted in selected urban centres to provide information on prices of poles. Stumpages for clear felling were obtained from the F.D.G.O (2006/2007). Since stumpage prices were used, harvesting costs were not included in the analysis as stumpage prices assume the buyer takes care of road construction and harvesting costs (Miina et al., 1998).

Revenue from thinning was calculated by multiplying the number of stems removed in each thinning by the price per stem for each species. Revenue from clear fells was done by scenario. Since these species put relatively small volume over a long period of time, the age at which the tree attain the diameter classes used in describing royalties in the F.D.G.O were used as the possible clear felling ages, especially after the trees have attained DBH greater than over 20cm. These ages (also considered as rotations) formed the scenarios. Total revenue was obtained by summing the amount obtained from thinning and the amount from clear fell for each scenario for each species. A cost-benefit analysis using net present value (NPV) was done for each scenario for each species.

2.6 Assumptions and Limitations

2.6.1 Assumptions

The study used silvicultural treatment for *J. procera* was as prescribed in the Forest Department Technical Orders (FDGOs). There were no FDGOs for the other species and best alternative scenarios was assumed by using that of *Vitex kenyensis* which is the only other indigenous species that FDGOs existed and likely to assume growth pattern.

Sale of round wood from these species is based on the royalties set by the forest department as indicated in Forest Department General Orders (FDGO, 2006/2007) that assumes any stem of between 15 and 30 cm diameter (DBH) over-bark is sold as pole while those exceeding 30 cm in diameter are sold as timber. Those measuring less than 15 cm DBH are sold as withies. Further, it was assumed that all the tree species are managed for sawn wood production cycle only but in reality the species could be managed for a variety of products.

Costing of planting material, land preparation, silvicultural treatments and others were been based on Forest Department rates, which in most cases are lower than what these items would cost in normal competitive markets. Because of these, the resulting NPVs may be higher than what they would be if competitive market prices were used. Further, in the computation of NPVs, an interest rate of ten percent has been assumed as recommended for public investments. However, if the interest rate in competitive markets were used, the resulting NPVs would have been lower.

2.6.2 Limitations

To come up with growth and yield curves for biological organisms, large amount of data collected over a long period of time (time series) is required. The data used in this study are limited in the sense that they cover not only a few ages but were not collected over a considerably long period and under diverse ecological condition. The data collection was hindered by lack of sufficient number of plantations of the species under study in the country. Most of these species were not been planted in plantations but were mostly planted as experimental plots or enrichment plantings except for *Juniperus procera*. These limitations have rendered the data, the growth and yield of the species reported in this study less likely to reflect the actual growth and yield potential biut best estimates based on the prevailing conditions.

3.0 Results and Discussions

The data obtained from both field and secondary sources for the selected species are presented and discussed in the forms of growth, yield and financial analysis models and scenarios in the flowing sections.

3.1: Species Growth Curves

The growth of each of the species generally followed an exponential pathway (Figures 1a, b and c). The age-dbh curves show that apart from *X. gillettii*, which has a very low correlation coefficient (R^2=0.3485), there is a very strong correlation (R^2>95%) between age and dbh growth for the other species. For *Prunus, Xanthoxylum and Polyscias*, growth is faster during the first 30 years, after which it experiences a decreasing increase and finally levels off. *P. africanum* grows faster in dbh than all the other species. It is followed in order by *X. gillettii*, *P. fulva*, and *J. procera* (Fig.1a).

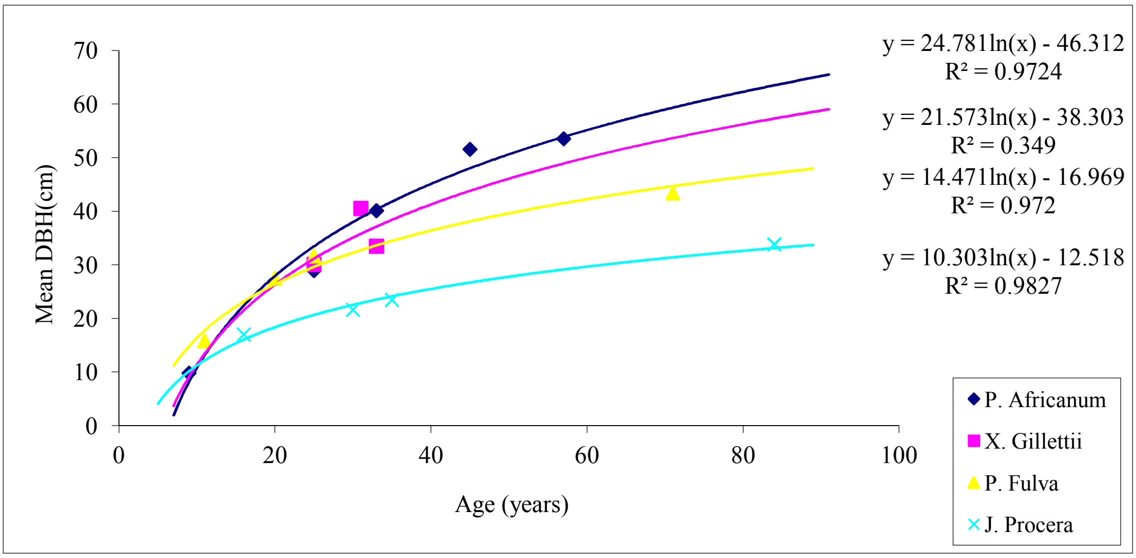


Figure 1a: Age-DHB growth curves for the species

The age-height curves on the other hand indicate that *X. gi;lettii* is the fastest growing followed by *P. Africana*, *P. fulva* and *J. procera* respectively. However, except for Prunus (R^2=50%) and Polyscias (R^2=85%), there is a very low and insignificant correlation between age and height for the other two species (R^2<40%) (Fig. 4.1.b).

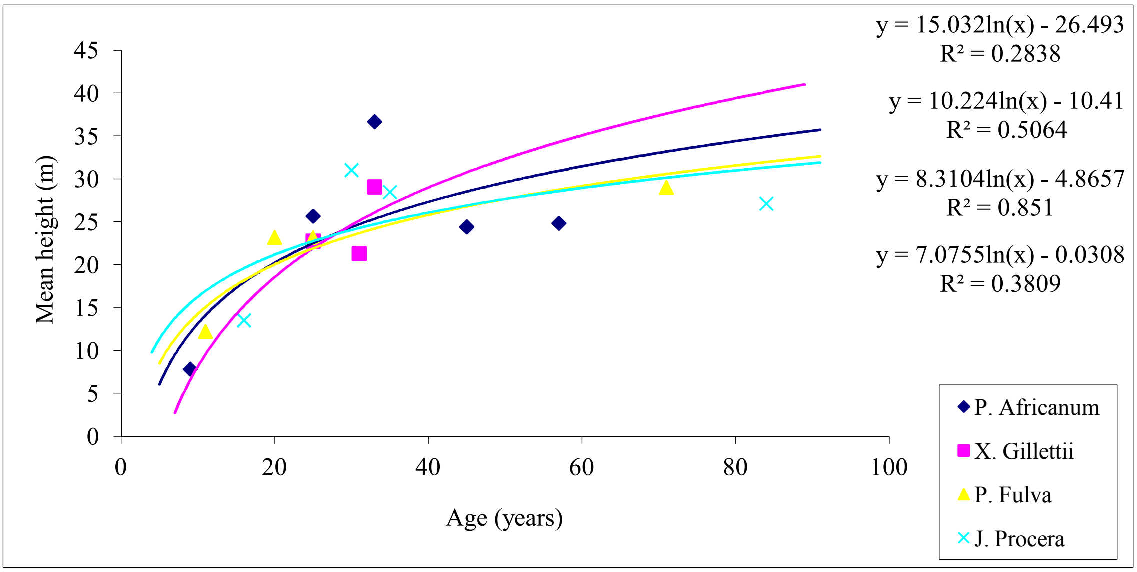
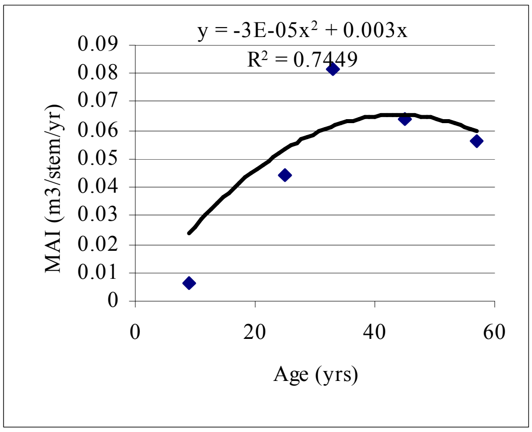


Figure 1b: Age-height growth curves for the species

There is a strong correlation between growth in yield per tree and age as the coefficient of determination of all the species is over 50%. The mean yield of individual trees, just as dbh, increases rapidly up to about 30 years of age and then experiences a decreasing increase before leveling off. For instance, the mean yield of a Prunus tree increases rapidly up to about the age of 30 (Fig.1c,b,c,d) after which it starts experiencing a decreasing increase in volume and finally levels off after age 40.



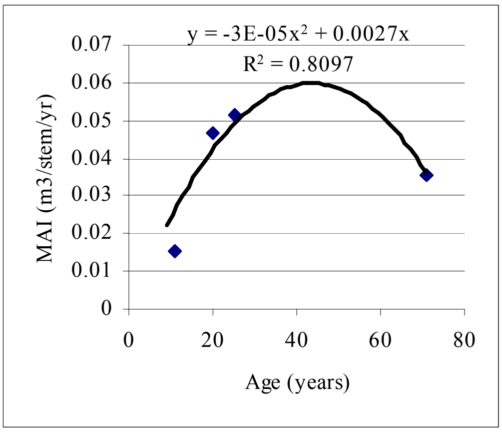
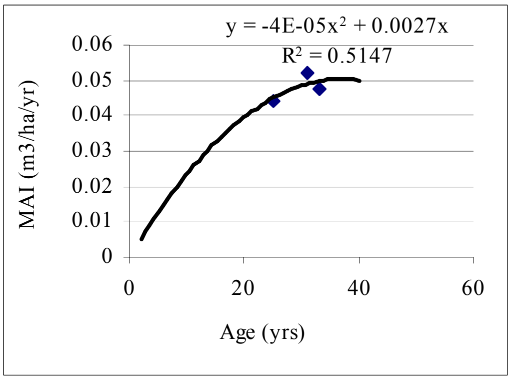


Figure 1c: Age-DBH curve for Prunus Figure 1d: Age-DBH curve for Polyscias



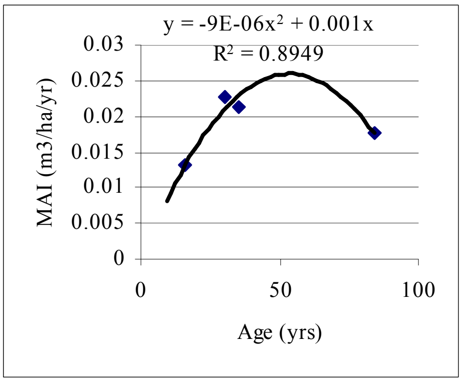


Figure 1e: Age-DBH curve for X. gillettii Figure 1f: Age-DBH curve for Juniperus

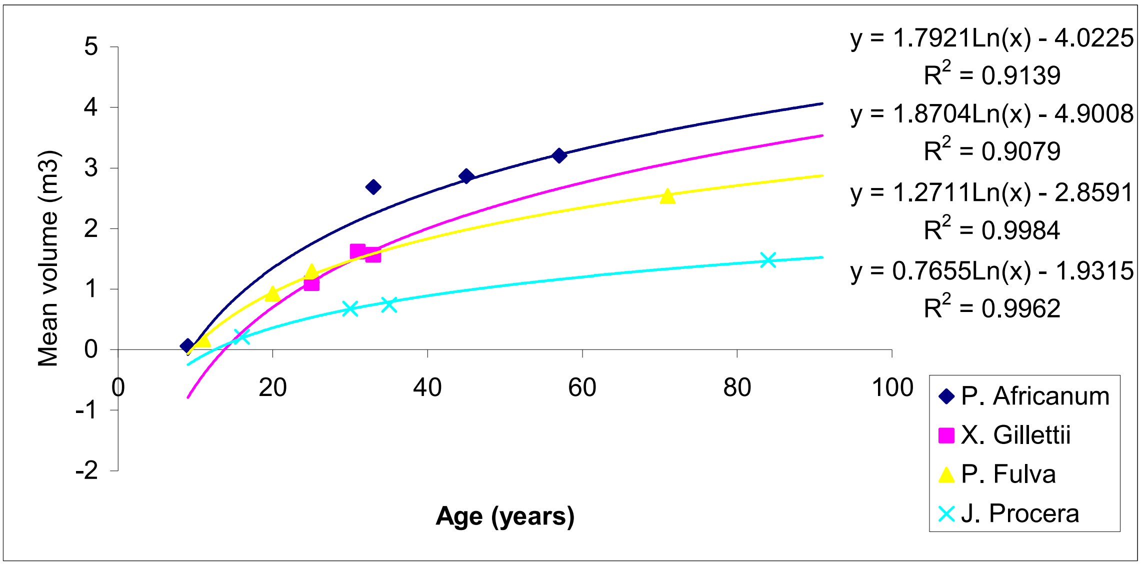


Figure 1g Growth (age-yield) curves of the species

3.2: Mean annual increment in DBH, height and volume

Figures 2.a, b, c and d show the mean annual growth in diameter at breast height (DBH), height and volume for each species. Xanthoxylum has a mean annual diameter growth of 1.17 cm/stem/yr; Polyscias, 1.72 cm/stem/yr;

Prunus, 1.11 cm/stem/yr; and Juniperus, 0.71 cm/stem/yr. In terms of height, Polyscias has a mean annual height growth of 0.9010 m/stem/yr; Xanthoxylum, 0.82 m/stem/yr; Prunus, 0.80 m/stem/yr; and Juniperus, 0.75 m/stem/yr. In volume growth, Prunus has a mean annual increment in volume per stem per year of 0.05 m^3/stem/yr; Xanthoxylum, 0.0478 m^3/stem/yr; Polyscias, 0.03 m^3/stem/yr; and Juniperus, 0.02 m^3/stem/yr.

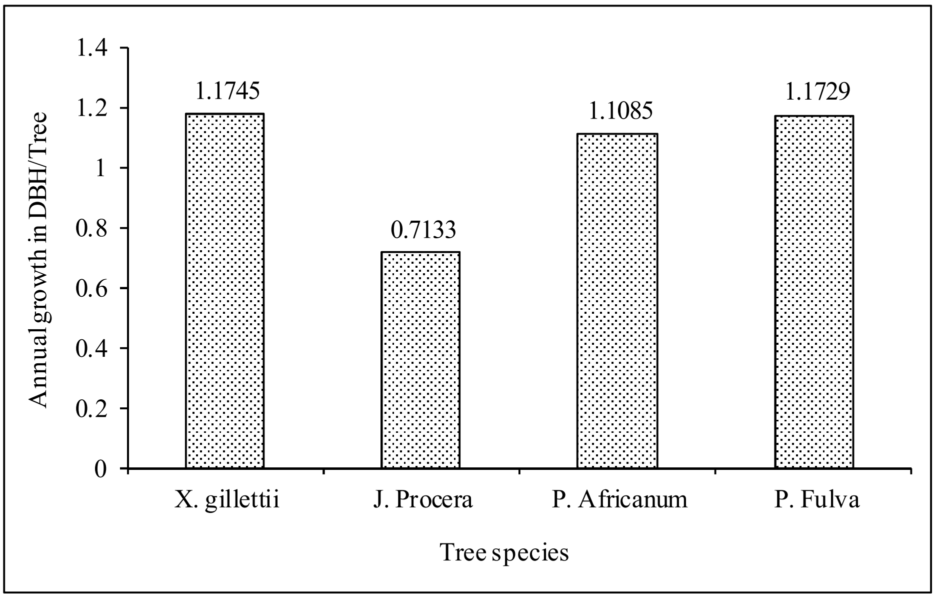


Figure 2a: Mean annual increment in dbh (cm/yr/tree)

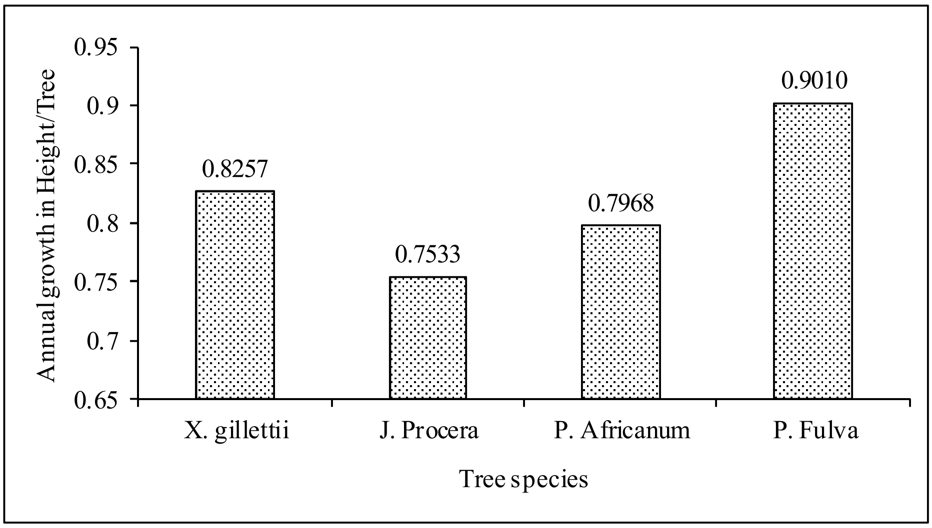


Figure 2b: Mean annual increment in height (m/yr/tree)

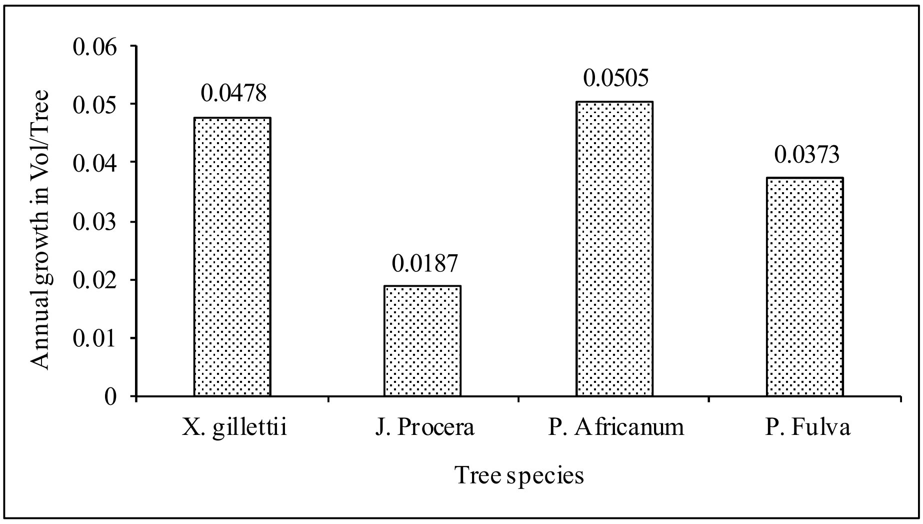


Figure 2c: Mean annual growth in volume (m^3/yr/tree)

3.3: Mean annual increment in volume per hectare

Figure 3 shows mean annual increment in volume for each of the species. Prunus has a mean annual volume of 10.09 m^3/ha; Xanthoxylum, 9.57 m^3/ha; Polyscias, 7.46 m^3/ha; and Juniperus, 3.73 m^3/ha.

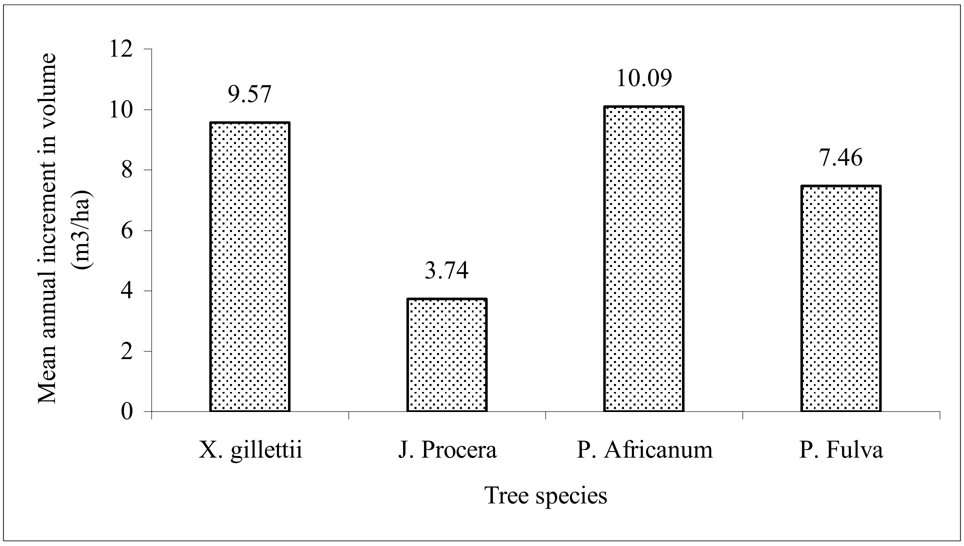


Figure 3: Mean annual increment (MAI) in volume (m^3/ha)

3.4: Yield at various possible rotation ages

Figure 4 shows the yield per hectare between age 38 and 60 years for each species. Prunus and Xanthoxylum have relatively higher yields over all the rotations, followed by Polyscias and Juniperus. For instance, at age 48 years, Prunus yields 484 m^3/ha, followed closely by Xanthoxylum with 459 m^3/ha. Polyscias follows with 358 m^3/ha and lastly Juniperus with 179 m^3/ha.

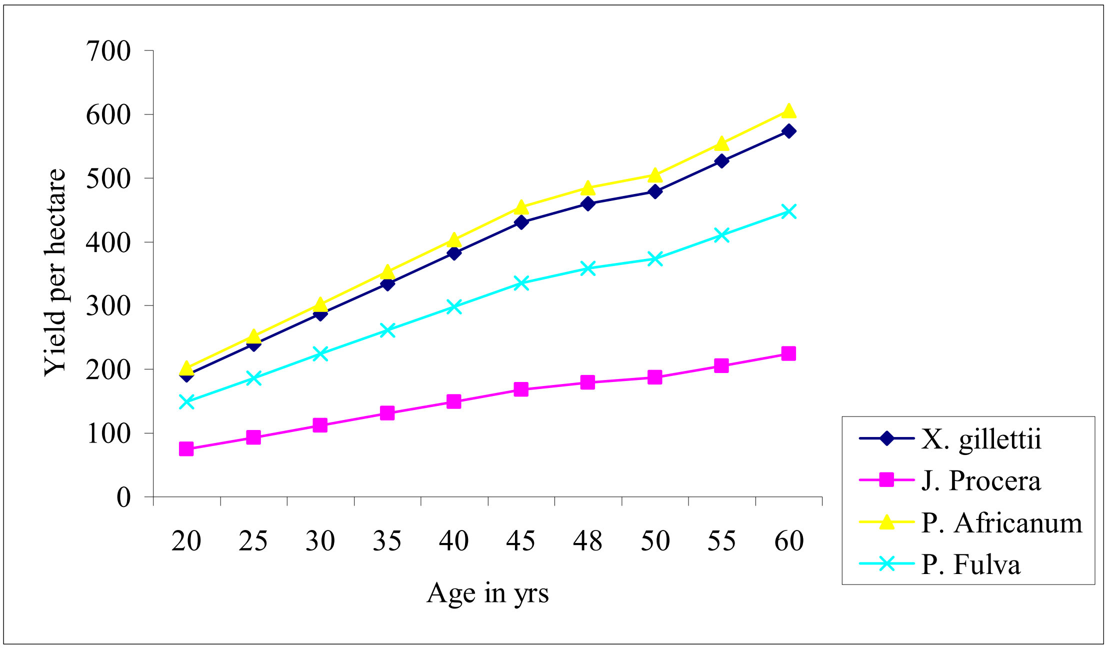


Figure 4: Yield at various possible rotation ages

3.5: Financial analysis of growing the species at three rotation ages

3.5.1: Financial analysis of growing *Xanthoxylum gillettii*

Figures 5 shows the Net Present Value (NPV) associated with growing the selected indigenous species in plantations at differing rotation periods. *Xanthoxylum gilettii* at a rotation of 38 years yields an NPV of Kshs 2,346,018; at 48 years, Kshs 2,465,796 and; Kshs 2,567,886 at a rotation of 60 years. It also shows that *Polyscias fulva* at a rotation of 38 years yields an NPV of Kshs 1,854,653 that increases to at 48 years, Kshs 1,946,437 and; at 60 years, Kshs 2,026,465. Similarly, *Prunus africanum* at a rotation of 38 years yields an NPV of Kshs 1,518,357; at 48 years, Kshs 2,407,084 and; at 60 years, Kshs 2,519,447.

The poor performing *Juniperus procera* at a rotation of 38 years yields an NPV of Kshs 508,013. The NPV increases to Kshs 670,392 at a rotation of 48 years. However, at a rotation of 60 years, the NPV declines to Kshs 587,519.

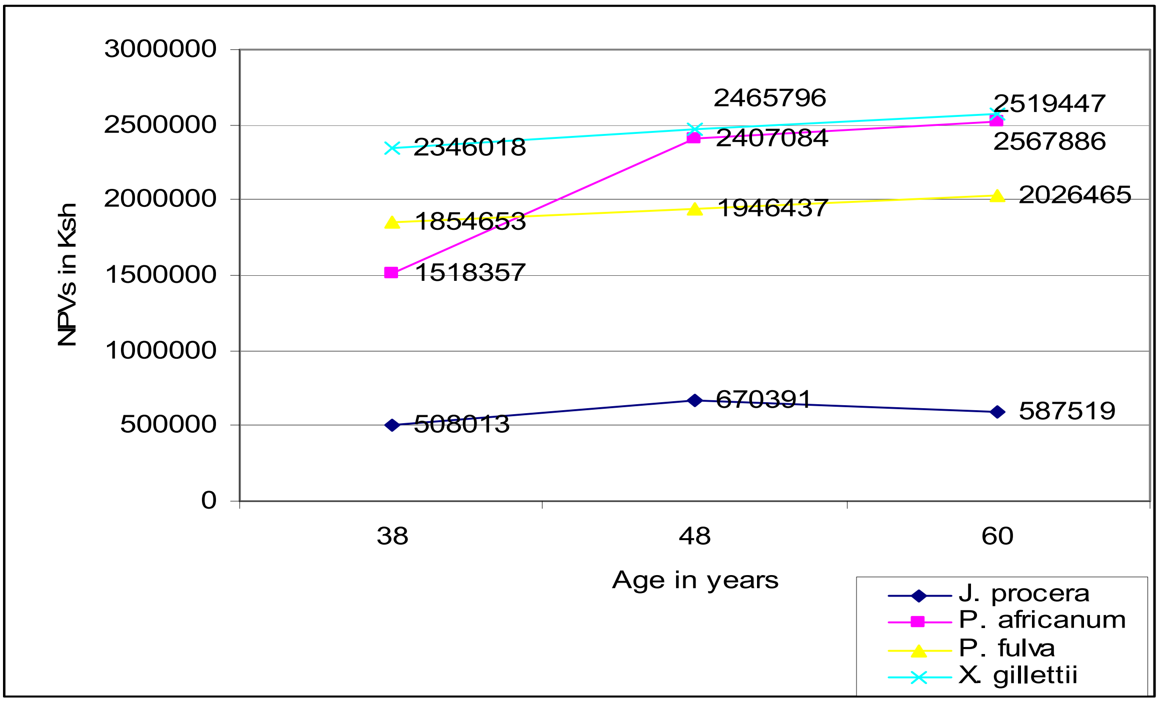


Figure 5: Financial analysis of growing the species under study (r=10%)

4.0 Discussion of Results

4.1: Species Growth Curves

The growth of each of the selected species depicted the sigmoid nature of growth, reported for most biological organisms that depict early acceleration, linear and saturation phases that is consistent with observation of Goudriaan and van Laar (1994). However, as Yin et al (2002) asserts the polynomial functions and their coefficients do not have any meaningful biological interpretation and therefore do not give much insight into the growth rate of the selected species.

The rapid growth rate of *Prunus africana* in the first 30 years agrees with the findings of Breitenbach (1965) that Prunus exhibits fast growth in the early ages and growth pattern after 30 years also is supported by the findings of Geldenhuys (1981) that observed decreasing growth in volume. From the DBH-age curve derived projects the Prnus volume to reach DBH of 90.3cm at the age of 250 years that agrees with suggestion by Geldenhuys (1981) that puts it at 80-90 cm at the same age. The faster growth rate at below 30 years of age could be due to the fact that Prunus is a pioneer species (Njunge, 1996) and therefore grows very fast in the early ages to secure a place in the canopy for light. The retardation in growth above this age could be attributed to the fact that after this age the trees devote their energy to building the density/strength of the fibre as the wood is usually denser after this period. The same arguments could hold for the other species.

The results show that height growth is independent of age, as suggested by the low correlation for all the species. This is because height growth is normally heavily influenced by site factors (Zutter et al., 1986; Richardson, 1991) hence young tree growing on a fertile soil are expected to grow taller than a tree of a similar age and species growing on a poor soils.

4.2: Species Mean annual increments

The results show that the mean annual diameter (DBH) increment for Prunus is 1.1085cm that fairly agrees with reports by O'Brien (2000) that indicated increment of 1.5 cm. The mean annual increment in height for Prunus of 0.8cm also agrees with reports by Breintenbach (1965) that recorded ranges of 0.6 to 0.8 m and fairly with O'Brien (2000) that observed excess of of a mean annual height increment in excess of 1m.

Results show that the mean annual increment (m^3/ha/yr) ranged from 3.73m^3/ha/yr for Juniperus to 10.09 m^3/ha/yr for Prunus, which fits well with reports by Evans (1982) that report increment range of 0.5 to 7 m^3/ha/yr for tropical hardwoods. However, the increments reported in this paper could be slightly higher than those reported by Evans (1982) because in this analysis a standard stocking has been assumed, which was not the case in his work. The volume equation used in estimating the volume of individual trees could also have overestimated individual tree volumes and hence the slight difference.

Compared with exotic species such as pines and eucalyptus, the mean annual increments of all the species and there yields at the different periods are significantly lower. Tropical pines have a mean annual increment of between 15 to 45 m^3/ha/yr while Eucalyptus has a mean annual increment of up to 60 m^3/ha/yr (Oballa et al 2013). This attests to the slow rate of growth of the selected indigenous species in general. For instance, Prunus could accumulate additional 202m^3 between age 20 and 40 while, Juniperus achieved 75m^3 that contrasts with *Eucalyptus grandis* that build over 400m^3 of wood over the same period.

4.3: Financial Viability for plantations of selected species.

Xanthoxylum and *Polyscias* are mature for sawn wood at age 38 years and the NPVs at this age are both positive. The DBH of the species at lower age were still below the minimum size of at least 20 cm (DBH), required for sawn wood production. As the age increases, the NPV of the species also rise. However, the increase in NPV with increasing age is comparatively marginal. For a ten year period from 38 and 48 year the increase in NPV is about Kshs 120,000. It would therefore be rational to harvest the trees at age 38 and invest the proceeds somewhere else.

Prunus is ready for sawn wood at age 38 and yield a positive NPV of 1,518,357 that increases to Kshs 2,407,084 at age 48, a difference of close to Kshs one million. Thus it would be economic to wait for another ten years and gain a half a million increase in NPV and therefore 48 years is the optimal economic rotation age for Prunus.

Juniperus yields a positive NPV at age 38 and 48 years. Above this age, the NPV, though positive, begins to decrease, thus it is not economical to harvest the trees after age 48 years. The NPV of the species at age 38 is significantly lower compared to other species and the increase recorded at 48 years remains marginal. It is therefore recommended that Juniperus be harvested at age 38 years. However, because of the relatively low NPV at this age, it is recommended that *Juniperus* be planted in enrichment planting or in fragile lands rather than in afforestation initiatives meant to establish plantations for commercial gains.

5.0 Conclusions and Recommendations

The study shows that selected indigenous species have a slow growth rate compared to exotic species. However, the growth rates of *Polyscias, Xanthoxylum* and *Prunus* are quite satisfactory for plantation establishments. The cultivation of all the selected indigenous species in plantations is financial viable. However, for *Juniperus*, the resulting NPVs are relatively lower for the considered rotations ages and should therefore not be established as commercial plantations but rather in enrichment planting and on fragile sites.

On the basis of these findings the some recommendations can be made to inform future decisions on the use of the selected species for rehabilitation/restoration and commercial plantations of activities for various purposes. Xanthoxylum, Polyscias and Prunus can be grown in commercial plantations while Juniperus be used only in enrichment planting schemes or on fragile sites.

The optimal financial rotation period for Xanthoxylum, Polyscias and Juniperus should be 38 years while that for Prunus should be 48 years.

There should be more concrete efforts to establish experimental plots for some high value indigenous species to facilitate elaborate studies on their growth performance and yields characteristics to enable development of volume equations and yield tables specific to each species and region.

There is need also to widen the scope of material yields and financial analysis to include a wide range of wood and non-wood products extracted from the specific species in order to take into account the multiple use of indigenous species to inform their future use in plantations, farm woodlots and restoration schemes.

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