Status of Genetic Resources of *Pinus merkusii* (Jungh et De Vriese) and *Pinus kesiya* (Royle ex Gordon) in Southeast Asia

Razal, R.A., Tolentino, E. L. T. Jr., Carandang, W. M., Nghia, N. H., Hao, P. S., Luoma-Aho, T.

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UPLBCFNR, Los Baños, Philippines & IPGRI-APO, Malaysia

Abstract

The relentless destruction of the natural stands of *Pinus merkusii* and *P. kesiyas* in the tropics has brought about the continuous decimation of valuable germplasm of the two species even before the full extent of their genetic diversity could be studied and mapped. To arrest the further erosion of these germplasm, a viable and efficient conservation and utilization programme of their remaining genetic resources is imperative. Such an effort should include, among others, the expansion of plantations of the two species and improvement of the overall plantation management system, upgrading of seeds and planting stock production technologies, enhancement of research on the genetics, breeding and tree improvement of the species, and increasing the awareness and participation of communities and other relevant sectors in efforts towards the genetic conservation of these species.

This report presents a synthesis of the natural distribution of *P. merkusii* and *P. kesiya* in the Philippines, Thailand and Vietnam as well as the status of their genetic resources, utilization practices, and existing initiatives towards the conservation of their remaining germplasm. A review has been made of the known patterns of genetic variations as documented through a number of provenance trials of the two species in the three southeast Asian countries. It was noted that among the three countries, Thailand has undertaken significant efforts towards understanding the patterns of variation and the identification of possible genecological zones of the species.

Finally, the report also attempted to identify populations of the two species that are at risk in the three countries, which can serve as the candidate populations on which to focus conservation efforts.

The information in the document is meant to provide the backdrop for a unified development and implementation of a regional strategy for the conservation of the genetic resources of the two species in the three countries. An indicative programme proposal on the genetic resource conservation program of the two *Pinus* species has also been formulated.

Introduction

Rationale and justification

Pinus merkusii (Jungh *et* De Vriese) and *P. kesiya* (Royle ex Gordon) are two tropical pine species with great biological and economic importance. Among all pine species, *P. merkusii* is said to have the most southerly distribution; it is perhaps the only pine species that extends its natural distribution south of the equator. It grows naturally and artificially in Vietnam, Laos, Cambodia, China, the Philippines, Malaysia, Thailand and Indonesia. It exists in large stands or in small groups in many provinces in Vietnam, but mainly in Kon Tum and Lam Dong Provinces. In the Philippines, it thrives in the Zambales Mountain Range northwest of Luzon Island, and in the western part of the Island of Mindoro. In Indonesia, it extends to $2^{o}06'S$ in the Barisian Range of Sumatra. The best-developed forests of this species are found around Lake Toba in northern Sumatra.

On the other hand, *P. kesiya* can be found in the region from the Eastern Himalayas to the Philippines, covering China, Thailand and Vietnam. The species usually grows in pure stands or mixed with certain broadleaved tree species, but does not form open pine forests. It is said to be shade tolerant, and thrives well on wet, subtropical climate with distinct dry and rainy season, and in areas with humidity not less than 70%. It can grow on poor soils if well-drained and abundant natural regenerations are observed on mineral soils.

P. merkusii can grow as high as 70 m, making it one of the world's tallest pines. The wood, which is heavy, is used in construction, matches, pulp for paper, furniture, pit props, electric poles, ship and vehicle building. The wood has high resin content, which is also a precious material for medicine, paints, printing and the perfume industry. In North Vietnam, it is one of the principal tree species planted for reforestation, soil erosion control and the rehabilitation of denuded forestlands. The species is included in the IUCN (2001) list of the world's threatened forest tree species.

Both species have been subjected to extreme exploitation because of their high economic value. *P. merkusii* forests in the Philippines are negatively affected by the following: poor regeneration in natural stands, destructive oleoresin tapping and cutting of trees for domestic purposes.

The relentless destruction of the natural stands has brought about the continuous decimation of valuable germplasm even before the full extent of their genetic diversity has been discovered and/or mapped. To arrest further genetic erosion, a viable and efficient conservation and sustainable utilization programme of their remaining genetic resources should be put in place.

For the above reasons, it is necessary to:

1. Initiate germplasm conservation of the species;
2. Increase the awareness and involvement of upland communities in the conservation of the species;

3. Support improved production of quality planting stocks and wood production of pine trees;
4. Increase the area of plantations of the species for production purposes, thus reducing pressure on natural stands;
5. Enhance research on the genetics, breeding and tree improvement of the species; and
6. Improve management systems of areas planted with the species.

Goal

The goal of this initiative is the development and implementation of a participatory regional strategy for the conservation of genetic resources of *P. merkusii* and *P. kesiya* in the Philippines, Thailand and Vietnam, as well as other countries in the range of natural existence of the species.

Objectives

The project aims to achieve the following specific objectives:

1. Compile information on the natural distribution, genetic resources, utilization and threats to the conservation of the two pine species in the Philippines, Vietnam and Thailand.
2. Draft a workplan for the effective conservation of the pine genetic resources in the region.
3. Draft a regional proposal for the conservation of the two pine species in the region.

Activities

1. Assessment of the status of natural distribution, genetic resource, utilization, threats and conservation activities for *P. merkusii* and *P. kesiya* in the three countries: Philippines, Vietnam, Thailand (literature reviews, field validation).
2. Writing of a comprehensive status report on the aforementioned aspects.
3. Developing a draft regional workplan for creating a genetic conservation programme for both species.
4. Developing a first version of a proposal on "Southeast Asia Genetic Resource Conservation Programme for *P. merkusii* (Jungh *et* De Vriese) and *P. kesiya* (Royle ex Gordon)" for submission to suitable donor.

Expected output

1. Status report on the natural distribution, genetic resources, utilization, threats, conservation activities of *P. merkusii* and *P. kesiya* in the three countries.
2. A first draft workplan for establishing a regional genetic conservation programme for the species.
3. First version of proposal on "Southeast Asia Genetic Resource Conservation Programme for *P. merkusii* (Jungh *et* De Vriese) and *P. kesiya* (Royle ex Gordon)."

Materials and Methods

To gather the information needed for this study, the research team did an extensive search of the literature, both published and unpublished. The "grey" materials used included progress and final technical reports of research centres in areas where natural and or planted stands of the two pine species exist, as well as graduate and undergraduate theses or research reports dealing with the various aspects of pine distribution, resource utilization, threats and conservation. Some materials were also sourced through the internet. In the Philippines, site visits were also undertaken either as part of the project or by riding on with other projects implemented by some members of the research team. Interviews with personnel in research stations known to have conducted/dealing with pines have likewise been done. Some photo-documentation of selected sites was also made and these are attached to this report. Early on into the project, the research team has also agreed on an outline around which the report will be written. The results, therefore, are presented in accordance with the outline earlier agreed upon by the team.

Results

Conservation status in the Philippines, Thailand and Vietnam

Description/Distribution of the species

Pinus kesiya

Pinus kesiya Royle ex Gordon is known by the official common name Benguet pine in the Philippines. Other vernacular names for this species in the Philippines are 'alal', 'balibo', 'bariat', 'bata', 'batang', 'bebe', 'bolbol', 'bubu', 'bulbul', 'olol', 'parua', 'sahing', 'saleng', 'salit', 'talang' and 'tapulau'. In Vietnam, the vernacular names for this plant are 'thong ba la' and Langbian pine, while in Thailand, it is known in the vernacular as 'son sambai'. Benguet pine is a large tree that grows up to 35 m high. It has a straight cylindrical bole usually 15 m long, with a thick and flaky bark and no pronounced buttress. Each fascicle has three needles that are acuminate, rarely in pairs, measuring about 12-24 cm long and 0.5 mm in diameter, and possess stomata on most of its surface. Its cones, measuring about 18-30 mm × 5 mm, bear pollens and seed cones that are ovoid to conical, about 4.5 to 10 cm × 3-5 cm, while the seeds are generally oval, dark brown, measure 5-8 mm × 3 mm and have a deciduous wing up to 2 cm long and 8 cm wide (Sotalbo, 2001).

The most easterly occurrence of *P. kesiya* is in the forests of the Philippines, with the major occurrence reported in the Central Cordillera mountains, (16º 05'-18º 15' N, 120º 30'-121º 10'E), within the altitudinal range 750-2450 m. Other occurrences are in the Caraballo mountains, which lie southeast of the Central Cordillera. The most southerly is to the north of Dingalan. As of 1980, small stands were also reported in the Zambales mountains in the province with the same name, which is on the west coast of Luzon. In Thailand, *P. kesiya* is confined to the northwest and north, occurring mainly in the mountain ranges west and

south west of Chiang Mai up to and across the border with Myanmar. Isolated occurrences are found to the north west of Maung Nan in the northern mountains, on the Phu Kradung Plateau near Loei, and the most southerly location in Thailand is in the Mieng Hills near Phetchabun to the east of Phitsanulok. The pine forms forests between 1000 and 1500 m, with the range of altitudinal distribution from 300–1800 m, although rarely below 800 m. In Vietnam, *P. kesiya* occurs in the Annam Cordillera mountain chain, which is in southern Vietnam. The best and most extensive stands are located in the Langbian Plateau near Dalat, which has a mean altitude of about 1500 m, although the species grows within the altitudinal range of 1300 and 2300 m on Langbian. Other locations in Vietnam are in the Haut Donnai Plateau southeast of Dalat in the forest of Yankar, at Tourland To, and at P'sore north of Kinda. Small stands have also been reported on the southern massif of Langbian, and also scattered in the semi-arid zones of the North, and further up in the highlands close to the border with China (Turnbull *et al*., 1980).

P. merkusii

P. merkusii Jungh et de Vriese is known by the official common name Mindoro pine in the Philippines and in the vernacular as 'tapulau', as 'son song bai', 'son haang ma', and 'kai plueak dam' in Thailand, as 'thong nhua' and 'thong hai' in Vietnam, and as 'damar batu', 'damar bunga' and 'uyam' in Indonesia. It is a medium to large-sized tree, commonly reaching a height of 30-35 m and a diameter of 140 cm. It has a straight and cylindrical trunk, which is very resinous. Its bark is thick, reddish-brown, splitting deeply longitudinally. Each typical fascicle has two needles. Its cones have rhomboid scale surface, and sharp margin. Seeds are ovate, slightly flat, bearing a thin wing, 1.5-2cm. (Nghia, 2004).

P. merkusii is considered as one of the few truly tropical pine species, occurring naturally in Southeast Asia including Myanmar, Thailand, Laos, Vietnam, Cambodia, in Sumatra in Indonesia, and in the islands of Luzon and Mindoro in the Philippines. The latitudinal range is approximately from 23 ºN to 2 ºS. Biggest areas are found in northwestern Thailand, southeastern Myanmar, and northern Sumatra (Nghia, 2004).

Regeneration

P. kesiya

P. kesiya produces abundant seeds annually and dispersal in the Philippines is very effective in its natural habitat, either by wind or by being washed down with rain water on the mountain sides. In Thailand, natural regeneration of *P. kesiya* is scarce despite an abundant annual seed crop, with the species most frequently found on abandoned cultivated areas or on other disturbed ground such as roadsides or landslips. In Vietnam, there is an abundant seed crop every year, and natural regeneration is good in Lam Dong. Wind distributes the winged seeds, with the shedding of the seeds coinciding with the time when herbaceous vegetation has died down and the seeds can fall on exposed ground between the plants (Turnbull *et al*., 1980).

P. merkusii

For *P. merkusii*, natural regeneration is generally good in open areas particularly when adequate protection from fires and other disturbances (e.g. seed predation) is provided. It flowers in May-June, and its fruits mature in October-November of the following year (Nghia, 2004).

Adaptation to fire

P. kesiya

In the Philippines, most *P. kesiya* seedlings establish themselves within one year of a fire. Provided the area is free of fire at least ten years, even-age stands could develop. Young pine seedlings are vulnerable to fire during the first five years but after the trees have reached a certain size, the effect of light surface fires is merely to thin the stand and to burn the herbaceous layer. At high elevations, frequent fires have severe thinning effect only until the trees have a diameter at breast height of 6 cm. Larger trees have a very high survival rate against fire. In Thailand, annual fires are responsible for the death of most *P. kesiya* seedlings. In Vietnam, frequent fires burn the ground cover or the accumulate litter, allowing the seeds to germinate on mineral soil where it has little competition. However, fire will destroy seedlings less than five years old and it is not until towards the 15th year that a *P. kesiya* stand can tolerate the passage of a fire without serious damage (Turnbull *et al*., 1980).

P. merkusii

As for *P. merkusii*, the so-called "grass stage" of the species is an adaptation to fires and seasonal drought (Sirikul, 1980 as cited by Theilade *et al*., 2000). At this stage, the seedlings remain suppressed for 2-4 years where a dense cover of long needles protects the shoot inside.

Land use changes in the Philippines, Thailand and Vietnam

The Philippines, Thailand and Vietnam have registered a negative change in forest cover since 1980.

Table 1. Change in forest cover in the 3 countries from 1980-2000*.

Country	Forest Cover			% land area protected
	1980 (%)	2000 (%)	Change in area, 1980-2000 (%)	
Philippines	38.4	19.4	-49.5	2.02
Thailand	36.4	28.9	-20.7	13.66
Vietnam	33.0	30.2	-8.7	4.03

*Brown *et al*., 2001.

Among the causes of this reduction in forested areas are land-conversion, unsustainable logging, pollution, manmade fires, encroachment and human settlement or occupancy even in protected areas. In the Philippine Cordilleras for instance, developments due to rapid urbanization are changing much of the landscape, where residential houses, commercial centers and other built-up structures such as roads and highways, as well as expanding agricultural activities have taken the place of pine forests. Thus, natural stands of *P. kesiya* and *P. merkusii* have diminished in size or are already totally gone in many areas owing to the destruction brought about by human–induced as well as by natural causes, for example, fires and landslides.

In Vietnam, particularly in Lam Dong, stands of P. *kesiya* are performing well, primarily due to the ease of planting and good adaptation of the species. Either pure or mixed plantations of *P. kesiya* (with *P. merkusii* and *P. massoniana*) are reported to have been established in the country (Nghia, 2004).

Utilization of natural and plantation forests

In Vietnam, the wood of *P. kesiya* is used for construction, packaging, and pulp and papermaking. In general, the tree is tapped for its resin before it is cut for timber. *P. merkusii* is primarily exploited for its resin, although use of the wood for construction and packaging purposes is quite common.

In the Philippines, *P. kesiya* timber was almost depleted, primarily to provide for the mine timber needed by the gold mining industry in the Cordilleras. Mine props from *P. kesiya* were used as supports in the construction and operation of underground tunnels, shafts, walls, and chambers. Lumber sawn from the timber has also been used as post, ceiling joist, beam, doors, for paneling, fabrication of furniture and other interior structures. Many users are attracted to the durability, beauty and finish of pine-made products. Tapping the *P. kesiya* for the collection of oleoresin also used to thrive as an industry supplying the resin requirement of Pigres, a local supplier of naval stores and other pine-based chemicals. But the company's operation has folded up when the supply of pine resin has dried up. Small trees are cut for Christmas trees during the holiday season, and recently, pine needles have started a cottage industry that fashioned decorative novelty items such as jars, fruit bowls, wall decors, mirror frames, flower vases and different shapes of baskets.

Plantations

P. kesiya

The establishment of *P. kesiya* plantations in the Philippines has already been tried as early as 1929. One such plantation, which is located outside areas where the species occurs naturally, can be found in Malaybalay, Bukidnon. The increase in diameter and height of the trees, however, is slow relative to growth in areas where the species is a native.

P. merkusii

Nghia (2004) reported that large areas of *P. merkusii* plantations have been established in Indonesia, Thailand and Vietnam. More than 100,000 ha of plantations of the Sumatran provenance were established in the late 1980s in Java. In Vietnam, 218,056 ha of pine plantation including *P. merkusii*, *P. kesiya* and *P. massoniana*, have so far been established. The reason for establishing plantations of this species is to prevent soil erosion in bare hills as well as to grow timber and for tapping the resin.

In Thailand, *P. merkusii* is not widely used as a reforestation species. However, in 1964, 32 ha of Si Sa Ket provenance was planted at Baw Kaew in Chiang Mai Province in a project supported by UNDP (DFSC, 2000).

Indigenous practices

In the Philippines, an indigenous practice call *tayan* is practiced among the indigenous people of Bontoc. Under this community forest management practice, trees including *P. kesiya* are harvested only based on a community member's need. A clan of elders serves as the institutional control for the harvest of trees (Guiang *et al*., 2001). In Ifugao, the natives retain patches of forest enclosed or adjacent to their settlements called *muyong* or *pinugu*. The *muyong* is usually planted to timber, fruit trees, climbing rattan, bamboo, palms and other associated natural vegetation which would include native trees like *P. kesiya*. The *muyong* is privately owned land and is properly demarcated. There are customary laws that the natives have developed that govern the use and harvesting of trees in the *muyong*. The trees, including *P. kesiya*, could be harvested but a person who illegally cuts them must plant two replacement trees and clean a large area of the *muyong* (Serrano and Cadaweng, 2005).

The role of protected areas in conservation of *P. kesiya/merkusii*

In the Philippines, the National Integrated Protected Area System (NIPAS) Act (Republic Act 7586) provides the major legal framework for the protection of biodiversity in the Philippines. Networks of protected areas were designated to protect the biodiversity of the country. In like manner, Thailand has a network of protected areas that contributes to the forest resources genetic conservation.

Policies on/relevant for the conservation and management of *P. kesiya and P. merkusii*

In the Philippines, the Forestry Administrative Order No. 74 prescribes the seed tree method for the pine forest. The procedure prescribes the selection of phenotypically superior seed or mother trees that serve as source of regeneration. It was suggested by Caleda (cited by Agpaoa *et al.*, 1976) that 16 to 20 seed trees per ha be retained. The seed trees are grouped in 4-5 trees per cluster. The practice lessens the difficulty posed by an even distribution of mother trees which is vulnerable to windthrow and also damage by felling during logging operations (Nicholson cited by Agpaoa *et al*., 1976).

The DENR (Department of Environment and Natural Resources) Administrative Order No. 95-18 comprises the "Guidelines for the formulation of policies for sustainable development and management of pine forest areas and biodiversity conservation". This policy allows only research undertakings to be conducted in the natural pine forests. Although DAO No. 95-18 allows timber extraction, it is limited for purposes of research. In effect, the policy has totally restricted, on a countrywide basis, the cutting of pine trees in the natural pine forests.

Future trends

Land use change patterns in the last century manifest the rapid conversion of forestlands into other non-forest uses in most Southeast Asian countries. This is coupled with the exponential increase in population both in the lowlands and uplands, which consequently exerts additional pressure on the remaining resources, particularly the genetic resources, which hang on precariously. Demand for pinewood is expected to remain significant in the wood market in the Southeast Asian region.

Genetic variation within *P. kesiya* and *P. merkusii*

Mirov (1967), in his classic treatise of the genus *Pinus*, noted that pines generally exhibit genetic variability even among trees belonging to the same species. Field trials have been extensively used in the characterization of the genetic variation within the two tropical *Pinus* species. As early as the 1970s, interest has been focused on the conduct of provenance trials for both tropical pine species. Such endeavors had taken the form of biosystematic and genecological studies that were undertaken through regional cooperation involving countries in the tropics where native habitats of the two pine species are found (Burley 1976). Specifically, the early trials were done to determine optimum sources of seeds and propagules for the establishment in plantation of the pine species in the various locations within the tropics.

P. kesiya

With regard to the Benguet pine seed collection done in the Philippines in 1969, Turnbull (1972) reported the probable occurrence of racial variations in the isolated stands of the Zambales and Caraballo Mountains. Some manifestations of these genetic variabilities, for instance, could be observed in the uneven growth rate among members of the same species, as well as in differing capacities to resist drought among those growing in either high or low altitude stands in the Central Cordillera Mountains.

Evidences of difference in growth rate and straightness of stem due to origin of the species *P. kesiya* were also affirmed by Keiding (1972). Great variation within and between trees in their floral phenology has been mentioned by Burley (1976) as a common feature of many tropical pines. This observation is especially true for *P. kesiya*.

Foremost among the studies conducted was the international provenance trial established under the guidance of Oxford and FAO which includes no less than 19 provenances or seed

lots from the Philippines (Burley and Burrows 1972; Turnbull and Burley 1972; Keiding 1972.)

In the Philippines, investigations on the genetic variation of the species were started by Maun (1976). Then in 1978, Padolina studied 15 provenances that included one coming from Thailand. The study included the following sources as listed in Table 2 below:

Table 2. *Pinus kesiya* Royle ex Gordon provenance trial; provenance location data (Orallo, 1981).

ORIGIN	PHYSICAL DESCRIPTION		
	Latitude	Longitude	Elevation (m)
1. Piddig, Ilocos Norte	18°12'	120°51'	946
2. Nueva Era, Ilocos Norte	17°53'	120°43'	1159
3. Malibcong, Abra	17°45'	120°57'	1372
4. Sagada, Mt. Province	17°04'	120°54'	1678
5. Cervantes, Ilocos Sur	16°57'	120°39'	1494
6. Mt. Data, Mt. Province	16°52'	120°44'	2226
7. Kabayan, Benguet	16°34'	120°49'	1464
8. Atok, Benguet	16°32'	120°42'	1616
9. Bobok, Bokod, Benguet	16°26'	120°49'	1464
10. Baguio City	16°25'	120°36'	1372
11. Kayapa, Nueva Vizcaya	16°24'	120°53'	1494
12. San Nicolas, Pangasinan	16°05'	120°49'	1098
13. Carranglan, Nueva Ecija	16°03'	121°07'	1190
14. Candelaria, Zambales	15°38'	120°08'	946
15. Mae-Rid, Chiang mai, Thailand	18°10'	98°50'	1190

The said study investigated the following parameters and the kinds of variations among them were also noted.

1. Cone length – highly significant variation among provenances
2. Cone diameter – significant variation
3. Seed yield per cone - significant variation
4. Seed weight – highly significant variation
5. Per cent germination – highly significant variation
6. Hypocotyl length – highly significant
7. Seedling height – highly significant
8. Root collar diameter – significant variation
9. Root length – significant variation
10. Shoot-root length ratio – highly significant
11. Shoot-root weight ratio – no variation
12. Shoot weight – significant variation
13. Root weight – highly significant

The same set of provenances was investigated by Orallo in 1981 using the same established provenance trials. This time the parameters studied were the following:

1. seedling height growth
2. seedling survival in the nursery
3. diameter growth in plantation
4. height growth in plantation
5. diameter/height growth ration in plantation

Table 3 summarizes the important results of the investigation by Orallo (1981).

Table 3. Summary of the provenance means on height, diameter/height ratio and survival of Benguet pine (*Pinus kesiya*) trees two years in a plantation in Baguio City, Philippines (Orallo, 1981).

PROVENANCE		PERFORMANCES				
		Height (cm)	% survival	Height (cm)	Diameter (cm)	Dia/Ht Ratio
1. Baguio City		23.52^{ab}	87.67^{ab}	145.46^{a}	34.75^{a}	4.60^{a}
2. Kayapa, Nueva Vizcaya		26.06^{a}	93.33^{a}	142.20^{a}	34.46^{a}	4.36^{a}
3. Carranglan, Nueva Ecija		23.67^{ab}	70.99^{ab}	135.79^{ab}	36.05^{a}	3.83^{b}
4. Malibcong, Abra		23.51^{ab}	76.67^{ab}	135.67^{ab}	31.37^{a}	4.50^{a}
5. Piddig, Ilocos Norte		22.35^{ab}	76.67^{ab}	135.12^{ab}	35.82^{a}	4.10^{ab}
6. Sagada, Mt. Province		23.52^{ab}	85.00^{ab}	133.72^{ab}	31.25^{a}	4.53^{a}
7. Candelaria, Zambales		22.42^{ab}	85.00^{ab}	131.34^{ab}	36.06^{a}	3.92^{ab}
8. Nueva Era, Ilocos Norte		23.45^{ab}	76.67^{ab}	129.00^{ab}	33.10^{a}	4.08^{ab}
9. Atok, Benguet		24.29^{ab}	66.67^{ab}	127.27^{ab}	30.40^{a}	4.50^{a}
10. San Nicolas, Pangasinan		18.98^{b}	80.00^{ab}	123.58^{ab}	32.28^{a}	4.08^{ab}
11. Bobok, Bokod, Benguet		26.12^{a}	69.99^{b}	123.48^{ab}	32.13^{a}	4.31^{a}
12. Cervantes, Ilocos Sur		23.05^{ab}	71.67^{b}	117.86^{ab}	28.01^{a}	4.44^{a}
13. Kabayan, Benguet		25.01^{a}	68.33^{b}	111.71^{ab}	30.49^{a}	3.99^{ab}
14. Thailand		24.29^{ab}	78.33^{a}	102.50^{b}	33.88^{a}	3.26^{b}

Note: Means followed by the same letter in a column are not significantly different.

Costales (1983) also looked into the variations of some wood characteristics of eight provenances of the species in the Philippines. Sources investigated included the following (Table 4).

The extent of variations among the provenances studied can be seen in the following table (Table 5).

Lastly, Manit (1982) looked at variations in terms of foxtailing on a number of provenances of *P. kesiya* established in the Province of Bukidnon, south of the Philippines. The sources of the different provenances are shown in Table 6.

Table 4. Provenances of *P. kesiya* for investigation of wood characteristics.

PROVENANCE	SITE DESCRIPTION			
	Latitude	**Longitude**	**Elevation**	**Rainfall**
Coto Mines, Zambales (SC 59)	15°32'	120°06'	700-1200	3845.49
Mt. Banben, Carranglan, Nueva Ecija (SC 108)	15°58'	121°05'	400-1200	3305.30
San Nicolas, Pangasinan (SC 109)	16°09'	120°48'	800-950	1767.33
Bobok, Kayapa, Nueva Vizcaya (SC 110)	16°19'	120°51'	1200-1500	1606.30
Bobok, Kabayan, Benguet (SC 111)	16°38'	120°52'	2100-2200	1864.36
Mt. Data, Mt. Province (SC 112)	16°54'	120°55'	1400-1550	2958.85
Lagangilang, Abra (SC 113)	17°33'	120°57'	1250-1350	3228.34
Nueva Era, Ilocos Norte (SC 114)	17°53'	120°44'	800-1000	2358.14

Table 5. Variations among the eight provenances studied by Costales (1983).

PROVENANCE	DBH	Inter-nodal Length	Needle Length	No. of Branch Whorls	No. of Branch per Whorl	Specific Gravity	Tracheid Length
Coto Mines, Zambales (SC 59)	14.87ab	41.11a	16.73a	5.05ab	2.50ab	0.4032a	2.32b
Mt. Banben, Carranglan, Nueva Ecija (SC 108)	14.93ab	37.05a	16.12a	2.20ab	2.94a	0.4091a	2.60ab
San Nicolas, Pangasinan (SC 109)	15.15ab	35.54a	16.28a	5.15ab	2.22b	0.4482a	2.66ab
Bobok, Kayapa, Nueva Vizcaya (SC 110)	15.02ab	38.63a	16.77a	5.52a	2.48ab	0.3945a	2.75a
Bobok, Kabayan, Benguet (SC 111)	12.33b	40.04a	16.13a	4.38b	2.97a	0.3787a	2.72a
Mt. Data, Mt. Province (SC 112)	13.87ab	35.93a	16.89a	4.79ab	2.37ab	0.3983a	2.76a
Lagangilang, Abra (SC 113)	16.11a	34.24a	15.76a	5.48a	2.28b	0.4072a	2.66ab
Nueva Era, Ilocos Norte (SC 114)	14.72ab	38.84a	15.82a	5.28ab	2.54ab		2.72a

Note: Means followed by the same letter in a column are not significantly different.

Table 6. Location and description of provenances sampled in Manit's study (1982).

Provenance		Latitude	Longitude	Elevation (m)	Rainfall (mm)
Code	Location				
59	Coto Mines, Zambales	15°32'	120°32'	700-1200	3825.49
108	Mt. Banben, Carranglan	15°58'	121°05'	400-1200	3305.30
109	San Nicolas, Pangasinan	16°09'	120°48'	800-950	1767.33
110	Bobok, Kayapa, Nueva. Vizcaya	16°19'	120°51'	1200-1500	1606.30
111	Bobok, Kabayan, Benguet	16°38'	120°42'	2100-2200	1864.36
112	Mt. Data, Benguet	16°33'	120°54'	1400-1550	2958.85
113	Lagangilang, Abra	16°33'	120°57'	1250-1350	3228.34
114	Nueva Era, Ilocos Norte	17°53'	120°44'	800-1000	2358.14
115	Lammin, Ilocos Sur	18°17'	120°54'	1100-1320	2294.13

The trials revealed significant variations among provenances in terms of % foxtailing, height and specific gravity. Branch whorls, length of foxtails and tracheid length, however, did not show any significant variation among the provenances studied. The trials showed the consistent high ranking of the Coto Mines provenance which had the least foxtails, highest specific gravity and considerable rate of growth.

The results of the provenance studies reported in the Philippines, particularly for the Philippine provenances, provide important baseline information that will be useful for the formulation of a genetic conservation strategy for the two native pine species. The results of the provenance trials will be used as inputs in delineating seed zones of *P. kesiya* within the country. This is valuable to decision making pertinent to seed sourcing for large-scale operational planting of pines in various areas around the country where conditions may prove suitable for the species' growth.

Thailand

The provenance trials of *P. kesiya* in the country started in 1971 at the Huey Bong Experiment Area in Hod District, Chiang Mai province. The study included 18 provenances: 7 from Thailand, 6 from the Philippines, 4 from Zambia, and one from Malawi. The trial was established in a randomized complete block design with 4 replications and consisted of 6 x 6 meters tree plots with individual trees spaced at 3 x 3 meters. An isolation row of the species was established around the experimental plantations to serve as buffer strip. At the age of 25 years, in 1996, the first performance evaluation was conducted. Results indicated that 3 provenances from Northern Thailand (Doi Inthanon, Baw Luang, and Doi Suthep all in Chiang Mai) had the highest growth rates. In terms of relative height, relative DBH growth rates, relative arc sin survival (transformed data), and relative importance value index (RIVI), the four provenances from Thailand (including the provenance of Nam Now, Petchabun) exhibited the best performances. Their RIVI rates were 5.94, 5.93, 5.90 and 5.84% respectively. The Philippine provenance from Kabayan, Benguet had the lowest RIVI of 4.75% among all provenances (Tongpradith *et al.*, undated).

Vietnam

Provenance trials of the species have been done in Vietnam, one in Dai Lai, Vinh Phuc Province and the other in Lang Hanh, Lam Dong Province, south Vietnam and Ba Vi, Ha Tay Province, North Vietnam (Phi Quang Dien, 1989, 1997). Tables 7 and 8 show the results of these trials.

Table 7. Results of provenance trials in Dai Lai, Vinh Phuc Province.

Provenance	**Dai Lai, 1976 (10 years old)**			**Dai Lai, 1977 (9years old)**		
	Diameter (cm)	Height (m)	Volume (m^3)	Diameter (cm)	Height (m)	Volume (m^3)
Zambia	12.9	8.49	0.0687	11.1	7.96	0.0422
Philippines	12.0	8.70	0.0499	10.2	7.22	0.0418
Hoang Su Phi	12.7	9.10	0.0588	10.6	8.49	0.0407
Da Lat, Lam dong	11.5	8.37	0.0488	9.2	6.85	0.0310

It was noted that for North Vietnam, the Zambia and Hoang Su Phi provenances were the most promising.

Table 8. Results of provenance trials in Lang Hanh and Ba Vi.

Provenance	**Lang Hanh, 1991-1998**			**Ba Vi, 1993 - 1998**		
	Diameter (cm)	Height (m)	Volume (dm^3)	Diameter (cm)	Height (m)	Volume (dm^3)
Benguet, Philippines	13.9	8.1	64	9.3	4.4	21
Tarlac, Philippines	15.0	7.6	70	11.0	5.0	29
Coto Mines, Philippines	14.7	7.9	74	10.0	4.1	22
Xuan Tho, Vietnam	14.9	7.2	68	11.2	4.5	28
Prenn Waterfall, Vietnam	14.9	8.9	78	10.3	4.4	25
Lang Hanh, Vietnam	15.1	8.4	76	10.7	4.6	27
Nong Krating, Vietnam	15.4	8.2	80	9.9	4.1	22
Doi Suthep, Thailand	15.9	8.3	85	11.2	4.6	28
Doi Inthanon, Thailand	13.3	6.9	53	11.0	4.6	28
Phu Kradung, Thailand	13.7	6.9	55	10.5	4.3	25
Nam Now, Thailand	13.7	6.7	55	11.1	4.6	28
Wat Chan, Thailand	14.2	7.3	61	10.7	4.4	25
Simao, China	15.3	8.8	78	11.1	4.9	29
Jingdung Arb, China	12.6	7.8	61	10.4	4.1	24
Zokhua, Myanmar	11.3	8.2	68	10.0	3.5	20
Aungban, Myanmar	14.4	8.2	67	9.5	3.8	20

The soil in Lang Hanh is basaltic, and the trial plantations were established in 1000 m asl in 1991. On the other hand, the soil in Ba Vi is ferralitic and the trial plantations were planted in 1993 at 600 m asl elevation.

For the two trial sites, the Simao and the Tarlac provenances were considered as the most promising provenances for Ba Vi, while for Lang Hanh, provenances identified as most promising were those from Doi Suthep and Prenn Waterfall. It should be noted that the Simao provenance is located near the Hoang Phi provenance, a popular provenance from North Vietnam as shown in the Dai Lai Provenance Trials.

Pinus merkusii

Vietnam

Trials consisting of provenances from Vietnam were established in Dong Ha, Central Vietnam in 1982. Phi Quang Dien (1989) reported the following results (Table 9.)

Table 9. Performance of *P. merkusii* provenances from Vietnam in Dongha, Central Vietnam in 1982.

Provenance	Seed Source Description			Performance	
	Latitude	Longitude	Altitude	Diameter (cm)	Height (m)
Ha Trung	20°20	105°55	20-50	6.8	2.9
Hoang Mai	19°20	105°35	50	6.7	2.9
Ria	20°30	105°55	20-50	6.5	2.8
Nam Dan	18°45	106°30	100	6.5	2.7
Bo trach	17°45	106°25	50-70	6.1	2.5
Hue	16°35	107°35	50	6.4	2.6

Growth of all provenances was observed to be slow.

Philippines

There are no reported provenance trials on *P. merkusii* in the country.

Thailand

A provenance trial of *P. merkusii* was established in 1971 at the Huey Bong Experimental and Gene Conservation Station in Northern Thailand. Eight provenances listed in Table 10 were included in the trial.

Table 10. Seed sources of *P. merkusii* represented in a provenance trial at Huey Bong Experimental and Gene Conservation Station, Northern Thailand (Hansen 1999 as cited in DFSC 2000).

Seed lot	**Location**	**Latitude**	**Longitude**	**Altitude (masl)**
1005	Khao Maa Lai, Tha Yang, Petchaburi	12°45 N	99°15 E	30
1008	Phu Kradeung, Loei	16°51 N	101°47 E	1300
1012	Khun Yuam, Mae Hong Son	18°50 N	97°47 E	600
1014	Mae Tha, Lamphun	18°21 N	99°20 E	800
1015	Fang, Chiang mai	19°52 N	99°15 E	5-600
1018	Hod, Chiang mai	18°04 N	98°10 E	1100
1019	Non Khu, Surin	14°43 N	103°50 E	180
1020	Huey Tha, Si Sa Ket	14°50 N	104°32 E	150

The Si Sa Ket provenance followed by the Surin provenance performed the best in the trials with the eastern lowland provenances showing significantly higher wood production than all the rest (DFSC 2000).

In Thailand, investigations on genetic variations among natural populations of P. merkusii were not limited to provenance trials in the field alone. An attempt was made by Changtragoon and Finkeldey (1995) to determine the existing genetic variations in 11 natural populations of the species using DNA markers. This study showed relatively high allelic differentiation and high outcrossing rates between populations. Furthermore, the study noted high selfing rates in some stands which the researchers attributed to scarcity of pollen due to low population density, poor synchronization of flowering, and overmaturity of the sands. These observations led the DFSC (2000) to believe that the different natural populations of the species in Thailand are quite isolated, and the genetic differences arising from such isolation justify the genetic conservation of such populations.

Genecological zonation of *P. kesiya* and *P. merkusii*

Populations of trees to be conserved are usually identified based on a knowledge of their genecological zonations. A genecological zone is a contiguous area where the species is known to be growing, where ecological conditions are more or less uniform and where there is no or limited gene flow from surrounding areas (DFSC 2000). A genecological zone is part of a seed zone, which is a group of areas having similar ecological conditions but do not necessarily form a contiguous area. Graudal *et al*. (1997) presented a more detailed discussion on the establishment of genecological zones.

Between the two species, *P. merkusii* has been the subject of a more detailed genecological zoning, which was initiated in Thailand. The identification of the genecological zones of the species in the country took off from the seed zones that were earlier developed for the species by Eis (1986) based on terrain, soil properties, climate, and existing vegetation. Results of provenance trial earlier mentioned were also used to support the genecological zones identified. In this manner, eight genecological zones were suggested (DFSC 2000) as shown in Table 11.

Table 11. Suggested genecological zones of *P. merkusii* in Thailand (DFSC 2000).

Genecological Zone	Location/Description
1	Slopes and ridges of Khao Son and Kaho Maa Lai at around 400 m asl around the Kaeng Krachan Dam. Southernmost limit is at Paa Chum Chon at 70 meters asl near the eastern coast of Cha-am District, Petchaburi.
2	Phu Toei National Park
3	Divided into three subzones. Subzone 3a is equivalent to the northernmost part of Eis' Seed zone 6, found at 430-450 m asl. Subzones 3b abd 3c are within Eis' seed zone 4. Subzone 3b includes the stands in the Omkoi plateau at 850-1080 m asl while subzone 3c forms the isolated stand at Doi Phra Luang plateau at 700 m asl.

Genecological Zone	Location/Description
4	Area encompasses Khun Yuam within the Mae Surin National Park, which is at 600 m asl.
5	Includes Ban Wat Chan, which is considered to be the third largest stand of *P. merkusii* in Thailand.
6	The populations are found within the Province of Nan near the border with Lao PDR. These are within the Doi Phu Kha National Park in Doi Phu Kha and another in Doi Phu Huat
7	Equivalent to Eis' seed zone 10 divided into two subzones of Phitsanulok (zone 7a) and Loei and Petchaburi (zone 7b). Specifically two stands are in zone 7a, Thung Salaeng Luang within the national park of the same same and Thung Nang. Zone 7b includes stands at Phu Kradeung, Phu Rua National Park and Phu Kieo and Phu Luang Wildlife Reserves.
8	Composed of the easternmost lowland stands near the border with Lao PDR and Cambodia and is equivalent to Eis' seed zone 14 and easternmost part of seed zone 12. Includes the stands at Non Khu, Khong Chiam and Kantharome (Si Sa Ket), Po Sai and Dong Na Than as well as the stand found at Buntharik.

These genecological zonations were supported by the multivariate analysis of the quantitative traits of the species as done by Hansen in 1999.

In the Philippines, while no attempt has been made on the genecological zoning of *P. merkusii*, it can be suggested that the two known populations located in the Island of Mindoro and the Zambales Mountain Range in the western coast of the Island of Luzon may constitute two different zones. Mirov (1967) reported that the species was growing on the northwestern part of the island of Mindoro which comprised, at that time, of scattered stands along the ridges and slopes of Mt. Halcon at about 300 m asl. At the southern part of the species range in the island it has been observed to be growing at altitudes of 60 m asl and possibly even lower than this. However, on the northern limit Mirov (1967) claims that the pine could be found at elevations not lower than 900 m asl.

The other population, as observed by Mirov (1967), can be grouped into three separate stands in the Municipalities of Candelaria, Masinloc and Palauig. The pine trees in the Zambales Mountains were observed at elevations between 150 and 300 m asl with some scattered trees at elevations between 90 to 100 m asl.

Identification of populations to be conserved and conservation measures to be applied

Pinus kesiya

Philippines

Five sites were initially identified for genetic resource conservation for *P. kesiya* (Appendix Table 1). The most northwestern population is the one in Lammin, Ilocos Norte. This population could be similar with the population in Abra, another northwestern province in Luzon. The southern populations are those in Coto Mines, Zambales in the western fringe and Kayapa, Nueva Vizcaya province in the eastern fringe. The Zambales population is a unique population being the lone stand in the western part of Luzon. The Kayapa population could be similar to the other populations in the southeastern range of the species, e.g. Nueva Ecija and Pangasinan. For the central zone, two populations were identified for conservation, the one in Cabunagan, Mt. Province and Club John Hay, Baguio. The Cabunagan population could also represent the Ifugao and Bontoc populations, while the Mt. Province population is represented by the Club John Hay.

As in most parts of the country, the areas are threatened by expansion of upland communities, illegal logging and forest fires. The northern and southern populations are under continuous threats thus protection of these populations are necessary. No active management of the three stands exists (Lammin, Zambales, and Kayapa), thus no accurate and reliable information is currently available. Consequently, information about the remaining trees in the population and their actual hectarage is unknown. Nevertheless, their inclusion as forest genetic resources conservation area is imperative because earlier results of provenance trials showed their excellent performance.

The DENR (Department of Environment and Natural Resources) Administrative Order No. 95-18 provides for the "Guidelines for the formulation of policies for sustainable development and management of pine forest areas and biodiversity conservation". This policy allows only research undertakings to be conducted in the natural pine forests. Although it allows timber extraction, it is limited for purposes of research. In effect the policy has totally restricted the cutting of the tree all over the country in the natural pine forests. The policy is very restrictive when it comes to extraction of the trees from the natural forest, which would highly favour the conservation of the remaining populations of the *P. kesiya*. Plantation grown trees are, therefore, exempt from the timber extraction restriction.

The protection of the Cabunagan population rests on the local government unit (LGU) while the Club John Hay is protected by the Camp John Hay Management Corporation. The other three populations are under the jurisdiction of the local DENR units (Community Environment and Natural Resources Office – CENRO). Of these units, the Camp John Hay Management Corporation has the most available resources for effective management and protection. LGUs are commonly plagued by lack of resources, both manpower and logistics, to protect the environment. In like manner, CENROs are understaffed and do not have specific allocations for genetic resources conservation. While the management

picture appear discouraging, these real situations highlight the need for re-focusing and creating ingenious ways of protecting these remaining populations of *P. kesiya*. Tapping private sectors and environmentally-concerned groups (non-governmental organizations, private corporations/companies) to finance the protection of the remaining populations could be explored. Many companies are enticed and are willing to participate in a "Adopt-a-forest" scheme or in actual tree plantings particularly during their company anniversaries or Arbor Day celebrations. Thus, local forestry officials have to identify the potential partners in their respective places who can complement their meager resources.

In all of the chosen populations, *in situ* conservation is necessary. While natural regeneration is occurring in all of these sites, only the population in Club John Hay could be relied upon for high success rates. Thus, a need to complement *in situ* with *ex situ* conservation is important particularly for the other four populations. For the Cabunagan population, the LGU may opt for a local botanical garden or arboreta. For the three other populations under the CENRO (Lammin, Kayapa and Coto Mines) gene banks proximate to the CENRO office or within its compound is a logical choice. This will lessen protection and management requirements. Creating a network of *in situ* and *ex situ* stands will be advantageous to decrease the chances of losing a population through the various destructive agents identified.

As the number of trees in the three populations (Lammin, Kayapa and Zambales) has not been established, it is recommended that the local CENRO conduct inventories of the remaining trees. It is also expected that the three populations (Lammin, Kayapa and Coto Mines) have fragmented stands, thus there is also a need to identify specifically which stands would be the initial focus of the *in situ* conservation. The possibility of involving local communities in these sites including the Cabunagan area should be explored as these areas are the most prone to encroachment and timber poaching. Identification of upland people's organizations (POs) that could participate in this endeavor should be made. The same POs could be encouraged to plant these populations in their communal forests. As pointed out earlier, *tayan* and *muyong* are indigenous practices employed by indigenous people in Bontoc and Ifugao to conserve trees, which ultimately lead to genetic resources conservation.

Seed collection from these sites should be made. These collected seeds could be stored or raised in the nursery. Medium to long term storage by the local CENROs and LGU is not possible since these units do not have the means to conserve genetic resources through seed storage. Alternatively, support from NGOs or private companies willing to plant these seeds or seedlings should be actively sought.

Fire problems could be addressed by tapping local POs. A small area assigned to them could be arranged to insure that they could adequately manage the site. Expansion to bigger areas could slowly be made when success in the small area have been assured.

Information, education and communication (IEC) programme to promote genetic resources conservation is imperative to increase the level of awareness of the local people on this critical issue of conservation. While conservation, as a whole, is generally promoted, focusing on genetic resources is seldom accomplished as this is usually presumed

accomplished whenever forest conservation is advocated. Concerns with sufficient interbreeding trees in the population are not emphasized. The IEC would also drum up interest in supporting forest genetic conservation for this pine species.

Vietnam

Four main/priority populations have been identified as seed source and conservation stands for the species of which three populations (total of about 1,000 ha) are in Lam Dong province (South) and one population in Ha Giang province (North Vietnam) (Appendix Table 2). Theses populations are in a very good condition. Using communities for conservation of these populations has great potential in Vietnam.

Thailand

An extensive list of potential populations for conservation is presented in Appendix Table 3. Initially, there were 47 sites identified for conservation. As the information is still incomplete, prioritization of the population based on their importance and threats will be made. Likewise, information on the number of trees remaining will be obtained to determine if the population needs to be enriched. Currently, there are two *in situ conservation* stands, the Non Khu, Sangkha, Surin and the Khong Chiam, Ubon Ratchatani and another an *ex situ* conservation stand – Ban Huey Bong, Hod, Chiang Mai.

In terms of the legal status of these potential conservation stands, some are protected forest, national parks, forest reserve, *in situ* or *ex situ* conservation stand, mixed forests, and wildlife reserve. Clearly, some stands lack the appropriate legal measures for continued protection. Once included in the final list of conservation stands, appropriate policies to insure their protection should be enacted. Threats that endanger these stands include: critically low tree density, resin tapping, fires, and shifting cultivation. Villagers in the stand in Ban Wat Chan, Mae Cham, Chiang Mai are actively involved in its conservation. Opportunities for community participation should be explored and intensified.

Pinus merkusii

Philippines

For *P. merkusii*, only two sites are identified for conservation, namely: Paragpagan/Kabilayan Barangay Pinagturilan, Sta. Cruz, Occidental Mindoro and Sta Cruz, Masinloc, Candelaria, Zambales. Obviously, these remaining populations hang precariously as there are only two such populations available. Active and intensive protection programs should be designed to insure that these populations are not threatened by extinction lest they will vanish from the earth's surface. Field surveys to confirm the available trees and stands will be initially made. This will insure that there will be adequate number of interbreeding trees to keep the population intact. Otherwise, enrichment planting will have to be resorted to.

The Mindoro population is within FB Harrison Game Refuge and Bird Sanctuary established under Executive Order # 9 dated Jan. 28, 1920. It is also within Mt. Paragpagan Forest Reserve established under Proclamation # 164 dated Feb. 13, 1967 (Republic Act # 3092). The area adjoins a CBFM (Community-based Forest Management) Project under CENRO (Community Environment and Natural Resources Office) Mamburao Office. Obviously, there is sufficient legal basis to insure the protection of this population. There is sufficient natural regeneration, but the species is threatened by grass fires which also affects the mature trees. Therefore, an efficient fire protection system should be designed to avoid further damage to the stand, particularly the natural regeneration. However, the area is claimed by Mangyans, a group of indigenous people native to the island. As the issue needs to be settled by DENR, it is difficult to prescribe appropriate conservation measures at this point in time. Nevertheless, the presence of this indigenous group could open windows for participatory approach in areas which are not subject to any land dispute or conflicting claims.

For the Zambales population, a different scenario is expected. With a revitalized mining industry in the country, this unique population is at risk. It appears imperative that the mining firm that will be awarded the area should have strict provisions of maintaining specific stands of the species. On the other hand, this is also a positive development considering that the presence of a mining firm provides an opportunity for an entity to assume responsibility in managing and conserving the selected stands. An effective monitoring and evaluation system of the firm's compliance to the provisions of environmental impact should be set in place.

The strategies for conserving this species would have close similarity with that of *P. kesiya*. *In situ* conservation is still recommended particularly for the Mindoro population. The Zambales population will require additional *ex situ* measures to address the threat that would result from the possibility of mining operations in the area. Maintaining a network of *in situ* stands will be the best option for both of these remaining populations.

Thailand

Based on the eight (8) genecological zonation of the Thailand presented in Table 11, the following populations have been suggested for conservation (DFSC, 2000):

Genecological Zone	**Stand Proposed for Conservation**
1	Pa Chumchon Kahoa Son; Khao Maa Lai
2	Phu Toei
3	Mae Sod; Omkoi, Huey Bong; Doi Phra Luang
4	Khun Yuam
5	Ban Wat Chan; another stand could be considered after further surveys
6	Doi Phu Kha
7	Thung Salaeng Luang National Park; Phu Kradeung
8	Non Khu and Khong Chiam; Non Khu and Kantharome (Si Saket)

In all of the above-mentioned stands, *in situ* conservation is proposed. In Zone 1, *ex situ* conservation of Pa Chumchon Khao Son as a complementary measure is recommended. Since the stand in Khao Maa Lai has very limited number of trees (≈10 trees), seed collection for *ex situ* conservation is also recommended.

In Zone 2, protection from fires is necessary to allow natural regeneration. There are more than 3,000 trees that can provide natural regeneration.

Extensive populations of *P. merkusii* are found in Zones 3, 4, 5 and 7. They are not in danger of extinction but are threatened with land conversion and shifting cultivation.

The stands in Zone 8 are in highly threatened since many stands have critically low population sizes. Fire-stick cutting, resin tapping and fires are serious threats that imperil these dwindling stands. Seed collection from Non Khu and Kantharome (Si Sa Ket) is recommended to increase the diminishing population.

DFSC (2000) found that forest conversion and forest fires are the most significant threats to the stands of *P. merkusii* in Thailand. Additionally, indiscriminate gathering of fire-sticks and resin tapping also endanger the stands. The implementation of a revitalized and socially-sensitive community forestry programme could address the important socio-economic issues that endanger the remaining stands of *P. merkusii*.

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Photographs

Natural *P. merkusii* stand in Pinagturilan, Sta. Cruz, Occidental Mindoro, Philippines.

Harvested *P. kesiya* logs for transport to processing mill in Mindanao, Southern Philippines.

P. kesiya forest and plus tree in the in the Cordillera Administrative Region.

P. kesiya introduced as plantation species in Mindanao, Southern Philippines showing excellent performance**.** The species can be planted in association with *Swietenia macrophylla*. However, the trees do not bear viable seeds in this area.

Appendix

Appendix Table 1. Candidate sites for conservation of *Pinus kesiya* in the Philippines.

Municipality/ Barangay	Latitude	Longitude	Elevation (masl)	Regeneration Potential	Population Size (ha/No. of trees)	History of Utilization	Seeding Ability	Legal Status	Threats
1. Cabunagan, Mt. Province	16°34' N	120°44' E	2,000-2,500	Plantation	4.0 170 trees	Seed collection area and watershed cover	Prolific seeders High regeneration potential	Protected by LGU Public Forest Reforestation Project Central Cordillera Forest Reserve (Proc No. 217 dated Feb 16, 1929)	Timber poaching and forest fire; very high
2. Club John Hay, Baguio City	16°26' N	120°36' E	1,200-1,500	Natural	2.0 163 trees	Seed collection area	Prolific seeders High regeneration potential	Protected by Camp John Hay Management Corporation (Proc No. 198 dated June 29, 1993) and LGU	Timber poaching Squatting Forest fire; very low
3. Lammin, Ilocos Norte	18°15' N	120°51' E	1,000-1,100					Public forest land	Timber poaching, squatting, fires
4.Kayapa, Nueva Vizcaya	16°19' N	120°51' E	1,140-1,290					Public forest land	Timber poaching, squatting, fires
5. Coto Mines, Zambales	15°32' N	120°07' E	900-1,100					Public forest land	Timber poaching, squatting, fires

Note: Additional field inventories and verification are required to establish the exact conditions of the stands e.g., the remaining trees in the stand.

Appendix Table 2. Candidate sites for conservation of *Pinus kesiya* in Vietnam.

Municipality/ Barangay	Latitude	Longitude	Elevation (masl)	Regeneration Potential	Population Size (ha/No. of trees)	History of Utilization	Seeding Ability	Legal Status	Threats
1. Hoang Su Phi, Ha Giang	$21^0$45’	$104^0$40’	100						
2. Lang Hanh, Lam Dong	$11^0$37’ N	$108^0$16’ E	1000						
3. Prenn Waterfall, Lam Dong	$11^0$52’ N	$108^0$27’ E	1250						
4. Xuan Tho, Lam Dong	$11^0$55’ N	$108^0$32’ E	1500						

Note: Additional field inventories and verification are required to establish the exact conditions of the stands e.g., the remaining trees in the stand.

Appendix Table 3.Candidate sites for conservation of *Pinus kesiya* in Thailand.

Municipality/ Barangay	Latitude	Longitude	Elevation (masl)	Regeneration Potential	Population Size (ha/No. of trees)	History of Utilization	Seeding Ability	Legal Status	Threats
1. Pha Chum Chon, Tha Yang, Phetchaburi	12º50'	90º47'	70-170		51	Cutting of fire-sticks.		Protected forest	Stand very small and disappearing. Less than 300 trees
2. Khao Maa Lai, Tha Yang, Phetchaburi	12º75'	99º45'	220-250			Resin Tapping			Less than 10 trees. Stand disappearing.
3. Khao Son, Tha Yang, Phetchaburi	12º60'	99º37'	250-400						Resin tapping practiced Stand very small and disappearing.
4. Phu Toei, Daan Chant, Suphan buri	14º59'	99º26'	600	Poor regenearation	200			National Park	May be due to annual fire
5. 20 km east of Mae Sod, Mae Sod , Tak	16º43'	98º49'	450						On gravelly ridges as small groups of almost 30 m tall
6. Phop Phra, Phop	16º23'	98º43'	430-450						*P. merkusii* is found

Municipality/ Barangay Phra, Tak	**Latitude**	**Longitude**	**Elevation (masl)**	**Regeneration Potential**	**Population Size (ha/No. of trees)**	**History of Utilization**	**Seeding Ability**	**Legal Status**	**Threats** on gravelly ridges.
7. Omkoi Plateau, Omkoi, Chiang Mai	17º30' - 17º80'	98º17'-98º35'	850-1080	Good regeneration				Forest reserve, Largest stand in Thailand	
8. Ban Huey Bong, Hod, Chiang Mai	18º10'	98º25'	800					*Ex situ* gene conservation of pines	
9. Baw Luang, Hod, Chiang Mai	18º10'	98º20'	850-950						A few *Pinus merkusii*
10. Doi Phra Luang, Tak	17º27'	99º13'	700						
11. Khun Yuam, Khun Yuam, Mae Hong Son	18º50'	97º56'	600					Reserve Forest, Extensive stand	
12. Rd. Mae Hon Son to Pai, Mae Tha, Lamphun	19º22'	98º24'	500-700			resin tapping		3 stand along road	Intensive Resin Tapping
13. Doi Khun Tan, Mae Tha, Lamphun	18º30'	99º16'	700-950					National Park	
14. Mae Om Long, Hod, Chiang Mai	18º30'	99º25'	1050					Mixed with *P. kesiya*	
15. Mae Win, San Pa Tong, Chiang Mai	18º30'	98º35'	800					Pine-dipterocarp-oak Forest	
16. Huey Tong, San Pa Tong, Chiang Mai	18º30'	98º35'	800					Pine-dipterocarp-oak Forest	
17. Doi Inthanon, Chomtong, Chiang Mai	18º41'	98º27'	1000-1100					National Park, Mixed with *P. kesiya*	

Municipality/ Barangay	Latitude	Longitude	Elevation (masl)	Regeneration Potential	Population Size (ha/No. of trees)	History of Utilization	Seeding Ability	Legal Status	Threats
18. Doi Suthep, Muang, Chiang Mai	18º80'	98º90'	1200					National Park, Pine-dipterocarp-oak forest	
19. Doi Saket, Doi Saket, Chiang Mai	18º85'	99º12'	400						Probably disappeared
20. Samoeng, Samoeng, Chaing Mai	19º00'	98º45'	1100						
21. Khung Lao, Wieng Pa Pao, Chiang Mai	19º02'	99º20'	780						
22. Phayao province	19º04'	99º50'	850						
23. Ban Wat Chan, Mae Cham, Chiang Mai	19º05'	98º18'	900					Third Largest area, Villagers involved in conservation of community forest.	
24.Phrao, Chiang Mai	19º06'	99º01'							
25. Khun Kong, Chiang Dao, Chiang Mai	19º19'	98º49'	1000					Mixed with *P. kesiya*	
26. Nong Kiew, Mae Hong Son	19º00'	98º07'	1100					Mixed with *P. kesiya*	
27. Doi Chiang Dao, Chiang Dao, Chiang Mai	19º25'	98º50'	900-1100					Wildlife reserve	Rare
28. Doi Mae Tae, Chiang Mai	19º32'	98º45'	700					45-52 m tall, dominantes less	

Municipality/ Barangay	Latitude	Longitude	Elevation (masl)	Regeneration Potential	Population Size (ha/No. of trees)	History of Utilization	Seeding Ability	Legal Status	Threats
								than broad-leaves. Second tallest trees in Thailand	
29. Wiang Haeng, Wiang Haeng, Chiang Mai	19º35'	98º39'	1100					Mixed with broad-leaves	
30. Rd. Wiang Haeng to Ban Na Tai, Muang, Chiang Mai	19º44'	98º46'	700						
31. Mae Suey (Suai), Mae Suey, Chiang Rai	19º42'	99º35'	680						
32. Fang, Chiang Mai	19º52'	99º15'	600						
33. Doi Phu Kha, Pua, Nan	19º30'	101º00'	730					National Park	
34. Doi Phu Huat, Nan	18º90'	101º10'	690-930						
35. Thung Nang, Phaya, Phitsanulok	16º33'	100º47'							
36. Thung Salaeng Luang, Lom Sak, Phitsanulok	16º34'	100º47'	700-900					National Park	Annual fire
37. Nam Nao, Lom Kao, Phetchabun	16º40'	101º33'	800					National Park	Shifting cultivtion
38. Phu Kradeung, Phu Kradeung, Loei	16º53'	101º53'	1300	Regeneration impeded by annual fire				National Park	Population no immediate danger of extinction
39. Phu Rua, Loei	17º30'	101º19'	1050-1300					National Park	
40. Phu Kieo,	16º20'	101º40'	850-950					Wildlife Reserve	

Municipality/ Barangay Khon San, Chayapun	**Latitude**	**Longitude**	**Elevation (masl)**	**Regeneration Potential**	**Population Size (ha/No. of trees)**	**History of Utilization**	**Seeding Ability**	**Legal Status**	**Threats**
41. Phu Luang, Loei	17º15'	101º52'	1200					Wildlife Reserve	
42. Non Khu, Sangkha, Surin	14º43'	103º50'	180	Poor regeneration	<1000 trees			*In Situ* conservation stand	
43. Buntharik, Ubon Ratchatani	14º45'	105º25'	140-150			resin tapping			The stand was declining due to resin tapping and encroachment. Population might be extinct
44. Kantharome, Si Sa Ket	14º10'	104º70'	160		<100 trees				Stand declining
45. Khong Chiam, Ubon Ratchatani	15º30'	105º30'	130-160	Poor regeneration due to annual fires	1000 trees	Intensive use of forest by locals.		*In Situ* conservation stand	Stand declining
46. Dong Na Than, Khong Chiam, Ubon Ratchatani	15º60'	105º50'	400-440		<100 trees				
47. Po Sai, Ubon Ratchatani	15º80'	105º30'	130-140		<100 trees			Forest Reserve	

Note: Additional field inventories and verification is required to establish the exact conditions of the stands e.g. the remaining trees in the stand.

Appendix Table 4. Candidate sites for conservation of *Pinus merkusii* in the Philippines.

Municipality/ Barangay	Latitude	Longitude	Elevation (masl)	Regeneration Potential	Population Size (ha)	History of Utilization	Seeding Ability	Legal Status	Threats
Paragpagan/kabilayan Pinagturilan, Sta. Cruz, Occ. Mindoro	13º02'31"N – 13º05'00"N	120º48'45"E - 120º 52'08" E	200-734	Natural	2.4	Watershed cover and Seed collection area	Prolific seeders	Protected by CENRO Mamburao	Forest/grass fire and ancestral domain claims
Sta. Cruz, Masinloc, Candelaria, Zambales				Natural	5,000 ha	Mining		Timberland	Undisturbed but with mining claims