MANUAL ON LARGE-SCALE REFORESTATION TECHNIQUES

(DRAFT FINAL)

MARCH, 1993

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

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SUMMARY

1. Objective of Large-Scale Reforestation

The urgent implementation of large-scale "environmental reforestation", a concept of reforestation to recover the water conservation function of forests, to prevent desertification and to control global warming, etc., is now imperative. Aerial reforestation with the goal of fast, large-scale, low cost reforestation has now surfaced as an attractive reforestation method which is suitable for "environmental reforestation" projects.

2. Characteristics of Aerial Reforestation

① Advantages

- a. As the work is largely conducted by air, there are few geographical and/or topographical constraints in regard to transportation.
- b. Large-scale reforestation in a short period of time is viable and involves little manpower due to the continuous nature of such work processes as transportation of reforestation material.
- c. Nurseries are unnecessary as the seeds are sprayed from an aircraft.
- d. The cost of reforestation is lower than that of reforestation using seedlings.

② Disadvantages

- a. The reforestation performance is not totally reliable.
- b. Uniform seeding may be difficult, depending on the topography.
- c. The sprayed seeds may be washed away by rain or eaten by small animals.
- d. Operation may be restricted by such weather conditions as strong wind and fog, etc.

3. Examination of Subject Areas for Aerial Reforestation

(1) Candidate Areas

The large-scale aerial reforestation is particularly advantageous in the following areas.

- a. Remote areas
- b. Areas requiring the urgent recovery of vegetation even if the tree density is low
- c. Areas with difficult access
- d. Sparsely populated areas
- e. Areas in which the production of a large volume of seedlings is difficult
- f. Extensive areas requiring reforestation

(2) Basic Surveys

When planning an appropriate aerial reforestation project, it is necessary to study various basic issues, including such natural conditions as the climate, topography, soil, vegetation and fauna of the subject area, possible constraints on project implementation and project-related socioeconomic conditions. Those issues which are considered particularly important for aerial reforestation are as follows.

① Climate
The main survey items in the case of climate are as follows.

a. Temperature... mean annual temperature, mean monthly temperature
b. Rainfall ... annual rainfall, monthly rainfall, maximum daily rainfall

Note: The meteorological data to be used should preferably cover at least 10 years.

② Topography
The main survey items in the case of topography are as follows.

a. Gradient
b. Elevation

③ Geology
The main survey items in the case of geology are as follows.

a. Geological categories
b. Parent material type and conditions of rock fracture and weathering

④ Soil
In the case of aerial reforestation, it is sufficient to confirm the existence of problematic soils vis-a-vis reforestation. Consequently, it is sufficient to select the most representative sites in terms of topography and vegetation and to conduct a soil survey at these sites. The main survey items in the case of geology are as follows.

a. Distribution of soil types
b. Soil texture
c. Soil hardness
d. Soil acidity (pH)

⑤ Vegetation
It is necessary to study the original vegetation of a candidate reforestation site based on the original types of vegetation, vegetation density and growth conditions in neighbouring forests in order to identify the natural regeneration conditions of the dominant species. A vegetation survey provides the necessary data for reference and the selection of appropriate species and varieties for reforestation purposes.

⑥ Socioeconomy
When planning an aerial reforestation programme, it is essential to obtain as much related information and data as possible. Preliminary investigation and examination by means of interviews and aerial photographs should also be conducted in regard to the local availability of labour, construction materials and equipment, etc., including the possible transportation method of such materials and equipment. The main survey items in the case of socioeconomy are as follows.

a. Distribution of population and settlements
b. Living conditions of local inhabitants and local industries
c. State of infrastructure, including that of neighbouring areas
d. National and/or regional plans and other future plans affecting the area in question

e. Social requirements vis-a-vis such environmental aspects as water utilization, landscape and ecosystem, etc.

(3) Use of Satellite Data and Aerial Photographs

The use of satellite data and aerial photographs is very effective to identify the vegetation and land use over an extensive area.

4. Selection of Aerial Seeding Species

(1) Selection of Species

The species to be selected for aerial seeding should be in line with the project targets and policies and should meet the following conditions as much as possible.

a. Good adaptability to a wide range of weather conditions
b. Good adaptability to a wide range of soil conditions
c. Prospect of vigorous germination and growth, particularly at the early stage
d. Prospect of luxuriant growth with a well-developed root system together with excellent land coverage and soil holding effects
e. Prospect of soil improvement effect for higher productivity
f. Strong resistance to the harmful effects of insects and diseases, etc.
g. Availability of a large quantity of seeds
h. High germination rate even after a relatively long period of storage

(2) Procurement of Seeds

As aerial reforestation uses a large quantity of seeds in a short period of time, study of the following for each species is essential prior to the preparation of an aerial seeding plan to determine the prospect of securing the necessary seeds.

① Production records and production plan
② Storage volume
③ Import records and availability of export from countries of production
④ Other plans to use seeds for traditional reforestation activities (man-made reforestation)

(3) Judgement of Seed Quality

The judgement of seed quality is mainly based on the following principles

① Seed quality is usually judged in terms of the germination rate and purity of the seeds. The germination rate is defined as the ratio of germinated seeds in the total number of seeds and is dependent on the seed collection and storage methods, the timing of collection and the time elapsed since collection.

② As the seeds are usually mixed with foreign matters, the weight ratio of pure seeds in the total weight is shown as the purity in percentages.

③ The weight of seeds (often given as the average number of seeds/unit weight) is an important factor in the judgement of seed quality. Those seeds with a below average weight have many blind seeds and are, therefore, inferior.

④ As calculation of the required seed quantity is based on the germination rate and purity of the seeds, the required seed quantity must be adjusted on the basis of purity to achieve the expected germination rate.

⑤ Germination tests should be conducted to determine the germination rate of those seeds for which there is no certificate, which were collected a long time ago or which have an unclear germination rate.

(4) Germination Rate and Number of Seeds/Unit Weight

The number of seeds/unit weight, which is an important factor to determine the spraying quantity, depends on both the species and the timing of seed collection and seed maturity, etc. As seeds which are directly sprayed onto the ground may be eaten by birds or damaged by insects, the possible damage rate should be taken into consideration in the direct seeding test.

5. Land Preparation

(1) Principle of Land Preparation

An important element of aerial reforestation is the achievement of low cost reforestation. Therefore, it is necessary to keep land preparation work to a minimum.

(2) Types of Land Preparation

The main land preparation methods applicable in the case of aerial reforestation are burning and mechanical preparation. While the use of herbicides is a possible land preparation method, the effects of herbicides on the natural environment and on human life must be carefully examined in advance.

6. Selection of Aircraft and Other Relevant Issues

(1) Selection of Aircraft

The selection of an appropriate type of aircraft for aerial seeding must be based on the functions and economy to achieve the objective in an efficient manner. The main characteristics of helicopters are listed below.

① Suitable for areas with many steep slopes and undulations as well as for flat areas
② Excellent mobility
③ Variable spraying speed (from high speed to low speed to hovering) to permit careful spraying
④ Larger loading capacity than a small fixed wing aircraft
⑤ Fewer constraints on take-off and landing, reducing the flight distance to the target area
⑥ Swift loading of materials and spraying operation depending on spraying apparatus
⑦ Skill required for seeding operation
⑧ More expensive hardware than a fixed wing aircraft

(2) Spraying Method

The selection of the spraying method to be used is mainly based on the scale of operation, such land conditions as soil type and inclination, the spraying apparatus to be used and the types of spraying materials. The work efficiency and reliability of spraying are additional factors in the selection of the spraying method.

(3) Spraying Apparatus

The selection of suitable spraying apparatus should be based on the spraying method, types and conditions of spraying materials, aircraft loading capacity, agitation and discharge performance and compatibility with the aircraft in use.

7. Project Planning

(1) Basic Conditions for Project Planning

The preparation of an aerial reforestation plan must be based on the following.

① Clear identification of the project objectives
② Proper understanding of the natural conditions of the subject area
③ Selection of species which have particularly vigorous growth at the early stage and which are highly resistant to unaccommodating natural conditions
④ Availability of a sufficient quantity of seeds
⑤ Examination of land preparation possibility and other construction work depending on the land conditions
⑥ Selection of appropriate equipment and materials
⑦ Selection of a suitable aircraft and spraying apparatus
⑧ Careful consideration of the social environment
⑨ Coordination of the work schedule
⑩ Establishment of site supervision and maintenance systems

(2) Machinery and Various Facilities

The planned scope of machinery and various facilities should be kept to a minimum, taking the locational conditions of the subject area, the necessity to use machinery to meet the project objectives and the possible period of using machinery, etc. into careful consideration.

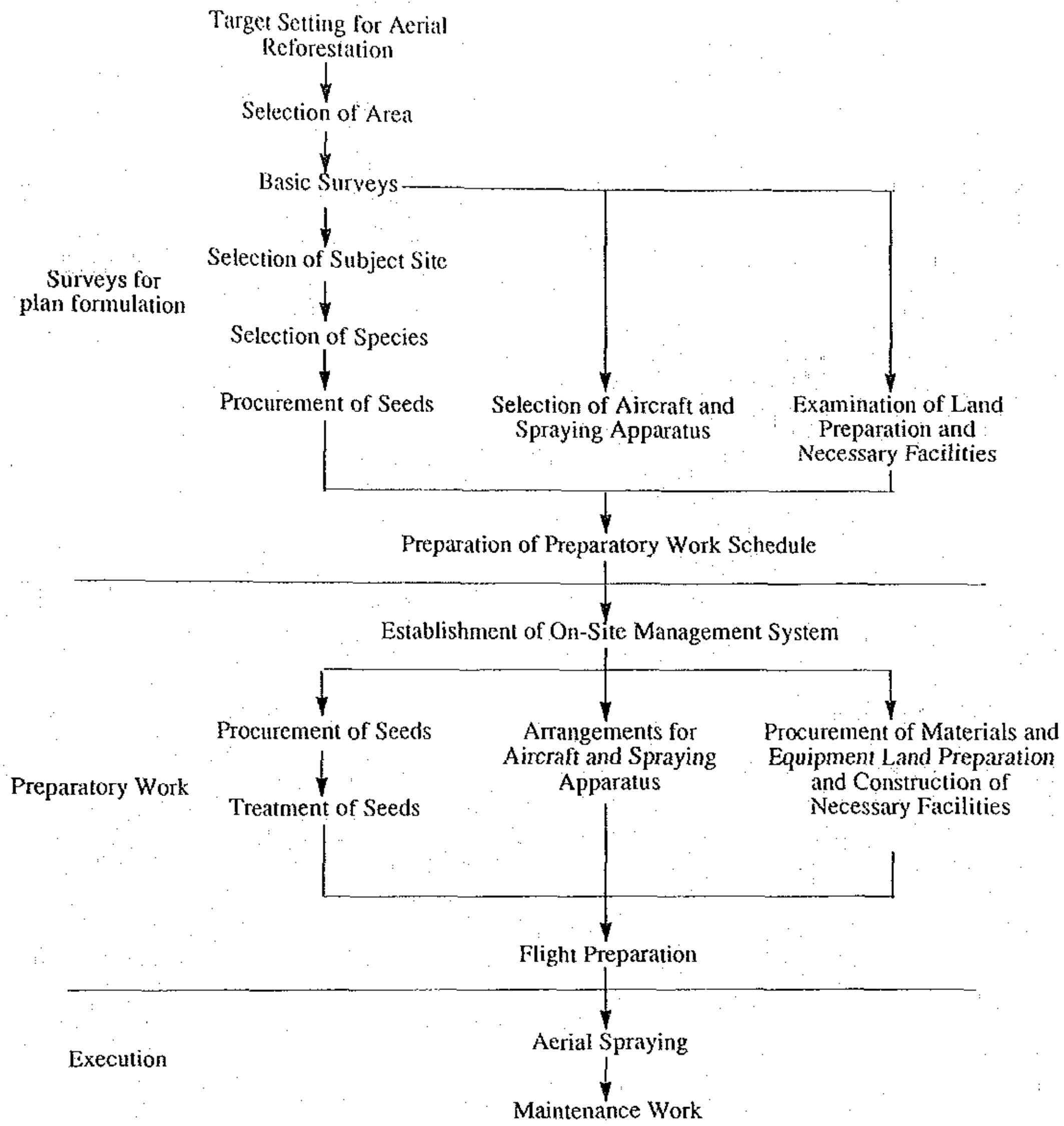
(3) Flight Cost and Cost Estimate

The transportation work by helicopter involves the following cost items.

- Transportation Cost by Helicopter
  - Flight Cost
    - Airlift cost (major airlift cost, minor airlift cost)
    - Operational flight cost
    - Survey and test flight cost
    - Wasted day charge
    - Depreciation and land transportation costs of auxiliary materials and equipment
    - Instruction fee
  - Auxiliary Costs
    - Weighing and packaging cost
    - Construction cost of heliport and loading/unloading yard
    - Rent for land
    - Hook operation cost
    - Night security cost
    - Safety control cost
    - Miscellaneous cost

(4) Work Schedule

The work processes involved are shown below. An actual work schedule should be prepared on the basis of seasonal preference for aerial spraying, taking local conditions and other relevant factors into consideration.



Aerial Reforestation Work Processes

8. Seed Preparation

(1) Procurement of Seeds

Seeds can be procured through self-production, domestic purchase or importation. In the case of the domestic purchase or import of seeds, it is desirable to obtain certification from a public organization to ensure the procurement of good seeds.

(2) Selection of Seeds

The selection of good seeds is crucial to achieve a high seed treatment efficiency and high germination rate. The removal of foreign matters from seeds can be conducted using one of the following 3 methods.

- Selection using sieves
- Selection using air pressure
- Selection using liquid

(3) Calculation of Required Seed Quantity

The required seed quantity is calculated using the following formula.

$$W = \frac{G}{S \times P \times B}$$

Where, W : required weight of seeds (kg)
G : expected number of grown seedlings (seedlings/ha)
S : average number of seeds (seeds/g)
P : purity (%)
B : germination rate (%)

(4) Storage of Seeds

Seeds can be stored in the following manner

① Dry Storage

a. Normal temperature storage
b. Low temperature storage

② Wet Storage

(5) Germination Stimulation Methods

There are many methods to stimulate germination, including the lighting method, dipping method, high and low temperature wet treatment method, shifting temperature method and scarificaiton method. The appropriate method should be selected based on the seed characteristics and storage method used. Many dry stored seeds are in a state of dormancy and require treatment to end this dormancy and to stimulate germination.

(6) Coating of Seeds

The objectives of the coating of seeds are to make the seeds heavier, to repel animals, to prevent bacteria damage, to stimulate germination, to reshape and to make it easier to identify sprayed seeds, etc. The coating of seeds for forestry work has been conducted on pines and other species in Canada and the US. Coating is not a standard practice and is conducted as and when deemed necessary. One characteristic of coating is that useful agents can be coated in layers, often mixed with a coating base powder or glue, to suit specific purposes.

9. On-Site Management System and Related Issues

(1) On-Site Management

An on-site management system and command system must be clearly established for project implementation to ensure the safety and efficiency of the work.

(2) Safety Control

Workers engaged in helicopter transportation work must be properly educated on the characteristics of the work to prevent accidents.

10. Maintenance

Maintenance after the initial spraying may be necessary depending on the objectives of the aerial spraying and the degree of necessity for such maintenance work.

(1) Tending

In principle, tending is not conducted in view of the basic objectives of "environmental reforestation". During the process of natural growth, the sprayed seeds may create such problems as inadequate germination, power growth and over-stocked stands. The following measures should, therefore, be adopted.

a. Additional seeding
b. Additional fertilizer
c. Weeding
d. Salvage cutting or thinning

(2) Monitoring

Monitoring of the growth conditions of the sprayed species and the state of the original vegetation, etc. should be conducted for a specific period of time in order to confirm the spraying results and to provide useful information for future aerial reforestation.

(3) Measures Against Harmful Insects and Diseases

Appropriate measures should be taken at each specific stage of growth to prevent damage due to harmful insects and diseases. Such damage can be avoided by the chemical and/or biological methods and also by silviculture control. The chemical method should, however, only be adopted after a careful examination of the environmental impacts.

(4) Forest Fires

It is very common to witness burning for shifting cultivation and/or stock raising purposes in and around reforestation sites. It is, therefore, necessary to enlist the cooperation of local inhabitants in the protection of reforestation sites by making them fully aware of the objectives and practical importance of reforestation and forests in general. Moreover, the employment of local inhabitants in reforestation work may be necessary to secure their cooperation.

While firebreaks are a very effective means of preventing the spread of forest fires, they do not have a 100% guarantee. Measures to prevent forest fires, including the construction of watch towers and the provision of fire-fighting equipment, should be seriously considered.

I. GENERAL

The present Manual (the Manual) has been prepared based on the findings of fact-finding surveys on aerial seeding activities in various countries and on the findings of the basic study on aerial seeding and the direct seeding experiment in South Kalimantan, Indonesia and a series of similar studies which have been conducted since 1988. The Manual is intended for use in Japan's technical cooperation overseas and to contribute to both the conservation and restoration of tropical forests and is the first step in the establishment of large-scale reforestation. Further elaboration of the contents of the Manual in the future is desirable based on various experiment results and the findings of case studies in Japan as well as in other countries.

1. Objectives of Aerial Reforestation

Some 17 million ha of forests (FAO Report, 1990) are lost every year in the tropics due to the expansion of shifting cultivation, excessive stock raising and the collection of firewood, all of which are the result of an ever increasing population, and also due to intensive commercial felling. The stands which remain are also deteriorating. Despite such critical conditions, many developing countries are able to reforest less than 10% of the forest area which is lost every year. This low level of reforestation has many causes, i.e. shortage of skilled forestry workers, lack of a reforestation system, absence of such reforestation-related infrastructure as nurseries and forest roads and severe financial constraints.

Against this background, realization of large scale reforestation, particularly, "environmental reforestation", has become indispensable for improvement of the Water-source conservation function of forests, for prevention of desertification and for control of global warming, etc. Aerial reforestation with the goal of fast, large-scale, low cost reforestation has now surfaced as an attractive reforestation method which is suitable for "environmental reforestation" projects.

2. Characteristics of Aerial Reforestation

Aerial reforestation which is designed to permit large-scale reforestation in a short period of time has the following advantages and disadvantages.

① Advantages

a) As the work is largely conducted by air, there are few geographical and/or topographical constraints in regard to transportation of material for reforestation.
b) Large-scale reforestation in a short period of time is viable without the involvement of much manpower due to the continuous nature of such work processes as material transportation and seeding.
c) Nurseries are unnecessary as the seeds are sprayed by aircraft.
d) The reforestation cost is lower than reforestation using seedlings.

② Disadvantages

a) The reforestation performance is not fully reliable.
b) Uniform seeding may be difficult, depending on the topography.
c) The sprayed seeds may be washed away by rain or eaten by small animals.
d) Operation may be restricted by such weather conditions as strong wind and fog, etc.

3. Current State of Aerial Reforestation

The aerial reforestation techniques developed in Canada in the 1930's were further developed in the US, New Zealand and Australia, etc. as a means of restoring denuded land and for the reforestation of cut-over sites throughout the 1950's and 1960's. These techniques were adopted in Japan and China in subsequent years for reforestation and forest conservation purposes. The aerial reforestation techniques in these countries have been steadily improving in accordance with technological developments in terms of coating seeds with repellent and/or fertilizer, seeding apparatus, land preparation methods and mixed seeding, etc.

The current aerial reforestation practices of individual countries are outlined in Table I-1.

1. Aerial reforestation has 2 main objectives, i.e. the regeneration of cut-over areas and the revegetation of denuded land. The regeneration of cut-over areas still plays an important part in reforestation work in such vast countries as Australia and Canada although the size of the subject area is becoming smaller. The revegetation of denuded land is mainly conducted in small areas, except China, and usually involves the mixed seeding of woody plants and grass.

2. In order to assist judgement on site suitability for aerial reforestation, a rough site suitability map is commonly prepared in China using rainfall as the criterion. At the implementation design stage, more precise judgement is made on the basis of the vegetation and topographical conditions.

3. The species generally used for aerial reforestation are needle-leaf trees in countries in the temperate zone, such as Canada and the US, and broad-leaf trees in the tropics.

4. The technological development of seed coating, including the mixture of repellent and fertilizer, etc. is fairly advanced in Canada and the US to the level of commercial operation.

5. Aerial reforestation commenced in the US in the 1950's, mainly in the South, using needle-leaf trees to reforest former forest fire areas and former open mining sites, etc. Full-scale operation was conducted in subsequent years, mainly to improve low quality forests. Since 1988, however, aerial reforestation has been losing popularity due to the decline of the felling area in view of the increasing emphasis on environmental conservation and also due to the growing popularity of intensive forestry.

6. Canada commenced aerial reforestation as far back as the 1930's. Since the 1960's, aerial reforestation projects have been implemented to reforest cut-over areas and to improve remote forests. Because of the wide distribution of thick surface soil which is a characteristic of cold regions, land preparation using large machinery is an integral part of aerial reforestation. Efficient spraying apparatus and spraying methods have been developed. While apparatus to drop seedlings from the air has been invented, this apparatus is not yet used in actual operations.

7. The main objective of aerial reforestation in Australia is the restoration of cut-over Eucalyptus forests. As in the case of the US, the increasing concern for environmental conservation has been reducing the size of aerial reforestation operations, resulting in the increased use of helicopters suitable for smaller operations.

8. Aerial reforestation in New Zealand is conducted to prevent soil erosion in areas of high elevation due to excessive grazing and/or topographical factors. The

mixed spraying of woody plant seeds and Leguminosae seeds has been conducted in remote areas with a harsh climate with positive results in preventing frost damage to the former.

9. Fixed wing aircraft have been used in China since the 1950's to spray pine and broad-leaf tree seeds in a variety of areas, ranging from dry regions to humid regions. When implementing aerial reforestation, the competent authority prepares a site suitability map based on the state of vegetation and enforces an entry ban on the spraying area during aerial reforestation operations.

10. Only small-scale aerial reforestation tests have been conducted so far in the tropics. In Indonesia, tests have been conducted on the likely effects of different land preparation methods on the germination rate, seedling survival rate and growth prospect of seeded species in Alang-alang grassland. Leucaena leucocephala and Callianddra calothyrsus have been found to be the most promising species with land preparation using a tractor recording the best results.

As many germinated seeds are burnt to death by the strong sunlight in Nigeria, ground surface coverage is believed necessary. Experimental revegetation work for restoration of denuded lands is underway in Nepal and several other countries using the mixed seeding method.

11. Finally, aerial reforestation commenced in Japan in the 1960's to control erosion at denuded land and the main targets are remote areas with daunting topography. As the spraying area is generally small, helicopters are used. The special features of aerial reforestation in Japan include the development of spraying apparatus and the establishment of technical standards.

Table I-1 Current State of Aerial Reforestation

Country	Year of Commencement and Level of Performance	Main Purpose(s)	Main Species Used	Aircraft Used
USA	Commenced in 1950's. Approx. 1 million ha reforested by 1980 (4-18% of annual reforestation area with some states achieving 50% level)	Reforestation of land devastated by forest fire and others. Improvement of poor stands	Douglas fir and Pinus spp.	fixed wing, helicopter (in southern states)
Canada	Commenced in 1930's. Large-scale application began in 1962 Examples: Ontario (1978) 20,000ha Quebec (1978) 7,000ha	Reforestation of cut-over areas	such needle-leaf trees as Pinus spp. and Black spruce	fixed wing, helicopter
New Zealand	Commenced in 1960's	Watershed reforestation in remote areas	Ladgepole pine (mixed with leguminous plants for rapid soil improvement)	fixed wing, helicopter
Australia	Commenced in 1960's. 8,000ha-12,000ha annually in 1980's. 1,000ha annually in more recent years	Reforestation of cut-over areas	Eucalyptus spp.	helicopter (Bell-206B)
Indonesia	Successful experiments in Barapuran and Riau (38ha and 65ha respectively) in 1970's	Reforestation of Alang-alang grassland	Sesbania grandiflora, Acacia auriculiformis, Leucaena, 3 other species	fixed wing (Piratus PC-6)
China	Commenced in 1958. 878,667ha in 1983. Some 18.6% of entire reforestation area in Szechwan Region between 1958 and 1980	Watershed reforestation	Pinus spp., Astragalus adsuragens, others	fixed wing
Japan	Commenced in 1963. Average area of 100-150ha per operation. Some application at former forest fire sites	Erosion control and reforestation of remote areas	mixed seeding of trees and herbacous plants	various helicopters
Nepal	2 small-scale experiments of 0.67ha and 0.06ha in 1988 (conducted by Naka-Nihon Koku, Ltd. of Japan)	Reforestation of collapsed sites	mixed seeding of trees and herbacous plants	helicopter (SA315B)

Other examples in the following areas:

- Pacific Islands
  Reforestation of Second World War damaged areas with Leucaena. Mixed growth of 15-20 species out of 35 seeded species at former forest fire area on Hawaii Island in 1926.

- Nigeria and India
  Experiment in Nigeria in 1960's using Azadirachta indica. Experiment in Gujarat in India in 1950's to stabilize dunes.

- Soviet Union
  Commenced in 1932 with a reported subject area of 36,100 ha in 1954 and 45,200 ha in 1955.

Continued from opposite page.

Seed Treatment	Land Preparation	Spraying Apparatus	Remarks
Coating using repellent (Endrin, etc.) and adhesion agent. Pre-treatment to stimulate germination	Mechanical tilling and burning in arid areas		Excellent repellent coating and seed mixing technologies although actual operation has been declining since 1988 due to reduction of watershed afforestation areas and felling areas
Coating of repellent and lubricant (not often used)	Burning	Various apparatus for fixed wing or helicopter use	Many soil types been tried. Development of seed spraying methods and apparatus suitable for various types of land preparation
Mixed seeding and fertilizer coating			Used in areas of reasonable rainfall. Development of coating technology and mixed seeding technique to use *leguminous plants*
Repellent, insecticide, colouring agent, coating	Burning	Improvement of spraying apparatus suitable for Eucalyptus spp.	Guidance on seed collection and storage by seed centre. Manuals for aerial reforestation. Consolidation of project implementation system
Mixed seeding	Burning, tilling by tractor. Non-treated seed experiment	Improvement of Canadian apparatus	Experiments on dry soils and on Grumusols soils with severe surface erosion
		Development of own spraying apparatus (suspended type)	Experiments on various soil types. Burning prohibited after spraying. Unclear results. Various scales
Mixture of fertilizer		Improvement of various apparatus	Guidelines for design and implementation of aerial revegetation work. Established technological framework. Development of seed treatment technologies
Mixing agent, adhesion agent, cure agent		Made in Japan	

II. SURVEYS FOR PLAN FORMULATION

1. Examination of Subject Areas for Aereal Reforestation

The urgent implementation of large-scale reforestation projects is necessary to stop the diminution or deterioration of forests and for their recovery. In general, developing countries face the following problems in connection with the efficient implementation of aerial reforestation.

a) Lack of Reforestation System

There are no well developed public or private (forestry cooperatives or similar) organizations responsible for reforestation. The absence of on-site organizations is particularly noticeable.

b) Shortage of Skilled Workers

There is a significant shortage of skilled workers, including on-site supervisors and machine operators.

c) Insufficient Funding and Absence of Subsidy System

In addition to insufficient funding for reforestation (particularly for pioneering investment), a system to smoothly provide subsidies or other forms of funding is not in place.

d) Lack of Infrastructure

Such infrastructural facilities as forest roads, large nurseries and seed orchards, etc., all of which are required for successful reforestation, are not well developed and the reforestation of remote water-source areas is particularly difficult.

e) Others

Organizations are not fully developed to support such reforestation-related activities as forest inventory, forest tree improvement, forest fire-fighting and experimental research.

The conventional reforestation method has various advantages, i.e. ① small quantity of required seeds, ② high survival rate after initial planting, ③ high growth rate, ④ production of timber of uniform, good quality and ⑤ ease of tending. While the cost is high, this method is very reliable. Aerial reforestation can be a useful addition to the conventional reforestation method for the quick restoration of large forest areas in developing countries.

1.1 Candidate Areas

Aerial reforestation is particularly advantageous in the following areas.

a) Remote areas
b) Areas requiring urgent vegetation recovery even if the tree density is low
c) Areas with difficult access
d) Sparsely populated areas
e) Areas in which the production of a large volume of seedlings is difficult
f) Extensive areas requiring reforestation

1.2 Basic Surveys

When planning an appropriate aerial reforestation project, it is necessary to study various basic issues, including such natural conditions as the climate, topography, soil, vegetation and fauna of the subject area, possible constraints on project implementation and project-related socioeconomic conditions. Those issues which are considered particularly important for aerial reforestation are briefly explained below.

(1) Climate

The germination and growth of plant life depend on various factors, including light, temperature, moisture content and nutrients. While these factors are common to almost all plant life, their degree of importance varies from one plant to another. Individual plant species have their own range of adaptability vis-a-vis each factor.

Temperature and rainfall are particularly important and must be referred to when deciding the species to be planted and the timing of seeding, etc. In the case of aerial reforestation, the daily maximum rainfall is crucial to judge the prospect of the successful growth of the sprayed seeds.

The relationship between weather conditions and plant colonies has been classified by many scientists into categories mainly based on the natural state of plant distribution. The usual categories used are vegetation zones and climatic zones and these categories are useful for reforestation attempts (Fig. II-1). The main survey items in the case of climate are as follows.

a) Temperature ... mean annual temperature, mean monthly temperature
b) Rainfall ... annual rainfall, monthly rainfall, maximum daily rainfall

Note: The meteorological data to be used should preferably cover at least 10 years.

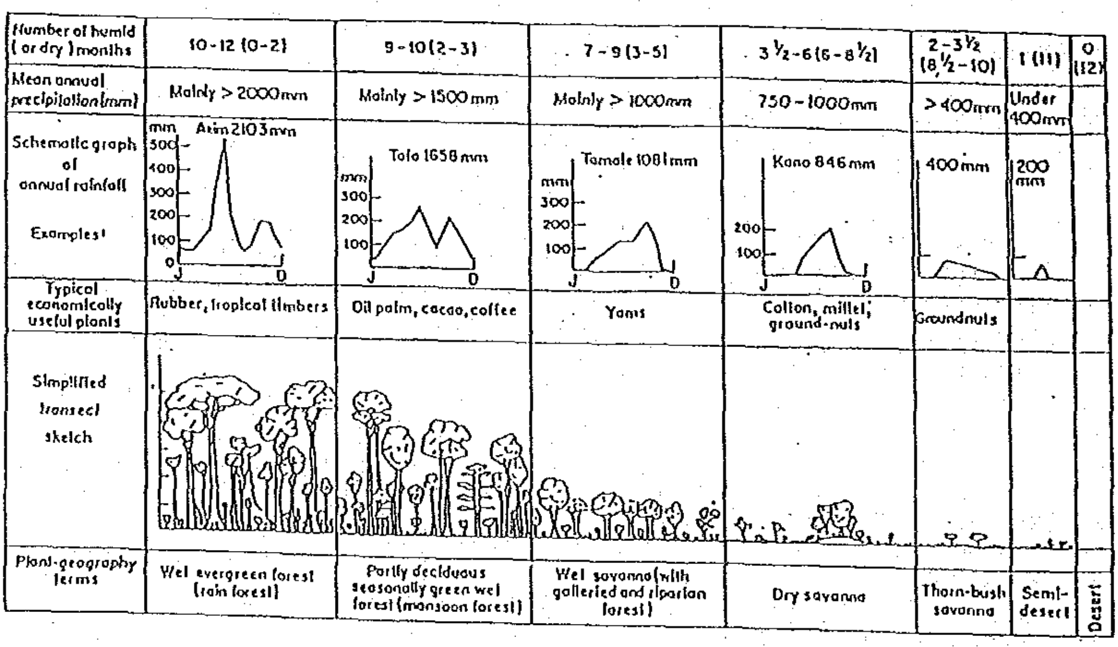


Fig. II-1 Relationship Between Climatic Zones and Vegetation Categories
(Jordan, C.F., 1985,: Nutrient Cycling in Tropical Forest Ecosystems)

(2) Topography

The topography is important in deciding the subject area, base location, degree of difficulty of mechanical work and prospect of ecesis of the sprayed seeds. Topographical maps are often difficult to obtain in developing countries and, in this case, the use of aerial photographs as a supplementary means is effective. The main survey items in the case of topography are as follows.

a) Gradient
b) Elevation

Note: In the case of the aerial seeding of sloping land, downward spraying is limited upto a gradient of 15°. Either upward or oblique spraying must be selected if the slope gradient is more than 15°.

(3) Geology

Since the geological conditions are generally related to the topographical conditions and the causes and types of land devastation, they can be used as planning data for the selection of work methods and locations of aerial revegetation work, hillside foundation work and revegetation foundation work, etc. A survey on the parent material provides useful information on soil properties. The main survey items in the case of geology are as follows.

a) Geological categories
b) Parent material type and conditions of rock fracture and weathering

(4) Soil

A geological survey mainly provides the necessary data for the planning of foundation work while soil data are used to select the planting species and to estimate plant growth and the necessity for fertilizer, etc. In the case of aerial reforestation, it is sufficient to confirm the existence of problematic soils vis-a-vis reforestation. Consequently, it is sufficient to select the most representative sites in terms of topography and vegetation and to conduct a soil survey at these sites.

1) Soil Texture

There are several ways of classifying soil texture. As soil texture is mainly used to judge the adaptability of plants, the introduction of such categories as sand, sandy soil, clayey soil, gravel, soft rock and hard rock is sufficient. Sandy soil dries faster than clayey soil while gravel is said to have a relatively good germination performance after aerial seeding as the gravel protect the seeds from drying. When most parts of an area are covered by hard rock, the area is unsuitable for aerial reforestation.

2) Soil Hardness

Tropical soil is often very hard and has extremely poor physical properties as it has undergone frequent burning due to shifting cultivation and grazing. Soil hardness relates to plant growth, development of the root system and the bearing capacity of soil and is measured using a relevant tester. One such device is the Yamanaka-type soil hardness tester which uses the repulsive power of a spring coil. The hardness is indicated by both bearing capacity and index scales. The latter is used to determine the soil suitability for plant growth. The relationship between the hardness index and plant growth, development of the root system and the bearing capacity is shown in the table below.

Hardness Index	Plant Growth
Less than 18mm	Good prospect of plant growth but a risk of landslides in sloping areas due to soil softness
18 - 23mm	Most suitable for root system development
23 - 27mm	Plant growth is possible but mainly poor growth
27 - 30mm	Plant growth is difficult due to soil hardness but a root system may develop provided the soil has sufficient pore space
More than 30mm	Root system development is impossible

3) Soil Acidity

Strong acid soil due to shifting cultivation and other reasons is often found in the tropics. While the use of soil improvement agents is possible, it is firstly necessary to select species with a strong resistance to acid soil in the case of aerial reforestation.

Given the same degree of acidity, plants generally fare better in soil which is rich in nutrients. Consequently, it is often sufficient to add fertilizer to relatively strong acid soil to allow plant growth.

Very strong acid soil (in general, pH of 4.0 or below) causes inferior germination or the premature death of young seedlings and, therefore, must be neutralized by lime. Lime application should be kept to a minimum, however, because of (i) the difficulty of mixing lime and soil, (ii) the diminishment of fertilizing effects following the simultaneous use of lime and fertilizer and (iii) possible chemical damage to seeds.

Soil acidity (pH) is determined using a pH meter or pH paper. A pH value of upto 3 is described as strongly acid. Similarly, weak acidity, neutrality, weak alkalinity and strong alkalinity correspond to the pH values of 4-6, 7, 8-10 and 11 or more respectively. The main survey items in the case of soil are as follows.

a) Distribution of soil types
b) Soil texture
c) Soil hardness
d) Soil acidity (pH)

(5) Vegetation

A vegetation survey focuses on plant growth, particularly in the case of such species as Alang-alang (Imperata cylindrica) which grows vigorously in savanna and grassland in the tropics. It is also necessary to study the original vegetation of a candidate reforestation site based on the original types of vegetation, vegetation density and growth conditions in neighbouring forests in order to identify the natural regeneration conditions of the dominant species. A vegetation survey provides the necessary data for reference and the selection of appropriate species and varieties for reforestation purposes.

(6) Socioeconomy

Aerial reforestation is an effective means of reforestation for remotely located areas, areas with difficult access, areas where the recovery of vegetation (forest) is urgently required even if the planting density is sparse and steep sloping areas where manual planting is difficult. In general, these areas are sparsely populated and have little infrastructure. In addition, socioeconomic data are usually unavailable.

When planning an aerial reforestation programme for such areas, it is essential to obtain as much related information and data as possible. Preliminary investigation and examination by means of interviews and aerial photographs should also be conducted in regard to the local availability of labour, construction materials and equipment, etc., including the possible transportation method of such materials and equipment. The main survey items in the case of socioeconomy are as follows.

a) Distribution of population and settlements
b) Living conditions of local inhabitants and local industries
c) State of infrastructure, including that of neighbouring areas
d) National and/or regional plans and other future plans affecting the area in question
e) Social requirements vis-a-vis such environmental aspects as water utilization, landscape and ecosystem, etc.

1.3 Land Use-Vegetation Survey Using Satellite Data

A survey using satellite data and/or aerial photographs is useful to identify vegetation and land use conditions over an extensive area.

(1) Available Satellite Data

The main satellites from which data can currently be used for aerial reforestation purposes are LANDSAT, SPOT and MOS (Table II-1). The image data from these satellites have the following characteristics.

① They contain of the latest information and also indicate time series changes through repeated observations over wide areas.

② As they allow digital processing, objective, physical interpretation of the data is possible. The resulting statistics can be efficiently processed by using computers.

③ They allow a free and quick visual representation due to their integration with an image processing system.

There are several levels on which image data can be used depending on the size of the subject area and the degree of required accuracy, ranging from the visual interpretation of synthesized images to interpretation by pixel based on digital processing. When the subject area is as large as one million ha or more, visual interpretation of the synthesized images is efficient. The scale of usable images in this case depends on the pixel size (minimum observation area) of the satellite's sensor. LANDSAT MSS data and MOS-1 data have an approximate scale of 1:200,000 while LANDSAT TM data and SPOT PX data have an approximate scale of 1:100,000 and 1:50,000 respectively, all of which are smaller than the scale provided by aerial photographs.

The interpretation of satellite image data is conducted on different levels depending on specific data and the standard of the technologies applied (Table II-2). In the case of Landsat data, Levels 1 and 2 and part of Level 3 can be interpreted. Table II-3 gives the interpretation criteria for LANDSAT image data.

Table II-1 Earth Observation Satellites and Sensors Used

Satellite	Orbit	Sensors	
		Main Sensors	Main Specifications
LANDSAT-4 (1982) LANDSAT-5 (1984)	Sun-synchronous Altitude - approx. 705km Inclination -approx. 98° Recurrence period - approx. 2 days Observation cycle - 16 days	TM (Thematic Mapper)	- Visible and near infrared: 4 bands - Intermediate and near infrared: 2 bands - Thermal infrared: 1 band - Resolution: 30m (visual near infrared), 120m (thermal infrared) - Observation width: 185km
		MSS (Multispectral Scanner System)	- Visual near infrared: 4 bands - Resolution: 80m - Observation width: 185km
SPOT-1 (1986) SPOT-2 (1987) SPOT-3 (1989)	Sun-synchronous Altitude - approx. 832km Inclination - approx. 99° Recurrence period - approx. 5 days Observation cycle - 26 days	HRV (High Resolution Visible Range Instruments)	- Visible and near infrared: 4 bands (1 for P and 3 for PX) - Resolution: 20m (10m for monochrome) - Observation width: 60km x 2 - Off nadir observation: +26°N -26°
MOS-1 (1987) MOS-16 (1989)	Sun-synchronous Altitude - approx. 909km Inclination - approx. 99° Recurrence period - approx. 17 days Observation cycle -18 days	MESSR (Multispectral Electric Self-Scanning Radiometer)	- Visible and near infrared: 4 bands - Resolution: 50m - Observation width: 100km x 2
		VTIR (Visible and Thermal Infrared Radiometer)	- Visible: 1 band - Thermal infrared: 3 bands - Resolution: 0.9km (visible) and 2.7km (thermal infrared) - Observation width: 1,500km
		MSR (Microwave Scanning Radiometer)	- Frequencies: 23.8 GHz and 31.4 GHz - Resolution: 31km (23.8 GHz) and 22km (31.4 GHz) - Observation width: 317km

Table II-2 Levels of Ground Interpretation Using Remote Sensing Data

Level 1	Level 2	Level 3	Level 4	Remarks
Covered by vegetation or rich vegetation	Forests	- Needle-leaf forests - Broad-leaf forests - Pine forests - Others	- Forest type - Density class - Hight class - Degree of mixture	Identification of man-made forests and natural forests and distinction between deciduous and evergreen trees of main species (including Pinus pumila and bamboo)
	Grassland	- Natural grassland - Man-made grassland - Denuded land - Others	- High grass, turf or bushes - Density class - Others	Identification of fields, grazing land, golf courses, bush land and swampy grassland, etc.
	Farmland	- Cereals - Vegetables and root crops - Orchards - Unused farmland - Others	- Maturity - Cereal species - Soil type - Humidity - Others	Identification of paddy rice, wheat, dry field rice, potatoes, vegetables, mulberry, tea plants and orchards, etc.
Little or no vegetation	Bare Land	- Developed land - Naturally bare land - Deserts - Rocky land - Volcanic ejecta - Others	Identification of quarries, reclaimed land, dried grass, collapsed land, rock outcrops, lava, sandy beaches, gravel beaches, river banks and playing fields, etc.	- Geological type - Soil type - Classification based on origin
	Urban Area Settlements	- Residential areas - Factories - Special Facilities - Roads - Settlements - Others	- High density urban areas - Urban areas with low buildings - Large flats - Transport, distribution and port facilities - Others	Identification of residential areas, commercial areas, playing fields, groups of greenhouses, oil tanks, railways and trunk roads, etc.
Water bodies	Rivers, Lakes, Sea, Swamps	- Clear or turbid water - Reservoirs - Water Channels - Chlorophyl grains	- Ingredients of turbidity - Degree of turbidity - Quantity of chlorophyll grains	
Snow/Ice		- Snow covered areas - Ice-covered areas	- Snow or ice type	
Cloud Cover				

Note: The interpretation accuracy is improved by the use of data on the same subject observed in different seasons.

Table II-3 Interpretation Criteria for LANDSAT Images

Item	Colour	Texture	Appearance Pattern	Location	Others
Forest	bright red	smooth and uniform	-	undulating mountain areas	-
Alang-alang	cream-pink	possible mosaic pattern depending on density of colony	-	unopened land or former farmland	different shades of colour depending on growth stage
Plantation	dull red-bright red	fine unevenness	often clearly compartmented by straight lines	-	as above
Paddy Field	cream-pink	smooth and uniform	as above	irrigatable lowland near river	whitish shade for dry field and reddish shade for watered field
Swamp	greeny red	fine unevenness if a swamp forest exists	-	lowland	-
Water Body	dark blue	smooth and uniform	-	river/lake	-
Settlement	greyish blue	-	rectangular shape or small clump	scattered along main road	-

(2) Obtaining of Satellite Data

LANDSAT data are quite useful as they provide periodic information. These data are controlled by ground stations and can be obtained or checked in the following manner.

① Firstly, find the LANDSAT orbit which covers the subject area on the LANDSAT coverage map. LANDSAT data are qualified by the Path Number (north-south) and Row Number (east-west). The circle mark on the map indicates the center of the orbit. Each LANDSAT data scene covers an area of 180km by 180km and overlaps with neighbouring scenes in the range of 20 - 30km.

② Using the cloud coverage list, then examine suitable cloud cover and image quality dates. Even if a particular scene has high cloud coverage, the study area may be void of cloud. In this case, it is possible to check the cloud locations with quick-look photographs.

③ Once the desired scenes have been decided on, they can be obtained from a remote sensing centre (in Indonesia, the National Indonesian Space Agency, Institute for Aeronautics and Space: LAPAN).

④ There are 2 types of data, i.e. analogue data (photographs) and digital data (magnetic tapes). Select the type of data required in accordance with the purpose of use.

1.4 Land Use-Vegetation Survey Using Aerial Photographs

(1) Interpretation of Aerial Photographs

Aerial photographs are not only used for the preparation of topographical maps but also for the preparation of various plans through their interpretation. The interpretation of aerial photographs usually consists of 2 stages, i.e. firstly wide area interpretation is conducted to summarise the subject area which is followed by more detailed interpretation to provide information for the preparation of a project implementation plan, etc.

a) Wide Area Interpretation

This aims at the rough identification of the vegetation, land use and other aspects of the subject area and the work involved is identification of the large-scale and medium-scale categories in Table II-4. It is useful if the interpretation results are entered onto topographical maps.

b) Detailed Interpretation

This aims at obtaining detailed information for the preparation of a project implementation plan and the work involved is identification of the small-scale categories in Table II-4. Again it is useful if the interpretation results are entered onto topographical maps. Moreover, on-site verification of the interpretation results is desirable to ensure their accuracy.

Table II-4 Vegetation and Land Use Interpretation Items (Examples)

Large-Scale Category	Medium-Scale Category	Small-Scale Category
a. Forests	1. Natural forest	Height classes, density classes
	2. Secondary forest	as above
	3. Low tree forest	
	4. Bush land	
	5. Regeneration area	Man-made forest, plantation
	6. Cut-over site	
	7. Mangrove forest	
b. Farmland	8. Farmland	Dry field, paddy field, orchard
	9. Former farmland	
c. Grassland	10. Natural grassland	
	11. Grazing land	natural grassland, man-made grassland
d. Denuded land	12. Gravel land	riverbed, sand bank, outcropped land
	13. Collapsed land	
e. Swamp	14. Swamp grassland	
	15. Swamp forest	
f. Rivers, Lakes		
g. Settlements, Facilities		
h. Roads		
i Others		

(2) Obtaining of Aerial Photographs

It is often difficult to obtain aerial photographs in developing countries because of military reasons. Official approval may be required to remove them from the country if this is not totally prohibited It is recommended that the official organization responsible for the intended study be requested to obtain such photographs. The taking of new photographs may be necessary as the available photographs are frequently out of date.

2. Aerial Seeding Species

2.1 Selection of Plant Species

The species to be selected for aerial seeding should be in line with the project targets and policies and should meet the following conditions as much as possible.

a) Good adaptability to a wide range of weather conditions
b) Good adaptability to a wide range of soil conditions

c) Prospect of vigorous germination and growth, particularly at the early stage
d) Prospect of luxuriant growth with a well-developed root system together with excellent land coverage and soil holding effects
e) Prospect of soil improvement effects for higher productivity
f) Strong resistance to the harmful effects of insects and diseases, etc.
g) Availability of seeds in large quantity
h) High germination rate even after a relatively long storage period

The main species in the tropics have the following growth characteristics.

a) Species Resistant to High Temperatures

Tropical pines (Pinus caribaea), Leucaena leucocephala, the Acacia families (Acacia mangium and Acacia auriculiformis), Albizia falcataria and such leguminosae plants as Parkia spp. Casuarina spp. and Tectona grandis (this species requires a dry season), etc. continue to grow even if the temperature is very high (35°C or higher).

b) Species Resistant to Dryness

Species which are highly resistant to dryness under high temperatures include Pinus caribaea, Acacia mangium, Acacia auriculiformis, Prosopis spp., Casuarina spp. and some types of Eucalyptus spp.

c) Species Resistant to Acidity

Poor soil containing pyrite is often found in the tropics and sulphuric acid originating from this pyrite causes problems in regard to plant growth. Species which can grow in such acid soil include Acacia mangium and Agathis spp.

The immediate objective of large-scale reforestation is the growing of trees on devastated land to contribute to environmental conservation. It is, therefore, essential for the seedlings to rapidly grow to form a forest. The aerial reforestation method cannot fully guarantee the creation of uniform forests. Should a uniform forest be created, however, natural regeneration may be opted for in subsequent years to enlarge the forest in order to guide it towards a closed forest. The spraying of seeds of those species with the following characteristics is desirable to make this option viable.

① Maturity in 2 - 3 years to produce seeds for natural regeneration
② Reproduction by means of root system or rhizomes
③ Regeneration by sprouting

Acacia spp. (Acacia mangium and Acacia auriculiformis, etc.) and Leucaena leucocephala are the best examples of species which start to produce seeds within a few years and have strong sprouting ability.

2.2 Procurement of Seeds

As aerial reforestation uses a large quantity of seeds in a short period of time (see III.1-3 - Calculation of Required Seed Quantity), study of the following for each species is essential prior to the preparation of a seed spraying plan.

① Production records and production plan
② Storage volume
③ Import records and possibility of export from countries of production
④ Other plans to use seeds for traditional reforestation activities (man-made reforestation)

2.3 Physiological Characteristics of Seeds

Depending on the species, seeds have the following morphological and physiological characteristics which must be taken into consideration when deciding on seeds for aerial reforestation purposes.

① Determination of the quality of seeds by appearance is quite difficult in the case of gymnosperm and needle-leaf species because the formation of seeds without any connection to embryo development tends to produce many blind seeds.

② In the case of dicotyledon, there are embryo plants which require albumen for the development of the embryo during the germination process and embryo-less plants with which cotyledon develops to store nutrients and opens up to start the photosynthesis process. The latter can grow under poor germination and growth conditions. The main embryo-less species are as follows.

- o Leguminoceae: Acacia spp., Prosopis spp., Robinia pseudoacacia, Leucaena leucocephala, Albizia falcataria and Intsia bijuga

- o Other species: Alnus spp., Eucalyptus spp., Betula spp., Salix spp., Populus spp., Tamarix juniperina, Ulmus spp. and Casuarina spp.

③ In the case of some seeds where nutrients are stored in cotyledon, the cotyledon only acts as a storage and does not conduct photosynthesis. Here, while the cotyledon does not open up and remains underground, epycotyl grows. Cotyledon which does not open up is described as hypogeal and Aesculus sp., Castanopsis spp., Pasania spp., Quercus spp., Corylus spp. and some types of Depterocarpaceae produce such seeds. These seeds die when they become dry.

④ It is possible to reduce the moisture content of some seeds to less than 10% of the dry weight so that they become physiologically inactive. Their physiological vitality revives through the absorption of water during the germination process. As these seeds can be stored without damage under normal temperatures, they present excellent handling scope. Seeds of the following species have this characteristic.

- o Needle-leaf trees: Pinus spp., Picea spp. and Abies spp.

- o Leguminoceae: Acacia spp., Leucaena leucocephala, Prosopis spp., Albizia falcataria, Intsia bijuga and Dalbergia cochinchinensis

- o Other species: Eucalyptus spp., Populus spp., Alnus spp., Betula spp., Tamarix juniperina and Ulmus spp.

⑤ The seeds of Quercus spp., Aesculus sp., Citrus spp. and Depterocarpaceae do not lose much water during the process of maturing and the seeds have a high moisture content after maturity. These seeds have vigorous physiological vitality even after maturity, releasing water through respiration and transpiration during storage and may germinate through the reabsorption of the water released by themselves. Some of these seeds with a high water content are resistant to low temperatures while other die at temperatures under 15°C. Many seeds of Depterocarpaceae with a high water content cannot survive in low temperatures. These seeds must, therefore, be classified as those which can survive in low temperatures (0°C - 15°C) and those which can only survive at temperatures above 15°C and must be handled accordingly.

2.4 Judgement of Seed Quality

The judgement of seed quality is mainly based on the following principles.

① Seed quality is usually judged in terms of the germination rate and purity. The germination rate is defined as the ratio of germinated seeds in all seeds and is dependent on the seed collection and storage methods, the timing of collection and the time elapsed after collection.

② As seeds are usually mixed with foreign matter, the weight ratio of pure seeds in the total weight is shown as purity in percentages.

③ The weight of seeds (often shown as the number of seeds/unit weight) is an important factor in the judgement of quality. Those seeds with a below average weight have many blind seeds and are, therefore, inferior.

④ As calculation of the required seed quantity is based on the germination rate and purity, the required seed quantity must be adjusted on the basis of purity to achieve the expected germination rate.

⑤ Germination tests should be conducted to determine the germination rate of those seeds without a certificate, collected a long time ago or with an unclear germination rate.

2.5 Germination Rate and Number of Seeds/Unit Weight

The number of seeds/unit weight, which is an important factor to determine the spraying quantity, depends on both the species and the timing of seed collection and seed maturity, etc. Table II-5 shows the number of seeds/unit weight and the average germination rate of the main species.

The germination rate of Acacia mangium and Acacia auriculiformis which were experimented with in South Kalimantan, Indonesia was 40 - 70% using planters but as low as around 10% in the case of direct seeding in the ground. In view of such a large difference, it is necessary to consider the germination rate based on direct seeding when deciding the required seed quantity in addition to the calculation of such quantity based on available documents and records.

As seeds directly sprayed onto the ground can be eaten by birds or damaged by insects, the possible damage rate should be taken into consideration in the direct seeding test.

Table II-5 Number of Seeds/Unit Weight and Methods to Stimulate Germination of Main Species

Species	Number of Seeds/Kg	Treatment Method(s)	Average Germination Rate (%)
Acacia albida	20,400-40,000	CSA (2)	45-75
A. auriculiformis	8,200-89,200	CSA (2), HW/BW (1)	40-80
A. mangium	40,000-70,000	BW (2), HW (80°C, 15 mins)	80
A. nilotica	1,700-11,000	CSA (1), BW (1)	60-90
A. senegal	7,900-33,000	CSA (2)	70-100
A. tortilis	12,000-16,100	CSA (2)	45-80
Albizia falcataria	40,900-50,000	HW/BW (1)	60-90
A. lebbek	6,000-16,000	CSA (1, 2), BW (1)	50-85
Anacardium occidentale	175-300	water	60-90
Anogeissus leiocarpus	112,000-120,000	CSA (?)	30-70
Anthocephalus chinensis	1,000,000-2,600,000	not required	
Araucaria cunninghamii	1,900-3,400	not required	30-70
A. hunsteinii	1,700-1,800	not required	
(seeds without wings)	2,000-2,500	-	
Azadirachta indica	2,800-6,300	water (12 hours)	35-65
Calliandra calothyrsus	19,500	HW (?)	
Cassia siamea	9,900-45,000	CSA (1), BW (1)	50-85
C. spectabilis	31,000-35,000	HW (1)	15-50
Casuarina equisetifolia	183,000-1,000,000	water (12 hours)	30-70
Cedrela odorata	30,000-227,200	not required	50-85
Cupressus lusitanica	7,200-250,000	not required	25-60
Dalbergia sissoo	12,000-52,800	CSA (3)	70-100
Eucalyptus camaldulensis	90,000-400,000	water (12 hours)	55-90
E. citriodora	108,000-1,240,000	water (12 hours)	60-90
E. cloeziana	141,000-3,605,000	water (12 hours)	45-80
E. deglupta	1,400,000-4,210,000	not required	35-65
E. globulus	70,000-350,000	not required	60-90
E. grandis	632,000 (200,000-3,000,000)	not required	35-65
E. microtheca	200,000-450,000	not required	70-100
E. paniculata	112,000-336,000 (-460,000)	not required	30-70
E. robusta	415,000 (140,000-1,000,000)	not required	45-80
E. saligna	25,000-2,000,000	water (12 hours)	55-90
E. tereticornis	90,000-4,000,000	water (12 hours)	55-80
E. torelliana	263,000-800,000	not required	30-70
E. urophylla	210,000-456,000	not required	
Gmelina arborea	400-3,000	CSA (3)	40-80
Grevillea robusta	51,000-150,000	water (24 hours)	30-90
Khaya senegalensis	2,500/3,200-18,000	water (12 hours)	70-100
Leucaena leucocephala	13,000-34,000	HW (1)	50-85
Melia azedarach	475-2,800	not required	55-85
Octomeles sumatrana	4,000,000	not required	
Parkia biglobosa	2,800,5,000	CSA (1)	75
Pinus caribaea var. hondurensis	46,000-200,000	water (15 hours)	70-100
P. merkusii	28,000-59,000	not required	60-70
P. oocarpa	38,000-78,000	water (15 hours)	70-100
P. patula	88,000-140,000	not required, cold treatment (60 days)	
P. radiata	28,000-37,540	cold treatment (1-3 weeks)	80
Prosopis africana	2,900-6,500	CSA (30 mins)	42
P. juliflora	8,000-30,000	scarification, CSA (?)	80-90
Pterocarpus indicus	1,100-2,100	HW(1), CSA (30 mins)	30-70
Sesbania grandiflora	17,000-20,000	not required	85-90
S. sesban		not required	
Swietenia macrophylla	2,000-2,500	not required	70
Tamarindus indica	700,2,600	BW (2), CSA (30 mins)	30-70
Tectona grandis	1,250-3,100	repeated water absorption and sun drying (24 hours)	60-80
Terminalia catappa	150-860		
T. ivorensis	5,500-6,600	-	
Triplochiton scleroxylon	3,000	repeated water absorption and drying	
Zizyphus mauritiana	650-3,500	not required -	

Notes

1) This table is mainly based on a similar table prepared by von Carlowitz (1986).
2) The number of seeds/kg varies from one document to another. The figures in the table indicate the approximate range.
3) The figures for Eucalyptus spp. are based on data provided by the FAO (1972). As Eucalyptus seeds contain a large quantity of sterile ovules called chaff, the number of seeds/unit weight largely varies depending on the rigorousness of the selection process.
4) Treatment Methods
   - o CSA (concentrated sulphuric acid) (1) : 5 - 15 minutes
     (2) : 20 - 3 minutes
     (3) : 45 - 60 minutes
     (?) : time length decided on each occasion

   In all cases, the seeds must be thoroughly washed by water and left soaking in water overnight.
   - o HW (hot water) : 12 hours in hot water (50°C?)
     (?) : time length decided on each occasion
   - o BW (boiling water) (1) : soaked in boiling water and then naturally cooled
     (2) : 3-5 minutes
   - o Repeated water absorption and sun drying: either repeated every 2 - 3 days or every day.
   - o Even if no treatment is required, it is preferable to soak the seeds overnight before seeding.
5) The germination rate considerably varies depending on the seed conditions. The figures in the table are approximate.

3. Suitable Sites for Aerial Reforestation

3.1 Principles

Suitable sites for aerial reforestation are likely to have the following conditions which must be taken into consideration when planning aerial reforestation.

a) Remote area
b) Urgent necessity to restore vegetation even if still rather sparse after restoration
c) Difficult access by land
d) Sparsely populated area
e) Difficult to produce a large quantity of seedlings locally
f) Need for large-scale reforestation

Not all species are likely to germinate and grow under the above conditions. As each species has its own specific growth conditions, the adaptability of the species of which the use is under consideration for aerial reforestation to the natural conditions of the site in question must be carefully examined.

3.2 Suitability Based on Natural Conditions

The following natural conditions must at least be taken into consideration when determining the suitability of a particular species for a particular reforestation site.

a) Climate (temperature and rainfall)
b) Topography (elevation, gradient and bearing)
c) Geology (parent materials)
d) Soil (soil texture, hardness and dryness/wetness)
e) Vegetation (type, coverage and succession)
f) Land use

Data on the above items can be collected from meteorological statistics (meteorological charts), soil maps, topographical maps, vegetation maps, aerial photographs and/or field survey results. The final decision on land suitability for aerial reforestation must be made in an integrated manner through the evaluation of such data. The preparation of a site suitability map may prove useful.

o Climate

Reasonable rainfall and temperature levels are required for the germination and growth of seedlings. In the tropics, rainfall is more important than temperature for plant growth. There is a risk of the seeds being washed away if the monthly rainfall is 300mm or more. The yardstick for suitability in terms of the monthly rainfall is 100 - 200mm and the subject site or season must be decided based on this yardstick. In addition to rainfall, the duration of the dry season also strongly affects the germination and growth of seeds in the tropics.

o Alang-alang

The density of Alang-alang is one of the most crucial factors affecting the selection of a suitable site. The direct seeding test results suggest that an Alang-alang density of 800 - 1,000g/m^2 is the limit to tolerate the germination and growth of seeded species.

o Topography

Steep slopes are unsuitable for the establishment of seeds. In contrast, gently undulating hills are suitable for reforestation. The demarcation point is a slope gradient of 20°. Some type of engineering work is necessary for slopes with a gradient of between 20° and 40° to ensure the establishment of seeds while the introduction of an erosion control or forest conservation-type work is desirable for slopes with a gradient of more than 40°.

o Soil

If the subject site is characterised by a soil type which is generally problematic in terms of the germination and growth of seeds, the site should, in principle, be classified as unsuitable. Nevertheless, it is necessary to consider the degree of unsuitability prior to rejecting the site. One reason why further consideration is necessary is that certain species, including Acacia mangium, have a strong resistance to acidy soil which is fairly common in the tropics.

- Commonly used soil texture categories are sand, sandy soil, clayey soil, gravel soil, soft rock and hard rock. Gravel soil is advantageous because it protects the seeds from drying up and is said to be a relatively good germination bed. Hard rock is unsuitable for seeding purposes.

- The soil hardness affects plant growth, development of the root system and the bearing strength. A hardness value of 18 - 23mm is said to be the best for plant growth and development of the root system while a hardness value of 30mm or more implies that the soil in question cannot be penetrated by the root system.

4. Land Preparation

4.1 Principles of Land Preparation

The objective of land preparation is the creation of good environmental conditions for the establishment, germination and growth of the sprayed seeds. While the forest floor conditions and necessity to conduct land preparation are discussed below, it must be noted that the scale of such preparation in association with aerial reforestation activities must be kept to a minimum to achieve a low operation cost which is by definition an over-riding reason to opt for aerial reforestation.

The forest floor of the subject reforestation area should be classified into one of the following types.

① Outcrop of a mineral soil layer (A horizon) with little existence of an organic matter layer (Ao horizon - litter, fermentation layer and humus layers) ... devastated land

② Many branches and tops with a thin organic matter layer ... former cut-over area

③ Many branches and tops with a thick organic matter layer ... former cut-over area

④ Much surface grass with a thin organic matter layer ... former savannah, deteriorated due to repeated burning (shifting cultivation) and other reasons

⑤ Much surface grass with a thick organic matter layer ... land subject to shifting cultivation but not as deteriorated as type ④

As former cut-over sites with abundant branches and tops on the floor are presumably selected for intensive reforestation using seedlings or through natural regeneration with a view to producing fine woods, the selection of such sites for aerial seeding is exceptional. A thin organic matter layer is very common in the tropics at former shifting cultivation sites or land subject to repeated burning due to the rapid decomposition of organic matter. Consequently, the likely subject areas for aerial reforestation in the tropics are believed to be mainly classified as Type ① or Type ④.

The relationship between these forest floor types and land preparation is discussed next.

a) The Type ① forest floor is found at such devastated land as collapsed sites or volcanic areas. There is no necessity for land preparation in the case of this type of forest floor. While the land is suitable for aerial reforestation, it often lacks such soil nutrients as nitrogen, phosphorous, potassium and lime.

b) Type ② and Type ③ with many branches and tops and Type ④ and Type ⑤ with much grass undergo frequent burning. When the organic matter layer is thin, the burning of branches, tops and grass also burns the soil's organic matter layer to ash, exposing the mineral soil layer. When the organic matter layer is extremely thick, mechanical land preparation may be required after burning. As Type ⑤ is rare in the tropics, there should not be many places requiring mechanical land preparation after burning. Land preparation by burning can cover a large area at one time and is, therefore, generally much cheaper than the mechanical method depending on the size of the subject land. Given the fact that burning is, in principle, prohibited in Indonesia, however, the relevant national regulations must be checked prior to the planning of burning.

c) In general, as an organic matter layer is not prominent in the tropics, there should be few occasions on which mechanical land preparation is necessary. Nevertheless, mechanical preparation is necessary in the following cases.

   ① To improve the physical characteristics of soil, particularly to reduce high soil hardness
   ② Furrowing by disk plough at arid areas
   ③ Furrowing by disk plough at swampy land for water drainage
   ④ To assist seed establishment and growth in areas with dense tall grass

d) To reduce the competition against weeds after germination, burning or mechanical land preparation may not be sufficient. In this case, a herbicide could be used with good results. The use of any herbicide, however, must be carefully examined in view of its possible negative effects on the environment and human life.

4.2 Types of Land Preparation

The main land preparation methods applicable for aerial reforestation are burning and mechanical preparation.

① Burning

Burning is an efficient method of removing vegetation, branches, tops and dead trees, etc. on the ground surface. While the employment of this method in an extensive area is possible, it must be conducted in small zones to prevent the spread of fire. For some species, burning both before and after seeding can stimulate germination and survival. Burning is obviously an effective method for these species.

② Mechanical Preparation

Mechanical land preparation is conducted by a tractor with or without such attachments as a blade, plough or disk plough. There are, in fact, several types of mechanical preparation as described below.

a) Clearing : removal of ground surface vegetation using a blade attached to a tractor
b) Ploughing : removal of ground surface vegetation using a plough or rotovator attached to a tractor
c) Furrowing : crushing of soil and cutting of roots using a furrow attached to a tractor
d) Rippering : soil scarification using a ripper attached to a tractor
e) Dozing : light cutting of a sloping surface using a blade attached to a tractor to create a work road

While mechanical preparation can be used for sloping land of around 15°, it is necessary to check the possible effects of soil excavation and the suitable season for operation in advance in view of soil conservation.

In this context, it is worth noting that mechanical land preparation using a rotovator and disk plough at Alang-alang grassland in South Kalimantan, Indonesia resulted in the creation of denser grassland and the vigorous growth of Saccharum sp., probably because of the fertility of the soil. The possibility of such an outcome should be considered prior to the use of the mechanical method. The use of herbicide is a possible land preparation method but the effects of herbicide on the natural environment and on human life should be carefully examined in advance as already mentioned earlier.

4.3 Land Preparation

Land preparation can be conducted by either burning or mechanical means as described in 3.2.

① Burning

In the case of sloping land, burning should commence at the top side provided there is no wind. If there is a wind, it is common to commence burning at the bottom side of the slope.

② Mechanical Preparation

There are many combinations to conduct mechanical preparation as shown below. The selection of the best combination is necessary depending on the project objectives, location of the subject area and the degree of necessity for such operation.

o Clearing - Ploughing - Furrowing
o Clearing - Ploughing
o Clearing - Furrowing
o Clearing
o Dozing - Ploughing
o Dozing

5. Aircraft

5.1 Selection of Aircraft

The following conditions should be taken into consideration in the selection of appropriate aircraft for aerial seeding.

① The aircraft can be either the fixed wing type or rotor blade type (helicopter).

② The selection of either a fixed wing aircraft or helicopter should be based on the topography and size of the subject area, expected seeding quantity/unit area, flight base location and estimated cost, etc.

③ Aircraft selection should also be based on thorough examination results in terms of the types of materials to be transported, maximum unit weight, container shape, total transportation weight, transportation period and conditions of work sites, etc. The selected aircraft must be capable of meeting all requirements and of economical operation.

The main fixed wing aircraft and helicopter characteristics are listed below.

Helicopter

① Suitable for areas with many steep slopes and undulations
② Excellent mobility
③ Variable seeding speed (from high speed to low speed to hovering) to permit careful spraying
④ Larger loading capacity than a small fixed wing aircraft
⑤ Fewer constraints on taking-off and landing, making the flight distance to the target area shorter
⑥ Swift loading of materials and seeding operation depending on seed spraying apparatus
⑦ Skill required for seed spraying operation
⑧ More expensive hardware than a fixed wing aircraft

Fixed Wing Aircraft

① Suitable for wide area seed spraying with low spraying density
② Suitable for land with few undulations, such as flat land or gently sloping land
③ Careful seed spraying is difficult due to a faster flying speed than a helicopter
④ Small loading capacity as a small aircraft is usually used
⑤ Some constraints on taking-off and landing as an airstrip is required
⑥ Long loading hours
⑦ Less expensive than a helicopter

5.2 Spraying Method

The selection of the spraying method to be used is mainly based on the scale of operation, such land conditions as soil type and inclination, spraying apparatus to be used and types of sprayed materials. The work efficiency and reliability of spraying are additional factors in the selection of the spraying method. Spraying method selection criteria are given in Table II-6 while possible spraying methods are illustrated in Fig. II-6.

Table II-6 Spraying Method Selection Criteria

Conditions	Method
Occasions other than those below	single spraying slurry method
When the single spraying slurry method cannot assure uniform spraying due to site conditions and/or the type of spraying apparatus used	dual or triple spraying slurry method
When the seed establishment and growth conditions are particularly poor or when the growth of woody plants must be assured	base method

① Slurry Method

This method involves the uniform spraying, using a tank or bucket, or slurries in which seeds, fertilizer, erosion prevention agent and others are mixed together. There are several ways of doing this, i.e. (i) the single spraying slurry method where all the materials are mixed together and sprayed at once, (ii) the dual spraying slurry method where an erosion prevention agent (particularly an asphalt emulsion) is sprayed on top of the previously sprayed mixture of all materials excepting this agent and (iii) the triple spraying slurry method where the spraying of erosion prevention and soil improvement agents is followed by the spraying of seeds and fertilizer and finally by another spraying of erosion prevention and soil improvement agents (so-called sandwich method). The triple spraying method, however, is not really used in recent years.

As the single spraying slurry method is the simplest method and is fairly efficient, it is currently the most popular method. The use of an asphalt emulsion for erosion control purposes should be avoided as it may cause chemical damage to the seeds.

The dual and triple spraying slurry methods can prevent coating damage to the seeds when the use of chemicals likely to damage the seeds is planned.

② Base Method

In the case of the base method, base materials in which seeds, fertilizer and a mixing medium are mixed together are firstly dropped and scattered on the ground, followed by the blanket spraying of slurries. As the highly viscous base materials have the required quantities of materials needed for plant growth, they are powerful plant growth bases. This method is particularly suitable for rocky areas with little soil for plant growth or for steep slopes where seed establishment is difficult. This method is also advantageous in that it can enhance the possibility of the successful growth of woody plants through the segregation of plant growth areas by means of using base materials with tree seeds and slurries with grass seeds. In this manner, undesirable pressure or competition from herbaceous plant life can be prevented to a certain extent.

The above 2 methods are illustrated in Fig. II-2 below.

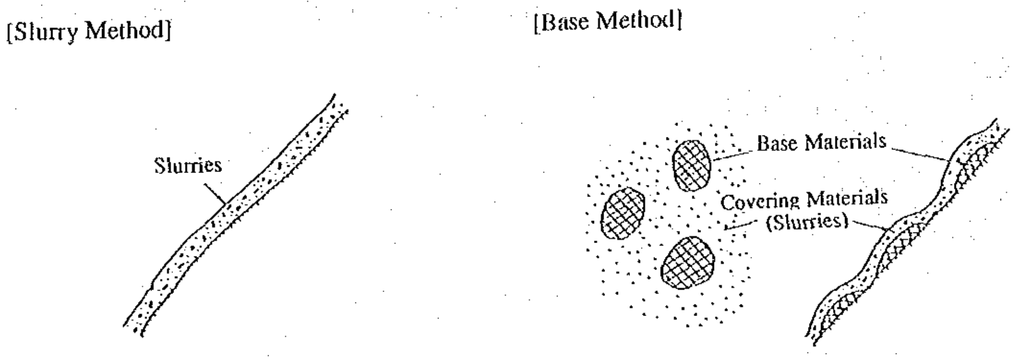


Fig. II-2 Illustration of Seed Spraying Methods

5.3 Spraying Apparatus

The selection of suitable spraying apparatus should be based on the spraying method, types and conditions of spraying materials, aircraft loading capacity, mixing and discharge performance and compatibility with the aircraft in use. The selection criteria for spraying apparatus are given in Table II-7 while various spraying apparatus are illustrated in Fig. II-3.

Table II-7 Spraying Apparatus Selection Criteria

Conditions	Apparatus
Single or dual spraying slurry method. Spraying of slurries as part of the base method	suspended bucket
Triple spraying slurry method, Mixed spraying of materials of similar shapes and sizes. Spraying of base materials as part of the base method	side-mounted hopper
Separate spraying of granular seeds and fertilizer, etc. Mixed spraying of granular materials of similar sizes	mounting of a granule spraying device to the hopper
Separate spraying of powdery fertilizer and other materials. Mixed spraying of powdery materials of similar sizes	mounting of a powder spraying device to the hopper
Separate spraying of liquid fertilizer and other materials. Mixed spraying of liquid materials of a similar nature	mounting of a liquid spraying device to the hopper

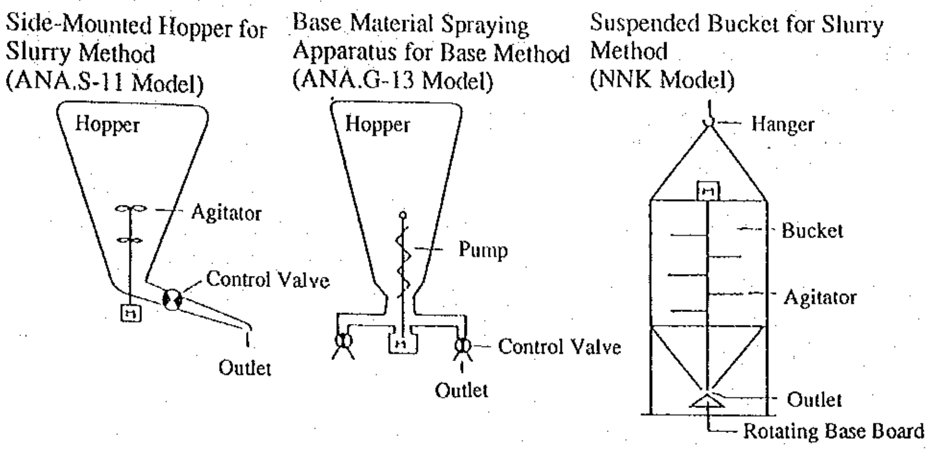


Fig. II-3 Illustration of Spraying Apparatus

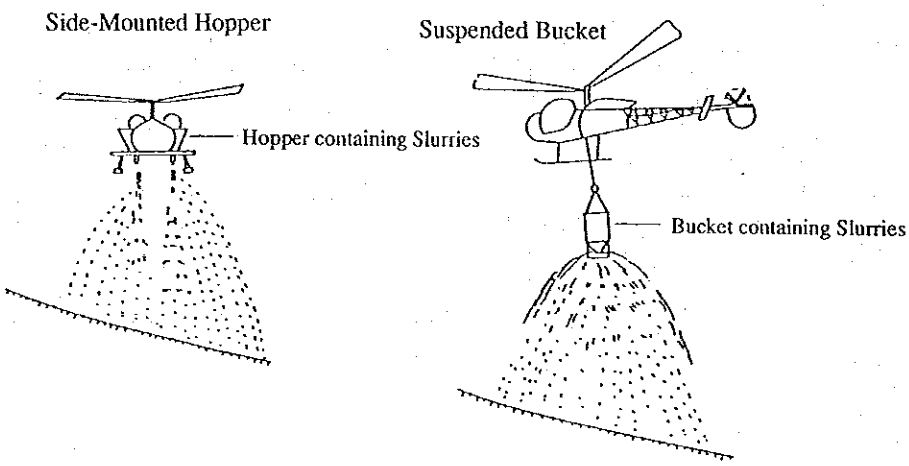


Fig. II-4 Illustration of Spraying Apparatus Mounting

① In general, there are 2 types of spraying apparatus (Figs. II-3 and II-4).

a) Side-mounted type: mounting of a hopper on both sides of the body
b) Suspended type: suspension of a bucket under the body

The side-mounted type is normally used for the spraying of a single material. Provided that the size and nature of the materials are almost identical, this type of apparatus can be efficiently used with the additional mounting of a granule spraying device (mainly for seeds, fertilizer or mixing medium), a powder spraying device (mainly for erosion prevention agents) or a liquid spraying device (atomizer, mainly for erosion prevention agents) to the outlet of the main spraying apparatus.

The suspended type is capable of mixing all the spraying materials and the feeding and mixing of materials is easier than in the case of the side-mounted type. As material separation and blockage of the outlet are less likely to occur, the discharge of a large quantity of materials can be efficiently conducted. When this type is selected, 2 buckets should be prepared for use in turn in view of higher work efficiency.

② If the spraying apparatus is equipped with an agitator, use of the latter makes the separation of materials less likely to occur. The discharge capacity depends on the apparatus used and the materials to be sprayed and is usually 170kg - 450kg/minute. Many types of spraying apparatus are equipped with a valve to control the spraying rate.

③ The device to spread the sprayed materials can be a ventury type or slinger type (power-driven type) for a fixed wing aircraft. The ventury type uses the difference in air currents rather than power while the slinger type uses centrifugal power created by the power-driven rotation of the outlet, the shape of which is either a disk or tube. Only the slinger type is used in the case of a helicopter.

④ The spraying volume is decided by the discharge capacity of the spraying apparatus, flying speed and effective spraying width as shown by the equation below.

$$X = \frac{a}{(1{,}000 \times b \times c) \div 60}$$

Where, X : spraying volume/unit area in single operation (kg/m^2)
a : discharge capacity of spraying apparatus (kg/min)
b : flying speed (km/hr)
c : effective spraying width (m)

For example, given a discharge capacity of 300kg/min, a flying speed of 20km at an altitude of 20m and an effective spraying width of 6m, 300kg of materials can be sprayed over an area of 2,000m^2/minute.

The equal distribution of the materials to the 2 side-mounted hoppers is important.

5.4 Flight Details

(1) Loading Weight

The loading weight is decided based on the aircraft model, type of spraying apparatus and elevation of the subject area. The loading capacity of the aircraft is determined by the engine output, in turn affected by air temperature, humidity and flying height, etc. As each aircraft of the same model has a slightly different body weight and performance and as spraying apparatus is manufactured to fit an individual body, the loading weight can differ from one aircraft to another.

(2) Helicopter Performance and Loading Capacity

① Operational Limit

The operational limit (maximum take-off weight) is decided by the Aviation Act for each helicopter model. The loading capacity is this maximum take-off weight minus the total weight of fuel, spraying apparatus and pilot. The loading capacity can also be affected by the flying height, air temperature, humidity and topographical conditions of the heliport.

② Calculation of Loading Capacity

Table II-8 and Table II-9 give the main specifications and design performances of helicopters frequently used for spraying. Using these tables, the loading capacity of a Hughes 300C (269C) Model helicopter is calculated as follows.

Maximum take-off weight (operational limit)		:	862kg
Helicopter's own weight		:	- 474kg
Weight of spraying apparatus		:	- 70kg*
Weight of fuel and lubricant		:	- 50kg
Weight of pilot		:	- 68kg
Nominal loading capacity (standard atmosphere)		:	200kg
Weather constraints	-		
Mechanical constraints	- safety coefficient	:	0.8 - 0.9
Topographical constraints	-		

The calculated maximum loading capacity, incorporating a safety coefficient, ranges from 160kg to 180kg.

* 70kg for spraying apparatus is the average weight. The weight varies from 40kg to 100kg depending on the type or model.

Table II-8 Specifications of Helicopters Used for Spraying (1/4)

Item \ Model	Bell 47G2	Bell 47G2A	Bell 47G3B-KH4	Bell 47G3B-1	Bell 47G4A
Engine Model	Reikaming VO-435 A1A, B, D	Reikaming VO-435 A1E	Reikaming TVO-435 B1A, D1A, D1B	Reikaming TVO-435 B1B	Reikaming VO-540 B1, B3
Output	200 hp	240 hp	260 hp	260 hp	280 hp
Main Rotor	wood & metal blades: 2	metal: 2 semi-rigid blades	metal: 2 semi-rigid blades	metal: 2 semi-rigid blades	metal: 2 semi-rigid blades
Tail Rotor	metal: 2 blades	metal: 2 blades	metal: 2 blades	metal: 2 blades	metal: 2 blades
Total Length (m)	12.62	13.17	13.30	13.17	13.30
Total Width (m)	10.71	11.32	11.32	11.32	11.32
Total Height (m)	2.83	2.88	2.84	2.84	2.84
Body Length (m)	9.27	9.63	9.94	9.63	9.63
Main Rotor Rotation Area (m^2)	90.02	100.80	100.80	100.80	100.80
Tail Rotor Rotation Area (m^2)	2.35	2.35	2.35	2.35	2.35
Fuel Consumption (litres/hr)	51.5	–	–	–	–
[Flight Performance]					
Maximum Flying Speed (km/hr)	161 (above sea)	169 (above sea)	169/15,000 ft	169	169
Economical Flying Speed (km/hr)	124 (above sea)	146	146	124	146
Ascending Speed (m/min)	244 (above sea)	283 (above sea)	283	325	277.8
Practical maximum Altitude (m)	4,115	3,962	6,218	–	3,414
Flight Duration (hrs)	3	3.5	3.9	4.2	4.3
Flight Range (km)	354	362	325	380	475
[Weight]					
Maximum Weight (kg)	1,111	1,293	1,293	1,293	1,338
Self Weight (kg)	726	743	777	814	823
Standard Loading Weight of Spraying Materials (kg)	120 – 140	160 – 180	160-200	180 – 200	200 – 20

Table II-8 Continued (2/4)

Item \ Model	Bell 47G4A Soloy	Bell 47G-5	Hughes 300C (269C)	Enstrom 280C	Hiller UH-12E
Engine Model	Alison 250-C20 B1	Reikaming VO-435 B1A	Reikaming H10-360 DIA	Reikaming H10-360 E1AD	Reikaming VO-540 C2A
Output	268 shp	265 hp	190 hp	205 hp	305 hp
Main Rotor	metal: 2 semi-rigid blades	metal: 2 semi-rigid blades	all metal joints: 3 blades	all metal joints: 3 blades	metal: 2 blades
Tail Rotor	metal: 2 blades	metal: 2 blades	metal: 2 blades	metal: 2 blades	metal: 2 blades
Total Length (m)	13.17	13.17	9.42	11.15	12.41
Total Width (m)	11.32	11.32	8.18	9.75	10.80
Total Height (m)	2.84	2.84	2.66	2.74	3.09
Body Length (m)	9.63	9.63	6.76	8.56	8.69
Main Rotor Rotation Area (m^2)	100.80	100.80	52.53	74.69	91.97
Tail Rotor Rotation Area (m^2)	2.35	2.35	1.32	2.02	2.21
Fuel Consumption (litres/hr)	75.7	–	35	49	–
[Flight Performance]					
Maximum Flying Speed (km/hr)	169	169 (above sea)	169	188	154 (above sea)
Economical Flying Speed (km/hr)	113 (above sea)	142	161	177	145 (above sea)
Ascending Speed (m/min)	579 (above sea)	262	–	351	393 (above sea)
Practical maximum Altitude (m)	4,877	3,109	3,658	5,921	4,938
Flight Duration (hrs)	2.9	–	3.5	3.7	2.7
Flight Range (km)	324	547	410	466	283
[Weight]					
Maximum Weight (kg)	1,338	1,293	862	1,000	1,270
Self Weight (kg)	811	721	474	681	801
Standard Loading Weight of Spraying Materials (kg)	270 – 300	180 – 200	160 – 180	120 – 140	240 – 260

Table II-8 Continued (3/4)

Item \ Model	Hiller UH-12E Soloy	Bell 206B	Hughes 500 (369HS)	Hughes 500D (369D)	Hughes 500E (369E)
Engine Model	Alison 250-C20B	Alison 250-C20B	Alison 250-C20	Alison 250-C20B	Alison 250-C20B
Output	301 shp	317 hp	317 shp	420 shp	420 shp
Main Rotor	metal: 2 blades	metal: 2 semi-rigid blades	all metal joints: 4 blades	all metal joints: 5 blades	all metal joints: 5 blades
Tail Rotor	metal: 2 blades	metal: 2 blades	metal: 2 blades	metal: 2 blades	metal: 2 blades
Total Length (m)	12.41	11.82	9.24	9.54	9.39
Total Width (m)	10.80	10.16	8.03	8.05	8.05
Total Height (m)	3.09	2.91	2.50	2.72	2.66
Body Length (m)	8.69	8.74	7.01	6.87	7.49
Main Rotor Rotation Area (m^2)	91.97	81.10	50.60	50.89	50.89
Tail Rotor Rotation Area (m^2)	2.21	1.95	1.32	1.32	1.53
Fuel Consumption (litres/hr)	-	–	–	–	–
[Flight Performance]					
Maximum Flying Speed (km/hr)	154	225 (above sea)	245	257 (above sea)	257 (above sea)
Economical Flying Speed (km/hr)	118	219 (above sea)	222	233 (EL 1,524m)	249 (EL 1,524m)
Ascending Speed (m/min)	520	384 (above sea)	518	518 (above sea)	572 (above sea)
Practical maximum Altitude (m)	3,658	6,096	4,389	4,877	448
Flight Duration (hrs)	3.5	–	–	2.3	2.8
Flight Range (km)	565	554 (above sea)	607	539	515
[Weight]					
Maximum Weight (kg)	1,406	1,452	1,157	1,361	1,361
Self Weight (kg)	748	660	493	599	608
Standard Loading Weight of Spraying Materials (kg)	270 – 300	300 – 350	300 – 350	300 – 350	300 – 350

Table II-8 Continued (4/4)

Item \ Model	AS 315B (Llama)	AS 350B	Bell 204B	Bell 204B-2
Engine Model	Turbomeka-Altoust IIIB	Turbomeka-Ariel 1B	Reikaming T531A	Reikaming T5313D
Output	562 hp	641 hp	1,100 shp	1,400 shp
Main Rotor	metal: 3 blades	glassfibre: 3 blades	metal: 2 semi-rigid blades	metal: 2 semi-rigid blades
Tail Rotor	metal: 3 blades	metal coated: 2 blades	metal: 2 blades	metal: 2 blades
Total Length (m)	12.92	12.99	17.37	17.37
Total Width (m)	11.00	10.69	14.63	14.63
Total Height (m)	3.09	3.08	4.42	4.42
Body Length (m)	10.26	10.91	14.66	14.66
Main Rotor Rotation Area (m^2)	95.00	89.75	168.12	168.12
Tail Rotor Rotation Area (m^2)	2.84	2.72	5.27	5.27
Fuel Consumption (litres/hr)	–	134	247	247
[Flight Performance]				
Maximum Flying Speed (km/hr)	–	246	222	222
Economical Flying Speed (km/hr)	120	235 (above sea)	217	217
Ascending Speed (m/min)	250 (above sea)	643 (above sea)	488	488
Practical maximum Altitude (m)	3,400	5,000	4,816	4,816
Flight Duration (hrs)	–	4.6	–	–
Flight Range (km)	510	740	531	531
[Weight]				
Maximum Weight (kg)	1,750	1,950	3,856	3,856
Self Weight (kg)	995	1,050	2,087	2,087
Standard Loading Weight of Spraying Materials (kg)	600 – 700	400 – 500	1,000	1,000

Table II-9 Flying Speed and Standard Spraying Volume (1/2)

Field of Application	Type of Work	Type of Sprayed Agent	Standard Spray Volume (l(kg)/ha)	Flying Speed (km (mile)/hr				
				Bell 47	Hughes 300	Hiller UH-12E	G4A Soloy	Hiller UH12E Soloy
Forestry	Prevention of Insect Damage and Diseases	Liquid	30-60 litres	48-56 (30-35)	48-56 (30-35)	48-56 (30-35)	48-56 (30-35)	48-56 (30-35)
		Liquid (use of gun nozzle)	120-300 litres				40 or less (25 or less)	40 or less (25 or less)
		Liquid (small quantity)	8 litres	48-64 (30-40)	48-64 (30-40)	48-64 (30-40)	48-64 (30-40)	48-64 (30-40)
		Liquid (small quantity)	2-10 litres	48-64 (30-40)	48-64 (30-40)	48-64 (30-40)	48-64 (30-40)	48-64 (30-40)
		Fine Granules	50-70 kg	48-64 (30-40)		48-64 (30-40)		
		Powder	20-70 kg	48-56 (30-35)		48-56 (30-35)		
		Granules	30-50 kg	48-64 (30-40)		48-64 (30-40)		
	Weeding	Fine Granules	50-130 kg	48-64 (30-40)		48-64 (30-40)		
		Granules	20-250 kg	48-64 (30-40)		48-64 (30-40)		
	Fertilizer	Granules	130-750 kg	48-64 (30-40)		48-64 (30-40)		
	Rat Extermination	Granules	0.5-1.5 kg	48-64 (30-40)		48-64 (30-40)		
Watershed Reforestation	Reforestation Work	Reforestation Materials (liquid/muddy)	1-20 tons	0-64 (0-40)		0-64 (0-40)	0-64 (0-40)	0-64 (0-40)
		Reforestation Materials (bulky)	1-20 tons					
		Coagulant (use of gun nozzle)	20 litres/m^2				2-4	2-4
Fisheries	Promotion of Laver Germination	Powder	6kg	64-80 (40-50)				
	Promotion of Laver Colour	Liquid	22 litres	64-80 (40-50)				
		Powder	16 kg	64-80 (40-50)				
		Granules	8-11 kg	64-80 (40-50)				

Note: Fine granules include fine granule F.

Table II-9 Continued (2/2)

Hughes 500	Bell 206B	AS350B	SA315B (Llama)	SE3160	Bell 204B (204B-2)	Burtle 107-2	Remarks
64-80 (40-50)	64-80 (40-50)	64-80 (40-50)	64-80 (40-50)				
40 or less (25 or less)	40 or less (25 or less)		40 or less (25 or less)				
64-72 (40-45)	64-72 (40-45)	64-72 (40-45)					
64-72 (40-45)	64-72 (40-45)	64-72 (40-45)					
48-64 (30-40)	48-64 (30-40)						
48-64 (30-40)	48-64 (30-40)		48-64 (30-40)	48-64 (30-40)	48-64 (30-40)		
48-64 (30-40)	48-64 (30-40)		48-64 (30-40)	48-64 (30-40)	48-64 (30-40)		
	60-80 (40-50)						
0-64 (0-40)	0-64 (0-40)	0-64 (0-40)	0-64 (0-40)	0-64 (0-40)	0-64 (0-40)		
					0-64 (0-40)		
2-4	2-4		2-4				
							Water depth around 1m

(3) Flying Speed and Flying Time

① The relationship between the flying speed and standard spraying volume is shown in Table II-9. A flying speed range of between 48km/hr and 64km/hr for a standard spraying volume of 130 - 750kg is preferable.

② The flying time should be calculated in 2 parts, i.e. the return flight time and the actual operation time.

a) The return flight time between the heliport (operation base) and site is calculated based on the horizontal flying distance, vertical flying distance and flying speed.

b) The operation time consists of the spraying time from the apparatus and circling time. The former is determined by the type of spraying apparatus used and considerably varies between 2hrs/100kg and 7 hrs/100kg depending on the actual apparatus. The latter is normally given as between one-quarter and one-half of the former.

(4) Flying Altitude and Flight Path Interval

For reference purposes, the flying altitude and flying interval in the case of spraying for agriculture, forestry or fisheries in Japan are given in Table II-10. The standard spraying altitude for aerial reforestation is 30 - 40m which should be altered to suit air current and topographical conditions. The standard flight path interval is 20 - 25m. As the spraying width varies depending on the seed conditions, the necessary flight path interval must be determined based on such conditions.

Table II-10 Flight Altitude and Flight Path Interval for Spraying Operation

Field of Applicaton	Type of Work	Type of Sprayed Agent	Flight Altitude and Flight Path Interval						Remarks
			Bell 47, Hughes 300, Hiller-UH-12E, G4A Soloy, Hiller-UH-12E Soloy		Hughes 500, Bell 206B, SE 3160, SA 315B (Llama), AS 350B		Bell 204B, Bell 204B-2, Burtle 107-2		
			Altitude (m)	Path Inteval (m)	Altitude (m)	Path Interval (m)	Altitude (m)	Path Interval (m)	
Forestry	Prevention of Insect Damage and Diseases	Liquid	5-15 AC	10 &20	10-15 AC	10 & 27			
		Liquid (use of gun nozzle)	5-10 AC	5	5-10 AC	5			
		Liquid (small quantity)	5-15 AC	22	10-15 AC	27			
		Liquid (small quantity)	5-15 AC	22	10-15 AC	27			
		Fine Granules	10-20 AC	15-20					
		Powder	5-15 AC	20					
		Granules	20-30 AC	20					
	Weeding	Fine Granules	10-20 AC	20	10-20 AC	20			
		Granules	30-40 AG 20-30 AC	20	30-40 AG 20-30 AC	20-25	30-40 AG 20-30 AC	30	AG for low trees and AC for high trees
	Fertilizer	Granules	30-40 AG 20-30 AC	25	30-40 AG 20-30 AC	25	30-40 AG 20-30 AC	30	
	Rat Extermination	Granules	30-60 AG	30-40	30-60 AG	40-50			
Watershed Reforestation	Reforestation Work	Reforestation Materials (liquid/muddy)	3-30 AG	3-20	3-30 AG	3-20	3-30 AG	3-20	
		Reforestation Materials (bulky)					3-30 AG	5-8	
		Coagulant (use of gun nozzle)	1-3 AG	2 (*width*) 5 (interval)	1-3 AG	2 (*width*) 5 (interval)			
Fisheries	Promotion of Laver Germination	Powder	5-10 AS	20					
	Promotion of Laver Colour	Liquid	5-10 AS	20					
		Powder	5-10 AS	20					
		Granules	5-10 AS	advance confirmation					

Notes:
1) Altitude: AC (above crown), AG (above ground), AS (above sea)
2) The path interval for granules and fine granules must be based on the effective spraying width which varies depending on the materials to be sprayed.
3) Fine granules include granular agent F.

(5) Spread of Sprayed Materials

The extent of the spread of the sprayed materials is determined by the flying speed and altitude of the helicopter. In general, the following relationships are upheld.

a) The spraying width narrows as the flying speed increases. As a high speed reduces the downwash effect with a longer time required for the materials to fall to the ground, a high level of material drifting occurs.

b) The spraying width narrows when the flying altitude increases. The materials are likely to be subject to wind interference due to a long falling time, resulting in much drifting.

These relationships are shown in Fig. II-5 and Fig. II-6.

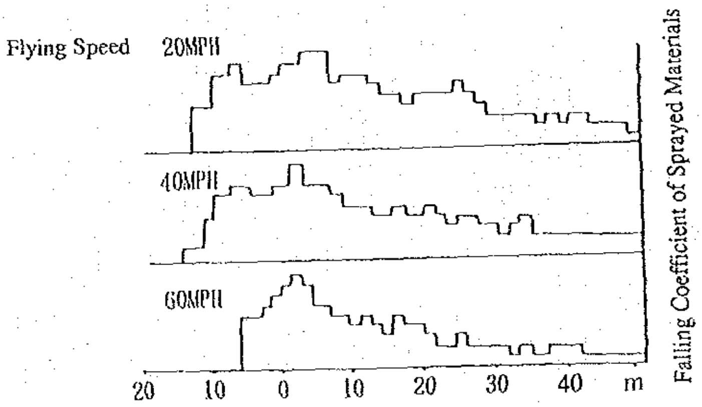


Fig. II-5 Flying Speed and Spread of Sprayed Materials (Flying Altitude: 7m)

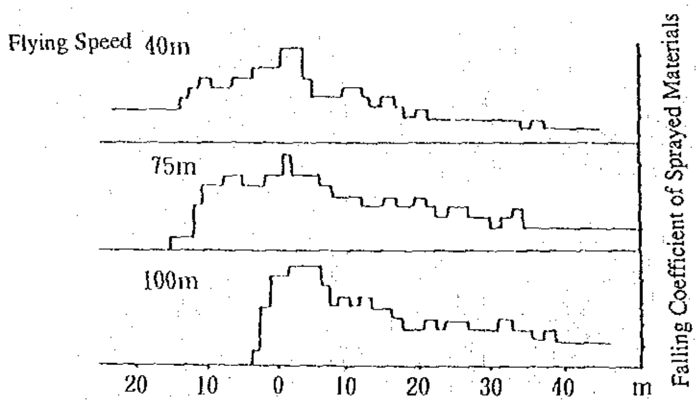


Fig. II-6 Flying Altitude and Spread of Sprayed Materials (Flying Speed: 40 MPH)

(6) Aerial Seeding Efficiency

The aerial seeding efficiency is calculated based on the following factors.

a) Type of aircraft (helicopter) in use
b) Type of spraying apparatus
c) Operational conditions
d) Spraying area
e) Spraying volume

A trial calculation of aerial seeding efficiency is given below based on the flight conditions shown in Table II-8 and other factors.
Conditions

Helicopter Model	:	Bell 206B
Spraying Apparatus	:	side-mounted hoppers
Operational Conditions	:	flying speed: 54km/hr spraying altitude: 20 - 30m effective spraying width: 25m loading capacity: 200kg spraying capacity: 80ha/hr or 400ha/day (5 hours operation/day)
Spraying Area	:	3,000ha
Spraying Volume	:	10,000 seeds/ha (Acacia mangium: 50,000 seeds/kg, 2kg/ha)
Planned Operation Duration	:	3,000ha ÷ 400ha/day = 7.5 days = 8 days
Operational Hours	:	7.5 days x 5 hrs/day - 37.5 hrs
Return Flight Time	:	(distance between base and site: 37.5km) 8 days x (37.5km x 2 ÷ 150km/hr) = 4 hrs
Transfer Time	:	(distance between main heliport and work base: 300km) 300km x 2 ÷ 150km/hr = 4 hrs

The total time from the original transfer from the main heliport to the completion of operation is 45.5 hours, i.e. approximately 9 days.

The operation cost includes survey and test flight expenses, waiting expenses, depreciation and the land transportation cost of auxiliary equipment and materials and the instruction fee, etc. in addition to the direct operation cost (see 5.2 - Flight Cost and Cost Estimate).

(7) Base Facilities

Aerial reforestation requires various supporting facilities. Facilities mainly associated with the use of a helicopter are discussed below.

1) Selection of Heliport Location

When selecting the heliport location, such issues as the safety of flying and work, work efficiency and possible adverse impacts of the noise and other negative aspects of helicopter operation must be taken into careful consideration. The following points are particularly important in regard to the location of a heliport.

① The candidate site must be large enough for smooth take-off and landing and the ground surface must be hard enough to support such operation. No obstacles should exist to adversely affect take-off and landing.

② The site must have easy access for transport vehicles and enough space for a fuel yard and car park.

③ The site must be sufficiently distant from houses or settlements in view of preventing noise pollution and safety hazards.

④ The topographical and climatic conditions of the site must not be unfavourable for helicopter operation. Special attention should be paid to the possibility of flooding, sudden gusts or wind and noticeable ascending or descending air currents.

⑤ This site must have economical prospects in terms of the relative location between the loading/unloading yard and expected flight paths.

2) Heliport Facilities

A landing site, fuel yard, loading/unloading yard and materials yard are usually provided at a heliport although only a landing site and materials yard are provided in some cases. The actual contents of these facilities must be determined based on the expected period of use and type of helicopter in use. The standard conditions for heliport facilities are described below.

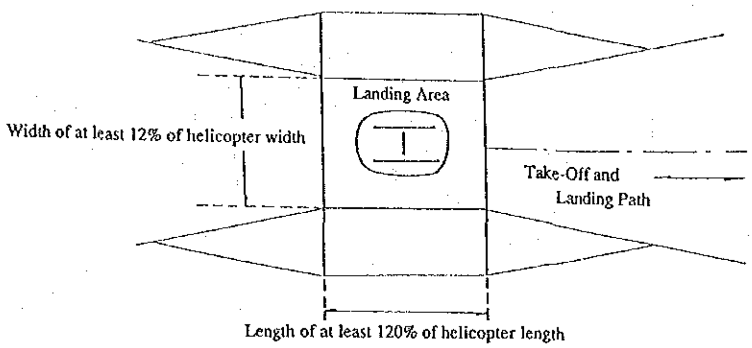
① Landing Site

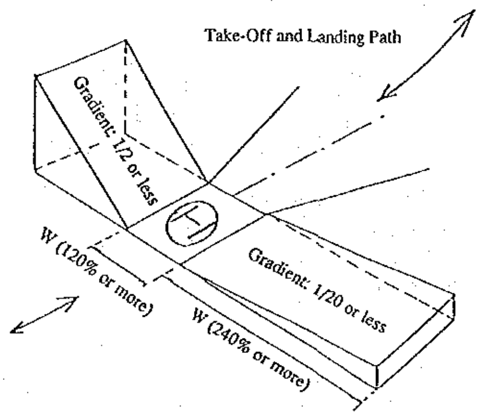
a) The minimum size of the landing site is 1.2 times the total length and width of the helicopter in use with the surrounding buffer zone shown in Fig. II-7.

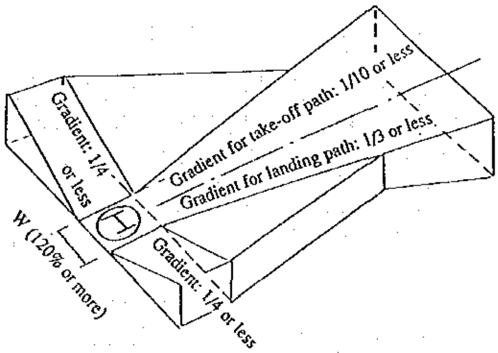
b) The landing site must be prepared by levelling the ground surface (a gradient of upto 5° is tolerated) and must have a structure capable of supporting the helicopter weight.

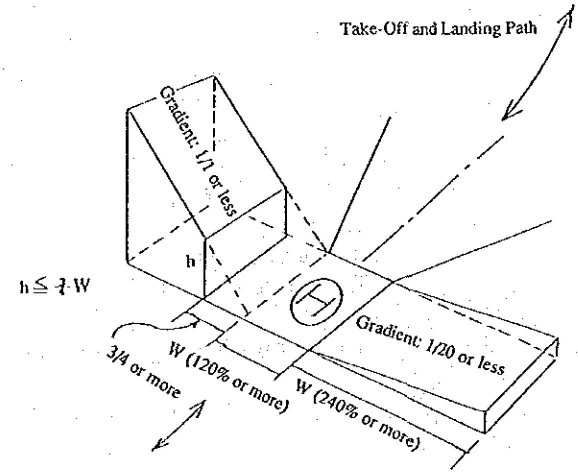
c) The landing site must be provided with a sprinkler system, paved surface and/or steel sheet surface to reduce the dust caused by helicopter operation.

d) The landing pad should be marked with an Ⓗ (minimum diameter of 4m) in white or another easily identifiable mono-colour.


Landing Area
Width of at least 12% of helicopter width
Take-Off and Landing Path
Length of at least 120% of helicopter length


Take-Off and Landing Path
Gradient: 1/2 or less
W (120% or more)
Gradient: 1/20 or less
W (240% or more)


Gradient: 1/4 or less
Gradient for take-off path: 1/10 or less
Gradient for landing path: 1/3 or less
W (120% or more)
Gradient: 1/4 or less


Take-Off and Landing Path
Gradient: 1/1 or less
h
3/4 or more
W (120% or more)
Gradient: 1/20 or less
W (240% or more)

[Placing of auxiliary facilities next to heliport]

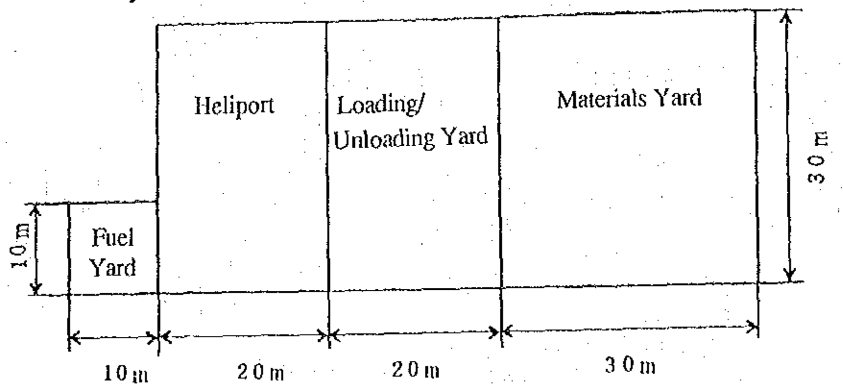


Fig. II-7 Heliport Requirements

② Fuel Yard

The fuel used by helicopters is classified as a dangerous substance and, therefore, its storage and handling are regulated by law. The fuel yard must satisfy the conditions required by law or other regulations. The standard conditions for a fuel yard are described below.

a) The fuel yard (outdoor storage) must be located at a site with good drainage and must not be located in a dumping area.

b) The fuel yard must be clearly separated from other facilities by fencing or other means.

c) The minimum size of the fuel yard is approximately $20m^2$ for a storage volume of 5,000 litres (equivalent to 25 drums) and $40m^2$ for a storage volume of 10,000 litres (equivalent to 50 drums).

d) The fuel yard must be surrounded by empty space, the size of which depends on the intended storage volume.

   - 5,000 litres (equivalent to 25 drums) .... 3m wide strip
   - 10,000 litres (equivalent to 50 drums) .. 6m wide strip

e) The fuel yard must be equipped with the legally required markings, notices and fire extinguishers.

f) The use of a tank lorry requires the same facilities as in the case of storage by drums.

③ Loading/Unloading Yard (Lifting/Dropping Yard)

The site of the loading/unloading yard depends on the types and quantities of the materials to be transported. Sufficient space is required to ensure that any items suspended by the helicopter does not come into contact with any other item. The standard conditions for a loading/unloading yard are described below.

a) The location of the loading/unloading yard must not interfere with the flight path of the helicopter.

b) The gradients of the landing path and take-off path must be similar to those for heliport facilities. Trees preventing smooth access or departure must be removed.

c) The width of both the landing and take-off paths must be at least 40m.

d) A loading bay of at least 10m x 10m = 100m² should be introduced in the case of a very small loading/unloading yard or steep (10° or more) loading/unloading yard.

④ Materials Yard

a) If a materials yard is necessary, its location must not interfere with loading/unloading.

b) A streamer should be erected in a place which does not interfere with take-off or landing to check the wind direction and velocity near the heliport in view of safe operation.

c) A warehouse to store tools and auxiliary materials and a rest house for workers, etc. should be constructed if necessary.

⑤ Communication Facilities

Communication facilities are essential for the safety and higher efficiency of transportation work. The standard facilities and equipment are described below.

a) Aviation radio equipment is used for communication between the helicopter and heliport.

b) Either exclusive radio equipment or a wire system is used for communication between the heliport and loading/unloading yard.

c) A loudspeaker system on board the helicopter or similar system is used for communication between the helicopter and loading/unloading yard.

d) In addition to the above, communication boards (blackboards) and communication case should be provided.

6. Project Planning

6.1 Basic Conditions of Project Planning

This Manual has been compiled to serve the purpose of environmental reforestation, i.e. large-scale reforestation activities using aircraft.

Areas which can benefit from aerial reforestation and the characteristics of aerial reforestation have already been discussed. In general, aerial reforestation is employed for remote areas and areas without forestry infrastructure, both of which are difficult constraints on reforestation. The preparation of an aerial reforestation plan must, therefore, be based on the following.

① Clear identification of the project objectives
② Proper understanding of the natural conditions of the subject area
③ Selection of plant species which have particularly vigourous growth at the early stage and which are highly resistant to unaccommodating natural conditions
④ Availability of a sufficient quantity of seeds

⑤ Examination of land preparation possibility and other construction work depending on the land conditions
⑥ Selection of a suitable aircraft and spraying apparatus
⑦ Careful consideration of the social environment
⑧ Coordination of the work schedule
⑨ Establishment of site supervision and maintenance systems

6.2 Machinery and Auxiliary Facilities

The present manual has been compiled to assist large-scale, low cost, rapid reforestation "environmental reforestation" using aircraft. Table II-11 lists the range of the main machinery and facilities required for environmental reforestation (other than an aircraft) and cost items. The planned scope of machinery and various facilities should be kept to a minimum, taking the locational conditions of the subject area, the necessity to use machinery to meet the project objectives and the possible period of using machinery, etc. into careful consideration. The procurement of machinery should be based on detailed examination results regarding the advantages of various methods of procurement, i.e. outright purchase, leasing and sub-contracting, etc. In addition, parts supply availability and the maintenance service must be checked prior to the actual procurement of machinery.

Table II-11 Machinery and Auxiliary Facilities

1. Main Items

① Machinery

Machinery	Main Purpose of Use
- Tractor	land preparation, construction of forest roads and firebreaks, leveling of ground
- Farm Tractor	as above
- Backhoe	construction of drainage facilities
- Dump Truck	transportation of soil and aggregates, etc.
- Motor Grader	construction and repair of forest roads
- Pick-Up Truck	transportation of materials and equipment
- Jeep	communication, on-site management
- Chain Saw	felling of obstructing trees
- Tractor Accessories	
Blade	
Bucket	
Rake	
Ripper	
Harrow	
Rotavator	
Winch	

② Auxiliary Facilities
- *Equipment to stimulate germination*
- Seed storage facility
- Fire-fighting equipment
- Office building with building services
- Miscellaneous tools

2. Cost Items for Operation of Machinery

① Hardware Cost
- Depreciation (procurement cost)
- Interest, insurance and taxes, etc.

② Operational Cost
- Fuel, lubricant oil, grease and filters
- Tyres
- Repair
- Spare Parts
- Operator Wages

③ Other General Administration Costs

6.3 Flight Cost and Cost Estimate

The transportation work by helicopter involves the following cost items.

- Transportation Cost by Helicopter
  - Flight Cost
    - Airlift cost (major airlift cost, minor airlift cost)
    - Operational flight cost
    - Survey and test flight cost
    - Wasted day charge
    - Depreciation and land transportation costs of auxiliary materials and equipment
    - Instruction fee
  - Auxiliary Costs
    - Weighing and packaging cost
    - Construction cost of heliport and loading/unloading yard
    - Rent for land
    - Hook operation cost
    - Night security cost
    - Safety control cost
    - Miscellaneous cost

(1) Flight Cost

① Airlift Cost

a) Major Airlift Cost

This is the return airlift cost between the nearest base station and the on-site heliport and is calculated in the following manner.

$$\frac{\text{Return Flight Distance (km)}}{\text{Flying Speed (km/hr) x Hourly Airlift Cost}} = \text{Major Airlift Cost/Operation}$$

b) Minor Airlift Cost

When several on-site heliports are involved in a project, this cost relates to the airlift cost between these heliports. Using the same formula for the major airlift cost, this cost is calculated based on the flight distance for a single journey or return journey, which ever the case depending on the stage of the project.

② Operational Flight Cost

a) Operational Flying Time

The operational flying time, which is the basis for the operational flight cost calculation, is given by the following formula.

o In the case of a flight path inclination (ratio between elevation different and horizontal flying distance) of 1/10 or less:

$$\frac{\text{Single Journey Distance (km)}}{\text{Outward Journey Flying Speed (km/mins)}} + \frac{\text{Single Journey Distance (km)}}{\text{Inward Journey Flying Speed (km/mins)}}$$

+ Loading/Unloading Time = Operational Flying Time/Single Operation (mins) .... A

o In the case of a flight path inclination of above 1/10:

$$\text{A (mins)} + \frac{\text{Elevation Difference Equivalent to 1/10}}{\text{Ascending Speed (m/min)}}$$

= Operational Flying Time/Single Operation (mins) .... B

o In the case of an on-site heliport being separately located from the loading/unloading yard:

$$\text{A or B (mins)} + \frac{\dfrac{\text{Distance Between Heliport and Loading/Unloading Yard x 2}}{\text{(Inward Horizontal Flying Speed (km/min))}}}{\text{Flight Frequency/Hour}}$$

= Flying Time/Flight .(mins) C

o Calculation Units

- Operational Flight Distance (single journey) (km): round to one decimal place
- Flight Distance (km) ÷ Flying Speed (km/min) (min): round to 2 decimal places
- Elevation Difference: 10m
- Elevation Difference (m) ÷ Ascending Speed (m/min) (min): round to 2 decimal places
- Flight Frequency x Hour ÷ (A or B): round to single decimal place

b) Calculation of Operational Flight Cost

In principle, the operational flight cost is calculated as the cost/unit weight (ton) as follows.

$$\frac{\text{Flying Time of Single Operation (mins) x (Operational Flight Fee/Hour ÷ 60)}}{\text{Load/Operation (tons)}}$$

= Operational Flight Cost/Ton .... D

D x Total Transportation Weight (tons) = Operational Flight Cost

If preferable, the following formula can also be used.

$$\frac{\text{Total Weight (tons)}}{\text{Load/Operation (tons)}}$$ = Transportation Frequency .... N

Flying Time/Single Operation (mins) x N =
Total Operational Flying Time (mins) .... T

T (mins) x (Operational Flight Fee/Hour ÷ 60) = Operational Flying Cost

③ Survey and Test Flight Cost

This is the test flight cost to survey desirable operational flight paths from the heliport and is calculated as follows.

$$\frac{\text{Return Flight Distance (km)}}{\text{Onward Journey Horizontal Flying Speed (km/min)}}$$

$$+\frac{\text{Elevation Difference of Flight Path Inclination of Above 1/10 (m)}}{\text{Ascending Speed (m/min)}}$$

$$\times\frac{\text{Operational Flight Fee/Hour}}{60}\times\text{ Flight Frequency}$$

= Survey and Test Flight Cost

Note: The calculation units for the operational flight cost are also applicable here.

④ Wasted Day Charge

This charge is the compensation for those days on which operational flights cannot be conducted due to bad weather conditions or other reasons. The daily charge is usually equivalent to one hour's airlift charge.

⑤ Depreciation and Land Transportation Costs of Auxiliary Materials and Equipment

The depreciation cost of auxiliary materials and equipment (buckets and wires, etc.) is calculated based on their original prices and special depreciation rates. The standard depreciation charge/hourly operational flight is equivalent to 0.04% of the purchase price. The land transportation cost is the land transportation cost of materials and equipment between the base and the on-site heliport.

⑥ Instruction Fee

This is the charge for instructions on decisions on the heliport, loading/unloading yard locations and flight routes, etc.

(2) Auxiliary Costs

Auxiliary costs are mainly borne by the project owner (project implementation body or contractor).

① Weighing and Packaging Cost

The weighing and packaging cost consists of the labour cost, packaging cost, depreciation of weighing instruments and machine operation cost. It is estimated by adding together the above costs which depend on the types and weights of the materials to be transported.

② Construction Cost of Heliport and Loading/Unloading Yard

This cost includes the labour cost, depreciation cost of machinery and instruments, machine operation cost and depreciation cost of timber and steel sheets, etc. for the temporary work of the felling of unwanted trees, land preparation, paving and all other work associated with the construction of a heliport and loading/unloading yard.

③ Rent for Land

This consists of the rent for the land used for temporary construction purposes and compensation for felled trees, etc.

④ Hook Operation Cost

This is the labour cost of hook operation and the handling of transported materials at the loading/unloading yard and is calculated based on the unit labour charge.

⑤ Night Security Cost

This is the cost of night security for the helicopter and other valuable items. It consists of the night guardsman charge which is calculated on a daily basis and the temporary construction cost and necessary expenses for a guardhouse.

⑥ Safety Control Cost

This involves the material cost of markings and signs designed to ensure safe operation and the labour cost of placing such markings and signs. The cost of safety control meetings is also included here.

⑦ Miscellaneous Cost

The miscellaneous cost is calculated against the total cost of ① through ⑥ above and is usually divided into the on-site management cost and the general management cost, both of which are calculated by applying a specific rate.

6.4 Work Schedule

The main work processes involved in aerial reforestation, from initial planning to actual execution, are shown in Fig. II-8. It is desirable that a concrete schedule be worked out on the basis of a suitable season for aerial seeding taking the local conditions into consideration.

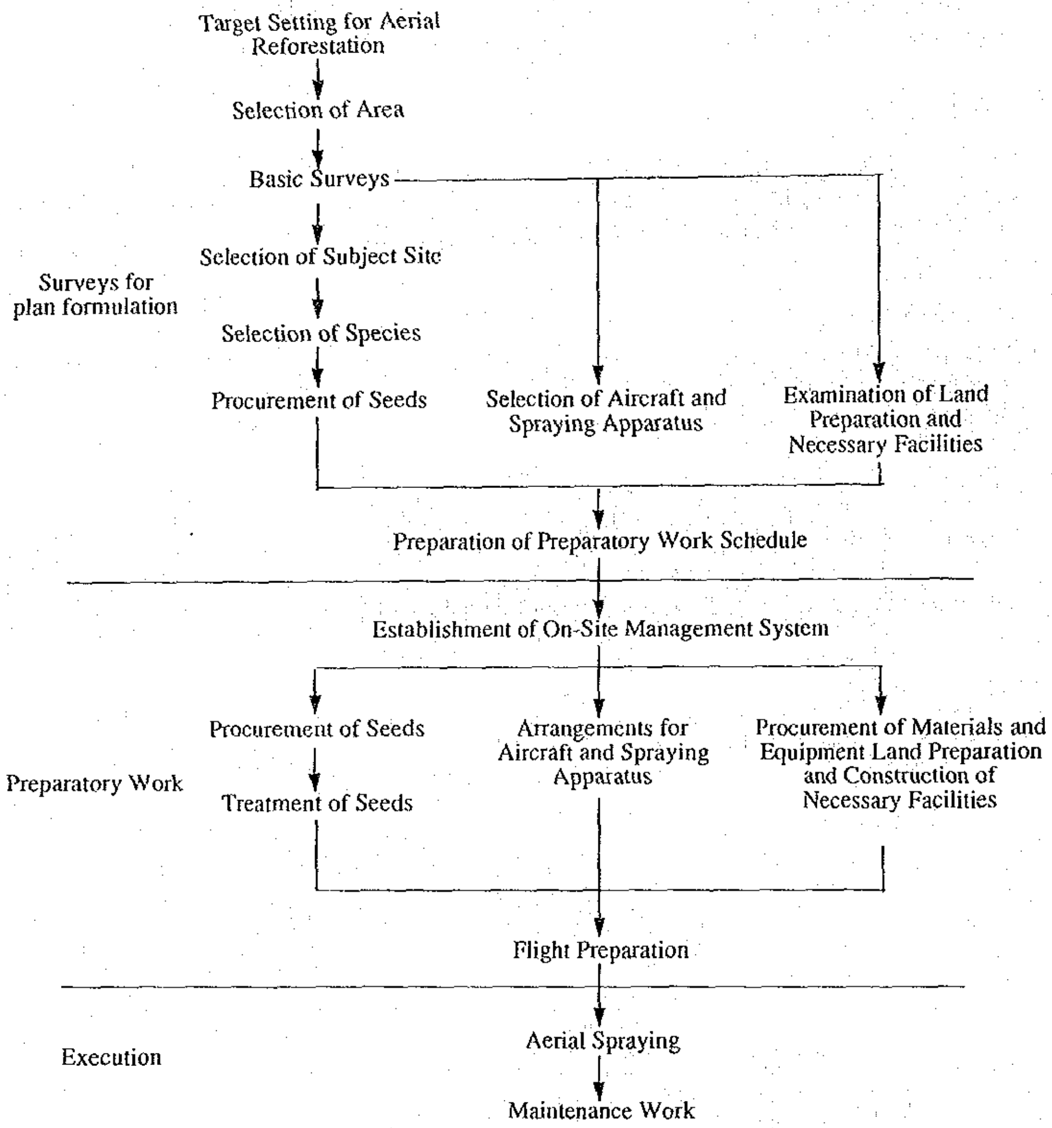


Fig. II-8 Aerial Reforestation work Processes

III PREPARATORY WORK

1. Seed Preparation

1.1 Procurement of Seeds

Seeds can be procured through self-production, domestic purchase or importation.

a) Self-Production

Seeds are supplied by the sources of seeds (seed forest, seed orchard and/or seed trees) individually owned by a person or company intending to conduct reforestation work.

b) Domestic Purchase

Seeds are procured from a seed stand or seed orchard run by a seed grower or public organization.

c) Importation

Seeds are imported from an overseas seed grower or public organization.

In the case of the domestic purchase or import of seeds, it is desirable to obtain certification of the following items from a public organization to ensure the procurement of good seeds.

- date of seed collection
- germination verification
- storage period and method
- Provenance

The procurement of seeds in Indonesia is described below for reference purposes.

① Related Regulations

The Ministry of Forestry considers seed production to be an important pillar of the forestry policy and has accordingly introduced the following regulations.

- Decree of the Minister of Forestry on Seeds for Forestry Applications (No.57/kpts, 11/1990)
- Regulations on Import and Export of Seeds for Forestry Applications
- Seed Import Approval Form (No.462/kpts, 11/1990)

② Seed Sources

Regulations on the handling of seeds and seedlings were enforced by the Ministry of Forestry in 1990. According to these regulations, only those producers which meet the criteria on technicians and seed inspection facilities as stipulated by the said regulations are permitted to handle seeds and seedlings in view of the prevention of inferior seed distribution. The production of seeds is also restricted to those seed sources authorised by the Ministry of Forestry.

The producers of seeds and seedlings authorised by the Ministry of Forestry are listed in Table III-1. Seed sources are classified by seed collection area, seed forest and seed orchard as shown in Tables III-2/4.

Table III-1 List of Authorised Dealers of Seeds and Seedlings

(as of December, 1990)

Company Name	Authorised Handling Items		Location of Head Office
	Seeds	Seedlings	
PT Kaltimex Jaya Group	-	O	Jakarta
PT Kayu Klaban Timber	-	O	Jakarta
PT Djajanti Group	-	O	Jakarta
PT Bina Merata	O	O	Jakarta
Perum Perhutani	O	O	Jakarta
PT Inhutani 1	O	O	Jakarta
PT Inhutani 2	O	O	Jakarta
PT Inhutani 3	O	O	Jakarta
CV Sumber Bibit	O	-	Bogor
PT ITCI	O	-	Jakarta

Table III-2 List of Designated Seed Collection Areas

Species	Designated Area	Size (ha)	Year of Designation	Competent Organization	Origin
Acacia mangium	Subanjeriji	50	1980	INHUTANI-1	Australia
		50	1981		East Kalimantan
		50	1982		Sumatera, East Irian
		150	1983		South Sumatera
		25	1981		South Sumatera, Australia
	Nanga pinoh	25	1981	BRLKT 13	Australia
		25	1982		Australia
		75	1983		Australia
		25	1984		Australia
	Bone	50	1983	BRLKT 13	Australia
	Gn. Kidul	6	1982	BRLKT 13	East Irian
	Gn. Walat	20	1981	BRLKT 4	Australia
Shorea seminis	Sanggau	25	1981	BRLKT 8	Haurbentes
		50	1982		Native
		25	1983		Native
		25	1984		Native
Dipterocarpaccae	Seri Beras	20	1981	BRLKT 8	Native
		20	1982		PT. GPI
		20	1983		PT. ITCI
Leucaena glauca	Takalar	25	1981	BRLKT 8	Native
Aleurites moluccana	Bima, NTB	50	1981	BRLKT 8	Native
	Takalar	50	1981		Native
Eucalyptus urophylla	Subanjeriji	2	1981	INHUTANI-1	NTT
Total		863			

Notes

BRLKT : Watershed Management Centre
PT. GPI : PT. Gunung Putih Indah
PT. ITCI : PT. International Timber Cooperation Indonesia
NTT : Nusa Tenggara Timor

Table III-3 List of Designated Seed Forests

Species	Location	Year of Designation	Size (ha)
Pinus merkusii	Takengon	1976	200
	Bandung Utara	1976	300
	Pekalongan	1976	251
	Lawn D.S.	1976	315
	Makale	1976	200
	Bandung Utara	1990	100
Tectona grandis	Banjar Utara, Ciamis	1976	75
	Sumedang	1976	100
	Sumedang	1990	113
Swietenia sp.	Tasikmelaya	1976	23
	Sumedang	1988	100
	Ngawi	1989	100
	Benakat	1990	50
Eucalyptus urophylla	Ende Maumere	1981	927
Eucalyptus deglupta	Sidrap	1977	100
	Benakat	1987	100
	Cawing	1988	100
Altingia excelsa	Cianjur and Bandung Sel	1976	257
Agathis loranthifolia	Sukabumi	1978	49
Agathis borneensis	Kamaratus	1988	100
	Sanpit	1989	100
Albizia falcataria	Ceuwiliang	1976	20
Diospyros celebica	Lambudolo	1987	100
Leucaena glanca	Kuningan and Cikampak	1986	197
Araucaria cunninghamii	Manckwari	1987	100
Gonystylus bancanus	Mempawah	1981	100
	?	1988	100
Dipterocarpaceae	?	1988	250
	Pulau Laut	1988	100
Shorea sp.	Batu Ampar	1988	100
	Musi Rawas	1988	200
Palaquium sp.	Bangka	1989	100
Total			5,027

Table III-4 List of Designated Seed Orchards

Species	Location	Size (ha)	Year of Designation	No. of Strains	Origin of seed	Remarks
Established Seed Orchards						
Pinus merkusii	West Java (Cijanbu)	16.0 16.0 16.0 16.0 16.0 16.0	1977 1978 1979 1980 1981 1982	200 200 200 200 200 200	Java	
	Central Java (Baturaden)	16.0 16.0 16.0 16.0 16.0 16.0	1977 1978 1979 1980 1981 1982	200 200 200 200 200 200	Java	
	Central Java	16.0 16.0 16.0 16.0 16.0 16.0	1977 1978 1979 1980 1981 1982	200 200 200 200 200 200	Java	
Eucalyptus urophylla	East Timor (Soe)	4.0 4.0 4.0 4.0	1982 1983 1984 1985	100 100 100 100	East Timor	8.0ha established in 1980 and 1981 abandoned due to fire
	South Sumatera (Subanjeriji)	6.4 6.4	1982 1983	100 100	East Timor	12.8ha established in 1981 and 1984 damaged by fire
E. deglupta	South Sumatera (Takalar and Subanjeriji)	4.0	1981	25	South Sulawesi	6.4ha established in 1983 and 1984 damaged by fire
Acacia mangium	South Sumatera	3.0		268	Queensland (Australia)	
Swietenia macrophylla	West Java	3.0		33	Java reforest-ation site	
Total		326.8				
Provisional Seed Orchards						
Eucalyptus urophylla	South Sumatera (Subanjeriji)	17.9 18.6 18.6	1981 1982 1984		East Timor	17.0ha established in 1983 damaged by fire
	East Timor (Soe)	21.0 21.0 21.0 21.0 21.0	1981 1982 1983 1984 1985		East Timor	
E. deglupta	South Sumatera (Subanjeriji)	21.8	1983		East Kalimantan	21.8ha established in 1984 damaged by fire
	South Sulawesi (Takalar)	46.0	1981		South Sulawesi	partially abandoned
Acacia mangium	South Sumatera	7.0		268		plus tree
Eucalyptus urophylla	West Java	2.0		33		plus tree
Total		236.9				
Clone Seed Orchards						
Pinus merkusii	South Sulawesi (Pettapang)	10.0	1982			10.0ha and 16.0ha established in 1982 and 1983 respectively abandoned
Tectona grandis	Central, West and East Java	320.0		389		plus tree
Total		330.0				

③ Seed Production and Import/Export Volumes

The actual and planned seed production volumes and the seed import/export volumes are given in Table III-5 and Table III-6.

Table III-5 Actual and Planned Seed Production Volumes in Indonesia

(Unit: kg)

Species	Actual Production Volume (1978-1988)	Planned Production Volume (1989-1999)
Acacia mangium	2,000	5,000
Swietenia macrophylla	20,000	20,000
Eucalyptus urophylla	5,000	5,000
Albizia falcataria	10,000	15,000
Pinus merkusii	15,000	5,000
Eucalyptus deglupta	2,500	5,000
Acacia auriculiformis	3,000	2,500
Schima wallichii var bancana	200	500
Peronema canescens	4,000,000*	8,000,000*

* Cuttings

Source: Directorate General of Reforestation and Rehabilitation, Ministry of Forestry, Indonesian

Table III-6 Indonesian Seed Imports/Exports in 1988

Imports			Exports		
Species	kg	Country (Region)	Species	kg	Country (Region)
Eucalyptus sp	50	Brazil Australia Africa	Leucaena leucocephala	200	Africa
			Calliandra callothyrsus	300	Africa
Gmelina arborea	30	Malaysia			
Pinus caribaea	30	Netherlands			
P. oocarpa	30	Netherlands			

Source: Directorate General of Reforestation and Rehabilitation, Ministry of Forestry, Indonesian

1.2 Selection of Seeds

The selection of good seeds is crucial to achieve a high seed treatment efficiency and high germination rate. The removal of foreign matters from seeds can be conducted using one of the following 3 methods.

- selection using sieves
- selection using air pressure
- selection using liquid

① Selection Using Sieves

In the case of selection using sieves, 2 sieves with a slightly larger and smaller mesh size than the seed size are generally used to select seeds prior to further separation between the seeds and foreign matters using the difference in specific gravity. A rotary seed selector or power-drive seed selector is used to deal with a large quantity of mixed seeds.

② Selection Using Air Pressure

Seeds of heavier specific gravity can be selected by the blowing off of lighter foreign matters. An electric fan is used to deal with a large quantity of mixed seeds, firstly on a weak setting and then on a strong setting. A suitable fan speed could be selected for specific type of seeds.

In reality, however, selection using air pressure is sometimes difficult in the case of seeds of a certain species, particularly when solid seeds and blind seeds have a similar weight. This method is said to have a solid seed selection rate of more than 95% for seeds with a different specific gravity value to that of foreign matters.

③ Selection Using Liquid

This method uses such liquids as water, alcohol, soapy water or glycerine to remove blind seeds, seeds damaged by insects and other inferior seeds. The selection of seeds which have a particularly large specific gravity uses water, the absorption rate by each type of seeds or foreign matters results in a different sinking time, or a saline solution to use the different specific gravity. In the case of soapy water, interfacial tension is utilised and the seeds must be washed immediately after selection as in the case of using such chemical agents as alcohol.

The use of chemical agents, including alcohol, is limited to seed inspection or other special purposes due to the high cost and is not used for the selection of a large quantity of seeds.

1.3 Calculation of Required Seed Quantity

In many cases, seeds are mixed with foreign matters. The number of seeds/unit weight differs from one species to another, as does the germination rate (Table II-5). It is inappropriate, therefore, to decide the seed quantity based only on the number of seeds/unit weight. In practice, the required seed quantity is calculated using the following formula.

$$W = \frac{G}{S \times P \times B}$$

Where, W : required weight of seeds (kg)
G : expected number of grown trees (trees/ha)
S : average number of seeds (seeds/g)
P : purity (%)
B : germination rate (%)

Calculation Example

Species: Acacia mangium
Expected Number of Grown Trees: 10,000 trees/ha
Average Number of Seeds: 55 seeds/g (55,000 seeds/kg)
Purity: 80%
Germination Rate: 10% (estimated based on direct seeding in the ground without ground surface preparation)

$$W = \frac{10,000}{55 \times 0.8 \times 0.1} = 2,273g$$

The required weight of seeds/ha is 2,273 grammes.

1.4 Storage of Seeds

Aerial reforestation requires a large quantity of seeds in a short period of time (see III.1.3 - Calculation of Required Seed Quantity). A seed storage facility is also required as the seed production volume of various species shows a cyclical pattern. Seeds can be stored in the following manner.

① Dry Storage

Dry storage is conducted under either normal or low temperatures. A cellar or well ventilated attic is used in the case of the former while an electric refrigerator or seed storage equipped with an electric device to maintain both a low temperature and low humidity is required for the latter. Dry storage is suitable for seeds with a low moisture content which allows a moisture reduction (dry weight) of upto less than 10% of the normal weight.

a) Normal Temperature Storage

A normal temperature storage can be either sealed off or not sealed off. In the case of the former, a desiccant or seed vitality suppression agent, sulphurated potash for example, is used.

b) Low Temperature Storage

The moisture content of the seeds must be reduced to 5 - 7%. The maximum temperature is 10°C. When a desiccant, seed vitality suppression agent and/or seed vitality restoration agent is used, the storage area should be sealed off.

② Wet Storage

Wet storage uses either an electric refrigerator for low temperature storage or in-the-soil storage. Either method is used for seeds which have a high moisture content and which become sterile if the dry weight drops to less than 20% of the normal weight.

For the storage of seeds which have a high moisture content, it is necessary to place them in, for example, a vinyl bag to suppress moisture loss in order to maintain the moisture content above the 20% level. As seeds which have a high moisture content are divided into those which can withstand low temperatures and those which die under 15°C, an appropriate storage temperature must be provided for both groups of seeds (0 - 15°C for the former and above 15°C for the latter).

Table III-7 and Table III-8 show the possible storage periods for seeds of tropical trees and the seed collection and storage methods employed in Indonesia respectively.

Table III-7 Possible Storage Periods for Seeds of Tropical Trees

Species	Possible Storage Period		
	Normal Temperature	21°C	4°C
Leguminosae			
- Parkia jaranica	more than 4 years	more than 4 years	more than 4 years
- Dialium cosiaccae	upto 3 years	upto 3 years	upto 3 years
- Intsia palembanica	more than a few years	more than a few years	more than a few years
- Pterocarpus spp.	a few years	a few years	a few years
Dipterocarpaceae			
(Red Meranti Group)			
- Shorea ojalis	4 months	more than 4 months	a few hours
- Shorea leprosula	2-3 months	more than 3 months	2 days
- Shorea parvifolia	a few months	a few months	2 days
- Shorea curtisii	a few months	a few months	a few hours
- Shorea platvclados	a few months	a few months	2 days
(White Meranti Group)			
- Shorea telura	more than 7 months	more than 7 months	more than 7 months
- Shorea assamica	a few months	more thana few months	2-3 months
- Shorea bracteolata	a few months	more thana few months	2 months
(Yellow Meranti Group)			
- Shorea resina-nigra	a few months	more thana few months	3 weeks
- Shorea multiflora	a few months	more thana few months	3 weeks
- Hopea odorata	a few months	more thana few months	more than 2 months

Table III-8 Seed Collection and Storage Methods in Indonesia

Species	Collection Season	Collection Method	Storage Method	Storage Period
Acacia mangium	Feb-Mar Aug-Sep	Pods collected by climbing up tree and cutting off branch. Capsules placed under direct sun for 2-3 days	Stored in sealed container in normal or air-conditioned room	upto 10 years
Swietenia macrophylla	June-Aug	Seeds pulled of or cut away by climbing up tree	Mixed with such absorbent as powdered coal or sawdust and germicide and wet stored in sealed container under low temperature of 15°C	2-3 months
Eucalyptus urophylla	July-Aug	Pods collected by climbing up tree and cutting off branch. Capsules placed under direct sun for 1-2 days	Dry stored in sealed container under low temperature (3–5°C, relative humidity of 40%)	upto 2 years
Albizia falcataria	July-Aug Feb-Mar	Pods collected by climbing up tree and cutting off branch. Capsules placed under direct sun for 2-3 days	Stored in sealed container under normal temperature	upto 10 years
Pinus merkusii	Feb-June	Cones collected by climbing up tree and cutting them off. Mature cones cut with a knife for collection of seeds by hand	Dry stored in sealed container under low temperature (3–5°C, relative humidity of 40%)	upto 12 months
Eucalyptus deglupta	Apr-Sep	Pods collected by climbing up tree and cutting off branch. Capsules placed under direct sun for 1-2 days	see Pinus merkusii	upto 2 years
Acacia auriculiformis	Feb-Mar Aug-Sep	see Acacia mangium	see Acacia mangium	upto 12 years
Schima wallichii var bancana	Apr-Aug	Fruit collected by climbing up tree. Fruit placed under direct sun for 3-4 days and seeds then collected	Wet stored in sealed container under low temperature (15°C, relative humidity of 60-80%)	upto 12 months
Peronema canescens	Aug-Nov	Dried inflorescence collected by climbing up tree and crushing it in a dry bag to collect seeds	Dry stored in sealed container in low temperature storage (3-5°C, relative humidity of 40%)	-