International Series of Provenance Trials of Pinus kesiya

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International Series of Provenance Trials of *Pinus kesiya*

Field Assessment Manual

by

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Results and Documentation No. 16

Danida Forest Seed Centre

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Danida Forest Seed Centre (DFSC) is a Danish non-profit institute which has been working with development and transfer of know-how in management of tree genetic resources since 1969. The development objective of DFSC is to contribute to improve the benefits of growing trees for the well-being of people in developing countries. DFSC's programme is financed by the Danish International Development Assistance (Danida).

Preface

This report describes the methodology used in the field assessment of the international series of provenance trials of *Pinus kesiya*.

The report can be read as a background note for the analysis reports of the individual trials, which are also published in the present publication series from Danida Forest Seed Centre. Furthermore, it is hoped that the report can serve as a source of inspiration for those involved in planning and implementation of field assessment of provenance trials.

Humlebaek, August 2003
The authors.

Contents

Abbreviations

CAMCORE	Central America and Mexico Coniferous Resources Cooperative, USA
CIEF	Centro de Investigaciones y Experiencias Forestales, Argentina
CSIRO	Commonwealth Scientific and Industrial Research Organization, Australia
Danida	Danish International Development Assistance
DFSC	Danida Forest Seed Centre, Humlebæk, Denmark
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária, Petrolona, Pernambuca, Brazil
FAO	Food and Agriculture Organization of the United Nations, Rome, Italy
ICFRE	Indian Council of Forestry Research and Education, Dehra Dun, India
IF	Instituto Florestal, São Paulo, Brazil
IPEF	Instituto de Pesquiasa e Estudos Florestais, Piracicaba, Brazil
OFI	Oxford Forestry Institute, United Kingdom
RFD	Royal Forest Department, Thailand

1. *Pinus kesiya*

The *Pinus kesiya* complex is widely distributed between 30°N and 12°N in South East Asia. It occurs in Burma, India, Tibet, Laos, Vietnam, Thailand, the Philippines and the People's Republic of China. It has a scattered distribution pattern suggesting a high degree of ecotypic variation. The taxonomic relationships between several three needled pines occurring in South East Asia (including *P. kesiya* and *P. yunnanensis*) are unsettled (Armitage and Burley 1980). Although there is good botanical and biochemical evidence of regarding the complex as elements of a single species, *P. kesiya*, the species (notably *P. kesiya* and *P. yunnanensis*) will be referred to as separate species in this context in order to minimise confusion.

Pinus kesiya is a conifer species for plantation programmes in the tropical zone. It grows best at medium to high rainfall and at medium altitudes (600-1800 m.a.s.l.). At lower altitudes it is superseded by *Pinus caribaea/oocarpa* and at higher altitudes it gives way for various sub-tropical pines, which are less frost sensitive, e.g. *Pinus patula* (Armitage and Burley 1980). It is fast growing, has the capacity to adapt to various growing conditions (high plasticity), is long living and produces a high quality, long-fibered pulp.

Poor stem form and branching characteristics have militated against the acceptance of *P. kesiya* as a plantation species (Armitage and Burley 1980). Stem defects as basal sweep, butt sweep, sinuosity, crookedness, nodal swelling, multiple stems commonly occur, as do whorls of heavy persistent branches and long internodes (Burley and Wood 1976). Like other fast growing tropical and subtropical pines it has a large juvenile core with less desirable characteristics such as lower density and tracheid length. On favourable sites fast growth may result in total tree collapse (flops) (Armitage and Burley 1980). In addition, the species is sensitive to even the slightest reduction of access to light.

2. Background

Due to the distribution pattern of the species, development of divergent local races is likely, and has also been shown in a number of studies. The first research on inter-population differences was undertaken in Zambia in the late 50's. The material tested included provenances from the Philippines, Vietnam and Assam. A comprehensive review of these studies is given in Armitage and Burley (1980).

During 1969, FAO and the Forest Research Institute of Australia sponsored seed collections of 19 seed sources of *Pinus kesiya* from the Philippines (17 provenance collections and 2 commercial seed lots). The material was complemented by two Zambian landraces (of Philippine and Vietnamese origin, respectively). These collections were used to establish provenance trials in a large number of countries for which the Commonwealth Forestry Institute supplied advice and assisted in data processing and interpretation (Burley and Wood 1976). Results from individual trials were reviewed by Gibson and Barnes (1984) who concluded that neither provenance representation, nor test site representation warranted an international evaluation. It was recommended that a more comprehensive exploration and analysis of the genetic variation of *P. kesiya* should be undertaken. Recommendations in this regard were also put forward by the Sixth Session of the FAO Panel of Experts on Forest Gene Resources (FAO 1988).

Exploration of provenance variation and collection of seed for field trials took place in the late 1980s in collaboration between national institutions in Brazil, Myanmar, China, Madagascar, Philippines, Thailand, Vietnam, Zambia, Zimbabwe, and Oxford Forestry Institute (OFI) and Danida Forest Seed Centre (DFSC). In 1988, seed collections were complete and distribution to collaborating countries could begin (Barnes and Keiding 1989). Distribution of seed was coordinated by OFI and handled by DFSC. During 1989-93, seed of 42 provenances and landraces from the above 9 countries was distributed to 20 institutions in 19 countries. Some of the seed lots were separated by family to allow progeny testing. The overall objectives of the international series of provenance trials of *P. kesiya* were to explore and analyse the genetic variation among provenances of *P. kesiya*, and to identify superior seed sources for the benefit of planting programmes.

Some 30 trials have been established in 17 countries. Trials in Argentina, Brazil, Colombia, the Republic of South Africa, Indonesia, Swaziland, Vietnam and Zimbabwe are reported with high survival and are in general in good condition. The status of trials in Burundi, India, Rwanda, Sri Lanka is uncertain as no information has been received from these countries. The trials established in Fiji, Kenya, Nepal, the Philippines and Thailand have suffered from fire damage, drought and have been abandoned.

In a circular letter sent out by OFI and DFSC in 1996, all host institutes were asked about their interest in undertaking a joint evaluation and were at the same time asked about the status of the trials (DFSC 1996 and Annex 1).

Positive responses in regard to the proposal of undertaking a joint assessment and analysis of trials have been received from all countries where existence of trials has been confirmed. The number, distribution and representation of provenances in these trials are considered sufficient to justify an assessment and analysis of the international series. Of special interest is the possibility of an in-depth analysis of provenance x site interactions which is possible due to the repetition of the same set of provenances in a number of trials.

3. Data collection

Information and data to be collected or assessed as part of the field work can be grouped in four categories:

1. Description of the site;
2. Description of trial;
3. Description of the seed sources included in the trial;
4. Assessment of characters on individual trees.

3.1 Description of the site

The description of the site should include a general site description plus a number of maps. Annex 3 presents a proposed site description format. The site registration should rely on the best possible sources of information. All sources should be cross-checked wherever possible. Some categories of information may be easier to locate centrally than locally (e.g. meteorological data). The purpose of the site description is to facilitate analysis and comparison of provenances over different trial sites. Patterns of variation can be analysed and compared with site conditions, and based on such analysis, it may be possible to identify specific trial regions (provenance regions, seed zones or 'macro sites').

To complement the general soil description, one soil sample will be taken in each trial with the use of a bucket auger to a maximum depth of 1.25 m. Samples are to be placed in plastic containers and labelled and analysed at an authorised soil laboratory**.**

The following maps should be included with the site description:

1. a location map showing the relative position of the site to towns, main roads and other characteristic landmarks in a scale from 1:100 000 to 1: 1 000 000;
2. a map showing in detail how to access the trial, usually in scale 1: 50 000 to 1: 100 000;
3. a detailed map of the layout of the trial with blocks and provenances marked. This map should show the location of each provenance within the blocks, and could also include information on the planting space and the date of planting, a description of the demarcation used for blocks and plots, border lines as well as surrounding vegetation and landscape features. Finally,
4. an environmental map showing the layout of the trial in relation to environmental variation would be useful. This could include either contours or a three-dimensional drawing.

3.2 Description of trial

It is proposed that in addition to the site description form mentioned above, a stand registration form is completed for each trial. A proposed format is given in Annex 4. The trial description records key information on the trial, its establishment, treatment and silviculture. The trial description should also include observations on the protection status of the trial and any other observations on the trial, the provenances and the management which might be of relevance to the assessment and later analysis.

3.3 Seed source description

Detailed information on seed sources is available from the original seed collection reports, which are held by the various institutes who collected, stored and distributed the seed. Seed source descriptions will be collected and summarised by DFSC as part of the evaluation program with the objective of establishing a common seed source register. A proposed standard format for seed source descriptions is attached as Annex 6.

A brief overview of the seed sources/provenances included in the international series is given in Annex 2 together with summary information on the individual seed lots.

3.4 Assessment of traits on individual trees

Data collection in the trials requires: (i) Precise registration of trees, plots, and blocks; (ii) Identification and selection of characters to be assessed and methods for their assessment, including preparation of data registration forms (see Chapter 4 and Chapter 5; and (iii) Organisation of the assessment and data collection (Chapter 6).

Data will be recorded on individual tree basis. In order to be able to link trees and recorded data, a system to register the position of trees in the plot should be applied. A possible system is illustrated in Figure 1, but other options, e.g. using a system of coordinates, could also be considered. It is, however, important to carefully describe the numbering system in the assessment report and to indicate field orientation (North arrow). Dead and missing trees should be numbered as well.

1	**2**	**3**	**4**	**5**
6	**7**	**8**	**9**	**10**
11	**12**	**13**	**14**	**15**
16	**17**	**18**	**19**	**20**
21	**22**	**23**	**24**	**25**

↑
North

Figure 1. An example of a numbering system of trees within a plot, here a plot with 25 trees.

4. Selection of characters for assessment

In selecting characters/traits to be included in field assessment and later analysis, priorities are required as many characters are of potential interest but cannot all be included as the assessment and analysis are constrained by time and financial resources available.

The characters to be included in the assessment have to fulfill a number of requirements, including: (i) they should be of high relevance to the overall objectives of the assessment and - as a consequence - reflect the use of the species in the countries; (ii) they should be of economic importance; (iii) they should be easy to assess; and (iv) they should preferable have - or be expected to have - high heritability.

The overall objective of the assessment is - as stated earlier - to examine any statistical significant differences between provenances/seed lots in respect to adaptability, growth and wood quality. The grouping of characters in adaptability, growth and wood quality traits will be followed in the below discussion and identification of characters to be assessed.

4.1 Adaptability

Adaptability characters should have a prominent role in the assessment program due to the important role of testing the general suitability/adaptability of the different provenances at various sites. Recommendations of provenances for use in planting programmes should rest on a detailed investigation of the adaptability of the material.

It is proposed that assessment of adaptability characters includes field assessment of survival, health status, social status, foxtailing tendency and reproductive capacity (flowering and fruiting), where only the four latter will be assessed in the trials. Survival can be calculated from the health status assessments (the ratio of missing and dead trees to total number of trees).

4.2 Growth characters

Growth traits will be given high emphasis in the assessment due to the importance of volume production on the economic value of *P. kesiya*. Assessment of growth will encompass measurement of diameter and height of all trees. From these data the standing volume can be calculated with the use of standard form factor tables for *P. kesiya*.

Growth characters normally have lower heritabilities compared with e.g. wood quality traits (see below), but given the important economic role of volume production, assessment of growth characters will be given a prominent role in the assessment program.

Height and diameter are normally highly correlated in even-aged, even-spaced stands and based on this assumption, it could be considered to exclude height assessment and concentrate on measurement of diameters, which is faster and therefore more cost-efficient. It is, however, proposed to include both diameter and height in the assessment in order to make a more precise assessment of the growth potential (volume production). Secondly, this will also facilitate comparison of height measurements with standard growth and yield tables for *P. kesiya*. Thirdly, the relatively young age of most trials makes it possible to do cost efficient (and fast) height measurements with a measuring pole, which is also in favour of including height measurements. Finally, the assessment of both growth traits will allow a test of the assumed correlation between diameter and height.

The measurement of height and diameter on all trees is therefore considered well justified.

The measurement of diameter will be used in adjusting the data on branching (see below) for variation in spacing.

4.3 Wood quality

Wood quality characters are of high interest, due to their economic importance and their often high heritabilities. On the other hand, many wood quality traits are difficult and expensive to assess. This is especially true for assessment of wood density which requires destructive sampling (bore holes or wood disc samples) and expensive analysis in a wood laboratory. Assessment of e.g. chemical properties, fibre length and angle, and proportion of juvenile wood will also require destructive sampling.

In the context of the present evaluation program, it has been decided to concentrate on characters easy to assess in the trials and to not engage in destructive sampling. It is proposed that the traits straightness of stem, branching habit, forking, crown length and relative wood density (pilodyn measurements) are included. A detailed description of the assessment methodology will follow in Chapter 5.

A few comments are given below on the traits and their identification.

Branching

Branching habit can be subdivided into a number of underlying traits, including number of whorls, average internode length, number of branches per whorl, and diameter of branches. All are important for the wood quality of *P. kesiya*, and hence of relevance to this study, but at the same time their assessment is time consuming and difficult. In this assessment, it is proposed to concentrate on the assessment of number and position of whorls on the lowest 4 meters of the stem, number of branches in each of the whorls, and diameter of thickest branch in the first whorl.

Wood density
As mentioned above, a detailed assessment of wood density requires destructive sampling and later analysis in a wood laboratory. This makes it a time consuming and expensive exercise. On the other hand wood density is an important trait with a high economic value, and a trait expected to have a high heritability (Zobel and Jackson 1995).

In order to have precise estimates of wood density on individual provenances, a relatively large sample is needed from each provenance. According to Olesen (pers. comm.) approx. 25-30 trees should be sampled from each provenance in order to have reliable results.

In collaboration with the participating institutions, the possibilities and feasibility of undertaking a detailed wood density assessment in one of the trials (i.e. undertaking destructive sampling) will be further investigated and considered. The trial should have a good representation of the provenances in the series. Assessment of wood density (with destructive sampling) should be considered in one trial only, as genotype x environment interaction is assumed to be limited. This assumption is based on e.g. experiences from *Pinus caribaea* trials (Birks and Barnes 1990).

As wood density studies using destructive sampling is still under consideration, and might not be found feasible in any of the trials, it is proposed to undertake pilodyn measurements in all trials in order to have some indication of wood density.

The pilodyn tester has proven useful in obtaining estimates of relative wood density for a number of forest tree species. Satisfactory results have been recorded, especially in regard to ranking of provenances and progenies, by a number of authors, e.g. in Eucalypts (Hoffmeyer 1979), *Pinus radiata* in New Zealand (Cown 1978) and *Pinus elliottii* (Gough and Barnes 1984).

Pilodyn assessments are cost and time efficient. Hansen (2000) elaborates on the use of the pilodyn and refers to recent comparative analysis of pilodyn versus density assessment using destructive sampling. It also gives instructions in the use of the instrument.

Other traits requiring destructive sampling
In addition to specific wood density, also fibre length and fibre angle have been considered for inclusion in the assessment. As for wood density, these traits are of high economic importance but expensive and difficult to assess. High heritabilities are expected. In recent years, the importance of fibre length has decreased due to improved technologies in pulp and paper production. Accordingly, there are no tree improvement programs where fibre length is included (Olesen 1997). Of higher interest is the fibre angle which is a good indicator on skewness and strength. The fibre angle will, however, be highly related to the presence of juvenile wood. As all trials are relatively young, and therefore likely to have a high proportion of juvenile wood at this stage, the relevance of assessment at this point of time is limited. For these reasons, assessment of fibre length and angle are not considered justified, and have been omitted from the assessment programme.

This also holds for assessment of chemical properties. Compared to wood density and fibre angle, their importance is minor for most uses, and the assessment methodology is complicated and expensive.

4.4 Summary of characters

The proposed characters to be included in the field assessment are summarised in the below table. Each character, as well as technical procedures for its assessment, is described in more details in Chapter 5.

Group	Character
Adaptability	Survival
	Health status
	Social status
	Foxtailing
	Flowering and fruiting
Growth	Height
	Diameter (DBH)
Wood quality	Straightness
	Branching
	Crown length
	Forking
	Relative wood density (Pilodyn)

Table 1. Summary of characters proposed for inclusion in the assessment program.

5. Assessment methodology

5.1 Health status

Health status will be assessed using the scoring scale and description standards shown in Table 2 and 3, slightly modified after MacDicken *et al.* 1991 and Wellendorf 1989 (cf. Graudal 1996). All trees in the plot are measured.

Symbol	Interpretation
Part of tree affected	
S	Stems/bark
B	Branches
N	Needles
F	Flowers/cones
R	Root system
W	Whole tree

Type of damage	
N (or blank)	No damage
M	Tree missing
X	Wrong species
I	Damage by insects or fungi
A	Other pest (animal)
D	Nutrient deficiency
H	Human
C	Frost (cold)
F	Fire
S	Water stress (drought)
L	Waterlogging
W	Wind
U	Unknown
O	Other

Table 2. Assessment of health status of single trees. Type of damage and part of tree affected. Adapted from MacDicken *et al.* 1991.

The health scoring system in Table 3 has been used by DFSC at several international assessments (Graudal 1996). The system is used in two steps: firstly by categorizing into one of the three main levels (Level 1 scoring) followed by a second level scoring. The cause of damage should be determined to the extent possible, where help often can be found in the general site and stand description (See Chapter 3 above).

Survival percentages (the ratio between number of remaining trees and originally planted) for plots, blocks and provenances can be calculated using the health status assessments.

Main class	Sub-class: % damaged of affected part	Value	Rohrmoser severity scale
Severe	> 90%	1	Affected plant parts dominate
	70-90%	2	
	60-70%	3	
Medium	50-60%	4	
	40-50%	5	
	30-40%	6	Healthy plant parts dominate the appearance of the plant
Slight	20-30%	7	
	10-20%	8	Symptoms scattered
	< 10%	9	

Table 3. Health score for single trees, scale at two levels, slightly revised after Wellendorf (1989). Compared with Rohrmoser severity scale (here after MacDicken *et al.* 1991).

5.2 Social status

Social status on single trees is assessed using the scoring scale in Table 4.

Symbol/score	Interpretation
Kraft index:	
5	Large dominating tree
3	Average tree
1	Suppressed tree
2 and 4	Intermediate trees
Position:	
B	Border tree
S	Solitary (free-growing) tree
I (or blank)	Tree inside the trial
Crown competition:	
5	Free crown
3	Free top, development of the lateral shoots of the crown restricted
1	Suppressed crown, development of all shoots of the crown restricted
2 and 4	Intermediate trees

Table 4. Scoring scale for social status of single trees. Kraft index after Röhrig 1982.

The registration of social status can be used to refine trial analysis by e.g. excluding suppressed trees from means. It can also be used as weight or co-variable explaining variation and differentiation within provenance.

5.3 Foxtailing

'Foxtailing' is an aberrant growth form, resulting in a branchless segment of up to 12 m of length. Foxtails occur during the juvenile phase of growth, mainly at sites with a less seasonal climate than those of the native environments, i.e. conditions which are conducive to continuous growth. Foxtailing is associated with poor diameter growth, lack of stability in stem and wind damage ('flops') (Armitage and Burley 1980).

The frequency of foxtailing will be assessed by recording all trees with foxtail with an 'F' on the assessment form.

5.4 Flowering and fruiting

Flowering and fruiting of single trees are quantified for each development stage present using the scoring scale in Table 5.

Average no. of flowers or fruits	Score value	No. of flowers or fruits	Corresponding crop rating
0	1	0	None
2	2	1-3	Light
8	3	4-15	
30	4	16-60	Medium
125	5	61-250	
500	6	251-1000	Heavy
2000	7	1001-4000	
8000	8	4001-16000	

Table 5. Wellendorf log score for flowering and fruiting of single trees (Sirikul *et al.* 1991). Compared with crop rating for a stand (a group of trees) according to Barner and Olesen, 1994.

The scoring scale has been constructed by multiplying the number of flowers and fruits with a factor 4 when going from one scoring class to the next (figures rounded to appropriate accuracy). The intervals between the logarithmic values of the classes are equidistant (approximately 0.6) and the score values (1, 2, 3, ...) should in this way be normally distributed enabling the application of standard analysis of variance.

Five development stages should be registered: male strobili, female strobili, conelets, closed cones, and old open cones. Occurrence of flowers or cones on the ground should also be recorded.

Stage and quantity are assessed with binoculars from the ground. Flowers and fruits are investigated more closely by collecting a few samples from the crown of selected trees. The total number of flowers/fruits can be estimated by counting the number on an average flower/fruit bearing branch and multiply by the number of such branches.

It should be noted that the objective of the assessment of flowering/fruiting is not a detailed crop assessment, but an assessment of the flowering/fruiting capacity as an indicator for adaptability.

5.5 Diameter

Diameter at 1.3 m (DBH) is assessed using calliper (two measurements at right angles) or diameter tape. Diameter is to be assessed on all trees in the plot. Measuring point (1.3 m above ground) is marked with chalk on the tree before measurement. Reading in centimetres with one decimal.

When using calliper, attention should be given to secure a random orientation of the calliper in order to eliminate any systematic errors which may occur by measuring using a fixed orientation (e.g. parallel to the row). In case of a whorl at 1.3 m, the diameter is measured as near to 1.3 m as possible without any contribution from the whorl itself. Sometimes the average of two readings, one below and one above the whorl, will provide the best diameter estimate.

5.6 Height

Tree height is defined as the vertical height from the ground to the highest growing point and is to be assessed on all trees in the plot. For trees less than 10 - 12 meters, measurements will be done using a labelled pole or telescopic height measuring rod, whereas measurement of taller trees requires the use of hypsometer or clinometer. Readings will be done in meters with one decimal.

5.7 Straightness

Stemform is assessed according to a scoring scale developed by Lauridsen *et al.* (1987 and 1995), see Table 6. All trees in the plot are to be assessed.

It is important that the assessment team discusses and tests the scoring scale before initiating trial assessment. It is further important to secure that the level does not change during the assessment. This can be secured by returning to selected reference trees at regular intervals (e.g. between blocks) to test and monitor the stem form scorings (cf. Chapter 6).

During the assessment, it is important to observe if any stemform defects can be related to certain damaging factors (e.g. attacks by squirrel or thunderstorms). Such information should be noted in the stand description (re. Chapter 3 and Annex 4) as this will be valuable information for the analysis of the trial results.

Unacceptable	1  Completely crooked tree with several serious to very serious faults	2  Better than 1	3  Better than 2
Fair	4  In principle almost straight stem, 1-2 serious faults (more serious than 5)	5 In principle almost straight stem, 1-2 serious faults	6 In principle almost straight stem, 1-2 more serious faults (less serious than 5)
Straight	7 Straight, with minor faults, also at lower stem	8 Straight, with minor faults at top/middle of stem	9 Straight stem, free of any faults

Table 6. Lauridsen stemform (straightness) scale (Lauridsen *et al.* 1987 and 1995).

5.8 Branching

Branching will be quantified by inclusion of the following traits in the assessment:

- Height above ground of all whorls between 0.5 and 4 meters;
- Number of branches in each of these whorls;
- Diameter of largest branch in lower whorl.

The position of whorls (height of whorl above ground) will be measured with measuring pole/telescopic height measuring rod and readings made in m with one decimal. The branch diameters will be measured in mm using calliper. Attention should be given to not overestimating branch diameter by measuring at the swollen branch base near the stem, but to measure just above this point.

Data will be recorded in the assessment form using a system where the data from each whorl is separated by brackets, e.g. will (1.5; 5; 22) describe a first whorl at 1.5 m, with five branches and a branch diameter of 22 mm.

Dead whorls and branches should be included in the assessment.

5.9 Crown length

Crown length will be estimated as the percentage of the crown of the total tree height. 10 classes are applied; crown length > 90%, 80-90%, ..., < 10%).

5.10 Forking

Forking is an important character, as a high frequency of forks is devastating for the economic value and provenances/families with pronounced forking are therefore to be avoided.

In the context of this assessment, a simple count of forks in the lower part of the main stem (< 8 meters) is proposed. Forked trees will be recorded in the assessment form with an 'F' followed by the number of forks. A fork is defined as a co-leading or previous co-leading top shoot with a maximum height of that of the tree as a whole. Dead forks are described as ramicorns, and recorded with an 'R' in the assessment form.

The position of first fork (height above ground) is assessed using the measuring pool, and recorded in the assessment form.

5.11 Wood density (Pilodyn)

The importance of wood density is discussed in details in Chapter 4. Relative wood density will be measured with pilodyn.

Two pilodyn measurements will be undertaken on each tree. Assessment will be done at DBH (1.3 m) with random positioning of the pilodyn (i.e. no fixed orientation on trees). Knots and knot base wood should be avoided. Test spots are debarked by knife before measurement; in doing so, attention should be given to not hurting the wood surface. Body force will be needed to attach the Pilodyn properly before 'shooting'. In shooting, the pilodyn should be pointing towards the core (pith) of the tree, and be held in horizontal level. Surprising readings or poor shooting may justify reshooting. Both pilodyn readings are noted on the assessment form. More detailed instructions in the use of the pilodyn are found in Hansen (2000).

6. General field assessment procedures

6.1 Organisation of the assessment

A single assessment team per trial is recommended for logistic reasons and to assure consistency in the assessment. An optimal assessment team consists of 3-4 persons, each with clearly defined tasks. It is recommended that the officer-in-charge of the field assessment is also appointed as rapporteur. It is the responsibility of the officer in charge not to force the speed beyond a reasonable level, and to secure sufficient time for a reliable and precise field assessment.

It is important that the assessment team carefully discusses the assessment, its objectives, the traits considered, assessment methodology and how the collected results are to be used and analysed. All equipment to be used in the assessment should be demonstrated, discussed and tested. This is especially important if the assessment team will split-up in smaller teams during the field assessment.

It is further recommended that the entire assessment team undertakes a general assessment of the trial with the objective to discuss the trial and the site (completion of site description and stand description) and to clearly identify and demarcate blocks and plots.

6.2 Monitoring of data collection

Subjective scoring scales might have a tendency to 'slide' over time. It is therefore recommended to carefully monitor the assessment and assessment methodology (scoring scales) at regular intervals, e.g. after completing each block of the trial. The monitoring should be done on labelled test trees which have been identified and scored/measured prior to the start of assessment. Any tendency of 'sliding' scoring scales should be carefully discussed as well as their implication.

A first analysis and examination of the collected data can prove very useful in pointing out assessment errors and mistakes occurred in the recording of data. As assessment data can be localised to individual trees, the data examination provides an option of re-assessing trees with obvious errors.

6.3 Data management

All data are recorded on the data assessment forms. All forms should be properly labelled with trial, block and plot identification, date of assessment and names of persons in-charge of the assessment.

It is essential to check all data before departing from the trial to assure that data is (i) complete; (ii) readable; (iii) understandable; (iv) free of at least non sense errors (re. the above discussion).

Although original assessment forms may be appearing in a poor or dirty condition it is important not to discard the original forms by transferring data to new sheets, as errors may occur in this process.

After completion of the field assessment the data will be entered into the computer in spreadsheet format.

6.4 Tools and equipment

The equipment for the assessment:

- Notebook, writing paper (squared)
- Clipboard, writing pad, pencils and eraser
- Permanent marker pens, ruler
- String and tags
- Compass
- Paint (yellow and light blue, spray)
- Chalk
- Electronic calculator
- Camera
- Binoculars, light efficient
- Magnifying-glass and Cone cutter
- Soil bucket auger and plastic containers
- pH test kit (optional)
- Clinometer (if trees > 15 m). Suunto
- Telescopic height measuring rod or measuring pole (10-15 m, in dm)
- Callipers (30-40 cm, in mm) or diameter tape/ linear tape measure (short, for diameter girth)
- Pilodyn and extra pins (2.0 and 2.5 mm Ø, 80 mm length)
- 3 measuring tapes, 20-50 m
- 1 telescopic pruner (for collection of flower/ fruit samples)
- Flexible saw and Slingshot
- 2 pairs of leather gloves and Plastic bags
- Sufficient number of assessment recording forms (see Annex 5).

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Annex 1. Status of seed despatch and field trials established

Table based on DFSC (1996) and DFSC (1997).

Country	Organisation	Seed des-patch	Trial id.	Type	No. provs	No. fams.	Date of planting	Comments
Argentina	CIEF	5/89	N02M104	P	39	-	8/90	
	CIEF	5/89	M02M103	P	39	-	8/90	
Brazil	EMBRABA	5/89	37-06-01D	P/P	6	41	?	
	KLABIN	5/89	37-26-01A	P/P	8	56	?	
Burundi	ISABU	6/89	Matana	P	29	-	2/90	Trial not confirmed
	ISABU	6/89	Rushubi	P	17	-	2/90	Trial not confirmed
Colombia	SMURFIT	4/89	Granada	P	29	-	4/90	
	SMURFIT	4/89	Romerito	P	32		4/90	
	CONIF	8/89	-	-	27	-	-	Trial not planted due to security problems.
Fiji	Fiji Pine Limited	7/89	-	-	11	-	-	High seedling mortality left too few for establishment of trial.
India	ICFRE	7/89	-	-	41	-	-	No report on trial
Indonesia	PT Kiani Sakti	1/91	-	-	25	-	-	No report on trial.
	PT Inti Indorayon Utama, Desa Sosor Ladang	11/91	-	-	11	-	-	
Kenya	KEFRI	7/89	Turbo	P	14	-	5/91	Low survival due to drought and browsing.
Nepal	Shankar Path	12/92	-	-	8	-	-	Low survival.
Philippines	Bukidnon Forests Inc.	2/93	-	P	6	-	8/93	Trial burned Feb. 1994.
Rwanda	ISAR	9/89	Ryamanyoni	P	42	-	3/91	No report on trial.
South Africa	Sappi	8/89	Grootgeluk	P/P	27	63	2/91	
	Sappi	8/89	Melmoth	P/P	16	52	2/91	Low survival because of fire.
Sri Lanka	Forest Department	2/91	-	P	20	-	6/92	No report on trial.
Swaziland	Usutu Pulp Co.	4/89	r136/J2	P	25		3/90	
	Usatu Pulp Co.	4/89	r136/G1	P	25		3/90	
	Usutu Pulp Co.	4/89	r136/A5	P/P	15		5/90	
Thailand	RFD	4/89	-	-	27	-	-	Poor survival. No report on trial.
Vietnam	Forest Science Institute	8/90	Langh Hanh	P	16	-	7/91	
	Forest Science Institute	8/90	Bavi	P	16	-	4/93	
Zimbabwe	Forest Research Centre	6/89	PB42	BSO	-	50	12/92	Limited value for the overall assessment (Madagascar only).
	Forest Research Centre	3/90	PB44	BSO	-	12	12/92	Limited value for the overall assessment (Zambia only).
	Forest Research Centre	2/90	PV144	P	25	-	12/92	Doing well, although infested by woolly aphid.

Annex 2.
Overview of *Pinus kesiya* provenances included in the international series

Acc. No. (DFSC)	Provenance	Country	Locality	Admin. unit	Latitude	Longitude	Quan. g	Altitude m.a.s.l.	Rainfall mm/year	Temp. oC	Reg. date	Coll. date	No. Coll.	Soil
Pinus kesiya														
01447/84	Mt.Province	Philippines	.	.	17 15 N	120 55 E	1105	2300	.		05/11/1984	01/02/1984	83	
01448/84	Benquet	Philippines	.	.	16 35 N	120 30 E	4805	1600	.		05/11/1984	01/02/1984	64	
01506/85	Tarlac	Philippines	Zambales	.	15 23 N	120 08 E	960	1120	.		11/02/1985	01/03/1984	11	
01515/8500	Dathien	Vietnam	Langbian	Lam Doung	11 58 N	108 27 E	2065	1550	1769	17.9	25/03/1985	17/11/1984	45	Sand-clay. Yellow podzol over granite/dacite
01516/8500	Xuan Tho	Vietnam	Langbian	Lam Doung	11 55 N	108 32 E	1000	1400	1769	17.9	25/03/1985	19/11/1984	12	Sand-clay. Yellow podzol over granite/dacite
01517/8500	Ho Tien	Vietnam	Langbian	Lam Doung	11 51 N	108 32 E	1010	1500	1769	17.9	25/03/1985	21/11/1984	11	Sand-clay. Yellow podzol over granite/dacite
01518/8500	Thac Prenn	Vietnam	.	Lam Doung	11 52 N	108 27 E	2270	1250	1769	17.9	25/03/1985	01/12/1984	30	Sandy clay. Yellow-red podzol. 2-3 meter deep
01519/8500	Lang Hanh	Vietnam	.	Lam Doung	11 37 N	108 16 E	1850	950	2059	21.5	25/03/1985	28/11/1984	22	1 m and deeper yellow clay. Yellow- red podzol
01521/8500	Nong Krating	Thailand	Omkoi	Chiangmai	18 05 N	98 35 E	1760	1080	1332	22.2	25/03/1985		17	Red Yellow podzol from acid rock
01522/8500	Doi Suthep	Thailand	.	Chiangmai	18 46 N	98 53 E	970	1300	2084	20	25/03/1985	16/01/1985	38	Red brown lateritic developed on metamorphic rock
01523/8500	Doi Inthanon	Thailand	Chomtong	Chiangmai	18 32 N	98 35 E	6340	1000	2084	20	25/03/1985	24/01/1985	30	Red-yellow podzol. Stony or red-brown lateritic
01524/8500	Phu Kradung	Thailand	.	Loei	16 51 N	101 47 E	3650	1250	1813	21.3	25/03/1985	31/01/1985	24	Sandy
01525/8500	Nam Now	Thailand	.	Petchaboon	16 40 N	101 33 E	4180	800	1316		25/03/1985	01/02/1985	35	Sandy clay loam
01546/85	Doi Suthep	Thailand	Meuang	Chiengmai	18 46 N	99 -- E	12740	1300	2084	20	22/05/1985		.	Red brown lateritic developed on metamorphic rock
01572/8500	Coto Mines	Philippines	S. & w. St. Lawis r.	Zambales	15 32 N	120 05 E	90	800	1000	25.1	17/12/1985	28/11/1985	9	Red-yellow podzolic
01635/86	Jindung(1)	China	.	Yunnan	24 26 N	100 51 E	988	1300	.		12/05/1986		30	
01636/86	Jingdung(2)	China	.	Yunnan	24 28 N	100 51 E	1038	1350	.		12/05/1986		34	
01637/86	Jinghong	China	.	Yunnan	22 25 N	101 10 E	600	1250	.		12/05/1986		24	
01638/86	Lancang	China	.	Yunnan	22 40 N	100 03 E	799	1620	.		12/05/1986		15	
01639/86	Simao	China	.	Yunnan	22 50 N	101 00 E	913	1370	.		12/05/1986		22	
01680/86	Dakha	Vietnam	.	Dakto-Gialai-Kotoum	14 48 N	107 56 E	4240	1200	2684	21.6	10/10/1986		40	
01766/88	Wat Chan	Thailand	.	Mae Hong Sorn	19 04 N	98 19 E	980	940	1450	26	03/05/1988		200	
01772/8800	Zokhua	Burma	Haka	Chin Hills	22 25 N	93 40 E	1060	1600	2335	15	22/06/1988	16/03/1988	20	Yellowish sandstone derivate. Loam content low
01773/8800	Aungban	Burma	Kalaw	Shan State	20 41 N	96 37 E	5040	1350	1303	20.5	23/06/1988	13/03/1988	61	Yellow podzolic - deep
01774/88	Anhembi CSO	Brazil			22 43 S	47 43 W	128				06/07/1988			
01775/8800	Planaltina SO	Brazil	.	.	14 40 S	47 39 W	375	.	.		06/07/1988		53	
01776/88	John Meikle CSO	Zimbabwe	Mukandi		18 43 S	32 51 E	249	1268	1725	17.9	06/07/1988		1	Granite/dolorite, brown clays
01777/88	John Meikle CSO	Zimbabwe	Mukandi	.	18 43 S	32 51 E	249	1268	1725	17.9	06/07/1988		1	Granite/dolorite, brown clays
01778/8800	Clonal Seed Orchard	Zambia		.	13 00 S	28 00 E	3620	1300			06/07/1988		10	
01779/88	John Meikle CSO	Zimbabwe	Mukandi	.	18 43 S	32 51 E	249	1268	1725	17.9	06/07/1988		1	Granite/dolorite, brown clays
01780/88	John Meikle CSO	Zimbabwe	Mukandi	.	18 43 S	32 51 E	249	1268	1725	17.9	06/07/1988		1	Granite/dolorite, brown clays
01781/88	Jingdung(3) Arboretum	China	.	.	24 28 N	101 05 E	703	1200	.		06/07/1988		.	
01782/88	Jmfrs	Zimbabwe	.	.	18 43 S	32 51 E	150	1268	1725	17.9	06/07/1988		1	Granite/dolorite, brown clays
01783/88	Bodana Population A8	Madagascar	.	.	20 35 S	47 30 E	1000	1500	.		06/07/1988		.	
01784/88	Bodana Population A9	Madagascar	.	.	20 35 S	47 30 E	1000	1500	.		06/07/1988		.	
01785/88	John Meikle CSO	Zimbabwe	Mukandi	.	18 43 S	32 51 E	249	1268	1725	17.9	06/07/1988		1	Granite/dolorite, brown clays
01786/8800	Morarano	Madagascar	.	.	18 40	47 02 E	910	900	.		06/07/1988		32	
Pinus yunnanensis														
01623/86	Shangbai	China	-	Yunnan	24 41 N	101 36 E	993	1300	-	-	12/05/1986	-	140	-
01624/86	Baoshan (1)	China	-	Yunnan	24 51 N	99 12 E	673	1750	-	-	12/05/1986	-	26	-
01625/86	Baoshan (2)	China	-	Yunnan	25 08 N	99 13 E	428	1400	-	-	12/05/1986	-	25	-
01626/86	Maguan	China	-	Yunnan	23 02 N	104 23 E	988	1100	-	-	12/05/1986	-	40	-
01627/86	Tengchong	China	-	Yunnan	25 01 N	98 05 E	888	1910	-	-	12/05/1986	-	21	-
01628/86	Huize	China	-	Yunnan	26 25 N	103 17 E	810	2060	-	-	12/05/1986	-	23	-
01629/86	Lan Ping	China	-	Yunnan	26 49 N	99 18 E	928	2450	-	-	12/05/1986	-	40	-
01630/86	Lufeng	China	-	Yunnan	24 30 N	101 50 E	928	2049	-	-	12/05/1986	-	120	-
01631/86	Weining	China	-	Yunnan	26 07 N	104 21 E	928	2240	-	-	12/05/1986	-	20	-
01632/86	Ceheng	China	-	Yunnan	24 24 N	105 34 E	933	800	-	-	12/05/1986	-	25	-
01633/86	Shangsi	China	-	Yunnan	21 37 N	107 57 E	958	530	-	-	12/05/1986	-	25	-
01634/86	Dukou	China	-	Yunnan	26 35 N	101 32 E	918	1800	-	-	12/05/1986	-	20	-

Annex 3. Site description form

International assessment of Pinus kesiya provenance trials

Description of the site of the trial
(Fill in one form - pages 1 and 2 - for each site)

LOCATION

Name of the site ....
Country ....
Province ....
District ....
Latitude (degrees and minutes) ....
Longitude (degrees and minutes) ....
Altitude (m above sea level) ....

Managing office/institution ....
Owner ....
User(s) ....

Distance to nearest office responsible for management of the trial (km) ....
Distance to nearest villages/towns (km) ....
Number of inhabitants in the nearest villages/towns ....
Type of area (e.g. research station, managed forest, etc.) ....

Add sketch map showing how to access the stand/stands of the area.

CLIMATE

Nearest weather station:

Name of the station ....
Latitude (degrees and minutes) ....
Longitude (degrees and minutes) ....
Altitude (m a.s.l.) ....

Climatic data[1]	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Rainfall (mm)													
Temp. mean (°C)													
Temp. mean max.[2] (°C)													
Temp. mean min.[3] (°C)													
Evapotranspiration[4] (mm)													

[1] Period of observations:.........(specify years)
[2] Average of daily maximum temperatures
[3] Average of daily minimum temperatures
[4] Potential evapotranspiration (ETP) - Penman's formula

Rainy season:

Number/type of seasons: ☐ one ☐ two ☐ even/irregular (tick only one box)
Period(s) .... (specify months)

Length of rainy season (cf. FAO 1984-1987):

No. of intermediate days (pre- and posthumid period of the growing season) ....
No. of wet days (growing season) ....

Number of dry months per year (< 50 mm rain/month) ....
Frost (number of days/year) ....
Prevailing winds (direction, period, speed) ....

Add specific (annual) meteorological data since establishment of the trial and climatic diagram if available (cf. e.g. Walter *et al.* 1967, 1975).

Local weather data of the site (if available):

Climatic data1	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Rainfall (mm)													
Temp. mean (°C)													
Temp. mean max.2 (°C)													
Temp. mean min.3 (°C)													
Evapotranspiration4 (mm)													

[1] Period of observations:.........(specify years) [2] Average of daily maximum temperatures
[3] Average of daily minimum temperatures [4] Potential evapotranspiration (ETP) - Penman's formula

Rainy season:
Number/type of seasons: ☐ one ☐ two ☐ even/irregular (tick only one box)
Period(s) .... (specify months)

Length of rainy season (cf. FAO 1984-1987):
No. of intermediate days ....(pre- and posthumid period of the growing season)
No. of wet days ....(growing season)

Number of dry months per year (< 50 mm rain/month) ....
Frost (number of days/year) ....
Prevailing winds (direction, period, speed) ....

TOPOGRAPHY (slope) of trial site

☐ Flat/gentle (0-8 %) ☐ Intermediate (9-30 %) ☐ Steep (>30 %) (tick only one box)

GENERAL SOIL DESCRIPTION

Percentage of rocks/large stones of total planting area

Please tick the following soil description

Soil texture		**Soil depth**		**Soil drainage/ Waterlogging**		**Gravel content, topsoil**	
1. Light/sandy		1. Shallow (< 50 cm)		1. Well drained		1. None (< 15 %)	
2. Medium/loamy		2. Deep (50-100 cm)		2. Seasonal		2. Gravelly (15-35 %)	
3. Heavy/clayey		3. Very deep (> 100 cm)		3. Permanent		3. Stony (> 35 %)	

Organic matter content		**Reaction (pH)**		**Soil salinity**		**Groundwater**	
1. Poor (< 2 % DM)		1. Acid (pH < 6.5)		1. None		1. Shallow (< 50 cm)	
2. Medium (2-5 % DM)		2. Neutral (6.5-7.5)		2. Moderate		2. Deep (50 - 150 cm)	
3. Rich (> 5 %)		3. Alkaline (pH> 7.5)		3. High		3. Very deep (>150 cm)	

Specify soil unit, soil association and phases (subdivisions of soil units) according to the Soil map of the world (FAO-Unesco 1971-1979), if known ....
....

SOIL SAMPLE NO .... (if taken)

VEGETATION

Natural (original) vegetation type ....
....
Dominant natural (original) genera/species ....
....
Land use history ....
....

....
(date and signature of responding officer)

ADDITIONAL INFORMATION

Please add published or unpublished documentation that may be of relevance.

REFERENCES (see text)

Annex 4. Trial description

International assessment of *Pinus kesiya* provenance trials

Description of the trial
(Fill in one form - pages 1 and 2 - for each stand)

TRIAL SITE
(cf. site description form)

Name of the site ....

Identification label (e.g. compartment no.) ....

Add sketch map of the area and neighbouring stands/land.

TRIAL

Establishment and management:

Year and month of establishment:............. Area:........(ha) Initial spacing:.........(m x m)

Soil preparation (time, method/intensity) ....

Planting method(age of seedlings, type)...

Plot size ....

Demarcation (blocks, plots) ....

Beating up (time, %) ....

Irrigation (time, amount) ....

Fertilization (time, type, amount) ....

Weeding (time, intensity) ....

Thinning (time, intensity) ....

Firelines ....

(add additional pages if required)

Protection:

Status (describe any disturbances/damages) ....
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Guarding (permanent, regular, none) ....
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ADDITIONAL INFORMATION

Comments to the performance, health, quality of individual provenances in the trial

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(add additional pages if required)

Please add published or unpublished documentation that may be of relevance.

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(date and signature of responding officer)

Annex 5. Assessment form

International assessment of Pinus kesiya provenance trials **(Fill in one form for each plot)**

IDENTIFICATION

Site:..	Block no.:..	Provenance name.: ....
Country:	Plot no.:	Seedlot accession no.: ....
Species:.	Date of assessment:..	Name of assessor:..

ASSESSMENT

No.	Health/damage status			Social status			Diameter (DBH) cm		Height m	Pilodyn		Crown lenght %	Stem-form 1-9	Branching			Forking		Flowering and fruiting	Foxtail Y/N
	Type	Part	Score	Kraft	Crown	Pos.	No.1	No. 2		No. 1	No. 2	Crown	Stem	Position of whorls	No. of branches in whorl	Diam	No.	Pos.		
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2																				
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No.	Health/damage status			Social status			Diameter (DBH) cm		Height m	Pilodyn		Crown lenght %	Stem-form 1-9	Branching											Forking		Flowering and fruiting	Foxtail Y/N
	Type	Part	Score	Kraft	Crown	Pos.	No.1	No. 2		No. 1	No. 2	Crown	Stem	Position of whorls					No. of branches in whorl					Diam	No.	Pos.		
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Annex 6. Seed source description

International assessment of *Pinus kesiya* provenance trials

Description of the seed source (seed collection report)
(Fill in one form - pages 1 and 2 - for each seedlot)

Species ....
Seedlot accession no. ....

PROVENANCE

Name of the collection site ....
Country ....
Province ....
District ....
Latitude (degrees and minutes) ....
Longitude (degrees and minutes) ....
Altitude (m above sea level) ....

Add sketch map showing how to access the collection site.

CLIMATE

Nearest weather station:

Name of the station ....
Latitude (degrees and minutes) ....
Longitude (degrees and minutes) ....
Altitude (m a.s.l.) ....

Climatic data[1]	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Rainfall (mm)													
Temp. mean (°C)													
Temp. mean max.[2] (°C)													
Temp. mean min.[3] (°C)													
Evapotranspiration[4] (mm)													

[1] Period of observations .... (specify years)
[3] Average of daily minimum temperatures
[2] Average of daily maximum temperatures
[4] Potential evapotranspiration (ETP) - Penman's formula

Rainy season:

Number/type of seasons: ☐ one ☐ two ☐ even/irregular (tick only one box)
Period(s) .... (specify months)

Length of rainy season (cf. FAO 1984-1987):

No. of intermediate days ....(pre- and posthumid period of the growing season)
No. of wet days ....(growing season)

Number of dry months per year (< 50 mm rain/month) ....
Frost (number of days/year) ....
Prevailing winds (direction, period, speed) ....

Add specific (annual) meteorological data and climatic diagram if available (cf. e.g. Walter *et al.* 1967, 1975).

TOPOGRAPHY (slope)

☐ Flat/gentle (0-8 %) ☐ Intermediate (9-30 %) ☐ Steep (>30 %) (tick only one box)

SOIL

Please tick the following soil description

Soil texture		Soil depth		Soil drainage/ Waterlogging		Gravel content, topsoil	
1. Light/sandy		1. Shallow (< 50 cm)		1. Well drained		1. None (< 15 %)	
2. Medium/loamy		2. Deep (50-100 cm)		2. Seasonal		2. Gravelly (15-35 %)	
3. Heavy/clayey		3. Very deep (> 100 cm)		3. Permanent		3. Stony (> 35 %)	

Organic matter content		Reaction (pH)		Soil salinity		Groundwater	
1. Poor (< 2 % DM)		1. Acid (pH < 6.5)		1. None		1. Shallow (< 50 cm)	
2. Medium (2-5 % DM)		2. Neutral (6.5-7.5)		2. Moderate		2. Deep (50 - 150 cm)	
3. Rich (> 5 %)		3. Alkaline (pH> 7.5)		3. High		3. Very deep (>150 cm)	

Specify soil unit, soil association and phases (subdivisions of soil units) according to the Soil map of the world (FAO-Unesco, 1971-1979), if known ....
....

STAND

Type: ☐ Natural or ☐ Plantation Original seed source: ....
Area: ....(ha)
Age: ....(years) or ☐ Young
☐ Middle-aged
☐ Old

Density: ☐ Dense } { Number of trees/ha ....
} or { Height: ....(m)
☐ Thin } { Diameter at breast height: ....(cm)
{ Basal area: ....(m^2/ha)

Stemform: ☐ Single ☐ Straight
☐ Multiple ☐ Fair
☐ Poor

Associated species: ....

Seed crop: ☐ Light ☐ Medium ☐ Heavy

Seed collection: No. of trees....... Min. distance apart:.......(m) Amount:.........(kg)

Date of collection:...............

Land use history ....
....

ADDITIONAL INFORMATION

Please add published or unpublished documentation that may be of relevance.

REFERENCES

FAO 1984-1987: Agroclimatological data for Africa, Latin America and Caribbean, and Asia.
FAO Plant Production and Protection Series No. 22, 24 and 25. Rome.
FAO-Unesco 1971-1979: Soil map of the world.
Walter, H., Lieth H. (1967): Klimadiagramm-Weltatlas. VEB Gustav Fischer, Jena.
Walter, H., Harnickell, E., Mueller-Dombois, D. (1975): Climate-diagram Maps of the Individual Continents and the Ecological Climate Regions of the Earth. Springer, New York-Berlin-Heidelberg.