AERIAL PHOTOGRAPHY AND FOREST MANAGEMENT PLAN IN THE ENCROACHED NATIONAL RESERVE FOREST IN THE KINGDOM OF THAILAND

ANNEX

I. GUIDELINES FOR FORMULATING A NATIONAL FOREST MANAGEMENT PLAN

II. MANUAL FOR MONITORING OF THE FOREST LAND USE BY MEANS OF REMOTE SENSING

MARCH 1988

JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)

I. GUIDELINES FOR FORMULATING A NATIONAL FOREST MANAGEMENT PLAN

INTRODUCTION

These Guidelines have been prepared as part of the Aerial Photography and Forest Management Plan in the Encroached National Reserve Forest in the Kingdom of Thailand, the relevant work being conducted in the 3 years between 1985 and 1988, to assist national forest management in the western mountainous area of the Kanchanaburi Region.

For proper management, the management method must be clearly determined and the subject areas properly confirmed. Consideration has been given simply to management so that the Guidelines may effectively assist those preparing forest management plans for the first time. We hope that the RFD will prepare experimental management plans for other areas based on the present guidelines and will establish a suitable management plan for the national reserve forest in Thailand.

CONTENTS

1. NECESSITY FOR NATIONAL FOREST MANAGEMENT PLANS

The objective of a national forest management plan is the achievement of effective national forest management, i.e. the full utilization of specific forest functions.

1－1 Special Features of Forestry

i) Long Production Cycle

Compared to other land use industries, such as agriculture and livestock raising, the production cycle of forestry is extremely long. Satisfactory production results can only be achieved under a consistent management policy over a long period of time.

ii) Extensive Production Area

The implementation of efficient and effective forestry work with forest resources covering an extensive area is difficult without a proper management plan.

iii) Different Stages of Tree Maturity

Trees above a certain size can produce a useful yield. However, the economically most efficient utilization of these trees can only be achieved with an appropriate management plan which takes the forest and economic conditions into consideration.

iv) Unsteady Relationship Between Stand and Yield Volumes

The relationship between the stand volume and the yield volume is similar to that between capital and interest.The stand volume will not decline if the extraction volume is less than the growth volume. As stated earlier, however, trees are only usable after reaching a certain state of maturity. Therefore, the extraction often exceeds the growth volume, resulting in a decline of the stand volume which in turn jeopardizes the basis of forest management. Forest management plans are required to prevent this and also to maintain sound forests.

1－2 Functions of National Forests

i) Supply of Forest Products

Forest management plans with a long-term perspective are necessary to secure a stable supply of timber for building and firewood essential for the country.

ii) Public Functions

Forests are expected to fulfil not only economic functions but also those functions of public benefit, such as water source conservation, natural parks, wildlife reserves and public recreation areas. Appropriate forest management plans are required as the management of national forests in terms of these public functions requires special consideration.

iii) Contribution to Local Economy

Continuous felling and reforestation work in the national forests greatly contributes to the local communities by the provision of forest products and employment opportunities and management plans are necessary for their systematic and continuous implementation.

1－3 Current State of National Forests in Thailand

Thailand's national forests cover an area of 22.2 million ha, amounting to 43% of the total land area, and greatly contribute to the national budget through the sale and export of timber and to the people through their economic and public functions. In recent years, however, the forest cover has been conspicuously declining, from over 53% of the total land area in 1961 to approximately 29% (14.91 million ha) in 1985.

Transition of Forest Cover

Year	Forest Area (km^2)	Ratio to Total Land (%)
1961	273,629	53.33
1973	221,707	43.21
1976	198,417	38.67
1978	175,224	34.15
1982	156,600	30.52
1985	149,053	29.05

(Source) Forestry Statistics of Thailand 1986, RFD based on Landsat survey

Excluding private forests which are negligible, the difference between the actual forest cover and the national forest area is some 7 million ha which is assumed to have been left devastated as a result of felling and the slash-and-burn method of agriculture. As the prevention of the further decline of the forest cover is one of the priority policy targets of the Thai Government, careful forest management is necessary for the achievement of this target based on well prepared, appropriate national forest management plans.

2. PREPARATION OF NATIONAL FOREST MANAGEMENT PLANS AND ESSENTIAL POINTS FOR MANAGEMENT

The contents of national forest management plans vary in accordance with the locations, areas and characteristics of the subject forests. Those considered to be of particular importance in terms of the preparation and implementation of a management plan are mainly described.

2−1 Basic Principles for Management Plan Preparation

Prior consideration should always be given to certain points in the preparation of a national forest management plan, i.e. ① future maintenance of the yield of the forest in question, ② effective utilization of the forest and ③ priority of land conservation and public benefits, including the improvement of national welfare.

2−2 Determination of Subject Forests

The subject area of a national forest management plan should be clearly determined, generally for each management unit. A management unit is an area whose treatment as a single entity is deemed convenient in terms of forest management and development. The actual designation of an area as a management unit should be made taking river basin control and forestry work intensity, etc. into consideration and it is advantageous if the unit coincides with an administrative area or a large river basin.

2−2−1 Land Use Survey

A land use survey should be conducted following the determination of the management plan's subject area, on which the basic policies for the management plan, confirmation of boundaries and national forest utilization by local inhabitants can be based. As national forests are large and often located in remote areas with poor transportation, the monitoring of them tends to be inadequate, resulting in illegal settlement, felling or farming. The survey should cover the follwing and it is recommended that it be conducted by aerial photography where possible to avoid dangerous situations.

i) Number of households, population, livelihood and area of each land use category for each village
ii) Locations of illegal forest use
iii) Locations of illegal felling
iv) Locations where land and/or trees belonging to a national forest have been sold
v) Locations where the use of the national forest is officially permitted or where the land is leased

2−2−2 Land Use Suitability Survey

In addition to the actual state of national forest utilization, the prior determination of for what purposes the subject area can be used is also useful for the preparation of a management plan.

Agriculture, forestry and livestock raising are considered to be suitable uses of a forest while incidental uses are considered to be its residential use by local inhabitants. Its use as a tourist attraction and its use as a location for country houses. With regard to its use for agriculture, forestry and/or livestock raising purposes, whether or not particular areas are more suitable than others can be determined using the workability and growth factors (in turn determined on the basis of the land gradient and soil type) provided the climatic and transportation conditions are similar.

The results of the land use suitability survey on the model area are given in the following table.

Land Use Suitability Based on Land Gradient and Soil Type

Soil Type / Division / Gradient	Ne			Be-c			Lv · Be-r			E · I		
	A	F	L	A	F	L	A	F	L	A	F	L
– 5°	1	1	1	1	1	1	2	2	2	3	3	3
6 – 8°	1	1	1	2	1	1	3	2	2	3	3	3
9 – 13°	3	1	2	2	1	2	3	2	2	3	3	3
14 – 18°	3	1	2	3	2	2	3	2	2	×	3	3
19 – 23°	×	2	3	3	2	2	×	3	3	×	×	3
24 – 30°	×	2	×	×	3	3	×	×	3	×	×	×
31° –	×	×	×	×	×	×	×	×	×	×	×	×

A: Agriculture, F: Forestry, L: Livestock Raising

(Note) 1 : Most Suited, 2 :Suited, 3:Not Particularly Suited, × : Unsuited

For the selection of reforestation or settlement sites, the suitability of candidate sites can be determined by conducting a land gradient and soil type survey and checking the survey results against the table. In addition, the question of water supply which is not dealt with in the table should be considered.

2-2-3 Confirmation of Boundaries

Although it is generally believed that the boundaries of national forests (also the boundaries of administrative areas) are clearly determined, this is in fact untrue. Particularly in those areas where customary rights of use exist, where local inhabitants have had monopoly use for a long period of time or where river channels frequently change due to flooding. Disputes may arise when boundary confirmation is planned without prior consultation with those responsible (or owners) for the neighbouring areas and customary users. As boundary confirmation relates to the existing rights of inhabitants, relevant materials and inhabitants' claims should be carefully checked. Inhabitants should be given a careful and adequate explanation with reference to the relevant acts and materials. Even when dealing with illegal settlers, care must be taken to persuade them that they have no legal rights to be where they are and to reach an agreement that they will move after a certain period of grace. Negotiations often proceed smoothly when an actual relocation site is given.

After agreements have been reached (forced agreements in some cases), boundary posts should be erected. Wooden posts are adequate for temporary purposes but serialized boundary stones should be subsequently positioned for permanent boundary indication. In some cases, existing rocks or bankings can be used instead of posts. Charcoal or ceramic pieces are sometimes used beneath the posts in the case of the latter being damaged or removed in view of easy boundary recognition. Trees can be planted to make a demarcation line if agreement can be reached with the neighbours concerned. Following the confirmation of boundaries, surveying should be conducted to prepare a boundary map which should be permanently stored together with all field notes.

2-2-4 Notification

After boundary confirmation, notices should be provided along roadsides, etc. to inform the public that the area is a national forest. In addition, notices clearly stating that unauthorized entry into the national forest for felling, firewood collection, burning and/or farming purposes is prohibited should also be provided.

Gates and barbed wire fences should be provided in those places where it is believed to be particularly important to prevent entry. In short, measures should be taken to clearly show the Government's decision to prohibit unauthorized entry into the national forest.

In the case of those areas in national forests where there is frequent illegal felling, illegal farming or fires, the possible causes should be carefully examined so that appropriate measures to improve the situation can be taken.

2—3 Plan Period

The implementation period for national forest management plans is generally between 5 and 10 years. New surveys should be conducted towards the end of the initial plan period (usually in the final year) and the subsequent plan should commence after any necessary adjustments have been made based on the survey results.

With regard to plan names, the serial numbering method using the same plan name should be employed to show the continuity of the plan, i.e. 1st Management Plan for so-and-so Working Area, 2nd Management Plan for so-and-so Working Area and so on. Provisional modifications should be made when a major revision of the plan appears necessary during the plan period due to a drastic change in the economy or other reasons. In this case, the revised plan should be named the 1st (or 2nd, etc.) Revised Plan of the 1st (or 2nd, etc.) Management Plan for so-and-so Working Area.

Although the standard plan period is 10 years, it has recently become a common practice to introduce a revised plan after 5 years in order to meet rapid social and economic changes.

2—4 Zoning

For the proper management of national forests, such essential information as location and available forest resources, etc. must be correctly understood and recorded. The zoning of forests into working areas, compartments and sub-compartmnents can be introduced to indicate unit subject areas for recording purposes.

2—4—1 Topographical and Other Maps

A map of the subject area must be prepared prior to zoning, showing major topographical features and structures such as rivers, lakes, falls, roads and buildings, etc. As map preparation using the ground surveying method is both costly and time consuming, aerial photography has been increasingly conducted in recent years. A scale of either 1 : 5,000 or 1 : 10, 000 is recommended in the case of a contour map based on aerial photographs being used as the basic map. As this map is extremely important for forest management, in addition to its zoning use, it should be permanently stored.

A forest type map can also be prepared from aerial photographs. Each stand, i.e. area of specific forest type, is classified as a sub-compartment which is the basic unit for forest management. Forest type descriptions are given later (see Page 13). The scale of the forest type map should be between 1 : 20,000 and 1 : 50,000 depending on the intensity of forestry work in the subject area. Forest type maps are sometimes prepared by transcribing the forest types onto the basic map. In this case, the scale of the forestry type map should naturally be the same as that of the original basic map.

2－4－2 Working Areas

As referred to in 2－2, a working area is a management unit and is also called a management area or a working unit. While there is no definition for the size of a working area, it is generally said that an area which can be supervised by one chief engineer is the maximum size. Accordingly, the size of a working area tends to be large when such forestry work as felling and reforestation is not intensive and small when there is a large labour input for intensive forestry work. It is appropriate to consider the question of sustained yield referred to in 2－1 within the framework of a working area.

2－4－3 Compartments

Compartments are fixed zones in a working area which areused to clarify forest locations and forestry uses. Compartment boundaries are usually either natural or administrative boundaries. A compartment generally consists of a small river basin or a slope on the right or left bank of a small river. When natural boundariesdo not exist, as in the case of forests on flat land, such artificial boundaries as roads and firebreaks are used to determine the compartment boundaries.

The size of a compartment depends on the topographical conditons and the forestry work intensity. However, the collection of forest information and the implementation of forestry work is difficult if the compartment is too large. In general, an approriate compartment size is 500 - 2,000 ha although compartments smaller than 100 ha do exist.

2—4—4 Sub-compartments

Sub-compartments are temporary zones within a compartment which are introduced to facilitate forestry work. In general, one sub-compartment is a stand where a specific tree type, stand age and forest use type are found to be common. Sub-compartments boundaries are also determined by land use demarcation lines and administrative boundaries.

Sub-compartments in the model area were provisionally introduced based on forest types and forest management plan, in turn based on aerial photograph interpretation, in view of the lack of adequate forest information. They will be further divided into proper sub-compartments with the accumulation of relevant information in the future, including forest use types and land use classification.

2—4—5 Missing Numbers and Suffixial Numbers

When part of a national forest is converted to farmland or to another type of land use, one or more compartments may become non-existent. In this case, the serial number of these compartments should be treated as missing. Conversely, when new compartments are added to a national forest, the original series should not be used and a new series should start, moving the figure up one place.

While all compartments are subject to a new series when anew management plan commences, suffixial numbers should be used to distinguish the different zones in the same sub-compartment where further division is deemed appropriate due to topographical or other factors involved.

2—5 Confirmation of Legal Regulations

Forestry work may be restricted by acts and ordinances and, therefore, competent departments and agencies should be consulted to obtain a clear understanding of the exact scopes of any restrictions and these must be clearly described in the management plans. Consideration should also be given to land classifications in force (for example, mining areas) by other departments. There are currently 7 regulated forests under the jurisdiction of the RFD.

In view of the fact that strong concern in regard to environmental conservation has been increasingly expressed all over the world in recent years, those responsible for forest administration, particularly those in charge of forest management planning, should execute their duties regarding the conservation of the natural environment with the utmost seriousness. It is recommended that protection measures for those forests deemed worthy of conservation by forest experts be implemented regardless of legal regulations to clearly demonstrate the determination of those responsible.

i) National Parks
ii) Forest Parks
iii) Wildlife Parks
iv) Wildlife Sanctuaries
v) Game Preserves
vi) Botanical Gardens
vii) Arboretums

2-6 Forest Surveys

Once the area of each forest zone has been determined, forest surveys should be conducted to decide the productive capacity of each zone so that an understanding of the contents of the forest resources and important materials for future use can be obtained.

2-6-1 Land Conditions Survey

The land conditions survey is intended to elucidate the conditions of the location to obtain a scientific basis for forest management in the subject area. Depending on the requirements, the survey should be conducted for each sub-compartment or for the entire area.

a. Location

Survey items include the latitude and longitude of the subject area, administrative boundaries, transportation facilities and the relationship with forest product markets. In addition, a location map should be prepared.

b. Climate

Using relevant data on the subject area and/or surrounding areas, the temperature (annual mean temperature and maximum and minimum temperatures, etc.), rainfall (monthly rainfall) and winds (prevailing, directions and storm wind directions, etc.) should be studied.

c. Topography

Survey items include the directions of main mountain ranges, major rivers, elevation (maximum elevation and coverage), gradient (flat, gentle, medium or steep) and gradient directions (8 directions).

d. Geology

The geological age and type of bedrock of the subject area should be studied using geological maps and other relevant materials and confirmed by the field survey.

e. Soil

Existing soil maps should be used to study the soil distribution conditions. As there is a close relationship between soil types and tree growth, it is recommended that soil maps be prepared by conducting a soil survey if maps are unavailable. The relationship between the soil types and tree growth in the model area is separately described (see Page 30). As the tree growth can be roughly understood by referring to the soil texture (given in terms of the soil's clay content), the soil depth (shallow, medium or deep), hardness (hard, medium, soft) and soil moisture (dry, moist or wet) should be studied.

2-6-2 Forest Conditions Survey

The forest conditions survey is intended to elucidate the current forest conditions to obtain a scientific basis for determining immediate and future forest uses.

a. Vegetation

The characteristics of both the geographical and ecological distribution of forest vegetation should be clarified using existing materials and survey data on sample plots. While various forest classifications are used by different countries and scholars, the following forest types currently in use in Thailand are deemed adequate.

i) Tropical Evergreen Forest
ii) Mixed Deciduous Forest

iii) Deciduous Dipterocarp Forest
iv) Mangrove Forest
v) Pine Forest
vi) Scrub Forest
vii) Para Rubber Plantation Area

Forests classified as iv) - vii) do not exist in the model area.

b. Tree Species

As a natural tropical forest consists of a number of species and as both useful species and unexploited species are mixed together, it is difficult to conduct a survey on each species. Nevertheless, survey accuracy should be gradually improved by using the yield survey results and other data so that a correct understanding of the stand volumes of the main species can be obtained. RFD circulars should be referred to for the species to be indicated in the survey results.

c. Forest Age and Age Class

A forest age survey on natural forests is not recommended as it would result in unnecessary confusion. The indication of the forest ages of artificial forests should suffice for immediate purposes.

d. Crown Density

The crown density is given as the ratio of the area shaded by crown to the entire area. In the case of a tropical forest where crown layers of upper, intermediate and lower are usually distinguishable from one another, the crown density of the forest is usually that of the upper layers. As a ground survey on the entire area is difficult, the crown density is usually determined from aerial photographs.

e. Forest Management Type

Areas are classified as either stocked areas (natural or artificial forests) or unstocked areas (cut-over areas, no standing tree areas or non-forest areas).

f. Forest Type

Forest type classification is extremely important to decide forest work policies and the following classifications can be used.

i) Artificial Forest, Natural Forest, Secondary (Natural) Forest and Cut-Over Area
ii) Coniferous Forest, Broad-Leaved Forest and Mixed Forest
iii) Mountain Forest, Hill Forest, Flat Land Forest, Swamp Forest and Coastal Forest

These classifications are often combined (for example, coniferous, artificial forest or broad-leaved, natural forest). Aerial photographs are used to identify forest types.

g. Forest Form

Although the forest form is usually determined by the crown cover conditions, it can also be determined by the height grade.

i) Crown Cover Classification (uniform forest, two-storied forest, multi-storied forest, selective felling forest and coppice forest)
ii) Tree Height Grade Classification (high, medium and low)
iii) Crown Diameter Classification (large, medium and small)

In regard to the forest type classification of the model area, the current forest conditions were indicated in detail by combining the forest type, forest form and crown density for the convenience of analysis and practical forest use (see example given below).

Example

T_E M La H_2 D_3

D_3 : Crown Density (Medium)

H_2 : Tree Height (Medium)

La : Crown Diameter (Large)

M : Mountain Forest

T_E : Tropical Evergreen Forest

The following table gives the forest type and forest form standards used in the survey on the model area.

Land Use and Forest Type Classification Standards		
General Classification	Forest Type and Land Use	Symbol
Forest	Tropical Evergreen Forest	T_E
	Mixed Deciduous Forest	M_D
	Deciduous Dipterocarp Forest	D_D
	Bamboo Forest	B_F
	Secondary Forest	S_F
Non-Forest	Farmland	A
	Grassland	G
	Village	V
	River	R
	Lake	L
	Barren Land	B
	Plantation	P
	Others	O

Forest Form Classification Standards			
Forest Type by Site	Crown Diameter	Tree Height	Crown Density
Mountain Forest M	La (17m or more)	H_3 (23m or more)	D_4 (61% or more)
Hill Forest H	Mi (11m - 17m)	H_2 (18m- 22m)	D_3 (51% - 60%)
Flat Land Forest F	Sm (10m or less)	H_1 (17m or less)	D_2 (41% - 50%)
			D_1 (40% or less)

h. Forest Stand Composition

With regard to the stand composition, the D.B.H. (or G.B.H.), total tree height, clear length , number of trees and the stand volume should be studied for each sub-compartment. However, as this is both expensive and time consuming, a forest type map based on aerial photograph interpretation can be used to establish a sample plot for each forest type. The stand composition of each sub-compartment should then be estimated using the field survey results on the sample plots.

The number, sizes and shapes of the sample plots depends on the required accuracy and actual conditions of the stands.

The decision on the required number of sample plots under given conditions follows the ordinary sampling method in statistical processing. Since supplementary surveys are difficult in the case of forests, a fairly large safety margin should be given to the fluctuation coefficient so that the resulting number of required samples tends to be on the larger side.

In the case of those sites where felling takes place in the plan period [1st working period (10 years)], either the all tree measurement method for the whole stand, or the sampling method of a large number should be used, so that planned felling can be accurately conducted.

As it is difficult to measure the heights of all trees in a sample plot, it is a common practice to measure the actual heights of standard trees and then to estimate heights of the stand based on the height curve which gives the relation between the D.B.H. and the tree height.

Clear length is an indispensable factor to identify the effective stand volume and is determined by hypsometer or is visually estimated.

With regard to the standing tree volume table (effective volume table), it is necessary to examine whether or not the table can be used for a subject area. If necessary, a new table should be prepared.

Sample plot survey results should be converted to the respective figures per ha in each sub-compartment and should then be totalled for each compartment and working area. All figures should be entered into a forest register. As the necessary work volume increase in proportion to an increase of a subject area, a computer is often used particularly when the subject area is extensive.

2—7 Forestry Work

2—7—1 Work Arrangement

It is presumed that the various conditions, including those of forests, in the subject area of a management plan have been correctly understood through the processes described so far. Work arrangement means that the actual contents of this knowledge are organized under certain preconditions to form the skeleton of the management plan.

(1) Decision on Work Method

The work method is the implementation of all forest production processes, from felling to regeneration and tending, following certain principles. Work methods are classified according to the felling and regeneration methods. To be more precise, felling is generally classified as either clear felling or selective felling while regeneration is classified as either natural or artificial regeneration.

These 2 types of classifications result in a combination of 4 types of work methods, i.e. ① selective cutting-natural regeneration, ② selective cutting-artificial regeneration, ③ clear cutting-natural regeneration and ④ clear cutting-artificial regeneration. If necessary, these work methods can be further divided. As far as the model area is concerned, however, only 2 types of work methods might be considered principally, i.e. selective cutting-natural regeneration and clear cutting-artificial regeneration.

While a work method should, in principle, be selected for each subcompartment, no decision on the work method should be made for those areas where felling cannot be conducted due to legal regulations or topographical reasons or where forestry work is not feasible because the area is other than forest.

(2) Tree Species

"The right tree on the right site" is an important principle for forest management. The actual performance of planted trees can be affected by even minor differences in the climatic, topographical and soil conditions. In this context, indigenous species do not present many problems. However, careful consideration should be given in advance to the introduction of exotic species.

The question of tree suitability does not arise in the case of natural regeneration but forest quality may deteriorate due to expected useful species failing to grow. Although the species given in the following table have been selected for reforestation work in the model area, it is preferable that more suitable species, if any, be selected through continuous experiments.

List of Main Planting Species

	Code No.	Species name	Planting type				Applied forest type	Natural growth in the study area	Rotation age (year)	Remarks
			open planting	under-tree planting	mixed planting	line planting				
Long cutting period species	101	*Dipterocarpus alatus* ROXB.		○		○	T_E	Yes	30 ~ 50	
	201	*Tectona grandis* LINN F	○				M_D	No	50	
	302	*Afzelia xylocarpa* CRAIB.	○				$T_E \cdot M_D$	Yes	30	
	305	*Hopea odorata* ROXB.		○	○	○	T_E	Yes	30 ~ 50	
	310	*Pterocarpus macrocarpus* KURZ.	○				$T_E \cdot M_D$	Yes	30 ~ 50	
	564	*Xylia kerrii* CRAIB. & HUTCH.			○		$T_E \cdot M_D$	Yes	30 ~ 50	
Fast growing species	–	*Acacia auriculiformis* A. CUNN.	○				$M_D(D_D)$	No	5 ~ 8	
	–	*Acacia mangium* WILLD.	○				$M_D(D_D)$	No	5 ~ 8	
	–	*Eucalyptus camaldulensis* DEHN.	○				$M_D(D_D)$	No	5 ~ 8	
	–	*Eucalyptus deglupta* BL.	○				$T_E(M_D)$	No	5 ~ 15	wet site
	–	*Melia azedarach* L.	○				$M_D(D_D)$	No	15 ~ 20	

(Note) In the case of under-tree planting, no designation is made in regard to kind of trees under which planting will be conducted (either fast growing or long cutting period species).

(3) Rotation Age and Felling Cycle

The rotation age is one of the most important items in a management plan. In some cases, the rotation age acts as an index for achieving management objectives.

The rotation age can be determined in various ways, including physical rotation, industrial rotation and maximum yield rotation. While it is relatively easy to decide the rotation age in the case of a single species forest (such as an artificial forest), it is difficult to determine a uniform rotation age for a natural forest due to the diversity of species, including uncommercial species, and due to the different log sizes to be utilized depending on species. The figures given in the Rotation Age column of the said Table are the estimated periods required for planted trees to reach their tree size classes for use.

In reality, the timing of felling depends on the growth situation. As stated earlier, the introduction of a uniform rotation age is difficult for a natural forest. As a result, selective felling is generally adopted and, in this case, it is more practical to indicate the tree size in terms of the D.B.H. (or G.B.H.) rather than tree age from the viewpoint of log utilization.

The felling cycle for selective felling is the length of time required for the stand, particularly the tree size class, to be restored to its original state before felling. In this context, a tropical forest has such problems as limited usable species, inadequate infrastructure (including forest roads) and almost no growth data. In addition, while a shorter felling cycle gives a small yield at each cutting and a longer felling cycle gives a large yield at each felling, the latter causes extensive damage to the forest environment. This dilemma is a difficult problem in forest management.

Felling in Thailand is currently conducted with a cutting cycle of 30 years with a girth limit for each species. Whether or not the original forest state can be restored within 30 years depends on such factors as the forest type prior to felling, the felling volume and the subsequent growth situation, etc. As data on the inter-relationship between these factors is scarce, it is difficult to argue the appropriateness of a 30 year felling cycle. However, a 40 year felling cycle will be adopted in the model area and further data accumulation is planned.

(4) Special Forestry Work

In the case of an extensive forest, special forestry work must sometimes be introduced due to legal regulations and other reasons.

The model area has been divided into a forestry area, a conservation area and an agroforestry area in view of the fact that part of the model area belongs to a national park and that the settlement of farmers is required. The forestry work for each of these 3 areas has been independently decided taking the current legal regulations and actual forest conditions into consideration. The following land/forest categories have been introduced in view of these legal regulations and forest conditions.

i) Unworkable Site

Those sites where work implementation cannot be expected for some time due to their difficult access or steep gradients.

ii) Mountain Conservation Forest

Mountain area with high elevation and steep gradient in the eastern part of the model area where no forestry work is anticipated in view of environmental conservation.

iii) River Basin Conservation Forest

Steep slope along rivers where no forestry work is anticipated in view of river basin conservation.

iv) National Park Forest

In principle, no forestry work will be conducted in view of environment conservation. However, an experimental forest, reforestation for rehabilitation and the provision of facilities for visitors will be permitted.

v) Bamboo Forest

Special foretry work for a bamboo forest will be conducted.

vi) Communal Forest

Forestry work to provide firewood for farmers will be conducted.

vii) Farmland and Residential Land

Farmland and residential land required for the settlement of farmers and for the provision of their livelihood.

Other legal categories, i.e. wildlife sanctuary and forest park, will be also introduced in the conservation area although they do not currently exist in the model area.

All aspects of the forestry work so far described should be compiled in a work arrangement table, such as that given below. The outline and crucial points of the management plan can be easily understood by referring to this table.

Work Arrangement Table (for Model Area)

(2–1)

Area Classification	Legal Designation	Forest Management Type	Area (ha)			Felling Method		Regeneration Method		Remarks
			Forest	Non-Forest	Total	Method	Rotation Age (Yrs)	Method	Species	
Forestry Area	None designation	Natural Forest				Selective	30	By natural seedings		30 Year Felling Cycle
		Artificial Forest				Dispersed Felling by Small Area		Artificial		
		General Species					50–60		Teak, etc.	
		Fast Growing Species					5 – 10		Eucalyptus, etc.	
		Bamboo Forest				Selective	1–2			
		Unworkable Site				No Work				
		Others								
Total		Sub-total								
Conservation Area		Mountain Conservation Forest				Felling Prohibited				
		River Basin Conservation Forest				Felling Prohibited				
		Others								
		Sub-total								
		Total								
	National Park	Mountain Conservation Forest				Felling Prohibited				
		River Basin Conservation Forest				Felling Prohibited				
		General Protected Forest				Felling Prohibited				
		Experimental Forest				Felling depends on Experimental Purposes				

Area Classification	Legal Designation	Forest Management Type	Area (ha)			Felling Method		Regeneration Method		Remarks
			Forest	Non-Forest	Total	Method	Rotation Age (Yrs)	Method	Species	
Conservation Area	National Park	Rehabilitation Forest						Artificial or by natural seedings	Indigenous Species	
		Facility Area								
		Others								
		Sub-total								
	Wildlife Sanctuary									
	Game Preserve									
	Wildlife Park									
	Forest Park									
	Botanical Gardens/ Arboretum									
	Others									
Total										
Agroforestry Area	None designation	Artificial Forest General Species Fast Growing Species								
		Communal Forest								
		Bamboo Forest								
		Farmland/ Residential Land								
		Others								
Total										
Grand-total										

2−7−2 Work Criteria

The fostering of a forest takes over a long period of time and changes of people in responsible positions may occur. However, forestry work continuity can be secured despite the changes of forest managers if the work method is clearly indicated in the management plan. The criteria to determine the basic forestry work required for each working block should be carefully decided in view of their long validity. Once decided, any arbitrary changes by a manager should be prohibited in order to ensure work continuity for the achievement of the initial planning objectives. Examples of the work criteria for the model area are given below.

(1) Basic Items

If properly conducted, forestry work contributes to not only increasing forest resources but also to the full utilization of the various public functions of forests. Conversely, the careless implementation of forestry work may result in many problems. The careful implementation of all forestry work should, therefore, be strongly stressed.

a. Forest To Be Conserved

The forests with the following features should be excluded from the felling plan and should be conserved.

i) Good natural forests which can be used as reference forests in terms of ecology and the preservation of genes.
ii) Forests where rare fauna and flora are found.
iii) Forests along rivers or on steep slopes where there is a danger of landslides.
iv) Forests used for forest recreation purposes, etc.
v) Forests within whose vicinity potable water sources are found.
vi) Forests where felling is prohibited by law.

b. Felling and Regeneration Methods

Selective felling with natural regeneration should be adopted for natural forests while reforestation based on the dispersed felling by small areas should be adopted for artificial forests. In principle,felling should not be conducted in those forests where regeneration cannot be expected. Forestry work should also be suspended for an indefinite period in the case of unprofitable forests.

c. Logging Facilities

Forest roads are important facilities for forest management. Routes should be located in view of not only efficient logging but also effective reforestation, management and the inhabitants' convenience. They should be constructed in areas of good drainage so that they can be used all the year round.

(2) Natural Forests

The felling methods for a natural forest are selective felling and regeneration by natural seeding. Selected sites should be those which are unsuitable for reforestation work due to the soil conditions even though the topographical and locational conditions may be suitable for forestry work.

a. Preservation of Succeeding Trees

In the course of selective felling, attention should be paid to the preservation of succeeding trees as the felling of trees with a high market value, particularly large trees, may result in a deterioration of the forest. The number of trees suitable for felling may be drastically reduced in the next felling cycle.

Despite the adoption of a 30 year felling cycle, the concentrated felling of teak is believed to be the reason for the decline of the yield of natural teak throughout Thailand. The only measures which will avoid a repetition of this undesirable situation in the future are the preservation of a certain percentage of high quality trees and the enrichment planting of high quality trees.

b. Felling Cycle

As described earlier (see Page 19), a felling cycle of 40 years is not based on concrete data. Generally speaking, there is a close relationship between increment of the stand volume, the selective felling ratio and the felling cycle. Several equations to calculate a felling cycle have been suggested.In the case of tropical forests, however, there are such disturbing factors as illegal felling and slash-and-burn agriculture to be considered, in addition to marketability and growth rate. As a result, any decision on a calculation method appears meaningless at present and the collection of relevant data while adopting the current felling cycle is more important.

(3) Artificial Forests

Since artificial forests require a lot of labour and incur great amount of expense, their locational conditions should be superior to those of natural forests in order to ensure good results.

a. Selection of Tree Species

Table 2-7-1 (2) List of Main Planting Species gives the selected species for artificial forests. The following points should generally be considered at the time of species selection.

i) Species with superior growth potential in the early stages to beat fast grass growth.
ii) Species with superior wood quality, excellent mean increment and that rapidly reaches to its maximum increment.
iii) Species with a strong resistance to diseases and insect attack.
iv) Species with wide flexibility in terms of climatic and soil conditions.

b. Reforestation Method

Even when reforestation is anticipated, the felling of natural forest it must be carefully conducted in the following manner.

i) The plantation should commence with abandoned farmland, secondary forests and at sites with bad forest types.
ii) In principle, the dispersed felling of small areas should be conducted.
iii) Neighbouring felling sites should be avoided. If felling sites are adjacent, they should be divided by roads, firebreaks or shelter belts.
iv) Natural trees which do not disturb reforestation work should be preserved and used for shelter.
v) Excluding those with commercial value, natural trees which have been felled should be offered to the local inhabitants for their own use. Those exceeding the local demand should be burnt at the time of land preparation.
vi) Although the spacing varies in accordance with the species and the land conditions, spacing of 4m x 4m (625 trees/ha) should be generally adopted.
vii) The growth of plants is likely to change drastically depending on their species and spacing. Therefore tending operation (i.e. replanting, weeding, vine cutting, improvement cutting, thinning, etc.) should be carefully carried out according to the actual situation.

(4) Bamboo Forests

Bamboo trees are often found to form the lower layer of a natural forest, especially in those forests where the upper layer trees are sparce. Those sites where bamboo growth is good should be developed as bamboo forests.

Bamboo trees of 3 - 4 years should be felled annually as these are considered to be the best quality. Poor or dead bamboo trees should be removed and the unfavorable trees blocking the light should be felled. In the case of those which are not designated as bamboo forest, it is expected that they will eventually die out following crown closure although they and their shoots will be utilized if possible. Those bamboo trees growing on planned reforestation sites should be felled and their roots removed at the time of land preparation.

(5) Mountain Conservation Forests

These are found in steep, mountainous areas and usually covered by poor forests. Since they are located upstream of dams and are important in terms of water source conservation, felling should be prohibited and, in general, no forestry work should be implemented.

(6) River Basin Conservation Forests

These are usually located on steep slopes upstream of dams. The forestry work principles for mountain conservation forests also apply here.

(7) National Parks

National parks have a protective function in terms of preserving beautiful landscapes and a public function in terms of providing recreation areas utilizing these landscapes.

a. Mountain Conservation Forests-see (5) above

b. River Basin Conservation Forests-see (6) above

c. Protected Forests

Felling should be generally prohibited in these forests.

d. Rehabilitation of Forests

These are deteriorated forests due to farming and forest fires, etc. In principle, indigenous species or natural regeneration should be implemented. After rehabilitation has been completed, these forests should be reclassified as protected forests.

e. Experimental Forests

As national parks, where the main objective is forest conservation, are most suited for various experiments (including increment surveys over a long period of time) experimental forests should be introduced in national parks. Separate work methods should be determined for these forests in accordance with their objectives.

f. Facility Areas

Park roads (for vehicle traffic), footpaths, observation platforms, camping sites, caravan sites, resting facilities, overnight accommodation facilities, kiosks and restaurants, etc. should be provided in national parks in view of their public recreation function and areas for these facilities should be planned in advance.

(8) Agroforestry Areas

Agroforestry has been introduced in national forests as a part of the governmental social policy and for providing the necessary labour for forestry work. Forest village and Sor Tor Kor plans are currently being implemented in Thailand and, in the case of the model area, the plan is established in the form of Forest Village.

a. Artificial Forests

Artificial forests provide places of work for the inhabitants of forest villages. While the creation of new forest resources is the primary objective, intercropping also takes place in these forests. The reforestation method, etc. is the same as for a forestry area.

b. Communal Forests

Communal Forests provide the inhabitants of forest villages with firewood for their own use. In principle, the clear felling and sprout regeneration method should be adopted. Waste wood and dead trees in natural forests should also be used as firewood by inhabitants.

c. Bamboo Forests

These forests provide inhabitants with bamboo for their own use. The work method is the same as that for a Forestry Area.

d. Farmland/Residential Areas

These are used for farming and residential purposes. An area of 2.4 ha per household is assumed in the Forest Village plan.

2－7－3 Standard Work Volume

Work locations and work volumes should be properly given in the forest management plan for the immediate plan period (1st working period) based on the estimated future trend of the work volume.

(1) Decision on Felling Volume

It has already been mentioned that a sustained yield is one of the most important points in the preparation of a management plan. A sustained yield means that a steady annual yield can be expected in the long term future in both the qualitative and quantitative aspects. There are, however, different concepts of a sustained yield and different calculation methods which reflect different forest states (for example, old forest, young forest, natural forest or artificial forest), forestry work intensities, forestry work technical levels and socio-economic backgrounds. As a result, no general conclusion is possible.

The most popular and basic idea is the normal forest concept. Such calculation methods as the Kameraltaxe Method and Hundeshagen Method were introduced to modify the gap between a normal forest (and its stand volume) and an actual forest (and its stand volume).

In view of the actual conditions of tropical forests and the state of forest administration in Thailand today, it appears difficult to enforce yield regulations based on growth volume and yield regulations based on an area allotment method should prove more effective. Although the felling area method (30 year felling cycle) currently in use in Thailand is an area allotment method, its allotment seems to have been determined in view of forestry work convenience and it lacks the perspective of a sustained yield.

The adoption of an area allotment method which takes land fertility and the scope of legal regulations, etc. into consideration should prove more effective than the simple adoption of an area allotment method.

In principle, the sustained yield should be calculated for each forest management type given in the Work Arrangement Table (Page 21～22). If it is difficult to calculate each sustained yield separately, calculation of the sustained yield for the entire subject area would be sufficient.

Note: In Thailand, the actual results of sustained yield calculations largely differ depending on how far current forests (mostly natural forests) are converted to artificial forests, whether natural regeneration or reforestation is adopted for non-forest areas and the ratio of fast growing trees planted. Although decisions on the above involve certain technical aspects, such as soil conditions, etc., they are primarily policy issues.

a. Natural Forests

The standard annual yield, i.e. the standard felling volume for a natural forest, can be calculated by the area allotment method as follows.

$$\text{Standard Annual cutting Area} = \frac{\text{Area of Natural Forest Work}}{\text{Cutting Cycle}}$$

The yield is basically given in terms of area. The yield per ha, which is assumed from existing yield data, should be multiplied by the area when the volume is required.

b. Artificial Forests

The immediate yield of an artificial forest can be found by answering the questions of how many years are estimated to be required to clear standing trees in planned artificial forest sites and how many trees should be left untouched in these sites. As these questions both relate to how reforestation work is implemented, their answers should take into consideration such factors as the labour and cost involved from the land preparation stage to the tending and protection stages and planting stock preparation, etc. For example, if annual reforestation of 100 ha is found possible, standing trees in these 100 ha will be subject to felling. The anticipated yield is found by calculating the total volume of subject trees with both the rate of reserved trees and the utilization rate.

The future yield of an artificial forest is calculated by multiplying the planted area by the estimated yield per ha. The resulting figure, however, only serves for reference purposes to show a possible change in the stand volume and should not be treated as being conclusive.

c. Others

In addition to the types of yields described above, there will also be damaged trees due to forest road construction or the preparation of farming area. As these do not provide a continuous yield, however, only the yield from damaged trees in known sites should be calculated.

(2) Decision on Reforestation Volume

The reforestation volume is given in terms of area, as described in (1) b. above. When enrichment planting and tending are planned to improve the quality of natural forests, such relative volume should also decided in advance.

3. POINTS TO NOTE IN PLAN IMPLEMENTATION

3－1 Soil Types and Forestry Work

"The right tree on the right site" is the most important principle for forestry work. Many natural factors are involved in forest growth, such as topography, geology, climate and vegetation, etc.and soil is formed by the complex interaction of these factors over a long period of time. In other words, examination of the soil makes a certain understading of the natural environment possible. It is, therefore, extremely important to understand the soil distribution of a subject area to determine the contents of forestry work.

Taking the relation between topography and soil for example, the water soluble materials of soil in the upper part of a slope are easily washed away and accumulated in the lower part of the slope. In addition, the upper part of a slope tends to be dry due to constant exposure to wind while the lower part tends to be moist due to running water.

Those materials which form soil are called parent materials and can be granite, limestone, andesite and/or volcanic ash depending on the area. The properties of these parent materials are strongly observed in the early stage of soil formation but change in the course of soil maturity due to the influence of such natural conditions as climate and vegetation. Thus soil properties originating from the same types of parent materials differ widely.

In a tropical zone where the temperature is constantly high and the dry season clearly distinguishable from the rainy season, the soil is affected in the following way.

i) In the moist areas organic materials are quickly decomposed. Unlike the case of a temperate or frigid zone, therefore, the accumulation of humic substance is seldom observed.

ii) In the areas where the evaporation exceeds the rainfall with a high ground water level, the soil not only becomes dry but salt is transported to the surface layer, making the soil strongly alkaline. Conversely, in areas of excessive rain-fall, not only salt but also iron and aluminium in the surface layer are washed away, causing eluviation.

Existing soil maps can be used to study soil conditions. However, if no map is available, a soil survey on the appropriate scale corresponding to the size of the subject area is required to determine the policy for forestry work.

There are many soil classification methods and the soil maps and method used for the model area is given in the Survey Report. The following points are important common knowledge for forestry work.

i) Thick soil has good fertility and is suitable for tree growth.

ii) Soft soil has good physical properties and is suitable for tree growth.

iii) Reforestations in those places where trees develop deep roots tend to produce good results.

iv) The existence of a blueish white layer (gley layer) indicates a stagnant condition and, therefore, the soil is unsuitable for tree growth.

v) The soil tends to be consolidated and, in most cases, is unsuitable for tree growth in those places where a red and grey mottling layer or plinthite is found.

3－2 Agroforestry

Agroforestry serves various purposes and its adoption is a matter for government decision. In the model area, agroforestry is considered to be a method to promote forest improvement and the contents of the work have been discussed based on the following.

i) Types of work and work volume required for forest improvement.

ii) Annual labour input required to achieve i) above.

iii) Required number of farming households to supply the labour given in ii) above.

iv) Land area and relevant measures to support these farming households.

The crucial point here is that while a forestry related program (requiring work volume) can be modified in later years, the settlers live depending on the employment in forestry work. Therefore, the work volume should be determined carefully in order to avoid any reduction of the work volume in subsequent years.

With the passing of time, however, settlers' attitudes to employment in forestry work and living standard will change. Corresponding to these changes, it is necessary that forest improvement work be carried out while the living standard of the settlers be improved through government efforts to secure markets for the agricultural products and to introduce profitable crops for these settlers.

3－3 Forestry Research

While there are many types of forestry research, the most important factor in the case of the model area is considered to be the growth volume research. The following points should be noted when growth volume research is planned.

a. Artificial Forests

i) Growth research plans should be prepared for each species. If possible, several research sites should be selected for each species.

ii) Each site should be duplicated and have an area of one ha and should be of a square shape. The sites should not be adjacent to felling sites and should preferably have the same topographical conditions.

iii) Signs indicating that the sites are research sites should be posted and bordering trees should be marked with paint or by other means. If possible, each test tree should be numbered.

iv) The tree height and volume should be measured every year for fast growing trees and every 5 years for slow growing trees and the measurement results should be recorded in the register.

v) The felling time and volume of damaged and thinned trees should also be recorded in the register.

vi) The time, volume, labour input and cost, etc. of the tending work (replacement planting, weeding, salvage cutting, climber cutting and thinning) should be recorded in the register.

b. Natural Forests

i) Research sites should be selected for each forest type.

ii) Each site should be duplicated and have duplicates an area of 2 ha and should be of a square or rectangular shape. The sites should preferably not be adjacent to felling sites and should have uniform topographical conditions.

iii) As in the case of artificial forests, the provision of signs and tree markings, etc. also apply to natural forests.

iv) The diameter, height, clear length, volume and commercial volume of each tree should be measured every 5 years and, together with the species, recorded in the register.

v) The provisions for damaged trees and thinned trees and for tending, etc. for artificial forests also apply to natural forests.

c. Storage of Register and Other Documents

As the growth volume research requires a long period of time to obtain results, the sections or persons responsible for the research may change from time to time. Therefore, the register and other documents should be carefully stored to ensure the continuity of the research. Interim reports should be published at suitable intervals.

d. Site Locations

Research sites should preferably be selected in national parks which do not have concessions and that are not subject to the impact of human habitation, recreation, etc.

3—4 National Park Utilization Program

National parks are expected to serve as recreational areas for the public as well as to preserve the precious natural environment and landscapes for future generations. Management plans for national parks should be prepared incorporating both conservation and utilization programs.

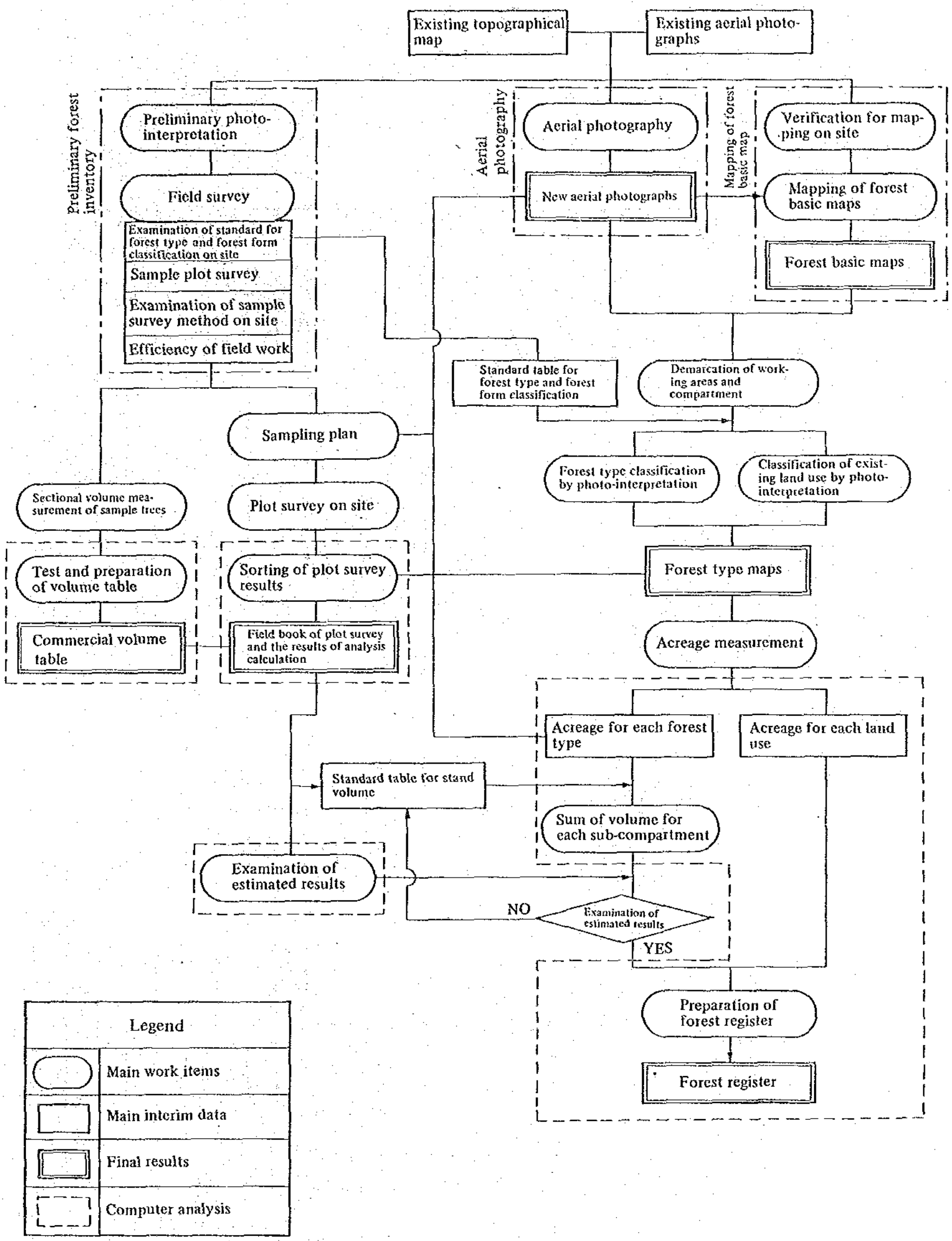
A conservation program for a national park can be easily implemented by the introduction of strict regulations on forest use and measures to restore damaged sites. The implementation of a utilization program, however, is more difficult because such factors as public needs, the facilities to be constructed, maintenance method for these facilities, coordination with conservation and forest utilization requirements and the financial burden must be firstly examined.

At present, all utilization programs must be discussed with and authorized by the National Park Commission. In the future, the opinions of local inhabitants and related people should be reflected in the programs to widen the scope of utilization. In the case of the model area, improvement of the road network for easy access should be given priority.

4. REFERENCE MATERIALS

4—1 An Example of Forest Inventory Flow

FLOW DIAGRAM OF FOREST INVENTORY



4—2 Form of Forest Register

FOREST REGISTER

Sheet №

Regional Forest Office	Planning Area	Working Area	Amphoe

Division		Forest land type	Acreage				Site Condition				Current Forest Condition				Working method	Forest type	Species	Stand age	Density	Mean D.B.H. (G.B.H.)	Mean height	Volume		Remarks
Compartment №	Sub-compartment №		Forest land	Non-forest land		Total	Altitude	Gradient	Land use capability	Land classification	Forest formation & land use	Crown density	Acreage	Volume								per ha	Total	
				Item	Acreage																			
			ha		ha	ha	m	°				%	ha	m³						cm	m	m³	m³	

II. MANUAL FOR MONITORING OF THE FOREST LAND USE BY MEANS OF REMOTE SENSING

INTRODUCTION

Remote sensing technique is very effective in order to understand the state of regional natural resources. Remote sensing is a technique which provides distinction and interpretation of subjects and phenomena, after information about these subjects and phenomena are collected from a distant place without direct contact.

Remote sensing technique in a broad sense include aerial magnetometry and subterranean exploration, but we define remote sensing as follows:

Remote sensing is a technique which uses a sensor mounted on a platform such as an aeroplane and a satellite to collect electromagnetic waves reflecting or radiating from subjects on the earth and to obtain information about the subjects and phenomena from the data.

Remote sensing data obtained through an aeroplane or a satellite are also very effective to collect information in a wide region within a short period of time and to grasp temporal changes. Therefore, these characteristics of remote sensing data are fully utilized to conduct surveys and investigations for various purposes, including environmental conservation, disaster prevention, rational utilization of national lands, understanding of agricultural, forestry and fishery resources, and exploitation of mineral resources.

This report focuses forest study among many types of remote sensing data utilization, and summarizes as manual for forest investigation. Part A deals with remote sensing, Part B describes the monitoring of the forest land use by means of remote sensing, and Part C summarizes a case study of the monitoring of the forest land use by means of remote sensing in Thailand.

CONTENTS

C. "CASE STUDY"

A. THE REMOTE SENSING

1. Outline

The remote sensing refers to a technique which collects data on subjects and phenomena reflecting or radiating electromagnetic waves by using sensors mounted on a platform such as an aeroplane and a satellite to provide information about the subjects and phenomena.

The remote sensing can provide data on information in a wide region within a short period of time and thus offer high efficiency in understanding temporal changes. These data are processed and analyzed for various types of surveys.

Platforms for data collection may be a satellite, an aeroplane, or a special ground vehicle. These platforms depend on the range of the survey to be conducted and the type of sensors to be used.

Sensors used in the remote sensing include camera, scanner and TV camera. Remote sensing utilizes a wide range of waves from γ rays and millimeter waves to centimeter waves. The ranges used most commonly are the visible light range and the near-infrared and thermal infrared range.

Collected data are processed to analog data such as photos and digital data for analysis by a computer. Analog data such as photos provide easy understanding of the location and distribution of subjects. On the other hand, digital data which are subjected to image processing such as automatic classification by a computer and image stressing can be changed to different types of image, and so can provide different aspects of the subjects.

2. Principle

Any kind of subjects (substances) carry inherent reflection characteristics of electromagnetic waves depending on their kinds, and the intensity of the reflected electromagnetic waves is measured for every wave length from a satellite or an aeroplane to identify substances on the earth surface. This is the principle of the remote sensing.

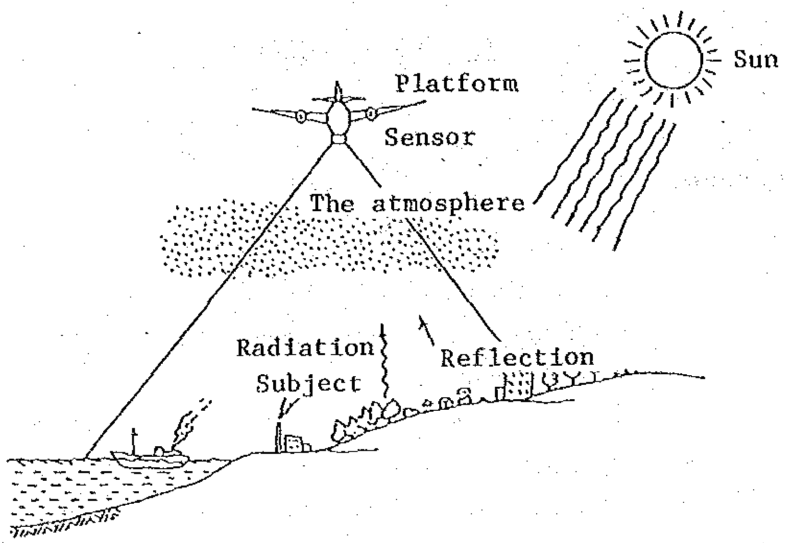


Fig. 1 Data collection by remote sensing

Electromagnetic waves are termed in accordance with wavelength bands. The wavelength region used in the remote sensing covers the range from ultraviolet rays to microwaves.

γ-ray	X-ray	Ultraviolet	Visible	Near-infrared (Sunlight)	Near-infrared	Far-infrared	Micro wave

0.5Å 50Å 0.4μ 0.7μ 3μ 14μ 1mm 10m

Fig. 2 Spectrum of electromagnetic waves

Visible rays are electromagnetic waves in the visible range; blue color has shorter wavelength, while red color has longer wavelength. Further longer wavelength is in the infrared region. Infrared rays are classified into near-infrared, medium infrared and far infrared (thermal infrared) depending on wavelength. Longer wavelength rays than infrared rays belong to so called electric waves, which are represented by microwaves.

The electromagnetic waves reaching the earth surface in the wavelength bands used in the ordinary remote sensing are used only for observation of the earth surface.

Figure 3 shows schematically characteristics of reflection spectra of representative substances on the earth surface.

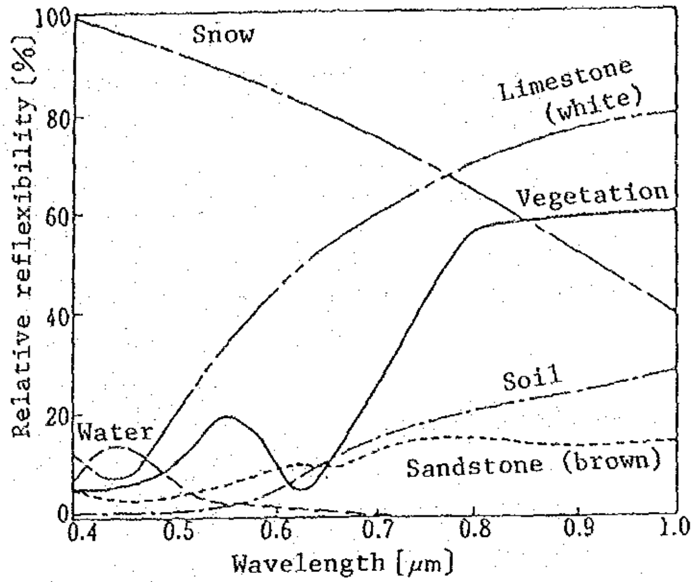


Fig. 3 Distribution of general reflection spectra
(From U.S. Geological Survey)

3. Flow of Analysis

The remote sensing is subjected to analysis consisting of (1) data collection, (2) data processing/analysis, and (3) application to survey.

(1) Data collection ⟶ (2) Data processing/analysis ⟶ (3) Application to survey

(1) Data Collection

1) Purchase from major agencies concerned

①LANDSAT Satellite data --- · EOSTA Ltd. (U.S.A.)
· Receiving centers in major countries

②NOAA Satellite data --- · NOAA (U.S.A.)

③SPOT Satellite data --- · SPOT IMAGE Ltd. (France)

2) Data collection by photography/observation

Data at the level of aeroplane --- Aerial photography surveying companies

(2) Data Processing/ Analysis

1) Data processing techniques

①Computer processing-based technique (Digital processing technique).

②Photo processing technique (Analog processing technique)

2) Data analysis techniques

①Analysis based on dialogue between an analysts and an image analysis system by computer

②Interpretation by analyst's eyes --- Interpretation by eyes using photos (for instance, extraction of geological structures)

(3) Application to Survey

① Use as preliminary information for a survey

② Use to check and correct in a field survey

③ Use to prepare necessary thematic maps

4. Remote Sensing Data

4.1. Types of Platforms

Currently used platforms are grouped into (1) satellite, (2) aeroplane, and (3) ground.

(1) Satellite

Table 1 summarizes the details of major satellites used for earth observation.

Table 1 Details of major satellite used for earth observation

Satellite for earth observation	Year of launching	Country of launching	Major mounted sensor	Wavelength range	Resolution (m)	Observation width (km)	Orbital height (km)	Observation period (day)	Covered field
LANDSAT No. 1 No. 2 No. 3	1972.7 (Functional stoppage) 1975.1 (Functional stoppage) 1978.3 (Functional stoppage)	USA	MSS	μm 0.5- 0.6 0.6- 0.7 0.7- 0.8 0.8- 1.1	80	185	920	18	Cover the earth and widely used for both land and water areas.
LANDSAT No. 4	1982.7 (Functional stoppage)		MSS	The same with the above	The same with the above	180	700	16	The same with the above
No. 5	1984.3	USA	TM	0.45- 0.52 0.52- 0.60 0.63- 0.69 1.55- 1.75 10.40-12.50 2.08- 2.35	30 120 30	180	700	16	The same with the above
SPOT No. 1	1986.2	France	HRV	0.51- 0.73 0.50- 0.59 0.61- 0.68 0.79- 0.86	10 20	60	830	26	The same with the above Preparation of geographical maps is possible because of stereo visibility

(2) Aeroplane

1) Bimotored aeroplane --- MSS for aeroplane mounting
2) Single-engined aeroplane --- Aerophotos
3) Helicopter --- Oblique photos
4) Model plane/ Model helicopter --- Very low

(3) Ground Platform

1) Crane vehicle
2) Cherry picker

{ Observation of reflection-characteristics and radiation characteristics of substances.

4.2. Types of Sensors

Figure 4 shows the relation between the ranges detected by currently used sensors and electromagnetic waves.

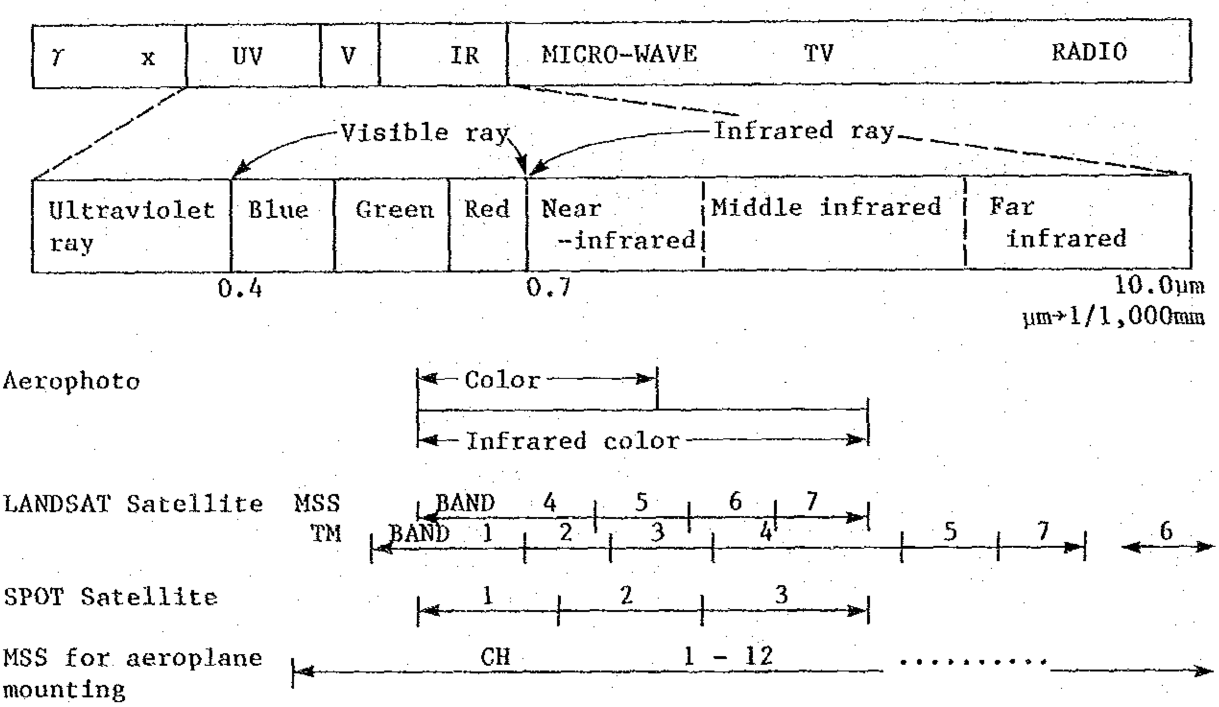


Fig. 4 Sensors and ranges of electromagnetic waves

(1) Camera

Aerophotos are grouped as follows, according to combinations with films and filters to be used:

1) Panchromatic photo

The visible ray range is recorded in a panchromatic film.

2) Color photo

The visible ray range is recorded in a color film.

3) Infrared color photo

Of the visible ray range, green and red lights and near infrared rays are recorded in a color film.

(2) MSS of LANDSAT Satellite

A MSS is a scanning type radiometer called Multispectral Scanner (MSS), which records visible rays (green and red rays) and near-infrared rays with 4 different wavelength bands. MSS is the sensor mounted on LANDSATs No. 1 through No. 5, and records 180km × 180km as one scene, with the minimum resolution of approximately 80m × 80m. Its appearance is shown in Figure 5.

1) Band 4 = 0.5 - 0.6 μm (Green light of visible rays)
2) Band 5 = 0.6 - 0.7 μm (Red light of visible rays)
3) Band 6 = 0.7 - 0.8 μm (Near-infrared rays)
4) Band 7 = 0.8 - 1.1 μm (Near-infrared rays)

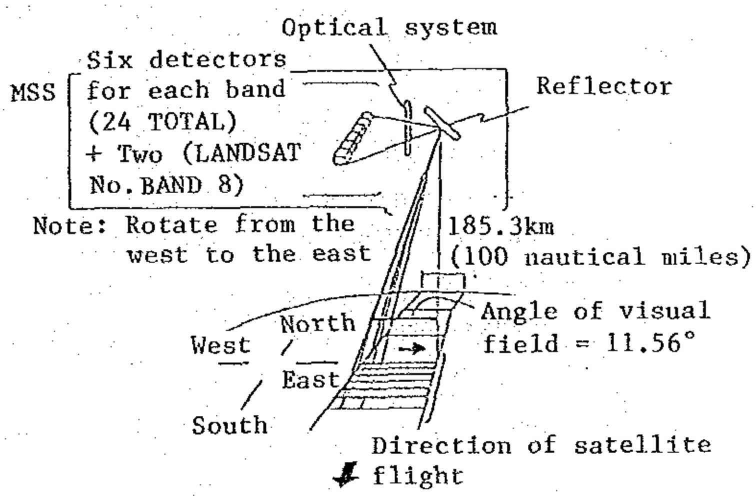


Fig. 5 Appearance of LANDSAT MSS

(3) TM of LANDSAT Satellite

A TM called Thematic Mapper (TM) is a scanning type radiometer similar to MSS, and records visible through far (thermal) infrared rays with 7 different wavelength bands. It has been mounted on satellites after No. 4. TM records 180km × 180km as one scene, with the minimum resolution of 30m × 30m. Its appearance is given in Figure 6.

1) Band 1 = 0.45 - 0.52μm (Blue light of visible rays)
2) Band 2 = 0.52 - 0.60μm (Green light of visible rays)
3) Band 3 = 0.63 - 0.69μm (Red light of visual rays)
4) Band 4 = 0.76 - 0.90μm (Near-infrared rays)
5) Band 5 = 1.55 - 1.75μm (Middle infrared rays)
6) Band 6 = 10.40 - 12.50μm (Far infrared rays)
7) Band 7 = 2.08 - 2.35μm (Middle infrared rays)

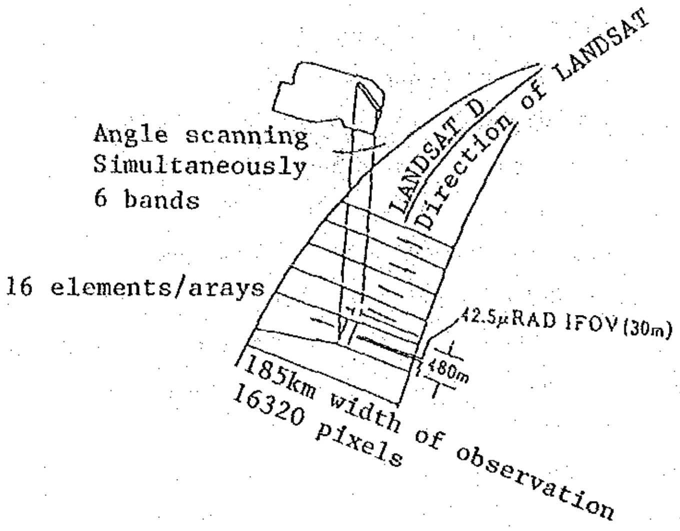


Fig. 6 Appearance of LANDSAT MSS

(4) HRV of SPOT Satellite

This is a sensor mounted on SPOT Satellite launched by France. HRV is an abbreviation of High Resolution Visible imaging instrument. HRV produces two types of data.

1) Panchromatic mode; Record 0.51 – 0.73μm with black-white single band

2) Multispectral mode; Band 1; 0.50 – 0.59μm
Band 2; 0.61 – 0.68
Band 3; 0.79 – 0.86

Rhw minimum resolution is approximately 10m × 10m, and 20m × 20m for the panchromatic mode and for the multispectral mode, respectively. The most marked characteristic of HRV is provision of stereo visibility.

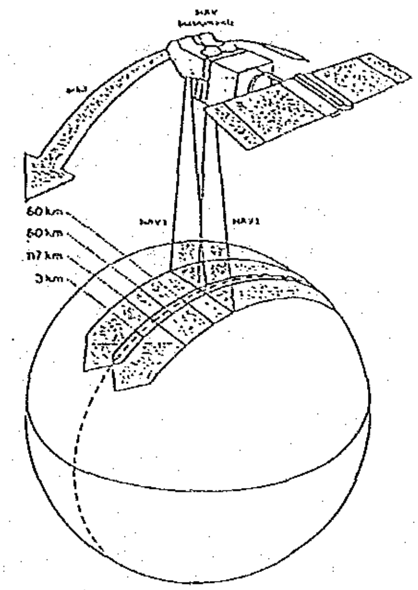


Fig. 7 Appearance of SPOT HRV

(5) MSS for Aeroplane Mounting

This is a MSS of a similar type with MSS of LANDSAT mounted on an aeroplane. The MSS records visible rays through far (thermal) infrared rays from low altitude in higher precision than that of LANDSAT MSS. Figure 8 gives its appearance. This sensor is used in a wide area including water temperature survey and geothermal survey.

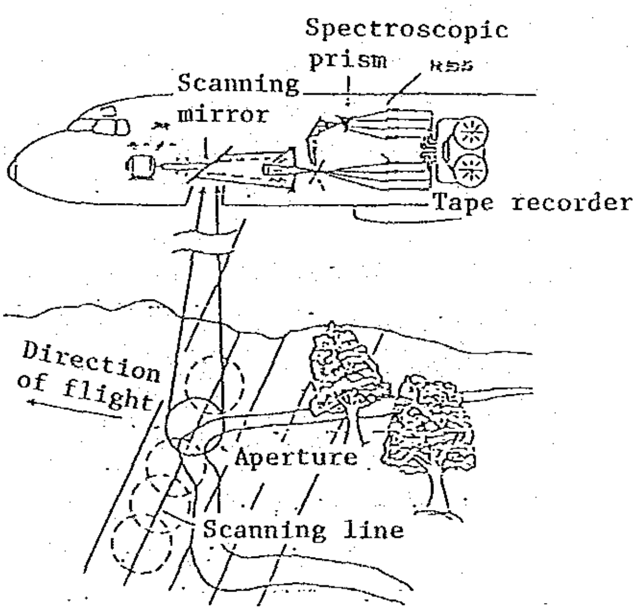


Fig. 8 Appearance of MSS for aeroplane mounting

4.3. Data Collection

(1) Visible ray data
Data in the wavelength range equal to our vision in daily life - (Example) Red light data of visible rays are best to analyze a polluted water pattern.

(2) Near-infrared data
Suitable to measure vitality of vegetation and water areas on the earth surface

(3) Middle infrared data
It is said to be best to analyze degrees of rock alteration and geological structures and distinction between vegetation and non-vegetation

(4) Far infrared ray data
Used to each thermal distribution such as terrestrial heat and water temperature

5. The Status of Remote Sensing Data Utilization

Remote sensing data have been widely utilized in many countries for various purposes. Fields where remote sensing data are utilized include agriculture, forestry, mining, land utilization, geology, fishery, oceanography, environmental science, geography, hydrology, galceology, volcanology, seismology, and civil engineering. Recently, they are utilized even in energy issues and archeology.

The followings are examples of remote sensing data utilization:

1) Estimation of wheat cropping area in major wheat producing countries in the world.
2) Study of changes in forest covers due to meteorological fluctuations.
3) Surveillance of volcanic explosion.
4) Monitoring of snow cover distribution.
5) Surveillance of water qualities of lakes, marine pollution in coastal areas, europhication of lakes and air pollution.
6) Understanding of temperature distribution on the sea surface.
7) Estimation of timber stocks in forests.
8) Surveillance of areas damaged by pests and cut over.
9) Estimation of crop planting area and production.
10) Surveillance of land utilization and land cover.
11) Updating of map information.
12) Investigation of flood damages.
13) Monitoring of water head areas.
14) Investigation of wildlife habitats.

6. Advantages of the Survey

Information about forests from remote sensing data can thus offer various information through image analysis and image interpretation. Their characteristics are summarized at each level of ground, aeroplane and satellite, as shown in Table 2.

Table 2 Comparison of various charcteristics among information collection methods by remote sensing

Charac- teristics in observa- tion / Remote Sensing System	Coverage	Simultaneous coverage	Periodicality	Emergency	Qualitative precision	Quantitative precision	Numerical precision	Cost effectiveness
Information collection from ground observation	△ Wide coverage requires many ground observation	△ Impossible	△ Continuous observation and periodical observation are extremely difficult.	○ Unavailable in emergency observation	◎ High precision	◎ Measurable	○ Possible but lacking of quantitative	△ Establishment of a network covering a wide area is too costly.
Information collection from aeroplane observation	○ Wide coverage requires a fairly large number of flights	○ A gap between flights can be ignored, but coverage is the same with the left	△ Periodical observation requires higher costs	◎ Appropriate, although waiting period of aeroplane has to be examined	◎ Excellent in resolution	△ Excluding certain subjects, quantative measurement is difficult certain	△ Possible but costly	△ Photographing a wide area requires higher costs
Information collection from satellite observation	◎ One characteristic of satellite observation is wide coverage	◎ One characteristic of satellite observation is simultaneous wide coverage	◎ One characteristic of satellite observation is periodicality (18 days for LANDSAT)	△ Only LANDSATs 1 and 2 have some problems	○ Limited resolution (80m for LANDSAT)	△ Excluding certain subjects, aquisition of data is not so costly of receiving equipments	◎	◎

◎ : Very excellent

○ : Slightly excellent or ordinary

△ : Slightly poor

Ground remote sensing gives excellent quantitative and qualitative precision, while it is inferior in wide coverage, periodicality and cost effectiveness.

Remote sensing from aeroplane is excellent in emergency observation and qualitative precision, while poor in quantitative and numerical precision and cost effectiveness.

Compared with these two, remote sensing from satellite is excellent in all conditions except for emergency observation.

In the light of these characteristics, forest monitoring by remote sensing will take an approach to establish a forest management system, which consists of processing of other geographical information to image database for systematic utilization.

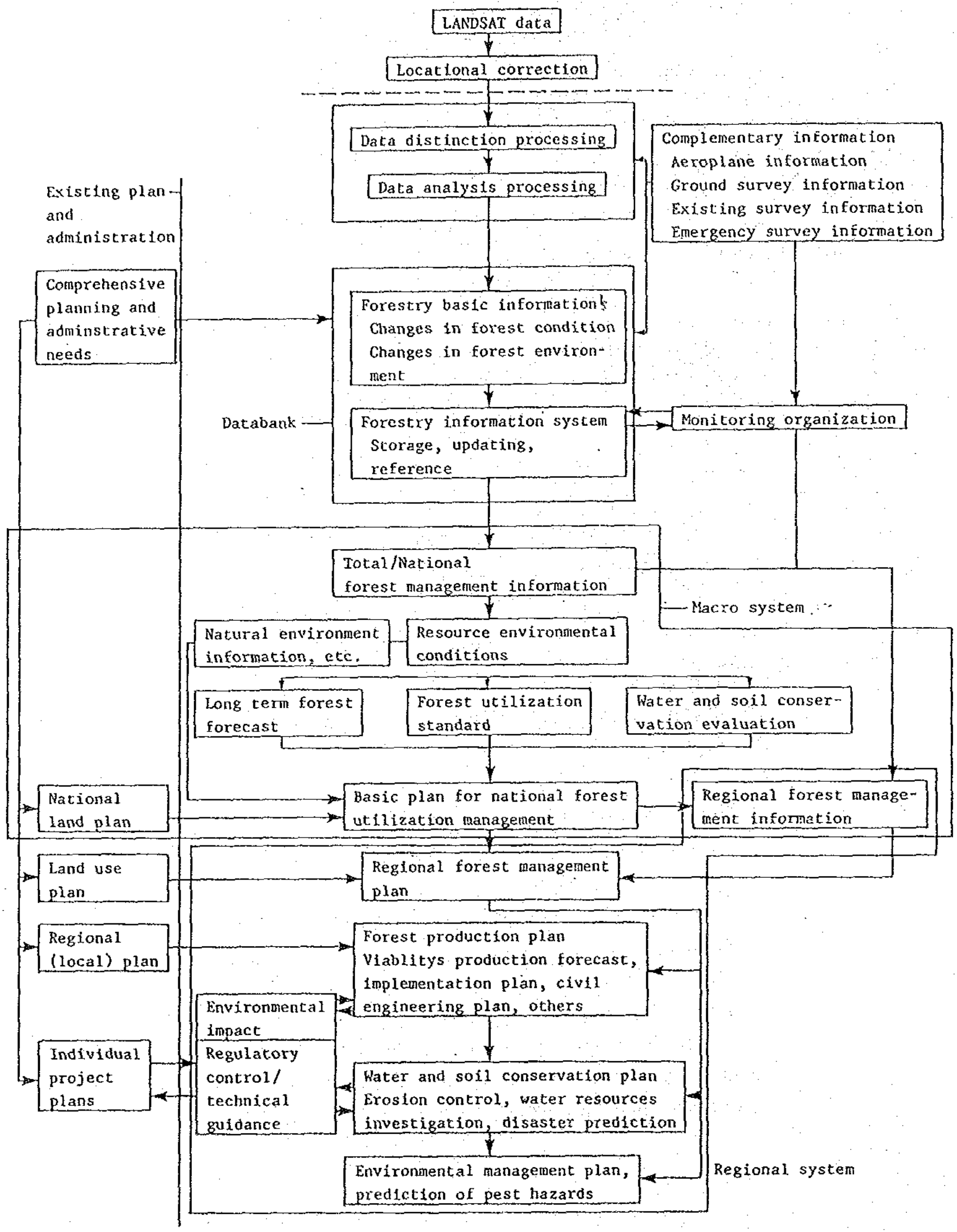


Fig. 9 A conceptual figure of forest management using remote sensing

B. MONITORING OF THE FOREST LAND USE BY MEANS OF REMOTE SENSING

1. Outline

A forest study is generally conducted to understand the present condition of a forest and to plan rational forest management in accordance with its local condition. Utilization of remote sensing data is extremely effective to conduct a forest investigation in a wide area in similar precision within a short period of time. Forest covers mostly distribute in mountainous area in the world, and so it is extremely difficult to implement field investigation, unless a very limited area is to be surveyed.

Remote sensing data appropriate to a forest investigation include those from satellites and aeroplanes. They have to be used differently for different subject areas and study items. Satellite data are suitable for macroscopic understanding of forests, while aeroplane data are advantageous because of changeability of scale in accordance with the study purpose.

General procedure for a forest study is:

1) Understand fully the study purposes
2) Examine the details of the study in accordance with the purposes.
3) Investigate availability of data.
4) Collect data.
5) Implement image analysis.
6) Examine results of image analysis and evaluate the forest resources.
7) Examine study results.

The monitoring procedure is explained below. Figure 10 gives a flowchart of general monitoring.

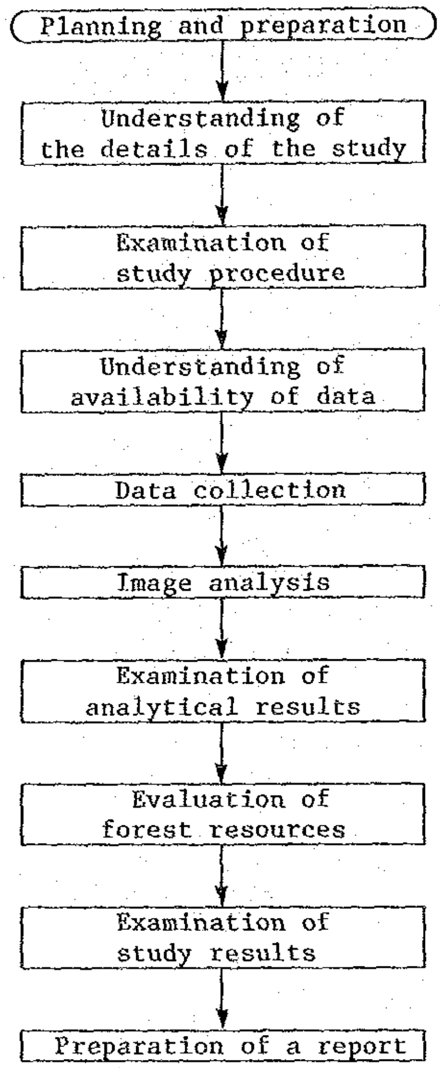


Fig. 10 Flowchart of general monitoring

2. Monitoring Procedure

2.1. Understanding of Survey Purposes

Purposes of the forest study is fully understood to examine comprehensively the study details which meet the purposes. In this case, the study area and precision have to be fully examined, before a rational study method is decided.

Generally speaking, major purposes of a forest study may be understanding of the present situation of the forest resources and collection of basic information required for forest management.

The present condition of the forest resources mainly includes understanding of the tree species, area, and stand volume. On the other hand, with respect to basic information necessary for forest management, analysis of relations between conditions such as geology, soils, land utilization, disasters and hydrology corresponding to the forest type and the forest is of great importance. Table 3 shows major items to be investigated in a forest study.

Table 3 Examples of major items to be investigated in a forest study

Study types	Major study items
National forest resources study	By major tree species, by tree diameter, area, stand volume, locality (5 years). (Forest stratification, specimen sampling, on the spot confirmation, etc.)
Study for planning local forest management	Revision of forest register (tree species by sub-group, stand volume growth) (5 years). Preparation of maintenance planning table, Preparation of estimated long-term production table Operation within 5 years (planting and cutting amounts), Designation of site, Designation of flood control works and earth works. (Preparation and updating of management map, forest type map, geological map and soil map, road construction plan maps and figures)
Overall study for erosion control (mainly for restoration of existing collapsed land)	Judgement of importance by basin (torrent devastation) (land conditions, geology, meteorology, subjects to be secured) Study for present/predicted situation of devastation by basin (amount of unstable soils, history of disasters, stand condition, etc.)
Study of potentially dangerous land in mountainous area (Prediction of the disaster occurrence due to torrential rain)	Mountenous land failure study (land condition, inclination of mountain slope, subject soils, condition of movement, subjects to be protected, etc.)
Study on forest damage information	Wind and flood damages, snow damages, pest damages, animal damages, smoke damages, fire, stealing, cutting obstruction, etc.
Study for timber supply-demand measures	Projects for timber storing, improvement of forestry structure, measures to improve forest products distribution

2.2. Examination of Survey Methods

Study methods which can meet the study purposes understood in 2.1. are reviewed and examined. Major items to be examined include:

1) Understanding of availability of data
   Availability of remote sensing data from satellites and aeroplanes are investigated, as well as topographical maps, thematic maps (geological maps, soil maps, vegetation maps and others) and references necessary for the study.
2) Data collection
   Data necessary for the study are acquired from agencies concerned. In case of the absence of necessary data, observation is made or other data are used.
3) Image analysis/image interpretation
   Data thus acquired are subjected to image analysis or image interpretation to prepare evaluation maps required for evaluating the forest resources.
4) Evaluation of forest resources
   Thematic maps and evaluation maps are used to evaluate the forest resources.
5) Examination of results
   The above mentioned study results are summarized for further examination.

2.3. Understanding of Available Data

For better understanding of availability of data, how to handle satellite data and aerophotographic data are explained below:

Of satellite data, LANDSAT data which can be obtained periodically and give reasonable resolution have been widely utilized. As mentioned previously, LANDSAT data are produced by two different types of sensors; MSS (resolution of 80m) and TM (resolution of 30m). These two types of data have to be used differently according to study purposes.

Availability of LANDSAT data can be checked for data of observation, cloudage and the quality of images at a local receiving center covering the study area.

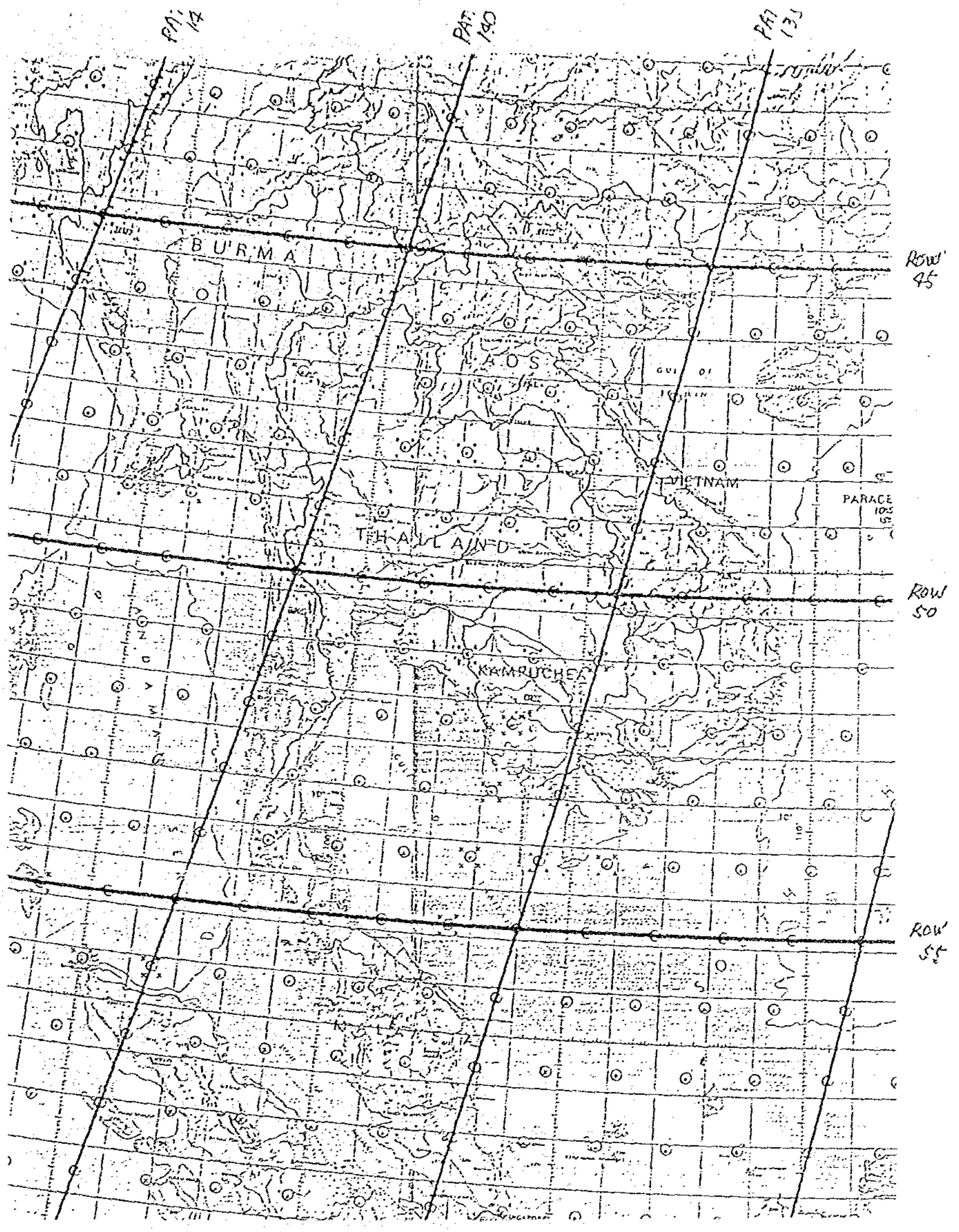


Fig. 11 Map of LANDSAT 1-3 coverage

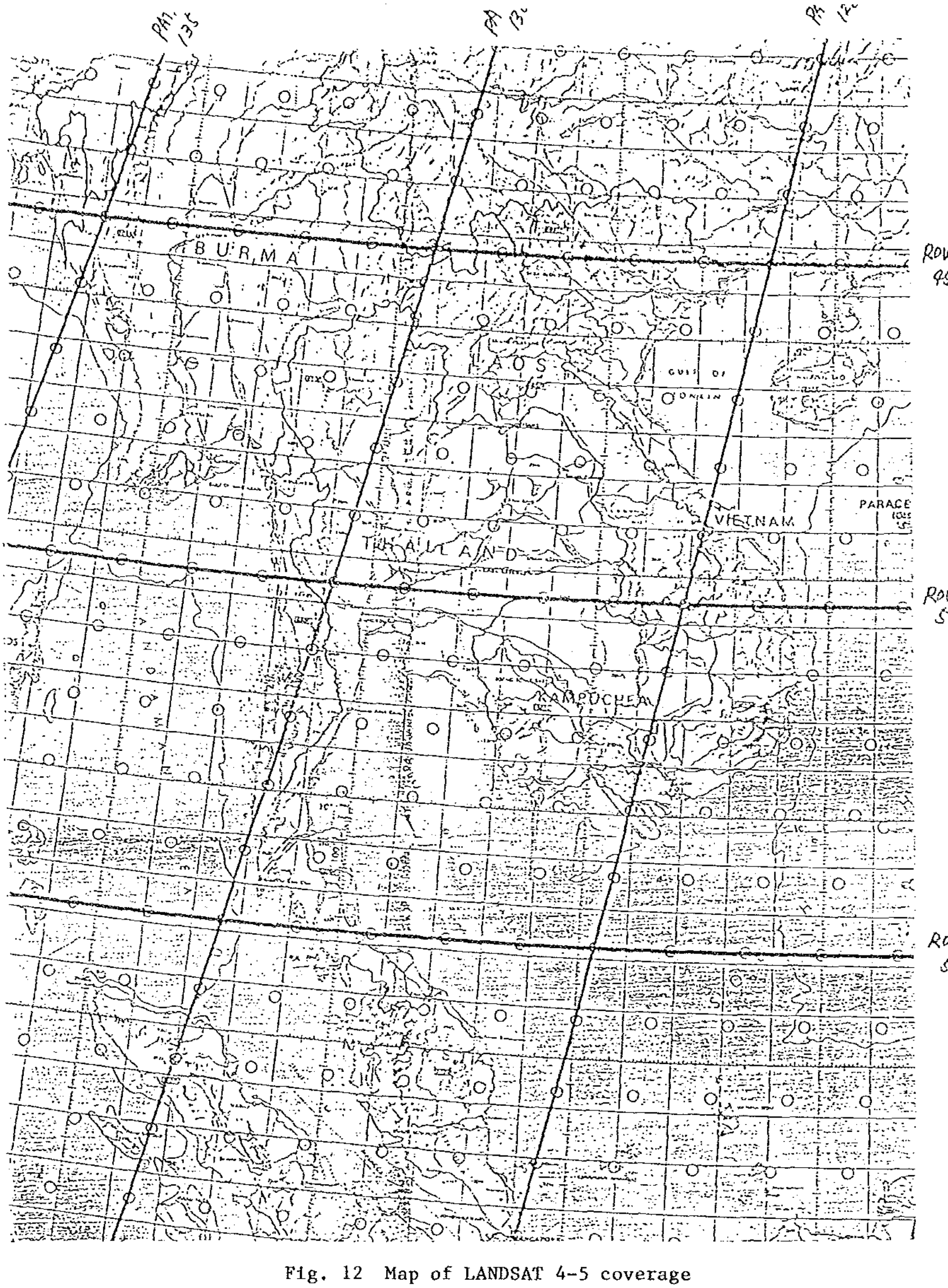


Fig. 12 Map of LANDSAT 4-5 coverage

Table 4 LANDSAT-4 catalog (Cloud cover list)

PATH-ROW	DD/MM/YY	NASA-ID.	CLOUD COVER 1	2	3	4	QUALITY
139-42	020186	41266-03562	9	3	8	3	8
	180186	41282-03555	3	1	5	4	8
	030286	41298-03553	1	0	0	0	8
	190286	41314-03550	2	0	0	0	8
	070386	41330-03543	1	4	0	0	8
	080486	41362-03542	0	5	0	6	8
	100586	41394-03545	4	2	1	1	8
	011086	41538-03563	8	9	9	8	8
	171086	41554-03564	9	9	9	9	8
139-43	020186	41266-03564	3	0	1	0	8
	180186	41282-03562	0	0	0	0	8
	030286	41298-03555	0	0	0	0	8
	190286	41314-03552	0	0	0	0	8
	070386	41330-03550	0	0	0	0	8
	080486	41362-03544	0	3	0	3	8
	100586	41394-03552	1	1	2	1	8
	011086	41538-03565	8	9	3	8	8
	171086	41554-03570	7	8	3	8	8
139-44	020186	41266-03571	0	0	0	0	8
	180186	41282-03564	0	0	0	0	8
	030286	41298-03562	0	0	1	0	8
	190286	41314-03555	0	0	0	0	8
	070386	41330-03552	0	0	0	0	8
	080486	41362-03551	0	2	0	2	8
	100586	41394-03554	1	1	1	1	8
	011086	41538-03572	8	8	9	7	8
	171086	41554-03572	1	5	0	1	8
139-45	020186	41266-03573	0	0	2	3	8
	180186	41282-03571	0	0	0	0	8
	030286	41298-03564	3	7	7	7	8
	190286	41314-03561	0	0	0	0	8
	070386	41330-03554	0	0	0	0	8
	100586	41394-03560	2	5	3	3	8
139-45	011086	41538-03574	8	4	7	1	8
	171086	41554-03575	0	1	0	1	8
139-46	020186	41266-03575	3	4	5	5	8
	190286	41314-03563	0	1	0	1	8
	100586	41394-03563	3	5	1	3	8
140-37	090186	41273-04002	1	2	1	2	8
	250186	41289-04000	0	0	0	0	8
	100286	41305-03593	0	1	0	0	8
	140386	41337-03583	2	3	3	1	8
	300386	41353-03581	8	7	3	4	8
140-38	090186	41273-04004	1	1	1	2	8
	250186	41289-04002	0	0	0	0	8
	100286	41305-03595	1	1	3	2	8
	260286	41321-03592	8	7	1	1	8
	140386	41337-03590	3	1	4	1	8
	300386	41353-03583	0	0	0	0	8
	010586	41385-03592	3	4	1	5	8
	081086	41545-04011	9	9	9	9	8
140-39	090186	41273-04011	1	1	1	1	8
	250186	41289-04004	0	0	0	0	8
	100286	41305-04002	5	2	2	0	8
	260286	41321-03594	0	0	0	0	8
	140386	41337-03592	2	0	1	3	8
	300386	41353-03590	1	0	2	0	8
	010586	41385-03594	1	3	1	1	8
	081086	41545-04013	9	9	8	8	8
140-40	090186	41273-04013	0	0	1	1	6
	250186	41289-04011	0	0	0	0	8
	100286	41305-04004	3	2	6	5	8
	260286	41321-04001	0	0	0	0	8

As to aerophotos, whether aerophotos in appropriate scale are available or not is checked taking account of the study purpose and the study area.

2.4. Data Collection

Satellite data and remote sensing data from aerial photos are acquired through agencies concerned.

Here, acquisition of LANDSAT data is especially described.

1) A LANDSAT orbit covering the study area is searched from the LANDSAT coverage maps shown in Figures 11 and 12. The LANDSAT satellite orbit is shown by PATH along the south-north direction and ROW along the west-east direction. The circle in the map indicates the center of the orbit. One scene of the LANDSAT data covers 180km × 180km, and overlaps 20-30km range with the adjoining scene.
2) Next, observation period, cloud cover and image quality are examined using the cloud cover list shown in Table 4. The cloud list shown in Table 4 is read as follows:

PATH-ROW	:	Already explained above
DO/MN/YY	:	Date of observation
NASA-ID	:	Code number of NASA
CLOUD COVER	:	One scene is divided into four, and cloud cover is shown in each the left upside (1), the right upside (2), the left downside (3) and the right downside (4). (For example, 0 and 8 mean 0% and 8%, respectively.)
QUALITY	:	Image quality (Values more than 8 indicate good quality.)

3) The study area may not be covered with cloud because of the observation period, even if high cloud cover is found in one scene. In such a case, quick look photos provided by Thailand can be used to confirm the position of cloud.
4) After a necessary scene is decided, then an Order Form shown in Table 5 is filled up to acquire the data through the Thailand Remote Sensing Center.
5) The data are grouped into analog data (photos) and digital data (magnetic tape). Necessary data are selected according to an analytical method.

Table 5 LANDSAT order form

LANDSAT ORDER FORM

THAILAND REMOTE SENSING CENTER
NATIONAL RESEARCH COUNCIL OF THAILAND
196 Phahonyothin Rd., Bangkhen, Bangkok 10900
Tel. 5790116, 5791370-9 Ext. 401 Telex no. 82213 NARECOU TH

PURCHASER :
Name ______________________ Date ______________
Address ______________________ Ref. no. ______________________
______________________ Objective ______________________
Phone ____________ Telex ____________
Type of order ☐ Standing order ☐ Priority ☐ General
SHIP TO : ______________________ Type of payment ☐ Standing account ☐ Check/Draft ☐ Cash
______________________ No. ______________________
______________________ REMARKS ______________________

I Standard Photographic Products Page ...... of ......

LS	PATH-ROW	DATE	PRODUCT CODE	B/W(Band) 4	5	6	7	COLOR Subscene ※ 1	2	3	4	TOTAL QTY.	UNIT PRICE	MASTER FEE	TOTAL PRICE

※ 1 2 / 3 4 Color Print ≥ 1:250,000 Subscenes

SUB TOTAL (I) ______

II Standard Digital Products (Computer Compatible Tapes)

LS	PATH-ROW	DATE	PRODUCT CODE	CCT CORR.	UNCORR.	FORMAT CCRS BIL	TELE BIL	EDC BSQ	TOTAL QTY.	UNIT PRICE	TOTAL PRICE

III Special Surcharges SUB TOTAL (II) ______

Special acquisition ☐ Classifying CLD COV ☐ not classifying	scenes	
Non standard framing	scenes	
Scale enhancement by Bulk Processing System	scenes	

[illegible]

Shipping and handling cost will be charged for shipment outside Thailand

*For accession aids (Catalog & inventory data) and special products (70mm. film, Diazochrome, etc.), please contact User Services directly at the above address.

TOTAL (I-II-III) ______
PRIORITY SURCHARGE 50 % ______
SHIPPING CHARGE 10 % ______
GRAND TOTAL (Page ....) ______

Received by .... or Mailed by .... Date ....

[illegible]

2.5. Data Processing/Analysis

2.5.1. Data Processing Techniques

Data processing techniques are broadly grouped into (1) the analog type method by photographic processing and (2) the digital type method by computer processing.

(1) Analog method by photographic processing
Preparation of color images using a color synthetic viewer. In case of LANDSAT, positive films for each bands are exposed to blue, green and red lights to prepare color images.

(2) Digital method by computer processing
Digital image analysis system

2.5.2. Analytical Method

The analytical method of data is broadly grouped into (1) analysis of photos by analysist's eyes, and (2) analysis based on dialogue processing between a digital image analysis sytem and an analyst.

(1) Analysis of photos by analyst's eyes
Interpretation of geological structure.

(2) Analysis based on dialogue processing between a digital image analysis system and an analyst.

① Analysis of single information from remote sensing data — traditional digital image analysis.

② Compound analysis of remote sensing data and other geographical information — a new type of digital image analysis, in which remote sensing data are treated as one geographical information system.

2.5.3. Flow of Data Image Analysis

A concrete flow for data analysis is shown in Figure 13.

①	Data collection	Observation	Purchase of satellite data (LANDSAT, SPOT)/Observation by aeroplane MSS and aerophotos
②	Pre-processing	Various treatments for correction	Locational correction for adjustment with maps Correction for radiation due to absorption by the atmosphere
③	Data characteristics extraction	Image characteristics	Dispersion in data for each wavelength band Characteristics by wavelength bands
④	Examination of image analysis methods	Analytical technique	Applicability of automatic classification Applicability of density division
⑤	Practice of image analysis	Image analysis	Implementation of image analysis by automatic classification Implementation of image analysis by density division
⑥	Post-processing	Proper arrangement of results of image analysis	Overlaying with maps
⑦	Color result pictures	Land utilization map, Temperature distribution map, Turbidity distribution map	

Fig. 13 Flow of data analysis

2.6. Digital Image Analysis

2.6.1. Outline

Data used in remote sensing are converted to images which can be easily examined through image analysis. The image analysis is made by an image analysis system exclusively for this use. The general procedure of the image analysis is shown below:

① Acquisition of data
② Brightness correction
③ Rectification
④ Preparation of false color images
⑤ Land cover classification
⑥ Collection of other geographical information
⑦ Construction of image data base
⑧ Overlay analysis of images

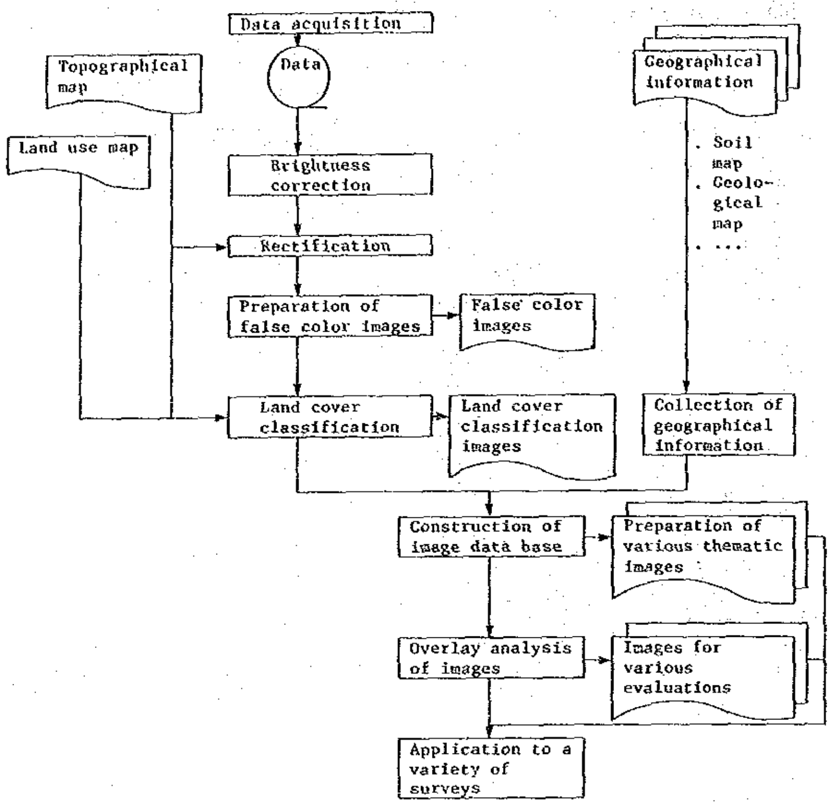


Fig. 14 Flowchart of general image analysis

2.6.2. Image Analysis System

A system for image analysis mainly consists of a general purpose computer, a minicomputer, a host computer for personal computers, and an image processor. At least, a magnetic tape equipment and a digitizer is necessary for input, while a color display is necessary for output. Figure 22 gives an example of an image analysis system.

2.6.3. Brightness Correction

The tone of images from LANDSAT, when they are displayed as their numerical values or processed to images, may become too dark. This may cause inconvenience, especially when more than two images are compared for verification. Then, usually they are subjected to brightness correction to make them more easily interpretable.

Here, a method of brightness correction for image data for two different periods is explained. The seasonal difference between these two observation periods when season and climate are different can be reduced by correcting brightness of each other.

1) Histograms are made for images of the same range for the two periods.
2) One histogram of them is used as a standard to arrange the peaks of the histograms in order.
3) A factor is multiplied to make the histograms similar as a whole.

Figure 15 outlines the concept of the brightness correction.

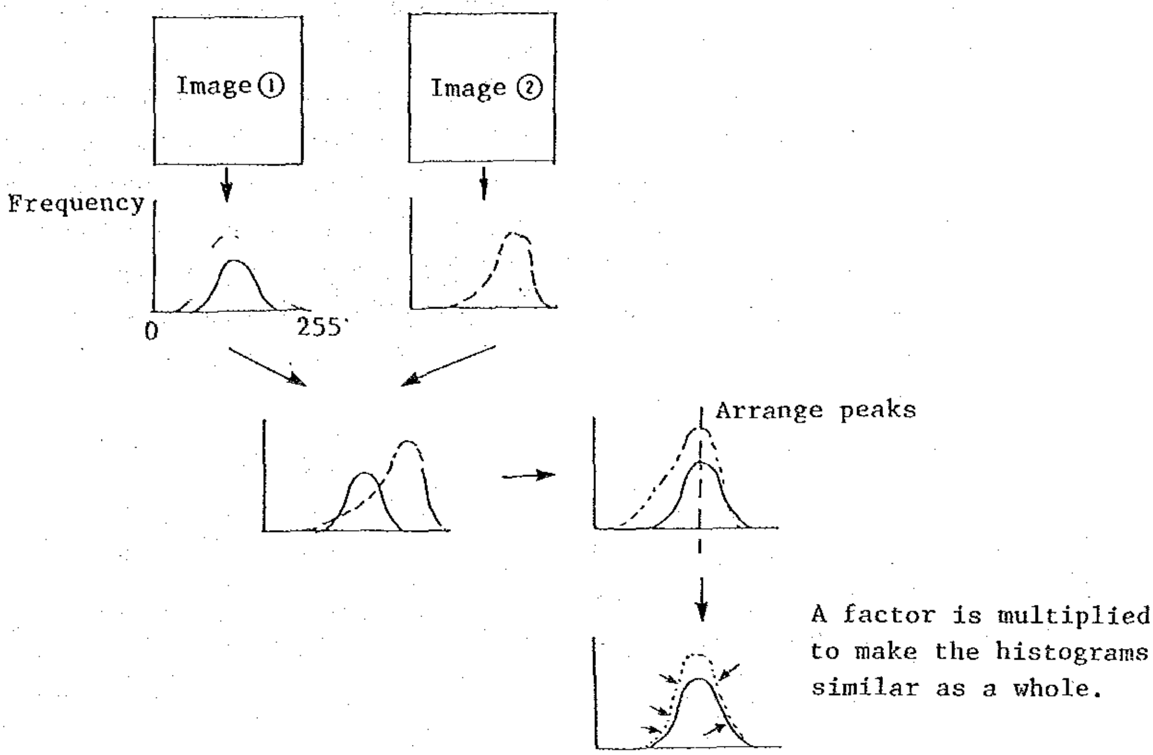


Fig. 15 Conceptual chart of brightness correction

2.6.4. Rectification

Images obtained from remote sensing data may have various types of distortion. Rectification is conducted for coordinate transformation to assure the right positional relation between the original observed data and the topographical map.

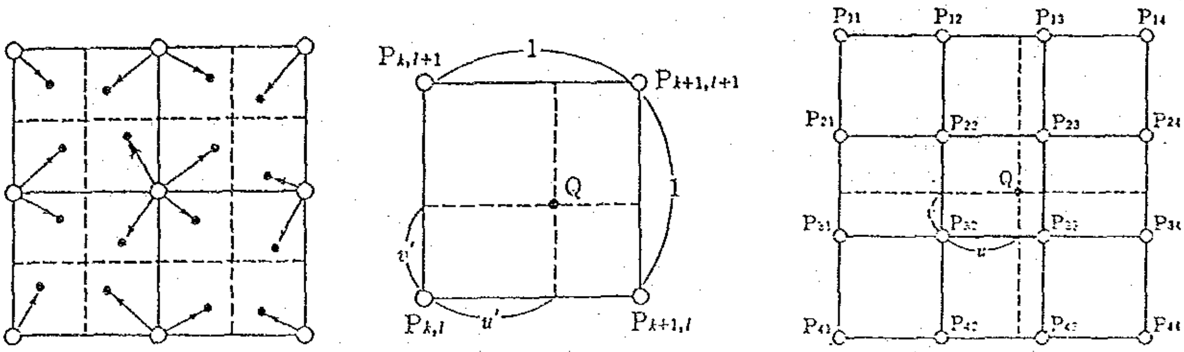
Rectification of a LANDSAT image firstly requires selection of a ground control point (GCP). The ground control point should be a point clear on the image and the topographical map, and desirably is a bending point of a water front line, a river or a road. The coordinates of the selected GCP is determined on the image and the topographical map to conduct coordinate transformation. When the coordinates on the map and the coordinates on the image are (x,y) and (u, v), respectively, the following equation is used for the transformation;

$$x = a_1u + a_2v + a_5$$

$$y = a_3u + a_4v + a_6$$

Unknown factors a_1 through a_6 are determined from the coordinates of more than 4 GCPs using the method of lease squares.

When the coordinate transformation is made, the original image corresponding to the position on the topographical map may not be available in many cases. In such a case, it is necessary to interpolate the image corresponding to the point from an input image of the neighbourhood using some method. The interpolation can be done with one of three methods; nearest neighbour interpolation, bi-linear interpolation and cubic convolution interpolation. The nearest neighbor interpolation is most widely adopted. Figure 16 gives a conceptual drawing of these three methods.



Nearest neighbor interpolation (the nearest points are applied)

Bi-linear interpolation (Grids in the four corners are used)

Cubic convolution interpolation (16 points in the neighbourhood are used)

Fig. 16 Conceptual drowing of three methods for interpolation

2.6.5. Preparation of False Color Images

As mentioned before, LANDSAT MSS data consist of 4 bands. Characteristics of monochrome photos for each band allow interpretation to some extent. However, color synthesis by combining them can provide interpretation of things which can not be seen on the monochrome photos.

The most widely used color synthesis includes;

Band 4: Blue (B) filter

Band 5: Green (G) filter

Band 7: Red (R) filter

It is called false color synthesis.

Color synthesis from the following bands which gives a color close to eyes' visibility is called natural color:

Band 4: Red (R) filter
Band 5: Blue (B) filter
Band 7: Green (G) filter
Table 6 summarizes characteristics for subjects on false color images.

Table 6 Characteristics on false color images

Subject \ Type / Band	False color 457 BGR	457 RBG
Snow	Pure white	Pure white
Thick cloud	Pure white (Shadowed)	Pure white (Shadowed)
Thin cloud	White	White
Haze	Slightly white	Slightly white
Forest	Red	Green
Cultivated land, Wild grasses	Pink (Yellow-brownish)	Yellow-brownish
Bare land	White	White
Wet land	Pale blue	Reddish purple
Urban area	Pale blue	Reddish purple
Water (Polluted)	Pale blue	Reddish purple
Water (Ordinary)	Dark blue	Bluish purple
Shadow	Black	Black

2.6.6. Land Cover Classification

Typical classification methods in remote sensing are broadly grouped as follows; classification using ground trace data (a subject on the ground corresponding image data and its surrounding environment are studied to know the relation between the image data and the subject), and classification not using ground trace data. There are two classifications using ground trace data such as maximum likelihood method and tree type method. On the other hand, a typical classification method not using ground trace data is cluster classification.

Land cover classification in a forest survey adopts very often the maximum likelihood method. The procedure of the classification is as follows:

1) Items to be classified are determined from a false color image and ground trace data.
2) An area which can be clearly classified on the image is selected as a training field to calculate statistical quantities (mean values of data and scattering).

3) Image elements contained in the sampled area as a training field are classified by classification items, and a discrimination efficiency in the classification is calculated to omit unnecessary training fileds. This calculation is repeated.
4) When the discrimination efficiency becomes reasonable, then the classification is applied to the entire image. In this case, to which item data of one image element should be classified is automatically judged.
5) Since the reflection characteristics of a same item (for example, forest) may vary under the sunlight and in the shade, they are firstly classified separately and finally integrated into the same item.

2.6.7. Other Geographical Information

In conducting monitoring for forest land utilization, image analysis based on only LANDSAT data can provide sufficient data to understand macroscopically the land use conditions. However, understanding of relations between these land use conditions and other geographical information (soils, topography, geology and others) offers very important basic information in forest management.

For example, the relation of the land use conditions with soils, that with topography and that with geology provide understanding of soils suitable to tree species, fitness to locational conditions, and conformity, respectively. These information are also very effective in planning land use.

Thus, collection of geographical information required for forest management is conducted. In such a case, information requiring existing study materials are acquired. When adequate information is not available, information will be prepared based on topographical maps, existing materials and field surveys.

2.6.8. Construction of Image Data Base

Thematic maps required for the study including satellite data are processed to image database as shown in the conceptual figure of Figure 17, to be utilized to image overlay to be explained later.

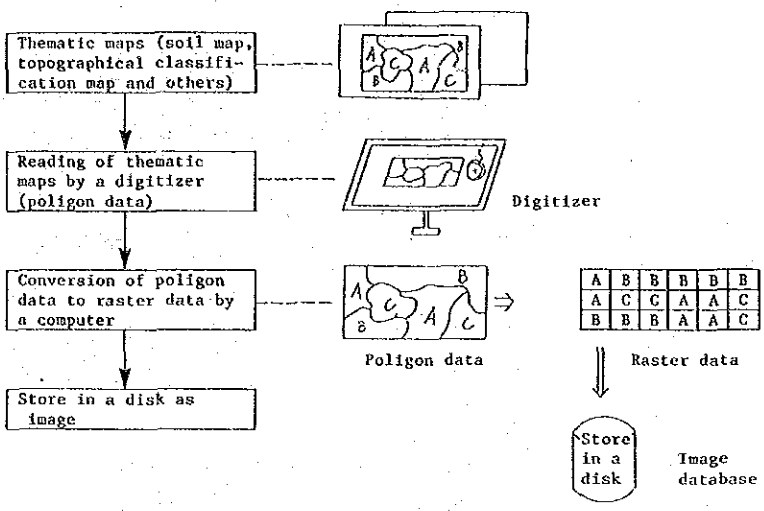


Fig. 17 Conceptual figure of image database

Thematic maps prepared from existing soil maps and topographical maps are a cluster of poligons. These poligon data can be input after processed by a digitized to give coordinate values (x,y) and attributes. The poligon data are converted to raster data in arbitrary size (1 pixel size is 100m x 100m) by a computer to unify the data for easy overlaying processing.

Thematic maps effective in a forest study include forest type maps, geological maps, soil maps, slope direction maps, slope inclination maps and others. These maps are processed to image database for examination of relations among them and for understanding of local characteristics.

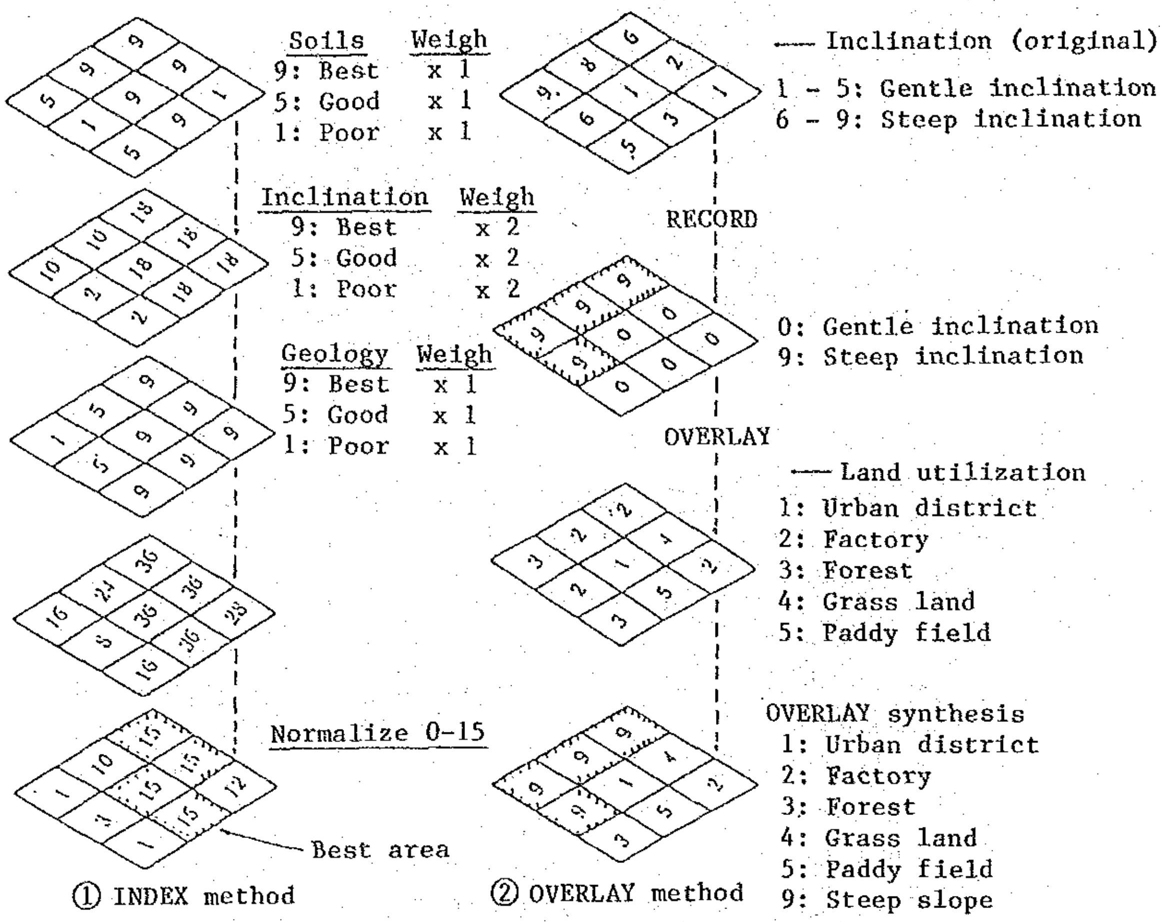
2.6.9. Image Overlay Analysis

By overlaying images, land classification and estimation of changes can be easily done. Generally, overlaying processing includes ①INDEX method, ②OVERLAY method, and ③MATRIX method. These methods are briefly explained below:

(1) INDEX method
In the INDEX method, thematic maps (soils, inclination, geology and others) and divisions (inclination of 0 — 5°, 6 — 10°...) are weighed to classify in accordance with total points of addition of the thematic maps. In the example of ① in Figure 18, weigh for inclination is 2.

(2) OVERLAY method
In the OVERLAY method, only specified divisions of information to be overlayed are subjected to overlay processing. The example of ② in Figure 18, is for insertion of steeply sloped areas.

(3) MATRIX method
In the MATRIX method, as shown in the example of ③ in Figure 18, two types of information (land utilization and inclination) are used to prepare matrixes in accordance with combinations of each division, and then effective values are set for each matrix for overlay processing.



Land utilization \ Inclination	0～3°	3～8°	8～15°	15°以上
Paddy field	1 (0)	2 (1)	2 (2)	2 (3)
Plowed field	1 (4)	2 (5)	3 (6)	4 (7)
Grass land	1 (8)	2 (9)	3 (10)	4 (11)
Forest	1 (12)	2 (13)	2 (14)	3 (15)

③ MATRIX method

Fig. 18 A conceptual figure of overlay processing