



## *Agathis macrophylla* (Pacific kauri)

Araucariaceae, araucaria family

*dakua makadre, dakua, takua makadre, makadre, makadri, dakua dina, da'ua* (Fiji); *duro* (Solomon Islands: Vanikolo); *hoë, kboë* (Vanuatu: Espiritu Santo); *kauri* (Vanuatu: Bislama); *marabete* (Solomon Islands: Nendo); *nejev* (Vanuatu: Aneityum); *nendu* (Vanuatu: Erromango); Pacific kauri (English)

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### IN BRIEF

**Distribution** Humid, lowland, and lower montane tropics in the southwestern Pacific.

**Size** Tall tree typically to about 30–40 m (100–130 ft).

**Habitat** Lowland subtropical and tropical forests with evenly distributed rainfall of 1900–6000 mm (75–236 in); grows in elevations of 5–1150 m (16–3770 ft).

**Vegetation** Occurs in association with many different angiosperm and gymnosperm trees; a dominant component of lowland tropical closed forests.

**Soils** Prefers well structured, friable, and freely drained soils.

**Growth rate** In favorable conditions, annual growth can reach about 1–1.5 m (3.3–5 ft) in height and 1.5–2 cm (0.6–0.8 in) in trunk diameter.

**Main agroforestry uses** Crop shade, silvopasture.

**Main products** Timber.

**Yields** Production of merchantable timber is conservatively estimated to be 2–3 m<sup>3</sup>/ha/yr (29–43 ft<sup>3</sup>/ac/yr).

**Intercropping** Preferably cultivated with a diverse tree/shrub understory.

**Invasive potential** Not considered to be an invasive species.



Seven-year-old Pacific kauri planted underneath moribund *Cordia alliodora* trees at Shark Bay, Santo, Vanuatu.

## INTRODUCTION

Pacific kauri (*Agathis macrophylla*) is a forest tree species of major ecological and economic importance in the south-west Pacific region of Melanesia. It is among the largest and longest living tree species found in the region, with individuals reaching up to 40 m (130 ft) in height and 3 m (10 ft) in bole diameter, with an estimated life span of 300–1000 years. The tree occurs naturally in the humid and mesic lowland and lower montane rainforests in the Solomon Islands, Vanuatu, and Fiji. Tropical cyclones occur at periodic intervals in all parts of its range, mainly during the months of November through March. Its ability to withstand strong winds is a major attraction for growing it in cyclone-prone areas. Pacific kauri generally prefers well drained, basalt-derived clay loams and clays with a well developed upper humus layer. The species is a gap opportunist, with seedlings dependent on large gap openings (more than 2–3 trees) in the canopy for establishment and growth. In mature trees the canopy is emergent and constitutes a unique structural element in the forests in which it occurs; i.e., the form/structure of Pacific kauri cannot be replaced by any other species. Hence it has major significance in conservation of the plant communities in which it is a component.

Its finely grained, pale, easily worked, and uniform timber is of major commercial importance with various high value end-uses, including furniture, handicrafts, veneer, boat building, light construction, and paneling. From a plantation viewpoint, Pacific kauri stands apart from most species in the genus because of its ability to grow moderately fast and establish in open, sunny sites.

Pacific kauri has good potential in several agroforestry situations, including interplanting in shifting gardens, improved fallows, boundary plantings, upper-story windbreaks (where space permits), and woodlots. It also has good potential for rehabilitation of degraded and secondary forests through line plantings. Its biological characteristics ensure that it is highly unlikely to become an environmental weed when planted outside of its native habitats.

The main factors limiting its wider re-planting are

- high early maintenance costs, with regular weeding and vine cutting being required during the first 4–5 years, especially in open-grown plantations
- long projected rotation length for timber production, which is expected to be 40–55 years (i.e., longer than for mahogany)
- difficulty in obtaining viable seed of the most desired sources from southern Vanuatu.

## DISTRIBUTION

### Native range

Pacific kauri naturally occurs as scattered trees and groves in lowland subtropical and tropical forests in the Solomon Islands, Vanuatu, and Fiji. It occurs more frequently on ridge crests. In the Solomon Islands it is found on four islands in the Santa Cruz group, namely Ndende, Vanikolo, Tevai, and Utupua. In Vanuatu it is found in the central-eastern parts of two southern islands, Erromango and Aneityum. In Fiji, the species occurs on the larger islands of Viti Levu, Vanua Levu, Taveuni/Qamea, Ovalau, and Kadavu.

### Current distribution

The species is still reasonably abundant throughout its natural range in the southwestern Pacific. It has been recorded as being cultivated in Hawai'i, and it has been planted in small-scale trials in Sarawak, Malaysia (Fahlman 1975) and New Zealand (Beveridge 2002).

## BOTANICAL DESCRIPTION

### Preferred scientific name

*Agathis macrophylla* (Lindley) Masters

### Family

Araucariaceae (araucaria family)

### Non-preferred scientific names

*A. obtusa* (Lindl.) Masters (for southern Vanuatu populations)

*A. vitiensis* (Seeman) Benth. & Hook f. ex Drake (for Fijian populations)

### Common names

*dakua makadre, dakua, takua makadre, makadre, makadri, dakua dina, da'ua* (Fiji)

*duro* (Solomon Islands: Vanikolo)

*hoe, khoe* (Vanuatu: Espiritu Santo)

*kauri* (Vanuatu: Bislama)

*marabete* (Solomon Islands: Nendo)

*nejev* (Vanuatu: Aneityum)

*nendu* (Vanuatu: Erromango)

Pacific kauri (English)

### Size

It is a tall tree to about 30–40 m (100–130 ft) height, rarely attaining 45–55 m (150–180 ft). In Fiji mature trees are typically 20–33 m (66–110 ft) tall. Bole diameters of older spec-

imens are around 1.2–1.6 m (4–5.2 ft) the Solomon Islands and up to 3 m (10 ft) in Vanuatu and Fiji.

## Form

Tree form varies considerably depending on seed sources (provenance), age, and habitat. The bole is slightly to strongly tapering, without buttresses, and in mature specimens is clear of branches for 9–20 m (30–66 ft). In younger specimens the form of the crown is conical and monopodial. Eventually the canopy becomes broad (diameter to 36 m [120 ft]) and deep (to 24 m [80 ft]) and develops a symodial form, often asymmetrical and ragged in outline. Branches may be erect to horizontal and massive. When trees are between 30 and 50 cm (12–20 in) dbh, the canopy shape changes from narrow-conical to a spreading crown with upward spreading branches (Beveridge 1975).

## Flowers

The tree a gymnosperm, i.e., it produces its male and female reproductive structures in cones and not in flowers. It is monoecious, having separate male and female cones on the same tree. The first female cones begin to be produced at about 10 years old. These take 2 years to mature; at the end of the first year they are egg-shaped, about 5 cm (2 in) long, and 3 cm (1.2 in) in diameter, and at the end of the second year they are more or less round and 8–10 cm (3–4 in) in diameter. In Fiji, very young female cones have been observed in early January.

At maturity, the male cones are cylindrical (20–25 mm [0.8–1 in] long by 8–12 mm [0.3–0.5 in] diameter) with the cupule wider than the cone base. They are borne on short side branches and rather inconspicuous green drying to light orange-brown. The microsporophylls are taxonomically important and a useful character for distinguishing between different *Agathis* species. In *A. macrophylla* the microsporophylls (as seen in the intact cone at anthesis) are strongly overlapping, 1.5–2 mm (0.06–0.08 in) across, margin thin, entire or irregularly incised, head in adaxial view 2(–2.5) mm (0.08[–0.1] in) across by 2 mm (0.08 in) radially, thick center thinning gradually to a narrow margin, stalk joining near head near abaxial edge. There are 6 to 14 pollen sacs.

## Leaves

The leaves are leathery, dark green, and shiny above and often glaucous below. The leaf blade is simple, entire, elliptic to lanceolate, about 7–15 cm (2.7–6 in) long and 2–3.5 cm (0.8–1.4 in) wide, with many close inconspicuous parallel veins. The leaves taper to a more or less pointed tip, rounded at the base, with the margins curved down at the edge. Petioles are short, from almost sessile up to 5 mm



**Top: Female cone. Bottom: Male cones.** PHOTO: GTZ-PACIFIC-GERMAN REGIONAL FORESTRY PROJECT

(0.2 in) long. The leaves are arranged decussately but held in one plane except on vertical growing tips. Juvenile leaves developed in shade are considerably longer than those in the upper canopy. The leaves of Solomon Islands plants are typically larger and broader than plants from drier and cooler parts of its range in Fiji.

## Fruit

Female flower cones are much larger than male cones, globular, about 8–13 cm (3–5 in) across, on thick woody stalks, green, slightly glaucous, turning brownish during ripening. Each brown, winged seed is attached to a triangular cone scale about 2.5 cm (1 in) across. About half the seeds are viable, these being located in the central part of the cone. The bulk of the seed crop has usually matured by early to mid-February, with later cones maturing in March, suggesting a maturation period of 12–15 months.



Leaves of a seedling. PHOTO: L. THOMSON

### Seeds

The seeds are brown, small, ovoid to globose, flattened, winged (wing about 3.5 cm [1.4 in] long), and attached to a triangular cone scale about 2.5 cm (1 in) across. Seeds are released during disintegration of the cone. Wind dispersal of seed is efficient: dispersal of up to 10 km (6 mi) has been recorded, and long-distance dispersal of tens to hundreds of kilometers is likely during cyclones.

### Rooting habit

Mature specimens have wide, spreading root systems that help stabilize soils on ridges and slopes (Beveridge 1975). Seedlings and young specimens have a vigorous taproot with one or more whorls of lateral roots. Roots of young seedlings are infected by the phycomycete *Endogone*, forming vesicular-arbuscular mycorrhizal associations.

### Similar or look-a-like species

*Agathis silbae* De Laub. (endemic to west coast Santo, Vanuatu)

*Agathis robusta* (C. Moore ex F. Muell) F.M. Bailey (endemic to Australia and Papua New Guinea and planted in some Pacific islands, especially Tonga)

### How to distinguish from similar species/look-a-likes

The main defining feature of *A. silbae* is the male cone: male strobili are cylindrical, oblong, somewhat broadened on the upper half, coppery-brown to red-brown, with a peduncle 3.5–4 mm (0.14–0.16 in) long. Pollen cones 37–55 by 15–18 mm (1.5–2.2 by 0.6–0.7 in), linear with the upper expanded part of the microsporophyll 2–2.5 mm (0.08–0.1 in) long and wide, with a 5–6-sided raised boss at the apical

end. Between the raised area (which crowds against those of the surrounding microsporophylls on immature cones) and the pendant pollen sacs is a broad raised area with a ridge along the centre, narrow where two sides of the raised area meet at its upper end and lanceolate (starting as wide as the adjacent side of the raised area) where one of those sides is located in the centre of the expanded part of the microsporophyll. Other differences in flower and fruit characters of *A. silbae* compared with *A. macrophylla* include the longer, more slender peduncles on the female cones of *A. silbae*, typically 6–9 cm (2.4–3.6 in), compared with 1–2 cm (0.4–0.8 in), and the typically longer male cones of *A. silbae*, about 4–5.5 cm (1.6–2.2 in) long compared with 2–5 cm (0.8–2 in) in *A. macrophylla*.

In *A. macrophylla* the microsporophyll head is more or less abruptly joined to the stalk, whereas in *A. robusta* the head narrows gradually into the stalk. In *A. macrophylla* the male flower cones (at anthesis) are shorter, about 2–5 cm (0.8–2 in) long compared with 5–10 cm (2–4 in) in *A. robusta*. The mature female cones of *A. macrophylla* are rounded (to 10 cm [4 in] diameter), whereas *A. robusta* has ovoid female cones (to 13 cm [5 in] long).

## GENETICS

### Variability of species

The populations of Pacific kauri from the Santa Cruz Group, Vanuatu, and Fiji exhibit considerable morphological differences in bole form, bark, and foliage, but they are nevertheless considered to comprise a single species. Whether the three geographic forms should be recognized as different subspecies is an open question. Even within one region, different varieties have been reported. For example, on the basis of differences in leaf characters and stem form, morphologically distinct forms have been recognized on Erromango and Aneityum in Vanuatu.

Within the species there is considerable variation in other traits of economic importance, especially self-pruning. Trees from the Santa Cruz Islands exhibit heavy branching and poor self-pruning. Southern Vanuatu provenances (formerly known as *A. obtusa*) combine moderately fast growth, especially in more open-grown situations, with good form and self-pruning and are considered to be among the most promising seed sources in the *Agathis* genus for use in plantation development.

### Known varieties

At Anelghowat (Aneityum, Vanuatu), villagers recognize three variants,

- nejev ahei, the most common type with white bark,
- nejev yang, with yellowish bark and timber, and,
- nejev apeng, with blackish bark and branches.

In Fiji, two different forms have been reported, one taller with fewer branches known as dakua balavu, and the other, dakua leka, shorter and more branched.

## ASSOCIATED PLANT SPECIES

In the Santa Cruz Islands (Solomon Islands) Pacific kauri is a dominant component of the lowland tropical closed forests, occurring as an emergent above a dense unstratified forest. The species is largely absent from early secondary forests, where it cannot compete with spreading, fast growing, secondary forest species. In Vanuatu the species occurs as scattered individuals or in small groups as an emergent or upper canopy tree, in various closed forest associations. In Fiji, it occurs in several forest associations, especially in moist montane closed forests and lower montane closed forests in the intermediate rainfall zone.

### Associated species of native habitats

Pacific kauri occurs in association with many different angiosperm and gymnosperm trees. In the Santa Cruz Islands it grows with *Camptosperma brevipetiolata*, *Fagraea* spp., and *Hernandia* spp.

Associates in Vanuatu include *Cryptocarya turbinata*, *Calophyllum neo-ebudicum*, *Garcinia vitiensis*, *Hernandia cordigera*, *Ilex vitiensis*, *Palaquium* spp., and *Podocarpus* spp. In Fiji some of the common associates are *Calophyllum vitiense*, *Dacrydium nidulum* and *D. nausoriense*, *Endospermum macrophyllum*, *Fagraea berteriana*, *Garcinia* spp., *Gymnostoma vitiense*, *Myristica* spp., *Palaquium hornei*, *Podocarpus* spp., *Retrophyllum vitiense*, and *Syzygium* spp.

## ENVIRONMENTAL PREFERENCES AND TOLERANCES

### Climate

The tree occurs naturally in the humid, lowland, and lower montane tropics. Tropical cyclones occur at periodic intervals in all parts of its range, mainly during the months of November through March. In the Santa Cruz Islands (Solomon Islands) Pacific kauri occurs from near sea level to 600 m (1970 ft). The climate is very wet (4500–6000 mm [180 in]) with no dry season and warm to hot throughout the year. In Vanuatu, the species is most frequent on ridges or steep, often exposed slopes, but also occurs on flat to undulating terrain. Rainfall on Erromango and Aneityum

is around 2200–2600 mm (87–102 in) per year with a short dry season from June to October but may reach 4000 mm (157 in) in wetter parts of Erromango. In Fiji, Pacific kauri is a component of lowland and lower montane subtropical rain forest from near sea level to 1150 m (3770 ft), mostly from 600 to 900 m (1970–2950 ft) elevation. Temperatures are warm to hot throughout the year. Annual rainfall is 2100–3600 mm (83–142 in) with a weak to pronounced dry season from June to October.

### Elevation range

5–1150 m (16–3770 ft)

### Mean annual rainfall

1900–6000 mm (75–236 in)

### Rainfall pattern

Pacific kauri prefers climates with summer or uniform rainfall patterns.

### Dry season duration (consecutive months with <40 mm [1.6 in] rainfall)

0–1 months. While there is a distinct dry season of several months in Fiji and Vanuatu, the average monthly rainfall in the driest months still exceeds 40 mm (1.6 in).

### Mean annual temperature

25–28°C (77–82°F)

### Mean maximum temperature of hottest month

29–31°C (84–88°F)

### Mean minimum temperature of coldest month

17–23°C (63–73°F)

### Minimum temperature tolerated

7°C (45°F) (Nadarivatu, western Viti Levu, Fiji)

### Soils

Pacific kauri generally prefers basalt-derived clay loams and clays with a well developed upper humus layer. It has also been reported on coral limestone terraces and bordering mangrove vegetation. Tree growth is poor on compacted and waterlogged soils, and the species is most commonly found on well structured, friable, and freely drained soils.

On Ndendo (Santa Cruz Islands) the stands are located on deep friable clays (Oxisols) derived from basalt, although the edges of the stands may occur on calcareous sandstones and siltstones. On Vanikolo trees grow over basalt on a latosolic soil without appreciable accumulation of humus and no sign of podsolization. It has been found that the to-

tal Ca<sup>2+</sup> and Mg<sup>2+</sup> levels are lower in soil samples obtained from below individuals of Pacific kauri than from samples obtained below individuals of *Calophyllum neo-ebudicum*. Although this data suggest that more extensive leaching of cations occurs under Pacific kauri, the species does not appear to promote podsolization to the same extent as some other species of *Agathis*.

In Vanuatu the species also generally occurs on clayey soils with a well developed upper humus layer. On Erromango the species grows on deeply weathered, well structured clays (Oxisols) derived from basalt. In Fiji the species occurs on various heavier soil types, including deep, friable, chocolate-brown clay over basalt, humic Latosols and red-yellow podzolics.

### Soil texture

The tree grows in heavy soils (sandy clays, clay loams, and clays).

### Soil drainage

Freely draining soils are required.

### Soil acidity

It grows in acid to neutral soils (pH 4.0–7.4).

## Tolerances

### Drought

It is likely to be tolerant only of short dry periods (e.g., 3–5 months) once established.

### Full sun

The tree grows most rapidly in well lit situations, but trees grown in full sun may have poorer self-pruning of side branches and heavier lateral branching compared with those grown under light, even shade (about 25% overhead shade).

### Shade

In lightly shaded situations plants may elongate moderately fast (sometimes faster than in full sun), but under heavy shade they grow very slowly (until such time as they are exposed to stronger sunlight). However, seedlings are able to endure heavy shade (up to 75%) for many years.

### Fire

Fires can kill mature trees; susceptibility to fire damage reportedly increases in over-mature specimens.

### Frost

Frosts are unknown in its native habitats, and accordingly

the species is likely to be tolerant only of the mildest frosts at infrequent intervals.

### Waterlogging

The tree is generally intolerant of waterlogging but might be able to tolerate short periods of waterlogging in lighter, well aerated soil types.

### Salt spray

Pacific kauri occurs in near-coastal situations and is tolerant of light salt spray.

### Wind

Trees are well adapted to growing in windy locations and cyclones.

## Abilities

### Regenerate rapidly

Seed production is sufficient to maintain occasional to moderately common and reasonably widespread populations of very slow growing seedlings. When large gaps in the canopy appear (>2–3 trees), the seedlings are released and can grow reasonably rapidly to become emergent trees.

### Self-prune

The extent of self-pruning is substantially affected by both environmental and genetic factors. In the Santa Cruz Islands open-grown trees develop persistent, heavy limbs that showed no sign of self-pruning during the first 10 years. However, mature plantations self-prune well, and pruning is not practiced in the Solomon Islands. Trees from Vanuatu exhibit much better self-pruning and branching characteristics than those from the Santa Cruz Islands (Fijian populations are intermediate).

### Coppice

Unknown for *A. macrophylla*. Some species of *Agathis*, including *A. borneensis* in Malaysia, will coppice when sapling size plants are cut.

## GROWTH AND DEVELOPMENT

Pacific kauri is reported to be among the fastest growing species in the genus (Bowen and Whitmore 1980a). However, annual diameter increment is variable and affected by several factors. The major factor appears to be the degree of exposure of the tree canopy to sunlight. The species is exceptionally long-lived with an estimated life span of 300–1000 years.

## Growth rate

In open and lightly shaded areas, with good weed control, the mean annual increment is about 1–1.5 m (3.3–5 ft) in height and 1.5–2 cm (0.6–0.8 in) in trunk diameter (Martin 1970, Neil 1990). Trees in undisturbed, native forest grow very slowly, e.g., 2.5–3.7 mm (0.1–0.15 in) per year and take more than 200 years to reach a dbh of 75 cm (30 in) (Ash 1985).

## Reaction to competition

Pacific kauri is very tolerant of shading, but growth rates are greatly reduced at higher levels of shading. It is reasonably tolerant of root competition, but seedlings/ saplings should be kept free of competition from grasses.

## PROPAGATION

The species is readily grown from freshly collected seed, and this is the recommended propagation method. Plants can also be propagated vegetatively using both main stem and lateral cuttings from 12-month-old seedlings. Lateral cuttings tend to retain a plagiotropic growth habit and should not be used for planting stock for timber plantation purposes.

## Propagation by seed

### Seed collection

Heavy cone crops are produced on older trees with massive, spreading crowns, although the larvae of *Agathiphaga* moths can cause major seed damage and loss (see “Pests and diseases”). The recommended collection technique is climbing (using appropriate safety equipment, ropes, harnesses, and spikes) into the upper canopy and using long-handled hooks to break off mature cones. Seed is most abundant in the early months of the year: February–April (Santa Cruz Islands), February–March and June (Vanuatu), and January–March (Fiji). Collection of recently matured cones will result in greater seed viability and longevity, but it is difficult to assess when the cone is fully mature, and it shatters shortly afterward.

### Propagule processing

Precautions have to be taken in seed collection, extraction, and handling to avoid damage due to lethal combinations of temperature or moisture content. Cones should be air dried in an open location, and seed should be extracted as soon as possible after collection to minimize fungal damage and/or germination in the cone. On average about half the seeds are viable; these are located in the central part of the cone. However, there is a very large variation in num-

bers of viable seeds per cone, from a few up to about 100. Freshly collected seed has about 5000–6000 viable seeds/kg (2270–2730 seeds/lb).

## Seed storage

Pacific kauri may be classed as intermediate in its seed storage characteristics. Its seeds are very sensitive to a range of conditions including drying, chilling damage, and carbon dioxide/oxygen balance. Seed storage life is affected by complex relationships among moisture content, temperature, and drying rate. For long-term storage, seed should be dried to around 9–13% moisture content and kept as cold as possible, preferably at –13°C (11°F). Drying below 7% moisture content reduces viability.

## Pre-planting treatments

In order to avoid reduction in viability during storage, it is recommended that dewinged seeds be sown immediately following collection and processing. No pretreatment is required, and fresh, undamaged seeds germinate rapidly, commencing within 2–7 days (at 26°C [79°F]) and completed by 14 days.

## Growing area

It is recommended that plants be germinated under shelter with about 50% shade.

## Germination

Sow seeds into potting medium in germination trays. The seeds are sown in a vertical position with wing end up and just covered by sand or potting mix. Seedlings are transplanted into individual pots at the two-leaf or cotyledon stage.

## Media

A standard potting medium with good draining properties is recommended. For introduction into areas outside of its natural range, it is likely to be advantageous to inoculate seedlings with appropriate mycorrhizal fungi.

## Time to outplanting

Seedlings reach a plantable size after about 6–12 months in the nursery.

## Approximate size

Seedlings are suitable for field planting when they have reached 25–30 cm (10–12 in) in height. However, larger seedlings grown in larger, deeper pots may be desirable in order to reduce the period of high-maintenance weeding following outplanting. If necessary, seedlings may be safely held in the nursery for a considerable period, e.g., up to 2 years, by transferring them into more shaded conditions.

## Guidelines for outplanting

Survival is expected to be very high (>95%) for larger seedlings that are planted into reasonably sunny sites and weeded at regular intervals, on an as-needed basis, during the first 4–5 years. It is important to cut away and cut down fast-growing climbers such as *Merremia peltata* and mile-a-minute (*Mikania micrantha*). These can quickly weigh down, bend over, and damage younger kauri plants. For grassy/weedy sites, pre-planting spraying of site with glyphosate herbicide is recommended.

## DISADVANTAGES

The main disadvantage is the high early maintenance cost, with regular weeding being required during the first 4–5 years, especially in open-grown plantations. Pacific kauri should not be planted in areas with heavy infestations of weedy climbers.

There may also be difficulties in obtaining planting stock, due to problems of collecting, maintaining, and/or procuring viable seed.

## Potential for invasiveness

The biological characteristics of the species ensure that it has a low weediness risk.

## Diseases and pests

The species has low susceptibility to termite attack and beetle larvae, but old trees are sometimes affected by these insect pests. Pink disease, caused by *Corticium salmonicolor*, and root fungi may be lethal to the plant but are usually restricted to waterlogged sites. Other pests and diseases include foliage blight (*Cylindrocladium macrosporum*), necrotic bark, leaf gall, canker, hollow butt, and *Phellinus noxius*. Plantations in the western Solomon Islands (outside the species' natural range) have been affected by a coreid bug (*Amblypelta cocophaga*). The most serious recorded pests are larvae of the primitive moth *Agathiphaga vitiense*. Attack by these caterpillar larvae may greatly reduce the amount of viable seed produced, with up to 95% of seed in a cone being destroyed. Plants may suffer from dieback especially when grown on soils of poor structure.

## Host to crop pests/pathogens

Unknown.

## Other disadvantages or design considerations

The nursery period is of a long duration for a tropical tree species, increasing the cost of seedling propagation and risk of seedling death from water stress.

In open-grown situations, trees of Santa Cruz Islands and Fiji origin showed no sign of self-pruning during the first 10 years and exhibited a tendency to form several leading shoots.

## AGROFORESTRY/ENVIRONMENTAL PRACTICES

### Soil stabilization

It is not suitable for situations where rapid soil protection and binding is needed, but it may be very useful for longer-term stabilization of less stable soil profiles.

### Crop shade/overstory

The tree is mainly suitable as a long-term or permanent overstory tree for more shade-tolerant understory crops; however, wide-spaced plantings of less dense forms of Pacific kauri (such as from Fiji) may provide light shade for a wider variety of crops.

### Alley cropping

It is not well suited to alley cropping in permanent agroforestry systems due to its eventual large stature and spread. It could be included in alleys in shifting gardens (which are then left to revert back to forest).

### Homegardens

The tree is usually not appropriate for homegardens due to its large size, but it could be included as a “landmark” tree (with high stability during cyclones). Because of its traditional and commercial importance, as well as its long life span and increasing rarity, the plant is ideal for planting in village and schoolyards.

### Improved fallows

It could be planted in shifting garden situations, but long rotations mitigate against its use for this purpose.

### Boundary markers

In certain situations it is suited as boundary marker, due to size and longevity, but it may shade neighboring crops.

### Windbreaks

Where space permits, Pacific kauri is an excellent upper story in a mixed-species windbreak (including faster growing species).

### Silvopasture

Pacific kauri is well suited to inclusion as a tree component in silvopastoral systems, being long-lived and providing high shade for cattle.



## Woodlot

It is suited only to woodlot plantings in which early financial returns are not required.

## Wildlife habitat

It is a very useful wildlife habitat tree, especially for birds, and provides a unique structural element in SW Pacific forest ecosystems.

## Ornamental

One of the most impressive trees in the Pacific islands, it deserves to be more widely planted in large public spaces, including along roads and as a landmark tree.

## USES AND PRODUCTS

Pacific kauri is of great importance to local people throughout its natural range in Melanesia. In a survey of 18 villages on the major islands in the Fiji Group, 41 of 42 respondent groups named the species as an important timber tree. Traditional uses for the tree are similar in different parts of its range. The timber is utilized for house and other construction, furniture, canoe making, and carving, while its resin is used for glazing pots, canoe caulk, lighting fire, glue, and in torches. The smoke of the resin is also used as a dye for hair and tattoos and to paint native clothes black. In some areas Pacific kauri may also have spiritual significance. For example, in Fiji it is the totem tree of several family clans, villages, and districts.

Pacific kauri is a highly valued commercial timber species, often generating much needed cash income for local communities through logging royalties.

## Medicinal

The young leaves and bark of the related *A. silbae* are used in traditional medicines on Santo, Vanuatu (Siwatibau et al. 1998).

## Timber

The wood is an important commercial timber with many end-uses, both for local and export markets (see “Commercial products”). It produces a finely textured, straight grained, pale, and uniform timber that is easily worked and glued and has excellent physical, mechanical, working, and veneering properties. The timber is valued for handicrafts, furniture, veneer, boat building, light construction, and paneling. It is not suitable for use in ground contact, as its natural durability class is rated as 3 or 4 (depending on source), indicating a service life in ground contact of about 5–10 years. The timber is amenable to preservative treatment, but its high value would normally preclude its use

for general construction purposes. The species is currently being commercially exploited in Fiji, mainly on the large islands of Vanua Levu and Viti Levu. The species is protected on Erromango, Vanuatu, in a Kauri Reserve: it is expected that this measure will generate ecotourism revenue for local communities. The species is not currently logged in Santa Cruz Islands, and exports of logs are prohibited.

## Fuelwood

The wood can be used as fuel, but is better suited to other purposes.

## Craft wood/tools

The wood is traditionally used for carving in Vanuatu.

## Canoe/boat/raft making

The wood has traditionally been used for making canoes in Vanuatu; the whole trunk is used, carved out to make canoe.

## Resin/gum/glue/latex

Manila copal produced from the living inner bark was an important component of many varnishes (Chaplin 1993) and is still used mixed with synthetics. Commercial export of the resin was formerly practiced in Fiji but was prohibited in 1941, as no method could be found for tapping an economic yield of gum without endangering the life of the tree. In Vanuatu *Agathis* resin is traditionally used as canoe caulk, and the resin soot was used for tattoos. In Fiji the resin was formerly used for glazing pots.

## Tannin/dye

Smoke residues of the burnt resin were traditionally used as a dye for hair.

## Illumination/torches

Resin from the inner bark was traditionally used for lighting and torches in Fiji and Vanuatu.

## Ceremonial/religious importance

In some areas the tree has spiritual significance. For example, in Fiji it is the totem tree of several family clans, villages, and districts.

## COMMERCIAL PRODUCTS

Pacific kauri is a highly valued commercial timber species. It has good peeling and gluing properties and is highly sought after for surface veneer. The pale cream to gold brown lustrous heartwood and straw yellow to pale brown sapwood are well known and highly appreciated in the timber industry. Damage from pinhole borers may occur

in standing trees, while drywood termites and *Anobium* borers may cause damage in service.

The wood is readily kiln dried with a medium shrinkage value. The air-dry density is 540 kg/m<sup>3</sup> (34 lb/ft<sup>3</sup>). In service the timber is very stable. The timber is suitable for a wide range of end-uses including laboratory bench tops, vats, sauna baths, battery separators, weatherboards, bowls, novelties, handles, furniture, veneer, and boat building.

The use of selected, superior seed provenances (notably from Vanuatu) and good silviculture will enable the commercial production of timber and veneer in plantations on a 40–55-year rotation period.

### Spacing

Selection of spacing regime will depend on the environment in which the plantation will be established:

- in secondary or logged forest, enrichment planting with a spacing of 2–3 m (6.6–10 ft) in lines 9–10 m (30–33 ft) apart
- in cleared areas a spacing of 4–5 x 4–5 m (13–16 x 13–16 ft) in association with agricultural intercrops for several years to reduce weeding costs.

### Management objectives

The overall management objective is to produce a high stocking of well formed stems. Accordingly, implementation of a thorough weeding regime in early years is essential, including regular removal of climbers and singling of any multi-stemmed seedlings/saplings.

An initial density of 400–500 stems/ha (160–200 stems/ac) is recommended, reducing to a final density of about 150 stems/ha (60 stems/ac) through mortality and one selective, non-commercial thinning at about half the rotation length, i.e., about 20–25 years.

In native forests it is recommended that natural regeneration be periodically tended, mainly release from vines and climbers, following opening up of the canopy through logging.

### Design considerations

The wood is valuable, and accordingly plantations do not necessarily have to be located especially close to markets but should preferably be located within economic range of processing facilities. Excessive delays in processing may diminish log quality due to sap stain and/or borer attack (including toredo, a type of marine borer, if exposed to the sea).

## CONSERVATION OF PACIFIC KAURI

The high-quality timber of Pacific kauri has led to heavy post-European exploitation, and it remains a species highly preferred by logging companies. Former extensive logging of the species has left just a few more-or-less pristine stands remaining in Vanuatu and Fiji, and some of these have some level of protection. Although under no imminent threat, which is indicated by its “near threatened” (LR/nt) listing in the International Union for Conservation of Nature and Natural Resources (IUCN) “red list,” it is an open question whether present conservation efforts are sufficient to maintain the remaining genetic resources of the species in the long term. An intensification of commercial timber harvesting may lead to a CITES listing for the Fijian populations.

### Yields

No data is available for older plantations of *A. macrophylla*. In the Santa Cruz Islands, Marten (1970) envisaged a 45–55-year rotation with a final crop of 60–80 stems/ha (24–32 stems/ac) with each stem yielding 2 m<sup>3</sup> (140 ft<sup>3</sup>). This equates to a growth increment for merchantable timber in the final crop of only 2–3 m<sup>3</sup>/ha/yr (29–43 ft<sup>3</sup>/ac/yr). Higher growth rates have been observed for other *Agathis* species, and Marten’s estimates appear conservative. Whitmore (1980) recommended that *A. dammara* be grown on a 50-year rotation on Java (Indonesia) for a total predicted yield of 22–28 m<sup>3</sup>/ha/yr (315–400 ft<sup>3</sup>/ac/yr) (volume increment, including thinnings, at 30 years of age was 23–32 m<sup>3</sup>/ha/yr [329–458 ft<sup>3</sup>/ac/yr]). *Agathis robusta*, another faster growing species in the genus, exhibited a merchantable wood increment of 11 m<sup>3</sup>/ha/yr (157 ft<sup>3</sup>/ac/yr) at age 22 years on a sub-optimal site in southern Queensland, Australia (Whitmore 1980).

### Market

The timber and veneer of the species has good local and export market prospects. Because of its deservedly high reputation in the timber trade and the multiple uses to which its timber can be put, demand and prices will remain solid for the indefinite future. In former times an annual output of around 10,000 m<sup>3</sup>/yr (35,300 ft<sup>3</sup>/yr) from the Solomon Islands was considered necessary to meet Australian demand and return a profit. There is currently no production, but there is estimated to be about 450,000 m<sup>3</sup> (15,900,000 ft<sup>3</sup>/yr) available, and logging may resume in near future.

## INTERPLANTING/FARM APPLICATIONS

Pacific kauri appears to be suitable for growing in monocultures but is preferably cultivated with a diverse tree/shrub understory.

### Example system

#### Location

Shark Bay, Espiritu Santo, Vanuatu.

#### Description

New system: Seedlings are underplanted as an understory in a moribund (stagnant growth with some deaths from *Phellinus Cordia subcordata* plantation, commenced in about 1997 on trial basis.

#### Yields/benefits

The trees have grown moderately fast, about 1–1.5 m (3.3–5 ft) per year, and have very good stem form.

#### Spacing

Spacing of *Agathis* trees is 5 x 5 m (16 x 16 ft).

## PUBLIC ASSISTANCE

See general extension links at: <<http://www.traditionaltree.org/extension.html>>.

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## *Agathis macrophylla* (Pacific kauri)

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