Australian Government

Australian Centre for International Agricultural Research

# Final report

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| *project* | **Realising genetic gains in Indonesia and Australian plantations through water and nutrient management** |
| *project number* | FST/2004/058 |
| *date published* | June 2011 |
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| *approved by* | Tony Bartlett, Forestry Research Program Manager, ACIAR |
| *final report number* | FR2011-07 |
| *ISBN* | 978 1 921738 72 2 |
| *published by* | ACIAR<br>GPO Box 1571<br>Canberra ACT 2601<br>Australia |

# Contents

# 1 Acknowledgments

We wish to thank all of the people and organizations who have contributed to this project. People include Russell Haines (former ACIAR Forestry Programme Manager) and Tony Bartlett (ACIAR), Tammi Short (CSIRO), Alex Lindsay, Dean Severino,and Justine Edwards, all formerly of Great Southern Limited, Prof. Dr. M Naiem (Dean of the Faculty of Forestry, Gadjah Mada University), Prof. Dr. Imron Zahri (Dean of the Faculty of Agriculture at Sriwijaya University) . Organizations include CSIRO, Gadjah Mada University, Sriwijaya University, PT Musi Hutan Persada, Forest Research and Development Agency (FORDA), and Great Southern Limited.

# 2 Executive summary

This project was established to improve the wealth of farmers and plantation growing communities in rural South Sumatra through gaining a deeper understanding of the *Acacia mangium* system. We focussed primarily on a greater understanding of the biophysical system, but also explored the socio-economics of smallholder growers. One of the premises for the project was that there would be a significant need to improve the management of *Acacia mangium* plantations to maximise the potential gains from using genetically improved planting material. Key objectives were to (1) quantify the role of site edaphic properties and climate on productivity, (2) develop a capacity to predict productive potential of *A. mangium*, (3) to evaluate the economic benefits of improved management, and (4) to develop practical tools to support improved management.

Several scientific advances were made during the project, including a mechanism for characterising site productive potential based on depth to plinthite, soil colour, consistency and structure, all of which are relatively easily assessed characteristics of soil profiles in this region, and an integration of these with climate to allow assessment of productive potential. We found that the productive potential of *A. mangium* in South Sumatra is high and farmers in this region have an excellent opportunity for a profitable *A. mangium* component of their enterprise. The growth rates in our experiments were higher than can be achieved in the vast majority of plantation areas in the world, with standing volume of up to 180 $m^3$/ha at age 3 (average 137 $m^3$/ha). There is a strong contrast in environment between Sumatra and Australia, and our observations and modelling of this effect on productivity suggests that growth rates of *A. mangium* on Melville Island are about one quarter of those in Sumatra. It is also evident that the long dry period on Melville Island causes significant stress in *A. mangium*, which is probably a contributing factor to the poor tree form in this region.

We found that improved seed sources gave gains in productivity at both sites in the first year (55-180% increase over local landrace seed source), but only at 1 of the 2 sites in the 2$^{nd}$ year (where there was a 70% increase over local landrace seed source), suggesting that these experiments need to be followed for a longer period of time to ascertain the full benefit of improved seed. Improved genotypes had a higher demand for Phosphorus (P) fertilizer, but only a small amount (<10 kg P/ha) was required to achieve maximum productivity levels at most or all sites in South Sumatra. This recommendation will save growers an estimated $14/ha because it reduces the quantity of Phosphorus fertilizer at planting by about 30%. It is likely that more P fertilizer would be required in the older soils of northern Australia. Phosphorus is the only nutrient that is required in South Sumatra, as there was no response to basal fertilizer at either of the 2 sites where this was tested. However, preliminary results from Melville Island showed that most sites will require additional nutrients to Phosphorus. Preliminary experimentation demonstrated that there was some capacity in South Sumatra to substitute weed-control for P fertilizer addition, with similar yields at age 1 in treatments without weed control and 20 kg P/ha applied as with complete weed control and no P fertilizer. However, these yields were only about half of those obtained with complete fertilizer and weeding treatments applied.

The project produced an *Acacia mangium* Growers Manual, and an Excel-based decision support system. The anticipated audience for the growers manual are outgrower farmers, through company extension officers, whilst company managers are the target audience for the DSS. These tools are designed to encapsulate the scientific findings from the project and integrate them with best-practice knowledge in a user-friendly format. A survey of the harvest results from the first cohort of outgrowers under the MHP scheme showed that yields obtained by outgrowers were only about 50% of those obtained by the company in nearby plantings (around 90 $m^3$/ha/rotation compared to around 180 $m^3$/ha/rotation), suggesting that outgrowers were not managing their plantations optimally, and could benefit from a tool such as the Growers Manual to assist them in making the best management choices.

An economic analysis demonstrated that improved management could increase the net return (in present values) by around $636 to growers, which equates to around $530/year for an average land-holding of 5 ha by outgrower farmers. Currently the profits from the plantations are divided between the company (60%) and outgrower (40%). The proportion is higher for the company to account for the upfront expenses that are borne by the company. However an analysis of these costs indicated that this split represented an implied interest rate of approximately 22%, which supports the perception amongst outgrowers of an inequitable profit sharing arrangement, and a change to this arrangement would potentially improve uptake of *A. mangium* planting in the future.

This project has potential for significant impact in Indonesia, with considerable scope to improve the productivity and profitability of outgrower farmers in South Sumatra, and for validating these findings beyond South Sumatra. The Indonesian Government, through the Ministry of Forestry, has established the “Hutan Tanaman Rakyat” programme to double the production of pulpwood by 2020. This will require a large and sustained effort into promoting and supporting smallholder farmers, whom it is anticipated will grow around 40% of the feedstock required. It is estimated that around 360 000 additional smallholder farmer families will be required to meet this target, all in Sumatra and Kalimantan. There are 2 apparent and significant technical issues that need to be addressed for this programme to be successful, including (1) the significant scope for improvement of plantations on outgrower land that has been identified through this study, and (2) root rot is becoming a significant threat to survival in many plantations, and this may require a species change at some stage in the future to overcome the problem. There is also an apparent need for farmers to be able to value add to their plantations through providing an option for sawlog as well as pulpwood.

# 3 Background

This project was established to explore the need to match the management of *Acacia mangium* plantations to the genetically improved planting material that is currently being deployed. The key scientific hypothesis that we tested was whether the genetically improved material has a higher requirement for natural resources (water and nutrients), and whether these resources need to be managed more closely to maximise the benefits provided by improved genotypes. The project was targeted towards benefiting smallholder farmers, and to facilitate this we worked in partnership with a key industrial company in the region, PT Musi Hutan Persada, who have strong outgrower and community development schemes. The industrial partner provides the project with a short pathway to adoption as the knowledge and tools generated through the project can potentially be disseminated directly to plantation managers and extension officers.

There is already a large pulp and paper industry based in Indonesia, and there are plans in place to double its size again over the next 10 years. In the past, the feedstock for these mills has been predominantly native forest, with around 1.7 MHa of natural forest having been cleared in the last 20 years to feed Indonesia's pulp industry. However, there is a strong internationally dictated requirement to cease unsustainable logging of natural forest areas and to source wood from sustainably grown plantations. Thus, large areas of highly productive plantations are going to be required to maintain the quantity of feedstock required for these mills. Acacia species are well suited to meeting escalating regional and global demand for wood because they have high growth potential under a range of soil conditions. Acacia wood is highly valued for pulp and paper and more recently in south-east Asia for sawn timber. In Indonesia more than 700 000 ha of Acacia plantations are already contributing strongly to that country's economy. In Australia, around 30 000 ha of *A. mangium* has been established on the Tiwi Islands, with the intention to supply woodchips to the Asian market. Acacia plantations are also expanding in other parts of South East Asia, notably Vietnam and Malaysia.

In Indonesia, companies are expanding the outgrower schemes to increase their capacity for producing wood to feed their installed and planned pulping capacity, actively involving small-holder farmers and local communities. For example, the Musi Hutan Persada (MHP) outgrower scheme, which began in 2001, currently manages approximately 2500 ha of plantations, with plans to increase this area by around 2000 ha/year. The current MHP outgrower scheme:

- provides genetically improved seedlings from company breeding programs,
- pays farmers for all costs (wages and materials) of plantation establishment and maintenance, including site preparation, planting, fertilizer application, singling and pruning, as well as weeding on an ongoing basis,
- pays farmers to harvest their plantation at rotation end, and
- guarantees to buy the wood at market value with the net profit shared between the farmers (40%) and MHP (60%).

The program provides considerable incentive for farmers to grow their woodlots with the best technology and management available to maximise returns from production of wood, and it removes the potential issue of farmers lacking the resources to practice improved management. Many farmers are keen to include wood production as another commodity from the farm to diversify their employment and income. Currently, *Acacia mangium* plantations in South Sumatra are managed on a 6-year rotation, with average yields of around 29 $m^3$/ha/y in the company estate. Managers currently have minimal guidelines for selecting sites, and nutrient management is based on a blanket recommendation of 14 kg P/ha at establishment (applied in the planting hole). Weeds are chemically controlled until canopy closure. The same management guidelines are applied to outgrower farmer plantings as to company plantings, but early indications were that outgrower farmers were not likely to achieve the same productivity levels as the company plantings. Harvesting of outgrower acacias had not commenced as of the start of this project, but this was due to start within the project lifetime, offering an opportunity to assess the productivity of outgrower plantings and the attitudes of these outgrower farmers to *Acacia mangium*.

MHP also has a strong community development scheme (established in 2001), which covers approximately 80 000 ha. The scheme has the following benefits: (1) employment within the local community as paid contractors for plantation operations, (2) return of a production fee, agreed between communities and MHP, to the community at rotation end, and (3) investment in roads (some are all-weather), bridges, schools, clinics, mosques, churches, village offices, cemeteries, water supply installations, electricity, and scholarships and textbooks for students. The project will have direct and indirect impacts on this scheme through helping to increase the income from wood sales, and strengthening the sustainability of the industry through additional wood supply from the plantation resource rather than from native forests.

Development of objective tools to improve site selection and silvicultural management of acacia plantations was also a high priority to maximise the benefits of these plantations for growers and industry. The socio-economic situation for outgrowers also needed to be explored to ascertain the nature of their farming enterprises, and the key drivers for them to participate in acacia plantings, and to adopt new technology such as outputs from this project.

Economic benefits from the project are expected to accrue to smallholder farmers and communities through (i) greater confidence in the ability to grow high-yielding acacia plantations, leading to an expansion in the MHP outgrower scheme, and (ii) increase in productivity of up to 5-9 $m^3$/ha/year, based on conservative estimates from similar work in India on eucalypts). We estimated that the project would return the investment by ACIAR to smallholder farmers within 4-5 years after project completion.

The project was directly aligned with ACIAR focus area ‘Sustainable management of tropical plantations’ within Theme 2: Improving the productivity and efficiency of food crop and forestry systems. It addressed the priority area of “Development of tree farming (out-grower scheme) models with improved smallholder and plantation company cooperation” identified in the “Indicative priorities for ACIAR projects in Indonesia” document, and was envisaged to contribute towards Australia’s “Plantations 2020” vision of trebling plantation area by 2020.

# 4 Objectives

The project aimed to maximise profitability of acacia plantations in Indonesia and Australia and deliver benefits to the small-holder farmers, communities and companies who are growing wood. Underpinning objectives were:

**Objective 1. To quantify the role of site edaphic properties and phosphorus in realising gains from deployment of genetic gain across sites, and to develop appropriate management strategies for maximising productivity and economic value.**

To achieve this objective we surveyed 11 existing plantations and established 26 field experiments from planting (some of these sites were common to the survey plantations) to quantify the response of contrasting genetic material to a range of site edaphic properties, soil phosphorus availability, response to phosphorus fertilizer, and N fixation. We also explored options for diagnosing response to P fertilizer, but we found a relatively common response across the sites that we established, thus obviating the requirement for a diagnostic to make recommendations on P fertilizer applications.

**Objective 2. To develop a capacity to predict potential productivity of *A. mangium* in relation to site factors in Indonesia and Australia**

Key activities supporting this objective were to integrate our current knowledge and learn more about the physiology of *A. mangium* so that we could parameterise the process-based model, CABALA, for this species. The newly parameterised model was validated against growth data from the sites in Objective 1.

**Objective 3. To evaluate economic benefits of improved management in outgrower schemes**

The main task within this objective was to apply simple economic models to the experimental outcomes to determine the most appropriate level of management for each of the stakeholders, including smallholder growers, industrial growers, and communities. This objective was designed to communicate the benefits of management and application of project recommendations in economic terms to facilitate uptake and adoption. The pathway to adoption through industry partners has proven in the past to be direct and to lead to rapid and widespread adoption of project outcomes, so the focus was on conveying this information to company managers and extension staff for wider dissemination.

**Objective 4. To develop practical tools to support improved management**

Key practical tools promised during the project were an operations manual for growing *A. mangium*, and a computer-based decision support system based on CABALA outputs to allow managers to explore predicted productivity under a range of site conditions and management options.

# 5 Methodology

Several methodological approaches were employed to address the objectives of this project, including an analysis of relationships between site edaphic properties and productivity across a range of sites, installation of core experiments to explore the main effects and interactions between genetic improvement and management, installation of satellite sites to understand the response to P fertilizer and relationship with site properties, and targeted physiological campaigns.

## 5.1 Effects of site edaphic properties on productivity

The majority of this work was conducted in Indonesia, with 11 sites selected for detailed soil and plantation assessment. Some key characteristics of these sites are shown in Table 1, and their locations are shown in Fig. 1. The sites were chosen to have a range in productivity, and were also selected to have low or no root rot incidence. The sites had a wide range of soil characteristics, with total C from 1.5 to 4.6%, and Bray P from 4.4 to 11 mg/g. The sites also represented two of the key geographic regions within south Sumatra planted by PT MHP, known as the Subanjeriji and Lematang regions.

*Table 1 – Key site characteristics of the initial survey sites*

| Site name | Age at measure | Standing volume ($m^3$/ha) | Bray P (mg/g) | Phosphate retention index | Total C (0-10 cm, %) | Total N (0-10 cm, %) | Surface soil texture |
|---|---|---|---|---|---|---|---|
| 02 Banding Anyar | 5.5 | 220.8 | 9.25 | 1105 | 3.36 | 0.25 | Silty clay |
| 10 Deras | 2.5 | 15.6 | n/a | 631.3 | 2.35 | 0.24 | Silty clay loam |
| 62 Ibul | 2.5 | 19.1 | 4.39 | 612.6 | 1.24 | 0.18 | Silty clay loam |
| 57 Keruh 1 | 3.5 | 53.7 | 7.91 | 914 | 2.17 | 0.2 | Sandy clay loam |
| 113 Lagan | 4.5 | 140 | 4.35 | 305.1 | 2.34 | 0.23 | Sandy clay loam |
| 115 Lagan | 2.5 | 62.9 | 4.77 | 557.3 | 1.47 | 0.22 | Silty clay loam |
| 134 Lagan | 2.5 | 16.3 | 5.39 | 684.6 | 2.41 | 0.26 | Silty clay |
| 75 Niru | 5.5 | 156.5 | 10.52 | 1027.6 | 4.64 | 0.32 | Silty clay loam |
| 79 Niru | 4.5 | 96.8 | 12.86 | 557.3 | 1.08 | 0.22 | Silty clay loam |
| 232 Niru | 5.5 | 226 | 11.01 | 1202.2 | 4.21 | 0.3 | Silt loam |
| 119 Subanjeriji | 5.5 | 226.8 | 8 | 1086.1 | 2.7 | 0.24 | Silty clay loam |

**Figure 1 – Map of locations of initial survey sites**

These sites (referred to as the initial survey sites) were characterised in a significant degree of detail, including soil descriptions (from pits dug to approximately 1.5 m), general surface soil chemistry (including total N, total C, Colwell K, electrical conductivity, pH, exchangeable cations, boron, aluminium, DTPA trace elements), and a range of potential diagnostics of P availability, including total P, Colwell P, Bray P, P buffering index, and acid extractable P. The key methodological reference for these analyses was Rayment and Higginson (1992).

Plantation productivity was assessed at the same location as the soil characterisation by measuring height and diameter at 130 cm on every tree in a diamond plot (0.5 ha), located at the same place as the soil characterisation. The tree dimensions were converted to standing volume using the standard volume equation of PT MHP, which was checked against the conical volume model as an independent measure of volume.

Climatic variation across the sites was explored but not used in this analysis because the source data does not have a high enough spatial resolution to be useful for comparing against sites.

Effects of site edaphic properties on productivity potential was assessed by exploring relationships between standing volume and soil properties.

## 5.2 Core experiments

The aim of the core experiments was to explore the effects of, and interactions between, phosphorus fertilizer, site and genotype. Two sites were established initially, at South Sodong (April 2007) and Lematang (February 2008). Locations of the core experiments are shown in Fig. 2. However the South Sodong experiment was abandoned at age 2 years because of high root rot infestation rates. A replacement experiment was established at Gemawang (April 2008). Based on first rotation productivity, the South Sodong/Gemawang experiments were located on high productivity sites, and the Lematang site was a low productivity site.

**Figure 2 – Locations of the core experiments**

### 5.2.1 Experimental design

The core experiments consisted of a phosphorus rate trial with the best genetic material, with rates of 0, 10, 40, 100, and 200 kg P/ha applied as triple super phosphate (referred to as P0, P10, P40, P100, and P200, respectively). Each of these treatments also had a basal fertilizer application (see Table 2) to ensure that no other nutrients were limiting. An additional treatment at each experiment was the P100 treatment without any basal fertilizer, to test the response to all nutrients other than P. The P0 and P100 treatments were applied to a range of genetic material. The genetic material used in the experiment effectively corresponded to different seed sources (provenances) as the breeding strategy currently focuses on identifying the best performing provenances rather than crossing between provenances (see Table 3 for details). The 'unimproved' and 'moderately improved' seed sources are likely to perform similarly as they are derived from the same seed source, whilst the 'best' and 'common' seed sources are likely to also perform similarly as they have been selected for high productivity. The latter group is likely to show a volume production increase of 30-50% over the former group (Harwood pers. comm.). The 'common' seed source was also included in the design in Australia, thus was common across both countries.

*Table 2 – Basal fertilizers applied*

| Nutrient | Quantity (kg element/ha) | Fertilizer form |
|---|---|---|
| N | 46 | Urea |
| K | 41.6 | Potassium chloride |
| Ca | 27.8 | Hydrated lime |
| Mg | 2.4 | Magnesium sulphate |
| Zn | 0.77 | Zinc sulphate |
| S | 1.48 | Sulphate salts |
| Mo | 0.04 | Sodium molybdate |
| Mn | 1.92 | Manganese carbonate, Manganese sulphate |
| Fe | 12.8 | Iron sulphate |
| Cu | 0.78 | Copper sulphate |
| B | 0.08 | Boric acid |

*Table 3 – Level of breeding and matching genotypes used in this experiment*

| Genetic improvement level | Short name | Seed source |
|---|---|---|
| Inferior land race | Unimproved | Subanjeriji landrace |
| Slight improvement from inferior land race | Moderately improved | Seed from seed production area established using selected trees from Subanjeriji land race |
| Improved seed developed from superior natural provenance | Best | Seed from the first generation of seedling seed orchard from Muting (West Papua) origin |
| Superior natural provenance | Common | Wipim Oriomo |

The matrix of treatments applied in the core experiments is shown in Table 4. The treatments were established in a randomised block design with 4 replications. The plots were square with 36 outer trees (6 rows by 6 trees per row), and 16 measure trees per plot. Tree spacing was 3m by 3m.

*Table 4 – Matrix of treatments (shaded cells indicates that the treatment was included in the design)*

| P level (kg/ha) | Basal fertilizer | Unimproved | Moderately improved | Improved | Common |
|---|---|---|---|---|---|
| 0 | + | ■ | ■ | ■ | ■ |
| 10 | + | | | ■ | |
| 40 | + | | | ■ | |
| 100 | + | ■ | ■ | ■ | ■ |
| 200 | + | | | ■ | |
| 100 | - | | | ■ | |

Weeds were controlled across the experiments by herbicide application.

### 5.2.2 Productivity assessments

Productivity was assessed across the sites with measurements of individual tree height and diameters at 0.5, 1, and 2 years. Productivity at Sodong was measured up to age 1, after which it was abandoned due to root rot infestation. Standing volume was calculated from individual height and diameter measurements using a volume equation derived by PT MHP.

## 5.3 Satellite Experiments

The key aims of the satellite experiments were to (1) understand the productive potential across the range of site types and climatic regions, and (2) to explore and develop diagnostics of P fertilizer response across a wide range of sites. A number of satellite sites were also established on Melville Island. The satellite sites in South Sumatra were established on a subset of the same sites examined in the site edaphic properties study (above). These sites were clear-felled in late 2006 or late 2007 and re-established with our experimental treatments in early 2007 or early 2008, respectively.

*Table 5 – Key properties of the satellite sites established in South Sumatra and Melville Island*

| Site | Establishment date | Productivity measurements at age (y) |
|---|---|---|
| South Sumatra | | |
| Keruh 57 | January 2008 | 0.5,1,2 |
| Ibul 62 | January 2008 | 0.5,1,2 |
| Lagan 115 | February 2008 | 0.5,1,2 |
| Lagan 44 | February 2008 | 0.5,1,2 |
| Lagan 113 | February 2008 | 0.5,1,2 |
| Niru 75 | February 2007 | 0.5,1,2,3 |
| Niru 79 | February 2007 | 0.5,1,2,3 |
| Niru 232 | February 2007 | 0.5,1,2,3 |
| Subanjeriji 119 | February 2007 | 0.5,1,2,3 |
| Banding Anyar 2 | February 2007 | 0.5,1,2,3 |
| Toman II | February 2007 | 0.5,1,2,3 |
| Melville Island | | |
| Taracumbi 5 | February 2007 | 0.5, 1.5 |
| Pickertaramoor 2 | February 2007 | 0.5, 1.5 |
| Andranangoo 4 | February 2007 | 0.5, 1.5 |
| Andranangoo 3b | February 2007 | 0.5, 1.5 |
| Pickertaramoor 3 | February 2008 | 0.5 |
| Pickertaramoor 11 | February 2008 | 0.5 |
| Andranangoo 11 | February 2008 | 0.5 |
| Bremer 11 | February 2008 | 0.5 |
| Tuyu 37 | February 2008 | 0.5 |
| Taracumbi 8 | February 2008 | 0.5 |

The key treatments installed at the satellite sites in Indonesia were a range of P rates, including 0, 10, 50 and 150 kg P/ha (P0, P10, P50, and P150, respectively), all applied with the same basal fertilizer mix as the core experiments (Table 2). In Australia, the satellite experiments had P rate treatments of 0, 10, 40, 100, and 200 kg P/ha (P0, P10, P40, P100, P200, respectively), all applied with a basal fertilizer mix (consisting of 75 kg/ha Micromax (Scotts Australia), 100 kg/ha potassium sulphate, 100 kg/ha urea, and 100 kg/ha gypsum), and an additional treatment of 100 kg P/ha without basal fertilizer (referred to as X100). The satellite sites in Indonesia were planted with the ‘best’ genetic material, whilst those in Australia were planted with the ‘common’ genetic material.

The locations of the sites in South Sumatra are shown in Fig. 3, and the Australian sites in Fig. 4.

Plot sizes in Sumatra were the same as in the core experiments (16 measure trees), whilst plot sizes in Australia were also 6 rows by 6 trees/row (with 16 inner measure trees), but the row spacing was 4 m, with 2.25 m between trees.

**Fig. 3 – Locations of the satellite sites in South Sumatra, also showing the locations of the town of Mauraenim and PT MHP region bases of Lematang and Subanjeriji.**

**Fig. 4 – Locations of the satellite sites in Australia**

## 5.4 Additional experimentation

In addition to the planned core and satellite experiments, two other experiments were established to assess N fixation (Lagan 134), and to start exploring the interactions between weed control and P fertilizer application (Niru 249). An N-fixation component was added to the 3$^{rd}$ core experiment at Gemawang 72. The key additional treatment in the N fixation experiments was the addition of an *E. pellita* treatment to act as a reference plant when determining N fixation through the natural $N^{15}$ abundance technique. This formed part of the PhD studies of Gunawan Wibisono (ACIAR John Allwright Fellow). The weed control x P rate experiment was established to determine whether there was some ability to substitute between weed control and addition of fertilizer, to ensure that our recommendations were not influenced by the fact that the experimental plots were maintained in a weed-free condition. The treatments imposed in this experiment included the matrix shown in Table 6.

*Table 6 – treatments imposed in the weed control x P rate experiment (shaded cells indicate treatments that were included in the design)*

| P rate (kg/ha) | Weed maintenance* Chemical (good) | Manual (poor) |
|---|---|---|
| 0 | ■ | ■ |
| 10 | ■ | |
| 20 | ■ | ■ |
| 40 | ■ | |
| 100 | ■ | ■ |
| 200 | ■ | |

The experiment comprised of 4 replications in a randomised complete block design, with 36 tree plots (16 inner measure trees). This experiment was established in April 2009.

## 5.5 CABALA Parameterisation

A key part of the project was to understand more about the physiology of *Acacia mangium* so that we could develop a parameter set to allow CABALA to model its productivity. Some of this information was collected from a search of the literature, but we needed to collect much of it ourselves during the project. Two key field campaigns were undertaken for this part of the project, both on Melville Island, in April 2007 (at the end of the wet season), and in September 2007 (at the end of the dry season). These campaigns were designed to assess physiological responses when there was no water limitation (April) and when the trees were highly water stressed (September). A supplementary campaign was conducted in Sumatra in October 2007.

An additional species, *A. crassicarpa*, was included in the physiology campaigns on Melville Island because it provided an interesting contrast in productivity in relation to environment – it had been qualitatively observed that *A. mangium* grew faster in the wet season than *A. crassicarpa*, but that *A. crassicarpa* continued growing further into the dry season, so we included this species in the design. The intensive physiology was conducted at a species trial that had been previously established by Great Southern Limited in the Yapilika compartment, near their base camp. The species trial included *A. mangium*, *A. crassicarpa*, and *E. pellita* in a replicated design.

During the wet season campaign (when the trees were not water limited), leaf responses to different levels of light, $CO_2$ and temperature were assessed using a LI-COR 6400 portable infra-red gas analyser. Responses to each of these factors were assessed individually rather than in combination.

At each of the Melville Island campaigns, and in Sumatra, a diurnal course of gas exchange and water potential was collected, with assessment of leaf gas exchange (allowing instantaneous assessment of photosynthetic rate and stomatal conductance) approximately every 2 hours using a CIRAS portable infra-red gas analyser. A coincident measure of leaf water potential was assessed at each time by collecting leaves from the upper 1/3 of the canopy and placing in a sealed bag on ice until their water status was able to be assessed using a pressure chamber, with measurements made within about 30 minutes after collection.

We also constructed allometric relationships relating tree height and diameter to biomass of leaf, stem wood, stem bark, and branch material.

Sapflow meters were installed in April 2007, and these were maintained through the dry season until September 2007. However, whilst the early data from this equipment was satisfactory, it became less consistent later in the dry season because it deteriorated faster than expected under the conditions on Melville Island. Missing data was patched using an algorithm which calculated unbiased arithmetic means for the faulty equipment, based on a comparison of results from when it was operational to the other operational equipment at any given time.

To get an integrated assessment of water stress that the two species were subjected to on Melville Island, leaf samples were collected from each species in dry (September 2007) and wet (April 2009) conditions for isotopic analysis. These samples were analysed for $\delta^{13}C$, which can be used to understand the level of water stress that the trees were subject to at the time that their carbon was fixed.

The data collected was used to develop a version of CABALA parameterised for *A. mangium*.

## 5.6 Economics

A cost-benefit analysis for the Indonesian situation was conducted based on the project recommendations. The costs of inputs were identified based on discussions with company managers and extension staff.

A more detailed analysis was conducted by the University of Sriwijaya, addressing 2 specific questions raised in relation to economic revenue that might actually benefit the outgrower farmers (specifically called MHR participants in the program with PT MHP), namely:

(1) Does MHR acacia provide a competitive net income to out-grower farmers, and could the program be made more attractive with a better package of biophysical research output?

(2) What changes are required to improve comparative advantage of the acacia outgrower scheme relative to other traditional crops?

## 5.7 Social studies

This study was sociologically aimed at formulating a systemic interface for effective delivery of new technical information or technological innovation for the tree crop agribusiness to achieve higher productivity and profitability, to benefit the outgrowers and the local economy. The delivery mechanism was targeted to avoid factors which may reduce positive responses from the target community.

(1) With the existing MHR's service procedure would current outgrower farmers readily participate in a second rotation?

(2) What kind of non-agribusiness information could appropriately encourage potential outgrowers to participate in the program?

## 5.8 Integration

CABALA was used to integrate the biophysical information and contribute to producing the project outputs, the DSS, and lookup tables. The *A. mangium* version of CABALA developed above (Section 5.5) was used.

### 5.8.1 Climate data

Good climate information is essential for running process-based models. In this study we used both gridded and locally collected climate information. In Australia we used the SILO (Jeffrey et al. 2001) gridded climate information (resolution of 0.05 degrees), however the accuracy of this information was found to be questionable for Melville Island because local orographic effects caused greater spatial variation in rainfall than could be accounted for by interpolation between the limited number of weather stations installed on the island. Thus we also used rainfall information collected locally for the duration of the study. For the sites in Indonesia we used gridded climate data (0.5 degree resolution) from the Climate Research Unit at the University of East Anglia (Mitchell et al. 2004). The gridded data was useful for exploring climate variability in the past 100 years. The gridded data was supplemented with locally collected rainfall data from Maxwell Creek (Melville Island) and Subanjeriji (South Sumatra).

### 5.8.2 DSS and lookup tables

A decision support system to allow managers and extension officers to explore productivity under a range of scenarios was developed as an Excel spreadsheet. Underlying the database is a series of pre-run CABALA scenarios, with a fixed combination of soil characteristics (depth soil organic carbon), planting month, and number of dry months in the growing year. The DSS uses fuzzy logic to predict the closest match to the users input site characteristics from the database of CABALA outputs. A subset of the underlying CABALA outputs were used in the development of the lookup tables for the growers manual (see next section).

### 5.8.3 Growers Manual

A growers manual (Appendix 3) was developed for Indonesia based on our current understanding of best-practice methods for site selection and management.

# 6 Achievements against activities and outputs/milestones

| no. | activity | outputs/ milestones | completion date | comments |
|---|---|---|---|---|
| 1.1 | Conduct field experiments to quantify the response of contrasting genetic material to (1) a range of water availability, (2) a range of soil phosphorus availability, and (3) response of A. mangium to phosphorus | A module of the final DSS that estimates productivity increases potentially achievable through deployment of planting stock at various sites, interaction with management | | A total of 16 experiments were established in Sumatra, and 10 on Melville Island, exploring (a) the interactions between genotype, site properties and nutrient management, (b) response to P fertilizer across different edaphic and climatic conditions, and (c) the interaction between weed management and P fertilizer addition, and (d) nitrogen fixation.<br>An Excel-based spreadsheet DSS was produced by the project, which has been road-tested by industry staff, and was released in April 2010. The DSS includes anticipated productivity response to site factors including soil depth (as defined by our project-derived methodology), soil fertility, rainfall, length of wet season, and harvest age. A key finding of the project was that the key property of soil depth can be characterised in the field using simple methodology, and this has a significant bearing on the site productive potential. |

| | | | | |
|---|---|---|---|---|
| 1.2 | Develop simple indices of phosphorus requirement, including broad soil descriptions, land-use history, and diagnostic tests. | Tools to underpin phosphorus fertilizer management guidelines | | A number of diagnostics of response to phosphorus fertilizer were screened, with key factors of soil depth and soil texture influencing response at age 12 months. However, responses to higher levels of P tended to decline by age 3, such that optimal returns were found with the lowest rate of P applied. Thus the growers manual recommends a fixed rate of P application of 45 g of triple super phosphate, which is lower than the current operational application of 70 g of triple super phosphate.<br><br>It was recognised in retrospect that this result may have partly been a consequence of an interaction with the full weed control practiced in our experiments, because we observed that the fertilized trees reached canopy closure up to a year ahead of the un-fertilized trees. To explore this possibility we established a separate experiment to explore the potential interactions between weed control and P fertilizer application. Preliminary outcomes at 12 months from this experiment are suggesting that the effects of weed control and P fertilizer use are additive rather than interactive, so it does appear feasible to trade off the management of weeds against fertilizer application, but the best gains are to be made through a combination of both practices.<br><br>A further finding of relevance to P fertilizer recommendation guidelines is that we found a residual benefit of P fertilizer applied in the previous rotation, so the effect of P fertilizer is long lasting. |

*PC = partner country, A = Australia*

## *Objective 2: To develop a capacity to predict potential productivity of* A. mangium *in relation to site factors in Indonesia and Australia*

| no. | activity | outputs/ milestones | completion date | comments |
|---|---|---|---|---|
| 2.1 | Parameterisation of the CABALA model for A. mangium, using a combination of existing published physiological data and data collected from older stands. | Model parameterised and available for project staff to predict productivity in Indonesia and Australia | | A significant amount of physiological data was collected, primarily on Melville Island, but with some supporting information from Sumatra. This included:<br>• Photosynthetic responses of *A. mangium* and *A. crassicarpa* to light and $CO_2$ availability under well watered and low water availability conditions<br>• Diurnal courses of gas exchange of *A. mangium* and *A. crassicarpa* on Melville Island under dry and wet conditions, and *A. mangium* in Sumatra under typical (wet) conditions.<br>• Studies on N fixation under different fertility conditions (PhD project)<br>This information, along with a range of information from the literature, was integrated into a preliminary CABALA parameter set. |

| | | | | |
|---|---|---|---|---|
| 2.2 | Validation of the new CABALA™ parameter set against the experiments established by the project | CABALA™ validated for A. mangium in Indonesia and Australia | | The newly developed CABALA parameter set was validated against observed productivity at 15 sites across both Sumatra and Melville Island. A few of the parameters needed slight modification to improve the prediction, but the modelling efficiency (degree of fit between model predictions and observed productivity) across the dataset was 0.89, suggesting a strong correlation between model output and actual productivity.<br>However, early growth in the experimental sites grown from establishment was higher than observed at the validation sites, which required a rethink of the CABALA model and resulted in changes to the model to include (1) changes in predictions of diurnal gas exchange, (2) changes in response of trees to soil water deficit, (3) inclusion of mortality due to water stress on hot days, (4) revising the treatment of the volume model within CABALA, and a number of other minor model changes. |
| 2.3 | Development of lookup tables of potential productivity based on broad climatic and edaphic information | Tables of productivity based on broad climatic and edaphic information | | A subset of information derived for the DSS was extracted in tabular form and included in the growers manual, which allowed the growers to see the productivity and profitability impacts of establishment and management of *A. mangium* in soils with different depths, dry season length and soil fertility. These lookup tables also allow growers to track productivity at annual time-steps, thus they can determine whether productivity is meeting expectation, and/or whether management needs to be improved to achieve productive potential. |

*PC = partner country, A = Australia*

### *Objective 3: To evaluate economic benefits of improved management in outgrower schemes*

| **No.** | **activity** | **outputs/ milestones** | **completion date** | **comments** |
|---|---|---|---|---|
| 3.1 | Application of economic models (NPV, IRR) to the experimental outcomes to determine the most appropriate level of management for the stakeholders | Report on best-bet package of practices for maximum returns to stakeholders | | The economics of growing acacias under different site, climatic and management regimes were calculated from a growers perspective, and these were included in the growers manual as indicative returns from high and low productivity stands. The economic benefits of acacias were also calculated from the perspective of the company, the local government, and the region (district). The key findings were that growers could increase the NPV of their plantations by \$636 by using improved management, and potentially more than this if the productivity potential of many sites is realised. |

| | | | | |
|---|---|---|---|---|
| 3.2 | Prepare and convey the outcomes of a case for the stakeholders to apply the appropriate level of management to give maximum returns | Document and/or presentation outlining the reason for adoption of any new practices that are recommended | | The economic benefits have been presented in 2 ways:<br>• The growers manual gives indicative returns from stands of different productivity<br>• A final project workshop held at Sriwijaya University on April 13th, 2010, entitled (translated from Bahasa Indonesia), "Social Forestry for wood production – involving industry, communities and local government to generate wealth and protect the environment." Attendees to the workshop included academics, provincial forestry service staff, and NGO's, representing several provinces in Sumatra as well as Sulawesi and Kalimantan. |

## *Objective 4: To develop practical tools to support improved management*

| No. | activity | outputs/ milestones | completion date | comments |
|---|---|---|---|---|
| 4.1 | Preparation of an operations manual based on the project outcomes | Operations manual | | An operations manual (referred to hereafter as a Growers Manual) was produced to help growers in Indonesia make the best management decisions in growing acacia plantations. The project socio-economic studies demonstrated that small growers are typically educated to at least high school level, and so are literate and have the capacity to utilize the manual effectively. We originally planned to produce a manual for growers in Australia as well, but the collapse of our industrial partner precluded this from being achieved. The growers manual was made available at the final workshop and at any time upon request to UGM |
| 4.2 | Integration of modelling and experimental results into a software package for use by managers and company extension staff especially working with small growers | Decision support system software | | An Excel-based DSS tool was developed through the project, and included feedback received during specific feedback sessions with industrial representatives (managers and extension officers). This tool is a companion to the operations manual, and allows the user to explore a greater diversity of potential site, climatic and management scenarios than the lookup tables in the manual. A promotional flyer has been produced which gives an overview of the project and its findings, and give a link to UGM for further information and/or copies of the growers manual and DSS. |
| 4.3 | Training of managers, extension officers and FORDA staff. | Extension officers trained and ready to start extending project outcomes | | Training of MHP managers and extension staff has occurred, and they have provided useful feedback to improve the utility of the release version of the DSS. The DSS is being demonstrated at the final workshop to a wider audience, including several FORDA staff and provincial government forestry staff.<br>In addition, specific training for FORDA staff was completed on 8 June, 2010. |

# 7 Key results and discussion

## 7.1 Effects of site edaphic properties on productivity

Sites and soil profiles were described according to FAO (1990). Productivity of *Acacia mangium* grown by PT Musi Hutan Persada is ranked according to the following levels: High productivity (> 30 $m^3$/ha/y MAI over the rotation), Medium productivity (20 to 30 $m^3$/ha/y MAI), and Low productivity (<20 $m^3$/ha/y MAI). According to this classification, there were 5 high productivity, 2 medium productivity, and 5 low productivity sites in this study (Table 7). It is important to note that the sites are different ages at the time of measurement, so the productivity levels are not directly comparable because MAI is not constant over the rotation – it is generally lower in the first year of growth, higher for the next few years, and likely to decline again towards the end of the rotation.

*Table 7. Description of the* Acacia mangium *stand at each location*

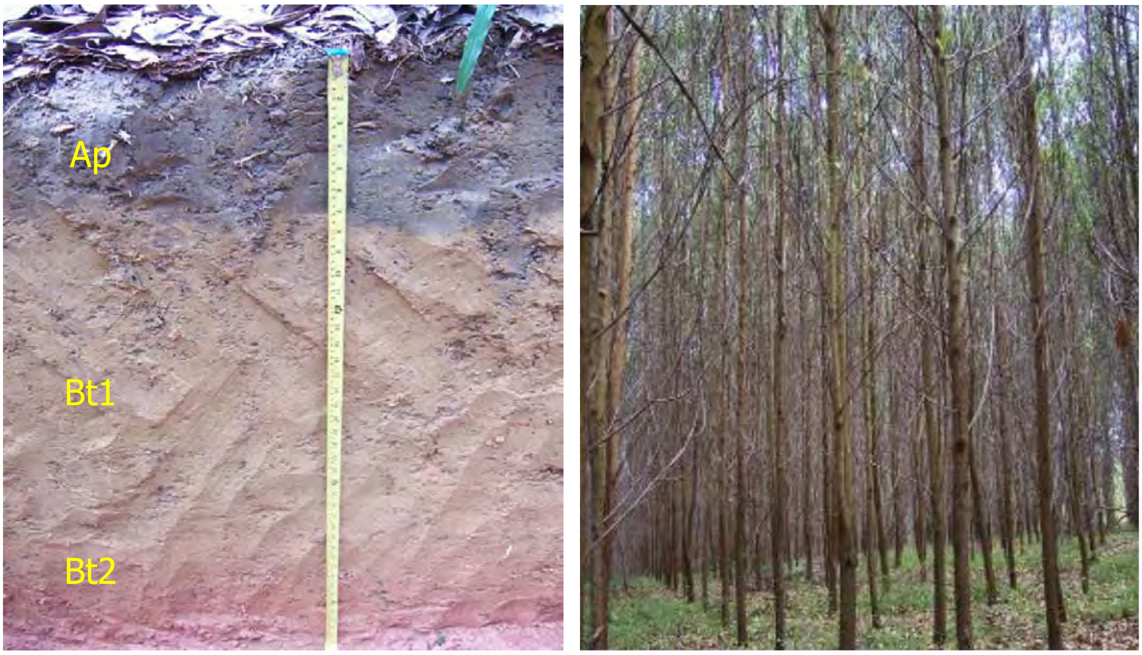
| Soil Codes | Region | Age (yr) | Stocking (stems/ ha) | Ave. height (m) | Ave. diameter (cm) | Volume ($m^3$/ha) | Productivity ($m^3$/ha/y) | Product-ivity ranking |
|---|---|---|---|---|---|---|---|---|
| 75 Niru | Subanjeriji | 5.5 | 833 | 20.8 | 15.0 | 156.5 | 28 | Medium |
| 79 Niru | Subanjeriji | 4.5 | 833 | 16.5 | 13.0 | 96.8 | 22 | Medium |
| 232 Niru | Subanjeriji | 5.5 | 666 | 22.8 | 19.0 | 226.0 | 41 | High |
| 119 Subanjeriri | Subanjeriji | 5.5 | 1041 | 22.3 | 15.7 | 226.8 | 41 | High |
| 2 Banding Anyar | Subanjeriji | 5.5 | 854 | 23.8 | 16.1 | 220.8 | 40 | High |
| 44 Lagan | Lematang | 2.5 | 854 | 11.5 | 8.8 | 30.0 | 12 | Low |
| 115 Lagan | Lematang | 3.5 | 833 | 12.8 | 12.3 | 62.9 | 18 | Low |
| 134 Lagan | Lematang | 2.5 | 937 | 7.4 | 7.6 | 16.3 | 7 | Low |
| 62 Ibul | Lematang | 4.5 | 1041 | 19.7 | 12.9 | 140.0 | 31 | High |
| 113 Lagan | Lematang | 2.0 | 833 | 7.9 | 7.8 | 15.6 | 8 | Low |
| 10 Deras | Benakat | 3.5 | 833 | 11.3 | 11.8 | 53.7 | 15 | Low |
| 57 Keruh | Benakat | 4.5 | 770 | 21.8 | 17.5 | 198.0 | 44 | High |

### 7.1.1 Productivity based on Characteristics of Soil Profiles

Many of the results from this part of the project were analysed and written up in Nurudin (2007), which should be referred to for more detail. According to the field description of soil profiles (Appendix 1), there were 2 Inceptisol soil profiles and 10 Ultisol soil profiles. Ultisols are characterized by their Bt (argillic) horizons, red-yellow color, texture of sandy clay loam or clay, structure of sub angular blocky, consistency of firm or very firm, and plinthite or hematite layer in their B horizons. Formation of plinthite or hematite in Ultisols is caused by historical (in geological terms) waterlogging. Ultisols with good drainage tend to form hematite, while plinthite is likely to be formed in poor drainage conditions. Poor drainage is usually caused by clayey texture of Ultisols and it is often associated with formation of gleyed layer. This process is autogleyzation, and is common in Ultisols from the study area, which have undulating relief with deep groundwater table. Inceptisols are characterized by their Bw (cambic) horizons, brown color, clay loam texture, weak medium sub angular blocky structure, and friable or firm consistency. Hematite or plinthite is not found in Inceptisols. This indicates that the studied Inceptisols in this study had good drainage characteristics. Two contrasting examples of the soils in this study are shown in Fig. 5 (low productivity site) and Fig. 6 (high productivity site).

**Fig. 5 Soil profile and stand performance at Lagan 113 (age 2.5, low productivity site). Credit: Makruf Nurudin**


**Fig. 6 Soil profile and stand performance at Subanjeriji 119 (age 5.5, high productivity site). Credit: Makruf Nurudin**




Key soil characteristics associated with the productivity levels found across the sites are shown in Table 8. Low productivity sites were characterised by a shallow plinthite layer and very firm consistency, whilst the high productivity sites had no evident plinthite, and a deep haematite layer. This result suggested that the depth to plinthite could potentially be used as a surrogate for rooting depth, which is supported by its very firm consistency and anaerobic conditions, which are likely to make it poorly accessible to roots.

*Table 8 – Key soil characteristics associated with productivity classes of A. mangium.*

| Characteristic | High productivity sites | Medium productivity sites | Low productivity sites |
|---|---|---|---|
| Plinthite/Haematite | Deep or no haematite | Shallow plinthite/little haematite | Shallow plinthite |
| Drainage | Good | Gley layer with low intensity | Gley layer |
| Colour | Red | Yellow-red | Brown-Yellow |
| Consistency | Firm | Very firm | Very firm |
| Structure | Medium subangular blocky | Strong subangular blocky | Strong subangular blocky |

The different minerals in the soils also impart different colours, which potentially provide another mechanism for rapidly assessing productive capacity. Soil color was measured using a soil colour reader on the basis of two colorimetric systems, i.e. Munsell Method and CIE Method. Colour was assessed on soils after the following three treatments (Souri 2006): Treatment 1; grinding soil (to pass through a 0.1 mm sieve), Treatment 2; grinding and heating soil to 105$^{o}$C, Treatment 3; grinding and heating soil up to 850$^{o}$C. The colour of in the CIE system is represented by three attributes, which are a*(redness-greenness), b*(yellowness-blueness), and L* (darkness-brightness). The value of a*/b* ratio was then calculated as described by Souri (2006). The Munsell colour representation has three attributes, which are hue, value and chroma. From this data the redness rate (RR) can be calculated. The information derived about soil colour is shown in Appendix 2, and a synthesis of this information is presented in Table 9. It shows that higher productivity sites had lower soil colour brightness/intensity, and had more red in the profile.

*Table 9 – Key soil colour relationships with productivity classes of* A. mangium. *Note all colour relationships here are based on soil heated to 850°C, and rankings are given relative to others in the dataset.*

| Characteristic | High productivity | Medium productivity | Low productivity |
|---|---|---|---|
| Intensity (CIE L* attribute) | low | high | high |
| a*/b* | high | medium | Low |

Whilst these diagnostics hold true in general, exceptions do exist, and the quantitative relationships don't necessarily appear very strong. To test the quantitative basis of these observations, we explored the relationships against a site productivity index. This index was calculated as observed productivity divided by the optimal productivity (ie. productivity measured in the long-term experiment at Sodong, near Subanjeriji), which is dependent on site age. The productivity at that site was represented by a linear equation of the form:

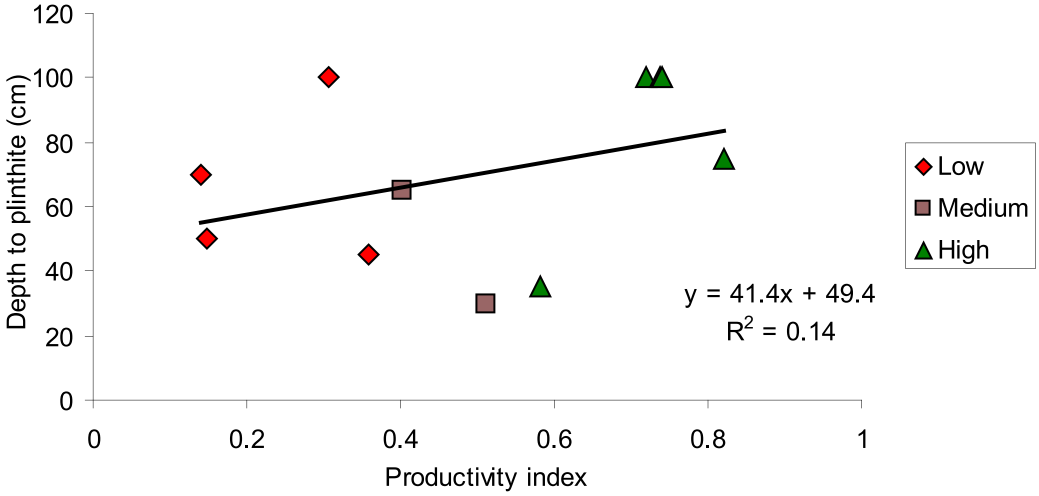
Optimal standing volume = 65 × age -53 (1)

This equates to a CAI of 65 after age 1 year, with a standing volume of 12 at age 1. The linear form of the relationship was strong, with an $R^2$ of 0.99, up to age 6 (the final available measurement). It is important to note that this relationship is not likely to hold much beyond 6 years because CAI will start to decline as the trees age. The productivity index was defined according to equation (2):

Productivity index = observed standing volume/optimal standing volume (2)

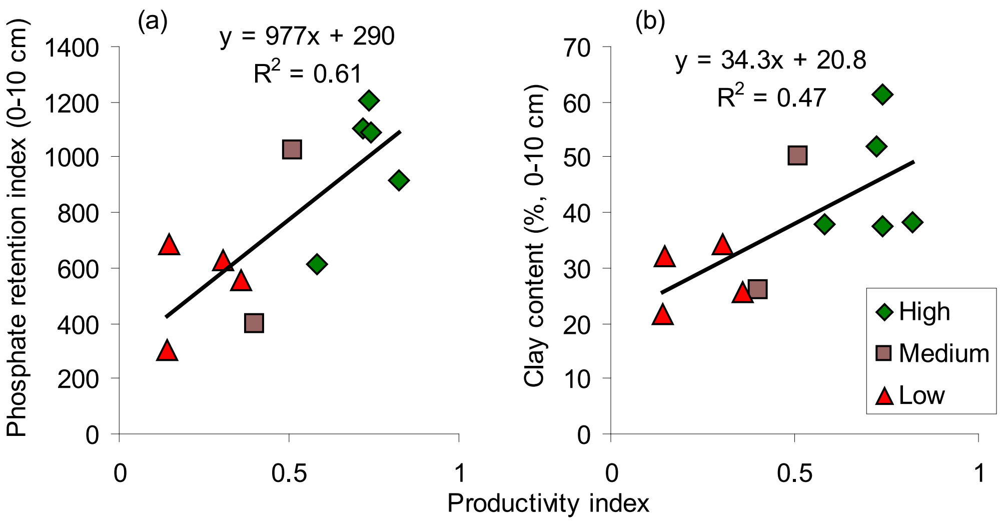
The relationship between depth to plinthite and site productivity index (Fig. 6) shows that lower productivity sites mostly had depth to plinthite of 40-70 cm, whilst the high productivity sites had depths to plinthite of over 70 cm. However, there are several outliers, with a moderate productivity site and a high productivity site both having shallow depths to plinthite (Niru 75 and Ibul 62). Additionally, Deras 10 is classified as a low productivity site but has no evident plinthite in the soil pit that we assessed.

**Figure 6 – Relationship between depth to plinthite and an index rating across the sites, based on the proportion of productivity in a fast-growing experimental stand.**



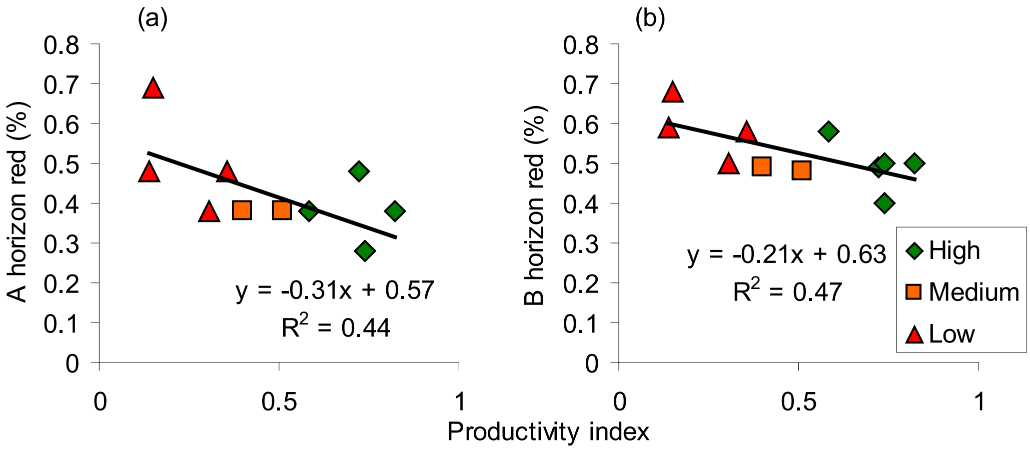

There were other more significant relationships between soil properties and productivity, suggesting that higher productivity was found on sites with higher P retention (Fig. 7a), and on sites with higher clay content in the upper 10 cm (Fig. 7b).

**Figure 7 – Relationships between productivity index and surface soil (a) phosphate retention index, and (b) clay content.**




Soil colour, as calculated from Munsell colours measured in the field, was also found to be a useful predictor, describing 44% (A horizon redness) and 47% (B horizon redness) of the variation in productivity index (Fig. 8)

**Figure 8 – Relationships between horizon redness (assessed through field-obtained Munsell colouration) and productivity index.**




Whilst these relationships were encouraging, it is important to recognise that they were made on existing plantations and of differing ages, so there are potentially confounding effects of management (eg. weed control, planting accuracy, genetic and physiological quality of seedligs etc.) as well as site. For example, the low productivity sites were generally from the Lematang region, and the trees were younger when they were assessed. Most of these sites were harvested and used for experimentation in latter parts of the project, so the experimental results are likely to provide more definitive information about the site productive potential under consistent management conditions. Given the constraints on this data set, we confined our analyses to this level, but the supporting site and soil data is used to analyse the more robust experimental data set in more detail later.

## 7.2 Core experiments

### 7.2.1 Genotype and management interactions

The aim of the core experiments was to understand the main effects and interactions between genotype (breeding level), site, and management. The main effect of P was highly significant at all three sites at age 1 (Fig. 9), but this effect was not carried through to age 2 years at the Lematang site (Fig. 10). However, the Gemawang site was still significantly responsive to P. Gemawang was the least productive of the 3 core sites, suggesting that the productivity at that site may have been limited by P.

**Figure 9 – Main effect of P at 1 year across the 3 core sites. Bars represent least significant difference (P=0.05) within each site, and significance is indicated by ***=P<0.001**

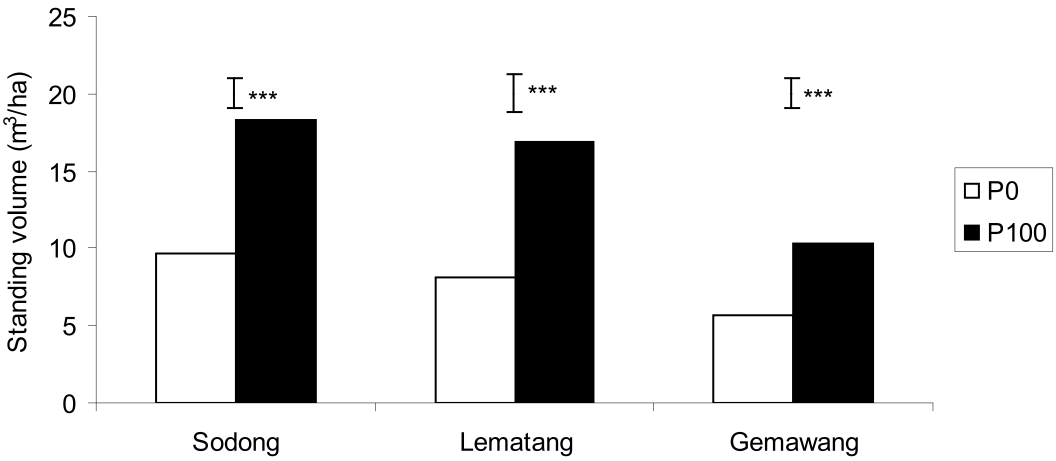
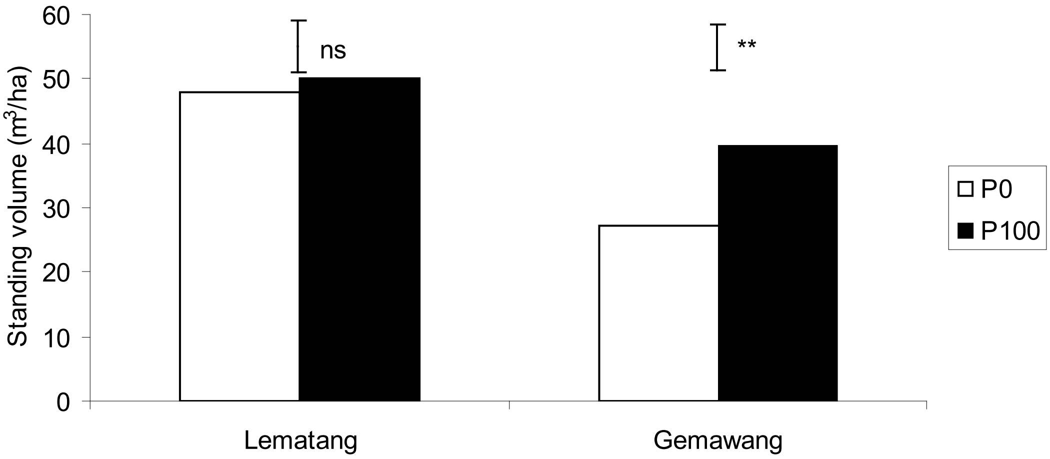



**Figure 10 – Main effect of P at 2 years of age at the older core experiments. Bars represent least significant difference (P=0.05) within each site, and significance is indicated by *** (P<0.001), and * (P<0.05).**




Seed source had a significant effect on the standing volume at age 1 (Fig. 11), especially at Sodong, but it was also significant at Lematang and Gemawang. The ‘common’ seedlot was a common provenance of seed to that used on Melville Island, thus allowing a comparison with the results from Australia. The productivity at each site approximately followed the level of selection, with the ‘best’ seed source performing significantly better than the unimproved land race and improved land race material, however this was not necessarily reflected at age 2 years, where the unimproved seedlot had similar productivity to the best material at Lematang (Fig. 12). The site at Gemawang had a generally lower productivity but followed the anticipated pattern of productivity with respect to level of breeding.

**Fig. 11 – Main effect of seed source across the three core sites at age 1 year. Bars represent least significant difference (P=0.05) within each site, and significance is indicated by *** (P<0.001), and * (P<0.05).**

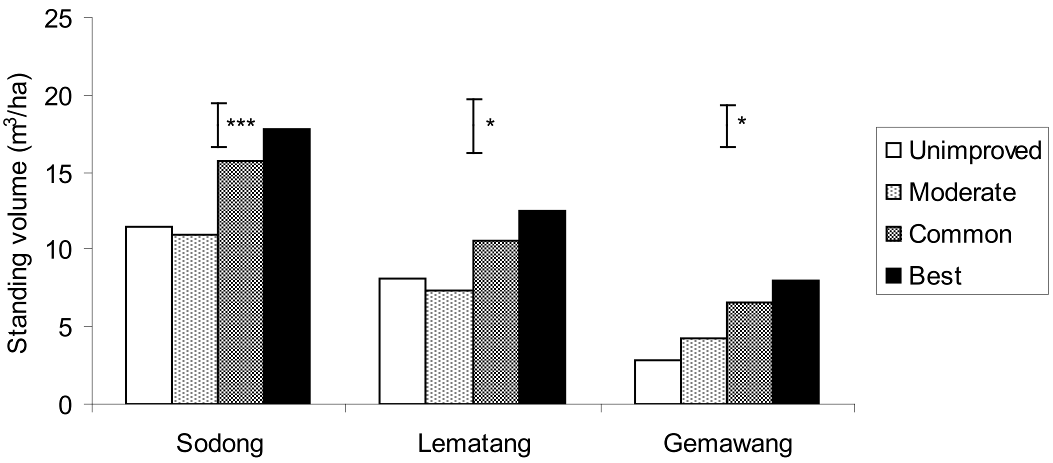
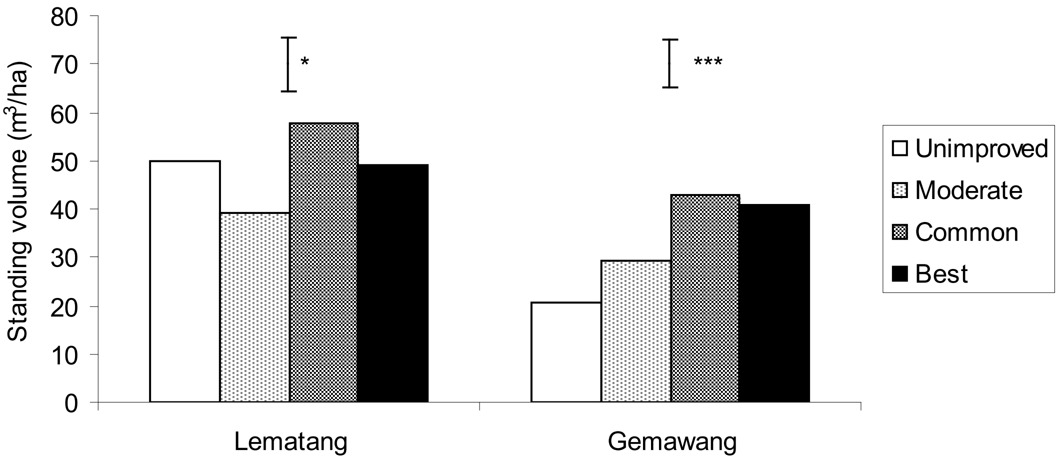



**Fig. 12 – Main effect of seed source across the two older sites at age 2 years. Bars represent least significant difference (P=0.05) within each site, and significance is indicated by *** (P<0.001), and * (P<0.05).**




The only interactions between seed source and P addition were observed at the first established core site at Sodong at age 1 year, with a significant interaction between genetic material and P fertilizer (Fig. 13a), suggesting that maximum productivity gains would require more intensive management to capture the benefit of the genetic gain. However, this interaction was not significant at the other two sites that were established (Gemawang and Lematang), where effects were additive, and the Sodong site was abandoned after age 1 due to root rot infestation. The effects of P and seed source were additive at age 2 years at both of the older core sites (Fig. 14).

**Fig. 13 – Standing volume at age 1 across the core experiments. The interaction at Sodong was significant (bar shows LSD at P=0.05).**

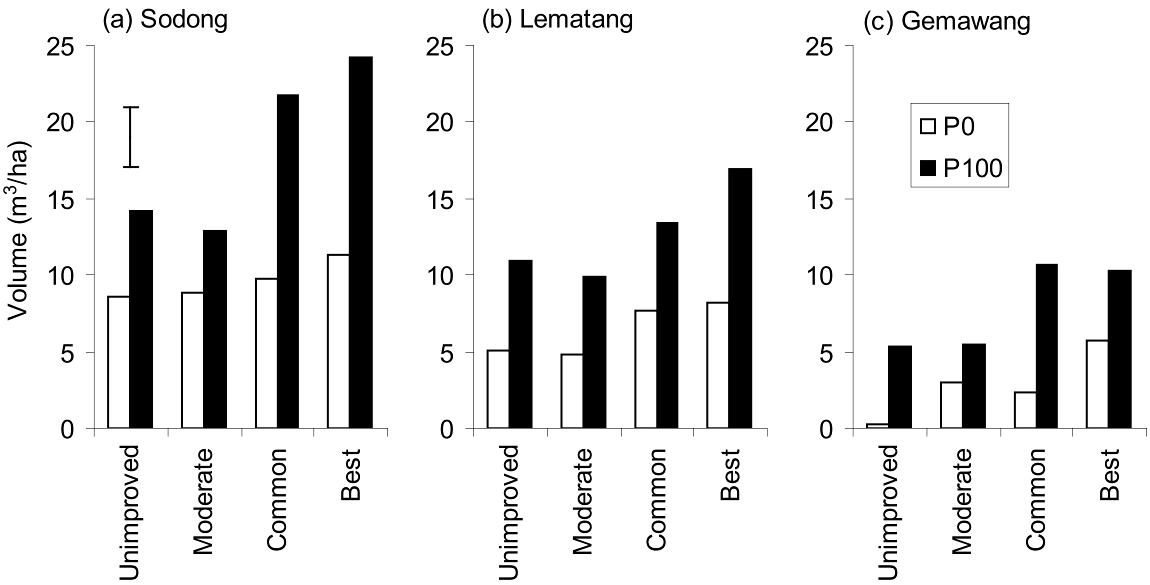
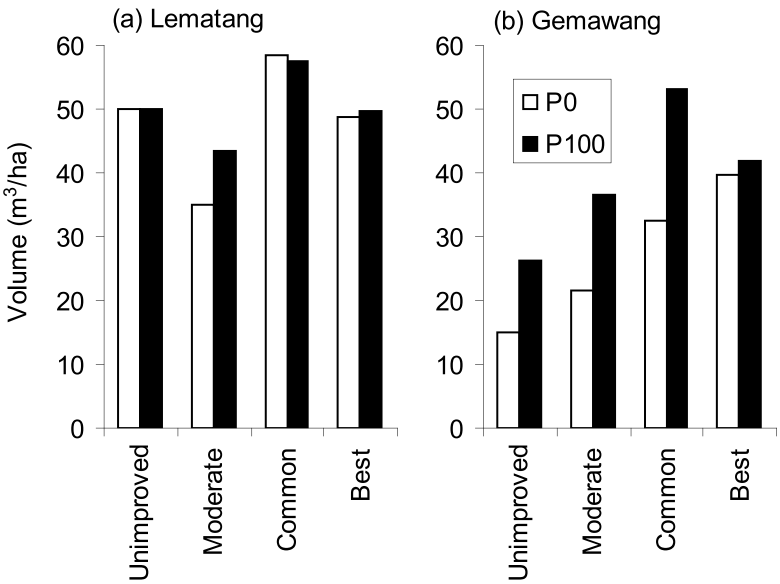



**Fig. 14 – Standing volume at age 2 across the older core experiments**




Whilst not significant, the best genetic material displayed a lower response to P at Gemawang than the other genetic material, such that the 'common' material performed better because it also responded better to P (Fig. 14b). This was probably due to greater mortality in the 'best' treatment at that site, rather than a lack of responsiveness *per se* because there was an absolute response to P in three of the four replicates. The mortality observed in the 'best' treatment did not appear to be attributable to any readily identifiable factor.

### 7.2.2 Effect of basal fertilizer

Application (or omission) of basal fertilizer did not significantly affect the productivity at either of the core sites in Indonesia (Table 10), but it did have a significant impact on productivity at the Melville Island sites. Every site had higher productivity in the treatment with P and basal fertilizer (P100), compared to that with P only (X100). Whilst this difference was significant only at 3 of the 9 sites at 6 months (Figure 15), the effect was more prevalent in the sites measured at age 1.5, where the effect was significant at 3 of the 4 sites. It needs to be recognised that this treatment was included to complement the main design, thus the statistical power of the 2-way comparison is relatively low, so a P value of 0.1 was used as the criterion for significance.

*Table 10 – effect of basal fertilizer on productivity at age 2 at the older core sites.*

| Fertilizer | Lematang | | | Gemawang | | |
|---|---|---|---|---|---|---|
| | Height (m) | Diameter (cm) | Volume ($m^3$/ha) | Height (m) | Diameter (cm) | Volume ($m^3$/ha) |
| No basals | 11.5 | 11.8 | 54.1 | 9.4 | 11.4 | 40.8 |
| With basals | 10.2 | 11.6 | 56.6 | 8.6 | 11.9 | 37.3 |

**Fig. 15 – Effect of basal fertilizer on standing volume at the Melville Island sites at age 6 months. Significance of each comparison is shown, where P<0.1='*'.**

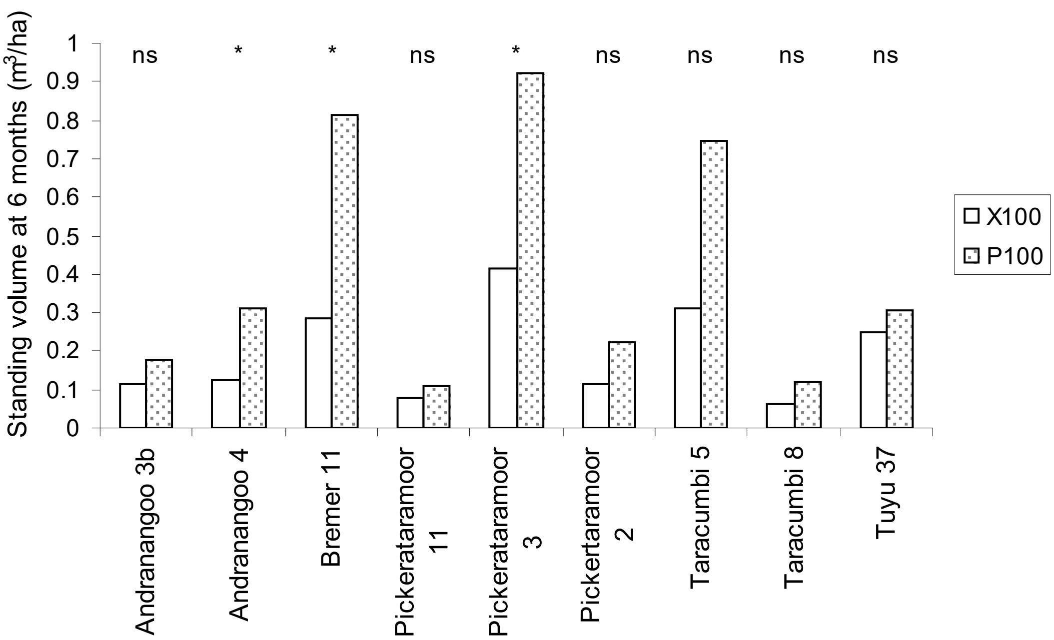
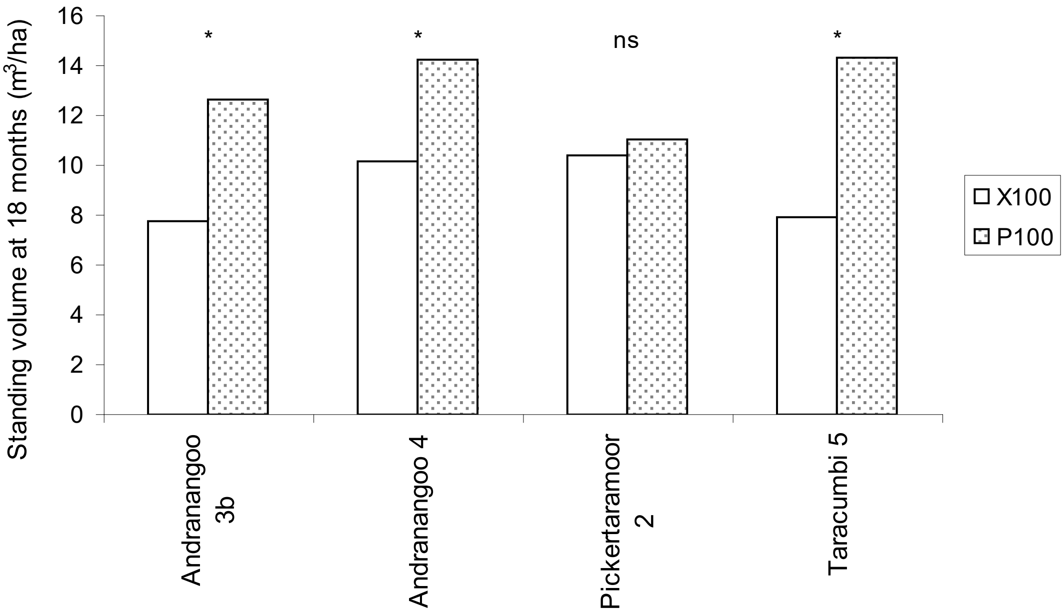


**Fig. 16 – Effect of basal fertilizer on standing volume at the Melville Island sites at 18 months. Significance of each comparison is shown, where P<0.1='*'.**

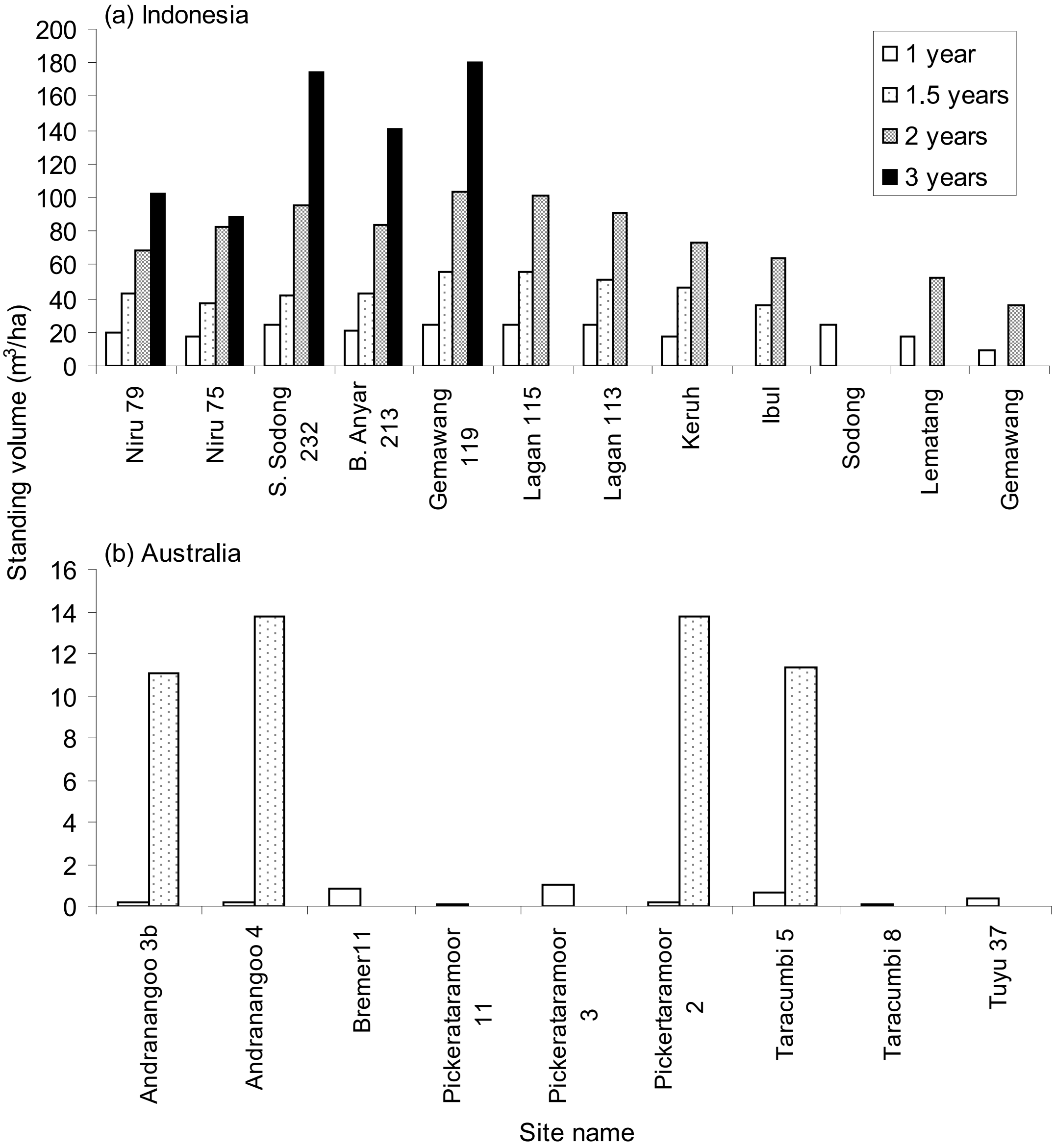



## 7.3 Satellite experiments

### 7.3.1 Site responses

Growth across the satellite sites in both Indonesia and Australia was variable, with generally much higher productivity in Sumatra compared to Australia (Fig. 17). Average productivity at age 1.5 years (the latest age for comparison between the two series of experiments) was 45.7 $m^3$/ha in Sumatra, and 12.5 $m^3$/ha in Australia. The sites that had been measured up to age 3 years were starting to show some interesting differences in productivity, notably the site at Niru 75 showed very slow growth between age 2 and 3 years, whilst South Sodong 232, Banding Anyar 213 and Gemawang 119 showed very significant productivity increases from age 2 to 3 years.

**Fig. 17 – Standing volume (not P limited) at each measure of the P-rate experiments in Indonesia (a) and Australia (b). Note that not all experiments were measured up to age 3, so some bars are not shown.**




## *Response to P fertilizer*

The sites also differed in their response to P fertilizer – all sites except Keruh had a strong early response to P (Fig. 18), which was very evident on the ground at 6 months to 1 year, with much lower leaf area in the non-P treated plots, although the proportional response tended to decline over time, especially in Sumatra. Whilst the proportional response was generally declining, the actual magnitude of the volume response increased over time at most sites (Fig. 19), with the sites in Indonesia having between 20 and 50 $m^3$/ha additional wood due to the addition of P fertilizer by age 3.

**Fig. 18 – Volume response to P fertilizer across the experimental sites in Indonesia (a) and Australia (b).**

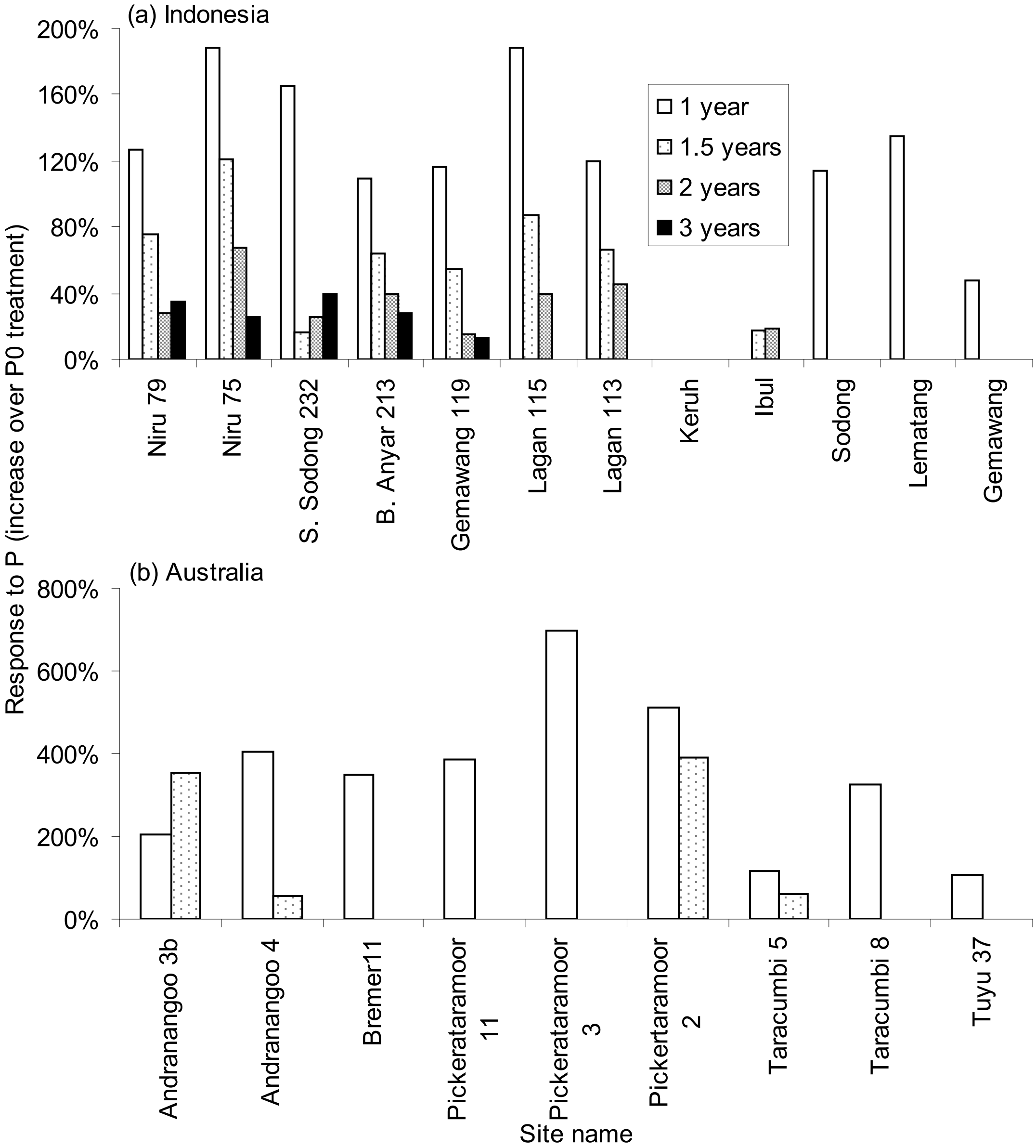
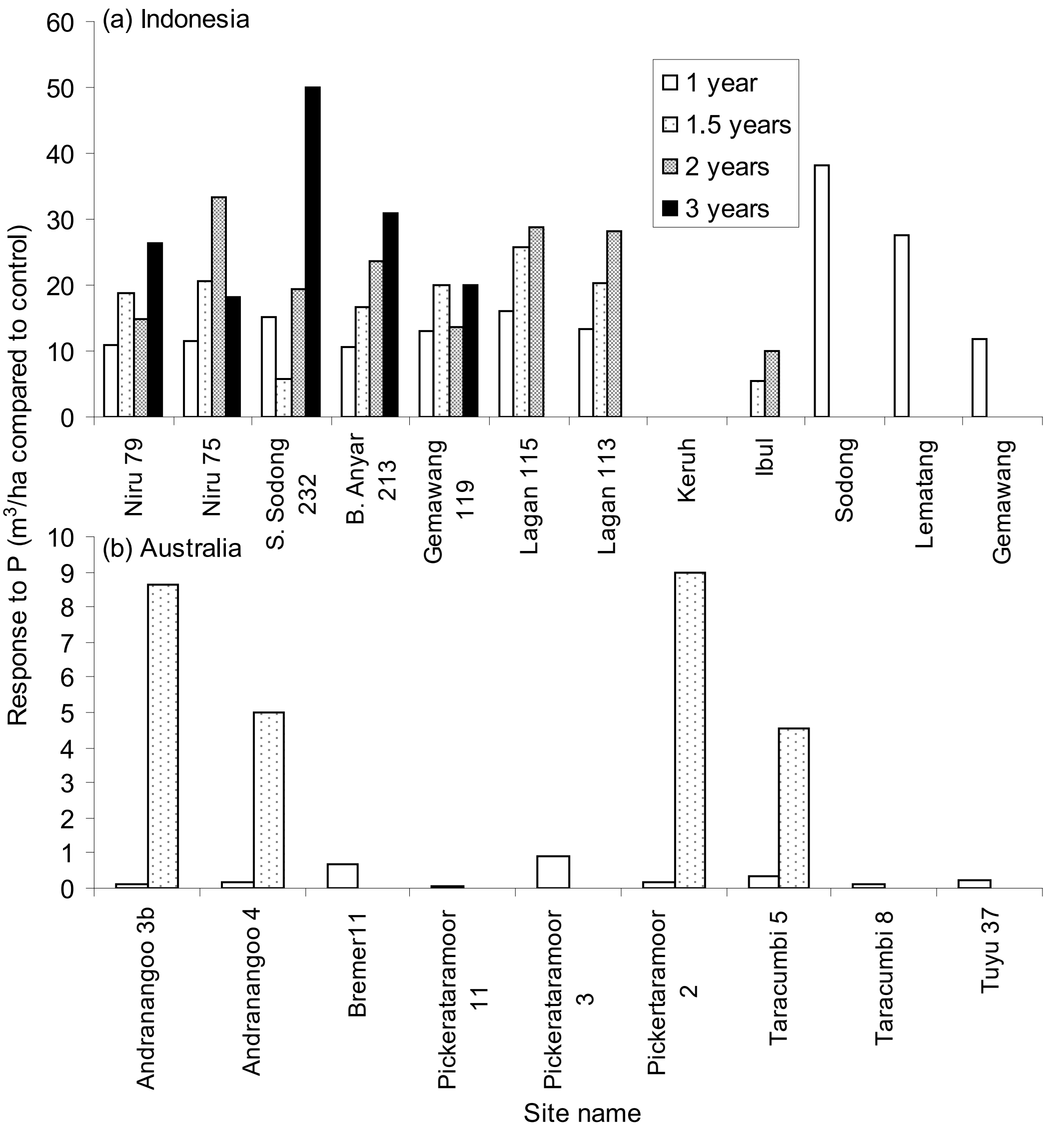


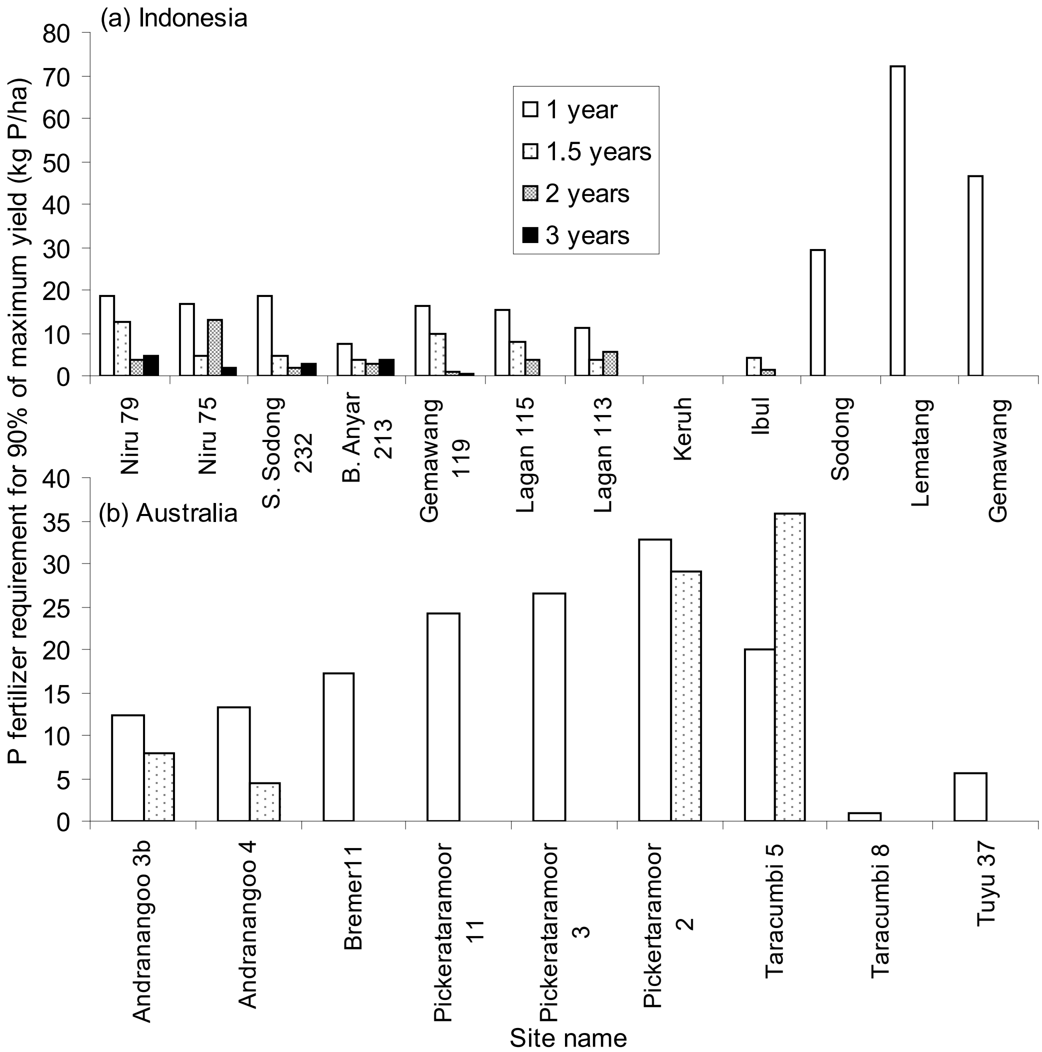
**Fig. 19 – Absolute volume response to P fertilizer at each of the experimental sites in Indonesia (a) and Australia (b).**




### *Fertilizer requirement*

The amount of fertilizer required at planting for 90% of maximum response was calculated from the response curves at each site, and from this we showed that early responses required around 20 kg P/ha in Sumatra at most sites, except the core sites (Sodong, Lematang and Gemawang), which had much higher P requirements (Fig. 20). However, the declining response to P fertilizer with age gave rise to lower P fertilizer requirement up to around age 2. Whilst there were strong responses to P fertilizer at age 2 and 3 (Figs. 18 and 19), the amount of P required to obtain these responses was generally less than 5 kg P/ha.

**Fig. 20 – Calculated P fertilizer requirement to achieve 90% of maximum yield at each of the experimental sites in Indonesia (a) and Australia (b).**

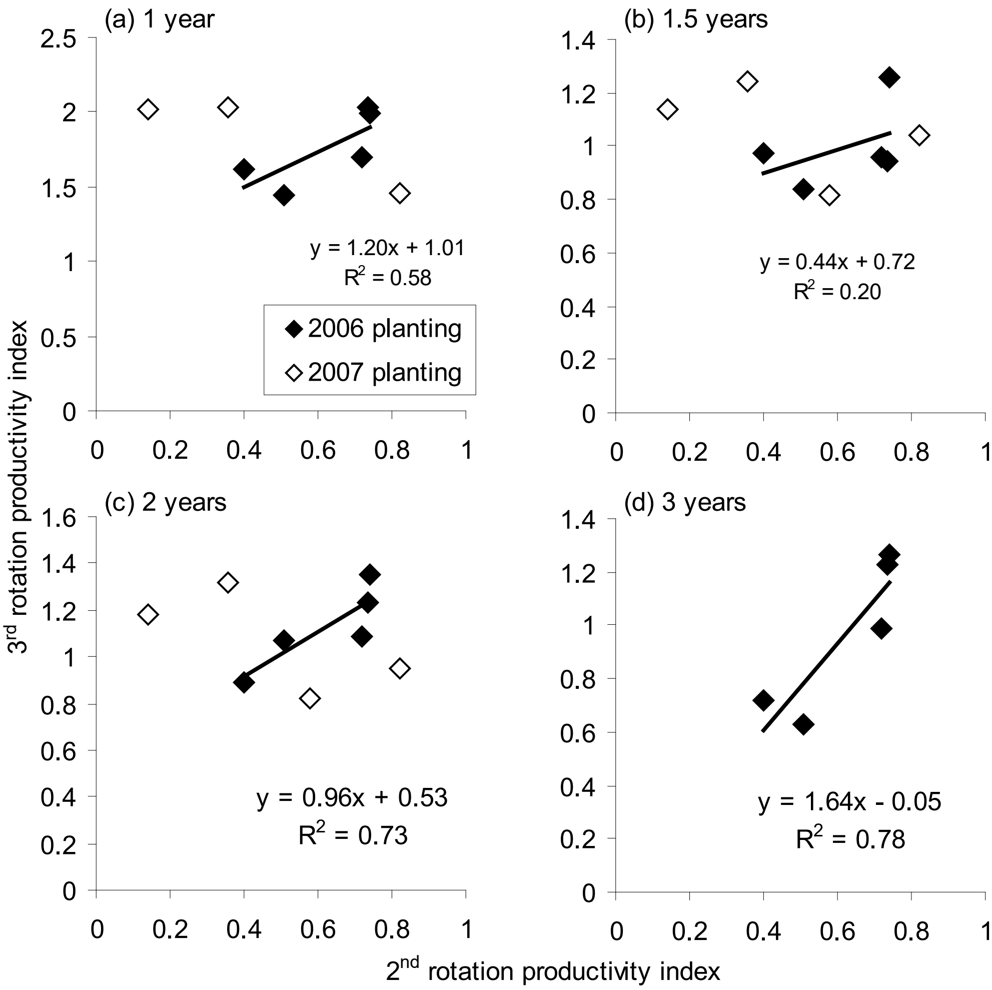



## 7.3.2 Integration across the experiments – Indonesia

### *Productivity*

Productivity in the 3rd rotation experiments was much higher than the operational plantings that were harvested prior to experimental establishment (Fig. 21), with most of the operational 2nd rotation plantings having a productivity index of 0.4-0.8 (productivity index calculated according to Equation 2 above). The experimental productivity was much higher in all cases, and at several sites it exceeded the already-high productivity used as the basis for the productivity index (ie. index values >1). Productivity of the experiments established in 2006 was significantly correlated with the 2nd rotation productivity, whilst the productivity in the 2007 experimental plantings was not related to the original productivity values, suggesting that productivity at the original plantations established at these sites had started to become limited by site factors, but the plantations established in 2007 may have had lower productivity due to lower intensity of management. The experiments established in 2006 were primarily located around Subanjeriji, which is one of the older planting regions, so the managers there are likely to have good experience at managing plantations in that environment, whereas most of the 2007 plantings were in the Lematang region, which has been under acacia cultivation for less time. Thus the 'low' productivity sites that we selected had much higher productivity potential than originally anticipated, with an average MAI of over 40 $m^3$/ha/year at age 2. This implies that relationships derived between soil characteristics and productivity in the operational plantings (section 7.1) are likely to underestimate actual productivity potential, and they need revising in light of the experimentally obtained productivity estimates.

**Fig. 21 – Comparison of productivity index between second and third rotation across the satellite sites at age 1 (a), 1.5 (b), 2 (c), and 3 (d) years. Note that productivity index is the proportion of the productivity observed at an experimental site near Subanjeriji.**




A wide range of soil chemical and physical characteristics were screened for their capacity to predict site productivity potential, with some selected relationships shown in Fig. 22. Some of these relationships showed promise, but they were not particularly powerful indicators of site productive potential. Across all of the sites, soil sulphur content (Fig. 22c) was the only soil property that was significantly ($P<0.05$) related to productivity, and for the other indicators there were only suggestions of a relationship. For example, the index of P buffering per unit total soil P was strongly correlated across 7 of the 9 sites used in this comparison (Fig. 22b), whilst higher growth was generally found in the deeper soils, but not always. The standing volume at age 2 is likely to represent a situation that is not as resource limited as the productivity beyond age 2, once the canopies have closed and the soil is fully explored. Thus we examined the soil factors in relation to the productivity beyond age 2 (ie. the CAI from age 2-3) on those experiments with sufficient data (Fig. 23). This analysis showed that depth to plinthite had a significant relationship ($P<0.01$) with the CAI between ages 2 and 3 across the experiments (Fig. 23e).

**Fig. 22 – Relationship between productivity in our experiments and soil characteristics of total nitrogen (a), phosphate buffering divided by total P (b), total soil sulphur (c), extractable iron (d), depth to plinthite or root impeding layer (e), and organic C (f).**

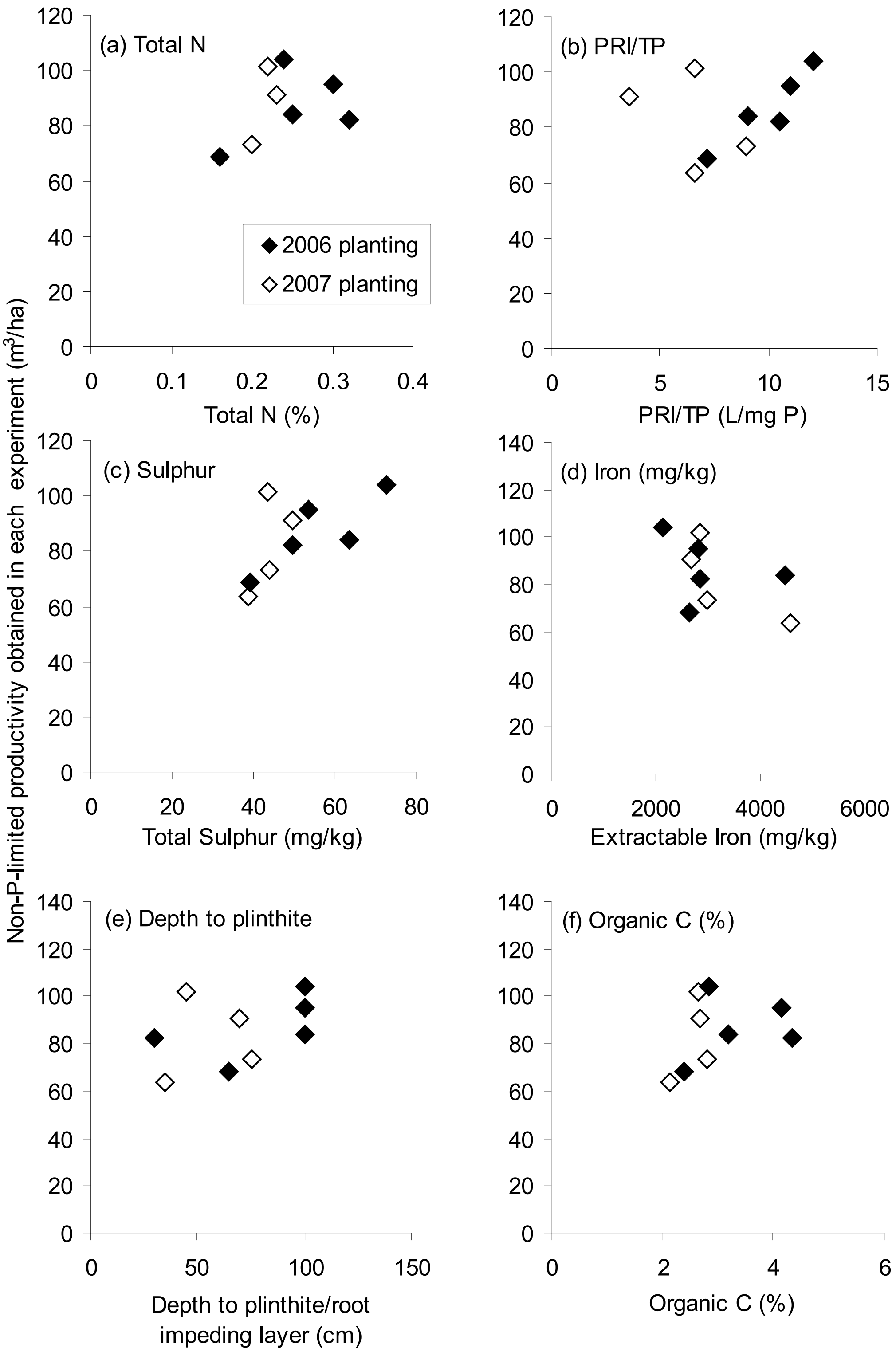
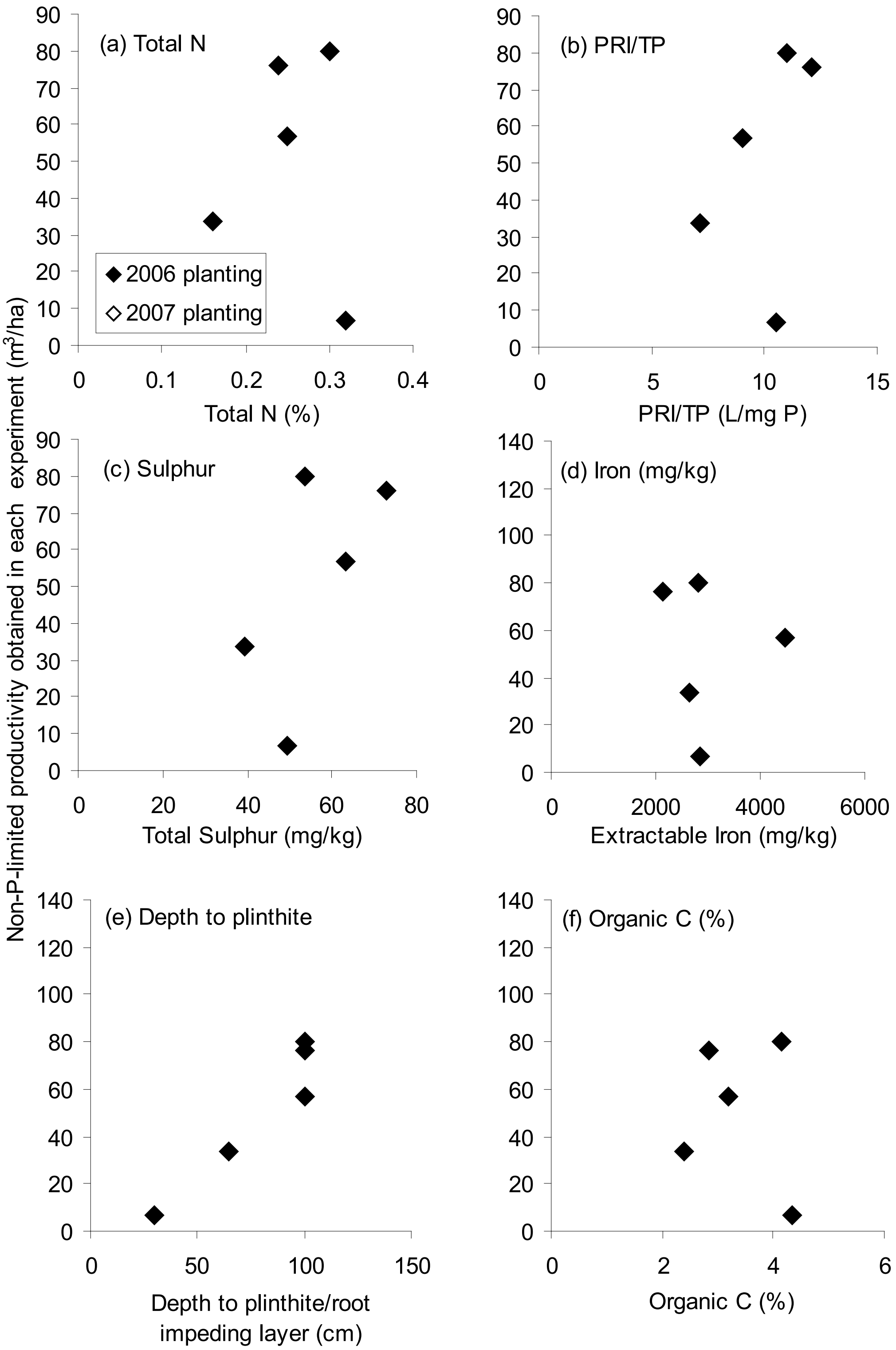


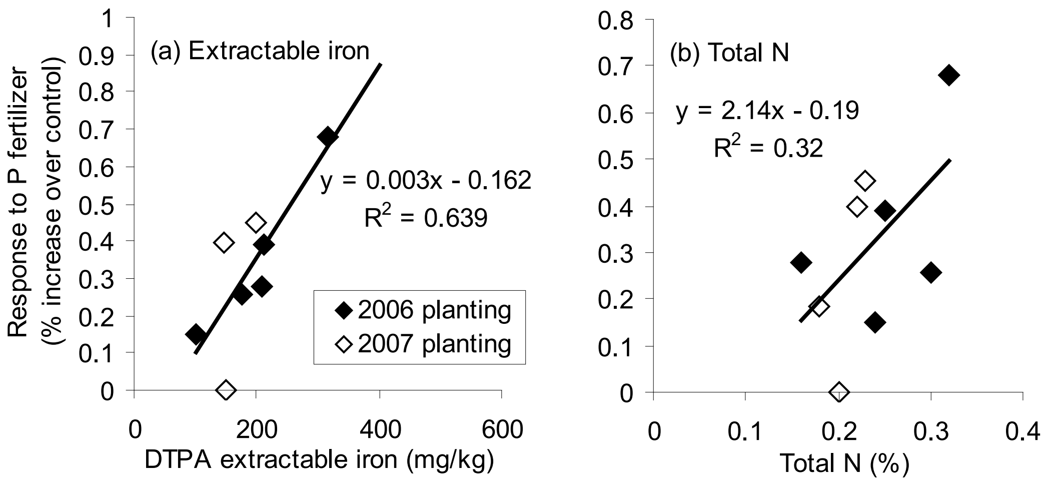
**Fig. 23 – Relationship between the same soil attributes as shown in Fig. 22 and CAI between age 2-3.**




### *Response to P fertilizer*

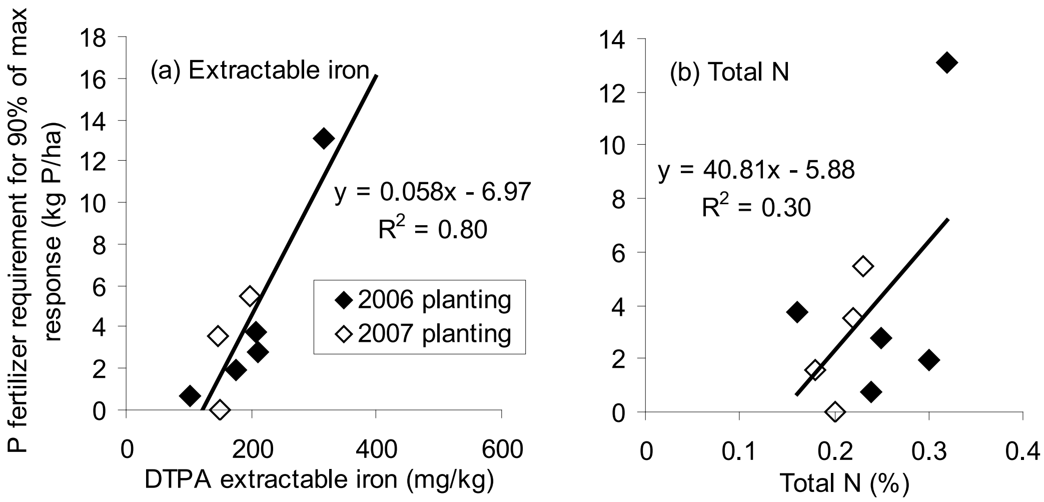
More significant relationships were found between some soil properties and response to P fertilizer (Fig. 24), notably a greater response to P in soils with higher DTPA extractable iron, and with greater N. The relationship with extractable iron ($P<0.01$) may be associated with the P buffering capacity of these soils, but P buffering capacity itself was not significantly related to response to P fertilizer. The relationship with total N is probably associated with soil fertility in general, so soils with more N have a greater capacity to respond to P fertilizer.

**Figure 24 – Relationships between response to P at age 2 years and soil DTPA extractable iron (a) and soil total N (b) across the experimental sites.**




In addition to its strong relationship with P fertilizer response, extractable iron was also particularly useful for explaining the requirement for P fertilizer (Fig. 25a), whereas total N was not as useful.

**Figure 25 - Relationships between requirement for P fertilizer (based on response at age 2 years) and soil DTPA extractable iron (a) and soil total N (b) across the experimental sites.**

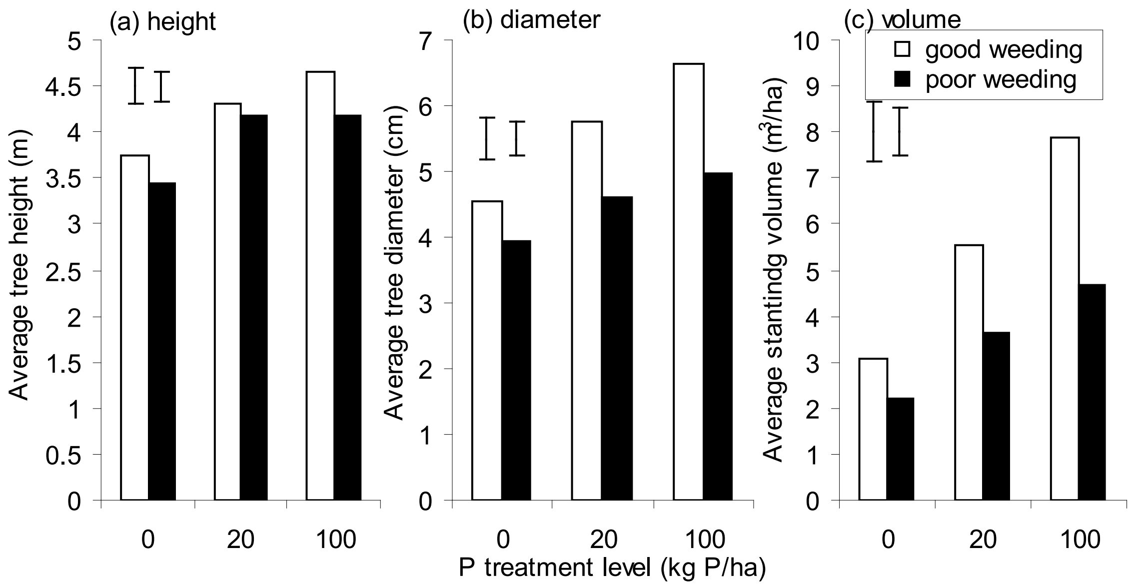



This series of experiments has demonstrated that P fertilizer is an important part of the management of *Acacia* plantations, however 8 of 9 sites required 5 kg P/ha or less at establishment for a response to be observed at age 2, whilst the site with highest P requirement (Niru 75) only required 13 kg P/ha. It is interesting to note that non-P-limited CAI at Niru 75 declined markedly between Age 2 and 3 (Fig. 17), suggesting that response to P fertilizer reduced at that site over time. The interpretation of the field experimental data suggests that potential for P fertilizer response may be able to be derived from soil chemistry, with extractable iron showing the most promise, however the availability and economics of soil testing are likely to be such that further refinement of these diagnostics is not warranted. Thus, we are confident in recommending that 10 kg P/ha at establishment will be sufficient for the great majority (if not all) of new planting sites.

### 7.3.3 Interactions between P fertilizer and weed control

It became apparent about mid-way through the project that we were likely to be recommending very low rates of P fertilizer as a result of the experimental outcomes, but we were not sure whether this recommendation would be entirely relevant in the field situation because of the differences in weed control: weeds were regularly controlled in our experiments, so the treatments with lower leaf areas would have initially had less weed competition than may have otherwise been experienced in an operational planting; large differences in leaf area and light penetration to the soil surface were evident at age 1 between the treatments. Thus we initiated an additional experiment to explore the interactions between weed control and P fertilizer. The results of this experiment (Fig. 26) showed that both weeding and P fertilizer are independently important and that the effects of each were additive at age 1 year (the latest age for which we had data available). However, there was some evidence for the interaction that we were hypothesising, especially in standing volume, where gains from good weeding treatment were much higher when more P fertilizer was applied (Fig. 26c). It was also evident that there may be some substitutability between weed control and P fertilizer (at least at age 1), with the well weeded treatment without P fertilizer having a similar standing volume to the non-weeded treatment with 20 kg/ha of P fertilizer (Fig. 26c). However, these standing volumes were low compared to the treatments with both good weeding and fertilizer applied.

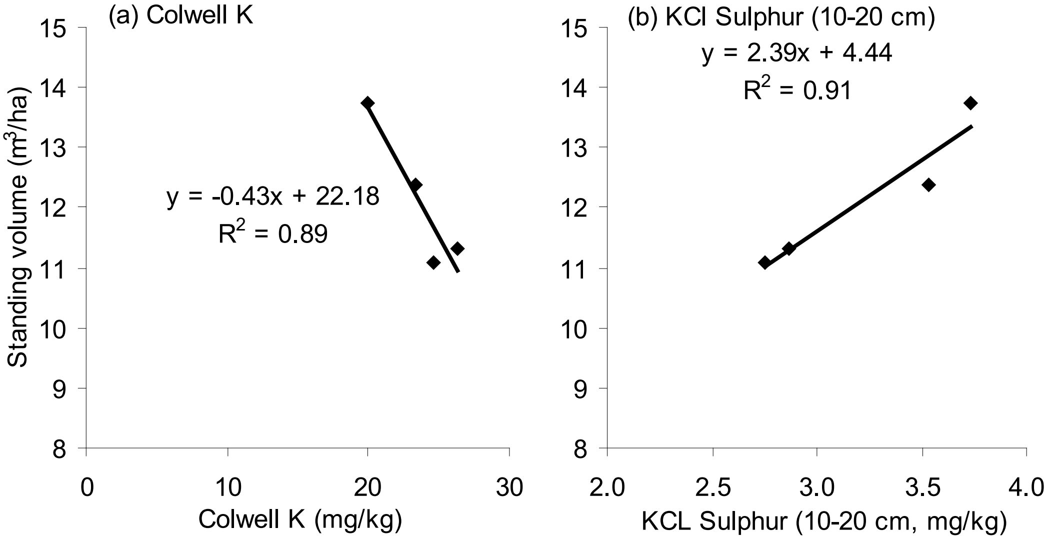
**Fig. 26 – Influence of weeding and P fertilizer addition on tree height (a), diameter (b), and volume (c) at age 1. The bars represent LSD of the main effects of P fertilizer (left) and weed control (right). The interaction was not significant for any of the 3 measures of productivity.**




### 7.3.4 Integration across the experiments – Australia

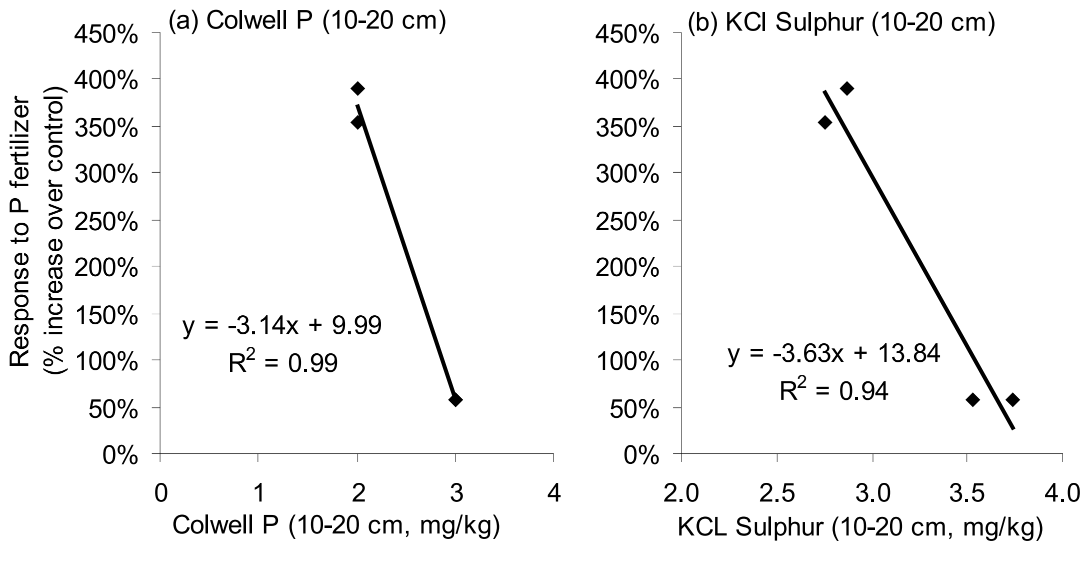
The experiments in Australia were not measured for as long as those in Indonesia due to the Australian partner company ceasing all research activities in 2008. Thus the latest measure was in 2008, when 4 of the experiments were 1.5 years of age and 6 were only 0.5 years of age. Thus the analyses of productivity and response to P fertilizer have less strength than they did for the Indonesian sites. Across the 4 early experiments, only a few soil factors were significantly related to productivity, soil Colwell K and KCl sulphur (at 10-20 cm depth) were 2 of the more significantly correlated characteristics (Fig. 27). However, this data should be regarded as preliminary only and would require testing across a greater number of sites and for older stands.

**Fig. 27 – Relationships between productivity at age 1.5 and Colwell K (a) and extractable sulphur (b).**



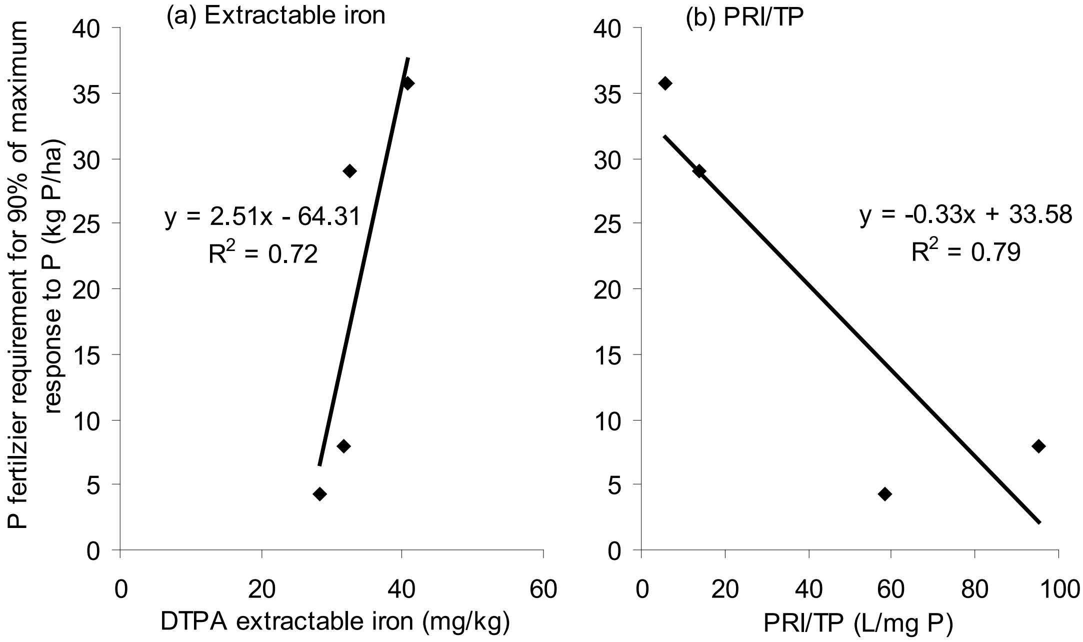

There were also some promising relationships between soil characteristics and response to P fertilizer across the 4 older sites (Fig. 28), although again the limited sample number means that caution must be used in interpretation. However, the strong relationship between Colwell P and response to fertilizer (Fig. 28a) demonstrates that this is worthy of further evaluation. There was also a relationship with KCl extractable sulphur (Fig. 28b), which would be worthy of further screening also. It should be noted that (to the best of our knowledge) these experiments are still in the ground and later-age measurements of standing volume would greatly add value to these results.

**Fig. 28 – Relationships between response to P fertilizer and 10-20 cm Colwell P (a) and KCl sulphur (b).**




There were also some promising relationships between soil test values and requirement for P fertilizer (Fig. 29), with extractable iron (Fig. 29a) related to P fertilizer requirement in these soils, as it was in the soil from Sumatra (Fig. 25a), with higher iron content soils having greater requirement for P fertilizer to get the optimum response.

**Fig. 29 – Relationships between P fertilizer requirement for 90% of maximum response to P and extractable iron (a) and the phosphate buffering divided by total P (b).**




## 7.4 CABALA parameterisation

### 7.4.1 Physiology campaigns

Three field campaigns were conducted to understand more about the physiology of *A. mangium* and its response to environment, so that it can be modelled using the process-based model, CABALA. We also included *A. crassicarpa* in our measurements on Melville Island as a comparison species with different water use characteristics. The 'best' material was used in the study in Sumatra.

#### *Response to $CO_2$ and light*

Tree responses to $CO_2$ and light were assessed independently in the post-wet season campaign (April 2007), when the trees were likely to be subjected to minimal water stress. *A. crassicarpa* had significantly higher levels of photosynthesis than *A. mangium* in response to both light (Fig. 30a) and $CO_2$ (Fig. 30b). The key attributes of the light response curve showed that *A. crassicarpa* had a higher light compensation point and higher dark respiration, but these effects would have been offset by the fact that it had a 11% higher quantum efficiency, and an approximately 30% higher $A_{max}$ value at a light level of 1500 µmol/m$^2$/s (Table 11). *A. crassicarpa* had approximately 17% higher $A_{max}$ value on average over the range in PAR above the light compensation point. Similarly for $CO_2$, the $CO_2$ saturated $A_{max}$ was 23% higher in *A. crassicarpa* compared to *A. mangium*.

**Fig. 30 – Resposes of photosynthesis to light (a) and $CO_2$ (b) in *A. mangium* and *A. crassicarpa*.**

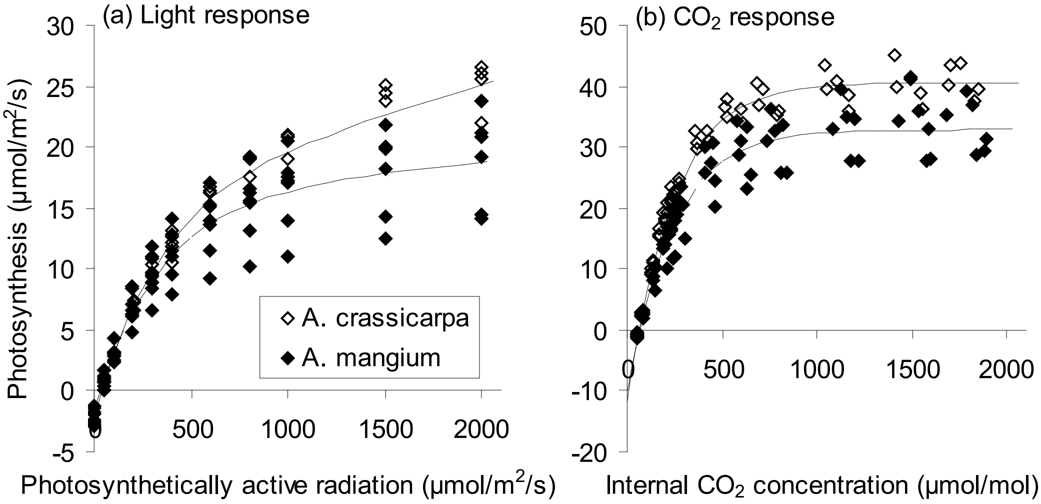


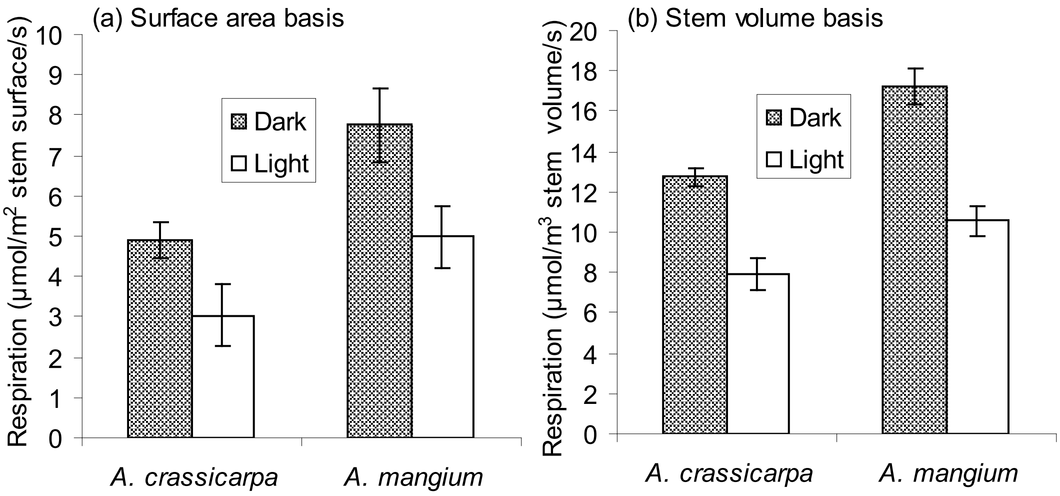

*Table 11 – Key attributes of the light and $CO_2$ response curves for the 2 species*

| | *A. mangium* | *A. crassicarpa* |
|---|---|---|
| Light response | | |
| Light compensation point (µmoles PAR /m$^2$) | 30.6 | 39.7 |
| Light saturated $A_{max}$ (at 1500 µmol/mol) | 17.8 | 22.6 |
| Quantum yield (µmol $CO_2$/µmol PAR) | 0.050 | 0.055 |
| Dark respiration (µmoles $CO_2$/m$^2$) | 1.59 | 2.26 |
| $CO_2$ response | | |
| $CO_2$ compensation point (µmoles $CO_2$/mol air) | 63.54 | 58.98 |
| $CO_2$ saturated $A_{max}$ (µmoles/m$^2$/s) | 32.85 | 40.62 |

### *Stem respiration*

Stem respiration was measured on 5-6 trees of each species under dark and light conditions (Fig. 31). The stems that were assessed were green, and thus still had the capacity to photosynthesise under illuminated conditions. The difference in respiration between the dark and light treatments predominantly reflects the amount that the stems were photosynthesising; 1.9 µmol/m$^2$/s in *A. crassicarpa* and 2.8 µmols/m$^2$/s in *A. mangium*. The two species had significantly different stem respiration rates, with respiration losses in *A. crassicarpa* stems about 30% less than those in *A. mangium*.

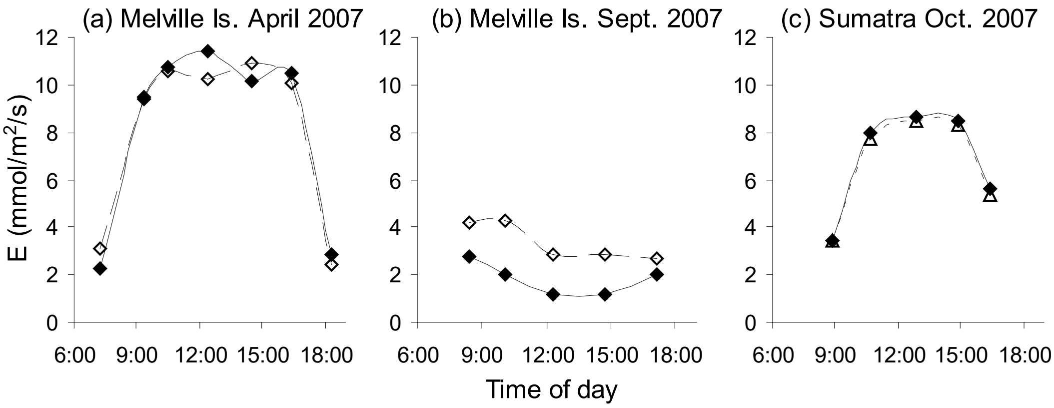
**Fig. 31 – Stem respiration measurements in each species in dark and light conditions. Respiration expressed per m² of stem surface (a) or per m³ of stem sectional volume (b). Bars represent the standard error of the means.**




## *Diurnal gas exchange*

Both species had markedly different gas exchange under wet compared to dry conditions. The trees at the dry measure time had much lower evaporation rates (Fig. 32), stomatal conductance (Fig. 33), and photosynthetic rates (Fig. 34), associated with the low soil water availability in September 2007. They also showed markedly different water status between the two measures (Fig. 36). There were also some interesting differences between the two species; their pattern of gas exchange at the wet measure (April 2007) was similar, but when they were water stressed in September 2007, the *A. crassicarpa* plants had consistently higher evaporation rates, photosynthetic rates, and instantaneous water use efficiency, suggesting that *A. crassicarpa* was better able to tolerate the dry conditions.

**Fig. 32 – Diurnal course of evaporation on Melville Island under wet conditions (a), dry conditions (b), and on Sumatra under wet conditions (c). For the data from Melville Island, hollow symbols are *A. crassicarpa*, and filled symbols are *A. mangium*. For the Sumatra data, filled symbols are *A. mangium* with high P fertilizer, and the hollow symbols are *A. mangium* with no P applied.**




Peak rates of photosynthesis and stomatal conductance were similar between the Melville Island measurements and those in Sumatra in October 2007, however the evaporation rate in Sumatra was lower than on Melville Island, reflecting the lower vapour pressure deficit. This imparted a higher instantaneous water use efficiency (Fig. 35c) early in the day, but the trees in Sumatra also showed a marked peak in photosynthetic rates early in the day, which declined thereafter, probably reflecting the pattern of light availability, as storm clouds started building at around 12 noon.

**Fig. 33 – Diurnal course of stomatal conductance to water on Melville Island under wet conditions (a), dry conditions (b), and on Sumatra under wet conditions (c). For the data from Melville Island, hollow symbols are *A. crassicarpa*, and filled symbols are *A. mangium*. For the Sumatra data, filled symbols are *A. mangium* with high P fertilizer, and the hollow symbols are *A. mangium* with no P applied.**

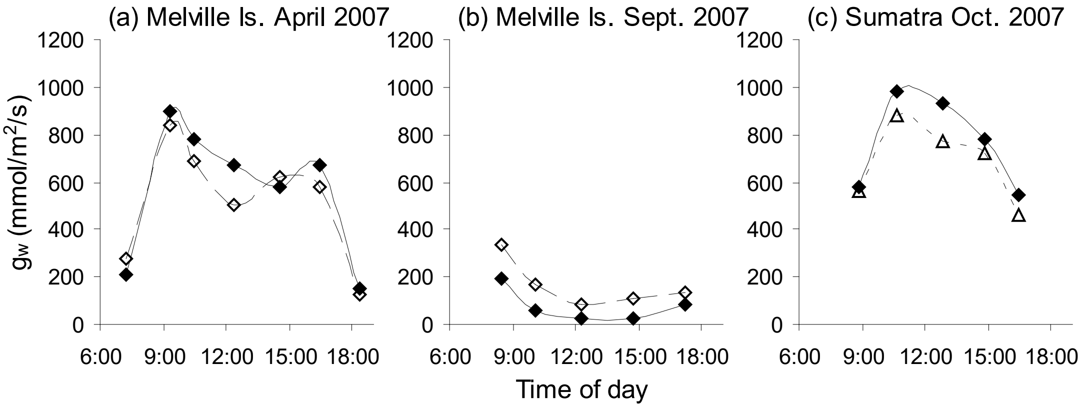



**Fig. 34 – Diurnal course of leaf photosynthetic rate on Melville Island under wet conditions (a), dry conditions (b), and on Sumatra under wet conditions (c). For the data from Melville Island, hollow symbols are *A. crassicarpa*, and filled symbols are *A. mangium*. For the Sumatra data, filled symbols are *A. mangium* with high P fertilizer, and the hollow symbols are *A. mangium* with no P applied.**

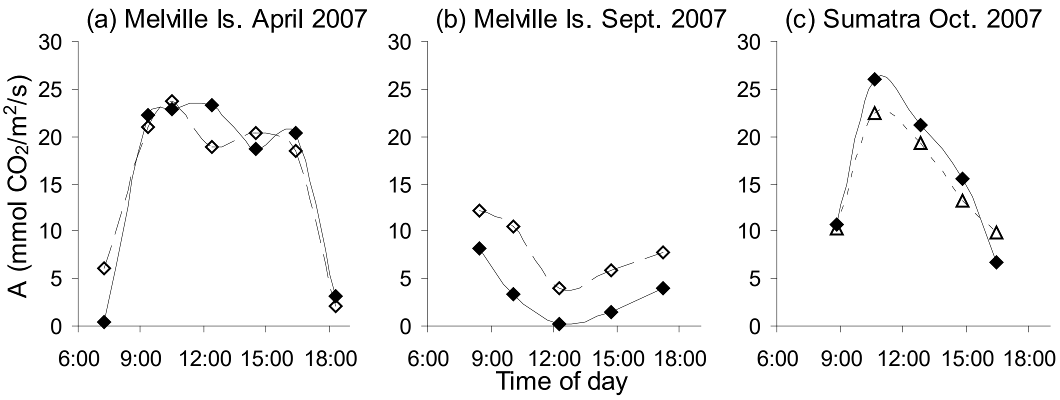
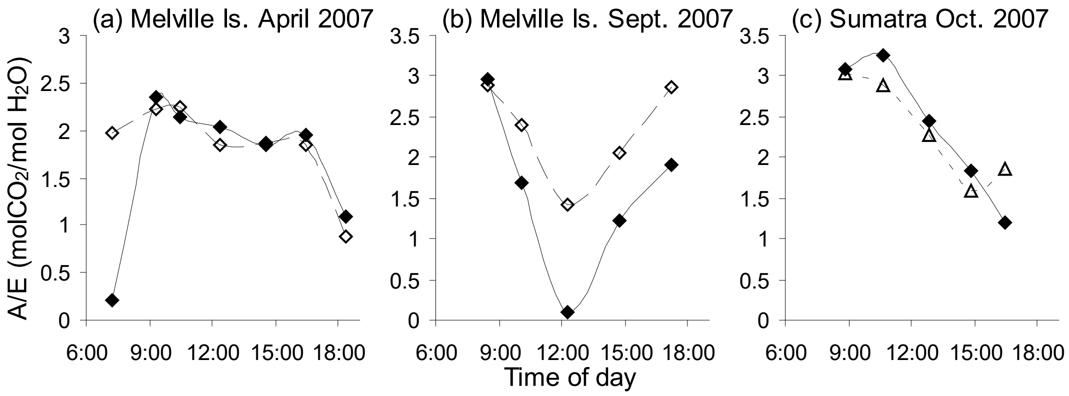
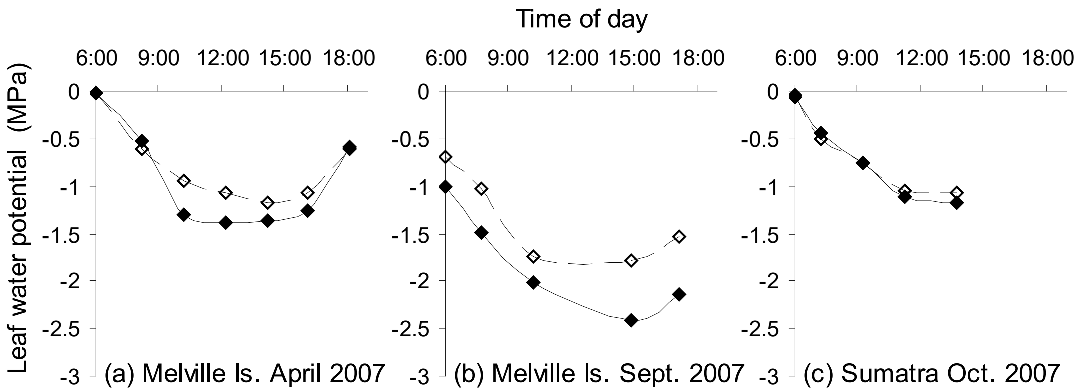


**Fig. 35 – Diurnal course of instantaneous leaf water use efficiency on Melville Island under wet conditions (a), dry conditions (b), and on Sumatra under wet conditions (c). For the data from Melville Island, hollow symbols are *A. crassicarpa*, and filled symbols are *A. mangium*. For the Sumatra data, filled symbols are *A. mangium* with high P fertilizer, and the hollow symbols are *A. mangium* with no P applied.**




The plantations in Sumatra, and on Melville Island in April did not exhibit strong water stress, with very high water potentials before dawn (close to zero). However, the September measurements on Melville Island showed that the trees were highly water stressed, with *A. mangium* having a pre-dawn water potential of around -1 MPa.

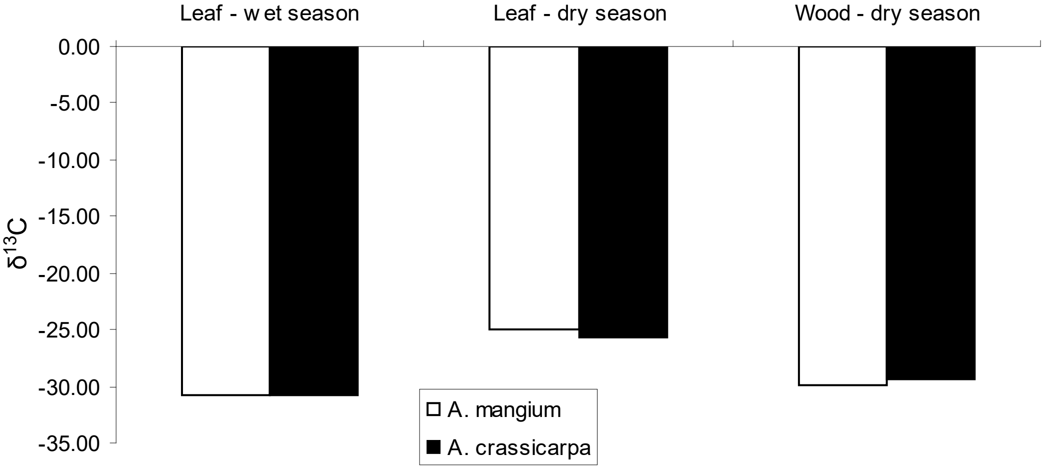
**Fig. 36 – Diurnal course of leaf water potential on Melville Island under wet conditions (a), dry conditions (b), and on Sumatra under wet conditions (c). For the data from Melville Island, hollow symbols are *A. crassicarpa*, and filled symbols are *A. mangium*. For the Sumatra data, filled symbols are *A. mangium* with high P fertilizer, and the hollow symbols are *A. mangium* with no P applied.**




## *Integrated water stress (isotopic ratios)*

The natural isotopic discrimination that occurs during the fixation of $CO_2$ by rubisco can be used to give a measure of plant water stress at the time of photosynthesis, and assessment of isotopic differences in plant components can give an integrated measure of water stress. There were no significant differences in isotopic composition between *A. mangium* and *A. crassicarpa* (Fig. 37), although there was a seasonal effect, with greater water stress (higher $\delta^{13}C$) in the dry season leaf samples. The isotopic composition of the wood samples was between the wet and dry season values for the leaves, and represented around 84% of the wet season values for *A. mangium*, and 71% of the wet season values for *A. crassicarpa*, suggesting (and supporting the observation) that *A. crassicarpa* continues growing more into the dry season compared to *A. mangium*.

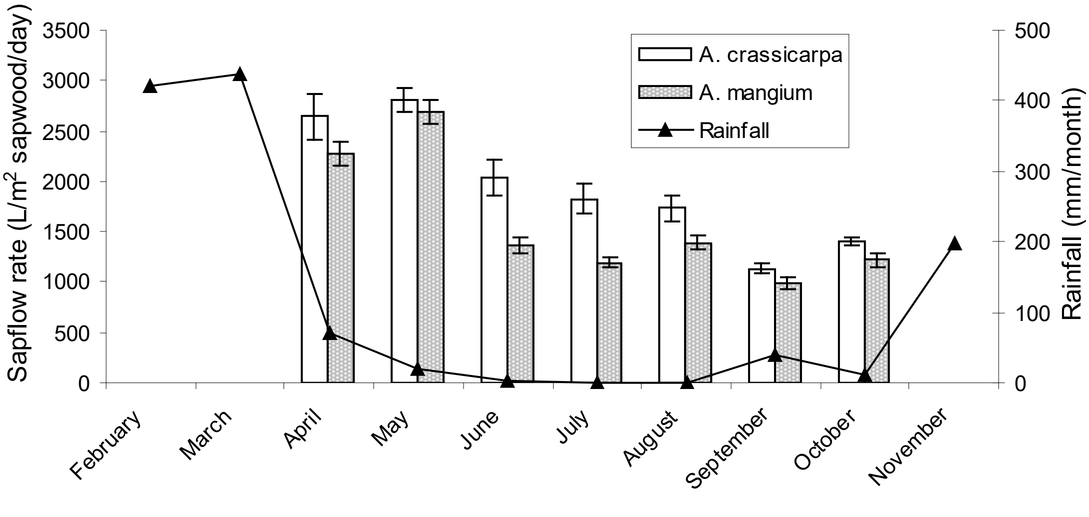
**Fig. 37 – $\delta^{13}C$ values in *A. mangium* and *A. crassicarpa* sampled in the wet and dry seasons.**




## *Sapflow*

Rates of sap flow were measured from April until October 2007 (Fig. 38). Whilst the sample numbers were small (n=4 for *A. crassicarpa* and n=6 for *A. mangium*), there was a consistent trend for lower sap flow rates in *A. mangium* in each month of measurement. The rates in *A. mangium* declined to around 1500 L/m$^2$/day by June, whereas sap flow rates in *A. crassicarpa* declined more slowly into the wet season. This information also supports the hypothesis that *A. crassicarpa* continues growing for longer into the dry season than *A. mangium*.

**Fig. 38 – Measured sapflow rates from April to October 2007, and the monthly rainfall from the nearest weather station at Pirlangimpi**

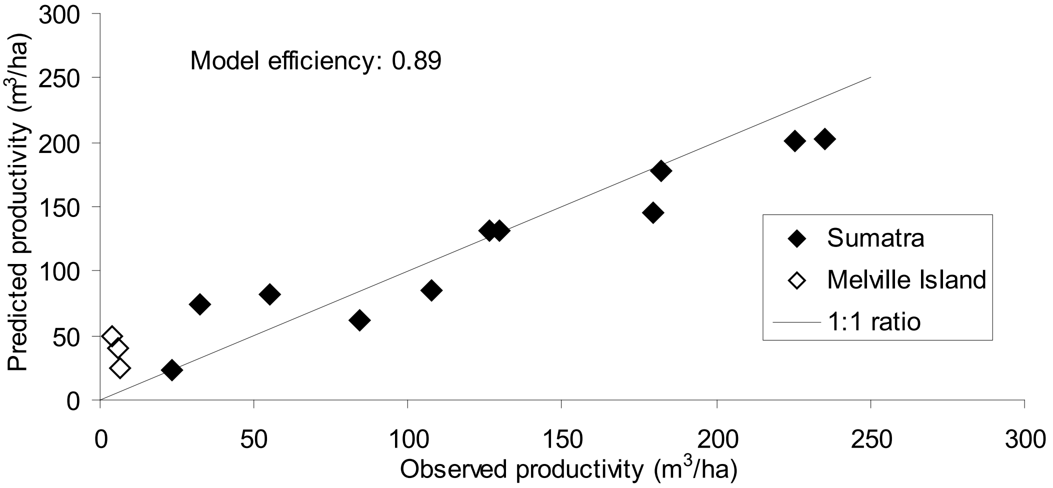



## *CABALA development*

The physiological information that was collected through the field campaigns, supported by information from the literature, was compiled into a parameter set for CABALA. The initial parameterisation was reasonably well correlated with standing volume found across the sites evaluated in 5.1 above (Fig. 39), with a model efficiency of 0.89, and a slope approaching 1 (note that model efficiency represents the fit of a model to the data, with a value of 1 indicating a perfect fit, a value of 0 meaning that the model is no better than the average, and a negative value means that the model predicts worse than the average).

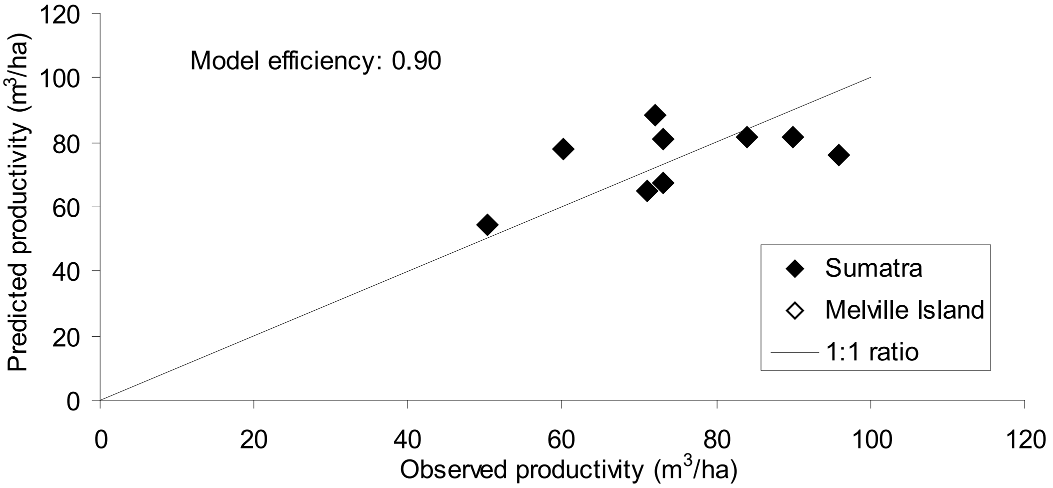
However, some lower productivity sites were overpredicted, especially those on Melville Island.

**Fig. 39 – CABALA predicted vs actual productivity across the initial surveyed sites**




However, we observed that productivity in our experiments (at least up to 2-3 years) was quite different to that in the second rotation (see section 7.3.2 above), especially in the Lematang region, and several modifications to the underlying model were needed to improve the CABALA predictions, including (1) changing the diurnal pattern of gas exchange, so that the photosynthetic rates were the same in the morning and afternoon, (2) allowing for N fixation, but at a cost of fixed carbon, (3) modifying the standing volume model, and (4) altering the relationships between soil water and plant water stress. Once these factors were included in the model, the relationship in Fig. 40 was obtained, with a model efficiency of 0.9. However, these experimental results will become more valuable as the stands get closer to harvest age – already it has become apparent that the CAI in year 2-3 is much more dependent on soil depth (Fig. 23) than the standing volume at age 2 which will influence the prediction by CABALA.

**Fig. 40 – Predicted vs actual productivity across the experimentally obtained productivity at age 2, using the modified version of CABALA.**




## 7.5 Economics

The economic benefit of improved management for growers is presented first, and then this information is aggregated to regional government and industry levels.

### *Economic benefit analysis – farmer and company level*

Table 12 shows the base case cost/benefit scenario for a single rotation of *Acacia mangium*. The yields are based on observed outgrower productivity ('Current management') and on potential yields under improved management. The 'improved' management scenario includes fertilizer application (as per our recommendation), chemical weeding up to 4 times (compared to a single manual weeding at establishment as currently practiced), and a singling to improve tree form. The difference in NPV over the whole rotation is $636/ha. Note that the returns are based on a wood value of Rp200,000/m$^3$, or approximately AUD$25/m$^3$, which is a conservative estimate of wood sale value. It also needs to be recognized that much of the cost in both the improved and current management is labour, which a farmer can undertake personally, thus saving much of the cash costs of management shown here. This case is only for a pulpwood rotation as the pulpwood can be readily sold to mills. A sawlog rotation is likely to be more profitable, but is not modeled here due to uncertainty around markets.

*Table 12 – Base case for costs of growing A. mangium under standard and improved management scenarios for outgrower farmers (Rp/ha).*

| Cost | Year | Current management | Improved management |
|---|---|---|---|
| | | (Rp/ha) | |
| 1. Site preparation | | | |
| 1.1 Manual, slashing | 1 | 430,000 | 430,000 |
| 1.2 Chemical site preparation | 1 | 425,000 | 425,000 |
| 2. Planting | | | |
| 2.1 Seedling and transport | 1 | 600,000 | 600,000 |
| 2.2 Planting | 1 | 350,000 | 350,000 |
| 2.3 Fertilizer application | 1 | | 875,000 |
| 3. Maintenance | | | |
| 3.1 Manual weeding | 1 | 449,500 | 449,500 |
| 3.2 Chemical weeding 1 | 1 | | 464,500 |
| 3.3 Chemical weeding 2 | 2 | | 428,500 |
| 3.4 Singling-pruning | 2 | | 113,000 |
| 3.5 Chemical weeding 3 | 3 | | 338,700 |
| 3.6 Chemical weeding 4 (if needed) | 3 | | 338,700 |
| 4. Harvesting and transport | 6 | 5,130,000 | 10,260,000 |
| Total cost (not discounted) | | 7,384,500 | 15,072,900 |
| Yield (t/ha) | | 90 | 180 |
| Return (@200 000 Rp/tonne) | | 18.0M | 36.0M |
| Net return NPV (discount rate of 10%, Rp/ha) | | 5.22M | 10.3M |
| NPV ($/ha at exchange rate of Rp8000/$AUD) | | $652 | $1288 |

Root rot is a significant emerging problem in some areas of the *A. mangium* estate, and if it became prevalent in South Sumatra, the benefits of improved management may be undermined through mortality due to root rot. Table 13 shows the effect of a sensitivity analysis around potential losses in productivity that would be associated with tree mortality. It is assumed that proportional volume losses would be similar for both the current and improved management, reflecting losses of similar numbers of trees in the different management scenarios. In all cases, the improved management has a net benefit of about double that of standard management.

*Table 13 - Effect of volume loss due to root rot (% volume losses the same for standard and improved management)*

| Volume loss due to root rot (%) | NPV current management | NPV improved management | Net benefit |
|---|---|---|---|
| 0 | $652 | $1,288 | $636 |
| 10 | $561 | $1,107 | $546 |
| 20 | $470 | $925 | $455 |
| 30 | $379 | $743 | $364 |
| 40 | $289 | $562 | $273 |

We have assumed that outgrower farmers will be able to produce 180 $m^3$/ha over 6 years, under an improved management regime. This productivity represents about 66% of the average productivity across our experiments (at age 3), suggesting that this productivity should be achievable by outgrower farmers. However, there is a possibility that this productivity may not be achieved even with improved management, so a sensitivity analysis to lower yields was conducted (Table 14). This analysis showed that improved management has a positive net benefit over current management as long as the volume is no less than 35% lower (117 $m^3$/ha). Below this level, improved management has a negative net benefit according to our analysis, although it needs to be recognized that (a) this would represent a very poor site that should be excluded at site selection, based on our project-derived site selection guidelines, and (b) that the productivity at such a site under current management would be likely to be much less than 90 $m^3$/ha, so the improved management is still likely to give a greater net benefit compared to current management.

*Table 14 - Effect on profitability if volume gain is not achieved from improved management*

| Volume loss below 180 $m^3$/ha (%) | NPV current management | NPV improved management | Net benefit |
|---|---|---|---|
| 0 | $652 | $1,288 | $636 |
| 10 | $652 | $1,107 | $455 |
| 20 | $652 | $925 | $273 |
| 30 | $652 | $743 | $91 |
| 40 | $652 | $562 | -$90 |

The returns from Acacia cropping (calculated above) were compared with the returns from rubber plantations, which are a competing land use amongst outgrower farmers in this region. Net economic revenue from *Acacia* cropping under the MHR program was lower than from rubber cropping. A survey of outgrower farmers showed that rubber cropping in the study region could generate a net income of around Rp11.7-27.5 M/ha/y (Table 15), compared to a return of Rp16M from acacias under improved management over the entire 6 year rotation (not discounted). However, the labour inputs between the 2 crops are markedly different, with latex tapping requiring an average of 4 hours/ha every 2 days to return this income. *Acacia* has a significant competitive advantage for many farmers because it allows farmers to utilize land that cannot otherwise be farmed due to labour constraints.

*Table 15. MHR participants' land plots dedicated to rubber cropping & the average reported revenue**

| Land Acreage (ha) | % of surveyed farmers | Production Cost Annually (MRp/year) | Production (tonnes) | Revenue (MRp/year) | Net Income (MRp/year) |
|---|---|---|---|---|---|
| 0.5-1.0 | 35.00 | 2.63 | 2.62 | 23.3 | 20.6 |
| 1.1-2.0 | 40.00 | 12.5 | 5.41 | 45.9 | 33.5 |
| 2.1-3.0 | 5.00 | 34.8 | 9.16 | 78.2 | 43.4 |
| 3.1-4.0 | 7.50 | 45.1 | 11.6 | 97.0 | 51.9 |
| 4.1-5.0 | 10.00 | 66.0 | 14.7 | 125.2 | 59.2 |
| 5.1-6.0 | 2.50 | 80.6 | 17.0 | 144.8 | 64.2 |

Note: *Revenue was calculated at a price level of Rp6000/Kg latex.

There are opportunities for improving the economic benefit and the competitive advantage that *Acacia* could provide, through improving productivity via improved silvicultural techniques and adjusting the revenue sharing arrangement. An improved return for farmers would increase the perceived degree of fairness in revenue sharing between the company and out-grower farmers.

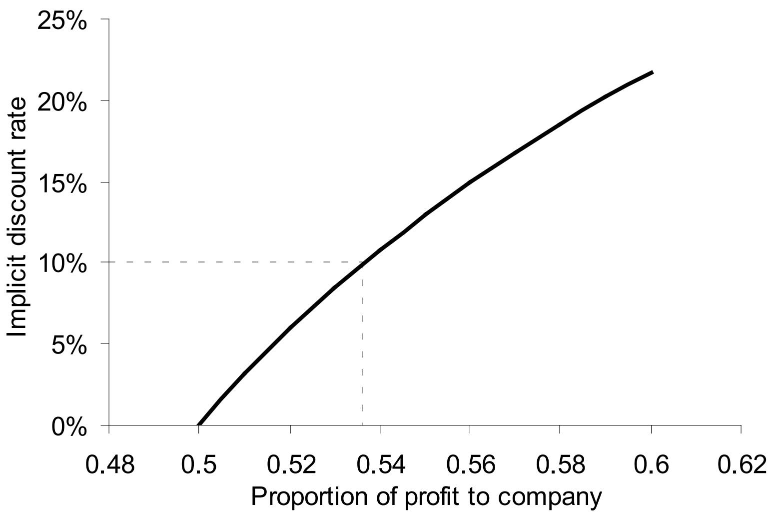
According to the current agreement between PT MHP and outgrower farmers, under the MHR Acacia program, farmers get 40% of the profits while MHP receives the remaining 60%. The return to the company is higher to cover the interest on expenditure incurred by the company in the first 6 years of the plantation. However, our calculations suggest that the implicit discount rate of the 60:40 ratio would be around 22% (Table 16), based on a productive plantation (200 $m^3$/ha at age 6). Sensitivity analysis around the implicit discount rate of different possible company profit-share arrangements (Fig. 41) shows that an interest rate of 10% would equate to a company profit share of around 53.6%.

*Table 16. Sensitivity analysis around the discount rate to show a 50:50 net income (in Rp million) share from an average 4.22 Ha MHR Acacia land plot. A discount rate of 21.81% is required to bring the present-value calculated costs (column 5) up to the same level as the 60% profit on accumulated (not discounted) costs (column 4).*

| Discount Rate (i, %) | Present Value of Acacia Log (harvestable in 2008, Rp) | Production Cost (2001-2008, Rp m) | | Comparable Net Revenue Share: Nominal ≤ NPV (Rp m) | |
|---|---|---|---|---|---|
| | | Nominal Accumulative (ACC) | Compounded Accumulative (CACC) | ACC+60% Profit (Nominal Accounting) | CACC+50% Profit (P.V. Accounting) |
| | **1** | **2** | **3** | **4 = 2 + 60% (1 - 2)** | **5 = 3 + 50% (1 – 3)** |
| 10.00 | 227 | 57.7 | 68.0 | 159 | 148 |
| 12.00 | 227 | 57.7 | 71.0 | 159 | 149 |
| 21.81 | 227 | 57.7 | 91.6 | **159** | **159** |

Note: Average size of MHR land acreage is 4.22 hectares; Planted in 2001 to gain a gross revenue = 843.45 $m^3$ x Rp 269,340.00 = Rp 227,174,823.00 in 2008. Calculation conducted in 2007, Doctoral Dissertation by Marwan Sufri promoted by Prof. Fachrurrozie Sjarkowi (2008).

**Fig. 41 – Sensitivity analysis around the effect of the potential profit share for the company on the implicit discount rate on money spent by the company earlier in the rotation, based on the assumptions used in Table 16. An example of a 10% discount rate is highlighted, which is returned through a 53.6% profit share for the company.**




Thus the revenue share to the farmer needs to be improved to provide greater encouragement to take up acacia cropping.  A greater income to farmers must be achieved by (among others) taking advantage of the experimental research outputs and their socio-economic implications. Three key attributes of the outgrower scheme that needs to be modified to make it competitive are as follows:

1. The implicit interest rate needs to be much lower than 21.81%
2. Allowing participant the option for additional income from their crop, such as charcoal making and marketing by using the unused tree branches, and
3. Allowing (and facilitating) the participant to grow a proportion of their stand on for higher value sawlogs as well as pulp.

### *Economic benefit analysis – District Government Perspective*

The outgrower scheme brings a positive benefit to the region as well as the individual outgrowers. Table 17 below shows an assessment of the source of benefits to the District Government at the current level of outgrower participation. Note that the majority of this revenue is related to productivity, so there is significant scope to increase it through increasing productivity of the plantations.

*Table 17 – Source of benefits from a District Government Perspective*

| Category | Component (target) | Benefit (MRp/y) | Cost (MRp/y) | Net Benefit (MRp/y) |
|---|---|---|---|---|
| Direct tax | PSDH tax (MHP)<br>PBB tax<br>PPh tax (Enclave community) | 17,903 | 300 | 17,603 |
| Indirect tax | Water tax and energy retributional tax | 28.9 | 10.0 | 18.9 |
| Derivative revenue | Vehicle tax and Value added tax | 500 | 10.0 | 490 |
| Total | | 18,432 | 320 | 18,112 |

### *Economic benefit analysis – industry level*

Table 18 shows the industry-wide benefit which could potentially be obtained if adoption of improved management is complete and all of the proposed new HTR scheme smallholder farmers eventuate, but recognizing that this total number must be treated with caution as the HTR scheme may not be fully subscribed. This shows a total potential benefit of close to $200M/year. Note that these economics are only for the smallholder sector of the industry, and do not account for (1) benefits derived by industrial players on their own plantations, and (2) downstream benefits (mills remaining open, protection of natural forest etc.). These benefits are also shared between the outgrowers and the company in a ratio that is defined by the outgrower scheme agreement.

*Table 18 - Full uptake/adoption case*

| | HTR prospective | Existing outgrower farmers |
|---|---|---|
| Number of farmers | 360000 | 15000 |
| ha/farmer | 5 | 5 |
| adoption/uptake level (%) | 100% | 100% |
| benefit/farmer/year* | $530.27 | $530.27 |
| benefit across all farmers ($/y) | $190,897,159 | $7,954,048 |

*benefit/year is $636.32 (from above) divided by 6 year rotation multiplied by average of 5 ha landholding

Recognizing that not all of the HTR program may eventuate or that there may not be complete adoption by smallholder growers, Table 19 shows the sensitivity of annual net benefits of the project under different levels of uptake and/or adoption of the project outcomes. This shows that if 1% of farmers fully adopt the project outputs, the net benefit would be around $2M/year.

*Table 19 – Net benefit across the industry (to smallholder farmers) under different adoption/uptake levels.*

| Adoption/uptake level (%) | Net benefit ($/y) |
|---|---|
| 1% | $1,988,512 |
| 5% | $9,942,560 |
| 10% | $19,885,121 |
| 20% | $39,770,241 |
| 50% | $99,425,604 |

Table 20 shows the sensitivity of benefits to adoption/uptake if only the existing (and planned in the next 5 years) MHP outgrower farmers are included in the analysis. There are currently 2500 ha being grown by outgrower farmers in conjunction with MHP, and this is planned to increase by 2000 ha/y. This group of farmers is much more likely to adopt the project outcomes because they are directly associated with, and being advised by, the company that we are working with. It shows a benefit of $1.3M/year if all of the existing and planned outgrower farmers adopt the project outputs.

*Table 20 – Net benefit to smallholder farmers if only the existing and planned outgrowers are included in the analysis*

| Adoption/uptake level (%) | Net benefit ($/y) |
|---|---|
| 20 | $265,134.94 |
| 40 | $530,269.89 |
| 60 | $795,404.83 |
| 80 | $1,060,539.77 |
| 100 | $1,325,674.71 |

## 7.6 Social studies

The response of outgrower farmers to the MHR outgrower program offered by MHP can be seen from four social perspectives, namely: (1) Socio-economic (productive tradition & consumptive expectation), (2) Socio-cultural (communal cooperation & collaboration); (3) Socio-ecological (habitual impact on natural-resource base & productivity), and; (4) Socio-psychological (institutional bound among villagers & local leaders).

### *Socio-economic perspective*

*Table 21 - Regression Analysis: Y (productivity, tonnes/ha) = f(Landhectareage, Mixedcost) with Recorded Production Data of n= 60 Sampled 'MHR' Participants (Out-growers); Logarithmic Equation Model, $R^2$ = 86.3%)*

| **Model** | **Unstandardised coefficients** | | **Standardized coefficients** | t | Sig. |
|---|---|---|---|---|---|
| | B | Std error | Beta | | |
| Constant | -7.741 | 0.542 | | 4.29 | <0.001 |
| Land (ha) | 0.027 | 0.014 | 0.094 | 1.88 | 0.065 |
| Cost | 1.370 | 0.076 | 0.909 | 8.129 | <0.001 |

*Table 22 - Regression Analysis: Y (productivity, tonnes/ha) = f(Land hectares, Mixed-cost, Dummy of max=1 & minimum= 0) of 5-Clusters of Out-growers, Each Cluster with Maximum & Minimum Recorded Production Data (Logarithmic Equation Model, $R^2$ = 98.3%)*

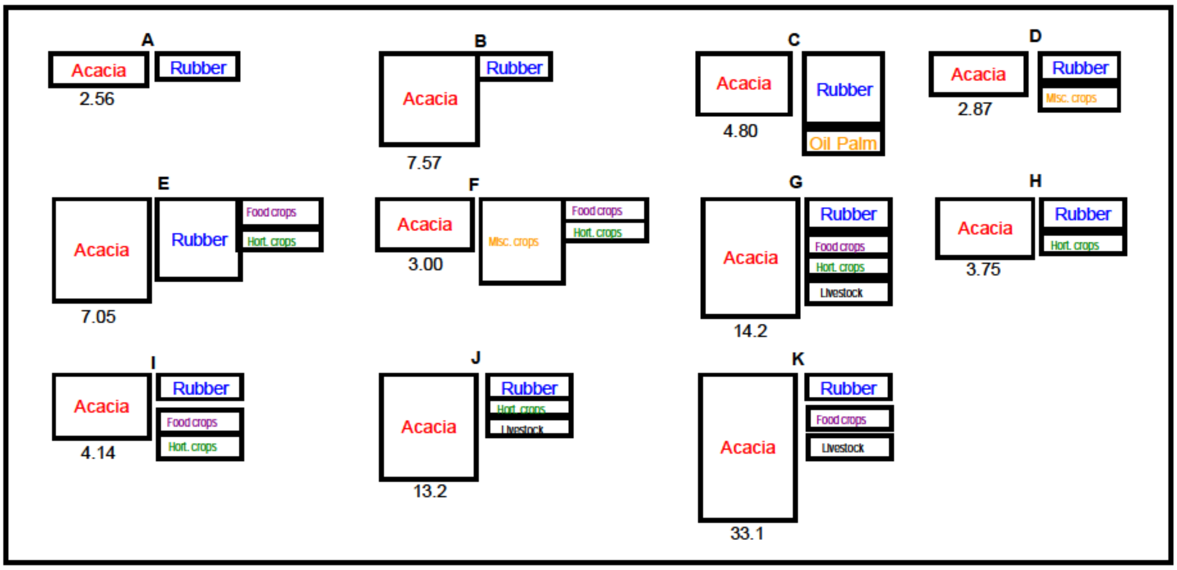
| **Model** | **Unstandardised coefficients** | | **Standardized coefficients** | t | Sig. |
|---|---|---|---|---|---|
| | B | Std error | Beta | | |
| Constant | -6.272 | 1.929 | | 3.252 | 0.017 |
| D | 0.070 | 0.095 | 0.141 | 0.74 | 0.487 |
| Land (ha) | 0.054 | 0.021 | 0.146 | 2.582 | 0.042 |
| Cost | 1.153 | 0.275 | 0.797 | 4.198 | 0.006 |

The positive regression coefficients in the two models (Tables 21 and 22) for land suggest that farmers with larger landholdings also have greater productivity per ha. Farmers with small land area under Acacia (<2 Ha) had lower productivity, apparently caused by inefficiencies in the system (e.g. fertilizer used on rubber instead of *Acacia* crop) while land cultivation on larger areas tends to be mechanically more efficient. Our studies also show that MHR participants with a small area of acacia in the first rotation tend to be less favourably disposed to participate in MHR acacia second rotation compared to larger landholders.

## Socio-cultural perspective

A survey of farmers showed that MHR-*Acacia* is not the only crop grown by outgrower farmers (Fig. 42). Acacias are grown alongside traditional crops such as rubber, oil palm crops & food crops. There are three to four crop species (3.68 on average) planted by each outgrower indicating a simple strategy to broaden a farming base for minimizing risk. There are 17 species, mostly perennial crops, traditionally planted in the area; for which not much human intervention is needed despite the relatively low soil fertility.

**Fig. 42 – Land cropping pattern among surveyed outgrowers. Space between the boxes indicates significant geographical distance between plots.**




Many MHR Acacia plots are scattered, and not in close proximity to each other, which tends to cause some difficulty to promote and arrange collective and collaborative operations among local Sumatran people, but this is less of an impediment between Javanese transmigrants whose spirit of unity seem to be stronger while their land plots are usually concentrated in one zoning area.

## Socio-ecological perspective

Slash and burn agriculture is still being practiced sporadically by members of the local community, which in practice may result in more negative impacts on the natural environment (as habitat of various species of fauna and flora) compared with *Acacia* planted as a monoculture according to the guidelines.

The acacia area is generally located at quite a distance from main crops (See Fig. 42) and outgrower's house, hence it may potentially suffer from neglect. The size of the acacia area varies from 2 to 7  ha, with an average of 4 ha per family indicating only a moderate population pressure (person/unit land area ratio) on the land resource.

## Socio-psychological perspective

Social ethnic diversity combined with a range of perennial pre-Acacia crops as traditional base of livelihoods may cause further complexity to promote institutional capacity building to support MHR-Acacia program with single management of a systemic agribusiness entity.

Suitable legal apparatus is not available currently to deal with communal land ownership as compared to state land with respect to growing Acacias, and there is a need to develop social forestry management units (SFMU's) to strengthen social partnership and communal cohesiveness for growing acacias on community land.

Socio-psychological perspective requires that the agreement between company and outgrower farmers be handled properly right from the very beginning in order to minimize and control effectively 2 types of potential conflict, namely:

- Social conflict between the participants and the company; Our empirical findings indicated that this type of conflict could weaken the business deal in that it would create social suspicion against every policy on MHR issued and implemented by the company.
- Social conflict between individuals as a group members. This 2nd type of conflict could cause serious friction at the end of a rotation especially when it comes for a group to determine a just but equitable share of economic benefit among each and every individual member

### 7.6.1 Sociological Lessons & Implications

Fig. 43 shows a schema which integrates the 4 sociological lessons above. Four determining factors must be taken into consideration to transform any package of technical innovation to improve profitability and economic benefit for out-grower farmers as follows:

#### *Institutional Factor*

Taking socio-psychological variables properly into consideration is important for an MHR program to obtain strong support from a target community, because a variety of socio-economic opportunities and benefit may be obtained by all participants as long as social harmony is developed as early as possible and maintained institutionally by both sides.

#### *Efficiency Factor*

The strength of the local population pressures onto existing natural resources may be measured (socio-ecologically) by the ratio of persons/unit land area. In a region where most of its people (and farmers in particular) depends upon traditional crop farming, they are likely to have relatively low productivity. Existence of permanent demonstration plot is therefore needed to show what is possible by example.

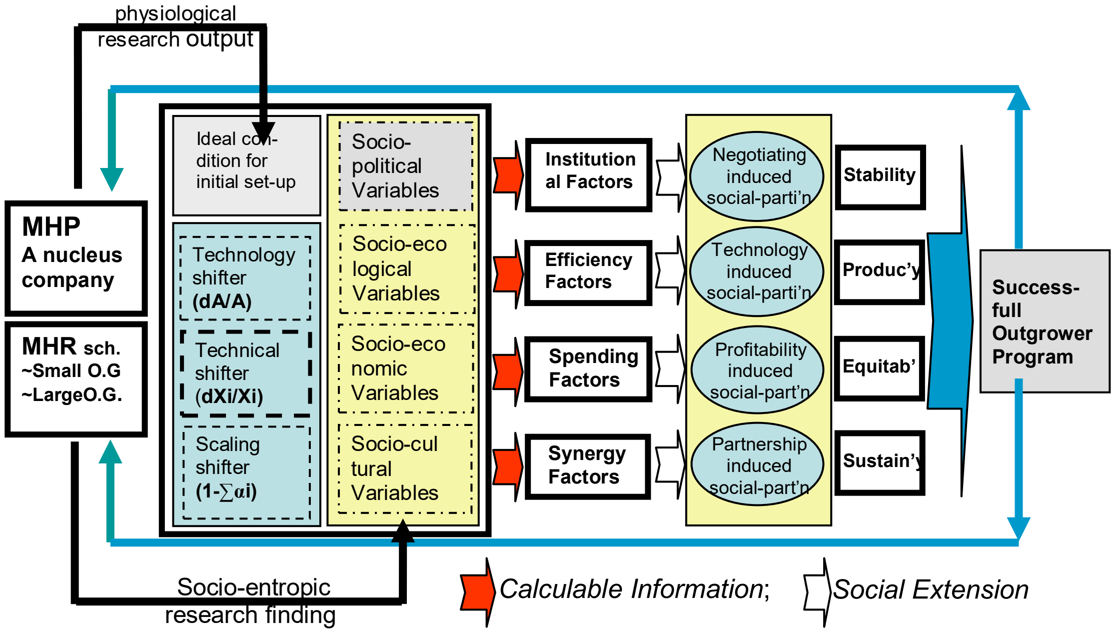
#### *Spending Factor*

Lack of spending power is clearly evident among communities, which can be counter productive to intensifying the silvicultural effort. The acacia growing guidelines and MHR scheme need to demonstrate logical economic advantages before they will be readily adopted.

#### *Synergy Factor*

Inter-group and within-group synergy must be considered as important factors in order for out-growers farmers to achieve sustainable land resource based prosperity. Otherwise, a business deal could be prone to break down easily at any time. In the eyes of community there should be no cheating ever conducted by staff of the company.

**Fig. 43 – Relationship between experimental and socio-entrophic research in social empowering program for acacia outgrowers in the MHR scheme.**




*Scheme-1: Relationship Between Experimental & Socio-Entrophic Research in Social Empowering Program for Acacia Outgrowers under MHR Scheme.*

## 7.7 Integration

The information obtained during the project was integrated into 2 key project outputs – a Decision Support System, and a growers manual.

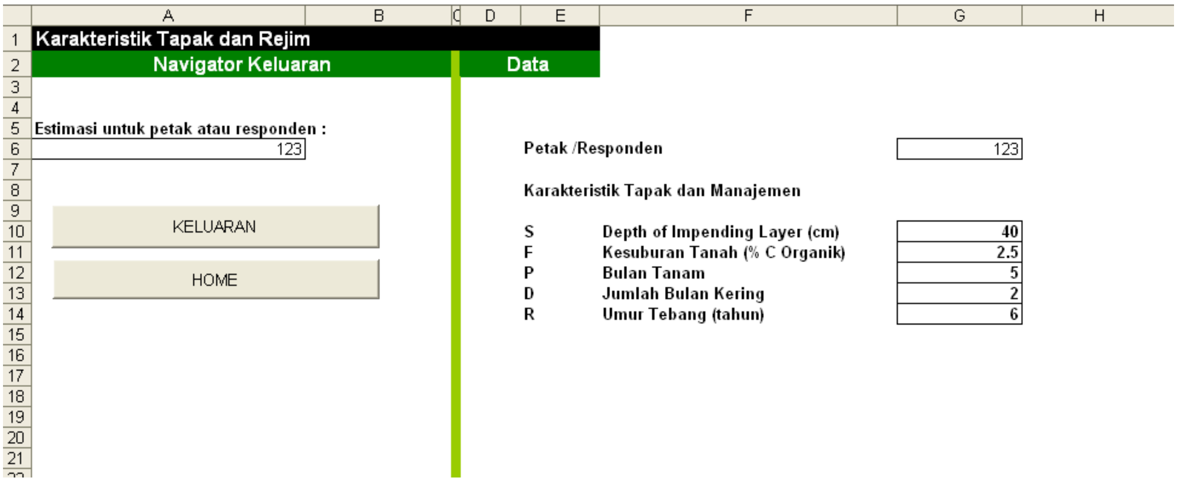
### 7.7.1 Decision Support System

The decision support system is an excel-based spreadsheet, which has a table with a large number of CABALA outputs, and an interface that allows the user to extract the information from this table. A factorial matrix of the factors shown in Table 23 was used to generate the lookup table. The input screen (Fig. 44) allows the user to name their site and enter its characteristics, and the DSS uses fuzzy logic to interpolate between the closest CABALA outputs to the scenario that the user enters.

*Table 23 – Factors included in the CABALA simulations*

| Characteristic | Levels modelled |
|---|---|
| Soil depth (m) | 0.2, 0.4, 0.6, 0.8, 1.0 |
| Soil organic C (%) | 1, 2, 3, 4, 5 |
| Planting month | January, February, March, April, May, June |
| Dry months in the year | 0, 1, 2, 3 |

**Fig. 44 – Screen shot of the input screen for the DSS**




Once the user has described the site, they can view the output (on the output tab, Fig. 45), which shows the predicted height, diameter, LAI, stocking and standing volume. This system was developed in partnership with key managers and extension officers from PT MHP, and the release version includes feedback from them on earlier versions. It is anticipated that this tool will be used by industry and extension officers, but not so much by smallholder growers, for which the growers manual is aimed.

**Fig. 45 – Screen shot of the output from the DSS**


## 7.7.2 Growers manual

A comprehensive 48 page growers manual was prepared (written in Bahasa Indonesia, see Appendix 3), and included information derived from the project, as well as general information on the culture of *A. mangium*. Sections in the manual were (1) Introduction, (2) Site Selection, (3) Nursery culture, (4) Cultivation, (5) Maintenance, (6) Pest and Disease Control, (7) Fire Control, (8) Thinning, and (9) Harvesting. Attachments were tables of (1) Productivity (which were a subset of the CABALA outputs produced for the DSS above), (2) Economics of pulpwood production, and (3) Economics of timber production.

# 8 Impacts

## 8.1 Scientific impacts – now and in 5 years

A number of scientific advances were made during the project, and this will have an impact in the future. Key impacts included the following

### *An improved understanding of the physiology of Acacia mangium and A. crassicarpa and their response to environment*

A number of detailed studies of the response of *A. mangium* to site and environment have been completed, and this has resulted in the development of a parameter set for the process-based model, CABALA. CABALA is primarily a research tool which integrates our understanding of plantation carbon, water, and nutrient cycling, and *A. mangium* was the first tropical species and first N-fixing species to be included in CABALA. The *A. mangium* system proved to be markedly different to the other systems represented in CABALA, most of which have a markedly lower productive potential. A parameter set was not developed for *A. crassicarpa*, but its inclusion in the physiological study provided an interesting contrast in response to environment, which we plan to publish.

### *Knowledge of the soil and environmental factors affecting A. mangium productivity*

Several key site factors affecting *A. mangium* productivity were identified in this study, most notably the relationships between soil physical characteristics and productive potential. The depth to plinthite appeared to be a good surrogate for rooting depth, which can be readily assessed in the field, and could be used as one of the key inputs for CABALA. Clay content and phosphate retention index also showed promise as potential indicators of site productive potential, and we plan to expand on these findings and test these relationships across a wider range of sites. The contrast in environment between Melville Island and Sumatra also highlighted the importance of water availability for productivity of *A. mangium*, where the prolonged dry season on Melville Island had a strong influence on both productivity and form of the plantations.

### *Understanding of responses to P and basal fertiliser in A. mangium*

The project has given us a better understanding of the requirements of *A. mangium* for P fertilizer in South Sumatra and on Melville Island, with it becoming apparent that whilst P is essential at almost every site, only a small amount needs to be added in South Sumatra, such that a standard recommendation across all sites is sufficient to achieve maximum productivity. Whilst our experiments on Melville Island were not measured beyond 1.5 years (or only 0.5 years for 5 of experiments), early responses were generally much greater, and there was greater variation between sites, suggesting that they may require more P at establishment to reach maximum productivity. A follow-up measure of these experiments nearer to rotation-end would be valuable for interpreting the P fertilizer requirements and the effect of fertilizers on tree form. The project has also provided information about the requirements of *A. mangium* for basal fertiliser (N, K, Ca and microelements). Whilst the basal fertiliser application had no effect on the growth of *A. mangium* in South Sumatra, it showed positive growth responses in Melville Island.

### *Understanding of N fixation capacity in A. mangium plantations*

Through the John Allwright Fellowship scheme, we have been able to establish a PhD project to explore the potential for N fixation in *A. mangium* plantations, and this has revealed that they are fixing large quantities of N (up to around 190 kg N/ha in the 1$^{st}$ 18 months), and that there is a strong interaction between genetic improvement and P fertilizer on N fixation, with low rates of N fixation in unimproved material with no P applied, but high rates in improved material with no P applied. This suggests that further study on the phosphatase activity around the roots of improved material is warranted, and P availability may be one of the factors that is inadvertently being selected for in faster growing material.

### *Understanding of the interactions between genetic improvement and management*

One of the premises upon which the project was conceived was that improved genetic material would require improved management to gain the maximum benefit, and there was some evidence that this is the case, with improved genetic material generally responding better to fertilizer application, and also that the improved material was able to fix more nitrogen, especially when in a low P situation. However, the amounts of applied P required were small (generally less than 10 kg/ha), and so the benefits of improved fertilizer management are likely to be minimal. However, this is likely to be quite different in a non-N-fixing species, where N requirements are likely to be greater than most soils can readily supply to fast-growing species.

### *Greater understanding of outgrower farmers*

This project has completed some detailed analyses of outgrower *Acacia* farmers, including surveys of some of the first farmers to participate in a full rotation under the PT MHP outgrower scheme. This has given us a greater understanding of the farmers, their farms, and the types of cropping regimes they employ. This information will be used to target future studies aimed at improving the adoption of acacias, and the adoption of technology appropriate for growing acacias for maximum benefit.

## 8.2 Capacity impacts – now and in 5 years

Key areas of impact on capacity are as follows:

### *Process-based understanding of the A. mangium system*

Process-based modelling was a core part this project, with many of the activities focussed on understanding the system in order to be able to model it effectively. Several of the Indonesian project staff participated in these activities, which included (i) experiments to explore the relationships between site edaphic properties and productivity, (ii) understanding the impact of variable rainfall and soil water storage on productivity, (iii) understanding the photosynthetic and water stress responses of trees to their environment over the course of a day, (iv) exploring the interactions between water use, nutrient availability, site type, and tree productivity in a simulation model. These studies also highlighted some of the limitations of process-based models, with some scenarios unable to be accurately represented by the model. The project also allowed the opportunity to examine and explore plantation forests growing in different environments. Dr Hardiyanto and Mr Wibisono visited the plantations on Melville Island and in south-western Australia, and Mr Nurudin also visited plantations in south-western Australia. Mr Prehaten completed his Masters degree at the University of Western Australia, the research component of which was based on gaining a deeper understanding of the photosynthetic and responses of *A. mangium* to drought and soil fertility.

### *DSS development*

Project staff in Indonesia (primarily Mr Soeprijadi and Dr Hardiyanto) were responsible for development of the excel-based DSS, using a lookup table of outputs from the process-based model (see above). This is the first time that such an approach has been taken in Indonesian plantation forestry for linking research outputs to users, and is being adopted in other projects by the Faculty of Forestry, University of Gadjah Mada.

### *Soil analysis*

Mr Nurudin developed his soil analysis skills through the project, including a visit to the CSIRO Perth laboratory, and also through a UNESCO project, “Application of soil color to assess productivity of *Acacia mangium* plantation in Indonesia”

### *John Allwright fellows*

We have hosted 2 John Allwright Fellows through this project. Mr Daryono Prehaten completed his Masters degree at the University of Western Australia, and Mr Gunawan Wibisono is most of the way through his PhD candidature at the University of Western Australia. Both of these projects allowed the candidates to understand more about the *A. mangium* system, with Prehaten focussing on the photosynthetic and gas exchange responses of *A. mangium* to environmental factors, and Wibisono focussing on quantifying N fixation in *A. mangium* plantations.

## 8.3 Community impacts – now and in 5 years

Most of the tangible impacts from the project will be economic or social, based on the following factors

### *Objective basis for farmers to make decisions on* Acacia *cropping*

The growers manual gives guidance to growers on the maximum expected productivity for different site types, and the flow-on impact on economic returns, thus allowing them to make an objective decision about whether to grow acacias or other crops on their land. This was released at the end of the project, so impacts are likely to occur into the future rather than now.

### *Improved capacity to grow* Acacia mangium

The production of a growers manual and DSS, as well as a range of experimental sites showing productive potential across the growing region and a range of site types gives growers a framework for best-bet management of acacias to give maximum returns. It has been found that outgrower farmer plantations tend to underperform (about 50% of comparable company plantings), so these tools will give farmers the knowledge to start addressing this yield gap. This will have direct economic impacts through improved returns to farmers, but could also change the pattern of land use as acacias become recognised as an alternative crop option for land that cannot be utilized because of labour constraints. Again, these tools were released at the end of the project, so are likely to have an impact into the future.

### *Better understanding of outgrower engagement models*

The social research undertaken in this project has demonstrated that current outgrower engagement models are perceived as being inequitable (in favour of the company), and that these need to be refined to attract more farmers (or retain existing farmers). Greater up-front transparency in the growing costs that are incurred by the company would assist the outgrowers in understanding the need for a higher share of the profits by the company, but also a review of the profit-sharing arrangements is warranted to reduce the implied interest rates (eg. 22% in our example above) that are probably too high.to be accepted by many outgrower farmers as being equitable.

### *Reduced input costs*

Our research has demonstrated that many (if not all) sites do not require the current levels of fertilizer inputs for maximum returns, and that the recommended application rates can be reduced by about 30%. This recommendation is being independently tested by PT MHP and is likely to be implemented soon.

### 8.3.1 Economic impacts

The economic impacts are likely to be positive and include the following

- Improved site selection and management of plantations, with the capacity to increase the productivity of outgrower plantings by about 2-fold, increasing the net present value of returns from $651.90 up to around $1288.23/ha over a 6-year rotation (see Table 12).
- Reduced input costs – we have shown that less phosphorus fertilizer needs to be applied at establishment, down from the current recommendation of 15.5 kg/ha to 10 kg/ha. At current prices, this would save around $14/ha at establishment, or around $469k/y across the 200 000 ha estate of PT MHP and its outgrowers.

### 8.3.2 Social impacts

Social impacts are likely to be positive, and in the following areas

- Improved targeting of *Acacia* plantations to productive sites and improved management will improve the returns associated with growing plantations, thus improving the wealth of outgrower farmers and their families
- Recommendations for improvements to the outgrower scheme, if adopted, should result in a more transparent profit-sharing arrangement, which will improve the relationship between the company and both the outgrower farmers and their communities

The magnitude of these impacts are likely to be low now, but has potential for significant impact in 5 years time.

### 8.3.3 Environmental impacts

The environmental impacts from this project are likely to be positive. The key areas for environmental impact are as follows

- A reduction in the demand placed on wood sourced from natural forest, due to an increased capacity to source wood from plantations
- A reduction in P fertilizer use, and commensurately a reduction in risk of loss to the environment, and
- Soil fertility improvement through incorporation of fixed N. The latter 2 points are mostly at a site level.

Whilst the direction of these impacts is positive, the actual impacts now are likely to be low, and projections for 5 years are difficult to quantify.

## 8.4 Communication and dissemination activities

Key communication and dissemination activities outside the project included the following

- Scientific presentations by Mendham and Hardiyanto at the CIFOR workshop on ‘Site Management and Productivity in Tropical Plantation Forests,’ Bogor, November 5-9, 2006
- A field day was held in South Sumatra in May 2009 with approximately 50 managers and extension officers from PT MHP. This was also attended by representatives from other growers, RAPP and Barito Pacific.
- A DSS feedback session was held in South Sumatra in February 2010. The session was attended by 37 participants from PT MHP, and included Deputy Director of Plantation, Chief officer of operational plantation, Deputy Director of Wood production, Staff of Plantation Division, Head of Region 2 and 3, Plantation

Division Head of Region 1 and 2,  Wood Production Head of Region 1, 2 and 3, Head of Unit (11 units), Head of Planning Division, Planning Head of Region 1, 2 and 3, Head of Community Development Division, and R&D Researchers. The aims of the day were to present, and get industry feeback on, the draft version of the DSS.

- Scientific presentation by Wicaksono and Hardiyanto at the International Seminar-Research on Plantation Forest Management : Challenges and Opportunities, 5-6 November 2009, Bogor, Indonesia.
- A final project workshop was held in Palembang, South Sumatra, in April 2010, to present the project outcomes and outputs to an audience of scientists, managers, and FORDA staff. Approximately 100 people attended this workshop. The workshop was held over 3 days. The DSS and growers manual were released at this event
- A workshop was held at the Center of Forest Plantation Research in Bogor in June 2010 to disseminate the project outcomes to FORDA staff, including several from Java, 1 from Riau, 1 from Palembang, and 2 from South Kalimantan. Copies of the Growers Manual were distributed.

# 9 Conclusions and recommendations

## 9.1 Conclusions

The project resulted in an advance in several areas of research relevant to assisting smallholder farmers in selecting sites and growing *A. mangium* plantations. Key advances included

- Sites can now be characterised based on relatively easily assessed soil profile characteristics (depth to plinthite, colour, consistency and structure), and an integration of these with climate to allow assessment of productive potential
- Productive potential of *A. mangium* in South Sumatra is high (we achieved up to 180 $m^3$/ha standing volume at age 3) and farmers in this region have an excellent opportunity to have a profitable *A. mangium* component of their enterprise. The growth rates in our experiments were higher than can be achieved in the vast majority of areas used for plantations in the world.
- Improved seed sources gave gains in productivity at both core sites in the first year (55-180% increase over local landrace seed source), but only at 1 of the 2 sites in the 2nd year (where there was a 70% increase over local landrace seed source), suggesting that these experiments need to be followed for a longer period of time to assess the full benefit of improved seed.
- There is a strong contrast in environment between Sumatra and Australia, and our observations and modelling of this effect on productivity suggests that growth rates of *A. mangium* on Melville Island will be much lower than in Sumatra (growth rates in our experiment were around 25% of those in Sumatra). It is also evident that the long dry season on Melville Island causes significant stress in *A. mangium*, which is probably a significant factor affecting tree form in this region.
- Outgrower farmers are currently achieving productivity levels of around only 50% of the adjacent industrial plantations, which in turn are achieving productivity levels around 60% of our experimental outcomes, suggesting that there is significant scope for improvement of productivity above current levels.
- Application of improved management could improve the returns to growers by around $636/ha/rotation
- Improved genotypes have a higher demand for nutrients, but only a low rate of P application (10 kg P/ha, which is 30% lower than current practice) is required to achieve maximum productivity levels at most or all sites in South Sumatra. It is likely that more will be required in the older soils of northern Australia, but our measurements ceased before this could be shown conclusively.
- Phosphorus is the only nutrient that is required in South Sumatra, as there was no response to basal fertilizer at either of the 2 sites where this was tested. However, preliminary results from Melville Island showed that most sites require additional nutrients to P.
- P fertilizer has an additive effect with weeding, i.e. that maximum productivity is only obtained when both weeding is conducted and P fertilizer is applied, but at sub-optimal productivity, there is some interchangeability between weed control and P addition. At the site where we explored this, we found that 20 kg P/ha addition with no weeding had the same productivity as a treatment with no P fertilizer but good weed control. It is important to recognise that these results were only assessed on 12-month-old trees, and need to be followed for a longer time to be more conclusive.

- The current 60:40 profit sharing arrangement is viewed by most outgrowers as being inequitable, partly due to the lack of transparency in the costs that are incurred by the company that need to be subtracted from the company share of the profits, but also because the implied interest rate on the company expenditure is quite high at around 22%.

The project produced some key outputs to encapsulate the findings and integrate them with best-practice knowledge in a user-friendly format. These were an *Acacia mangium* Growers Manual, and an Excel-based decision support system. The anticipated audience for the growers manual are outgrower farmers, through company extension officers, whilst company managers are the target audience for the DSS. The pathway to adoption in forestry projects like this is often found to be relatively short because the hierarchical structure of forestry organizations means that new technology need only be transferred to a few intermediate personnel for it to be adopted.

## 9.2 Recommendations

This project has potential for significant impact in Indonesia, and the key findings could/should be validated beyond South Sumatra. The Indonesian Government, through the Ministry of Forestry, has established the “Hutan Tanaman Rakyat” programme to double the production of pulp by 2020. This will require a very large and sustained effort into promoting and supporting smallholder farmers, whom it is anticipated will grow around 40% of the feedstock required. It is estimated that around 360 000 additional smallholder farmer families will be required to meet this target, all in Sumatra and Kalimantan. There are two significant technical issues that need to be addressed for this programme to be successful, including (1) the apparent underperformance of plantations on outgrower land that has been found in the current study, and (2) root rot is becoming a significant threat to survival in many plantations, and this may require a species change to overcome the problem. There is also an apparent need for farmers to be able to value add to their plantations through providing an option for sawlog as well as pulpwood. These key opportunities have been presented to ACIAR in a new project proposal, FST2009/051, “Increasing profitability of forest plantations in Indonesia by sustaining yields in the smallholder sector.”

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# 11 Appendixes

## 11.1 Appendix 1: Soil profile descriptions for sites used in the characterization of site edaphic properties

*Table A1.1 Soil profile descriptions*

| Soil Profile | Horizon | Depth (cm) | Description | Soil Classification |
|---|---|---|---|---|
| | | | **Low productivity** | |
| 44 | Ap | 0-15 | dull yellowish brown (10 YR 4/3); moist; SaCl; moderate medium subangular blocky; firm; many fine roots; clear wavy boundary to | Ultisols |
| LAGAN | Bt1 | 15-40 | dull yellowish brown (10 YR 5/4); moderately dry; SaCl; moderate medium subangular blocky; very firm; few fine roots; gradual smooth boundary to | |
| | Bt2 | 40-65 | grayish yellow brown (10 YR 6/2), mottling dull reddish brown (5 YR 5/4); moderately dry; SaCl; moderate medium subangular blocky; very firm; gradual wavy boundary to | |
| | Bt3 | 65-100 | dull yellowish orange (10 YR 7/2), mottling dull reddish brown (2.5 YR 4/4); moderately dry; SaCl; plinthite; moderate medium subangular blocky; very firm | |
| 134 | Ap | 0-10 | bright yellowish brown (10 YR 7/6); moderately dry; SaCl; moderate medium subangular blocky; firm; few fine and medium roots; clear wavy boundary to | Ultisols |
| LAGAN | A/B | 10-30 | Orange (7.5 YR 6/6); moderately dry; SaCl; moderate medium subangular blocky; very firm; few fine roots; gradual wavy boundary to | |
| | Bt1 | 30-50 | dull yellowish orange (10 YR 7/4), mottling bright reddish brown (5 YR 5/6); moderately dry; SaCl; moderate medium subangular blocky; very firm; clear wavy boundary to | |
| | Bt2 | 50-73 | dull yellowish orange (10 YR 7/3), mottling reddish brown (2.5 YR 4/6); moderately dry; SaCl; plinthite; moderate medium subangular blocky; very firm; gradual smooth boundary to | |
| | Bt3 | 73-100 | dull yellowish orange (10 YR 7/2), mottling brown (10 YR 4/6); moderately dry; ; moderately dry; SaCl; gley layer; moderate medium subangular blocky; very firm | |
| 113 | Ap1 | 0-20 | dull yellowish brown (10 YR 5/3); moderately dry; SaCl; moderate medium subangular blocky; firm; few fine and medium roots; gradual smooth boundary to | Ultisols |
| LAGAN | Ap2 | 20-50 | yellowish brown (10 YR 5/6); moderately dry; ; SaCl; moderate medium subangular blocky; very firm; few fine and medium roots; clear wavy boundary to | |
| | Bt1 | 50-70 | bright yellowish brown (10 YR 6/6), mottling dark reddish brown (2.5 YR 3/6); moderately dry; ; C; moderate medium subangular blocky; very firm; clear wavy boundary to | |
| | Bt2 | 70-100 | bright yellowish brown (10 YR 6/6), mottling reddish brown (5 YR 4/6); moderately dry; C; plinthite; moderate medium subangular blocky; very firm | |
| 10 | Ap | 0-16 | grayish yellow brown (10 YR 4/2); moderately dry; Cl; moderate medium crumb; friable; many fine and medium roots; clear wavy to | Inceptisols |
| DERAS | A/B | 16-44 | dull yellowish brown (10 YR 5/4); moderately dry; Cl: | |

| | | | | |
|---|---|---|---|---|
| | | | moderate medium subangular blocky; firm; few fine and medium roots; clear wavy boundary to | |
| | Bw1 | 44-85 | bright brown (7.5 YR 5/6); moderately dry; Cl; moderate medium subangular blocky; firm; few fine roots; gradual smooth boundary to | |
| | Bw2 | 85-100 | dull yellowish brown (10 YR 5/4); moderately dry; Cl; moderate medium subangular blocky; firm. | |
| 115 | Ap | 0-10 | dull yellowish brown (10 YR 5/3); moderately dry; SaCl; moderate medium crumb; friable; many fine and medium roots; gradual smooth boundary to | Ultisols |
| LAGAN | A/B | 10-25 | dull yellowish brown (10 YR 5/3), mottling brown (7.5 YR 4/4); moderately dry; SaCl; moderate medium crumb, firm; few fine roots; clear wavy boundary to | |
| | Bt1 | 25-45 | grayish yellow brown (10 YR 6/2), mottling dark reddish brown (2.5 YR 3/6); moderately dry; C; moderate medium subangular blocky; very firm; few fine roots; gradual wavy boundary to | |
| | Bt2 | 45-73 | grayish yellow brown (10 YR 6/2), mottling dark reddish brown (2.5 YR 3/6); moderately dry; C; plinthite; moderate medium subangular blocky; very firm; clear wavy boundary to | |
| | Bt3 | 73-100 | light grey (10 YR 7/1), mottling reddish brown (2.5 YR 4/6); moderately dry; C; plinthite;moderate medium subangular blocky; very firm | |
| | | | **Medium Productivity** | |
| 75 | Ap | 0-10 | dull yellowish brown (10 YR 4/3); dry; SaCl; moderate medium crumb; friable; many fine roots; clear wavy boundary to | Ultisols |
| NIRU | Bt1 | 10-30 | dull yellowish brown (10 YR 5/3); dry; C; strong medium subangular blocky; very firm; few fine roots; gradual wavy boundary to | |
| | Bt2 | 30-50 | grayish yellow brown (10 YR 6/2), mottling bright yellowish brown (10 YR 6/6); moderately dry; C; plinthite; strong medium subangular blocky; very firm; few fine roots; gradual smooth boundary to | |
| | Bt3 | 50-70 | light grey (10 YR 7/1), mottling reddish brown (2.5 YR 4/6); moderately dry; C; plinthite; strong medium subangular blocky; very firm; gradual smooth boundary to | |
| | Bt4 | 70-100 | light grey (10 YR 7/1), mottling orange (7.5 YR 6/8) and dark reddish brown (2.5 YR ¾); moderately dry; C; plinthite; strong medium subangular blocky; very firm | |
| 79 | Ap | 0-10 | grayish yellow brown (10 YR 4/2); dry; C; moderate medium crumb; friable; many fine, medium and big roots, clear wavy boundary to | Ultisols |
| NIRU | Bt1 | 10-30 | yellowish brown (10 YR 5/6); dry; C; strong medium angular blocky; very firm; few fine roots, clear wavy boundary to | |
| | Bt2 | 30-65 | bright yellowish brown (10 YR 6/6); moderately dry; C; strong medium angular blocky; very firm; few fine roots, clear wavy boundary to | |
| | Bt3 | 65-100 | light grey (10 YR 7/1), mottling dull reddish brown (2.5 YR 4/4); moderately dry; plinthite; moderate medium angular blocky; very firm | |
| | | | **High Productivity** | |
| 232 | Ap | 0-20 | brownish black (10 YR 3/2); moderately moist; Cl; moderate medium crumb; friable; many fine and medium roots; clear wavy boundary to | Inceptisols |
| NIRU | Bw1 | 20-42 | Brown (7.5 YR 4/6); moderately moist; Cl; weak moderate subangular blocky; firm; few medium roots; | |

| | | | | |
|---|---|---|---|---|
| | | | gradual smooth boundary to | |
| | Bw2 | 42-64 | Brown (7.5 YR 4/6); moderately moist; Cl; medium moderate subangular blocky; firm; few medium roots; gradual smooth boundary to | |
| | Bw3 | 64-86 | Brown (7.5 YR 4/6); moderately moist; Cl; medium moderate subangular blocky; firm; few medium roots; gradual smooth boundary to | |
| | Bw4 | 86-100 | Brown (7.5 YR 4/6); moderately moist; Cl; medium moderate subangular blocky; firm; few medium roots | |
| 62 | Ap | 0-23 | dull yellowish brown (10 YR 4/3); moderately dry; SaCl; moderate medium crumb; firm; many fime and medium roots; clear wavy boundary to | Ultisols |
| IBUL | A/B | 23-35 | dull yellowish orange (10 YR 6/4), mottling bright reddish brown (5 YR 5/6); moderately dry; SaCl; moderate medium crumb; firm; few fime and medium roots; clear wavy boundary to | |
| | Bt1 | 35-50 | dull yellowish orange (10 YR 6/3), mottling reddish brown (2.5 YR 4/6); moderately dry; SaCl; many plinthite; moderate medium subangular blocky; very firm; few medium roots; gradual smooth boundary to | |
| | Bt2 | 50-75 | dull yellowish orange (10 YR 6/3), mottling dull reddish brown (2.5 YR 4/4); moderately dry; SaCl; many plinthite; moderate medium subangular blocky; very firm; few medium roots; gradual smooth boundary to | |
| | Bt3 | 75-100 | light grey (10 YR 7/1), mottling dark reddish brown (2.5 YR ¾); moderately dry; SaCl; many plinthite; moderate medium subangular blocky; very firm; few medium roots; gradual smooth boundary to | |
| 57 | Ap | 0-12 | grayish yellow brown (10 YR 4/2); moderately dry; SaCl; moderate medium crumb; friable; many fime and medium roots; clear wavy boundary to | Ultisols |
| KERUH | A/B | 12-30 | Brown (10 YR 4/4); moderately dry; SaCl; moderate medium subangular blocky; firm; few fine roots; gradual smooth boundary to | |
| | Bt1 | 30-50 | bright brown (7.5 YR 5/6); moderately dry; SaCl; moderate medium subangular blocky; very firm; few fine roots; gradual smooth boundary to | |
| | Bt2 | 50-75 | bright brown (7.5 YR 5/6); moderately dry; SaCl; moderate medium subangular blocky; very firm; few fine roots; clear wavy boundary to | |
| | Bt3 | 75-100 | bright brown (7.5 YR 5/6), mottling dark reddish brown (2.5 YR 3/6); moderately dry; SaCl; many hematite; moderate medium subangular blocky; very firm; | |
| 119 | Ap | 0-18 | brownish black (10 YR 3/2); moderately dry; SaCl; moderate medium crumb; friable;fine and medium roots; clear wavy boundary to | Ultisols |
| SUBAN | Bt1 | 18-42 | bright brown (7.5 YR 5/6); moderately dry; SaCl; medium medium subangular blocky; firm; few medium roots; gradual smooth boundary to | |
| JERIJI | Bt2 | 42-82 | Orange (7.5 YR 6/6); moderately dry; SaCl; medium medium subangular blocky; very firm; few medium roots; clear wavy boundary to | |
| | Bt3 | 82-100 | bright reddish brown (2.5 YR 5/6); moderately dry; SaCl; many hematite; medium medium subangular blocky; very firm; few medium roots | |
| 02 | Ap | 0-12 | dull yellowish brown (10 YR 5/3); moderately dry; C; moderate medium crumb; friable; many fine roots; clear wavy boundary to | Ultisols |
| BANDING | Bt1 | 12-50 | dull yellowish brown (10 YR 5/4), mottling bright brown (7.5 YR 5/6); moderately dry; C; moderate medium subangular blocky; firm; few fine and medium roots; | |

| | | | |
|---|---|---|---|
| | | | gradual smooth boundary to |
| ANYAR | Bt2 | 50-75 | Brown (10 YR 4/6); moderately dry; SaC; few hematite; moderate medium subangular blocky; firm; few medium roots; clear wavy boundary to |
| | Bt3 | 75-100 | yellowish brown (10 YR 5/6), mottling reddish brown (2.5 YR 4/6); moderately dry; SaC; many hematite; moderate medium subangular blocky; very firm |

Note: SaC (sandy clay), C (clay), SaCl (sandy clay loam), Cl (clay loam).

# 11.2 Appenix 2: Soil profile colours for sites used in the characterization of site edaphic properties

*Table A2.1 – Munsell colours at each of the sites*

| | | | Air dried | | Oven 105°C | | Oven 850°C | |
|---|---|---|---|---|---|---|---|---|
| Soil profile | Horizon | Depth (cm) | Munsell | RR | Munsell | RR | Munsell | RR |
| | | | **Low Productivity** | | | | | |
| 44 | Ap | 0-15 | 10 YR 6/3 | 0 | 10 YR 6/3 | 0 | 5 YR 7/6 | 4.3 |
| LAGAN | Bt1 | 15-40 | 10 YR 7/4 | 0 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| | Bt2 | 40-65 | 7.5 YR 7/4 | 1.4 | 7.5 YR 7/4 | 1.4 | 5 YR 7/6 | 4.3 |
| | Bt3 | 65-100 | 5 YR 7/4 | 2.9 | 5 YR 7/4 | 2.9 | 5 YR 7/6 | 4.3 |
| 134 | Ap | 0-10 | 10 YR 7/3 | 0 | 10 YR 6/3 | 0 | 5 YR 7/6 | 4.3 |
| LAGAN | A/B | 10-30 | 10 YR 7/4 | 0 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| | Bt1 | 30-50 | 10 YR 7/4 | 0 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| | Bt2 | 50-73 | 5 YR 7/6 | 4.3 | 7.5 YR 7/4 | 1.4 | 5 YR 7/6 | 4.3 |
| | Bt3 | 73-100 | 7.5 YR 7/4 | 1.4 | 7.5 YR 7/4 | 1.4 | 5 YR 7/6 | 4.3 |
| 113 | Ap1 | 0-20 | 10 YR 6/3 | 0 | 10 YR 6/3 | 0 | 5 YR 7/6 | 4.3 |
| LAGAN | Ap2 | 20-50 | 10 YR 7/4 | 0 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| | Bt1 | 50-70 | 10 YR 7/4 | 0 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| | Bt2 | 70-100 | 7.5 YR 7/4 | 1.4 | 7.5 YR 7/4 | 1.4 | 5 YR 7/6 | 4.3 |
| 10 | Ap | 0-16 | 7.5 YR 6/3 | 1.3 | 10 YR 6/3 | 0 | 5 YR 7/6 | 4.3 |
| DERAS | A/B | 16-44 | 10 YR 7/3 | 0 | 10 YR 7/3 | 0 | 5 YR 7/6 | 4.3 |
| | Bw1 | 44-85 | 7.5 YR 7/3 | 1.1 | 7.5 YR 7/4 | 1.4 | 5 YR 7/6 | 4.3 |
| | Bw2 | 85-100 | 7.5 YR 7/3 | 1.1 | 7.5 YR 7/3 | 1.1 | 5 YR 7/6 | 4.3 |
| 115 | Ap | 0-10 | 10 YR 6/2 | 0 | 10 YR 6/2 | 0 | 5 YR 7/6 | 4.3 |
| LAGAN | A/B | 10-25 | 10 YR 7/3 | 0 | 10 YR 6/3 | 0 | 5 YR 7/6 | 4.3 |
| | Bt1 | 25-45 | 7.5 YR 7/4 | 1.4 | 7.5 YR 7/4 | 1.4 | 5 YR 7/6 | 4.3 |
| | Bt2 | 45-73 | 7.5 YR 7/4 | 1.4 | 7.5 YR 7/4 | 1.4 | 5 YR 7/6 | 4.3 |
| | Bt3 | 73-100 | 7.5 YR 7/3 | 1.1 | 7.5 YR 7/3 | 1.1 | 2.5 YR 7/6 | 6.4 |
| | | | **Medium Productivity** | | | | | |
| 75 | Ap | 0-10 | 10 YR 6/2 | 0 | 10 YR 6/2 | 0 | 5 YR 7/6 | 4.3 |
| NIRU | Bt1 | 10-30 | 10 YR 7/3 | 0 | 10 YR 7/3 | 0 | 5 YR 7/6 | 4.3 |
| | Bt2 | 30-50 | 10 YR 7/4 | 0 | 2.5 YR 7/3 | 3.2 | 5 YR 7/6 | 4.3 |
| | Bt3 | 50-70 | 10 YR 7/3 | 0 | 10 YR 7/3 | 0 | 2.5 YR 7/6 | 6.4 |
| | Bt4 | 70-100 | 7.5 YR 7/3 | 1.1 | 7.5 YR 7/3 | 1.1 | 5 YR 7/4 | 2.9 |
| 79 | Ap | 0-10 | 10 YR 6/2 | 0 | 10 YR 6/2 | 0 | 5 YR 7/6 | 4.3 |
| NIRU | Bt1 | 10-30 | 10 YR 7/4 | 0 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| | Bt2 | 30-65 | 10 YR 7/3 | 0 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| | Bt3 | 65-100 | 5 YR 7/4 | 2.9 | 5 YR 7/4 | 2.9 | 2.5 YR 7/6 | 6.4 |
| | | | **High Productivity** | | | | | |
| 232 | Ap | 0-20 | 10 YR 5/2 | 0 | 10 YR 5/2 | 0 | 5 YR 6/6 | 5 |
| NIRU | Bw1 | 20-42 | 7.5 YR 6/4 | 1.7 | 7.5 YR 6/4 | 1.7 | 5 YR 6/6 | 5 |
| | Bw2 | 42-64 | 7.5 YR 6/4 | 1.7 | 7.5 YR 6/4 | 1.7 | 5 YR 6/6 | 5 |
| | Bw3 | 64-86 | 7.5 YR 6/4 | 1.7 | 7.5 YR 6/4 | 1.7 | 5 YR 6/6 | 5 |
| | Bw4 | 86-100 | 7.5 YR 6/4 | 1.7 | 7.5 YR 6/4 | 1.7 | 2.5 YR 6/8 | 10 |
| 62 | Ap | 0-23 | 10 YR 6/3 | 0 | 10 YR 6/3 | 0 | 5 YR 6/6 | 5 |
| IBUL | A/B | 23-35 | 7.5 YR 6/4 | 1.7 | 10 YR 6/4 | 0 | 2.5 YR 6/8 | 10 |
| | Bt1 | 35-50 | 7.5 YR 6/4 | 1.7 | 10 YR 6/4 | 0 | 5 YR 6/6 | 5 |
| | Bt2 | 50-75 | 10 YR 6/3 | 0 | 10 YR 6/4 | 0 | 5 YR 6/6 | 5 |
| | Bt3 | 75-100 | 5 YR 6/4 | 3.3 | 7.5 YR 6/4 | 1.7 | 5 YR 6/6 | 5 |
| 57 | Ap | 0-12 | 10 YR 6/2 | 0 | 10 YR 6/3 | 0 | 5 YR 7/6 | 4.3 |
| KERUH | A/B | 12-30 | 7.5 YR 7/4 | 1.4 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| | Bt1 | 30-50 | 7.5 YR 7/4 | 1.4 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| | Bt2 | 50-75 | 5 YR 7/4 | 2.9 | 5 YR 7/4 | 2.9 | 2.5 YR 6/6 | 7.5 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Bt3 | 75-100 | 10 YR 6/3 | 0 | 10 YR 6/3 | 0 | 5 YR 7/6 | 4.3 |
| 119 | Ap | 0-18 | 10 YR 7/3 | 0 | 2.5 YR 7/3 | 3.2 | 5 YR 7/6 | 4.3 |
| SUBAN | Bt1 | 18-42 | 10 YR 7/3 | 0 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| JERIJI | Bt2 | 42-82 | 5 YR 7/4 | 2.9 | 5 YR 7/4 | 2.9 | 2.5 YR 6/6 | 7.5 |
| | Bt3 | 82-100 | 10 YR 7/3 | 0 | 10 YR 6/3 | 0 | 5 YR 7/6 | 4.3 |
| 2 | Ap | 0-12 | 10 YR 7/4 | 0 | 10 YR 7/4 | 0 | 5 YR 7/6 | 4.3 |
| BANDING | Bt1 | 12-50 | 10 YR 7/4 | 0 | 7.5 YR 7/4 | 1.4 | 5 YR 7/6 | 4.3 |
| ANYAR | Bt2 | 50-75 | 7.5 YR 7/4 | 1.4 | 5 YR 7/4 | 2.9 | 2.5 YR 7/6 | 6.4 |
| | Bt3 | 75-100 | 7.5 YR 7/4 | 1.4 | 5 YR 7/4 | 2.9 | 5 YR 7/4 | 2.9 |

*Table A2.2 – CIE colours at each of the sites*

| | | | Air dried | | | | Oven 105°C | | | | Oven 850°C | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil profile | Horizon | Depth (cm) | a* | b* | L* | a*/b* | a* | b* | L* | a*/b* | a* | b* | L* | a*/b* |
| **Low Productivity** | | | | | | | | | | | | | | |
| 44 | Ap | 0-15 | 5.1 | 15.5 | 59.7 | 0.33 | 5.6 | 18.1 | 62.8 | 0.31 | 20.8 | 31.1 | 68 | 0.67 |
| LAGAN | Bt1 | 15-40 | 8 | 22.8 | 67.4 | 0.35 | 8.4 | 24.7 | 70.5 | 0.34 | 20.8 | 31.5 | 67.9 | 0.66 |
| | Bt2 | 40-65 | 12.2 | 23.9 | 63.4 | 0.51 | 13.1 | 25.9 | 67.5 | 0.51 | 22.6 | 32.1 | 65.6 | 0.7 |
| | Bt3 | 65-100 | 14.2 | 22.8 | 63.6 | 0.62 | 15.4 | 23.9 | 68 | 0.64 | 21.3 | 27.8 | 64.9 | 0.77 |
| 134 | Ap | 0-10 | 5.8 | 17.3 | 65 | 0.33 | 6 | 18.3 | 64.9 | 0.33 | 18.3 | 29.3 | 70.2 | 0.63 |
| LAGAN | A/B | 10-30 | 9 | 25.4 | 71.3 | 0.36 | 8.8 | 25.7 | 73.2 | 0.34 | 20.3 | 31.9 | 69.6 | 0.64 |
| | Bt1 | 30-50 | 11.4 | 26.1 | 69.9 | 0.44 | 11.2 | 26.6 | 72.1 | 0.42 | 21.1 | 32.8 | 69.1 | 0.64 |
| | Bt2 | 50-73 | 14.6 | 26.4 | 67.2 | 0.55 | 14.1 | 26 | 69.2 | 0.54 | 21.9 | 31.5 | 66.4 | 0.7 |
| | Bt3 | 73-100 | 12.3 | 21.5 | 68.5 | 0.57 | 12.8 | 22.3 | 71.2 | 0.57 | 18.7 | 25.9 | 67.6 | 0.72 |
| 113 | Ap1 | 0-20 | 4.6 | 15.5 | 60.7 | 0.3 | 5.5 | 17.4 | 60.5 | 0.32 | 21.9 | 30.6 | 65.6 | 0.71 |
| LAGAN | Ap2 | 20-50 | 9.7 | 25 | 67.6 | 0.39 | 10 | 25.7 | 68.7 | 0.39 | 22.6 | 32.3 | 64.5 | 0.7 |
| | Bt1 | 50-70 | 11.1 | 25.4 | 67.4 | 0.44 | 12.3 | 26.8 | 67.9 | 0.46 | 23.3 | 32.2 | 63.4 | 0.72 |
| | Bt2 | 70-100 | 12.7 | 26 | 66.5 | 0.49 | 13.4 | 27.4 | 69 | 0.49 | 24.2 | 32.3 | 63.1 | 0.75 |
| 10 | Ap | 0-16 | 5.5 | 14.2 | 57.9 | 0.39 | 6.3 | 16.7 | 60.8 | 0.38 | 19.8 | 29.3 | 66 | 0.68 |
| DERAS | A/B | 16-44 | 7.7 | 18.5 | 64.1 | 0.42 | 8.2 | 20.9 | 66.4 | 0.39 | 20.4 | 29.8 | 67.3 | 0.68 |
| | Bw1 | 44-85 | 8.3 | 18.8 | 65.9 | 0.44 | 8.5 | 20.7 | 67.5 | 0.41 | 19.5 | 28.9 | 68 | 0.67 |
| | Bw2 | 85-100 | 8.4 | 17.6 | 64.3 | 0.48 | 9.1 | 19.6 | 66.8 | 0.46 | 19.4 | 27.9 | 67.8 | 0.69 |
| 115 | Ap | 0-10 | 4 | 11.6 | 57.8 | 0.35 | 4.6 | 13.8 | 58.3 | 0.34 | 17.8 | 28.4 | 67.9 | 0.63 |
| LAGAN | A/B | 10-25 | 5.7 | 18 | 65.5 | 0.32 | 6.3 | 19 | 65.3 | 0.33 | 18.6 | 28.7 | 68 | 0.65 |
| | Bt1 | 25-45 | 11.1 | 22.6 | 65.2 | 0.49 | 11.7 | 23.8 | 66.9 | 0.49 | 21.6 | 30.8 | 66.1 | 0.7 |
| | Bt2 | 45-73 | 11.1 | 23.1 | 65.8 | 0.48 | 11.2 | 23.7 | 68.9 | 0.47 | 21 | 29.7 | 67 | 0.71 |
| | Bt3 | 73-100 | 9 | 17.8 | 68.6 | 0.51 | 9.8 | 19.2 | 71.2 | 0.51 | 17.9 | 23.8 | 68.5 | 0.75 |
| **Medium Productivity** | | | | | | | | | | | | | | |
| 75 | Ap | 0-10 | 3.7 | 11.3 | 58.7 | 0.33 | 4.2 | 14.2 | 65 | 0.29 | 15.5 | 26.8 | 72.2 | 0.58 |
| NIRU | Bt1 | Oct-30 | 5.7 | 19.3 | 70.6 | 0.3 | 5.4 | 20.4 | 73.4 | 0.27 | 17.8 | 27.8 | 71.6 | 0.64 |
| | Bt2 | 30-50 | 5.7 | 22.4 | 72.3 | 0.25 | 5.5 | 23 | 75.6 | 0.24 | 19.3 | 30.3 | 70.8 | 0.64 |
| | Bt3 | 50-70 | 7.5 | 19.1 | 67.9 | 0.4 | 8 | 19.4 | 73.9 | 0.41 | 17 | 23.8 | 69.5 | 0.72 |
| | Bt4 | 70-100 | 7.9 | 14.5 | 64.8 | 0.55 | 9.1 | 15.8 | 71.4 | 0.58 | 15.5 | 19.1 | 66.7 | 0.81 |
| 79 | Ap | 0-10 | 4.4 | 11.7 | 56.7 | 0.37 | 4.9 | 13.7 | 57.2 | 0.36 | 19.1 | 30.5 | 67.6 | 0.63 |
| NIRU | Bt1 | 10-30 | 7.4 | 22.9 | 67.5 | 0.32 | 7.9 | 25.5 | 69.8 | 0.31 | 21.8 | 31.7 | 66 | 0.69 |
| | Bt2 | 30-65 | 5.8 | 21.1 | 69.1 | 0.27 | 6.3 | 23.4 | 72.5 | 0.27 | 19.7 | 30.6 | 68.3 | 0.64 |
| | Bt3 | 65-100 | 13.2 | 21 | 66.2 | 0.63 | 13.4 | 20.6 | 68.6 | 0.65 | 21 | 26.1 | 65 | 0.8 |
| **High Productivity** | | | | | | | | | | | | | | |
| 232 | Ap | 0-20 | 4.3 | 11 | 49.8 | 0.39 | 5.1 | 13.5 | 51.9 | 0.38 | 21.4 | 30 | 63.1 | 0.71 |
| NIRU | Bw1 | 20-42 | 8.9 | 19.6 | 54.3 | 0.45 | 9 | 21.8 | 58.8 | 0.41 | 23.8 | 32.2 | 61.2 | 0.74 |
| | Bw2 | 42-64 | 9.3 | 20 | 56.3 | 0.46 | 10.1 | 23.5 | 59.9 | 0.43 | 24.7 | 32.5 | 60.7 | 0.76 |
| | Bw3 | 64-86 | 9.5 | 20.2 | 57.6 | 0.47 | 10.5 | 24.9 | 61 | 0.42 | 24.5 | 32.1 | 60.9 | 0.76 |
| | Bw4 | 86-100 | 10.9 | 21.9 | 57.9 | 0.5 | 11.5 | 25 | 61.1 | 0.46 | 25.5 | 32.6 | 60.2 | 0.78 |
| 62 | Ap | 0-23 | 4.8 | 16.9 | 64 | 0.29 | 5.3 | 18 | 63.9 | 0.3 | 19.3 | 28.5 | 65.7 | 0.68 |
| IBUL | A/B | 23-35 | 8.4 | 24 | 71.1 | 0.35 | 8.1 | 23.7 | 72.4 | 0.34 | 19.7 | 30.1 | 68.2 | 0.65 |
| | Bt1 | 35-50 | 9.4 | 23.8 | 70.8 | 0.39 | 9.5 | 22.9 | 71.1 | 0.42 | 18.7 | 28.9 | 68 | 0.65 |
| | Bt2 | 50-75 | 12.4 | 22.2 | 66.2 | 0.56 | 12.8 | 21.7 | 67.9 | 0.59 | 18.4 | 25.1 | 64.3 | 0.73 |
| | Bt3 | 75-100 | 10.6 | 18.8 | 67.8 | 0.56 | 11.5 | 18.3 | 68 | 0.63 | 17.6 | 21.4 | 63.3 | 0.82 |
| 57 | Ap | 0-12 | 5.8 | 15.6 | 55.9 | 0.37 | 6.7 | 18.6 | 57.7 | 0.36 | 22.9 | 30.8 | 60.1 | 0.74 |
| KERUH | A/B | 10-30 | 8.4 | 20.9 | 59.9 | 0.4 | 9.3 | 24.5 | 63.2 | 0.38 | 24.8 | 31.6 | 58.5 | 0.79 |
| | Bt1 | 30-50 | 8.8 | 21.4 | 59.7 | 0.41 | 10.1 | 25.4 | 63.3 | 0.4 | 25.1 | 31.4 | 58.6 | 0.8 |
| | Bt2 | 50-75 | 8.2 | 18.7 | 56.2 | 0.44 | 10.6 | 25.6 | 63.3 | 0.41 | 24.7 | 31 | 58.5 | 0.8 |
| | Bt3 | 75-100 | 13.1 | 19.3 | 56.5 | 0.68 | 15.1 | 24.8 | 62 | 0.61 | 24.3 | 28.7 | 56.4 | 0.85 |
| 119 | Ap | 0-18 | 4.7 | 13.6 | 57.9 | 0.35 | 5.5 | 17.3 | 61.2 | 0.32 | 22 | 20.4 | 64.4 | 1.08 |
| SUBAN | Bt1 | 18-42 | 8.3 | 21 | 64.9 | 0.39 | 8.5 | 23.7 | 68.6 | 0.36 | 22 | 30.2 | 64.1 | 0.73 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| JERIJI | Bt2 | 42-82 | 8.7 | 21.7 | 65.8 | 0.4 | 9.4 | 25.4 | 70.4 | 0.37 | 22.6 | 30.9 | 63.4 | 0.73 |
| | Bt3 | 82-100 | 14.1 | 20 | 64.4 | 0.7 | 15.1 | 22.7 | 67.2 | 0.67 | 23 | 26.6 | 61.1 | 0.86 |
| 2 | Ap | 0-12 | 3.7 | 14.7 | 61.5 | 0.25 | 4.6 | 17.8 | 64.6 | 0.26 | 19.7 | 30.8 | 65.8 | 0.64 |
| BANDING | Bt1 | 10-50 | 5.5 | 20.2 | 67.1 | 0.27 | 6.2 | 23.4 | 71.3 | 0.27 | 20.9 | 31.9 | 66.5 | 0.66 |
| ANYAR | Bt2 | 50-75 | 6.1 | 21 | 68.9 | 0.29 | 7 | 23.7 | 72.8 | 0.29 | 20.6 | 30.1 | 65.7 | 0.68 |
| | Bt3 | 75-100 | 13.4 | 18.9 | 63.3 | 0.71 | 14.4 | 20.3 | 66.9 | 0.71 | 21.8 | 25.5 | 61.6 | 0.85 |

## 11.3 Appendix 3 – Reproduction of growers manual (in Bahasa Indonesia)


Panduan Budidaya Pohon
*Acacia mangium*

Dipersiapkan oleh:
Eko Bhakti Hardiyanto
Djoko Suprijadi
Agus Wicaksono
Slamet Untung
Makruf Nurudin

**Maret 2010**

## Pengantar

Dewasa ini budidaya pohon telah dipandang sebagai investasi yang menguntungkan bagi investor di hutan tanaman dan petani pohon di Indonesia. Beberapa jenis pohon seperti jati, sengon, dan mahoni telah banyak diusahakan di berbagai tempat dengan keuntungan finansial yang baik. Jenis pohon lain, yang relatif baru bagi masyarakat adalah *Acacia mangium*. Jenis pohon ini memiliki pertumbuhan yang cepat, kayunya sangat baik untuk pembuatan pulp dan kertas, serta sangat bagus untuk bahan konstruksi dan pertukangan. Untuk pulp, pohon *Acacia mangium* mungkin dipanen pada umur 6-7 tahun, sedangkan untuk kayu pertukangan pohon dapat dipanen pada umur 8-10 tahun.

Panduan ini dipersiapkan bagi para pihak yang tertarik dalam budidaya *Acacia mangium*, baik untuk produksi kayu untuk pulp, maupun untuk kayu pertukangan. Panduan ini diharapkan juga bermanfaat bagi para pihak yang ingin meningkatkan pertumbuhan dan produktivitas tegakan *Acacia mangium* yang dimilikinya.

Panduan ini memberikan petunjuk selangkah-demi selangkah bagaimana membuat tegakan *Acacia mangium*, mulai dari pembibitan, persiapan lahan, penanaman, pemeliharaan dan pemanenan.

Maret 2010

Tim Penyusun,

Eko Bhakti Hardiyanto
Djoko Soeprijadi
Agus Wicaksono
Slamet Untung
Makruf Nurudin

## Daftar Isi





## Daftar Isi





## 1. Pendahuluan

Tujuan utama dari panduan ini adalah membantu para pihak, khususnya masyarakat petani yang berkeinginan untuk menanam pohon *Acacia mangium* sebagai penghasil kayu, baik untuk keperluan sendiri maupun tujuan komersial. Pendekatannya adalah penanaman *Acacia mangium* tidak bertujuan untuk menggantikan komoditas tanaman yang sudah lama dibudidayakan oleh para petani seperti karet, kopi, sawit dan sebagainya, tetapi memberikan pilihan atau tambahan produk lain dari lahan pertanian yang penggunaanya kurang optimal atau pun belum dimanfaatkan.

### 1.1 Mengapa menanam pohon?

Di Indonesia kebutuhan kayu terus meningkat sejalan dengan pertambahan penduduk, sementara itu produksi kayu terutama dari hutan alam menurun secara drastis. Produksi kayu dari hutan alam di Indonesia sebelum tahun 2004 sebesar lebih dari 25 juta $m^3$/th, akan tetapi pada tahun 2008 produksinya hanya sebesar 7,4 juta $m^3$/ha. Sementara itu kebutuhan kayu secara nasional sebesar 33 juta $m^3$/th. Kekurangan produksi kayu nasional ini harus dipenuhi dari hutan tanaman industri dan hutan rakyat. Penanaman pohon telah terbukti merupakan investasi yang sangat menguntungkan. Sebagai contoh penanaman sengon dan jati di beberapa tempat di Indonesia, terutama di Jawa telah mampu meningkatkan kesejahteraan petani secara nyata.

### 1.2 Mengapa *Acacia mangium*?

*Acacia mangium* tumbuh alami di Kepulauan Maluku (Seram, Taliabu, Mangole, Sanana dan Kepulauan Aru), Papua (sekitar Tanah Merah dan Digul serta Manokwari), Papua New Guinea dan Queensland (Australia).

Jenis pohon ini dicoba dibudidayakan pertama kali di Indonesia, yakni Sumatera Selatan pada tahun 1979 dengan tujuan untuk merehabilitasi padang alang-alang yang luas di wilayah ini. *Acacia mangium* ternyata mampu beradaptasi dan tumbuh sangat baik pada padang alang-alang, serta lahan-lahan yang tidak subur. *Acacia mangium* dapat bersimbiosis dengan bakteri *Rhizobium* membentuk bintil-bintil akar yang mampu menambat nitrogen (N) bebas dari udara. Simbiosis ini saling menguntungkan karena *Acacia mangium* mendapatkan N yang dibutuhkan dari penambatan N oleh bakteri, sedangkan *Acacia mangium* menyediakan energi untuk kehidupan bakteri. Bintil-bintil yang luruh akan terdekompisi sehingga N yang dilepaskan akan menyuburkan tanah. Serasah daun *Acacia mangium* juga akan meningkatkan kesuburan tanah, bila serasah terdekomposisi kandungan N-nya tinggi (2,3 % N) akan dilepaskan ke dalam tanah.

*Acacia mangium* tumbuh cepat, kayunya sangat baik untuk bahan baku juga sangat baik untuk bahan bangunan dan mebel. Warna kayu *Acacia mangium* yang kecoklatan mirip dengan warna kayu jati, yang membuat kayu *Acacia mangium* di beberapa daerah dinamakan *jati mangium*. Untuk pembuatan pulp, pohon dapat dipanen pada umur 6-7 tahun, sedangkan untuk kayu pertukangan pohon dapat dipanen pada umur 8-10 tahun.

Tegakan Acacia mangium umur 12 tahun yang tumbuh baik di Sumatera Selatan. Kayunya dapat dipergunakan untuk kontruksi dan pertukangan yang bermutu baik

### 1.3. Apakah *Acacia mangium* merusak tanah?

Seperti yang telah disampaikan sebelumnya *Acacia mangium* termasuk jenis legum yang justru meningkatkan kesuburan tanah, karena bersimbiosis dengan bakteri *Rhizobium* yang mengikat nitrogen (N) bebas dari atmosfer. Pohon ini telah ditanam di Sumatera Selatan sejak tahun 1979 dan tidak ada bukti bahwa *Acacia mangium* merusak tanah, maupun menambah kemasaman. Serasah daunnya yang banyak dan kandungan nitrogennya yang tinggi (2,3 % N) dan dapat terdekomposisi relatif cepat menghasilkan humus yang tebal dan meningkatkan kandungan nitrogen di dalam tanah.





## 2. Pemilihan lokasi

### 2.1 Di mana *Acacia mangium* dapat ditanam?

Meskipun *Acacia mangium* termasuk jenis pohon yang kurang menuntut persyaratan hidup yang rumit, *Acacia mangium* akan memiliki pertumbuhan dan produktivitas yang tinggi bila penanamannya memerhatikan kondisi tapak sebagai berikut:

- Tinggi tempat kurang dari 400 m dari permukaan air laut.
- Curah hujan: 1.500 – 3.000 mm per tahun dengan musim kemarau pendek (kurang dari 4 bulan).
- Kemasaman tanah (pH): 3,5-6,0. Tanah-tanah di Sumatera dan Kalimantan kebanyakan memiliki tingkat kemasaman pada kisaran ini.
- Dapat ditanam pada berbagai jenis tanah, misalnya podsolik merah kuning, aluvial dsb.

### 2.1 Di mana *Acacia mangium* sebaiknya tidak ditanam?

*Acacia mangium* kurang memberikan pertumbuhan yang baik bila ditanam pada:

- Lahan gambut atau tanah yang dalam waktu cukup lama tergenang air.
- Tanah yang sudah kehilangan lapisan tanah atas (*topsoil*) dan lapisan bahan organik (humus) menyebabkan pertumbuhan lambat.
- Tanah dengan lapisan konkresi/butiran besi (hematit) atau bercak merah (plintit) atau bercak abu-abu kebiruan (*gley*) yang dangkal juga menyebabkan pertumbuhan dan produktivitas rendah.
- Pertumbuhan akan kerdil bila ditanam pada tanah-tanah dengan lapisan kwarsa yang tebal.
- Pertumbuhan *Acacia mangium* juga lambat bila ditanam pada daerah dengan musim kering yang panjang (lebih dari 4 bulan).





Tanah yang dalam tanpa adanya lapisan konkresi besi, sangat baik untuk *Acacia mangium*

Tanah dengan lapisan bercak merah (plintit) dan konkresi besi (hematit) mulai kedalaman 50 cm (tanda anak panah)

## 3. Pembibitan

### 3.1 Di mana mendapatkan benih?

- Penggunaan benih yang bermutu sangat penting untuk menjamin pertumbuhan dan kualitas pohon yang baik.
- Benih *Acacia mangium* yang digunakan hendaknya berasal dari tegakan benih atau kebun benih. Tegakan dan kebun benih ini sebaiknya dibangun dengan benih dari tempat asal (provenans) yang telah diketahui unggul, seperti Papua New Guinea dan Merauke, Papua (sekitar Tanah Merah dan Digul).
- Benih unggul ini dapat diperoleh dari perusahaan seperti PT. Musi Hutan Persada yang telah memiliki kebun benih yang menghasilkan benih *Acacia mangium* unggul.
- Hindarkan menggunakan benih yang dikumpulkan dari pohon atau tegakan yang tidak diketahui asal-usulnya, pohon yang tumbuh menyendiri atau pohon-pohon di pinggir jalan. Kualitas genetik benih dari pohon-pohon seperti ini rendah dan menghasilkan pertumbuhan pohon yang kurang optimal. Pohon yang tumbuh menyendiri atau tumbuh sangat jarang menghasilkan benih hasil kawin kerabat (*inbreeding*) yang berkualitas genetik rendah.





### 3.2 Berapa banyak benih dibutuhkan per hektar?

- Dalam 1 kg benih mengandung 70.000-80.000 butir.
- Bila dalam 1 ha ditanam 1.100 bibit (jarak tanam 3 m x 3 m), diperkirakan daya kecambah benih 80 %, kematian dan kerusakan selama di persemaian sebesar 20 %, maka dalam 1 ha diperlukan benih sebanyak 20-25 g.

### 3.3 Wadah bibit apa yang sebaiknya digunakan?

Untuk persemaian sederhana dan berskala kecil, wadah bibit dapat menggunakan kantong plastik (*polybag*) dengan ukuran panjang 15 cm, lebar 10 cm (rata) dan tebal 4 mm. Untuk persemaian permanen berskala besar, wadah bibit sebaiknya menggunakan *root trainer* (*tube, pot-tray* atau *side slit*).

Kantong plastik (*polybag*) merupakan wadah yang paling sederhana untuk pembibitan

Root trainer- berupa gabungan wadah (*pottray*) dan setiap wadah terdapat celah di didingnya (*side slit*)

### 3.4 Media persemaian apa yang baik?

- Untuk persemaian sederhana, media bibit dapat menggunakan tanah lapisan atas (*topsoil*) atau campuran kompos atau pupuk kandang dengan tanah lapisan atas dengan perbandingan 30-40 % kompos dan 60-70 % tanah.
- Tanah diambil dari lapisan sampai kedalaman 10-20 cm. Warna tanah kehitaman dan gembur. Bersihkan tanah ini dari sampah, akar dan batu-batuan, untuk itu tanah perlu disaring dengan ayakan kawat ukuran 1 cm x 1 cm,
- Kompos yang dapat digunakan untuk media, misalnya berasal dari sekam padi, janjang sawit, sisa-sisa tumbuhan dan sebagainya.
- Untuk persemaian permanen dan berskala besar di mana wadah biasanya menggunakan *tube* atau *side slit*, media bibit sebaiknya menggunakan bahan yang ringan dan berserat seperti kompos kulit kayu, kompos sabut sawit atau sabut kelapa (*coco peat*).

Kompos yang masih kasar hendaknya disaring dengan ayakan kawat dengan ukuran 1 cm x 1 cm, hanya yang lolos dari saringan ini yang dipergunakan untuk media.

## 3.5 Perlukan pemberian pupuk dasar?

- Pemberian pupuk dasar, terutama pupuk fosfor (P) perlu diberikan agar perakaran tumbuh secara baik dan ekstensif, serta mengandung bintil-bintil akar. Bibit yang kekurangan hara P ditandai oleh perakaran yang jarang (kurang ekstensif), bintil-bintil akar sedikit atau bahkan tidak terbentuk. Tersedianya hara P yang cukup diperlukan dalam pembentukan bintil-bintil akar oleh bakteri *Rhizobium*.
- Untuk media tanah tambahkan pupuk dasar TSP atau $SP_{36}$ dengan dosis 5 kg TSP (atau 6,5 kg $SP_{36}$) per $m^3$ media. Pupuk dasar ini harus diaduk dengan media secara merata. Untuk media dari kompos atau campuran kompos berikan pupuk dasar sebanyak 1 g TSP atau 1,25 g $SP_{36}$ per wadah. Pemberian pupuk dasar ini sebaiknya dilarutkan dalam air dan disiramkan pada media secara merata 3-5 hari sebelum penaburan benih.
- Untuk media yang miskin unsur hara seperti sabut kelapa, pupuk dasar yang diberikan adalah 5 kg TSP dan 4-5 kg NPK per $m^3$ media. Pupuk dasar harus diaduk merata dengan media.

## 3.6 Bagaimana membuat bedengan?

- Buat bedengan dengan ukuran: lebar kurang lebih 1 m dan panjang tergantung pada ketersediaan lahan, tetapi idealnya ukuran 1 m x 4 m. Tinggi bedengan dari permukaan tanah kurang lebih 10 cm. Jarak antara bedengan 50-60cm untuk memudahkan aktivitas di persemaian

Penyusunan wadah dalam bedengan pada persemaian tradisional (kiri) dan modern (kanan)





- Isikan media pada wadah (*polybag, pot-tray dsb.*) sedemikian sehingga cukup padat, tetapi jangan terlalu padat.
- Susun wadah yang telah berisi media dalam bedengan. Untuk *polybag* beri pembatas dari kayu atau bambu mengelilingi bedengan sehingga wadah bibit tidak rebah. Untuk persemaian modern dengan wadah yang berbentuk *pot-tray*, wadah disusun membentuk bedengan dengan ukuran yang seperti yang disampaikan di atas.

## 3.7 Bagaimana cara menyemaikan benih?

- Agar benih dapat berkecambah dengan segera dan serentak, benih perlu diperlakukan (diskarifikasi) terlebih dahulu, karena benih *Acacia mangium* memiliki kulit yang keras sehingga sulit menyerap air.
- Rendam benih dalam air yang baru saja mendidih selama 5 menit, buang air panas ini, ganti dengan air dingin dan biarkan selama 12 jam. Perbandingan antara volume benih dan air paling tidak 1:10.
- Sebelum benih ditabur, siram media dengan air sehingga media cukup basah.
- Buat lubang kecil dengan kedalaman kurang lebih 2 cm pada media (di wadah) dengan potongan kayu (stik) kecil runcing (seperti pensil), masukkan benih yang telah diskarifikasi dan tutup kembali dengan media.
- Tabur 4-5 benih di sejumlah wadah untuk cadangan penyulaman di wadah-wadah yang benihnya tidak tumbuh.
- Dalam waktu 6-7 hari setelah penaburan benih mulai berkecambah. Segera lakukan penyulaman pada wadah-wadah di mana benih tidak tumbuh. Kecambah untuk penyulaman sebaiknya pada stadia *penthol korek*, yakni keping biji belum membuka guna mengurangi penguapan.
- Persemaian *Acacia mangium* umumnya tidak memerlukan naungan, tetapi bila cuaca sangat panas sebaiknya menggunakan naungan (intensitas sinar 50 %) pada saat penaburan benih sampai minggu ketiga setelah penaburan benih.

## 3.8 Penyiraman dan pemupukan pertumbuhan

- Lakukan penyiraman secara teratur, 2 kali per hari pada pagi (jam 8:00-9:00) dan siang hari (jam 13:00-14:00). Bila ada hujan dan kondisi media sudah cukup basah, penyiraman tidak perlu dilakukan.
- Tiga minggu setelah penaburan, lakukan pemupukan pertumbuhan dengan pupuk NPK (15:15:15); dosis pupuk NPK ini tergantung pada media yang digunakan. Untuk media tanah atau kompos jadwal dan dosis pupuk adalah sebagai berikut:





**Jadwal dan dosis pemupukan pertumbuhan**

| Umur (minggu setelah ditabur) | Dosis (g/liter air/100 bibit) | Frekuensi (kali/minggu) |
|---|---|---|
| 3 | 5 | 2 |
| 3-6 | 10 | 2 |
| 6-8 | 15 | 2 |
| 8-10 | 10 | 1 |
| di atas 10 | Tidak dipupuk | |

- Untuk media yang miskin hara seperti sabut kelapa (*coco-peat*), pemupukan pertumbuhan dengan dosis seperti di atas, tetapi dengan frekuensi pemupukan lebih sering, yakni 3 kali per minggu. Penambahan pupuk TSP atau $SP_{36}$ mungkin juga diperlukan dengan dosis 5 g TSP atau 6,5 $SP_{36}$/liter air/100 bibit diberikan setiap minggu sekali mulai umur 3 sampai 10 minggu.
- Larutkan pupuk dalam air dan semprotkan (siramkan) larutan pupuk tersebut pada bibit. Segera setelah pemupukan selesai, lakukan pembilasan dengan air bersih untuk menghilangkan sisa (residu) pupuk pada daun yang dapat menyebabkan kerusakan daun (seperti terbakar).
- Pada saat bibit berumur 10 minggu sampai bibit akan ditanam, hentikan pemupukan dan kurangi penyiraman agar bibit mengalami proses pengerasan (pengayuan) batang.

Penyiraman dilakukan secara manual pada persemaian sederhana (kiri). Penyiraman secara otomatis pada persemaian modern (kanan)

## 3.9 Pengendalian gulma dan pemangkasan akar

- Gulma sering tumbuh subur di persemaian, yang dapat mengganggu pertumbuhan dan kesehatan bibit. Di dalam bedengan dan wadah bibit, gulma dapat dicabut dengan tangan dan sebaiknya dilakukan secara teratur agar gulma tidak tumbuh membesar. Di antara bedengan gulma dapat dikendalikan secara manual atau disemprot dengan herbisida.





- Akar bibit dalam *polybag* dan *pot-tray* yang diletakkan di permukaan tanah sering kali tumbuh keluar dari wadah dan mungkin masuk ke dalam tanah. Untuk itu akar yang keluar dari wadah ini perlu dipangkas. Segera lakukan penyiraman setelah pemangkasan akar agar bibit tidak layu. Pemangkasan akar biasanya dilakukan pada saat bibit berumur 6-8 minggu dan diulangi lagi 7-10 hari sebelum pengepakan bibit untuk ditanam.
- Pemangkasan akar bermanfaat untuk merangsang pertumbuhan akar lateral (tumbuh ke samping), mengurangi kerusakan akar dan mempercepat pekerjaan dalam pengemasan bibit.

Bibit telah mengalami pengerasan, batangnya berwarba coklat kekuningan, keras dan tidak mudah patah bila bibit ditekuk

## 3.10 Mengapa perlu pengerasan batang?

- Pengerasan batang bibit diperlukan agar bibit mampu beradaptasi terhadap kondisi lapangan yang mungkin tidak menguntungkan segera setelah selesai bibit ditanam, terutama tidak adanya hujan selama beberapa waktu setelah tanam.
- Bibit yang batangnya belum mengeras (berkayu) akan mudah layu atau patah selama pengangkutan. Bibit yang batangnya belum berkayu juga lebih rentan terhadap kematian setelah ditanam di lapangan, lebih-lebih bila tidak ada hujan beberapa hari setelah ditanam di lapangan.

### 3.11 Adakah penyakit yang menyerang bibit di persemaian?

Ada beberapa jenis penyakit yang mungkin menyerang bibit di persemaian sebagai berikut:

- **Busuk pangkal batang (*damping off*)**: Jamur (*Rhizoctonia* sp.) kadang menyerang leher akar pada saat benih baru saja berkecambah, menyebabkan batang busuk dan bibit rebah. Dapat dikendalikan dengan fungsida seperti Dithane M-45 dsb.
- ***Embun tepung*** **-** Serangan penyakit ini ditunjukkan dengan gejala bercak-bercak putih seperti tepung atau bedak di permukaan daun. Serangan lebih lanjut menyebabkan seluruh permukaan daun tertutup oleh masa putih seperti tepung, daun berubah menjadi kuning, kemudian coklat atau hitam. Penyakit ini disebabkan oleh jamur *Oidium sp.* Menjaga agar kelembaban persemaian tidak berlebihan dan mengusahakan bibit tumbuh optimal merupakan cara yang efektif untuk pengendalian serangan embun tepung. Bila bibit telah terserang sebaiknya disingkirkan dan dibakar agar tidak menjadi sumber penular ke bibit yang masih sehat. Penyemprotan dengan fungisida yang mengandung belerang (sulfur) seperti Benomil, Klorotalonil, Triadimerfon dapat pula mengendalikan penyakit ini.
- **Karat daun:** Jamur (*Atelocauda digitata*) menyebabkan terbentuknya kutil (tumor) pada daun, dan pembengkaan pada batang muda. Penyakit dapat dikendalikan dengan memisahkan bibit yang terserang dan membenamkan dalam tanah atau membakarnya. Untuk pencegahan bibit perlu disemprot dengan fungisida yang berbahan aktif triokonazol seperti Anvil, Nustar dsb. Upayakan persemaian dalam keadaan bersih dari kotoran atau rumput, tidak lembab atau becek yang memberikan kondisi lingkungan yang kondusif bagi perkembangan penyakit.

Penyakit karat daun dapat menyerang bibit di persemaian





### 3.12 Adakah hama yang menyerang bibit?

Hama jarang dijumpai pada pembibitan *Acacia mangium*. Beberapa hama yang mungkin menyerang adalah belalang dan ulat tentara/grayak (*Orgyia postica*). Ulat grayak menyerang daun di malam hari dan memakan hampir seluruh daun, tetapi tidak mematikan bibit. Pada siang hari ulat grayak bersembunyi di bawah serasah atau rumput-rumputan, untuk itu jaga kebersihan di sekitar persemaian.

### 3.13 Seperti apa ciri-ciri bibit yang baik?

Bibit yang baik memiliki ciri-ciri sebagai berikut:

- Batang kokoh dan tegar, tumbuh tegak, tampak seimbang antara tinggi dan diameter, tinggi 30-40cm, diameter lebih dari 3 mm.
- Batang telah mengayu (keras)
- Sehat (tidak terserang hama-penyakit), terdapat beberapa pasang daun yang nampak segar berwarna hijau.
- Akar telah berkembang dengan baik dan membentuk gumpalan yang kompak, banyak mengandung bintil-bintil akar, media tidak pecah.

Contoh bibit yang baik yang telah memenuhi standar yang dipersyaratkan-akar mengandung bintil-bintil akar (gambar paling kanan)





### 3.14 Seperti apa ciri-ciri bibit yang buruk?

Bibit yang buruk memiliki ciri-ciri sebagai berikut:

- Batang tidak kokoh dan tegar, tinggi lebih dari 40 cm atau kurang dari 30 cm.
- Batang berwarna hijau lemah, lunak belum mengayu (keras), melengkung karena keberatan daun, tampak tidak seimbang antara tinggi dan diameter.
- Umumnya tidak sehat, warna daun tidak hijau atau hijau kelam, tetapi kekuningan atau kecoklatan atau adanya bercak-bercak kering atau mati
- Akar tidak kompak, media pecah.

Pada tapak yang sama satu hari setelah tanam: bibit nampak layu (kiri) -berasal dari bibit yang batangnya belum mengeras; bibit nampak tetap segar (kanan)-berasal dari bibit yang batangnya telah mengeras

### 3.15 Pengepakan bibit

- Pengepakan bibit bertujuan untuk memudahkan pengangkutan dan distribusi bibit di lapangan, dan mengurangi kerusakan bibit selama pengangkutan.
- Bibit yang telah diseleksi dimasukkan dengan rapi pada wadah (umumnya kantong plastik/kresek) yang bagian bawahnya diberi lubang sebagai jalan air keluar. Jumlah bibit disesuaikan dengan





ukuran kantong plastik serta wadah dari bibit timbuhkan (*polybag* atau *pot-tray*). Untuk pot-tray biasanya sekitar 35 bibit per kantong plastik. Untuk menjaga sirkulasi udara bagian atas dari kantong plastik perlu diturunkan (digulung) sampai dengan pangkal batang.

- Pada bagian tengah batang bibit diikat dengan tali (rafia) melingkar tidak terlalu kencang dan menyatukan bibit untuk merendam goncangan dalam pengangkutan.
- Selama menunggu pengangkutan, bibit dalam pengepakan perlu disiram agar tidak layu.

Bibit telah diseleksi dan dikepak, siap diangkut ke lapangan

## 4. Penanaman

### 4.1 Penyiapan lahan sebelum penanaman

- Lahan perlu disiapkan sebaik mungkin agar pertumbuhan pohon dan produktivitas kayu *Acacia mangium* tinggi.
- Lahan dapat disiapkan secara manual dengan menebas belukar dan rumput-rumputan, yang dilanjutkan dengan penyemprotan dengan herbisida sehingga pada saat penanaman lahan bersih dari belukar dan rumput-rumputan.
- Sejauh mungkin hindarkan penggunaan api dalam penyiapan lahan, karena pembakaran akan menghilangkan bahan organik (humus) dan hara, terutama nitrogen yang diperlukan untuk pertumbuhan *Acacia mangium* yang optimal.
- Bila menggunakan alat berat, hindarkan kerusakan lahan pada saat penyiapan lahan, terutama kehilangan lapisan atas tanah (*topsoil*) dan lapisan bahan organik, serta pemadatan tanah. Pertumbuhan dan produktivitas *Acacia mangium* akan banyak ditentukan oleh adanya lapisan tanah atas dan bahan organik.

## 4.2 Berapa jarak tanam yang ideal?

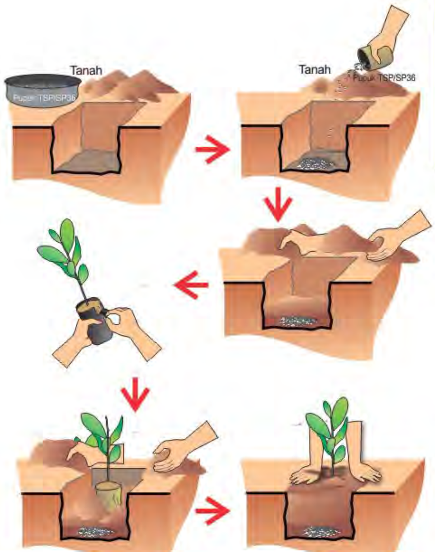
- Bila seluruh lahan ditanami dengan *Acacia mangium*, bibit sebaiknya ditanam dengan jarak tanam 3 m x 3 m (1111 pohon/ha) pada lahan yang subur dan dengan jarak tanam 3 m x 2,5 m (1333 pohon/ha) pada lahan yang kurang subur.
- Bila ditanam dengan sistem tumpang sari, *Acacia mangium* dapat ditanam dengan jarak tanam yang lebar, misalnya 6 x 3 m atau 8 x 3 m untuk memberi ruang tumbuh yang cukup bagi tanaman tumpangsari.
- *Acacia mangium* dapat juga ditanam di batas-batas lahan milik.

## 4.3 Bagaimana cara menanam yang berhasil?

Menanam pohon kelihatannya sederhana, tetapi bila tidak dikerjakan dengan baik akan menyebabkan kematian bibit dan pertumbuhan pohon yang buruk. Penanaman yang baik sebaiknya mengikuti prosedur sebagai berikut:

- Siapkan lubang tanam dengan ukuran 20 cm x 20 cm x 20 cm.
- Berikan pupuk fosfor (P) misalnya $SP_{36}$ atau TSP pada lubang tanam dengan dosis 55-75 g $SP_{36}$ per lubang, atau 45-60 g TSP/lubang. Timbun pupuk dengan lapisan tanah setebal kurang lebih 5 cm untuk menghindarkan akar bibit tidak langsung bersentuhan dengan pupuk. Pupuk TSP atau $SP_{36}$ yang mulai larut memiliki tingkat kemasaman sangat rendah (pH 1,5). Bila akar menyentuh pupuk yang mulai larut ini maka akan menyebabkan bibit mati.
- Untuk bibit dalam *polybag,* lepaskan *polybag* dari media dan upayakan media tidak pecah. Jangan menanam bibit bersama-sama dengan *polybag* karena perkembangan akar akan terhambat.
- Tanam bibit pada lubang yang telah diberi pupuk, timbun lubang kembali dengan tanah sampai permukaan tanah dan sedikit padatkan agar tidak terbentuk kantong udara. Kantong udara bila terisi air akan menyebabkan kematian akar dan bibit karena akar kekurangan oksigen.
- Penanaman sebaiknya dilakukan pada saat awal musim hujan agar pertumbuhan pohon optimal dan produktivitasnya tinggi.
- Segera lakukan penyulaman bila bibit yang baru ditanam ditemukan mati atau tumbuh buruk






Tahapan penanaman: buat lubang (20x20x20 cm), masukkan pupuk dasar TSP (45 g) atau SP36 (60 g) dalam lubang dan tutup dengan lapisan tanah tipis, lepaskan *polybag* dan pegang bola akarnya, masukkan bibit kedalam lubang dengan hati-hati dan masukkan kembali tanah kedalam lubang dan sedikit padatkan tanah di sekitar bibit.





# 5. Pemeliharaan

## 5.1 Pengendalian gulma

Lakukan pengendalian gulma secara teratur untuk membebaskan tanaman muda dari persaingan gulma.

- Waktu yang krusial (penting) untuk pertumbuhan pohon adalah pada tahun pertama. Bila dalam tahun pertama pohon dipelihara dengan baik maka pertumbuhan selanjutnya akan baik pula.
- Bila penyiapan lahan dilaksankan dengan baik dan lahan bersih dari gulma, penyiangan (*weeding*) pertama baru dilakukan pada tanaman umur 3 bulan. Ini dilakukan secara manual dengan menebas gulma dengan parang atau alat lain dan sebaiknya dilanjutan 2 minggu kemudian dengan penyemprotan herbisida. Penyemprotan herbisida harus dilakukan secara hati-hati agar tidak mengenai tanaman *Acacia mangium*. Untuk rumput-rumputan herbisida yang diajurkan adalah herbisida yang mengandung glifosat seperti Roundup dengan dosis 3-4 liter per hektar dalam 300 liter air, tergantung kondisi gulma. Untuk gulma daun lebar pengendalian dapat menggunakan herbisida dengan bahan aktif metsulfuron methyl seperti Ally, Metafuron (150-200 g/ha). Untuk gulma campuran rumput dan daun lebar, pengendendaliannya dapat menggunakan campuran glyfosat dengan metsulfuron, misalnya 2 liter Roundup dan 200 g Ally per hektar.
- Penyiangan kedua dilakukan pada saat tanaman berumur 6 bulan dengan penyermprotan dengan herbisida. Lakukan lagi pengendalian gulma bila masih terdapat gulma yang mengganggu sampai tajuk menutup. Dengan pemeliharaan yang baik, tajuk akan menutup pada saat tanaman berumur 10-12 bulan.
- Setelah tajuk menutup pengendalian gulma praktis tidak diperlukan.

Contoh tanaman yang dipelihara dengan baik (kiri) dan kurang terpelihara (kanan) berumur 1 tahun.



Tegakan *Acacia mangium* milik petani Cik Dan di Muara Enim, Sumatera Selatan umur 2,5 tahun

## 5.2 Untuk produksi kayu pulp perlukah pemangkasan cabang?

- Untuk produksi kayu pulp pemangkasan berupa penunggalan (*singling*) dan pemangkasan cabang (*pruning*) perlu dilakukan, yang bertujuan agar pohon berbatang tunggal karena *Acacia mangium* cenderung berbatang ganda. Pemangkasan cabang juga bertujuan untuk memudahkan akses ke tegakan dalam pemeliharaan, serta mengurangi kelembaban udara dalam tegakan untuk mencegah berkembangnya hama-penyakit.
- Dari beberapa pertimbangan pohon berbatang ganda tidak diinginkan, misalnya batang mudah rebah bila terkena angin kencang, biaya pemanenan lebih besar, ukuran rerata diameter batang lebih kecil dsb.

## 5.3 Bagaimana cara memangkas cabang yang baik?

Cara memangkas cabang yang baik adalah sebagai berikut:

- *Acacia mangium* seringkali berbatang ganda, untuk itu pada umur 3-4 bulan lakukan penunggalan (*singling*) dengan memotong batang ganda dan meninggalkan satu batang yang terbaik.

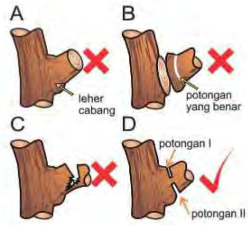
- Pada umur 6 bulan, lakukan pemangkasan cabang (*pruning*), maksimum memangkas cabang sebanyak 40 % dari tinggi pohon. Pemangkasan yang lebih keras akan mengurangi pertumbuhan pohon.
- Penunggalan dan pemangkasan cabang hendaknya menggunakan gunting pangkas atau gergaji pangkas yang tajam.
- Pangkas cabang yang masih hidup, sedekat mungkin dengan batang, tetapi jangan merusak leher cabang. Pemangkasan yang merusak leher cabang menyebabkan luka bekas pangkas memerlukan waktu lama untuk sembuh.
- Jangan meninggalkan tunggul cabang yang panjang. Tunggul cabang biasanya akan mati dan busuk, yang akan menjadi jalan penyakit masuk ke dalam batang.

Penunggalan: memotong batang ganda dan meninggalkan satu batang terbaik (kiri). Tinggi pangkasan cabang maksimum 40 % dari tinggi pohon agar pertumbuhannya tidak terganggu (kanan)

Pemangkasan cabang yang baik: pemangkasan dengan gergaji tajam, potongan rata tepat dekat dengan leher cabang (kiri). Pemangkasan cabang buruk: meninggalkan tunggul cabang (kanan)








Cara pemangkasan cabang yang benar ( ) dan salah (x)

## 5.4 Untuk produksi pertukangan perlukah pemangkasan cabang?

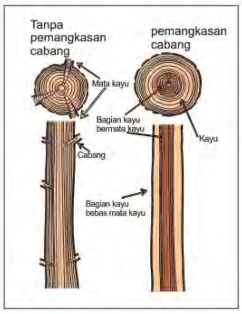
Tujuan utamanya adalah meningkatkan kualitas batang, yaitu mendapatkan batang yang tidak bermata kayu atau tidak bermata kayu lepas (berlubang). Pada pohon yang cabangnya dipangkas cacat mata kayu terbatas pada bagian di tengah batang (10-12 cm), sedangkan bagian batang lainnya bebas mata kayu. Batang dengan banyak mata kayu atau mata kayu lepas akan memiliki nilai yang rendah, di samping itu rendemen kayu gergajian juga menjadi rendah.

Adanya mata kayu (dalam lingkaran), lebih-lebih bila terdapat mata kayu lepas (bolong) karena tidak ada pemangkasan akan menurunkan kualitas kayu pertukangan





Pengaruh (*pruning*), pemangkasan cabang terhadap perbaikan kualitas kayu




## 5.5 Apakah cara pemangkasan cabang untuk kayu pertukangan sama seperti untuk kayu pulp?

- Cara penunggalan dan pemangkasan cabang untuk produksi kayu pertukangan pada prinsipnya sama seperti untuk kayu pulp. Akan tetapi, pemangksan cabang terus dilanjutkan sampai ketinggian yang diinginkan, biasanya 5,5 m.
- Hanya lakukan pemangkasan pada pohon yang pertumbuhannya baik dan batangya lurus. Pohon yang pertumbuhannya buruk dan berbatang bengkok akan ditebang dalam penjarangan.

Pemangkasan cabang (*pruning*) untuk mendapatkan batang dengan kualitas kayu pertukangan yang baik





# 6. Pengendalian hama-penyakit

## 6.1 Hama

Ada beberapa hama yang mungkin menyerang *Acacia mangium* sebagai berikut:

- **Ulat kantong**. – Hama ulat kantong (*Pteroma plagiophelps*) kadangkala menyerang *Acacia mangium*. Ulat memakan jaringan permukaan daun bagian bawah sehingga warna daun nampak kuning kecoklatan. Ulat juga memakan lapisan luar dari cabang dan batang. Serangga dewasa hidup di dalam kantong kecil dan menggantung pada ranting atau cabang. Serangan bersifat sementara dan akan menghilang dengan sendirinya, serta tidak menimbulkan kerusakan yang berarti.
- **Penggerek batang**.- Penggerek batang *Xyleborus* sp. kadangkala menyerang pohon *Acacia mangium*, terutama bila kelembaban di dalam tegakan tinggi. Larva menggerek batang dan cabang yang ditandai dengan adanya lubang-lubang kecil (1,5 cm) berwarna hitam. Lubang gerek biasanya tertutup oleh serbuk gerek. Serangan hama umumnya terjadi pada pohon yang mengalami stres. Hama ini tidak terlalu membahayakan. Upayakan pohon tumbuh baik dan kondisi tegakan tidak terlalu rapat.
- ***Helopeltis* spp**. – Hama menyerang tanaman muda. Serangga menghisap cairan tanaman pada tunas-tunas muda, menyebabkan bercak-bercak berwarna hitam dan tunas-tunas ini menjadi salah bentuk atau mati. Serangan hama ini jarang menimbulkan kerugian yang berarti.

## 6.2 Penyakit

- **Penyakit busuk akar**. – Penyakit busuk akar merah mungkin menyerang tanaman *Acacia mangium*. Penyakit ini disebabkan oleh jamur *Ganoderma* spp., antara lain *Ganoderma philippii* and *Ganoderma australe*. Gejala serangan mirip dengan yang terjadi pada tanaman karet, yakni daun menguning pada tajuk bagian atas pohon, kemudian merambat ke tajuk bagian bawah. Daun-daun selanjutnya rontok dan pohon akhirnya mati. Gejala penyakit lainnya berupa perubahan kulit akar menjadi kecoklatan atau merah tua bila dibasahi dengan air. Serangan yang berat menyebabkan beberapa pohon (*spot*) mati. Seperti pada tanaman karet dan sawit, metode pengendalian penyakit busuk akar yang efektif belum ditemukan. Untuk mengurangi penyebaran penyakit ini, pohon yang terserang sebaiknya akar-akarnya dibongkar dan kemudian dibakar.

Penyakit busuk akar menyerang tanaman muda (kiri). Kulit akar dari pohon yang terserang penyakit busuk akar berwarna kecoklatan atau merah tua bila dibasahi dengan air (tengah); Serangan jamur akar merah dapat menyebabkan kematian pohon (kanan)

- **Penyakit mati layu.** – Gejala penyakit mirip seperti penyakit busuk akar. Penyakit disebabkan oleh jamur *Ceratocystis acaciivora* dan *Ceratocystis manginecans*. Penyakit ini biasanya menyerang pohon yang masih muda dan sering dalam kondisi stres. Pelukaan karena pemangkasan cabang yang kurang baik dan gangguan hewan membantu terjadinya serangan penyakit. Pada pohon yang terserang dijumpai lendir (*gum*) yang keluar dari batang, berbau agak busuk, seringkali ada buih warna putih, daun menguning, layu, rontok dan akhirnya pohon mati. Gejala serangan lain yang muncul dicirikan oleh tumbuhnya kanker kulit, yaitu kulit pecah-pecah dan mengerut ke dalam. Serangan penyakit ini biasanya diikuti oleh hama penggerek batang. Serangga penggerek batang ikut menyebarkan penyakit ini. Agar penyakit tidak menyebar, pohon yang terserang perlu segera ditebang dan dibakar.





Gejala penyakit mati layu antara lain munculnya lendir berbau busuk pada batang, daun layu dan kemudian rontok

## 7. Pencegahan kebakaran

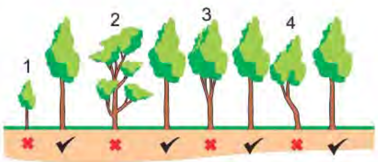
- Upayakan sejauh mungkin tegakan *Acacia mangium* tidak terbakar dengan mengusahakan lahan dalam tegakan relatif bersih dari tumbuhan bawah dan belukar.
- Dalam penyiapan lahan dengan cara pembakaran (pada lahan masyarakat), upayakan api tidak merembet ke tegakan *Acacia mangium* di dekatnya dengan membuat sekat bakar dan mengawasinya dengan baik pada saat pembakaran.





## 8. Penjarangan

- Bila tujuannya untuk produksi kayu pulp, tegakan tidak perlu dijarangi sampai dipanen.
- Penjarangan perlu dilakukan untuk tegakan yang ditujukan untuk menghasilkan kayu pertukangan. Dalam hal ini penjarangan dilakukan dalam dua tahap.
- Penjarangan pertama dilakukan pada saat tegakan berumur 2,5-3,0 tahun, yaitu menebang kurang lebih separo (50 %) dari jumlah pohon awal dengan meninggalkan kurang lebih 550-600 pohon per ha. Pohon yang ditebang adalah pohon yang pertumbuhannya lambat, tertekan, bentuknya tidak baik (bengkok, menggarpu) atau terserang hama-penyakit. Pada penjarangan pertama ini volume kayu yang dapat dimanfaatkan kecil, kurang lebih 15 $m^3$.
- Penjarangan kedua dilakukan pada saat tegakan berumur 4,5 – 5,0 tahun dengan meninggalkan pohon sebanyak 250-300 pohon per ha. Pada penjarangan ke dua ini volume kayu yang dapat dimanfaatka kurang lebih 30 $m^3$. Kayu hasil penjarangan dapat dijual untuk kayu pulp atau kayu bakar.
- Bersamaan dengan penjarangan pertama dan kedua, pemangkasan cabang perlu dilakukan agar kayu pertukangan yang dihasilkan tidak memiliki mata kayu yang lepas (bolong). Kayu pertukangan dengan mata kayu yang lepas akan menurunkan nilainya. Rincian pemangkasan cabang dapat dilihat pada Tabel 1 dan Tabel 2.
- Tegakan siap dipanen untuk kayu pertukangan pada umur paling tidak 8-10 tahun.




Penjarangan menebang pohon yang pertumbuhannya lambat(1), percabangan besar (2), menggarpu (3) dan bengkok (4)





**Tabel 1.** Panduan pemangkasan cabang untuk kayu pertukangan

| Tinggi pohon (m) | Tinggi pemangkasan cabang (m) |
|---|---|
| 6 | 2,0 |
| 10 | 4,0 |
| 12 | 5,5 |

**Tabel 2.** Panduan penjarangan untuk kayu pertukangan

| Umur (th) | Kegiatan |
|---|---|
| 2,5 – 3,0 | Penjarangan pertama, meninggalkan 550-600 pohon/h |
| | Pemangkasan cabang sampai tinggi 2 m, dilakukan setelah penjarangan |
| | Kayu hasil penjarangan mungkin dibiarkan di lapangan (penjarangan non-komersial) atau dijual untuk kayu pulp atau kayu bakar bila dinilai ekonomis |
| 3,0 | Pemangkasan cabang sampai tinggi 4 m pada pohon-pohon yang baik |
| 4,5-5,0 | Penjarangan kedua dengan meninggalkan 250 - 300 pohon/ha |
| | Kayu hasil penjarangan dapat dipergunakan untuk bahan baku pulp atau kayu bakar |
| | Pemangkasan sampai tinggi 5,5 m |
| 8 -10 | Pemanenan dengan diameter batang minimal 20 cm |

Tegakan *Acacia magium* umur 10 tahun di Sumatera Selatan, 170 pohon per hektar, rerata tinggi: 26 m, rerata diameter: 36 cm

# 9. Pemanenan

## 9.1 Kapan sebaiknya tegakan ditebang?

- Bila tegakan akan dipanen dan kayunya dijual untuk pulp, tegakan mungkin dipanen pada umur 6-7 tahun. Pada umur ini kayu yang akan diperoleh 175-300 $m^3$/ha tergantung pada tingkat kesuburan tanah, iklim dan praktik budidaya yang diterapkan.
- Untuk kayu pertukangan tegakan mungkin dipanen paling tidak pada umur 8-10 tahun, akan menghasilkan kayu sebesar 150-200 $m^3$/ha tergantung pada kesuburan lahan, dengan diameter batang minimum 30 cm. Sebanyak 30 % dari volume kayu ini dapat digunakan untuk kayu pertukangan dan sisanya untuk pulp atau keperluan lain.





## 9.2 Penebangan

- Penebangan dapat dilakukan secara manual dengan menggunakan *chain-saw*. Bagi perusahaan besar selain penebangan secara manual, penggunaan alat mekanis seperti *harvester* mungkin dipilih.
- Upayakan memotong batang serendah mungkin dekat dengan permukaan tanah, tinggi tunggul maksimum 10 cm.
- Segera setelah pohon rebah, lakukan pemangkasan cabang (*trimming*) dan pembagian batang (*bucking*). Untuk kayu pulp tergantung dari pembeli kayu, batang mungkin dipotong dengan ukuran 2,50 m – 4,0 m. Diameter terkecil yang dapat dimanfaatkan berukuran 5,0 – 7,0 cm.

## 9.3 Penyaradan

- Untuk penebangan skala kecil, penyaradan kayu dari petak ke tepi jalan dapat dilakukan secara manual dengan dipikul (dikenal dengan cara *halo-halo*) atau menggunakan kabel yang dipasang pada roda truk atau dihubungkan ke transmisi truk (dikenal dengan *king-kong*).
- Untuk perusahaan besar penyaradan mungkin menggunakan *forwarder*, ponton darat dsb. Dalam penyaradan ini diupayakan tidak merusak lahan, untuk itu *forwarder* harus berjalan di atas residu tebangan yang telah disiapkan.

Penyadaran kayu dengan *forwarder* (kiri) - alat berjalan di atas residu tebangan untuk mengurangi pemadatan. Penyaradan kayu dengan kabel (*kingkong*)- bagus untuk lahan miring atau luas tebangan yang relatif kecil





Lampiran 1. Tabel pertumbuhan tegakan *Acacia mangium*

Kedalaman lapisan penghambat pertumbuhan : 20 cm

Kandungan C Organik : 1 %

| Umur (th) | Jumlah Bulan Kering : 0 bulan | | | | Jumlah Bulan Kering : 1 bulan | | | | Jumlah Bulan Kering : 2 bulan | | | | Jumlah Bulan Kering : 3 bulan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
| 1 | 2,4 | 3,0 | 1.111 | 0,7 | 2,3 | 2,9 | 1.111 | 0,6 | 2,0 | 2,5 | 1111 | 0,4 | 1,3 | 1,6 | 1111 | 0,1 |
| 2 | 8,5 | 9,6 | 1.044 | 25,3 | 8,2 | 9,4 | 1.044 | 23,0 | 7,3 | 8,6 | 1044 | 17,1 | 6,4 | 7,4 | 1044 | 11,3 |
| 3 | 11,7 | 13,5 | 981 | 64,5 | 11,3 | 13,7 | 981 | 60,6 | 10,4 | 12,8 | 981 | 47,7 | 9,3 | 11,7 | 981 | 35,4 |
| 4 | 14,1 | 16,2 | 922 | 104,4 | 13,5 | 16,4 | 922 | 97,1 | 12,4 | 15,6 | 922 | 78,7 | 11,4 | 14,4 | 922 | 61,4 |
| 5 | 15,3 | 19,1 | 867 | 136,9 | 14,9 | 18,8 | 867 | 128,0 | 14,0 | 17,6 | 867 | 104,9 | 12,7 | 16,1 | 867 | 80,0 |
| 6 | 16,6 | 20,9 | 815 | 165,1 | 16,1 | 20,3 | 815 | 151,5 | 15,2 | 19,1 | 815 | 127,4 | 13,9 | 17,5 | 815 | 96,7 |
| 7 | 17,7 | 22,4 | 766 | 190,7 | 17,3 | 21,8 | 766 | 175,5 | 16,2 | 20,4 | 766 | 144,1 | 14,8 | 18,6 | 766 | 110,0 |

Kandungan C Organik : 2 %

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2,8 | 3,3 | 1.111 | 1,0 | 2,7 | 3,4 | 1.111 | 1,0 | 1,7 | 2,2 | 1111 | 0,2 | 1,0 | 1,3 | 1111 | 0,1 |
| 2 | 9,5 | 10,9 | 1.044 | 36,6 | 9,1 | 10,5 | 1.044 | 31,7 | 8,0 | 9,3 | 1044 | 21,8 | 7,3 | 8,6 | 1044 | 17,0 |
| 3 | 12,5 | 14,3 | 981 | 77,8 | 12,0 | 14,3 | 981 | 71,1 | 10,8 | 13,1 | 981 | 53,1 | 10,0 | 12,6 | 981 | 44,1 |
| 4 | 14,9 | 17,0 | 922 | 123,1 | 14,3 | 16,8 | 922 | 111,8 | 12,8 | 16,1 | 922 | 85,8 | 11,9 | 15,0 | 922 | 69,5 |
| 5 | 16,4 | 19,9 | 867 | 163,7 | 15,8 | 19,4 | 867 | 147,4 | 14,4 | 18,1 | 867 | 115,0 | 13,3 | 16,8 | 867 | 91,8 |
| 6 | 17,9 | 21,8 | 815 | 200,9 | 17,2 | 21,3 | 815 | 180,7 | 15,7 | 19,8 | 815 | 141,1 | 14,6 | 18,3 | 815 | 112,0 |
| 7 | 19,1 | 23,7 | 766 | 232,7 | 18,3 | 23,1 | 766 | 209,8 | 16,8 | 21,2 | 766 | 161,8 | 15,5 | 19,6 | 766 | 128,2 |

Kandungan C Organik : 3 %

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5,4 | 6,0 | 1.111 | 6,8 | 5,6 | 6,4 | 1.111 | 8,0 | 4,8 | 5,9 | 1111 | 5,3 | 5,3 | 6,5 | 1111 | 7,0 |
| 2 | 10,4 | 12,1 | 1.044 | 48,5 | 10,2 | 12,2 | 1.044 | 47,1 | 9,3 | 11,2 | 1044 | 35,5 | 9,0 | 11,3 | 1044 | 33,8 |
| 3 | 13,3 | 15,1 | 981 | 92,6 | 13,0 | 15,1 | 981 | 88,3 | 11,7 | 14,6 | 981 | 69,2 | 11,3 | 14,2 | 981 | 62,7 |
| 4 | 15,4 | 17,9 | 922 | 139,4 | 15,1 | 17,7 | 922 | 131,4 | 13,5 | 17,1 | 922 | 102,0 | 13,0 | 16,4 | 922 | 90,5 |
| 5 | 17,0 | 20,3 | 867 | 179,7 | 16,6 | 20,0 | 867 | 168,0 | 15,0 | 18,9 | 867 | 130,2 | 14,4 | 18,1 | 867 | 114,3 |
| 6 | 18,4 | 22,4 | 815 | 218,2 | 18,0 | 21,9 | 815 | 204,1 | 16,3 | 20,5 | 815 | 155,9 | 15,6 | 19,6 | 815 | 137,3 |
| 7 | 19,5 | 24,3 | 766 | 250,8 | 19,1 | 23,8 | 766 | 235,0 | 17,4 | 21,9 | 766 | 180,1 | 16,6 | 20,9 | 766 | 156,2 |

Keterangan : D : Diameter (cm), H : Tinggi pohon (m), N/ha : Jumlah pohon per ha, Vol : Volume tegakan ($m^3$/ha)



Kedalaman lapisan penghambat pertumbuhan : 20 cm

Kandungan C Organik : 4 %

| Umur (th) | Jumlah Bulan Kering : 0 bulan | | | | Jumlah Bulan Kering : 1 bulan | | | | Jumlah Bulan Kering : 2 bulan | | | | Jumlah Bulan Kering : 3 bulan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
| 1 | 6,0 | 6,6 | 1.111 | 9,3 | 7,0 | 8,3 | 1.111 | 16,0 | 4,3 | 5,4 | 1111 | 3,9 | 5,3 | 6,7 | 1111 | 7,6 |
| 2 | 11,1 | 12,7 | 1.044 | 58,3 | 11,2 | 13,4 | 1.044 | 62,3 | 9,3 | 11,0 | 1044 | 35,1 | 9,4 | 11,6 | 1044 | 38,0 |
| 3 | 14,2 | 15,7 | 981 | 109,2 | 14,0 | 16,2 | 981 | 109,1 | 12,1 | 14,7 | 981 | 75,0 | 11,8 | 14,8 | 981 | 71,6 |
| 4 | 16,3 | 18,8 | 922 | 163,9 | 16,0 | 18,8 | 922 | 157,5 | 14,1 | 17,7 | 922 | 114,6 | 13,4 | 16,9 | 922 | 98,7 |
| 5 | 18,0 | 21,2 | 867 | 211,6 | 17,6 | 21,0 | 867 | 198,8 | 15,5 | 19,5 | 867 | 143,5 | 14,7 | 18,5 | 867 | 122,8 |
| 6 | 19,4 | 23,3 | 815 | 253,8 | 19,0 | 22,9 | 815 | 237,2 | 16,9 | 21,3 | 815 | 174,4 | 16,0 | 20,2 | 815 | 149,2 |
| 7 | 20,5 | 25,2 | 766 | 287,2 | 20,1 | 24,9 | 766 | 271,8 | 18,0 | 22,7 | 766 | 200,4 | 17,1 | 21,6 | 766 | 171,6 |

Kandungan C Organik : 5 %

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7,3 | 8,8 | 1.111 | 18,4 | 7,0 | 8,5 | 1.111 | 16,4 | 5,8 | 7,0 | 1111 | 9,1 | 5,2 | 6,6 | 1111 | 7,1 |
| 2 | 11,3 | 13,2 | 1.044 | 61,7 | 10,8 | 13,1 | 1.044 | 56,4 | 9,7 | 11,9 | 1044 | 40,9 | 8,9 | 11,3 | 1044 | 33,1 |
| 3 | 13,9 | 15,8 | 981 | 106,2 | 13,4 | 15,8 | 981 | 97,6 | 12,0 | 15,1 | 981 | 74,9 | 11,2 | 14,2 | 981 | 62,1 |
| 4 | 15,9 | 18,5 | 922 | 152,2 | 15,3 | 18,4 | 922 | 140,4 | 13,8 | 17,3 | 922 | 106,8 | 13,0 | 16,4 | 922 | 90,1 |
| 5 | 17,4 | 20,8 | 867 | 192,9 | 16,7 | 20,6 | 867 | 176,6 | 15,2 | 19,1 | 867 | 134,6 | 14,4 | 18,1 | 867 | 114,4 |
| 6 | 18,8 | 22,8 | 815 | 231,5 | 18,1 | 22,5 | 815 | 212,0 | 16,4 | 20,7 | 815 | 160,2 | 15,6 | 19,6 | 815 | 137,5 |
| 7 | 19,8 | 24,7 | 766 | 263,6 | 19,2 | 24,2 | 766 | 241,8 | 17,5 | 22,1 | 766 | 183,8 | 16,6 | 20,9 | 766 | 156,5 |

Keterangan : D : Diameter (cm), H : Tinggi pohon (m), N/ha : Jumlah pohon per ha, Vol : Volume tegakan ($m^3$/ha)

## Kedalaman lapisan penghambat pertumbuhan : 40 cm

### Kandungan C Organik : 1 %

| Umur (th) | Jumlah Bulan Kering : 0 bulan | | | | Jumlah Bulan Kering : 1 bulan | | | | Jumlah Bulan Kering : 2 bulan | | | | Jumlah Bulan Kering : 3 bulan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
| 1 | 1,4 | 1,8 | 1.111 | 0,1 | 1,1 | 1,4 | 1.111 | 0,1 | 1,4 | 1,8 | 1111 | 0,1 | 4,5 | 5,3 | 1111 | 4,2 |
| 2 | 8,7 | 9,9 | 1.044 | 27,7 | 8,2 | 9,3 | 1.044 | 23,1 | 8,1 | 9,2 | 1044 | 22,3 | 9,3 | 11,3 | 1044 | 35,9 |
| 3 | 12,1 | 13,9 | 981 | 71,0 | 11,7 | 13,5 | 981 | 64,3 | 11,4 | 13,4 | 981 | 60,6 | 11,9 | 14,8 | 981 | 72,3 |
| 4 | 14,6 | 16,5 | 922 | 114,3 | 14,1 | 16,1 | 922 | 104,0 | 13,7 | 16,1 | 922 | 98,6 | 13,7 | 17,3 | 922 | 105,8 |
| 5 | 16,1 | 19,9 | 867 | 156,7 | 15,5 | 19,3 | 867 | 142,6 | 15,2 | 18,9 | 867 | 133,6 | 15,0 | 18,9 | 867 | 130,3 |
| 6 | 17,5 | 22,0 | 815 | 194,8 | 17,0 | 21,2 | 815 | 176,2 | 16,6 | 20,9 | 815 | 165,7 | 16,2 | 20,4 | 815 | 153,0 |
| 7 | 18,8 | 23,7 | 766 | 227,0 | 18,2 | 22,9 | 766 | 205,5 | 17,9 | 22,5 | 766 | 194,2 | 17,3 | 21,8 | 766 | 177,1 |

### Kandungan C Organik : 2 %

| Umur (th) | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 5,7 | 6,3 | 1.111 | 8,0 | 3,1 | 3,7 | 1.111 | 1,3 | 6,5 | 7,4 | 1111 | 12,2 | 5,7 | 6,3 | 1111 | 8,1 |
| 2 | 11,2 | 13,2 | 1.044 | 60,9 | 10,0 | 11,7 | 1.044 | 42,8 | 10,9 | 13,0 | 1044 | 57,0 | 10,3 | 12,3 | 1044 | 47,6 |
| 3 | 14,2 | 16,2 | 981 | 113,9 | 13,2 | 14,9 | 981 | 89,7 | 13,5 | 16,0 | 981 | 100,8 | 12,6 | 15,5 | 981 | 85,9 |
| 4 | 16,6 | 19,3 | 922 | 172,6 | 15,8 | 17,5 | 922 | 141,4 | 15,6 | 18,6 | 922 | 146,6 | 14,5 | 18,3 | 922 | 125,2 |
| 5 | 18,4 | 21,6 | 867 | 223,1 | 17,4 | 20,3 | 867 | 187,9 | 17,1 | 20,8 | 867 | 186,2 | 16,0 | 20,1 | 867 | 157,1 |
| 6 | 19,9 | 23,6 | 815 | 269,9 | 19,0 | 22,3 | 815 | 232,2 | 18,5 | 22,8 | 815 | 223,8 | 17,3 | 21,8 | 815 | 188,0 |
| 7 | 21,1 | 25,6 | 766 | 308,7 | 20,2 | 24,4 | 766 | 269,7 | 19,6 | 24,7 | 766 | 256,2 | 18,4 | 23,2 | 766 | 213,3 |

### Kandungan C Organik : 3 %

| Umur (th) | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7,1 | 8,1 | 1.111 | 15,8 | 7,7 | 8,9 | 1.111 | 20,9 | 7,4 | 8,5 | 1111 | 18,3 | 7,5 | 8,6 | 1111 | 18,8 |
| 2 | 12,1 | 13,7 | 1.044 | 73,9 | 12,3 | 14,0 | 1.044 | 77,6 | 11,7 | 13,7 | 1044 | 68,5 | 11,3 | 13,8 | 1044 | 65,3 |
| 3 | 15,2 | 16,6 | 981 | 132,8 | 15,2 | 16,7 | 981 | 133,4 | 14,4 | 16,5 | 981 | 117,7 | 13,7 | 16,8 | 981 | 109,4 |
| 4 | 17,5 | 19,9 | 922 | 198,5 | 17,3 | 19,8 | 922 | 193,1 | 16,4 | 19,1 | 922 | 166,9 | 15,5 | 19,5 | 922 | 152,7 |
| 5 | 19,3 | 22,6 | 867 | 257,2 | 19,0 | 22,2 | 867 | 245,1 | 18,0 | 21,6 | 867 | 213,5 | 17,0 | 21,4 | 867 | 189,6 |
| 6 | 20,8 | 24,8 | 815 | 307,3 | 20,4 | 24,5 | 815 | 293,7 | 19,3 | 23,9 | 815 | 257,0 | 18,4 | 23,2 | 815 | 226,9 |
| 7 | 22,0 | 26,7 | 766 | 349,1 | 21,5 | 26,5 | 766 | 333,3 | 20,5 | 25,8 | 766 | 292,6 | 19,6 | 24,7 | 766 | 255,7 |

Keterangan : D : Diameter (cm), H : Tinggi pohon (m), N/ha : Jumlah pohon per ha, Vol : Volume tegakan ($m^3$/ha)



## Kedalaman lapisan penghambat pertumbuhan : 40 cm

### Kandungan C Organik : 4 %

| Umur (th) | Jumlah Bulan Kering : 0 bulan | | | | Jumlah Bulan Kering : 1 bulan | | | | Jumlah Bulan Kering : 2 bulan | | | | Jumlah Bulan Kering : 3 bulan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
| 1 | 6,0 | 6,6 | 1.111 | 9,3 | 7,0 | 8,3 | 1.111 | 16,0 | 4,3 | 5,4 | 1111 | 3,9 | 5,3 | 6,7 | 1111 | 7,6 |
| 2 | 11,1 | 12,7 | 1.044 | 58,3 | 11,2 | 13,4 | 1.044 | 62,3 | 9,3 | 11,0 | 1044 | 35,1 | 9,4 | 11,6 | 1044 | 38,0 |
| 3 | 14,2 | 15,7 | 981 | 109,2 | 14,0 | 16,2 | 981 | 109,1 | 12,1 | 14,7 | 981 | 75,0 | 11,8 | 14,8 | 981 | 71,6 |
| 4 | 16,3 | 18,8 | 922 | 163,9 | 16,0 | 18,8 | 922 | 157,5 | 14,1 | 17,7 | 922 | 114,6 | 13,4 | 16,9 | 922 | 98,7 |
| 5 | 18,0 | 21,2 | 867 | 211,6 | 17,6 | 21,0 | 867 | 198,8 | 15,5 | 19,5 | 867 | 143,5 | 14,7 | 18,5 | 867 | 122,8 |
| 6 | 19,4 | 23,3 | 815 | 253,8 | 19,0 | 22,9 | 815 | 237,2 | 16,9 | 21,3 | 815 | 174,4 | 16,0 | 20,2 | 815 | 149,2 |
| 7 | 20,5 | 25,2 | 766 | 287,2 | 20,1 | 24,9 | 766 | 271,8 | 18,0 | 22,7 | 766 | 200,4 | 17,1 | 21,6 | 766 | 171,6 |

### Kandungan C Organik : 5 %

| Umur (th) | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7,8 | 9,1 | 1.111 | 22,0 | 7,9 | 9,1 | 1.111 | 22,1 | 7,7 | 9,1 | 1111 | 21,5 | 7,8 | 9,1 | 1111 | 21,9 |
| 2 | 12,5 | 14,1 | 1.044 | 81,1 | 12,3 | 14,1 | 1.044 | 79,2 | 11,8 | 13,8 | 1044 | 71,1 | 11,5 | 14,1 | 1044 | 69,4 |
| 3 | 15,5 | 16,8 | 981 | 140,1 | 15,2 | 16,8 | 981 | 135,1 | 14,5 | 16,5 | 981 | 120,7 | 13,8 | 17,1 | 981 | 113,4 |
| 4 | 17,7 | 20,0 | 922 | 204,7 | 17,3 | 20,1 | 922 | 196,5 | 16,5 | 19,2 | 922 | 170,6 | 15,6 | 19,6 | 922 | 156,5 |
| 5 | 19,5 | 22,6 | 867 | 262,4 | 19,0 | 22,5 | 867 | 248,2 | 18,0 | 21,9 | 867 | 218,6 | 17,1 | 21,6 | 867 | 193,9 |
| 6 | 20,9 | 24,8 | 815 | 313,0 | 20,4 | 24,5 | 815 | 294,9 | 19,4 | 24,1 | 815 | 261,3 | 18,5 | 23,3 | 815 | 230,3 |
| 7 | 22,1 | 26,9 | 766 | 355,8 | 21,7 | 26,1 | 766 | 332,9 | 20,5 | 25,9 | 766 | 295,5 | 19,7 | 24,8 | 766 | 259,9 |

Keterangan : D : Diameter (cm), H : Tinggi pohon (m), N/ha : Jumlah pohon per ha, Vol : Volume tegakan ($m^3$/ha)



## Kedalaman lapisan penghambat pertumbuhan : 60 cm

### Kandungan C Organik : 1 %

| Umur (th) | Jumlah Bulan Kering : 0 bulan | | | | Jumlah Bulan Kering : 1 bulan | | | | Jumlah Bulan Kering : 2 bulan | | | | Jumlah Bulan Kering : 3 bulan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
| 1 | 6,6 | 7,6 | 1.111 | 12,8 | 6,4 | 7,4 | 1.111 | 12,1 | 6,5 | 7,3 | 1111 | 12,0 | 6,1 | 6,9 | 1111 | 10,0 |
| 2 | 11,5 | 13,5 | 1.044 | 66,2 | 11,4 | 13,5 | 1.044 | 64,4 | 11,0 | 13,0 | 1044 | 57,8 | 10,5 | 12,7 | 1044 | 51,4 |
| 3 | 14,4 | 16,3 | 981 | 117,6 | 14,2 | 16,2 | 981 | 112,9 | 13,7 | 15,8 | 981 | 102,5 | 12,9 | 15,8 | 981 | 90,8 |
| 4 | 16,6 | 19,3 | 922 | 173,9 | 16,3 | 19,1 | 922 | 166,3 | 15,7 | 18,7 | 922 | 149,3 | 14,7 | 18,4 | 922 | 129,7 |
| 5 | 18,4 | 21,5 | 867 | 224,3 | 18,1 | 21,4 | 867 | 213,8 | 17,2 | 20,8 | 867 | 188,5 | 16,1 | 20,3 | 867 | 162,2 |
| 6 | 19,9 | 23,7 | 815 | 271,6 | 19,5 | 23,3 | 815 | 255,7 | 18,6 | 22,7 | 815 | 225,7 | 17,5 | 22,0 | 815 | 194,3 |
| 7 | 21,1 | 25,8 | 766 | 311,8 | 20,6 | 25,4 | 766 | 291,2 | 19,7 | 24,5 | 766 | 256,6 | 18,7 | 23,6 | 766 | 222,9 |

### Kandungan C Organik : 2 %

| Umur (th) | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6,5 | 7,3 | 1.111 | 12,1 | 6,6 | 7,5 | 1.111 | 12,8 | 5,7 | 6,2 | 1111 | 7,7 | 5,8 | 6,4 | 1111 | 8,5 |
| 2 | 11,9 | 13,4 | 1.044 | 69,7 | 11,8 | 13,5 | 1.044 | 69,3 | 11,0 | 12,7 | 1044 | 56,8 | 10,8 | 12,6 | 1044 | 54,0 |
| 3 | 15,0 | 16,5 | 981 | 129,0 | 14,8 | 16,5 | 981 | 125,8 | 14,0 | 15,7 | 981 | 106,8 | 13,5 | 15,9 | 981 | 100,4 |
| 4 | 17,4 | 19,7 | 922 | 194,1 | 17,0 | 19,4 | 922 | 184,0 | 16,2 | 18,5 | 922 | 157,7 | 15,5 | 18,4 | 922 | 143,4 |
| 5 | 19,2 | 22,4 | 867 | 252,3 | 18,8 | 22,1 | 867 | 239,1 | 17,9 | 20,9 | 867 | 204,3 | 17,0 | 20,5 | 867 | 180,8 |
| 6 | 20,6 | 24,8 | 815 | 302,6 | 20,3 | 24,2 | 815 | 286,3 | 19,3 | 23,0 | 815 | 247,4 | 18,3 | 23,0 | 815 | 222,3 |
| 7 | 21,7 | 26,6 | 766 | 339,4 | 21,3 | 26,3 | 766 | 323,1 | 20,3 | 25,1 | 766 | 281,2 | 19,4 | 24,5 | 766 | 250,2 |

### Kandungan C Organik : 3 %

| Umur (th) | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7,7 | 8,9 | 1.111 | 20,5 | 7,4 | 8,4 | 1.111 | 17,9 | 7,7 | 8,9 | 1111 | 20,5 | 7,9 | 9,3 | 1111 | 22,7 |
| 2 | 12,4 | 14,0 | 1.044 | 79,6 | 12,1 | 13,8 | 1.044 | 75,1 | 11,9 | 13,7 | 1044 | 71,7 | 11,7 | 13,9 | 1044 | 70,3 |
| 3 | 15,4 | 16,8 | 981 | 138,9 | 15,1 | 16,7 | 981 | 131,9 | 14,7 | 16,4 | 981 | 122,1 | 14,2 | 16,8 | 981 | 117,1 |
| 4 | 17,7 | 20,1 | 922 | 204,9 | 17,3 | 20,0 | 922 | 194,7 | 16,6 | 19,3 | 922 | 173,5 | 16,1 | 19,0 | 922 | 160,5 |
| 5 | 19,4 | 22,7 | 867 | 262,3 | 19,0 | 22,4 | 867 | 247,5 | 18,2 | 21,6 | 867 | 220,2 | 17,6 | 21,5 | 867 | 203,6 |
| 6 | 20,9 | 24,7 | 815 | 312,2 | 20,5 | 24,5 | 815 | 295,4 | 19,7 | 23,7 | 815 | 263,2 | 18,9 | 23,8 | 815 | 244,6 |
| 7 | 22,2 | 26,6 | 766 | 354,4 | 21,7 | 26,3 | 766 | 335,6 | 20,8 | 25,5 | 766 | 299,0 | 20,1 | 25,3 | 766 | 275,9 |

Keterangan : D : Diameter (cm), H : Tinggi pohon (m), N/ha : Jumlah pohon per ha, Vol : Volume tegakan ($m^3$/ha)



## Kedalaman lapisan penghambat pertumbuhan : 60 cm

### Kandungan C Organik : 4 %

| Umur (th) | Jumlah Bulan Kering : 0 bulan | | | | Jumlah Bulan Kering : 1 bulan | | | | Jumlah Bulan Kering : 2 bulan | | | | Jumlah Bulan Kering : 3 bulan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
| 1 | 7,9 | 9,3 | 1.111 | 22,7 | 7,6 | 8,9 | 1.111 | 20,2 | 7,8 | 9,1 | 1111 | 21,6 | 7,4 | 8,5 | 1111 | 18,2 |
| 2 | 11,7 | 13,9 | 1.044 | 70,3 | 12,2 | 14,0 | 1.044 | 77,2 | 12,0 | 13,8 | 1044 | 73,1 | 11,4 | 13,4 | 1044 | 64,9 |
| 3 | 14,2 | 16,8 | 981 | 117,1 | 15,2 | 16,8 | 981 | 134,1 | 14,7 | 16,4 | 981 | 123,5 | 14,0 | 16,5 | 981 | 112,2 |
| 4 | 16,1 | 19,0 | 922 | 160,5 | 17,4 | 20,1 | 922 | 197,0 | 16,6 | 19,4 | 922 | 175,6 | 16,0 | 18,8 | 922 | 156,3 |
| 5 | 17,6 | 21,5 | 867 | 203,6 | 19,1 | 22,4 | 867 | 249,9 | 18,2 | 21,8 | 867 | 221,8 | 17,4 | 21,4 | 867 | 199,3 |
| 6 | 18,9 | 23,8 | 815 | 244,6 | 20,6 | 24,5 | 815 | 298,5 | 19,6 | 23,8 | 815 | 265,0 | 18,8 | 23,7 | 815 | 240,5 |
| 7 | 20,1 | 25,3 | 766 | 275,9 | 21,8 | 26,2 | 766 | 336,9 | 20,8 | 25,6 | 766 | 300,0 | 20,0 | 25,2 | 766 | 271,9 |

### Kandungan C Organik : 5 %

| Umur (th) | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8,0 | 9,5 | 1.111 | 24,2 | 5,6 | 8,0 | 1.111 | 10,1 | 7,9 | 9,4 | 1111 | 23,3 | 7,9 | 9,3 | 1111 | 22,8 |
| 2 | 12,6 | 14,3 | 1.044 | 82,9 | 13,6 | 12,5 | 1.044 | 84,7 | 12,0 | 13,9 | 1044 | 74,3 | 11,7 | 13,8 | 1044 | 70,1 |
| 3 | 15,5 | 16,9 | 981 | 141,8 | 20,6 | 15,4 | 981 | 225,7 | 14,7 | 16,5 | 981 | 124,3 | 14,2 | 16,8 | 981 | 117,0 |
| 4 | 17,8 | 20,1 | 922 | 207,3 | 26,7 | 17,5 | 922 | 407,7 | 16,7 | 19,4 | 922 | 175,9 | 16,2 | 18,9 | 922 | 160,6 |
| 5 | 19,5 | 22,8 | 867 | 265,8 | 32,2 | 19,2 | 867 | 608,5 | 18,3 | 21,7 | 867 | 222,1 | 17,6 | 21,5 | 867 | 204,1 |
| 6 | 20,9 | 25,2 | 815 | 317,5 | 37,3 | 20,7 | 815 | 829,6 | 19,7 | 23,7 | 815 | 264,2 | 18,9 | 23,8 | 815 | 245,0 |
| 7 | 22,1 | 27,1 | 766 | 359,2 | 41,8 | 21,9 | 766 | 1.032,4 | 20,8 | 25,6 | 766 | 300,6 | 20,1 | 25,3 | 766 | 275,9 |

Keterangan : D : Diameter (cm), H : Tinggi pohon (m), N/ha : Jumlah pohon per ha, Vol : Volume tegakan ($m^3$/ha)

## Kedalaman lapisan penghambat pertumbuhan : 80 cm

Kandungan C Organik : 1 %

| Umur (th) | Jumlah Bulan Kering : 0 bulan | | | | Jumlah Bulan Kering : 1 bulan | | | | Jumlah Bulan Kering : 2 bulan | | | | Jumlah Bulan Kering : 3 bulan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
| 1 | 4,3 | 4,8 | 1.111 | 3,4 | 4,4 | 4,9 | 1.111 | 3,8 | 6,2 | 7,0 | 1111 | 10,5 | 6,4 | 7,3 | 1111 | 11,7 |
| 2 | 10,5 | 12,4 | 1.044 | 50,3 | 10,5 | 12,5 | 1.044 | 51,1 | 10,9 | 12,8 | 1044 | 56,4 | 10,6 | 12,7 | 1044 | 52,9 |
| 3 | 13,6 | 15,6 | 981 | 100,3 | 13,6 | 15,6 | 981 | 100,1 | 13,6 | 15,6 | 981 | 100,6 | 13,1 | 15,8 | 981 | 94,1 |
| 4 | 16,1 | 18,3 | 922 | 154,0 | 16,0 | 18,4 | 922 | 152,6 | 15,5 | 18,6 | 922 | 146,7 | 15,0 | 18,5 | 922 | 135,6 |
| 5 | 17,9 | 20,9 | 867 | 204,8 | 17,8 | 21,0 | 867 | 202,5 | 17,1 | 20,8 | 867 | 186,2 | 16,3 | 20,6 | 867 | 168,2 |
| 6 | 19,5 | 23,0 | 815 | 252,2 | 19,3 | 23,0 | 815 | 246,6 | 18,5 | 22,7 | 815 | 223,0 | 17,7 | 22,3 | 815 | 200,1 |
| 7 | 20,7 | 25,0 | 766 | 290,7 | 20,4 | 25,1 | 766 | 283,4 | 19,5 | 24,6 | 766 | 254,7 | 18,8 | 23,7 | 766 | 227,0 |

Kandungan C Organik : 2 %

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6,6 | 7,4 | 1.111 | 12,6 | 6,6 | 7,6 | 1.111 | 13,1 | 5,6 | 6,1 | 1111 | 7,6 | 5,6 | 6,1 | 1111 | 7,6 |
| 2 | 11,9 | 13,5 | 1.044 | 70,6 | 11,8 | 13,6 | 1.044 | 70,0 | 11,1 | 12,7 | 1044 | 57,6 | 11,1 | 12,7 | 1044 | 57,6 |
| 3 | 15,1 | 16,4 | 981 | 129,6 | 14,9 | 16,6 | 981 | 127,5 | 14,1 | 15,7 | 981 | 108,5 | 14,1 | 15,7 | 981 | 108,5 |
| 4 | 17,4 | 19,7 | 922 | 195,0 | 17,1 | 19,6 | 922 | 187,3 | 16,2 | 18,7 | 922 | 160,9 | 16,2 | 18,7 | 922 | 160,9 |
| 5 | 19,2 | 22,4 | 867 | 253,4 | 18,9 | 22,3 | 867 | 244,1 | 18,0 | 21,1 | 867 | 208,4 | 18,0 | 21,1 | 867 | 208,4 |
| 6 | 20,6 | 24,8 | 815 | 302,9 | 20,4 | 24,5 | 815 | 292,4 | 19,3 | 23,2 | 815 | 250,4 | 19,3 | 23,2 | 815 | 250,4 |
| 7 | 21,7 | 26,7 | 766 | 339,2 | 21,5 | 26,3 | 766 | 327,5 | 20,4 | 25,2 | 766 | 284,8 | 20,4 | 25,2 | 766 | 284,8 |

Kandungan C Organik : 3 %

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7,7 | 8,9 | 1.111 | 20,6 | 7,6 | 8,8 | 1.111 | 19,8 | 7,5 | 8,6 | 1111 | 19,0 | 7,9 | 9,2 | 1111 | 22,5 |
| 2 | 12,4 | 14,0 | 1.044 | 79,4 | 12,3 | 14,0 | 1.044 | 78,2 | 11,9 | 13,6 | 1044 | 70,8 | 11,8 | 13,7 | 1044 | 70,3 |
| 3 | 15,4 | 16,8 | 981 | 138,5 | 15,3 | 16,8 | 981 | 136,5 | 14,7 | 16,3 | 981 | 122,1 | 14,4 | 16,3 | 981 | 117,9 |
| 4 | 17,7 | 20,0 | 922 | 204,1 | 17,5 | 20,1 | 922 | 200,2 | 16,6 | 19,3 | 922 | 174,8 | 16,3 | 19,0 | 922 | 164,9 |
| 5 | 19,4 | 22,6 | 867 | 261,6 | 19,2 | 22,7 | 867 | 255,5 | 18,3 | 21,7 | 867 | 221,6 | 17,8 | 21,2 | 867 | 206,9 |
| 6 | 20,9 | 24,7 | 815 | 311,7 | 20,6 | 24,8 | 815 | 303,6 | 19,7 | 23,7 | 815 | 264,4 | 19,2 | 23,5 | 815 | 249,1 |
| 7 | 22,2 | 26,5 | 766 | 353,1 | 21,8 | 26,7 | 766 | 344,0 | 20,9 | 25,5 | 766 | 300,4 | 20,3 | 25,5 | 766 | 282,8 |

Keterangan : D : Diameter (cm), H : Tinggi pohon (m), N/ha : Jumlah pohon per ha, Vol : Volume tegakan ($m^3$/ha)



## Kedalaman lapisan penghambat pertumbuhan : 80 cm

Kandungan C Organik : 4 %

| Umur (th) | Jumlah Bulan Kering : 0 bulan | | | | Jumlah Bulan Kering : 1 bulan | | | | Jumlah Bulan Kering : 2 bulan | | | | Jumlah Bulan Kering : 3 bulan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
| 1 | 7,9 | 9,3 | 1.111 | 22,9 | 7,6 | 8,8 | 1.111 | 20,1 | 7,8 | 9,2 | 1111 | 22,1 | 7,4 | 8,6 | 1111 | 18,7 |
| 2 | 12,5 | 14,2 | 1.044 | 82,2 | 12,3 | 14,0 | 1.044 | 78,4 | 12,1 | 13,9 | 1044 | 74,3 | 11,6 | 13,4 | 1044 | 66,2 |
| 3 | 15,5 | 16,9 | 981 | 141,3 | 15,3 | 16,8 | 981 | 136,4 | 14,8 | 16,5 | 981 | 125,6 | 14,3 | 16,1 | 981 | 113,8 |
| 4 | 17,8 | 20,0 | 922 | 206,7 | 17,5 | 20,2 | 922 | 201,1 | 16,7 | 19,5 | 922 | 177,9 | 16,2 | 18,7 | 922 | 160,3 |
| 5 | 19,5 | 22,7 | 867 | 265,2 | 19,2 | 22,8 | 867 | 257,2 | 18,4 | 21,8 | 867 | 224,8 | 17,7 | 21,0 | 867 | 201,9 |
| 6 | 21,0 | 24,9 | 815 | 315,4 | 20,6 | 25,0 | 815 | 306,0 | 19,8 | 23,8 | 815 | 267,2 | 19,1 | 23,1 | 815 | 242,3 |
| 7 | 22,2 | 26,8 | 766 | 357,0 | 21,9 | 26,7 | 766 | 345,6 | 20,9 | 25,6 | 766 | 303,5 | 20,2 | 25,3 | 766 | 277,7 |

Kandungan C Organik : 5 %

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8,0 | 9,5 | 1.111 | 24,1 | 8,1 | 9,5 | 1.111 | 24,3 | 8,1 | 9,5 | 1111 | 24,2 | 7,9 | 9,4 | 1111 | 23,1 |
| 2 | 12,6 | 14,3 | 1.044 | 83,2 | 12,5 | 14,3 | 1.044 | 82,8 | 12,2 | 14,0 | 1044 | 76,6 | 11,8 | 13,8 | 1044 | 70,8 |
| 3 | 15,6 | 16,9 | 981 | 142,3 | 15,5 | 17,0 | 981 | 140,5 | 14,9 | 16,6 | 981 | 127,6 | 14,4 | 16,4 | 981 | 118,3 |
| 4 | 17,8 | 20,4 | 922 | 210,0 | 17,6 | 20,3 | 922 | 205,4 | 16,8 | 19,6 | 922 | 180,6 | 16,3 | 19,0 | 922 | 165,4 |
| 5 | 19,5 | 22,9 | 867 | 266,6 | 19,3 | 22,9 | 867 | 260,5 | 18,4 | 22,0 | 867 | 228,8 | 17,8 | 21,2 | 867 | 207,3 |
| 6 | 20,9 | 25,3 | 815 | 317,6 | 20,7 | 25,0 | 815 | 308,8 | 19,8 | 24,1 | 815 | 271,7 | 19,2 | 23,4 | 815 | 248,2 |
| 7 | 22,2 | 26,8 | 766 | 357,0 | 22,0 | 26,6 | 766 | 347,1 | 20,9 | 25,9 | 766 | 307,0 | 20,3 | 25,3 | 766 | 281,8 |

Keterangan : D : Diameter (cm), H : Tinggi pohon (m), N/ha : Jumlah pohon per ha, Vol : Volume tegakan ($m^3$/ha)



## Kedalaman lapisan penghambat pertumbuhan : 100 cm

Kandungan C Organik : 1 %

| Umur (th) | Jumlah Bulan Kering : 0 bulan | | | | Jumlah Bulan Kering : 1 bulan | | | | Jumlah Bulan Kering : 2 bulan | | | | Jumlah Bulan Kering : 3 bulan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
| 1 | 4,7 | 5,2 | 1.111 | 4,5 | 3,5 | 4,1 | 1.111 | 2,0 | 6,4 | 7,2 | 1111 | 11,4 | 6,3 | 7,3 | 1111 | 11,4 |
| 2 | 10,7 | 12,6 | 1.044 | 52,9 | 10,2 | 12,0 | 1.044 | 45,7 | 11,1 | 13,1 | 1044 | 59,2 | 10,6 | 12,8 | 1044 | 52,9 |
| 3 | 13,8 | 15,6 | 981 | 102,7 | 13,4 | 15,3 | 981 | 95,7 | 13,8 | 15,8 | 981 | 104,1 | 13,1 | 15,6 | 981 | 93,5 |
| 4 | 16,1 | 18,5 | 922 | 156,6 | 15,9 | 17,9 | 922 | 147,2 | 15,7 | 18,8 | 922 | 150,4 | 15,0 | 18,6 | 922 | 135,6 |
| 5 | 18,0 | 21,0 | 867 | 208,1 | 17,6 | 20,6 | 867 | 196,3 | 17,3 | 20,9 | 867 | 191,6 | 16,4 | 20,5 | 867 | 168,3 |
| 6 | 19,6 | 23,1 | 815 | 254,8 | 19,2 | 22,7 | 815 | 241,2 | 18,6 | 22,9 | 815 | 228,9 | 17,7 | 22,2 | 815 | 200,1 |
| 7 | 20,7 | 25,1 | 766 | 291,8 | 20,4 | 24,7 | 766 | 279,4 | 19,6 | 24,7 | 766 | 258,0 | 18,8 | 23,6 | 766 | 224,9 |

Kandungan C Organik : 2 %

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 6,5 | 7,3 | 1.111 | 12,0 | 6,5 | 7,3 | 1.111 | 11,9 | 5,8 | 6,4 | 1111 | 8,5 | 5,8 | 6,4 | 1111 | 8,5 |
| 2 | 11,8 | 13,5 | 1.044 | 69,6 | 11,8 | 13,4 | 1.044 | 69,0 | 11,2 | 12,9 | 1044 | 59,8 | 10,9 | 12,6 | 1044 | 55,6 |
| 3 | 15,0 | 16,5 | 981 | 129,0 | 14,9 | 16,4 | 981 | 127,2 | 14,3 | 15,9 | 981 | 112,0 | 13,8 | 15,6 | 981 | 103,6 |
| 4 | 17,4 | 19,8 | 922 | 194,3 | 17,2 | 19,3 | 922 | 186,4 | 16,4 | 18,9 | 922 | 165,3 | 15,8 | 18,5 | 922 | 150,3 |
| 5 | 19,1 | 22,5 | 867 | 251,8 | 19,0 | 21,8 | 867 | 242,5 | 18,1 | 21,2 | 867 | 213,4 | 17,4 | 20,7 | 867 | 191,7 |
| 6 | 20,5 | 24,7 | 815 | 300,2 | 20,5 | 24,1 | 815 | 292,8 | 19,6 | 23,4 | 815 | 257,3 | 18,7 | 22,8 | 815 | 229,6 |
| 7 | 21,6 | 26,6 | 766 | 337,0 | 21,7 | 26,1 | 766 | 331,6 | 20,6 | 25,3 | 766 | 290,1 | 19,7 | 24,7 | 766 | 259,1 |

Kandungan C Organik : 3 %

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 7,7 | 8,9 | 1.111 | 20,4 | 7,6 | 8,7 | 1.111 | 19,8 | 7,5 | 8,6 | 1111 | 18,8 | 8,0 | 9,3 | 1111 | 23,3 |
| 2 | 12,4 | 14,0 | 1.044 | 79,7 | 12,3 | 14,0 | 1.044 | 78,5 | 11,9 | 13,6 | 1044 | 71,7 | 12,0 | 13,7 | 1044 | 72,6 |
| 3 | 15,4 | 16,8 | 981 | 138,7 | 15,4 | 16,7 | 981 | 136,7 | 14,8 | 16,4 | 981 | 124,5 | 14,6 | 16,3 | 981 | 121,0 |
| 4 | 17,7 | 20,1 | 922 | 204,8 | 17,6 | 19,9 | 922 | 200,6 | 16,8 | 19,6 | 922 | 180,0 | 16,5 | 19,2 | 922 | 170,1 |
| 5 | 19,4 | 22,7 | 867 | 263,3 | 19,3 | 22,4 | 867 | 256,7 | 18,4 | 22,2 | 867 | 229,9 | 18,0 | 21,4 | 867 | 211,7 |
| 6 | 20,9 | 24,9 | 815 | 313,8 | 20,8 | 24,6 | 815 | 306,8 | 19,8 | 24,3 | 815 | 273,1 | 19,3 | 23,5 | 815 | 253,1 |
| 7 | 22,1 | 26,8 | 766 | 355,5 | 22,0 | 26,5 | 766 | 347,6 | 20,9 | 26,0 | 766 | 309,5 | 20,5 | 25,2 | 766 | 285,8 |

Keterangan : D : Diameter (cm), H : Tinggi pohon (m), N/ha : Jumlah pohon per ha, Vol : Volume tegakan ($m^3$/ha)



## Kedalaman lapisan penghambat pertumbuhan : 100 cm

Kandungan C Organik : 4 %

| Umur (th) | Jumlah Bulan Kering : 0 bulan | | | | Jumlah Bulan Kering : 1 bulan | | | | Jumlah Bulan Kering : 2 bulan | | | | Jumlah Bulan Kering : 3 bulan | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol | D | H | N/ha | Vol |
| 1 | 8,0 | 9,3 | 1.111 | 23,2 | 7,6 | 8,8 | 1.111 | 20,1 | 7,9 | 9,1 | 1111 | 22,1 | 7,4 | 8,5 | 1111 | 18,3 |
| 2 | 12,6 | 14,2 | 1.044 | 82,9 | 12,3 | 14,0 | 1.044 | 78,8 | 12,1 | 13,9 | 1044 | 75,4 | 11,6 | 13,4 | 1044 | 66,7 |
| 3 | 15,6 | 16,9 | 981 | 142,4 | 15,4 | 16,7 | 981 | 136,9 | 14,9 | 16,5 | 981 | 127,8 | 14,4 | 16,1 | 981 | 115,0 |
| 4 | 17,8 | 20,2 | 922 | 207,9 | 17,6 | 20,1 | 922 | 202,6 | 16,9 | 19,6 | 922 | 182,4 | 16,3 | 19,0 | 922 | 163,8 |
| 5 | 19,5 | 22,8 | 867 | 266,0 | 19,3 | 22,9 | 867 | 259,8 | 18,5 | 21,9 | 867 | 230,6 | 17,8 | 21,2 | 867 | 205,4 |
| 6 | 21,0 | 24,9 | 815 | 315,5 | 20,7 | 25,0 | 815 | 307,2 | 19,9 | 24,0 | 815 | 273,9 | 19,1 | 23,4 | 815 | 246,7 |
| 7 | 22,2 | 26,8 | 766 | 357,3 | 21,9 | 26,6 | 766 | 346,2 | 21,1 | 25,7 | 766 | 310,3 | 20,3 | 25,1 | 766 | 280,5 |

Kandungan C Organik : 5 %

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8,0 | 9,5 | 1.111 | 24,0 | 8,0 | 9,4 | 1.111 | 23,6 | 8,0 | 9,4 | 1111 | 23,4 | 7,9 | 9,3 | 1111 | 22,9 |
| 2 | 12,6 | 14,2 | 1.044 | 82,8 | 12,5 | 14,3 | 1.044 | 82,0 | 12,2 | 14,0 | 1044 | 76,3 | 11,9 | 13,7 | 1044 | 71,3 |
| 3 | 15,6 | 16,9 | 981 | 141,8 | 15,4 | 16,9 | 981 | 140,2 | 14,9 | 16,6 | 981 | 128,5 | 14,6 | 16,3 | 981 | 119,7 |
| 4 | 17,8 | 20,1 | 922 | 207,2 | 17,6 | 20,2 | 922 | 204,6 | 16,9 | 19,8 | 922 | 183,6 | 16,4 | 19,2 | 922 | 168,3 |
| 5 | 19,5 | 22,7 | 867 | 264,8 | 19,3 | 22,8 | 867 | 261,4 | 18,5 | 22,0 | 867 | 231,8 | 17,9 | 21,5 | 867 | 211,2 |
| 6 | 21,0 | 24,9 | 815 | 315,3 | 20,8 | 24,9 | 815 | 309,8 | 19,9 | 24,1 | 815 | 274,5 | 19,3 | 23,5 | 815 | 252,2 |
| 7 | 22,2 | 26,6 | 766 | 356,1 | 22,0 | 26,6 | 766 | 349,2 | 21,1 | 25,8 | 766 | 310,9 | 20,4 | 25,5 | 766 | 286,6 |

Keterangan : D : Diameter (cm), H : Tinggi pohon (m), N/ha : Jumlah pohon per ha, Vol : Volume tegakan ($m^3$/ha)

**Lampiran 2. Rincian biaya dan pendapatan investasi budidaya hutan rakyat *Acacia mangium* untuk produksi kayu pulp**

| No. | Komponen | Jumlah (Rp/ha) Tahun 1 | Tahun 6 | Total |
|---|---|---|---|---|
| **BIAYA** | | | | |
| **1.** | **Penyiapan lahan** | | | |
| | a. Tebas dan tebang | 430.000 | - | - |
| | b. Penyemprotan herbisida | | | |
| | • Untuk daun lebar, misal Garlon 0,5 liter @Rp 300.000 | 150.000 | - | - |
| | • Untuk rumput-rumputan, misal glifosat 4 liter @ 41.000 | 164.000 | - | - |
| | • Tenaga | 200.000 | - | - |
| **2.** | **Penanaman** | | | |
| | a. Bibit dan transpor | 600.000 | - | - |
| | b. Planting | 350.000 | - | - |
| | • Pembuatan lubang 6 HOK @40.000 | 240.000 | - | - |
| | • Pupuk TSP, 45 g/phn | 297.000 | - | - |
| | • Tenaga pempukan 2 HOK, @Rp 40.000 | 80.000 | - | - |
| | • Tenaga penanaman 4 HOK @40.000 | 160.000 | - | - |
| **3.** | **Pemeliharaan** | | | |
| | a. Pengendalian gulma 1 (umur 3 bulan) | | | |
| | • Tebas manual umur 3 bulan 5 HOK @Rp 40.000 | 200.000 | - | - |
| | • Penyemprotan herbisida | 464.500 | - | - |
| | - Bahan: 3 liter glifosat @Rp41.000 dan 0,2 kg metsulfuron @Rp 340.000 | 191.000 | - | - |
| | -Tenaga penyemprotan 5HOK @Rp 40.000 | 200.000 | - | - |
| | b. Pengendalian gulma 2 (umur 6 bulan) | 428.500 | - | - |
| | • Bahan: 2 liter glifosat @Rp41.000 dan 0,2 kg metsulfuron @Rp 340.000 | 150.000 | - | - |
| | • Tenaga penyemprotan 5HOK @Rp 40.000 | 200.000 | - | - |



| No. | Komponen | Jumlah (Rp/ha) Tahun 1 | Tahun 6 | Total |
|---|---|---|---|---|
| | c. Pengendalian gulma 3 (umur 9-10 bulan) | 338.700 | - | - |
| | • Bahan: 2 liter glifosat @Rp41.000 dan 0,1 kg metsulfuron @Rp 340.000 | 116.000 | - | - |
| | • Tenaga penyemprotan 5HOK @Rp 40.000 | 200.000 | - | - |
| | d. Penunggalan dan pemangkasan cabang 3 HOK @Rp 40.000 | 120.000 | - | - |
| **4.** | **Pemanenan (180 m³/ha)** | | | |
| | a. Tebang Rp 29.000/m³ | - | 5.220.000 | - |
| | b. Sarad Rp 28.000/m³ | - | 5.040.000 | - |
| | Jumlah biaya pemanenan: | 5.279.700 | 10.260.000 | - |
| | • Nilai sekarang dengan tingkat bunga 9 % | 4.843.761 | 6.117.703 | 10.961.464 |
| | • Nilai sekarang dengan tingkat bunga 12 % | 4.714.018 | 5.198.035 | 9.912.053 |
| | • Nilai sekarang dengan tingkat bunga 15 % | 4.591.043 | 4.435.681 | 9.026.725 |
| | • Nilaii sekarang dengan tingkat bunga 18 % | 4.474.322 | 3.999.744 | 8.474.066 |
| **5.** | **Pemanenan 150 m³/ha** | | | |
| | a. Tebang Rp 30000/m³ | - | 4.350.000 | - |
| | b. Sarad Rp 27.000/m³ | - | 4.200.000 | - |
| | Jumlah biaya pemanenan | 5.279.700 | 8.550.000 | - |
| | • Nilai sekarang dengan tingkat bunga 9 % | 4.843.761 | 5.098.086 | 9.941.847 |
| | • Nilai sekarang dengan tingkat bunga 12 % | 4.714.018 | 4.331.696 | 9.045.714 |
| | • Nilai sekarang dengan tingkat bunga 15 % | 4.591.043 | 3.696.401 | 8.287.444 |
| | • Nilaii sekarang dengan tingkat bunga 18 % | 4.474.322 | 3.333.120 | 7.807.442 |



| No. | Komponen | Jumlah (Rp/ha) Tahun 1 | Tahun 6 | Total |
|---|---|---|---|---|
| **PENDAPATAN** | | | | |
| **6.** | **Pendapatan sekarang (*Present Income*), produksi 180 m³/ha** | | Harga kayu per m³ | |
| | Pendapatan bruto | 27.000.000 | 36.000.000 | 45.000.000 |
| | • Tingkat bunga 9 % | 16.099.218 | 21.465.624 | 26.832.030 |
| | • Tingkat bunga 12 % | 13.679.040 | 18.238.720 | 22.798.400 |
| | • Tingkat bunga 15 % | 11.672.845 | 15.563.793 | 19.454.742 |
| | • Tingkat bunga 18 % | 10.001.652 | 13.335.535 | 16.669.419 |
| | Nilai pendapatan neto (*Net Present Value*) | | | |
| | • Tingkat bunga 9 % | 5.137.754 | 10.504.160 | 15.870.565 |
| | • Tingkat bunga 12 % | 3.766.987 | 8.326.667 | 12.886.347 |
| | • Tingkat bunga 15 % | 2.646.120 | 6.537.069 | 10.428.017 |
| | • Tingkat bunga 18 % | 1.527.586 | 4.861.469 | 8.195.353 |
| **7.** | Pendapatan sekarang (*Present Income*), produksi 150 m³/ha | | Harga kayu per m³ | |
| | | Rp150.000 | Rp200.000 | Rp250.000 |
| | Pendapatan bruto | 22.500.000 | 30.000.000 | 37.500.000 |
| | • Tingkat bunga 9 % | 13.416.015 | 17.888.020 | 22.360.025 |
| | • Tingkat bunga 12 % | 11.399.200 | 15.198.934 | 18.998.667 |
| | • Tingkat bunga 15 % | 9.727.371 | 12.969.828 | 16.212.285 |
| | • Tingkat bunga 18 % | 8.334.710 | 11.112.946 | 13.891.183 |
| | Nilai pendapatan neto (*Net Present Value*) | | | |
| | • Tingkat bunga 9 % | 3.474.168 | 7.946.173 | 12.418.178 |
| | • Tingkat bunga 12 % | 2.353.486 | 6.153.220 | 9.952.953 |
| | • Tingkat bunga 15 % | 1.439.926 | 4.682.383 | 7.924.840 |
| | • Tingkat bunga 18 % | 527.268 | 3.305.504 | 6.083.741 |

Catatan: Produksi kayu dalam perhitungan merupakan kayu komersial (diameter lebih dari 7 cm), kurang lebih 80 % dari volume total



**Lampiran 3. Rincian biaya dan pendapatan investasi budidaya hutan rakyat *Acacia mangium* untuk produksi kayu**

| No. | Komponen | Jumlah (Rp/ha) Tahun 1 | Tahun 3 | Tahun 5 | Tahun 10 | Total |
|---|---|---|---|---|---|---|
| **Biaya** | | | | | | |
| **1.** | **Penyiapan lahan** | | | | | |
| | a. Tebas dan tebang | 430.000 | - | - | - | - |
| | b. Penyemprotan herbisida | | - | - | - | - |
| | • Untuk daun lebar, misal Garlon 0,5 liter @Rp 300.000 | 150.000 | - | - | - | - |
| | • Untuk rumput-rumputan, misal glifosat 4 liter @ 41.000 | 164.000 | - | - | - | - |
| | • Tenaga | 200.000 | - | - | - | - |
| **2.** | **Penanaman** | | - | - | - | - |
| | a. Bibit dan transpor | 600.000 | - | - | - | - |
| | b. Planting | 350.000 | - | - | - | - |
| | • Pembuatan lubang 6 HOK @40.000 | 240.000 | - | - | - | - |
| | • Pupuk TSP, 45 g/phn | 297.000 | - | - | - | - |
| | • Tenaga pempukan 2 HOK, @Rp 40.000 | 80.000 | - | - | - | - |
| | • Tenaga penanaman 4 HOK @40.000 | 160.000 | - | - | - | - |
| **3.** | **Pemeliharaan** | | - | - | - | - |
| | a. Pengendalian gulma 1 (umur 4 bulan) | | - | - | - | - |
| | • Tebas manual umur 3 bulan 5 HOK @Rp 40.000 | 200.000 | - | - | - | - |
| | • Penyemprotan herbisida | 464.500 | - | - | - | - |
| | - Bahan: 3 liter glifosat @Rp41.000 dan 0,2 kg metsulfuron @Rp 340.000 | 191.000 | - | - | - | - |
| | -Tenaga penyemprotan 5HOK @Rp 40.000 | 200.000 | - | - | - | - |
| | b. Pengendalian gulma 2 (umur 6 bulan) | 428.500 | - | - | - | - |
| | • Bahan: 2 liter glifosat @Rp41.000 dan 0,2 kg metsulfuron @Rp 340.000 | 150.000 | - | - | - | - |
| | • Tenaga penyemprotan 5HOK @Rp 40.000 | 200.000 | - | - | - | - |
| | c. Pengendalian gulma 3 (umur 9-10 bulan) | 338.700 | - | - | - | - |
| | • Bahan: 2 liter glifosat @Rp41.000 dan 0,1 kg metsulfuron @Rp 340.000 | 116.000 | - | - | - | - |
| | • Tenaga penyemprotan 5HOK @Rp 40.000 | 200.000 | - | - | - | - |
| | d. Penunggalan dan pemangkasan cabang 3 HOK @Rp 40.000 | 120.000 | - | - | - | - |

| No. | Komponen | Jumlah (Rp/ha) Tahun 1 | Tahun 3 | Tahun 5 | Tahun 10 | Total |
|---|---|---|---|---|---|---|
| **4.** | **Penjarangan 1** | | - | - | - | - |
| | a. Tenaga seleksi dan penebangan 10 HOK@Rp40.000 | - | 400.000 | - | - | - |
| | | | 298.000 | | | |
| | b. Sewa chainsaw (2 unit @Rp50.000, bahan bakar campur (22 liter @ Rp9.000) | - | | - | - | - |
| **5.** | **Pemangkasan cabang lanjutan** | - | 400.000 | - | - | - |
| **6.** | **Penjarangan 2** | | | | | |
| | a. Tenaga seleksi dan penebangan 7 HOK@Rp40.000 | - | - | 280.000 | - | - |
| | b. Sewa chainsaw (2 unit @Rp50.000, bahan bakar campur (10 liter @Rp9.000) | - | - | 90.000 | - | - |
| | c. Sarad kayu 30m³ @Rp30.000 | - | - | 900.000 | - | - |
| **7.** | **Pemanenan (180 m³/ha)** | | | | | |
| | a. Tebang Rp 29.000/m³ | - | - | - | 5.220.000 | - |
| | b. Sarad Rp 28.000/m³ | - | - | - | 5.040.000 | - |
| | Jumlah biaya: | | | | | |
| | • Nilai sekarang dengan tingkat bunga 9 % | 5.279.700 | 10.98.000 | 1.370.000 | 10.260.000 | 18.007.700 |
| | • Nilai sekarang dengan tingkat bunga 12 % | 4.843.761 | 8.47.857 | 890.406 | 4.333.935 | 10.915.960 |
| | • Nilai sekarang dengan tingkat bunga 15 % | 4.714.018 | 7.81.535 | 777.375 | 3.303.445 | 9.576.373 |
| | • Nilaii sekarang dengan tingkat bunga 18 % | 4.591.043 | 7.21.953 | 681.132 | 2.536.115 | 8.530.244 |
| **8.** | **Pemanenan 150 m³/ha** | | | | | |
| | a. Tebang Rp 29000/m³ | - | - | - | 4.350.000 | - |
| | b. Sarad Rp 28.000/m³ | - | - | - | 4.200.000 | - |
| | Jumlah biaya: | 5.279.700 | 913.000 | 384.000 | 8.550.000 | - |
| | • Nilai sekarang dengan tingkat bunga 9 % | 4.843.761 | 705.004 | 249.574 | 3.611.612 | 9.409.951 |
| | • Nilai sekarang dengan tingkat bunga 12 % | 4.714.018 | 649.855 | 217.892 | 2.752.871 | 8.334.636 |
| | • Nilai sekarang dengan tingkat bunga 15 % | 4.591.043 | 600.312 | 190.916 | 2.113.429 | 7.495.701 |
| | • Nilai sekarang dengan tingkat bunga 18 % | 4.474.322 | 555.680 | 167.850 | 1.633.601 | 6.831.453 |

| No. | Komponen | Jumlah (Rp/ha) Tahun 1 | Tahun 3 | Tahun 5 | Tahun 10 | Total |
|---|---|---|---|---|---|---|
| | Pendapatan | | | | | |
| **1.** | **Pendapatan sekarang (*Present Income*), produksi kayu 180 m³/ha** | | Harga kayu pertukangan per m³ | | | |
| | | | Rp400.000 | | Rp500.000 | Rp600.000 |
| | a. Kayu pertukangan: 60 m³ | | 24.000.000 | | 30.000.000 | 36.000.000 |
| | b. Kayu pulp: 120 m3 @Rp 200.000 | | 24.000.000 | | 24.000.000 | 24.000.000 |
| | c. Total pendapatan panen akhir | | 48.000.000 | | 54.000.000 | 60.000.000 |
| | d. Pendapatan penjarangan ke 2: 30m³ @Rp150.000 | | 4.500.000 | | 4.500.000 | 4.500.000 |
| | Pendapatan bruto | | | | | |
| | • Tingkat bunga 9 % | | 23.200.410 | | 25.734.875 | 28.269.340 |
| | • Tingkat bunga 12 % | | 18.008.136 | | 19.939.976 | 21.871.815 |
| | • Tingkat bunga 15 % | | 14.102.161 | | 15.585.269 | 17.068.378 |
| | • Tngkat bunga 18 % | | 11.138.086 | | 12.284.473 | 13.430.859 |
| | Nilai pendapatan neto (*Net Present Value*) | | | | | |
| | • Tingkat bunga 9 % | | 12.284.450 | | 14.818.915 | 17.353.380 |
| | • Tingkat bunga 12 % | | 8.431.763 | | 10.363.603 | 12.295.442 |
| | • Tingkat bunga 15 % | | 5.571.918 | | 7.055.026 | 8.538.134 |
| | • Tngkat bunga 18 % | | 3.436.326 | | 4.582.713 | 5.729.100 |
| **2.** | **Pendapatan sekarang (*Present Income*), produksi 150 m³/ha** | | Harga kayu pertukangan per m³ | | | |
| | a. Kayu pertukangan: 50 m³ | | 20.000.000 | | 25.000.000 | 30.000.000 |
| | b. Kayu pulp: 100 m3 @Rp 200.000 | | 20.000.000 | | 20.000.000 | 20.000.000 |
| | c. Total pendapatan panen akhir | | 40.000.000 | | 45.000.000 | 50.000.000 |
| | d. Pendapatan penjarangan ke 2: 30m³ @Rp150.000 | | 4.500.000 | | 4.500.000 | 4.500.000 |
| | Pendapatan bruto | | 19.821.124 | | 21.933.178 | 24.045.232 |
| | • Tingkat bunga 9 % | | 15.432.350 | | 17.042.216 | 18.652.083 |
| | • Tingkat bunga 12 % | | 12.124.684 | | 13.360.607 | 14.596.531 |
| | • Tingkat bunga 15 % | | 9.609.570 | | 10.564.892 | 11.520.215 |
| | • Tngkat bunga 18 % | | | | | |





| No. | Komponen | Jumlah (Rp/ha) Tahun 1 | Tahun 3 | Tahin 5 | Tahun 10 | Total |
|---|---|---|---|---|---|---|
| | Nilai pendapatan neto (*Net Present Value*) | | | | | |
| | • Tingkat bunga 9 % | | 10.212.424 | | 12.324.478 | 14.436.533 |
| | • Tingkat bunga 12 % | | 6.917.236 | | 8.527.102 | 10.136.968 |
| | • Tingkat bunga 15 % | | 4.464.585 | | 5.700.508 | 6.936.432 |
| | • Tngkat bunga 18 % | | 2.627.929 | | 3.583.251 | 4.538.574 |

Catatan: Produksi kayu dalam perhitungan merupakan kayu komersial (diameter lebih dari 7 cm), kurang lebih 80 % dari volume total