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Harnessing Fast Growing Trees for Timber and Carbon Sequestration: The Case for Growing Jabon in South-East Asia

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Abstract

Deforestation not only destroys habitats for many plant and animal species but also releases billions of tons of carbon dioxide annually into the atmosphere. In order to meet our growing demand for timber without worsening deforestation, one solution that has received increasing acceptance over the past two decades has been fast growing trees, which produce timber and sequester carbon faster than most trees. This paper focuses on South-East Asia, which is home to about 15% of the world's tropical forests and a major timber supplying region. The two most commonly cultivated fast growing trees here are eucalyptus and acacia. However, because both are exotic to most of South-East Asia, as well as to the majority of regions where they are grown for timber, they have invasively disrupted local ecologies. The damage includes excessive water consumption, suppression of local ground vegetation and lower plant and animal biodiversity. Hence, this paper examined a potential native alternative, the jabon species (*Anthocepalus cadamba*), and compared its performance as timber producer and carbon capturer with other fast growing trees. From existing research, the dimensions of three different species at various ages from planting to harvest were obtained, from which the above-ground biomass (a measure of timber produced) and carbon weight were calculated. This paper found that compared to eucalyptus, jabon was superior in both metrics by the time of its first harvest, while compared to acacia, jabon produced more timber but captured less carbon. These findings suggest that jabon is a very deserving candidate for sustainable timber in South-East Asia, with the added benefit that it is indigenous and non-invasive. Two areas of further study are exploring factors other than species that affect productivity and carbon capture, and extending the study to harvests beyond the first.

Keywords: Jabon, Cadamba, Fast growing trees, Antocephalus cadamba, Timber plantations, Carbon sequestration

1. Introduction

During the period 2015 to 2017, about 4.8 billion tons of carbon dioxide a year (or about 8 to 10% of annual human CO_2 emissions) were released into our atmosphere due to deforestation (Dean, 2019). In addition to making space for agriculture, grazing livestock and human settlement, one significant driver behind the clearing of forests was the demand for timber, which is forecasted to quadruple from 2012 to 2050 to about six billion cubic meters (Indufor Group, 2012). We face the challenge of meeting this rising demand without exacerbating deforestation. Sustainable timber plantations, where trees are continuously grown and harvested, will be an important part of the solution.

Sustainable timber can benefit the environment in three ways other than reducing the need to chop down trees in natural forests. Firstly, according to a 2023 report by the World Economic Forum, since the manufacturing processes of more common building materials such as concrete and steel are highly carbon-intensive, contributing to 5% of global emissions, wood is becoming a crucial environmental-friendly alternative (Burrell, 2023). Much of the carbon that trees sequester is retained in the wood even after being processed into building structure or furniture, so for a

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typical commercial building, using wood rather than concrete and steel would result in capturing 2000 metric tons of CO_2 versus releasing the same amount (Robbins, 2019). Secondly, wood insulates ten times better than concrete and 400 times better than steel, conserving energy for cooling during summers and heating during winters (Mitchell, 2022). According to the International Energy Agency, the electricity and heat used in buildings account for 18% of global energy-related emissions (IEA, 2023). Thirdly, replacing older trees with new ones can lead to higher carbon sequestration because the former release much carbon from the decomposition of leaves and branches that they shed. For instance, according to a report by the British Broadcasting Corporation (Smedley, 2019), Canadian forests have become a carbon source rather than a sink because mature trees were no longer being felled for timber to be replaced by younger ones. The report concluded that "Arguably, the best form of carbon sequestration is to *chop down* trees: to restore our sustainable, managed forests, and use the resulting wood as a building material." Although this paper does not advocate indiscriminately cutting down natural forest trees to be replaced by plantations, the Canadian experience illustrated that continuously planting younger trees while harvesting more mature ones for construction material can reap dual benefits of increasing carbon capture and reducing emissions by replacing concrete and steel.

Timber plantations first appeared in Europe and America, with oak, pine and spruce being popular choices. In recent decades, as the global demand for timber has increased with urbanization in developing countries, attention has shifted to fast growing species, which take five to eight years to grow tall enough for harvest, compared to decades for the trees traditionally grown. This can become a powerful tool to fight climate change because faster tree growth means not only faster carbon sequestration (Coghlan, 2019), but also stronger economic incentives for the private sector to produce timber sustainably by shortening the time needed to recoup investments. Although the profit motive has the potential to create a win-win situation, regulation and strict enforcement are still necessary to prevent abuse. For example, according to a report by the Tropical Forest and Climate Initiative of the Union of Concerned Scientists (Elias & Boucher, 2014), forest clearing and replacing them with fast growing plantations accounted for more deforestation between 2000 and 2010 in Indonesia than oil palm plantations and coal mining, inflicting massive ecological damage. The positive role that plantations play in producing timber and capturing carbon does not justify the unrestrained or illegal clearing of natural forests.

Many of the fast growing tree species are in the tropics, due to the relative abundance of rainwater and sunlight. This paper focused on South-East Asia, which is home to about 15% of the world's tropical forests and has one of the world's highest rates of deforestation, with at least 1.2% of its forests lost annually (Lai, 2022), destroying the habitats of much of the local flora and fauna, with one study showing that up to 42% of its biodiversity could be lost by 2100 (Sodhi et al., 2004). The region is also a leading supplier of plantation timber (Barua et al., 2014), which is concentrated in Indonesia, Malaysia, Thailand and Vietnam. The two most common fast growing trees cultivated here belong to the eucalyptus and acacia genera, which are respectively also the global and Asian leaders (Elias & Boucher, 2014). In 2014, there were at least 2.6 million hectares of acacia and 4.3 million hectares of eucalyptus plantations in South-East Asia, with short rotation cycles of 5 to 8 years (Harwood & Nambiar, 2014a). The wood produced is used for pulp, woodchips, sawn timber, veneer, fiberboard, furniture and construction material. *Acacia mangium* is the most popular species from its genus, whereas a number of species from the eucalyptus genus are commonly grown, including *E. pellita, E. camaldulensis*, *E. urophylla* and *E. grandis*. Surprisingly, neither of the two genera are native to most of South-East Asia; both of them have been transplanted here, primarily from Australia (Harwood & Nambiar, 2014a).

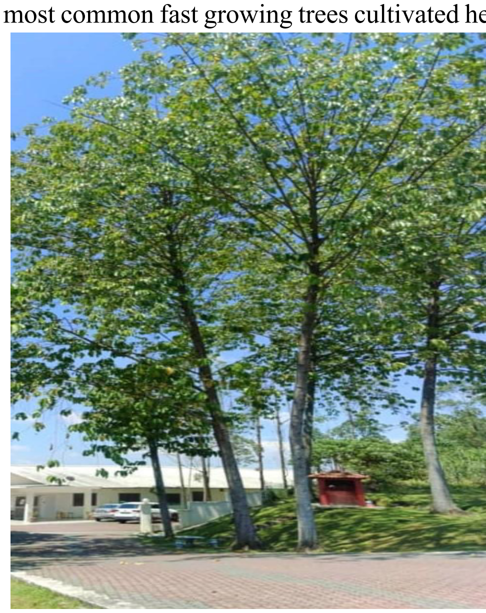
Figure 1: Five-year-old jabon tree in Malaysia

This paper explored the feasibility of an alternative to eucalyptus and acacia: the jabon, scientifically named *Anthocephalus cadamba* or *Neolamarckia cadamba*. See Figure 1. Jabon (also known as cadamba or kadam) is native to South-

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East Asia, India and parts of China and Australia. Its wood is classified as lightweight hardwood and is white with a yellow hue. Its applications include plywood, light construction materials, flooring, beams, crates and furniture. Jabon is easy to craft with hand or machine tools, yielding a clean surface. It can also be readily infused with synthetic resins to enhance its density and strength (Krisnawati et al., 2011), which is necessary for outdoor use. Jabon's leaves and bark also have various medicinal properties (Dwevedi et al., 2015).

1.1 Cultivation of Jabon

Jabon is generally considered a low maintenance species to plant. Weeding is needed during the seedling stage. Fertilizer use is typical in the first two years to expedite growth (Krisnawati et al., 2011). Manual pruning is unnecessary because the species self-prunes (Figure 2), with dead branches and leaves falling off naturally, which improves the level of soil organic carbon, carbon exchange capacity and plant nutrients. Coppicing is the practice of cutting down a tree to allow new shoots to grow up from the stump. This encourages the tree's regenerative capability and expedites sustainable tree growth since replanting is unnecessary. Jabon coppices well (Fern, 2024), with the first felling occurring at the age of around six to seven years (Bijalwan et al., 2014). Therefore, growth after initial planting and regrowth after first felling are both fast. By contrast, acacia coppices poorly and is generally replanted after felling.

Figure 2: Jabon Trunk with Marks from Self-Pruning

1.2 Advantages of Jabon's Indigenousness

Studies in Indonesia showed that jabon has not encountered serious diseases (Krisnawati et al., 2011), possibly because its indigenousness enhances its ability to coexist with local pests. Some insects and fungi have been reported to cause defoliation but it has usually recovered well. By contrast, acacia and eucalyptus trees introduced to South-East Asia have been exposed to new diseases that did not exist in their native homeland. For example, leaves and shoots of eucalyptus trees in Laos, Vietnam, China and Thailand have been seriously damaged by the gall wasp (*Leptocybe invasa*), stunting growth, leaf expansion and wood production, because the wasp's naturally-occurring Australian parasitoid is absent in Asia to check its spread (Harwood & Nambiar, 2014a). Likewise, acacia plantations in Sumatra, Indonesia and Sabah, Malaysia have been severely attacked by stem canker disease, caused by the fungi *Ceratocystis acaciivora sp.nov.* (Harwood & Nambiar, 2014a).

Both acacia and eucalyptus have been classified as invasive species in many regions where they have been transplanted and cultivated in plantations. An invasive species is defined as one which is exotic to an area, spreads rapidly and harms the environment or ecosystem of its adopted home. Acacia outcompetes local plants for light and water and alters the ecosystem, leading to lower biodiversity and species richness. (Souza-Alonso et al., 2017). Even the diversity of birds and small mammals have dropped due to a transformed ecosystem and a degradation in habitat quality (Dures and Cummings, 2010), (Manor et al., 2008). According to Richardson et al. (2015), since acacia was introduced to South Africa from Australia around 1860, the damage from its invasiveness has outweighed its benefits, to the point where the government has had to implement initiatives to eradicate or contain the plants. The authors argued that although the South-East Asian experience with acacia has not been as bad as South Africa's, it may be too early to tell since South African plantations preceded South-East Asian ones by about a century, and the detrimental effects take multiple decades to manifest. Similarly, eucalyptus trees have been blamed for lowering biodiversity, absorbing excessive water resulting in lower stream flow, and stifling neighboring vegetation and food crops (Rojas-Sandoval & Acevedo-Rodriguez, 2019).

1.3 Relative Disadvantages of Jabon

One important disadvantage of jabon compared to acacia and eucalyptus is its shorter history of large-scale commercial cultivation. Acacia has been grown for timber in South Africa as early as the mid-1800s (Richardson et al., 2015) and eucalyptus from Australia has been cultivated in Europe and studied by botanists there since the early 1800s, and large-scale plantation in California began in the 1870s (Rowland, 2011). Jabon, on the other hand, was not grown on a large scale until the 1930s (Krishnawati et al., 2011). The longer track records of acacia and eucalyptus resulted not only in more accumulated cultivation experience, but also in greater genetic advances via selective breeding and hybridization.

A second disadvantage is jabon's lower wood density of 0.35 g/cm^3, compared to 0.65 g/cm^3 and 0.75 g/cm^3 for acacia and eucalyptus respectively (International Tropical Timber Organisation, n.d.), which results in lower durability and hardness. Fortunately, jabon is easily impregnated with synthetic resins to significantly increase its density, compressive strength, durability and termite resistance, a treatment that is quite common among many wood species. (Rahayu et al., 2024).

1.4 Economic Factors

Although it is beyond the scope of this paper to compare the economic merits of growing jabon versus other fast growing species because of large uncertainty and variation in input costs, yield and log prices across geographies, some background information is discussed here. The usual economic analysis of a plantation is to calculate a net present value based on forecasts of expenses and income from selling the logs upon harvest (Hoang, 2015). The largest expenses occur during the first two years, for site preparation and purchase of seedlings and fertilizers. Subsequently, the ongoing costs, usually for weeding and application of insecticide, tend to be relatively low. No income is generated until harvest. For the plantation owner, the main considerations are the expenses during the first two years, the expected log prices at harvest and the opportunity cost. Hence, the growth rate of the tree is an important determinant of the economic feasibility of the plantation.

In recent years, the topic of carbon offsets has gained prominence. Companies hoping to reduce their net carbon emissions can purchase offsets from carbon capturers, such as plantations, supplementing their incomes. Unfortunately, in practice, this has been difficult to realize because the trading of carbon credits is still in its infancy in much of South-East Asia. Malaysia and Indonesia set up their carbon exchanges only in 2022 and 2023 respectively. The lack of standardization on carbon credit certification and suspect integrity of offsets have eroded confidence in the carbon markets (Tracy, 2023). Furthermore, as of this writing, Malaysia has yet to implement a carbon tax, whereby corporations are incentivized to reduce emissions (Bahrin & Edhan, 2023). Indonesia's implementation of a carbon tax in 2022 is an encouraging first step. As South-East Asian countries pursue policies to help achieve their climate goals, creating disincentives for carbon emitters and incentives for carbon capturers should be a constructive component, but currently, carbon offsets only play a minor role, if any, in the economic decision making of farmers and plantation owners.

1.5 Current Research and Literature

Current research is lacking in direct comparisons of carbon sequestration between jabon and other fast-growing trees across different ages. The literature for acacia and eucalyptus is more complete given their longer cultivation history. Levan et al. (2020) explored acacia carbon sequestration in Southeastern Vietnam and Du et al. (2015) performed a similar study for eucalyptus in Southern China. Although Sarjono et al. (2017) analysed jabon carbon sequestration in North Kalimantan, Indonesia, differences in methodology prevent direct comparison with studies of the other two genera.

1.6 Objectives

This paper sought to compare jabon's timber productivity and carbon sequestration rate with those of eucalyptus

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and acacia, particularly during the first six to seven years of growth, at which point jabon will be harvested for the first time. The comparison is necessary to determine jabon's merits as a viable alternative because if a native can produce timber and capture carbon as effectively as exotic species, it deserves consideration and promotion.

2. Methods

This paper conducted a detailed literature review using Google Scholar for research articles on the growth trajectory of jabon over multiple years. Google Scholar was used because of its coverage of about 200 million academic articles and its ranking as the best academic search engine by Paperpile. To screen the search, the following search terms were used: 'Anthocephalus cadamba,' 'growth rate,' 'age,' and 'diameter at breast height' or 'dbh.' Diameter at breast height is a standard metric of the diameter of a trunk of a standing tree. The search yielded 172 results. Only one research article (Krisnawati et al., 2011) examined the relationship of diameter and height of jabon trees with age that covered their growth path from planting to first harvest. With these dimensions, this paper calculated the above-ground biomass of the tree (a measure for the timber produced) and the amount of carbon sequestered using step-by-step formulas shown below (Fransen, 2024):

$$AGB = 0.25 \times DBH^2 \times h \tag{1}$$

Where AGB is the above-ground biomass (in pounds), DBH is the mean trunk diameter at breast height (in inches) and h is the height of the tree (in feet).

$$BGB = 0.2 \times AGB \tag{2}$$

Where BGB is the below-ground biomass and is typically 20% of the AGB.

$$TB = AGB + BGB \tag{3}$$

Where TB is the total biomass of the tree.

$$TDW = TB \times (1 - MC) \tag{4}$$

Where TDW is the total dry weight and MC is the wet basis moisture content of the tree and varies across species. MC was obtained from existing research, summarized in Table 1 below.

Table 1: Moisture Content of Freshly Cut Tree (on Wet Basis)

Type of Tree	**Moisture Content**
Jabon (*Anthocephalus cadamba*)	56%
Acacia (*Acacia mangium*)	42%
Eucalyptus (*E. urophylla* x *E. grandis*)	55%

Source: Siregar et al. (2017) and Zhang et al. (2020).

$$TC = TDW \times 0.5 \tag{5}$$

Where TC is total carbon, since average carbon content is generally half of the total dry weight.

$$CO_2\ weight = TC \times 3.67 \tag{6}$$

Where CO_2 weight is the weight (in pounds) of the carbon dioxide sequestered and is calculated as above because the ratio of CO_2 to carbon is 44/12 or 3.67. All units were converted to metric, and the steps were repeated for acacia and eucalyptus.

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3. Results

Table 2: AGB and CO_2 Sequestered by Jabon (Anthocephalus cadamba) with age

Age	Jabon AGB (kg)	Jabon CO_2 weight (kg)
3	83.1	80.5
4	135.1	130.9
5	214.6	207.9
6	302.7	293.3
7	404.8	392.2
8	473.0	458.2
9	601.4	582.7
10	709.6	687.6
11	785.0	760.5
12	895.8	867.9

Source: Calculated based on diameter and height data from Krisnawati et al. (2011)

Note that Krisnawata et al. (2011) calculated DBH versus age and height versus age relationships for five different site qualities, but for simplicity, this paper used only the data from the case of the medium site quality.

Table 3: AGB and CO_2 sequestered by Eucalyptus (E. urophylla x E. grandis) with age

Age	Eucalyptus Above-Ground Biomass (kg)	Eucalyptus CO_2 weight (kg)
3	80.5	79.8
4-5	114.3	113.3
6-8	235.5	233.4

Source: Calculated based on diameter and height data from Du et al. (2015)

As seen in Tables 3 and 4, the height and diameter data for acacia and eucalyptus were not available for every year. Note that in the eucalyptus data in Table 3, because the original raw data for height and diameter cited from Du et al. (2015) had single y-values (height and diameter) corresponding to a range of x-values (age), when this paper computed the AGB and CO_2 weight from the raw data, the same issue persisted. For example, a single AGB value of 235.5 kg corresponded to the age range of six to eight years. For purposes of plotting the graph, the paper took the midpoints of the ranges as the x-coordinates so as to better compare the plots in Figures 3 and 4.

Table 4: AGB and CO_2 sequestered by Acacia (A. mangium) with age

Age	Acacia Above-Ground Biomass (kg)	Acacia CO_2 weight (kg)
4	161.3	206.0
7	333.0	425.2
11	519.9	664.0

Source: Calculated based on diameter and height data from Levan et al. (2020)

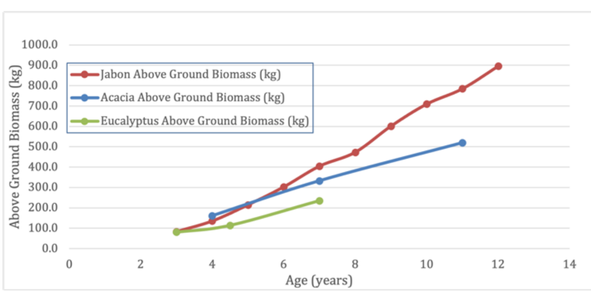

Figure 3: Above Ground Biomass (kg) of Different Species by Age

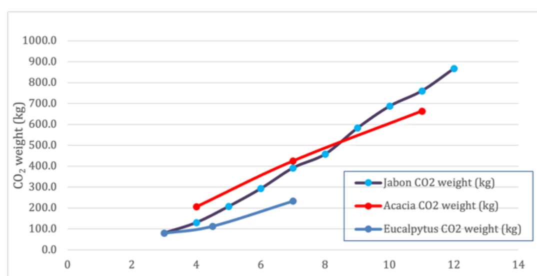

Figure 4: Carbon Sequestration (kg) of Different Species by Age

4. Discussion

Figures 3 and 4 showed that by year seven, jabon's AGB accumulation (a measure of timber production) exceeds eucalyptus's by around 72% and acacia's by about 22%. For carbon capture over the same period, jabon sequesters 68% more than eucalyptus, but 8% less than acacia. Eucalyptus's performance for both metrics is the slowest among the three. Simply put, by the time it is harvested, jabon would have produced more timber than both acacia and eucalyptus. The AGB data above actually understate the output advantage of jabon because logs are sold by volume rather than weight, and jabon, being less dense than the other two, would show even greater production differentials in terms of volume. In Malaysia, the price of jabon timber is the same as acacia because they are both classified under the same Mixed Light Hardwood category by the Malaysia Timber Board. Therefore, given similar pricing, jabon's higher growth rate, indigenousness and easier cultivability, in terms of its self-pruning ability and better coppicing, this paper argues that jabon is a viable, if not superior, candidate for sustainable timber plantations in South-East Asia.

There are a number of shortcomings in the comparison study above. Most importantly, there are factors other than species that influence the growth and carbon weight of trees, such as soil conditions, rotation intensity, fertilizer usage, stand density, management practices and others. Due to different pre-existing conditions and the length of time required to grow the trees, it is difficult to conduct experiments controlling for these factors. Secondly, there is no data to compare subsequent productivity beyond the first harvest. Thirdly, the carbon sequestration comparison only considered the tree component rather than the entire plantation ecosystem. It did not account for the carbon captured in the understorey (the smaller shrubs growing under the trees), the litter (the fallen leaves and twigs) or the carbon in the soil. One study of acacia plantations in Vietnam (Levan et al., 2020) found that the carbon mass in the soil up to a depth of 50 cm exceeded that of the trees.

One area of further research is the potential damage that monoculture plantations may incur on the level of soil nutrient and future growth after multiple rotations. Although a study on this topic for eucalyptus and acacia plantations was inconclusive (Elias & Boucher, 2014), it still deserves future research. A second area of exploration should be new genetic improvements that can enhance the qualities of jabon. Due to their longer cultivation history, eucalyptus and acacia have undergone major advances from the creation of different provenances to match different environments via hybridization, selective breeding and cloning. Such improvements are much rarer for jabon.

5. Conclusion

This paper showed that jabon produces about 72% more timber than eucalyptus and 22% more than acacia by time of first harvest. This provides an economic incentive for plantations to choose jabon over the other two despite their more established track record. Carbon sequestration by jabon is much higher than by eucalyptus, but about 8% below that by acacia. From an ecological perspective, jabon's indigenousness to South-East Asia also presents an advantage because of the invasiveness of acacia and eucalyptus. The farmers and plantation owners of the region that have historically only grown acacia or eucalyptus may be hesitant to cultivate jabon because of unfamiliarity and unwillingness to take risks. Since experimentation with a new species is time-consuming and entails risks, the agriculture departments of local governments can provide technical assistance and guidance to plantations to encourage growing jabon on a trial basis.

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