Case Study:

Melaleuca cajuputi (gelam) – a useful species and an option for paludiculture in degraded peatlands

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Cover photo: *Melaleuca cajuputi* has showy flowers and pale, papery bark that is shed (here in South Kalimantan, September 2007).

Note: all photographs are by the author, except Photo 4

Introduction

Indonesian paperbark, 'kayu putih' or 'gelam' (*Melaleuca cajuputi*) as it is known in Indonesia is a member of the eucalyptus family, and like the other members of the family it sheds its bark, produces showy flowers and contains fragrant oils. It is a remarkably resilient small tree, as it can withstand frequent flooding and acidic soils, but also mildly brackish conditions and it also survives mild fires reasonably well. It is therefore often found in disturbed areas behind mangroves, where swamp forests have been cleared and burnt, and there one may find large stands of same aged gelam trees. While it prefers clayey soils, it may also occur on peat and even deep peat. Its wood is very strong, durable and resistant to rot; at the same time it is very heavy and does not float. It is therefore often seen on construction sites where it is used for scaffolding, but also as piles driven into the soil upon which houses or other constructions (even roads!) may be built. It is very versatile and has many other uses as well. Its wood is used for making charcoal, and used by the pulp-and-paper and active carbon industries. Its leaves contain etheric oils that may be distilled and used for medicinal purposes, and in ointments and liniments. The showy flowers produce honey and support beekeeping, while the bark is traditionally used for caulking boats. In a wider landscape, gelam may be cultivated together with sedges (purun, *Lepironia articulata*) used for weaving mats, hats and so on, while fish may be kept in pools, ditches, ponds and segments of canals common in the disturbed habitats favoured by this species.

In this case study information is collated about the ecology and propagation of the species, while the confusing taxonomy is detailed in an annex. Also included are sections on its various uses, production systems, productivity and markets. Opportunities for cultivating gelam for economic benefit in disturbed but rehabilitated peatland areas (aka 'paludiculture' or swamp cultivation) are addressed, and the main section concludes with an overview of knowledge gaps and research needs. Lastly, the case study includes a list of references for additional reading, followed by the annex on taxonomy and a lengthy description of the species.

Photo 1: Natural stand of *Melaleuca cajuputi* with mangrove ferns (*Acrostichum*) at the mouth of the Kahayan River, Central Kalimantan (26th Jan. 2008)

1. Uses of Gelam

Wood

Gelam poles are used for construction, as they last well in moist conditions and are not readily attacked by termites. They are widely used in Indonesia for construction purposes (scaffolding, piles) and for lining watercourses, while thicker trunks are used for sawn timber, high quality fuel wood and charcoal (Photo 2). The sawn timber is used for construction, building posts and piles, fencing posts, carpentry, and shipbuilding. It is durable under wet conditions, but requires treatment when used in dry outdoor conditions. The wood is hard and fine to medium textured; it is difficult to plane, but saws well, but the high silica content dulls saws. The timber is moderately hard to hard, heavy (sinker), and the sapwood is light pink-brown.

Gelam wood chips from Vietnam are sold for producing paper, pulp, medium-density fibreboard (MDF), cement board and particle board. A study in Vietnam (Nguyen, 2008) compared locally grown gelam with strains of *Eucalyptus* and *Acacia* and found its properties (cellulose & lignin content, fibre length) to be very comparable to *Acacia*. The species is specifically cultivated for pulp production in Vietnam.

Photo 2: *Melaleuca cajuputi* poles being transported by boat and truck to Banjarmasin, South Kalimantan, and from there to Surabaya (25th Sept. 2007)

Oil

Like other members of the Myrtaceae (myrtle) family (e.g. *Eucalyptus*, cloves/*Syzygium aromaticum*), gelam contains aromatic, etheric oils. The main etheric oil product from gelam is cajuput (or cineole) oil, a valuable *Eucalyptus*-like oil that is extracted from gelam leaves in restricted parts of Indonesia (e.g. Sulawesi, Tanimbar, Buru, Java) and Southeast Asia where the subspecies (*Melaleuca cajuputi* ssp. *cajuputi*) containing higher concentrations of the oil occurs (Craven, 1999). *M. cajuputi* has been planted in Central Java since 1926 for oil production, using seeds from Buru, and it is also planted in Malaysia (Doran, 1999). The cineole content of gelam varies per subspecies (see annex 1) and location (Doran, 1999). Measurements for *Melaleuca cajuputi* subspecies *cajuputi* shows that cineoles comprise 43.7% of the essential oils found, while for *M. cajuputi* subspecies *platyphylla* this was found to be 41.0% (Silva et al., 2007).

Cajuput oil is used in various ointments, balms (e.g. tiger balm), shampoos, medicines, insect repellents and aromatherapy (Photo 3). Leaves are crushed and heated (distilled), releasing the oil which is then collected and bottled. In Vietnam, the oil content was found to be low and of a poor quality (compared to Australian *Melaleuca* oil), with an annual yield of "more than US$ 40 per hectare" (Maltby *et al.*, 1996), and hence the introduction of the Australian species *Melaleuca alternifolia* for this purpose (Huynh et al. 2011). In Thailand, though, the species is widely used for this purpose (Nuyim, 2001). Safford (pers. comm. 1996) reports that by proper management, cineol-rich forms can be produced.

The oil is used as a medicine for many ailments. It is used internally for the treatment of coughs and colds, and against stomach cramps, colic and asthma. It is used externally for the relief of neuralgia and rheumatism, and for the relief of toothache and earache. The oil repels insects, used as a sedative and relaxant, and is useful in treating worms. Lastly, it is used as a fragrance in soaps, cosmetics, detergents and perfumes, and in flavouring cooking (Doran, 1999).

Photo 3: Kayu putih *Melaleuca cajuputi* oil and balms containing this oil are commonly used throughout Indonesia

Honey

Melaleuca flowers produce good quality honey and are favoured by honeybees (Photo 4). Honey – mainly from the migratory Asian Giant Bee, *Apis dorsata* – is harvested from wild beehives in the swamp forest. In general, the harvesting of honey is currently of a very small-scale, and almost entirely for subsistence purposes only. There is obvious scope for honey production in Indonesia, as the country is a net importer of this product. The market is potentially great, as honey is perceived to be of medicinal value (*obat*). *Gelam* flowers profusely all-year round and produces copious amounts of nectar, making it an ideal host species for bees. Bee-keeping is proposed by the project to be carried out on a modest scale, in conjunction with the *gelam* plantation. Maltby *et al.* (1996) report that 5-6 litres of honey can be harvested per hectare per year.

Mulder (1993) reports on honey production from the Mekong Delta, and found that both professional beekeepers and honey hunters operated in the area. The Song Trem State Forest, with about 2500 ha of replanted *Melaleuca,* produced about 13-15 tons of honey annually, but Mulder (1993) points out that the resource is under-utilised. The best forests are 4-6 year old stands which are still quite open, with 'rafters' being placed to attract bees; Mulder found a rafter occupancy of 50-60% in the dry season and 60-90% in the rainy season. Honey is collected during two major seasons, each nest being cropped 3-4 times per season. The first harvest is usually done three weeks after the observed first arrival of the colony, followed by the next harvest after a two week interval. The yield per harvest is about 4 kg of honey. Mainly the upper part of the comb is cut, leaving brood comb in the nest. Later in the season more brood comb is cut away because this would eat away the honey during the remaining season. Brood is protein rich, and is eaten fresh or baked (Mulder, 1993).

Photo 4: Gelam flowers are favoured by honeybees and produce excellent honey[1]

Other uses

Melaleuca fruits are used as a substitute for black pepper (Brinkman & Vo Ting Xuan 1988). In Thailand, young shoots of *Melaleuca cajuputi* are considered edible, while an edible mushroom called "Samet" is also harvested from the Thai *Melaleuca* forest Nuyim, 2001). Fishing and harvesting of edible ferns (young fronds of *Stenochlaena palustris*) is common in seasonally flooded gelam areas and trees are often intercropped with sedges (e.g. *Lepironia articulata*) to provide material for weaving (Giesen, 1990; Maltby et al., 1996). In the Mekong Delta, farmers tending stands of gelam also cultivated frogs for the regional market. The papery bark is used for caulking boats, packing material, filling mattresses and pillows, as insulation material, and for roofing of temporary shelters (Doran, 1999). In the estuarine environment, the species provides a habitat for birds, fish and shrimps.

[1] http://theoddsock-ericnp.blogspot.nl/2014/05/walk-report-mega-extravaganza.html

2. Economics of Gelam

In the following, value figures have been quoted from various authors and dates. These need to be reconciled and corrected for inflation in order to compare them and attempt an overall calculation of potential productive value per hectare per year.

Vietnam

Duc and Hufschmidt (1993) and Maltby et al. (1996) report that for the Mekong Delta of Vietnam, 10,000 trees can be harvested per hectare on a 9-year cycle that includes 6 growth years. The maximum size of these poles is 20 centimetres. The model developed in the Mekong Delta was based on:

- A 9 year cycle: with years 1-2 = preparation & planting, 3-8 = growth, 9 = harvest
- Initial investments: bund & drainage system construction, land preparation, nursery & planting, bee-hive installation
- Recurrent investments: fertilizer, labour
- Benefits: honey (yrs 4-8), thin poles (yrs 4-6), large poles (yr 9)
- Total investment Dg 6.5 million (about USD 600); while total returns are Dg 35 million (about USD 3,200) per hectare.

This represents a net return of USD 290/ha.yr.

Kalimantan

Potential calculated for South Kalimantan (Giesen, 1996) for one hectare, based on a 9-year cycle and only on pole production:

- 5,000 small poles (thinning cycle, yrs 4-6) @ Rp700 each = Rp. 3.5 million (at the time of calculation, i.e. 1996, this was about USD 1,500)
- 10,000 large poles @ Rp2,500 each = Rp 25 million (for 9-year cycle; at the time of calculation, i.e. 1996, about USD 11,000)

This leads to a return of about USD 1390/ha.yr.

Sumatra

On a study by ICRAF in Mesuji and Sugihan areas, South Sumatra, Suyanto et al. (2002) found that the farm gate price for timber was Rp. 150,000/m³ (about 13 USD), while for sawn timber this was Rp. 500-600,000/m³ (about USD 44-52; unfortunately, these values are, however, not linked to unit labour or area).

Java

In Central Java, 9,000 ha of plantation were found to produce about 31 kg of cinerol oil per hectare per year (Doran, 1999), which at a market price of about USD 9.4/kg leads to an average of USD 292/ha.yr for the oil alone.

Options for home industries, & small- versus large-scale production

Beekeeping offers several options for home industries, based on commodities such as honey, beeswax, pollen and royal jelly. Increasing the quality (e.g. by reducing water content of honey), packaging and labelling, and linking with upscale markets (e.g. at provincial or national rather than local level) can further enhance incomes.

Weaving based on *Lepironia articulata* forms a basis for home industries in South Sumatra (e.g. Ogan-Komering) and South Kalimantan (e.g. Negara), and products include mats, hats and an assortment of basketry. Again, linking with upscale markets can further enhance incomes, especially if combined with other local initiatives (e.g. small woven baskets for packaging jars of locally produced honey).

Charcoal making can also be conducted on a small-scale basis, and offers opportunities for home industries, especially where the demand is high (e.g. near provincial capitals, or in close proximity to Jakarta, Singapore or Kuala Lumpur).

Cajuput or cineol oil is extracted from *Melaleuca cajuputi* leaves by means of staged distillation, i.e. several rounds of distillation, and in most cases this is conducted on a moderately large to large scale basis (e.g. small factories; see Huynh et al 2011). Such production could be considered at a village level, but not at household level. The latter also poses a health risk, as cineol oil is (mildly) toxic and inappropriate for distilling in a domestic setting.

Most products from *Melaleuca* can ideally be done on a small-scale, as much is labour intensive (thinning of stands, collection of honey, reeds and mushrooms, etc...). Only pole, pulp and timber production could be done at an industrial scale, although this could also be carried out by farmers providing raw materials for a larger company.

Markets

Fuel wood and pole markets are generally local, although poles from South and Central Kalimantan are also marketed to Java, via Banjarmasin and Surabaya.

Cajuput oil is marketed world-wide via national companies that produce ointments, balms (e.g. tiger balm), medicines and aromatherapy. In Indonesia, most of these companies are based in Java (esp. Jakarta, Surabaya).

The market for honey is generally local, although some is marketed regionally, for example, from the local producers to the district and provincial capitals.

3. Gelam as a paludiculture species

Degradation and conversion of peat swamp forests of Sumatra and Kalimantan has led to enhanced carbon emissions and contributed to Indonesia being a major emitter of greenhouse gases. Drainage of peatland not only increases oxidation and fire risk, but leads to soil subsidence and undrainable conditions. 7 Mha of peatland on Sumatra and Kalimantan are licensed for plantation crops such as oil palm and *Acacia crassicarpa* that require drainage and contribute to carbon emissions and subsidence. It is suggested that planting useful peat swamp forest species that do not require drainage in a ‘paludiculture’ (swamp cultivation) programme could provide an economically attractive and sustainable alternative. Gelam is a species that could be considered in paludiculture programmes.

Apart from 9,000 ha of plantation in Central Java, *Melaleuca cajuputi* is known in Indonesia from natural stands only, especially in disturbed near coastal habitats, including shallow to moderately deep peat (Giesen, 1990). In the U Minh forest in the Mekong Delta, Vietnam, it has been widely cultivated on deep peat, as part of a restoration programme following widespread deforestation and fires (Maltby et al., 1996). Peat hydrology is not elaborated in the accounts and papers available on these Vietnamese programmes, but it can be assumed that the hydrology was not intact when paludiculture attempts were initiated. Also, given that these plantations suffer from fires it may be assumed that hydrological rehabilitation had not occurred prior to plantation establishment.

The example from the Mekong Delta (see 2. Gelam economics) shows that multiple products (poles, cineol oil, honey) can be derived from *Melaleuca* paludiculture stands. This can be further expanded (see Duc & Hufschmidt, 1993) to include seasonal fisheries (during season when peatland is flooded) and reeds (e.g. *Lepironia articulata*, which provides excellent weaving material). In principle, other trees or shrubs could be intercropped with rows of *Melaleuca*, as the species does not provide much shade and hence does not compete strongly for light. In Central Java (albeit on dryland), young stands of gelam are intercropped with cassava, maize and groundnuts during the first two years, with gelam planted at a density of 5,000 per hectare (Doran, 1999). However, leaves and bark shed by *Melaleuca* are allelopathic, i.e. they release compounds that are (mildly) toxic to other plant species and thereby suppress their growth and possible competition (for space, nutrients). This has not been studied in any detail and certainly not in production systems (such as paludiculture), and this would need to be assessed case-by-case via trials with potential intercropping species. However, it does not visibly affect *Lepironia.*

Once production systems have been established on peat, one needs to consider adopting a low impact means of harvesting gelam poles. Clear-felling of areas is to be avoided as this will lead to desiccation of peat, and subsequent subsidence and a much increased fire risk. This can be mitigated to some degree by planting mixed age stands and selectively felling older specimens, or by felling alternate rows or small blocks (<5x5m).

4. Summary of issues and knowledge gaps.

The species has a wide tolerance range, but there has not been much in the way of selection in order to improve the product. Ideally, the species would i) produce tall, straight boles and grow quickly (for timber), ii) produce leaves with high concentrations of cajuput oil, and iii) produce prodigious amounts of flowers all year round (for honey and seed production). However, all these aspects range widely in natural settings, and there seems lots of room for improving the stock.

Cineole oil content of leaves can readily be determined using near infrared (NIR) spectroscopy on air dried leaf samples (Schimleck et al., 2003). This could be used as a rapid technique for selecting trees for oil content and use in breeding programmes.

For paludiculture, the cultivation of *Melaleuca* on (deep) peat needs to be better understood. Trials need to be carried out on degraded peatland (with rehabilitated hydrology) to assess growth and production rates (of timber, poles, oil) on deep peat.

While in Central Java gelam has been successfully cultivated in dryland plantations since 1926, elsewhere in Indonesia there seems to be little or no success. One of the few attempts known from outside Java (mineral soil swamp in South Kalimantan, MoF in 2004) experienced 100% failure within a few years (pers. observation in 2007; see Photo 5). Hence, there is dependence in Indonesia on naturally regenerating stands.

Little is known about the social aspects of *Melaleuca* cultivation and/or harvesting, especially in Indonesia, and information on usufruct rights, access and tenure have generally not been studied. Tenure seems the greatest obstacle at present, as most *Melaleuca* is harvested in the wild from degraded areas under MoF jurisdiction. Community forestry areas would seem a good alternative, but such stands do not exist at present. Opportunities for this need to be studied.

Market studies are required, to understand where the major demands are (for oil, pulp, wood), and how this could best be cultivated in order to upscale production.

Photo 5: 25 ha area in South Kalimantan planted by the Forestry & Plantation Service with three tree species, including gelam in 2004 (visited Sept 2007).

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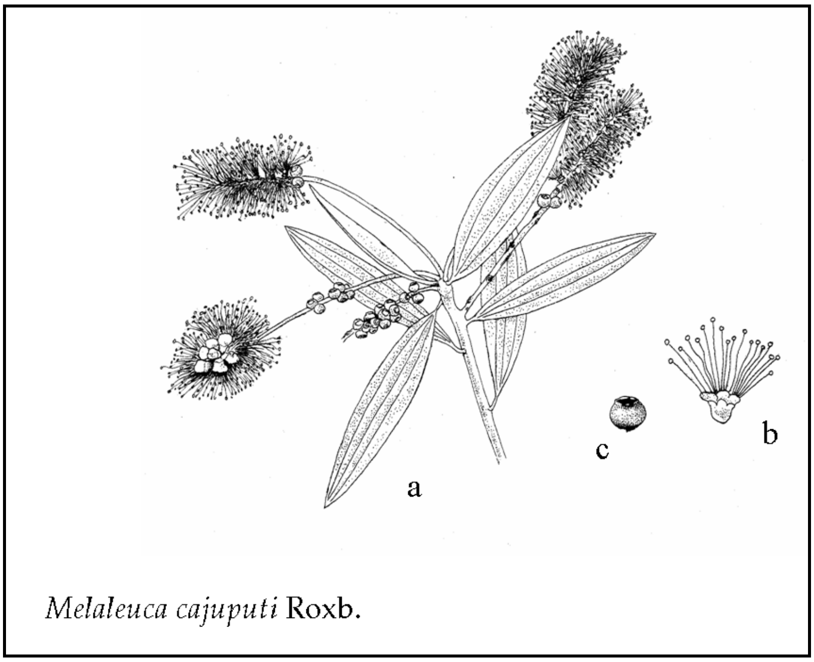
Annex 1. Taxonomy & description of *Melaleuca cajuputi* Roxb.



(a) Branchlet with flower and fruit clusters, (b) flower, and (c) fruit; adapted from Giesen et al (2007)

a. Taxonomy & distribution: *Gelam* is the common Indonesian name for trees of the genus *Melaleuca*, which in English are called "paperbark" because of their thin, papery white bark. The taxonomic status of *gelam* in Indonesia is often confused and at least two species are known to occur. The species occurring in western Indonesia is *Melaleuca cajuputi,* which extends from mainland Asia to northern Australia, while a second species, *Melaleuca leucadendra*, is confined to eastern Indonesia (Papua, Moluccas, Nusa Tenggara Timor) and northern Australia (Blake, 1968; Craven, 1999). At least three subspecies are known of *Melaleuca cajuputi*: ssp. *cajuputi,* ssp. *cumingiana* and ssp. *platyphylla* (Craven & Barlow, 1997), of which ssp. *cajuputi* occurs in Moluccas and Australia (Western Australia and Northern Territory), ssp. *cumingiana,* occurs in Burma, Vietnam, Thailand, Sumatra, southwestern Kalimantan, western Java; and ssp. *platyphylla* occurs in Papua, Papua New Guinea and Australia (Queensland). In the Indonesian and Southeast Asian literature the species in Western Indonesia is often incorrectly described as *Melaleuca leucodendron* or *M. leucadendra.* In summary, *Melaleuca cajuputi* occurs from Burma eastwards to Thailand, Cambodia, Vietnam, Southern China, Malaysia, Singapore, Brunei, Indonesia (Sumatra, Borneo, Java, Lesser Sundas, Moluccas), The Philippines, East Timor, Papua New Guinea and northern Australia.

b. Synonyms: *Melaleuca commutata* Miq., *Melaleuca lancifolia* Turcz., *Melaleuca leucadendron* L.

c. Vernacular name(s): English: paperbark tree, white-wood, Melaleuca; Indonesian: gelam, kayu putih, inggolom, baru galang, waru galang iren, bus, irono ngelak, sakelan, ai kelane, ai elane

d. Description: Large shrub to tall evergreen tree, up to 24(-30) m tall but usually 5-15 m, with a narrow, dense, greyish-green bushy crown and a stout, often twisted trunk. Bark whitish to light grey or greyish-brown, often tinged with orange-brown, fissured and papery flaky in coarse elongate shaggy pieces. Young twigs covered with silky hairs. Leaves spirally arranged, leaf stalk 6-12.5 mm long, leaf blade 5-12.5 by 1.25-3.75 cm, greyish-green, lanceolate, often slightly curved, base tapered, with 5-7 longitudinal nerves, young leaves silky hairy. Flowers white, without a stalk, arranged in groups of three along a terminal spike, 7.5-15 cm long, fluffy because of the many stamens, fragrant; petals 5, stamens numerous. Fruit a small, 3 mm wide woody capsule, without a stalk, cushion-shaped, greyish-brown, with a narrow groove round the top surrounding a small crater-like cup marked with 5 radial grooves, long persistent on the twigs. Seeds: many and tiny. The terminal 'spike' is really the leafless part of an axillary shoot, and after flowering the end bud continues growth to produce a flush of leaves before dropping. Leaves have a high content of highly aromatic cajuput oil (*minyak angin* in Malaysia and Indonesia). It is locally common to very common.

e. Ecology: *Melaleuca cajuputi* occurs naturally in coastal freshwater swamps, both on mineral soils and moderately deep to deep peat, and at the landward end of mangroves. Natural stands of *Melaleuca cajuputi* appear to be located in the transition zone between mangroves and freshwater swamps/peat swamp forests (van Steenis 1938; see photo 6). The species is also planted along roadsides. In can grow in perennially wet areas, but also in dryland areas with a pronounced dry season. It is fairly wind resistant but can snap in severe gales. Pollination is by insects. *Melaleuca* occurs on heavy, deeply flooded acid sulphate soils (e.g. in Mekong Delta in Vietnam; Ogan-Komering floodplain in South Sumatra, and Negara River floodplain in South Borneo), coppices readily, and can withstand repeated fires. In swamps that have been disturbed, for instance by clearing and fires, it tends to dominate the secondary regrowth, sometimes forming large, dense stands of almost uniform sized trees. The secret of its success seems to be its tolerance of fires, flooding and acid soils. Its papery bark offers insulation against heat, and its growth appears to be promoted by burning, mainly because most other woody species are thereby eliminated (Van Steenis 1954, Paijmans 1976, Giesen 1990). Throughout much of its range, gelam appears to coincide with the occurrence of potential acid sulphate soils, and it has been considered that it might be a useful indicator species (Brinkman & Vo Tong Xuan 1988). It can withstand acid waters and can be found in the pH range of 3-7. Gelam can maintain growth under hypoxic (flooded) conditions due to adaptations of its metabolism (Kogawara et al., 2006), and hence is able to outcompete other species in such environments.

It is a pioneer species, is light tolerant, and can quickly colonise areas, for example, areas that have been burnt. Unlike in Vietnam, where it also occurs on deep peat (e.g. U Minh forest; Maltby et al., 1996), gelam generally does not occur on peat soils in Central Kalimantan, although it has been recorded on shallow to moderately deep peat (1-2 m) in South Kalimantan (Giesen, 1990). There are few known pests, but it may be attacked by the fungus *Cylindrocladium macrosporum* and *C. pteridis* (Brinkman & Vo Tong Xuan 1988). The tree produces little shade and has little undergrowth.

Photo 6. Natural stand of *Melaleuca cajuputi* adjacent *Nypa fruticans* near the mouth of the Kahayan River in Central Kalimantan; in foreground with the fern *Acrostichum aureum* and *Eleocharis* sedges (24th Jan. 2008).

Annex 2 Cultivation, propagation & production of gelam

a. Seedling establishment

The species often regenerates naturally after fires, as the fruits open after fire, spreading the numerous, tiny, wind borne seeds. The seeds may also germinate underwater, provided that oxygen levels are at least 4 mg/l, but under flooded conditions seedlings are slow to anchor their roots. Cuttings of immature wood or slender roots form new plants readily, provided they are kept wet. Fruit-bearing twigs are dried for two days under shelter/off the ground, after which the fruits have opened and the seeds can be collected along with the chaff – these should not be separated, as the chaff facilitates germination; seeds are tiny, with 1000 seeds weighing 30 mg. Seeds should be soaked in cold water for 24 hours then sown in a seedbed without shade; 70% germination is normal. Once established, seedlings will tolerate flooding of up to six months, but will stop growing. Under flooded conditions they will grow for about 50 days, provided that they are not completely submerged. In Vietnam, the 'bog' technique of watering has been adopted to avoid tiny seedlings being damaged by overhead watering (Doran, 1999). In this technique, trays with medium and seedlings are kept permanently in water but not submerged or flooded. After about 4 weeks the seedlings are sturdy enough to withstand overhead watering.

b. Planting & tending

On Java, seedlings are planted at an initial density of 5,000 per hectare, and during the first two years they may be intercropped with cassava, maize or groundnuts (Doran, 1999). Weeds need to be removed manually, as these may smother the plants, but also add to increased fire hazard.

c. Growth & flooding

Melaleuca cajuputi grows taller on a water-saturated soil than on a moist, well-drained soil. In water saturated soils the trees are taller and straighter, which is more desirable for timber, though for leaves/oil production a dryland situation produces better results (Brinkman & Vo Ting Xuan 1988).

Photo 7. A uniform post-fire stand of *Melaleuca cajuputi* being drained (and ultimately cleared) for development in South Kalimantan (25th Sept. 2007)

d. Growth & fires

In Thailand, *Melaleuca cajuputi* is one of the few species to recolonise burnt peatland, as described by Tomita et al (2000). In Narathiwat, a fire removed the top 25 cm in a shallow peatland (90cm depth) along with all plants species including underground parts. Recolonisation was by *Melaleuca,* ferns such as *Blechnum indicum,* a host of sedges such as *Lepironia articulata, Scleria sumatrana, Cyperus procerus* and *Fimbristylis natans,* and the shrub *Melastoma malabathricum.* Dense *Melaleuca* seedlings appeared 7±6.3/m² three months after the fires, from wind dispersed seeds. After three years height had increased to 29-187 cm and a cohort of *Melaleuca* had overcome other species by 1.5 years on average. Elsewhere as well, post fire regeneration results in large, uniform cohorts of *Melaleuca* (Photos 7 & 8).

Photo 8. Gelam in Wasur NP in Papua: seemingly unaffected by flooding and fires (note the blackened trunks; 1996)

e. Production

e.1 Natural stands in Australia: Stands in Northern Territory, Australia, have 293 trees/ha, with an average dbh ranging from 13-62 cm (median 30-35 cm) and an aboveground fresh weight of 1009 kg (±51 kg) per tree and 263 tons/ha (± 0.3 tons/ha). On ground litter was 582-2176 g/m² (dry weight), while litter fall had a maximum of 108 g/m² (dry weight; Finlayson et al, 1993).

e.2 Natural stands in Thailand: Samati (undated) found in swamp forests of Narathiwas, Thailand, extending over 15,200 ha, that aboveground biomass was 32.1 tons/ha, segregated into stems (24 tons/ha), branches (5.5 tons/ha) and leaves (2.6 tons/ha). Net primary productivity was found to be 9.27 tons/ha.yr, of which stems 3.12 tons/ha.yr, branches 1.53 tons/ha.yr and leaves 4.62 tons/ha.yr.

e.3 Natural stands in Kalimantan: In Central and South Kalimantan, gelam is harvested from wild stands and is not cultivated in any way. Documentation about the gelam industry in Kalimantan is scant, and economic analyses on gelam systems do not appear to have been carried out in Indonesia. As a result, gelam forests are generally regarded as unproductive wasteland and are targeted for conversion (e.g. for transmigration agriculture or oil palm). According to Forestry Department figures (Giesen, 2009), just over 70,000 ha of gelam forest occurs in the EMRP area of Central Kalimantan. The main gelam products in Central Kalimantan are poles and fuel wood. Poles are often marketed to

Banjarmasin, and beyond to Java, while fuel wood appears to be mainly for the local market. Locally, there is some harvesting of fern fronds and sedges, and limited honey and charcoal production. These products appear on local village markets and in village stalls. Cajuput oil does not appear to be produced in the province. Most of the gelam (-related) product harvesting and trade appears to be carried out by local entrepreneurs and not directly involve the Forestry Department. Attempts in 2004 by the Ministry of Forest at planting *Melaleuca cajuputi* in degraded areas in South Kalimantan (Desa Babat Raya, Kec. Wanaraya) were unsuccessful. However, these trials were not evaluated by MoF and the cause of failure remains unknown, although (from observation of the site in 2007) it is guessed that it may be related to lack of tending after planting, as there was no sign of recent fires.

e.4 Natural stands in Eastern Indonesia: Natural stands in Eastern Indonesia on the islands of Buru, Seram, Ambon and adjacent islands extend over about 200,000 ha and figures suggest that annually about 90 tons of oil are produced annually (Doran, 1999).

Photo 9. Harvesting gelam poles (sinkers!) in the Ogan-Komering lebaks, South Sumatra (August 1990)

e.5 Plantations in Vietnam: Due to the use of napalm, agent orange, and canal and road construction, *Melaleuca* in the Mekong Delta of Vietnam declined from 40,000 ha to only a few thousand hectares by 1980. In the 1980s and 1990s various *Melaleuca* rehabilitation projects were implemented, usually incorporating three key elements: pole-, honey- and cineol oil production. It was expected that a very productive system could thus be developed, with a very high internal rate of return (IRR) of 56% (Duc & Hufschmidt, 1993). *Melaleuca* poles and leaves (for oil production) were harvested manually, and transported by boat (wet season) or by cart and truck (dry season). Harvesting was timed to coincide with a period during which labour is not required in the ricefields. Leaves were brought for processing at a (mobile) cineol oil production plant, while poles will be transported to temporary holding area near one of the main jetties, from where they were shipped. As a result of these programmes, the area of *Melaleuca* increased again to about 16,000 ha by 1986, and in all a total of 50,000 ha of *Melaleuca* was re-established.

Many of these sites in the Mekong delta are now abandoned or operating at sub-optimal capacity, apparently due to a combination of harsh working conditions and poorer than expected results, and fires had reduced the area to about 3,000 ha by the mid-1990s. Key issues: i) canals providing access led to peat drying out and high fire risk; ii) no thinning and little maintenance was carried out, so stock densities were too high, increasing fire risk, but also infestations with swamp ferns *Stenochlaena palustris* (Photo 10); iii) poor farmers who were not involved set fire to the *Melaleuca* to make way for rice cultivation; iv) local farmers perceive that even low returns from rice on peat (<1 ton/ha.yr) is greater benefit than long term benefit from *Melaleuca* (short-term needs must be met); and v) no fire management due to lack of budget.

When still about 120,000 ha of gelam occurred, about 100 tons of oil was produced annually in the Mekong Delta (Doran, 1999).

Photo 11. A stand of *Melaleuca cajuputi* in the Mekong Delta, Vietnam (March 1998) overgrown by the fern *Stenochlaena palustris*

e.6 Plantations in Java: Production from an estimated 9,000 ha of government owned plantation in Central Java amounted to about 280 tons in 1993 (Doran, 1999). This is about 31 kg of oil per hectares per year.