Table 1-5-1 Types and Volume of Input Data

Types of Input Data

Images (Raster Data):

LANDSAT, MOD-1, SPOT, SAR, AIR-Photo, etc.

Spatial Data (Vector Data such as Point and Line):

maps (scale: 1/250,000 - 1/5,000), thematic maps (elevation, water channels and soil, etc.)

Tables:

Attributes, census data, crop harvest data, rainfall data, sunshine data and temperature data, etc.)

Volume of Input Data

LANDSAT-MSS Data:

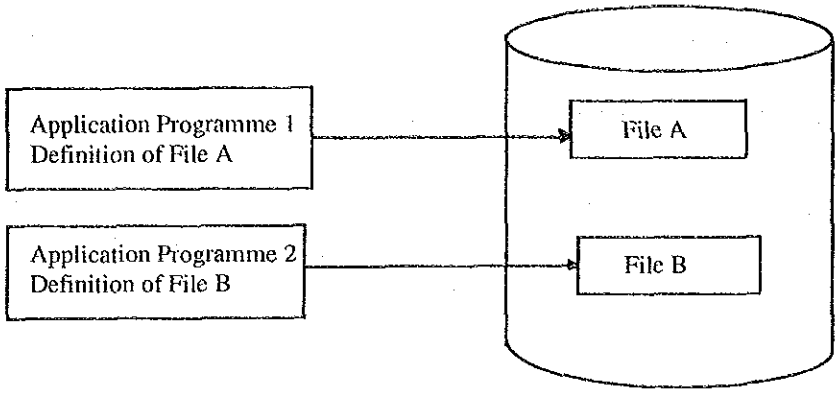
approximately 179 scenes, i.e. 5 G bytes, to cover Indonesia

Map Data:

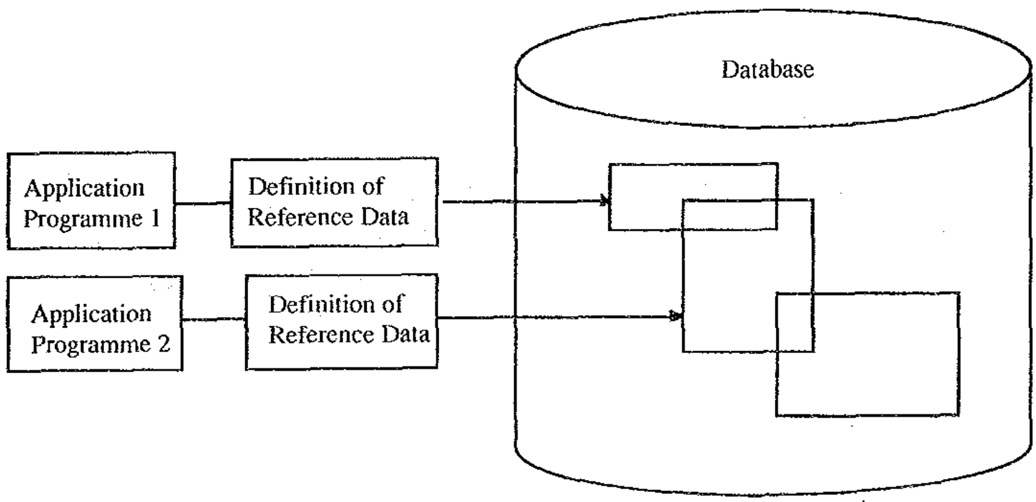
some 100 maps (scale: 1/250,000) to cover the entire area (1,904 x 1,000km^2). Assuming the volume for each map (vector and attribute data) is approximately 1MB, the total data volume for one thematic map will be 100MB (1MB x 100 scenes). Since 11 themes are planned, the total data volume will be 1.1GB. In multi-stage analysis, the data volume will be some 2GB with pyramidal structures, including data on the main subject areas (data based on the scale of 1/50,000 - 1/2,500)

Tabulated Data:

Insufficient reference materials on the data volume



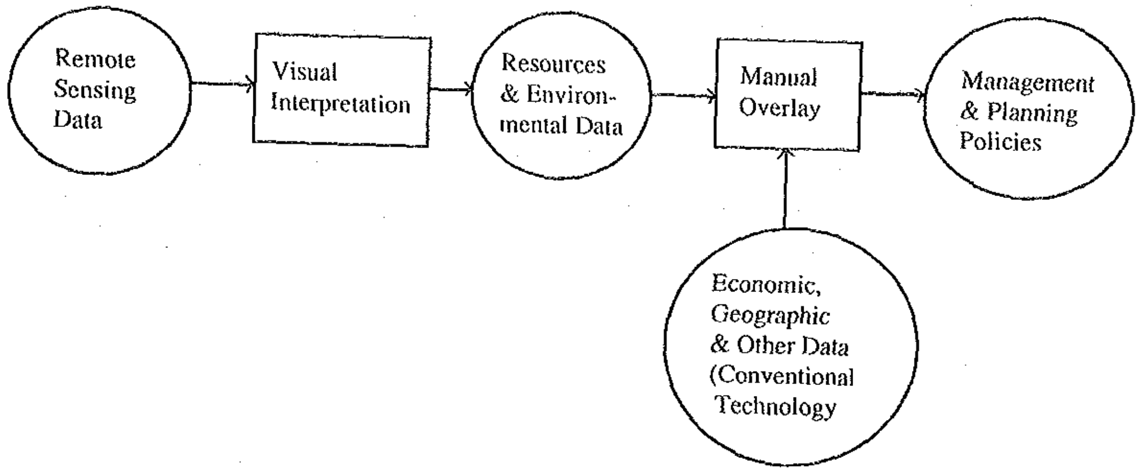
(i) File Processing



(ii) Database Processing

Fig. 1-5-1 Correspondence Between Application Programme and Data

a) Upto Early 1970's



b) Late 1970's

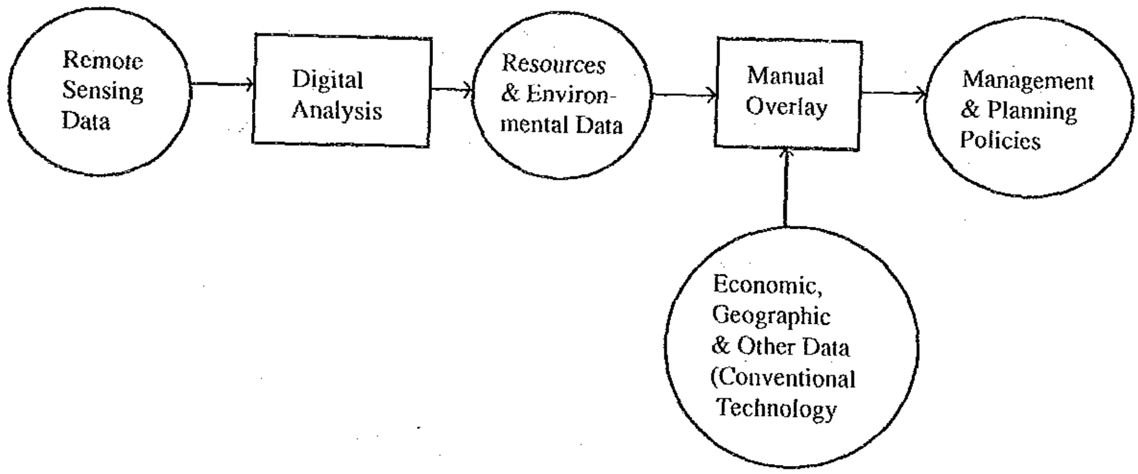
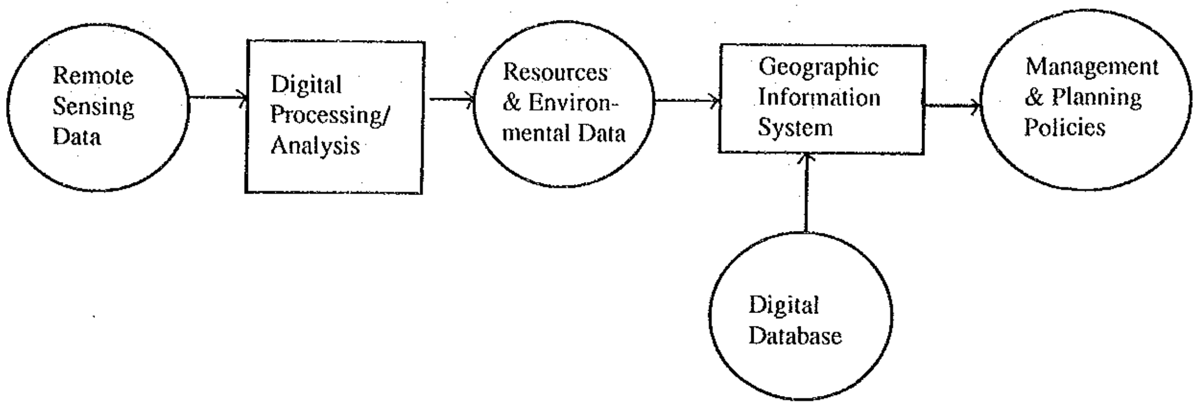
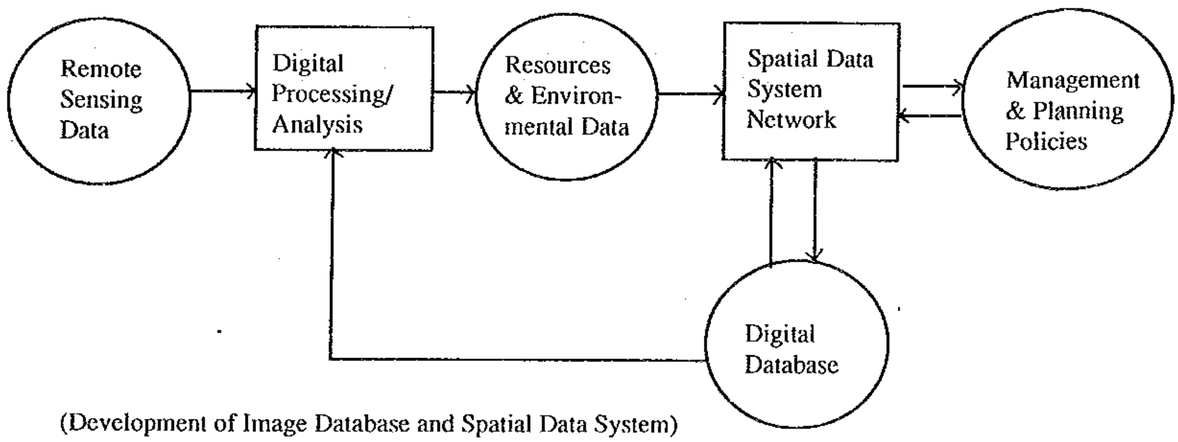


Fig. 1-5-2 Progress of Data Processing Technology in Remote Sensing

c) Early 1980's



d) Late 1980's



(Development of Image Database and Spatial Data System)

Fig. 1-5-2 Progress of Data Processing Technology in Remote Sensing

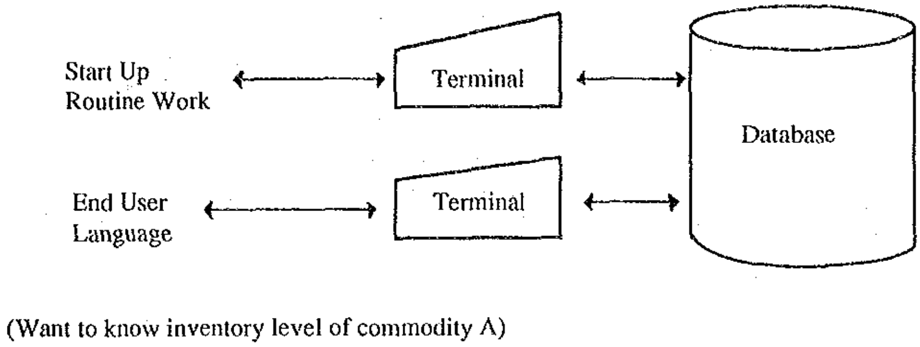


Fig. 1-5-3 Database Viewed by End User

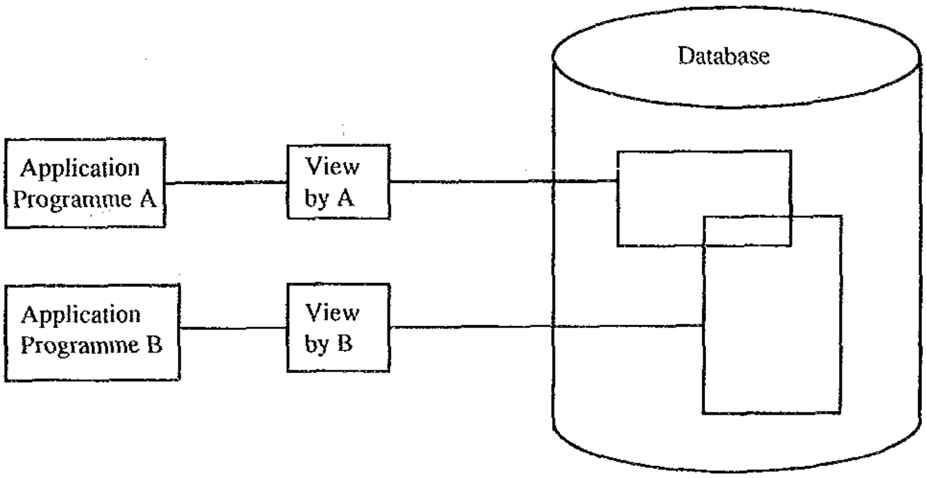


Fig. 1-5-4 Databased Viewed by Application Programme

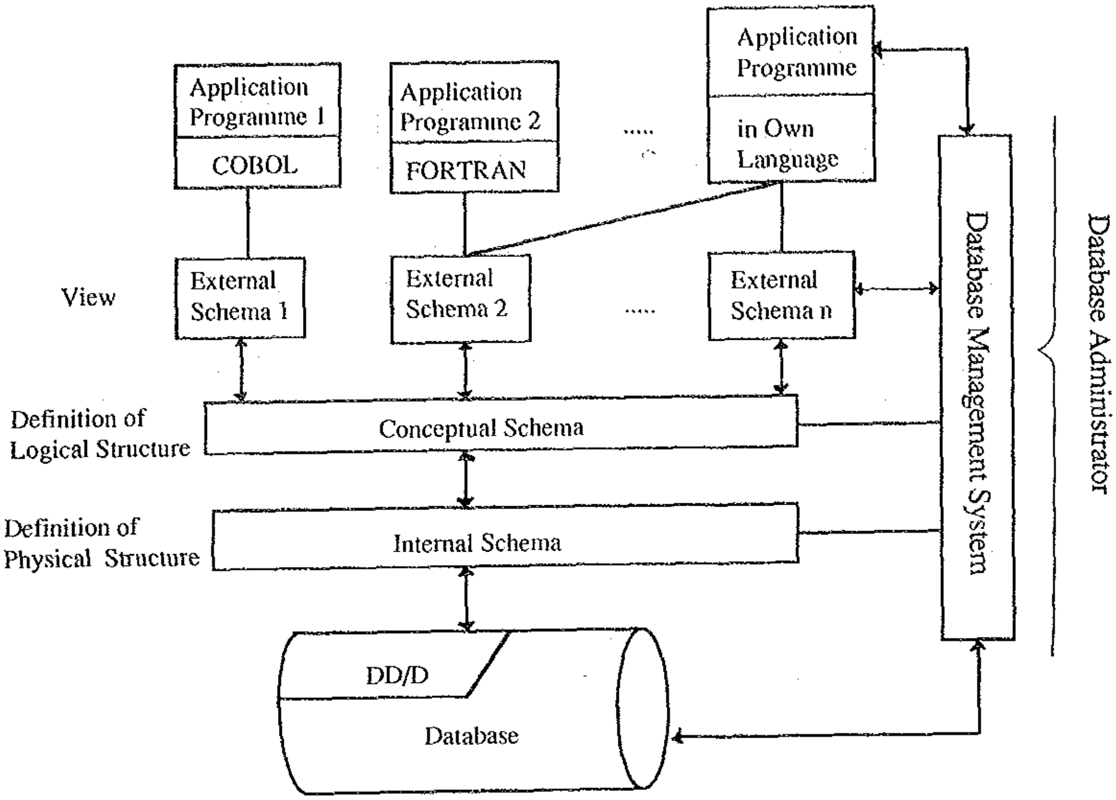


Fig. 1-5-5 Databased Viewed by Database Administrator
(Database System with Three-Layered Schemata

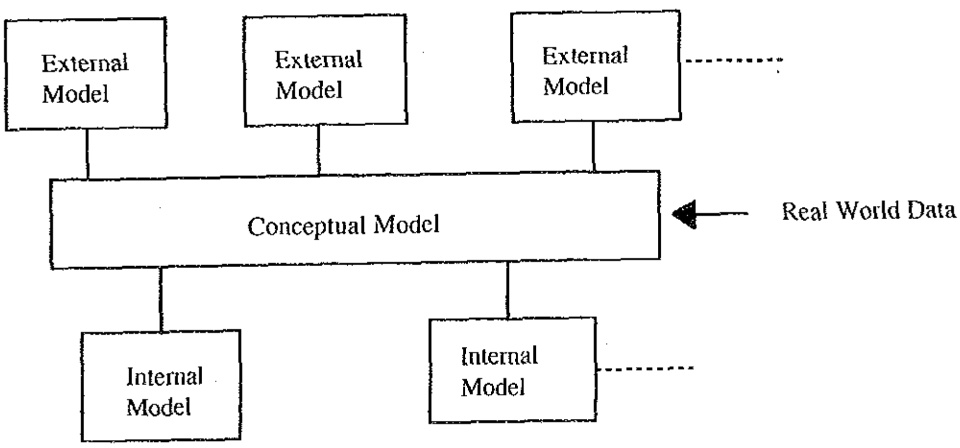


Fig. 1-5-6 Three-Layered Data Model

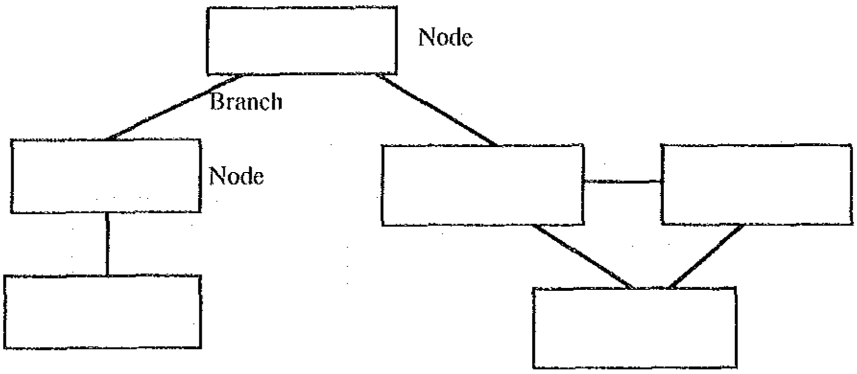


Fig. 1-5-7 Example of Tree

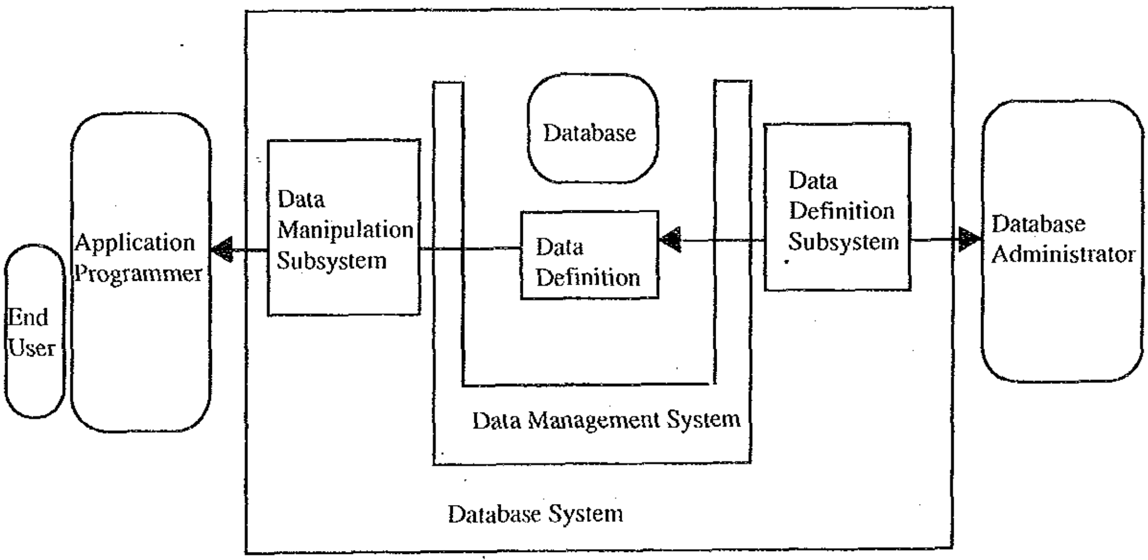


Fig. 1-5-8 Application Concept of Database System

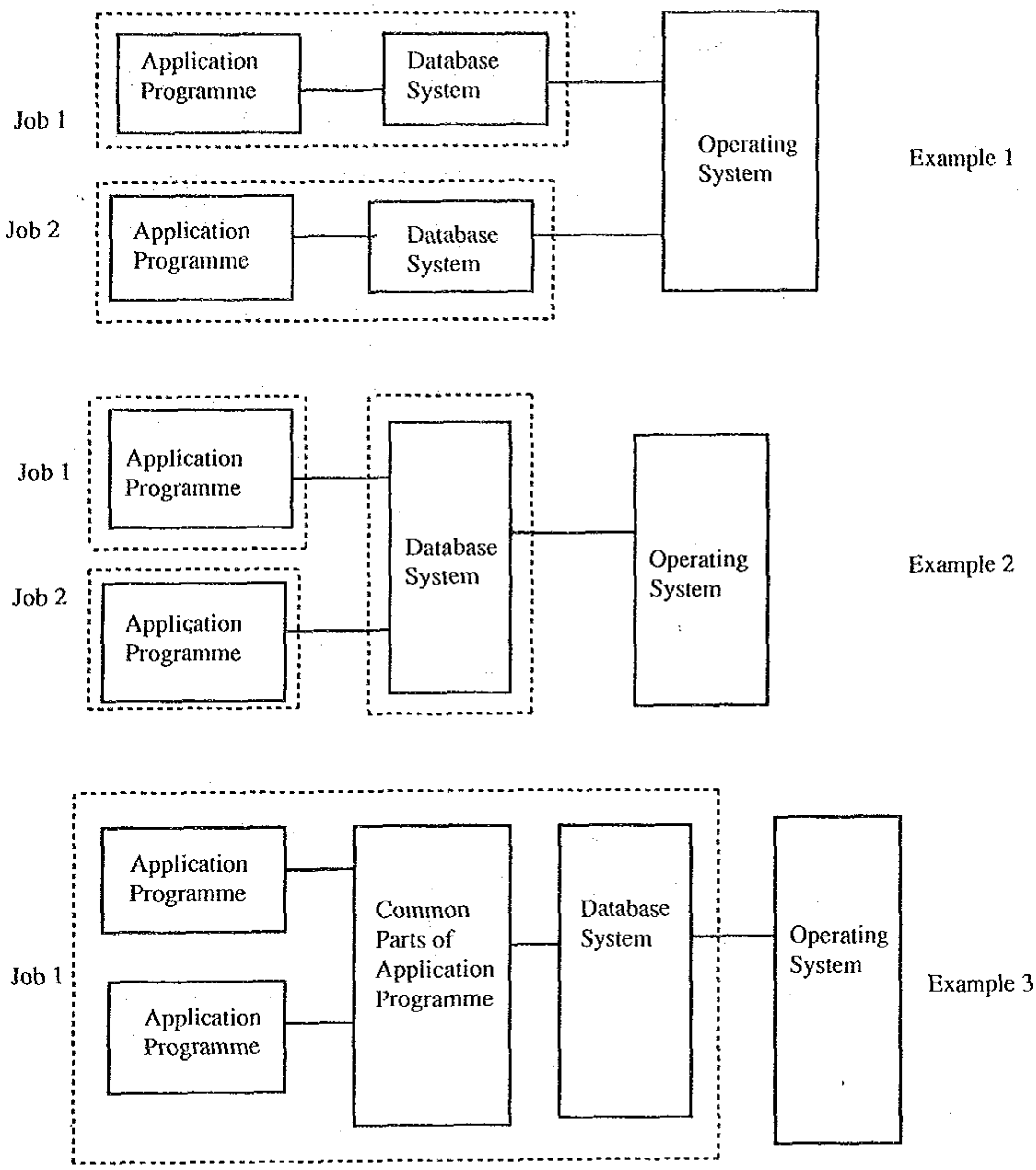


Fig. 1-5-9 Relationship Between Application Programmes (GIS) and Database System

In general, a relational table is given as follows:
Related Field Name (Attribute1, Attribute 2...)

Example A

Vegetation	(Area Code, Type, Area, Biomass Volume)

Example B Remote Sensing Data

Satellite	Sensor	Observation Parameter
SEASAT	SMMR	SST
SEASAT	SMMR	WIND
SEASAT	ALT	WIND
NIMBUS	SMMR	SST
NIMBUS	CZCS	Ocean Color

Fig. 1-5-10 Relational Table

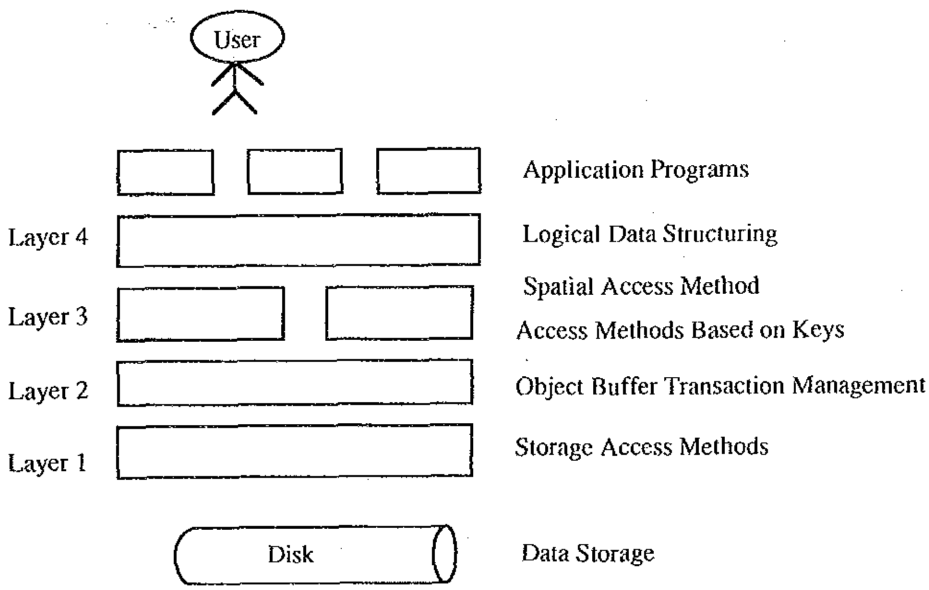


Fig. 1-5-11 Layers of Geographic Database Management System

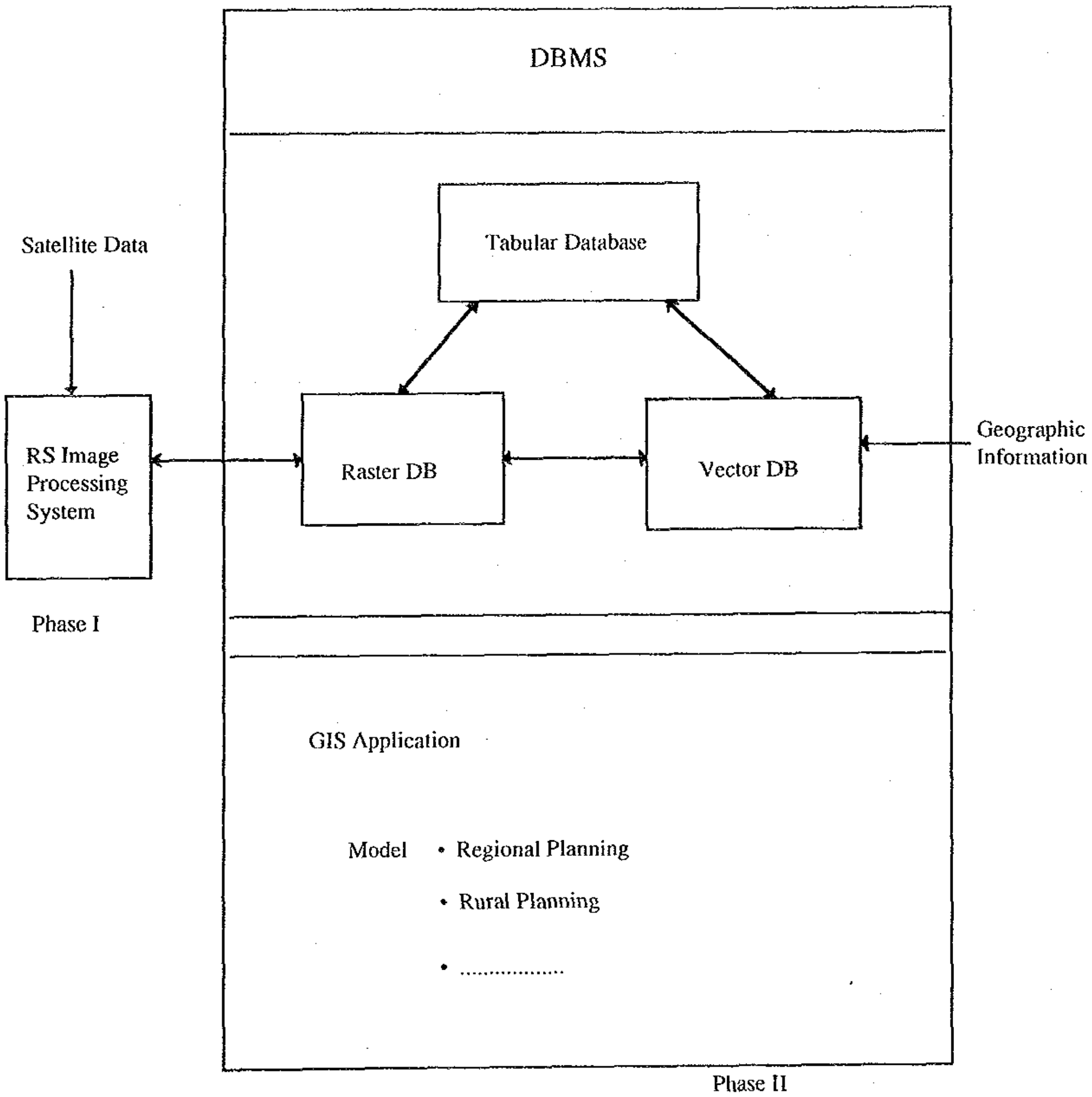


Fig. 1-5-12 Remote Sensing Database

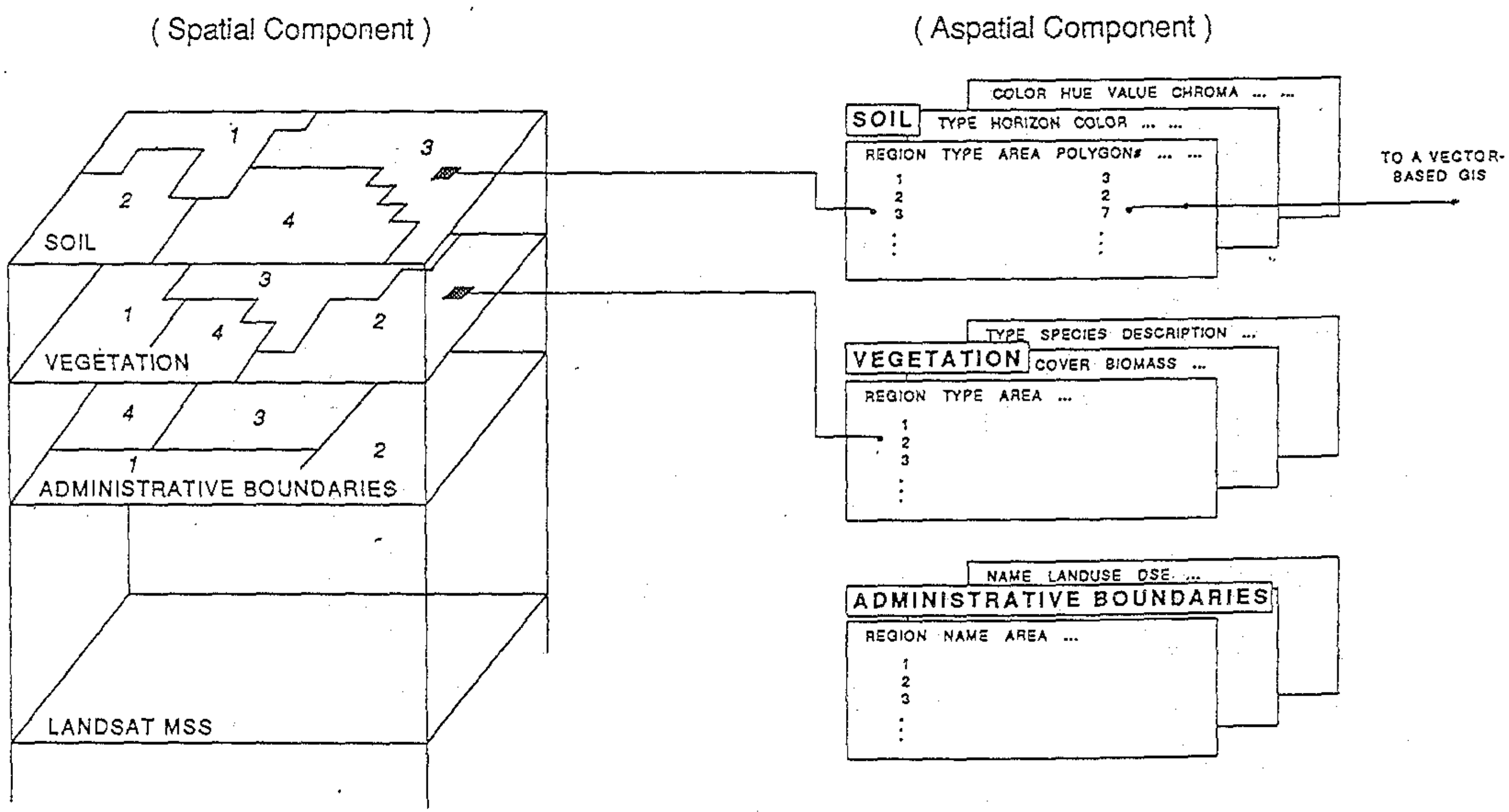


Fig. 1-5-13 Relationship Between Tabular Tables and Images (Raster Data) of Relational Spatial Data System

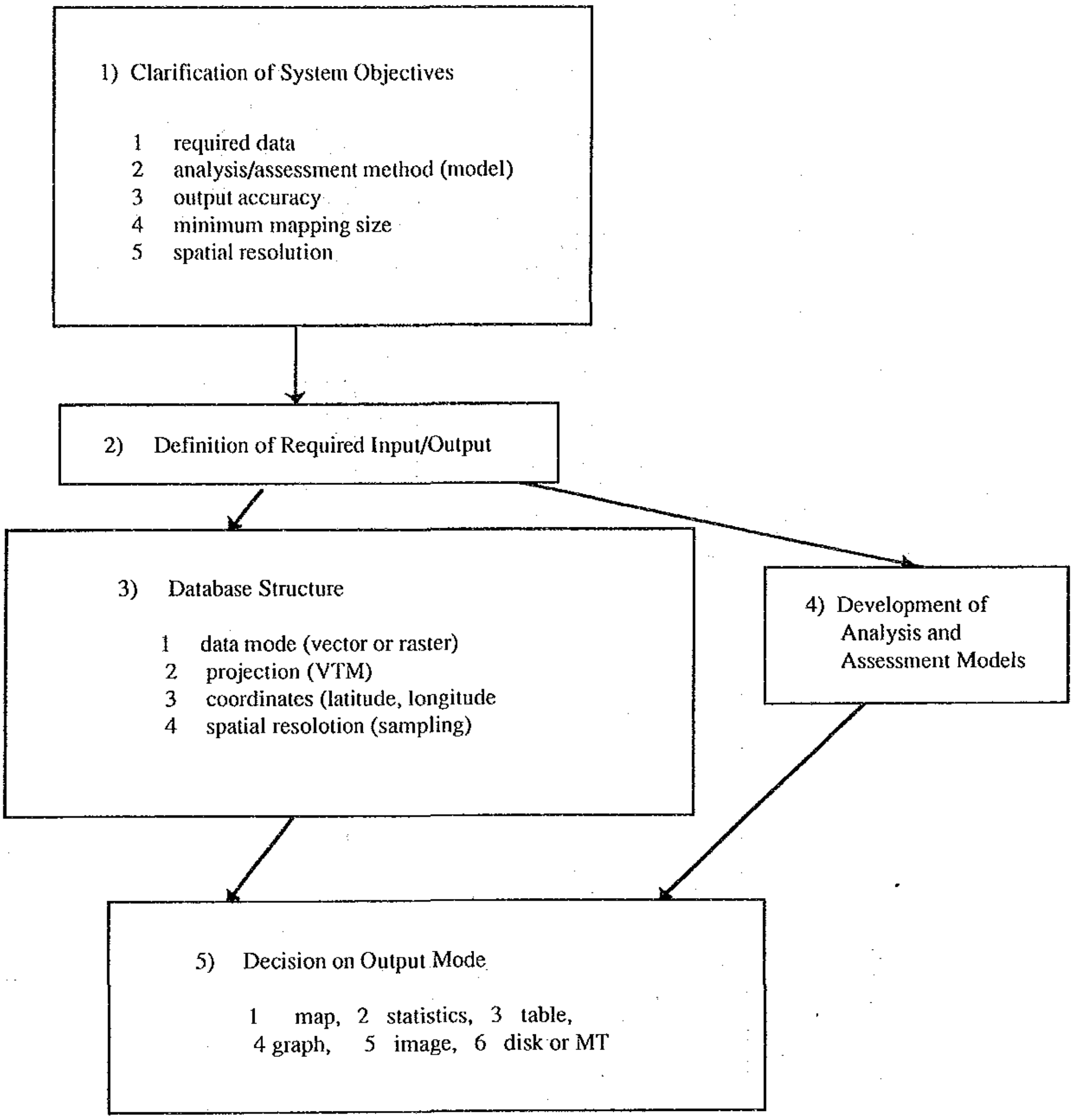


Fig. 1-5-14 Development Flow of Spatial Database

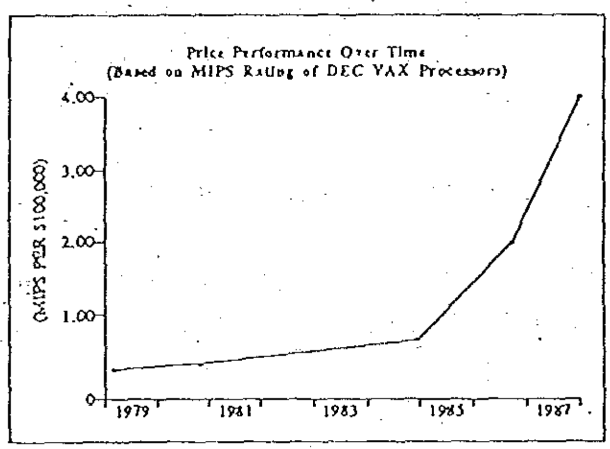
Computer Processor Trends

1950's : large, single tasking mainframes.

1960's : multitasking computers using third generation programing.

1970's : development of minicomputers and interactive processing.

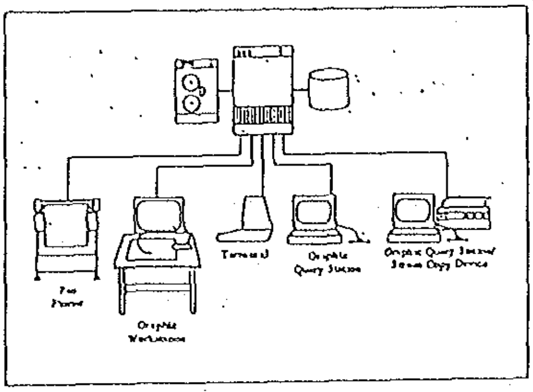
1980's : distributed computing with powerful computers of different sizes (WS. and PC) being computing resources and data.



The past decade has seen a dramatic increase in the performance/cost ration of computer processors.

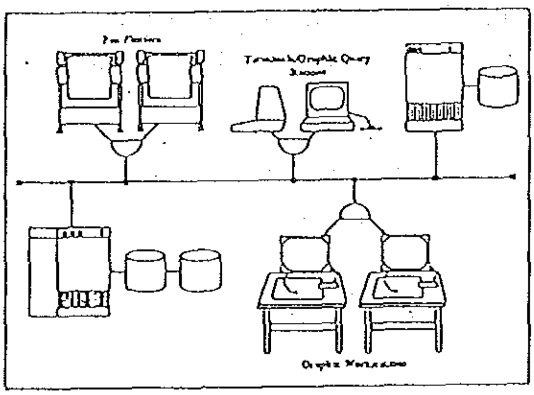
Fig. 1-5-15 Development Trend of Computer Technologies

1) Host Centralization Environment (Centralized Processing by a General Purpose Computer)



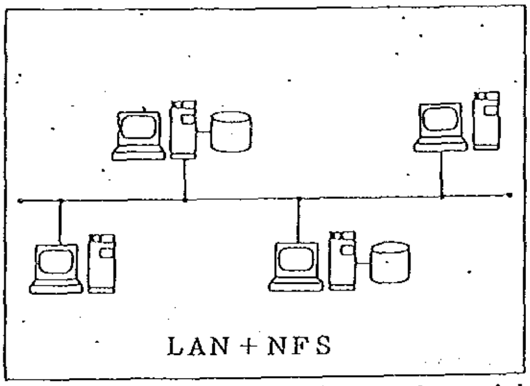
" Asynchronous Connections. "

2) Distributed Processing Environment (Super Mini Computer Connected by Network (LAN)



System 2 is capable of completing the same job at one-third of the cost of 1 .

3) Open Type Distributed Processing Environment (Horizontal Type Distributed Processing Using Work Stations (Lan + Distributed File System)



System 3 is capable of completing the same job or a better job at one-tenth of the cost of 1 .

Fig. 1-5-16 Progress of Processing Environment for Spatial Information Database: 1) ⟶ 3).

PART II

APPLICATION OF REMOTE SENSING

TO

AGRICULTURAL DEVELOPMENT

2.1 Relationship Between Agricultural Development Plan Standards and Remote Sensing Technologies

Teitaro Kitamura

Introduction

In Part II, remote sensing application technologies are explained with a view to the promotion of the ongoing remote sensing project (the Project: the Remote Sensing Engineering Project for the Development of Agricultural Infrastructure in the Republic of Indonesia: Phase II) of the Ministry of Public Works on the basis of Part I which deals with the basic aspects of remote sensing. In this chapter (2.1), the main objective is to explain the processes involved in the Establishment of Guidelines for the Formulation of Rural Development Plans which is listed under 1-2-(2)-① of the Record of Discussions (dated June 6, 1988) for the Project. 1-2-(2)-②, the Establishment of Guidelines for the Formulation of Irrigation and Drainage Plans, and 1-2-(2)-③, the Production of Farmland Conservation Maps for Critical Land, are also briefly discussed as these 2 themes are considered sector plans of the overall rural development project referred to in ①.

Since the main focus of the Project is on the technical development aspect of how to formulate a rural development plan using remote sensing technologies, the discussion in this chapter centers on the creation of a computer aided system for a rural development plan using remote sensing technologies. The production of tables and figures to assist the formulation of such a plan is also intended. Moreover, my personal views on how to achieve the practical applicability of remote sensing technologies are briefly explained.

2.1.1 Changing Technologies in Remote Sensing: From "Picture" Formation to "Map" Formation

While the research history in the field of remote sensing technologies in Japan only dates back some 15 years, tremendous progress has already been made. There has been a remarkable variety of research themes with unprecedented success and many application fields have been invented.

There is strong interest in remote sensing technologies in developing countries, as witnessed in the case of the present Project. However, it can be pointed out that there appears to be some discrepancies between what developing countries demand and what industrialized countries are prepared to supply.

Researchers in industrialized countries are particularly interested in the development of remote sensing technology applications in specific fields and the contents of their research are extremely specialized. As a result, the advancement of remote sensing technology applications has taken a different path in each application field and experts in one field are increasingly isolated from the progress made in other fields. Unlike their predecessors, remote sensing engineers today tend to have profound knowledge in individual technologies but lack a general view of remote sensing. It may be natural for a researcher to focus his/her efforts on a specialized technology in view of the academic acknowledgement of such efforts. The same situation prevails in individual application fields where the progress in one field can far exceed the progress in other fields. In addition, researchers in application fields are great pressure to follow the incessant progress of computer softwares.

Many remote sensing technology researchers come from the computer technology field and have inadequate knowledge of maps which are an important part of the computer analysis of remote sensing data. In fact, many researchers have no experience of dealing with mapping data or conducting a field survey relating to mapping (surveys on vegetation, soil and land use, etc.) prior to working with remote sensing data. It is, therefore, to be expected that few researchers have any knowledge of interpretation. This situation has led to insufficient development in relating remote sensing technologies to mapping technologies, especially ground truth data.

In the case of developing countries, many remote sensing researchers have had no previous access to computers and, therefore, computer operation poses an immediate problem. Despite the low level of computer knowledge, however, the concrete application of remote sensing data to regional development or resources development is often demanded. As remote sensing data are two-dimesional information, their use is advocated for the development and/or conservation of an area for which a map does not even exist.

The essence of the demand by developing countries for remote sensing technologies is the provision of land data in the form of "maps" rather than the technologies themselves. These countries require highly accurate remote sensing results in the form of "maps" rather than technical precision. This kind of demand is accelerating due to the recent availability of the 20m mesh data given by SPOT and other satellites. A 20m mesh means 0.4mm on a scale of 1/50,000 and 2mm on a scale of 1/10,000. As such, remote sensing is regarded by developing countries as a tool for map production. In Japan, however, map production using remote sensing data is still at the infant stage. Remote sensing images are mainly regarded as "pictures" but not "maps". Nevertheless, the remote sensing technologies to be transferred to developing countries must have a high application standard for map production on the basis of advanced, highly precise technical components and firm integration with ground truth technologies.

The change in the emphasis on remote sensing is due to bridging the gap between the remote sensing technologies to be supplied by Japan and the technologies required by developing countries. The age of remote sensing for the creation of "maps" must replace the age of remote sensing for the creation of "pictures". Efforts to transfer technologies must emphasize the mapping aspects of remote sensing.

As far as the present Project is concerned, Phase I can be described as a period in which remote sensing technologies for the creation of "pictures" are introduced. It must be noted that particular emphasis is given Phase II to the introduction of remote sensing technologies for the creation of "maps". The Record of Discussions refers to such map-oriented technologies and specifies that efforts will be made to establish guidelines for the formulation of a rural development plan as the basis for the development of the agricultural infrastructure. The aforegoing discussion indicates that the desired course for project development is the establishment of remote sensing technologies which will assist the formulation of a rural development plan in a practical manner.

2.1.2 Contents of Rural Development Plan

The contents of the rural development plan as part of the Project are not clearly stipulated in the Record of Discussions but are suggested as guidelines for the development, of the agricultural infrastructure (Record of Discussions: 1-2-(2)). As the rural development plan is the basis for the development of the agricultural infrastructure, it is understood to include an agricultural infrastructure development plan in a broad sense.

A rural development plan is usually used in international development terminology as a synonym for a small-scale village development plan or a community development plan. If this meaning of a rural development plan is adopted for the Project, there are few advantages in using remote sensing data for the present purposes due to map scales and other conditions.

In the project formation process, however, the rural development plan was understood to be a comprehensive plan to materialize a regional development plan for rural area. In contrast, the irrigation and drainage plan and the farmland conservation map were understood to be sector plans of such a comprehensive plan [1]. The contents of a comprehensive plans as a regional development plan for a rural area may vary depending on the size of the subject area but can be technically classified into either a regional development plan focusing on resources distribution over a wide area (wide area rural development plan where the map scale is 1/50,000 or smaller) or a rural development plan focusing on land use (medium size rural development plan with the map scale of approximately 1/25,000 - 1/10,000). Not all these regional development plans or rural development plans are suitable for the application of remote sensing data. The application of such data demands the existence of a physical plan, such as the following.

① land use plan as a macroscopic physical plan within the framework of a rural development plan
② land use plan as a microscopic physical plan within the framework of a rural development plan

In view of the utilization limits of remote sensing data and the approximate map scale for the rural development plan of 1/10,000, the use of remote sensing data to establish guidelines for a microscopic land use plan appears difficult. As a result, the rural development plan for the Project should be understood as a macroscopic plan for practical reasons.

In other words, the rural development plan in question is a regional development plan in a narrow sense. In the overall rural development framework for Indonesia, it addresses both the Kecamatan and Kabupaten levels and the establishment of planning technologies at these levels should improve the practical applicability of regional development plans for rural areas in Indonesia. In some cases, these technologies can also be applied to planning at a provincial level.

Even though the rural development plan is understood as described above, it includes a socioeconomic plan as well as many other sector plans. However, it is desirable that the understanding of the rural development plan be restricted as follows.

① physical plans where possible with a land use plan at the core
② master plan but not an implementation plan of projects
③ sector plans are restricted to the irrigation and drainage plan (IDP) and farmland conservation map (FLCM), excluding the forest plan and agricultural structure plan which are considered in the framework of the overall rural development plan
④ details of plan contents are judged from the perspective of the 5 year plan period only

If the rural development plan is understood as a regional master plan, its contents can be as diverse as shown in Table 2-1-1. Since such a regional master plan deals with many fields, many of which are abstract or demand spatial representation, plan maps and tables are usually produced to help people's understanding of the plan contents. This practice is very popular in western European countries (particularly Germany). The word plan in regional development plan (or urban development plan and rural development plan) originates from to plan (meaning to map) and accordingly means more than mere planning or programming. A development plan only becomes meaningful when the plan contents are expressed in terms of maps. In Germany and other European countries, regional development plans are accompanied by an extensive collection of related maps and tables, etc. A similar tendency can be observed in the development planning processes in Indonesia where the Dutch influence of the past is still observed. The spatial development plan for the Kabupaten level which is described later includes many plan maps.

Given the regional development plan shown in Table 2-1-1, there are many related plan maps as shown in Table 2-1-2. As it is impractical to prepare all these maps for each development plan, an appropriate selection of maps should be made to reflect the specific planning purposes.

In the case of the present remote sensing project, it appears extremely important to try to obtain map outputs in view of the project objective of developing a system to assist the formulation of a rural development plan to meet the 4 criteria mentioned earlier. Such a target can be justified to maximize the efficiency of using a computer system and to ensure the practicality of the rural development plan.

Judging from the anticipated contents of the Project, the following 2 sector plans should be given priority.

① irrigation and drainage plan (RD-1-2-(2)-②)
② farmland conservation map (RD-1-2-(2)-③)

The preparation of these 2 sector plans necessitates the provision of a land classification map which is slightly more detailed that the macroscopic land use plan described earlier and a land conservation assessment map (critical land assessment map). In short, the preparation of the following 4 plans is deemed necessary.

① land classification and land use plan
② critical land assessment and farmland conservation plan

③ irrigation plan
④ drainage plan

2.1.3 Rural Development Plan and Remote Sensing Technologies

It is desirable to prepare many regional analysis maps and plan maps as described above for the rural development plan under the Project.

However, it is practically impossible to prepare all the maps given in Table 2-1-2 within the time limit of 5 years. Consequently, a selection process should be adopted to select the important maps to be prepared from the list given in Table 2-1-2 based on past examples of similar plans in Indonesia. Once the selection has been made, the methodologies to prepare regional development plan maps must be determined and the technologies involved in such preparation work must be transferred to the Indonesian side.

As concrete examples of development plan maps in Indonesia, those of the Directorate of City and Regional Planning of the Directorate General of Human Settlement are examined below. Fig. 2-1-1 shows the spatial planning structure adopted by the Bureau. Among these plans of different status, that which is similar to the rural development plan is the Kabupaten spatial development plan (map scale: 1/50,000 - 1/100,000).

The Kabupaten spatial development plan anticipates the preparation of the following maps.

① geomorphologies map (KEMIRINGAN LAHAN)
② soil map (TANAH)
③ watershed map (SUB DAS)
④ land use map (PEGGUNAAN LAHAN)
⑤ forestry plan map (KAWASAN HUTAN)
⑥ wet land suitability map (KESESUA IAN LANHAN PADI SAWAH)
⑦ dry land suitability map (KESESUA IAN LAHAN UNTUK TANAMAN PANGAN LAHAN KERING)
⑧ crop suitability map (KESESUA IAN LAHAN UNTUK TANAMAN TAHUNAN
⑨ transportation map (POLA ORI EENTASI PERGERAKAN
⑩ structure plan (RENCANA STRUKTUR TATA RUANG)
⑪ macroscopic land use plan (RENCANA ALOKASI PENGGUNAAN RUANG)
⑫ road map (KONDISI JALAN)

The criterion for the preparation of these maps is currently underway. Those officials responsible for their preparation have expressed the opinion that these maps are still insufficient and require the inclusion of remote sensing data and the use of a computer system. The inadequacy of the above maps is evident when compared to the list given Table 2-1-2.

It is obvious from the above that the advancement of the mapping technology together with remote sensing technology application will certainly improve the technical aspects of development planing. The hardware the installation of which is anticipated under the Project, is capable of producing such maps although a suitable software has yet to be developed.

The relevant map scales for the plan maps are given in Fig. 2-1-1 as follows.

① regional/Kabupaten spatial development plan: 1/50,000 - 1/100,000
② area detail development plan: 1/20,000

Given these scales, it is now a practical possibility that these maps can be prepared by the application of remote sensing technologies.

The work in Phase I has made it possible to prepare a soil map, land use map, vegetation of a land suitability map. While the preparation of a land suitability map has been particularly emphasized in Phase I in addition to the introduction of the relevant remote sensing technology, a technical system to prepare the maps in an efficient manner has not yet been established. The lack of recognition of the mapping aspects of remote sensing technologies is partially responsible for this failure.

The above shortcoming in Phase I has led to a strong request by the Indonesian side for the practical application of remote sensing technologies in map preparation to be achieved in Phase II. It is stressed that the Project will pay more attention to the mapping aspects of remote sensing.

Table 2-1-2 also shows the relative importance of each map in a remote sensing project in terms of 5 categories (I - V where I is the most important map category) based on the author's own judgement. The maps in both Category I and Category II are listed below and it is hoped that a system to assist the preparation of these maps will at least be established under the Project.

I.	Environmental Thematic Maps	-	topographical map, soil map, hydrological map, land cover map
	Environmental Assessment Maps	-	critical land map, swamp assessment map, farmland suitability map (paddy field suitability map, dry field suitability map, orchard suitability map), water environment and resources evaluation map
	Spatial Maps and Plans	-	administrative boundaries map, regional classification map, current land use map, planning subregion map, land use plan
	Sector Maps and Plans	-	agricultural facilities map, water facilities map, farmland improvement plan, water utilization plan
II.	Environmental Thematic Maps	-	climatological map
	Environmental Assessment Maps	-	topographical classification map
	Spatial Maps and Plans	-	Central place evaluation map, Central place and developing axis plan map
	Sector Maps and Plans	-	settlement facilities map, settlement improvement plan map, public facilities map, public facilities plan, road and transportation facilities map, road and transportation plan

2.1.4 Establishment of Rural Development Plan Guidelines

The work procedure relating to the formulation of the rural development plan under the Project is outlined in this section to serve for the establishment of rural development plan guidelines.

2.1.4.1 Planning Method

The process to prepare a regional development plans usually consist of the following 7 stages.

① initial planning (setting of targets)
② formation of a planning body
③ survey (collection of data)
④ analysis
⑤ plan formulation (master plan and implementation plan)

⑥ implementation of planned project and introduction of planning regulations
⑦ project evaluation and management

③ , ④ and ⑤ are the core stages of the planning process. The objective of the Project is the systematization of these 3 stages to allow the maximum use of a computer as well as remote sensing data. In other words, the project intends to produce a computer system to assist the formulation of the rural development plan.

The above system can be divided into the following 3 components (Fig. 2-1-2) which must be prepared in the Project implementation process.

① regional database
② regional analysis report
③ regional planning report

The key issue in the preparation of a regional database is the quantification of as many data as possible. Regional analysis results using these data are compiled into a regional analysis report which provides the basic for a regional planning report.

These 3 planing components correspond to the input, computing and output stages of computer operation as shown in Fig. 2-1-3. The input and output stages have many features in common while the contents of the computing stage vary depending on the purpose behind the regional data processing, regional analysis or regional diagnosis and design. These features of the 3 components must be carefully taken into consideration in the implementation of the Project.

2.1.4.2 Procedure to Establish Rural Development Plan Guidelines

With regard to establishing the rural development plan guidelines, it is proposed that the initial emphasis be placed on the preparation of rural development plan maps (Category I Table 2-1-2) and on the formulation of a computer assisted regional planning system.

As explained earlier, these guidelines are appropriate for provincial and Kabupaten planning in Indonesia and, as such meet the planning requirements of these levels. The preparation of these maps enables the compilation of a master plan for the development of the agricultural infrastructure with maps of a scale of 1/50,000 and the clarification of the targets of the irrigation and drainage plan and the farmland conservation plan.

For further clarification of the guideline preparation process, it is useful to produce a regional database, regional analysis report and regional planning report for a model area. Guidelines should then be prepared for each map production system. The initial step is the completion of a set of regional analysis and planing maps regardless of the levels of the analytical and planing technologies involved. Facilitation of the improvement of the analytical and planning technologies can be expected with use of actual maps.

In addition to the preparation of the guidelines, another important task for the successful implementation of the Project is the establishment of a system whereby the cooperation of related government agencies is easily obtained. The establishment of a proper understanding of the maps, planning papers, statistics and databases, etc., involving project-related agencies, is essential so that any request from these agencies can be promptly dealt with. Therefore, it should prove useful to collect Indonesian maps, statistics and planning papers to assist the completion of the above task.

2.1.5 Guidelines for Rural development Plan Formulation

It is desirable that guidelines for rural development plan formulation be compiled for the 3 planning components, i.e. database processing, regional analysis report and regional planning report.

2.1.5.1 Preparation of Database

Despite the great progress of remote sensing technologies, the ground data collection technology which is essential to compare remote sensing data with ground data and the technology to link these technologies have not yet been fully developed. Without a ground data collection technology and a technology to compile the collected data into a database, further progress of remote sensing technologies cannot be expected.

The technology to compile ground data into a database was not successfully developed in Phase I of the Project. The full development of this technology is, however, crucial to make the Project practical. It is not an easy task and many aspects have yet to be explored. Some of the most important points in the preparation of regional database must at least be noted.

Regional database preparation consists of 3 stages, i.e. ① preparation of primary data, ② preparation of secondary data and ③ preparation of a database. It must be reminded that a fair amount of work is required before the input operation at the third stage. Much effort should still be made to simplify the work. In the case of the Project, a system to collect local data must be thoroughly established as the lack of such a system will make it impossible to conduct a meaningful exchange of data between the Center and local areas.

(1) Primary Data Preparation Subsystem

The core of this subsystem is the technology to collect concrete data. While the preparation of a database is not a difficult process, the required survey method must be correctly recognized. In addition, as standard questionnaire survey form should be prepared in advance if the implementation of a questionnaire survey is intended.

The preparation of a database uses the following 7 subsystems.

① field survey system
② questionnaire survey system
③ general information collecting system
④ designated statistics collection system
⑤ map collection system
⑥ photo information collection system
⑦ database information collection system

A survey system should been established to collect each type of data. The actual types of the data required for a rural development plan vary depending on the survey system. The types of data which appear to be required for the immediate technological development of each system are shown in Table 2-1-3. The stablishment of a data collection system to cover the data items in Table 2-1-3 should be considered for the Project.

At the planning level involving a map scale of 1/50,000, a questionnaire survey should be conducted at the Desa and Kulurahan levels. The Center should prepare a Desa data card for the entry of the relevant data.

(2) Secondary Data Preparation Subsystem

This subsystem converts primary data to secondary data. Secondary data for a regional development plan must satisfy the following 2 criteria.

① The data in question are those for regional unit data or interregional-unit data which are essential for regional analysis.
② The data should be arranged to facilitate their input into a computer system.

The preparation pf secondary data firstly requires the preparation of a regional unit map and the numerical values of the primary data must be converted to reflect the conditions of each regional unit. Data such as those on roads must be converted to interregional-unit data. Regional analysis has so far been based on these converted data.

The type of data, i.e. either raster data or vector data, must be determined for each datum for the input of map-related data. Tracing and other work may be required to enable automatic input operation.

(3) Database Preparation Subsystem

The main purpose of the database preparation subsystem is the creation of a database by inputing regional unit data and interregional-unit data in order to make regional analysis easier. This subsystem also has 3 stages (input, computation and output) just like the system, shown in Fig. 2-1-3.

The database preparation subsystem is a newcomer in the regional planning process, following the introduction of a computer in the process. Computerization demands more work but is useful due to the following.

① centralized storage of bulk data
② easy procedure to analyzed data
③ labour saving and speeding up of regional analysis and planning report preparation processes
④ centralized preparation of regional analysis and planning reports

③ and ④ are the main objectives of the introduction of a database.

Each subsystem must be equipped with the following functions

① Secondary Data Input (Conversion) System

The secondary data input system deals with the secondary data input work and the work to convert and input the original database to the system.

In general, 5 types of data are conceivable for input into this system

① statistical database
② map information database

③ remote sensing database (for example, Landsat MSS data)
④ existing regional information database
⑤ general information database

The important point of this system is the preparation of useful data for regional analysis. In the case of a statistical database, useful data means the unification of data into regional unit data or interregional-unit data. In the case of demographic data for example, data by demographic survey units should be converted to regional unit data which are useful for the project purposes.

With regard of the map information database, the input of regional boundaries is essential. In the case of the remote sensing database, Landsat mesh data must be converted to regional unit data. It can be said that the remote sensing data available today differ from the original data vis-a-vis regional planning requirements.

② Database Inspection System

A database inspection system is required to provide a process whereby the quality of data is roughly inspected. Inspection of possible mistakes in data is also required. The system is expected to be capable of conducting at least histogram computation, mean value computation and standard deviation computation.

③ Database (Output) System

The format of the database should be predetermined so that the data analysis of each regional analysis item can be easily conducted.

2.1.5.2 Preparation of Regional Analysis and Planning Map

Regional analysis and regional planning are closely related. Although their results differ in the form of a regional analysis report for the former and a regional planning report for the latter, these 2 processes have many common features. The important points to note in preparing the guidelines for regional analysis and regional planning are discussed below.

(1) Planning Premises

The planning preconditions are classified into the external conditions relating to neighboring areas of the subject area and internal conditions of the subject area.

For both types of conditions, those items which must be considered preconditions for planning must be identified and shown on a map. In the case of external conditions, the trunk transportation routes and water utilization system are the most important items together with land use conditions of neighboring areas. In the case of internal conditions, those items of which the current status must be maintained and the infrastructure and/or facilities to be constructed by the plan must be clearly presented. Although remote sensing technologies are not essential to determine these preconditions, the introduction of an integrated mapping technology is required.

(2) Environmental Conservation Plan

Environmental conservation takes place in 2 fields, i.e. conservation of the natural environment (topography, geology, soil, hydrology, vegetation and animals, etc.) and conservation of the human environment (cultural assets and ruins, etc.) The basic environmental data required for regional planning are those relating to topography, geology, soil, hydrology, climate and vegetation. Animal habitat data and cultural asset distribution data are included where necessary. A map for environmental conservation purposes can be an environmental thematic map or an environmental assessment map. The former does not involve any human assessment of nature while the latter provides the basis for an environmental conservation plan, socioeconomic plan, physical plans and sector plans (agricultural plan, forestry plan, transportation plan and water utilization plan, etc.) by making a human assessment of nature represented in the former. Consequently, an environmental assessment map is not a map which simply provides data on subjects related to environmental conservation.

Among all maps relating to environmental conservation, the most basic data relating to remote sensing are topographical data. With the further development of remote sensing technologies in the future, remote sensing data which will allow topographical analysis will be obtained (such as SPOT data). For the time being, however a digitizer is required to input the relevant data to a topographical map. Other environmental thematic maps, such as a geological map, soil map, vegetation map, animal habitat map and climatological map, can be prepared using local training data and remote sensing data. In the case of a hydrological map, remote sensing data are not required as this type of map can be prepared based on the topographical analysis results. When the analysis of a hydrological storage zone, infilitration zone and seepage zone is made possible in the future based on rainfall and evapotranspiration data, remote sensing data (on temperature and ground cover) will be essential. At present, such a computation system is still at the research and development stage.

The evaluation maps shown in Table 2-1-2 are generally required for the preparation of regional planning although the actual combination of the required maps depends on the characteristics of the region subject to regional planning. At present, all regional planning reports contain some of those evaluation maps but not all. These maps are only obtained through assessment model analysis based on various assessment criteria. Since there is no standard environmental assessment model available at present, a standard model for each case should be established. Given the present conditions surrounding an environmental conservation map, the environmental map preparation system using remote sensing data takes the structure shown in Fig.. 2-1-4. If special thematic models for geological, soil, vegetation and other maps are not established, the map preparation process is the same as that for a topographical map.

The preparation of an environmental conservation plan follows the flow given in Fig. 2-1-5. The main objective of the Project is the development of a software for the model analysis shown in Fig. 2-1-4. Expert evaluation of each map is essential for the development of such software and the cooperation of the organizations related to the Project must be sought. Likely organizations to extend such cooperation in Indonesia are listed in Table 2-1-4 and the maps and reference data of these organizations should be collected and analyzed with a view to enlisting their cooperation environmental assessment in the future.

(3) Spatial Plan

While the concept of a spatial plan has so far been unclear, a plan to prepare the following maps is called a spatial plan here.

① planning subregion map
② central place and developing axis plan
③ macroscopic land use plan

① shows the proposed planning subregion, while ② shows their characteristics and locations of the respective central places and developing axis, ③ includes a facility distribution map and shows the planned structure of land use by indicating forest conservation areas, including industrial location.

A current administrative map, regional classification map, population density map, current land use map, etc. are required for the preparation of these maps. The regional classification map is the most important to judge the future regional structure.

With regard to the Project, assistance will be required for the input of an administrative map. A regional classification software based on regional information, including socio-economic data, should be developed for a regional classification map. Regional classification requires a current land use map, indicating the importance of remote sensing technologies in the preparation of the map. In fact, the preparation of current land use maps using remote sensing data has not yet acquired wide popularity. Many of the maps prepared by remote sensing technologies are land coverage maps which are different from current land use maps. The following categorial items are desirable for a current land use map in Indonesia.

① urban areas/settlements
② paddy fields
③ dry fields
④ orchards
⑤ plantations
⑥ tree gardens
⑦ forests
⑧ grassland/shrubland
⑨ wasteland
⑩ swamps
⑪ transportation-related areas
⑫ water utilization areas (rivers, lakes, ponds and other water surfaces)

Administrative boundaries (or regional classification boundaries), major facilities and the mapping scale must be entered on a current land use map on the basis of field data. In view of these requirements, the development of a software to prepare a current land use plan is very important for the Project. For the preparation of a comprehensive location analysis, data on both the population and population density, calculated on the basis of land use area measurement results, must be supplied. The flow of spatial structure analysis and planning is outlined in Fig. 2-1-6.

The following analyses are essential for there analysis of the physical structure.

① regional unit analysis
② current land use analysis
③ land use area calculation
④ regional classification
⑤ comprehensive location analysis

The development of a software which covers all these fields of analysis is apparently difficult and no software addressing all aspects of a spatial plan has yet been developed anywhere in the world. It is suggested that the first step for the Project should be the establishment of a current land use map subsystem.

(4) Socio-economic Plan

A socio-economic plan today commands important status at the national plan level. As a result, a socio-economic plan tends to be given priority over spatial plans, sometimes causing an excessive burden on specific spaces. In contrast, the preparation of a socio-economic plan is quite different vis-a-vis the regional level to which the Project addresses, mainly because of the shortage of data. The accumulation of data in Indonesia is virtually non-existend at the Desa level and the socio-economic structure begins to appear at only the Kecamatan level. Consequently, the socio-economic analysis for the Project must be conducted at the Kecamatan level for the time being with some new data added to the existing data.

In fact, as little research on a socio-economic model for regional planning at the Kecamatan or Desa levels has been conducted in the past, the Project should commence with a basic analysis of the current socio-economic structure at the Kecamatan level to develop a graphical display method for the structure and should then move to a higher level in accordance with the progress of the socio-economic model analysis.

For the immediate purpose of the Project, a socio-economic plan is understood to consist of a population plan and an economic plan. With regard to a socio-economic plan map, the analysis and planning results relating to population and economy will be charted on the same size with other planning maps. For example, the population distribution and regional (Kecamatan) economic characteristics are shown on the corresponding parts of the map in the form of a circular or bar graph for easy recognition of the regional socio-economic structure.

While the spatial presentation of socio-economic phenomena is often seen nowadays, a standard method for the spatial presentation of a planning map has not yet been developed. The existence of various formats makes the situation worse. For the purpose of the Project, efforts should be made to prepare some concrete plan maps, taking the existing plan maps at the Kecamatan level into consideration. The following maps and charts are expected to assist such efforts.

① population estimate map
② population distribution map
③ trend analysis of regional gross product
④ production volumes and ratios of regional industries
⑤ import/export structure by industry

(5) Infrastructure and Facility Plan

An infrastructure and facility plan is usually understood to be a sector plan covering industrial and living structures for a general regional plan. In the case of the Project, however, the infrastructure and facility plan will be limited to the preparation of infrastructure and facility improvement maps in view of the emphasis on physical planning (refer to 1.2.1). The following 7 maps indicated in Table 2-1-2 are considered to be relevant to this limited objective.

① agricultural infrastructure improvement plan map
② forestry infrastructure improvement plan map
③ commerce and industry improvement plan map
④ settlement improvement plan map
⑤ road and transportation plan map
⑥ water utilization plan map
⑦ supply and disposal facilities plan map

A mining development plan, fisheries development plan and recreation plan, etc. may be included where deemed appropriate although they are omitted from the Project for the time being.

Based on the qualitative contents of these plans, plans ① and ② can be combined as an agriculture and forestry infrastructure improvement plan while plans ③ and ④ can be combined as a settlement improvement plan. With the inclusion of the water supply and sewerage plan of the supply and disposal facilities plan in the water utilization plan and with the exclusion of the power and communications plan of the supply and disposal facilities plan, the following 4 plans remain as target plans for the Project.

① Agriculture and forestry Improvement Plan

This plan intends to outline the infrastructure and facilities at sites which have been selected as suitable for the construction of such infrastructure and facilities. If the target is limited to agricultural infrastructure, this plan is the core of the Project.

While the methods of agriculture suitability maps have already been completed in Phase I, these maps alone are inadequate for the preparation of an agricultural infrastructure and facility plan and it is necessary to survey the agricultural irrigation facilities and farm roads, etc. and to identify the agricultural structure of the subject area. For analytical purposes, therefore, a technology which can show not only suitable land but also the agricultural structure and agricultural irrigation facilities on a map is required.

② Settlement Improvement Plan

Rural development plans in the past tended to place excessive emphasis on agriculture infrastructure improvement . In the future, however, proper attention must be paid to settlement improvement. A settlement improvement policy must be firmly established as part of the land use plan and this policy must address such other issues as housing improvement, community environment and facility improvement and commerce and industry improvement.

③ Transportation Plan

Although the main transportation system is stipulated in the land use plan, it is necessary to establish a plan which addresses the road conditions and priority roads, etc. The preparation of an OD table and road traffic volume analysis are essential for transportation analysis.

④ Water Utilization Plan

An irrigation and drainage plan is at at the center of a water utilization plan for a rural area. All plans relating to water, including a water supply and sewerage plan, should be integrated.

Conclusion

The establishment of guidelines for a rural development plan will be an epoch-making achievement in the history of technological development in rural development planning. Since these guidelines can contribute to not only rural development plans but also regional plans in general, their successful establishment is strongly hoped for.

The present regional planning technology is not as advanced as technologies in other scientific fields, for which there are many reasons. One is the slow development of information processing technologies relating to regional planning. A research system where interdisciplinary information is efficiently handled to allow researchers more time to develop planning technologies should be established. In the case of regional planning today, preliminary data processing takes too much time to allow enough tine for the examination of plan contents. It is hoped that the Project will improve this situation.

The development of a versatile computer software for a personal computer is also strongly desired to reduce the burden on planners who reluctantly face complicated computer operations. This is why the use of personal computers is stressed in the establishment of the guidelines in question. The use of computers in the planning process will be further facilitated with such software.

It is also necessary to break away from the conventional line of thought that guideline are part of a Geographical Information System (GIS). The establishment of guidelines should instead be considered as a step forward in the creation of a Planning Information Processing System. From the viewpoint of remote sensing technology application, a technical system to use remote sensing data to prepare proper maps is urgently required. The combination of the ground truth technology and remote sensing technologies should prove useful in this sense. It must be remembered in the implementation of the Project, therefore thats not only the further refinement of computer technologies but also the establishment of information collection technologies, including ground data collection technologies, is expected.

A development plan cannot be created by the simple overlay of map data but requires the integration of new regional design technologies. It is hoped that a programming software for regional development planning which breaks away from the conventional ARC/INFO and ERDAS will be developed in the future, incorporating the features which currently characterize CAD softwares for building design and construction purposes.

Note

1) Comprehensive Plan and Sector Plan: the former deals with the entire subject area and takes the form of a population plan, land use plan or regional economy plan as shown in Table 2-1-1. The latter addresses a plan for each industrial field, such as agriculture or the manufacturing industry. In Japan, a comprehensive plan means a master plan for a regional plan. An integrated rural development plans has a similar meaning although the word "integrated" stresses the nuance of integrating many projects.

Table 2-1-1 Structure of Regional Planning Report

Foreword
Planning Organization
Summary

Introduction - Planning Orientation
1. Objectives of the Plan
2. Object and Period of the Plan
3. Planning Method

Part I - General (Regional Pilot Plan)

Chapter 1 - Plan Premises
- 1.1 General Background of Subject Country
- 1.2 Regional Conditions
- 1.3 Planning Administration
- 1.4 Planning Level

Chapter 2 - Planning Subjects
- 2.1 Environment
- 2.2 Space
- 2.3 Society
- 2.4 Economy
- 2.5 Physical Phenomena
- 2.6 Industry
- 2.7 Life
- 2.8 Infrastructure/Facilities

Chapter 3 - Concept of Comprehensive Plan
- 3.1 Concept of Environmental Conservation
- 3.2 Concept of Spatial Plan
- 3.3 Concept of Regional Society
- 3.4 Concept of Regional Economy
- 3.5 Concept of Physical Plan

Chapter 4 - Concept of Sector Plan
- 4.1 Concept of Industrial Development
- 4.2 Concept of Life and Welfare
- 4.3 Concept of Administrative Plan

Chapter 5 - Concept of Implementation Plan
- 5.1 Principles of Implementation
- 5.2 Planning Organization and Finance
- 5.3 Development Strategy

Part II - Comprehensive Plan

Chapter 6 - Environmental Conservation Plan
- 6.1 Conservation of Natural Environment
- 6.2 Conservation of Cultural Environment

Chapter 7 - Spatial Plan
- 7.1 Classification of Planning Region
- 7.2 Central Place and Developing Axis Plan
- 7.3 Macroscopic Land Use Plan

Chapter 8 - Regional Society Plan
- 8.1 Population Plan
- 8.2 Employment Plan
- 8.3 Social Organization Plan

Chapter 9 - Regional Economy Plan
- 9.1 Income Improvement Plan
- 9.2 Industrial Structure Plan
- 9.3 Land Economy Plan
- 9.4 Finance Plan

Chapter 10 - Physical (infrastructure and Facilities) Plan
- 10.1 Public Facilities Plan
- 10.2 Road and Transportation Plan
- 10.3 Water Utilization Plan
- 10.4 Supply and Disposal Facilities (Power, Gas, Information and Sewerage)

Part III - Sector Plans

Chapter 11 - Industrial Development Plan
- 11.1 Mining Development
- 11.2 Agricultural Development
- 11.3 Forestry Development
- 11.4 Fisheries Development
- 11.5 Industrial Development
- 11.6 Commerce Development
- 11.7 Tourism Development

Chapter 12 - Life and Welfare Plan
- 12.1 Family Life and Housing
- 12.2 Health, Sanitation and Medical Care
- 12.3 Social Welfare
- 12.4 Education and Research
- 12.5 Recreation

Chapter 13 - Public Administration Plan
- 13.1 Administration Plan
- 13.2 Disaster Plan
- 13.3 Military Plan
- 13.4 Public Facility Management Plan

Part IV - Implementation Policies

Chapter 14 - Concept of Forming Planning Body
- 14.1 Concept of Project Implementation Organization
- 14.2 Extension Services

Chapter 15 - Concept of Planning Finance

Chapter 16 - Concept of Development Strategy
- 16.1 Concept of Regional Plan Implementation
- 16.2 Concept of Regional Plan Regulations
- 16.3 Concept of Regional Planning Projects

Table 2-1-2 Structure of Regional Planning Maps

Analysis Maps	Priority Grade a)	Planning Maps	Priority Grade a)
1 - Plan Premises			
1) Neighboring Area Conditions Map	III		
2) Existing Planning Administration Map	III		
2 - Environmental Conservation Plan (Comprehensive Plan)			
2A - Environment Thematic Maps			
1) Climatological Maps (Temperature and Rainfall Distribution Maps)	II		
2) Hydrological Map	I		
3) Land Coverage Map	I		
4) Topographical Map	I		
5) Topographical Classification Map	II		
6) Geological Map	III		
7) Soil Map	I		
8) Vegetation Map	III		
9) Animal Distribution Map	V		
2B - Environmental Assessment Maps			
1) Critical Land Map	I	Environmental Conservation Plan Map 1)	III
2) Wet Land Assessment Map	I		
3) Mining Resources Assessment Map	III		
4) Farmland Suitability Maps (Paddy Field, Dry Field and Orchard Suitability Maps)	I		
5) Forest Suitability Map	III		
6) Inland Fisheries Resources Assessment Map	V		
7) Water Environment and Resources Evaluation Map	I		
8) Plant Ecology Assessment Map	IV		
9) Animal Ecology Assessment Map	V		
10) Cultural Assets Assessment Map	V		
3 - Spatial Plan Maps			
1) Administrative Boundaries Map	I		
2) Regional Classification Map	I	Planning Subregion Map	I
3) Central Place Evaluation Map	II	Central Place and Developing Axis Plan	II
4) Current Land Use Map	I	Land Use Plan	I
4 - Socioeconomic Plan Maps (Comprehensive Plan)			
1) Population Map 1)	II	Population Plan 1)	II
2) Economic Structure Map 1)	III	Economic Plan 1)	III

5 - Physical Plan Map				
1)	Public Facilities Map	II	Public Facilities Plan	II
2)	Road and Transportation Facilities Map	II	Road and Transportation Plan	II
3)	Water Utilisation Facilities Map	I	Water Utilisation Plan	I
4)	Supply and Disposal Facilities Map	III	Supply and Disposal Plan	IV
6 - Sector Plan Maps				
1)	Mining Facilities Map	V	Mining Implement Plan	V
2)	Agricultural Facilities Map	I	Agricultural Improvement Plan	I
3)	Forestry Facilities Map	III	Forestry Improvement Plan	III
4)	Fisheries Facilities Map	V	Fisheries Improvement Plan	V
5)	Commercial and Industrial Facilities Map	IV	Commerce and Industry Improvement Plan	IV
6)	Settlement Facilities Map	II	Settlement Improvement Plan	II
7)	Recreation Facilities Map	IV	Recreation Facilities Improvement Plan	IV
8)	Disaster Prevention and Protection Facilities Map	V	Disaster Prevention and Protection Plan	V
9)	Public Facilities Map	II	Public Facilities Plan	II
10)	Road and Transportation Facilities Map	II	Road and Transportation Plan	II
11)	Water Utilisation Facilities Map	I	Water Utilisation Plan	I
12)	Supply and Disposal Facilities Map	III	Supply and Disposal Plan	IV

Notes:

a) Priority grades I - V are determined vis-a-vis the remote sensing project requirements (I is given the highest priority).

b) There may be more than one map.

Table 2-1-3 Collection of Examples of Primary Data

1. Field Survey	
Environment	geology; soil; vegetation sampling
Space	current land use inspection; administrative boudaries inspection
Infrastructure/Facilities	infrastructure and facilities inspection
2. Questionnaire Survey	
Environment	environment inspection and interviews
Space	land use issues interviews
Socio-economy	socio-economic indices by Desa (population; working population; income per capita; production value by industry)
Infrastructure/Facilities	① public facilities index (number of public workers) ② infrastructure and facilities inspection and interviews)
Industrial/Living Structure	① agricultural indices (number of farming households; farmland area; agricultural production value) ② industrial indices (number of factories; shipment volume by product; number of industrial workers) ③ commerce indices (indices of shops; sales value by merchandise; number of commerce workers) ④ living indices (number of houses; average floor area)
3. Statistical Data	
Socio-economy	(similar to items under Questionnaire Survey)
4. Maps	
Environment	topographical map; geological map; soil map; vegetation map; animal distribution map; cultural assets distribution map
Space	administrative map; current land use map
Infrastructure/Facilities	agricultural facilities map; forestry facilities map; public facilities map; road map; river and water channel map; irrigation facilities map; others (water supply network map; sewerage network map; power grid map; telephone network map; gas network map)
5. Photographs and Others	aerial photographs; Landsat data

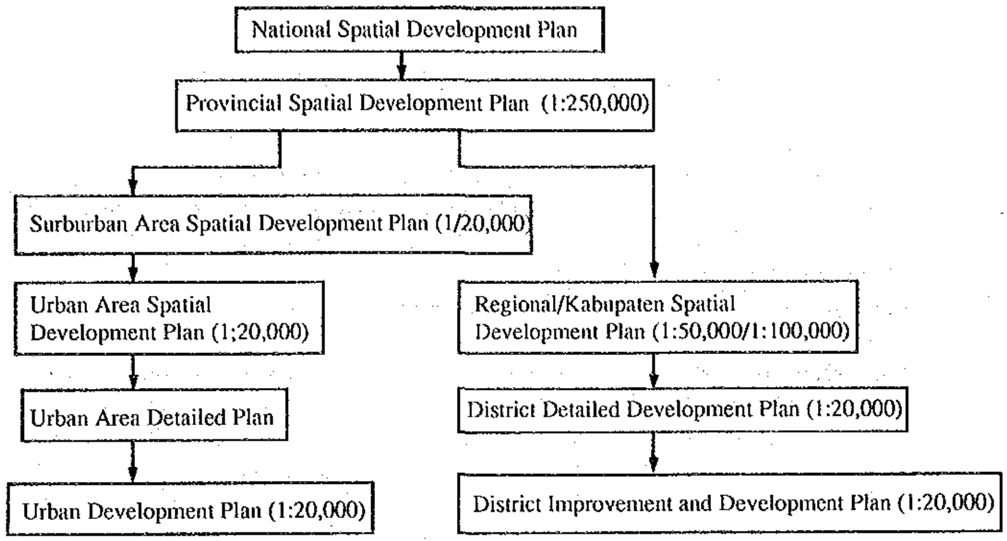


Fig. 2-1-1 Spatial Plan in Indonesia

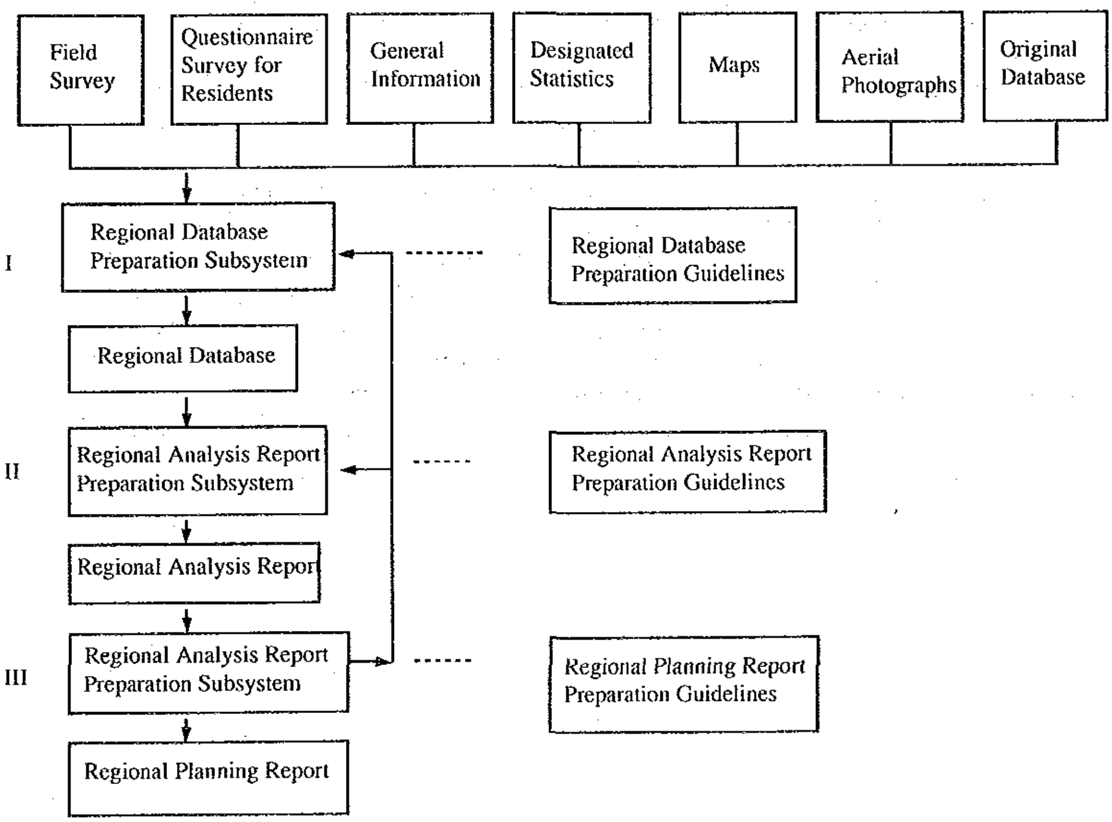


Fig. 2-1-2 Regional Plan Preparation System

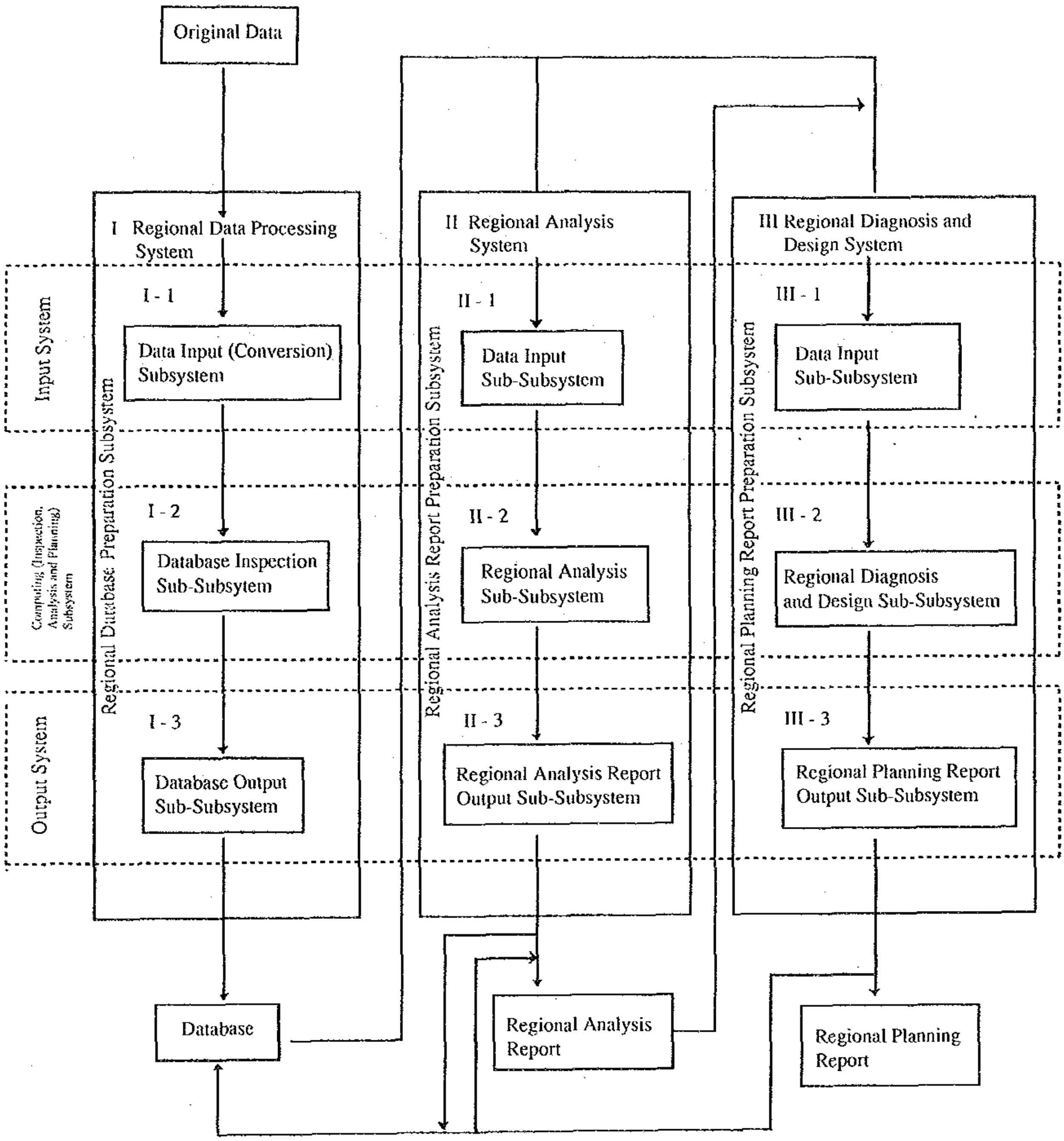


Fig. 2-1-3 Regional Planning Report Preparation Procedure

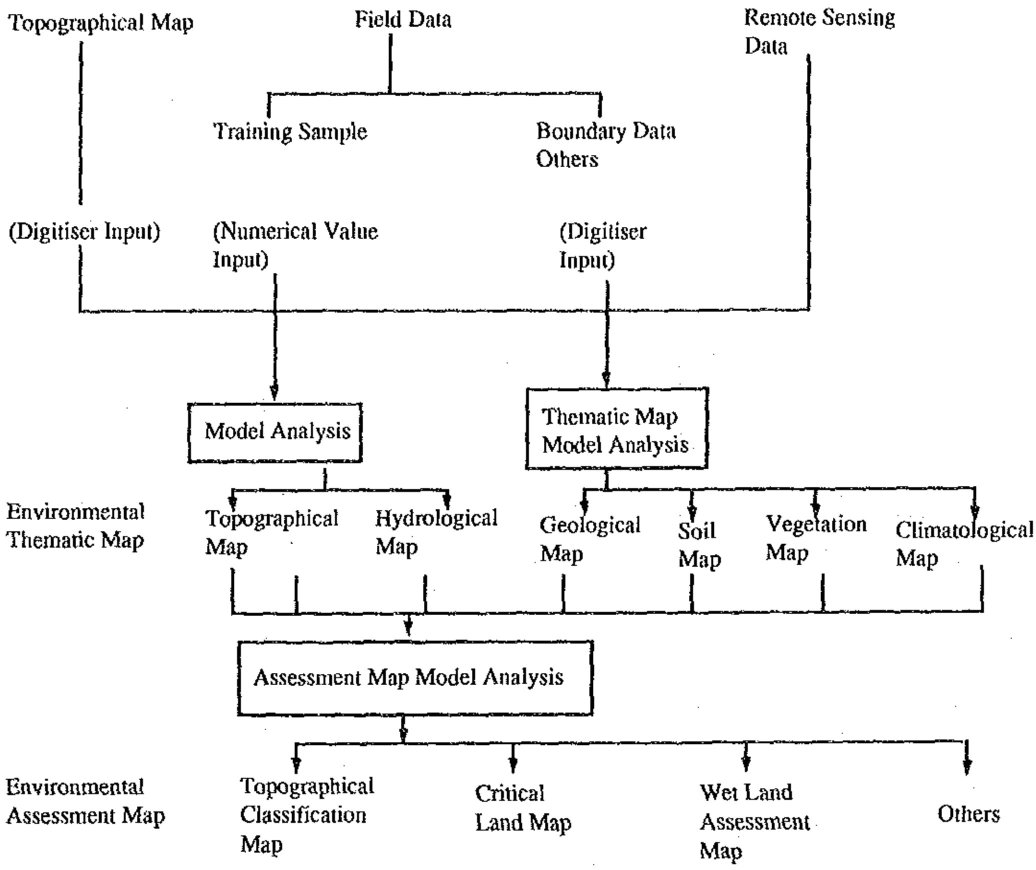


Fig. 2-1-4 Environmetal Map and Input Data

Table 2-1-4 Map Related Organizations

Map	Related Organizations
Geological Map	Directorate General of Roads; National Land Survey Agency
Soil Map	Ministry of Agriculture; Ministry of Forestry; National Land Survey Agency
Vegetation Map	Ministry of Forestry; National Land Survey Agency
Hydrological Map	Directorate General of Water Resources
Topographical Classification Map	National Land Survey Agency
Critical Land Map	Directorate General of Roads; Directorate of City and Regional Planning
Wet Land Assessment Map	Directorate General of Eater Resources
Assessment Map	Ministry of Population and Environment

Source: National Land Survey Agency (Bakosurtanal)

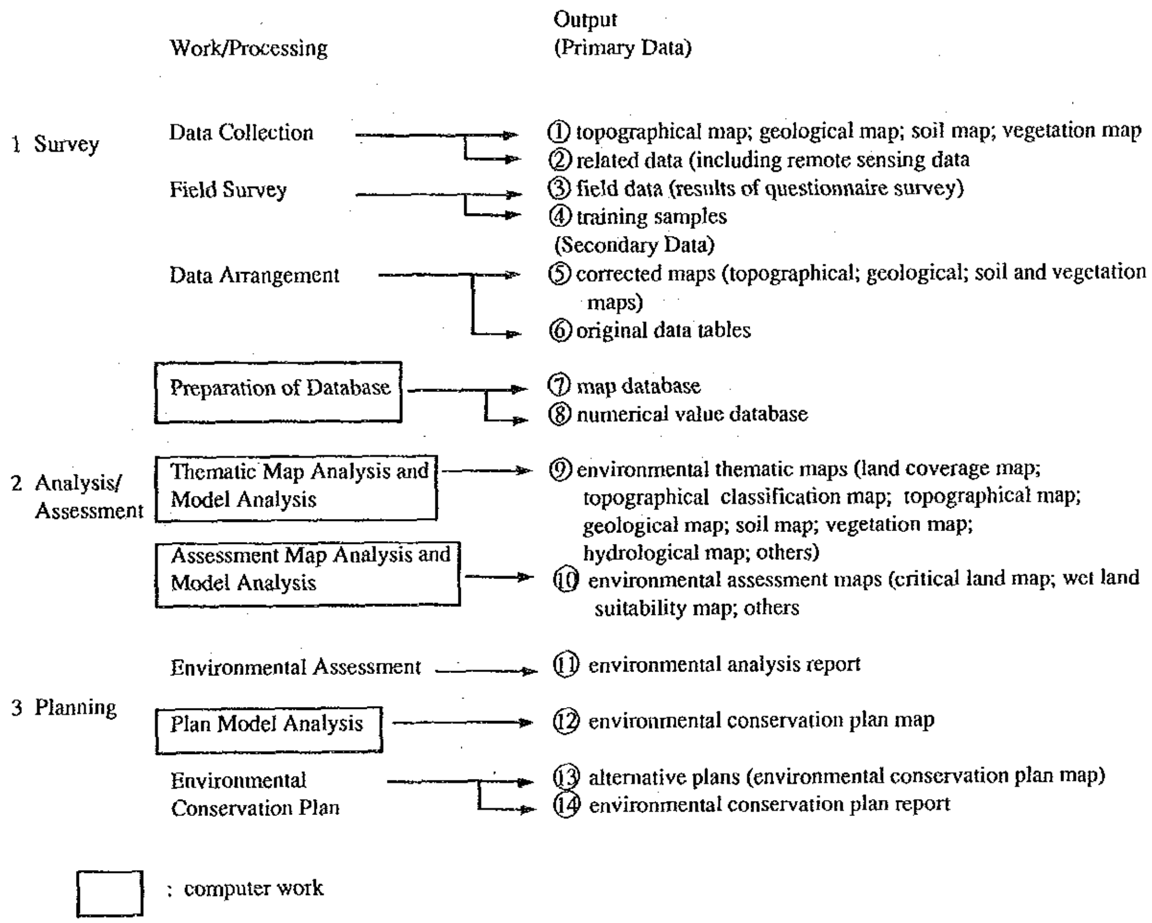


Fig. 2-1-5 Flow Chart for Environmental Conservation Plan

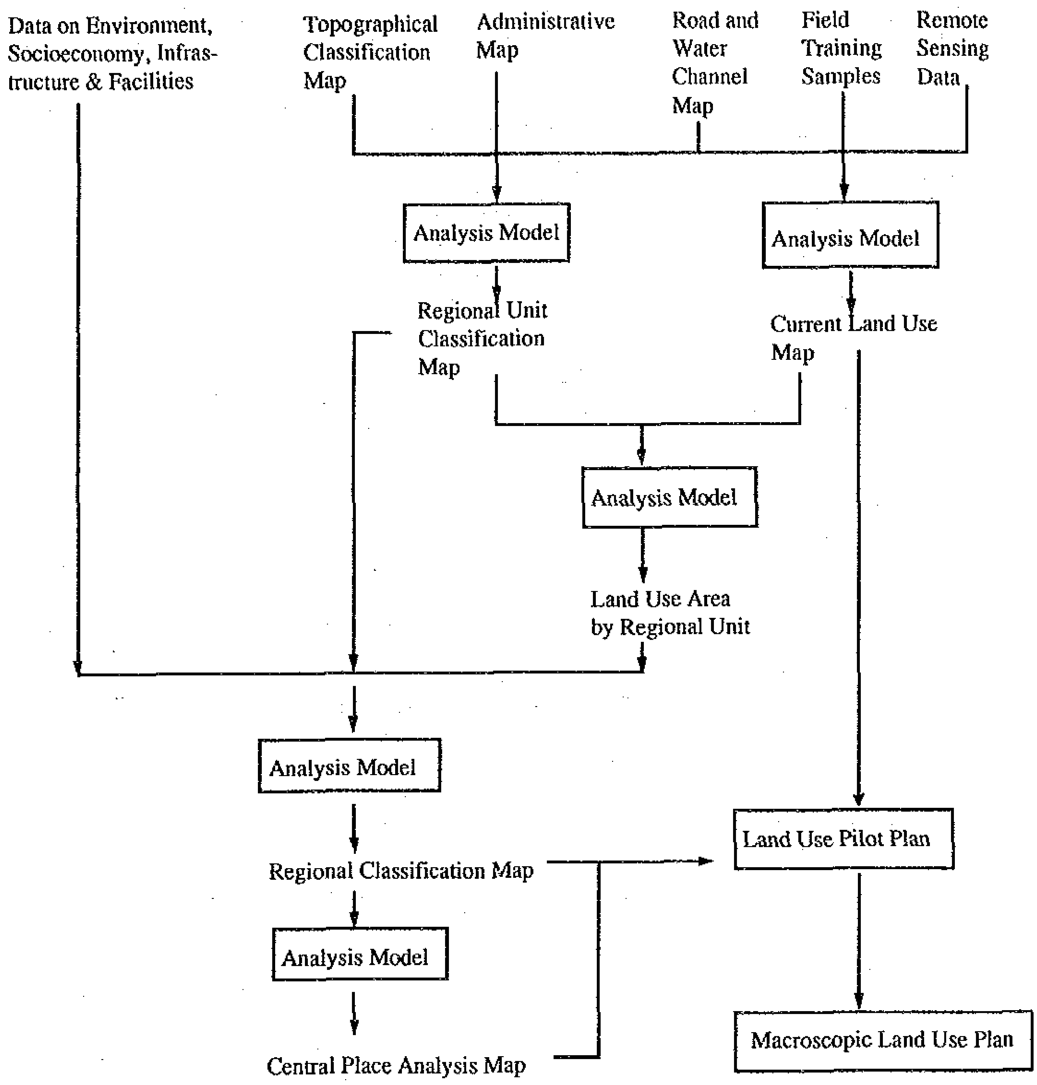


Fig. 2-1-6 Physical Structure Analysis Model

2.2 Characteristics of Natural Elements Affecting Agricultural Development Planning

Michikazu Fukuhara

2.2.1 Spectral Characteristics of Natural Elements and Their Observation Conditions

The natural elements affecting agricultural development include land use (land cover), vegetation, water systems, topography (elevation and gradient), soil, geology and climate (temperature, rainfall and sunshine hours). Data on land use, vegetation and water systems mainly come from remote sensing while data on other elements predominantly come from topographical maps and other existing reference materials [1].

Remote sensing analyses the spatial and temporal changes of the spectral characteristics which are peculiar to each elements (either physical phenomena or objects) and extracts the required data.

Fig. 2-2-1 shows the spectral characteristics of various objects at spring farmland which are observed on Landsat TM data [2]. The intensity of reflectance of such vegetation as wheat or grazing grass is lower than that of soil in Band 3 but higher in Band 4. By comparing these 2 bands, vegetation can be distinguished form soil. They can also be distinguished using Bands 5 and 7. Urban areas and rivers show different intensities of reflectance from soil in Bands 5 and 7. With regard to soil itself, but brown volcanic soil with a low moisture content and alluvial soil show a stronger intensity of reflectance than black volcanic soil with a high moisture content. This difference is particularly noticeable in Band 3.

Fig. 2-2-2 shows the time series changes of the spectral pattern of a rice species (Akeno-hoshi [3], indicating that the reflectance of the same species can largely change due to changing leaf colour and volume throughout the growth process.

The appearance of land cover at the same place constantly changes due to seasonal and annual changes of vegetation and it is absolutely essential that accurate records of these changes be kept. Table 2-2-1 shows the optimal observation conditions in terms of season, elevation and frequency, etc. [4]

The land use categories which are required to prepare land use maps for Indonesia are urban areas, settlements, paddy fields, dry farming fields, orchards, plantations, nurseries, forests, grassland/shrubland, wasteland and denuded land, swamps (wet land), transportation land and water areas (rivers, lakes and water surfaces). The availability of Landsat TM and SPOT data and the progress of the satellite data analysis technology have increasingly made satellite data the main sources of topographical and soil data. Therefore, determination of the optimal observation conditions for each category is essential.

2.2.2 Characteristics of Vegetation and Level of Information

Vegetation can be understood as the representation of various natural elements (climate, soil and topography, etc.) in the form of plant mass, including the interaction between these elements and living things. As a result, all environmental elements reflect on vegetation in one way or another and the locational conditions can be diagnosed through vegetation.

Table 2-2-2 shows the relationship between the main forest groups in tropical South East Asia and the locational (environmental) elements compiled by Whitemore [5]. The tropical rain forests and monsoon forests which cover most of Indonesia are divided into 15 groups and are related to soil moisture, parent rock properties and elevation, etc.

In the case of remote sensing data, such as Landsat data, vegetation is classified on the basis of land cover differences and, therefore, a vegetation map can be prepared using the same procedure for the preparation of a current land use map. This relationship of the qualitatively different levels of information on forest resources is given in Table 2-2-3 [6]. Satellite data can be used for Levels 1-3. Forest classification can be made by the multiple seasonal data for Level 2 with the addition of other data such as topographical data for Level 3. Levels 4 and 5 use aerial photographs.

The following formula is generally used for the evaluation of biomass.

$$RVI = IR/R$$
$$NDI = (IR - R) / (IR + R)$$
$$TVI = NDI^{1/2}$$
$$K = IR - aR - b$$

This formula uses the characteristics of the spectral reflectance curve of vegetation where the intensity is low in the 400 - 500nm (blue) band and 650 - 690nm (red) band due to the absorption of chlorophyll and high in the 750 - 1,200nm (near infrared) band.

2.2.3 Characteristics of Soil and Data Extraction

The procedure to prepare a soil map using remote sensing data is essentially the same as that for aerial photograph interpretation. The leading aerial photograph interpretation method for soil survey purposes is the element analysis method developed by Buring (1960) which conducts systematic analyses of all elements closely related to soil conditions (in practice, the most influential elements are selected) as shown in Table 2-2-4. In general, the relationship between the listed elements and soil analysis results of the selected elements are compiled to prepare a provisional soil map which is verified with the necessary corrections by a field survey [7].

In a place like Indonesia where the subject areas for agricultural development tend to be covered by vegetation throughout the year, it is important to interprete the topography and vegetation to determine the relationship between the topography and soil and/or between the vegetation and soil, it is also necessary to obtain direct soil data for already developed areas. In view of these necessities, the soil characteristics obtained from satellite data and a data extraction model are explained below.

① Spectral Characteristics of Soil

Fig. 2-2-3 shows the spectral reflectance patterns of soil in the visible - near infrared bands. The reflectance of soil varies depending on the contents of humus, iron oxide and water, etc. A high concentration of iron oxide reduces the soil reflectance in the blue and green wave-lengths bands of less than 500nm while a high concentration of humus reduces the soil reflectance in all wavelength ranges, Iron oxide does not affect longer wavelengths than red, making it possible to estimate the humus content in soil. Wet soil reduces the reflectance in all wavelength bands.

When soil is dry, the humus content has a strong correlation to the reflectance in the red wavelength band (Fig. 2-2-4). Based on this fact, Hatanaka prepared a humus content map of the surface soil of dry farmland in Tokachi, Hakkaido 2). The arbitrary classification of the humus content of soil is possible using Landsat TM data. Shiga also prepared a humus content map of the submerged surface soil of a paddy field using the double regression analysis of Landsat TM data [8]. The highest correlation was recorded by a combination of Band 3 (630 - 690nm) and Band 1 (450 - 520nm).

Land where humus naturally accumulates on the surface tends to be wet with poor drainage because of the microrelief showing a concavo character and underlying aquiclude. Accordingly, the humus content of the surface soil can be an indicator of soil drainage. Humus itself is a determining factor of the physical properties of soil, such as the water capacity and soil breakage. Humus is also the source of nitrogen supply. The quantitative assessment and distribution of humus based on Landsat TM data make swift, microscopic and highly accurate preliminary estimates of land drainage, soil breakage and notrigen supply possible, all of which are essential to proceed with land improvement work or land diagnosis.

② Soil and Plant Data Extraction Model

Farmland data obtained by remote sensing contain the spectral reflectance data of both soil and plants. To obtain data on either land or plants, it is necessary to eradicate unnecessary data using a computing process. For pixels where the vegetation coverage is low, the soil values (excluding the effects of vegetation refection) can be estimated using the near infrared (IR) and red (R) bands as shown in Fig. 2-2-5 [9].

The soil reflectance values in the red band and infrared band are the same or the latter are slightly higher than the former, showing close correlation. All types of soil are distributed on the regression line of equation 1 below.

$$IR = aR + b \qquad (1)$$

where, IR : reflectance of plant mass in neat infrared band
a&b: constants

This regression line is called the soil line and indicates the characteristics of soil's spectral reflectance, knowledge of which is important to extract soil data or crop growth prospects.

The spectral reflectance of dry farmland with no vegetation cover is on the soil line (Point S). Observation data (A) with low vegetation cover is strongly affected by the soil. With an increase of the vegetation cover, the value approaches Point P which represents 100% vegetation cover, If the soil is the same for all observed data, the SAPs are lined up in a straight line and an equation to emphasis the soil type is obtained from this model. Assuming that the reflectance values of soil and plants in the red and near infrared bands of SP, SIR, PR and PIR are respective to the reflectance values in the red and near infrared bands of dry farmland where the soil and plant reflection of R and IR are mixed, the following equation is given.

$$SI = (PIR - IR) / (R - PR) = (PIR - SIR) / (SR - PR) \qquad (2)$$

The value of SI is constant for each type of soil and is considered an index of soil surface characteristics. Here, it is called the optical soil index, The actual value of this optical soil index varies depending on the humus and water content. In the case of dry soil, it changes in proportion to the humus content. As the humus content does not change in a short period of time, a change in the optical soil index value can be considered a change in soil moisture. it must be noted, however, that the error margin for this soil index is very large for land with high vegetation coverage and that soil type classification is by definition impossible for land with 100% vegetation coverage.

Many undeveloped areas where remote sensing surveys are required rend to be covered by thick vegetation and, therefore, it is often difficult to obtain soil data from Landsat data, Saito created a soil colour map for the northwestern part of Java Island, which is one such undeveloped area, showing the tones of the surface soil and soil distribution from Landsat MSS CCT data, The following process was followed to obtain a soil colour map representing colours as natural as possible and the results were quite successful.

(1) extraction of denude land and determination of the soil values in Bands 4 (green) and 5 (red)

(2) estimation of the unobserved blue band values in Bands 4 (green(and 5 (red) using the spectral reflectance characteristics of soil

(3) estimation of the soil index values for pixels of low vegetation coverage, having eradicated the effects of vegetation reflection

(4) substitution of pixels with high vegetation coverage by neighboring pixels where the estimation of soil values is possible

③ Preparation of Soil Map

A surface soil distribution map using Landsat data can be prepared using certain soil data items, such as extracted soil types, by removing the effects of vegetation reflection and the enhanced spectral characteristics of soil.

Fukuhara et, al. 9 used the following indices to analyse dry farmland (in the planting season) using Landsat MSS data.

Soil Index	:	SI
Organic Matter Index	:	R
Iron Oxide Index	:	(G - R) / (G + R) or G/R
Biomass Index	:	(IR - R) / (IR + R) or IR/R

Here, G, R and IR relate to Band 4, Band 5 and Band 7 respectively. The value of the 100% vegetation coverage point to determine the SI value was computed on the basis of K = (53 - Band 7) / (Band 5 - 10) using the lowest values of the red band (RP = 10) and the infrared band (IRP = 53) obtained from statistical data of grazing land images.

2.2.4 Climate

Only general attempts have so far been made to estimate the evapotranspiration volume, temperature, solar radiation volume and rainfall using NOAA and Himawari data and to calculate the surface temperature and evapotranspiration volume using Landsat data. In view of the fact that cloudless data are hard to obtain in the tropics, the issue of handling climatological data for agricultural development planning still remains largely insolved.

Here, an example of estimating the evapotranspiration volume using NOAA data (Horiuchi, et.al. 11) is introduced for reference purposes. A regional evapotranspiration volume can be estimated using NOAA data which give a fairly accurate value of the surface temperature. The Priestley - Taylor method (equation (3)), which provides a comparatively simple equilibrium evapotranspiration model, was used to estimate the evapotranspiration volume from NOAA data.

$$I\Sigma = \alpha \cdot \frac{\Delta}{\Delta + 7} (Rn - G) \quad (3)$$

where, I : latent heat of evaporation

Δ : surface temperature gradient of temperature saturated vapour pressure curve

7 : psychrometer coefficient

Rn : net radiant quantity

G : ground heat transfer quantity

α : parameter

The values of α for forests and paddy fields were calculated using the equilibrium evapotranspiration value (obtained by assuming α = 1) and the evapotranspiration volume by the heat balance method. The resulting values of α were 1.09 for forests and 1.06 for paddy fields. Using this a value, the evapotranspiration of a forest was estimated. In fact, for the estimation of the evapotranspiration volume based on NOAA data using equation (3) above, data on the net radiation quantity (Rn) and the ground heat transfer quantity were required in addition to NOAA data on the surface temperature. The Rn value was assumed to be 0 using the following equation (4).

$$Rn = (S \quad + L \quad) - (S \quad + L \quad) \tag{4}$$

where, S : downward short wave radiation (actual value)

L : downward long wave radiation (calculated from equation (3) using the vapour volume and temperature)

S : upward short wave radiation (calculated from the visual and near infrared band data of NOAA)

L : upward long wave radiation (calculated from the surface temperature data of NOAA)

$$L \; : \; \acute{O}\Theta^4 (0.73 + 0.20\,X - 0.06X^2) \tag{5}$$

where, Θ : ground temperature

X : log10W when W is the total effective water vapour volume

The latent heat flux over a forest was calculated using 1987 and 1989 NOAA data (Table 2-2-5). Moreover, the latent heat flux of all Hokkaido was calculated using data collected on September 23rd, 1987 based on the assumption that the value of £ is 1.09 for all Hokkaido and that the solar radiation volume is constant. The latent heat flux is generally large for a forest and small for a farmland.

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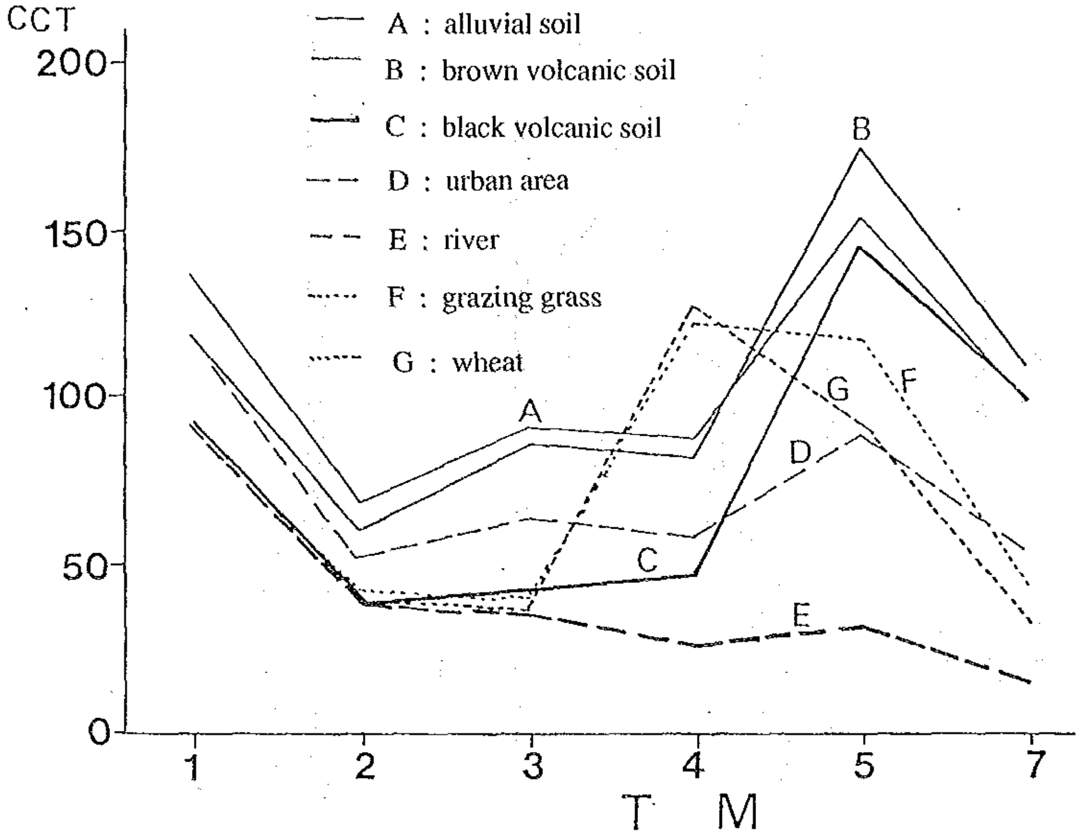


Fig. 2-2-1 Spectral Reflectance Characteristics of Various Objects on Tokachi Plain (TM Data on May 24, 1985)

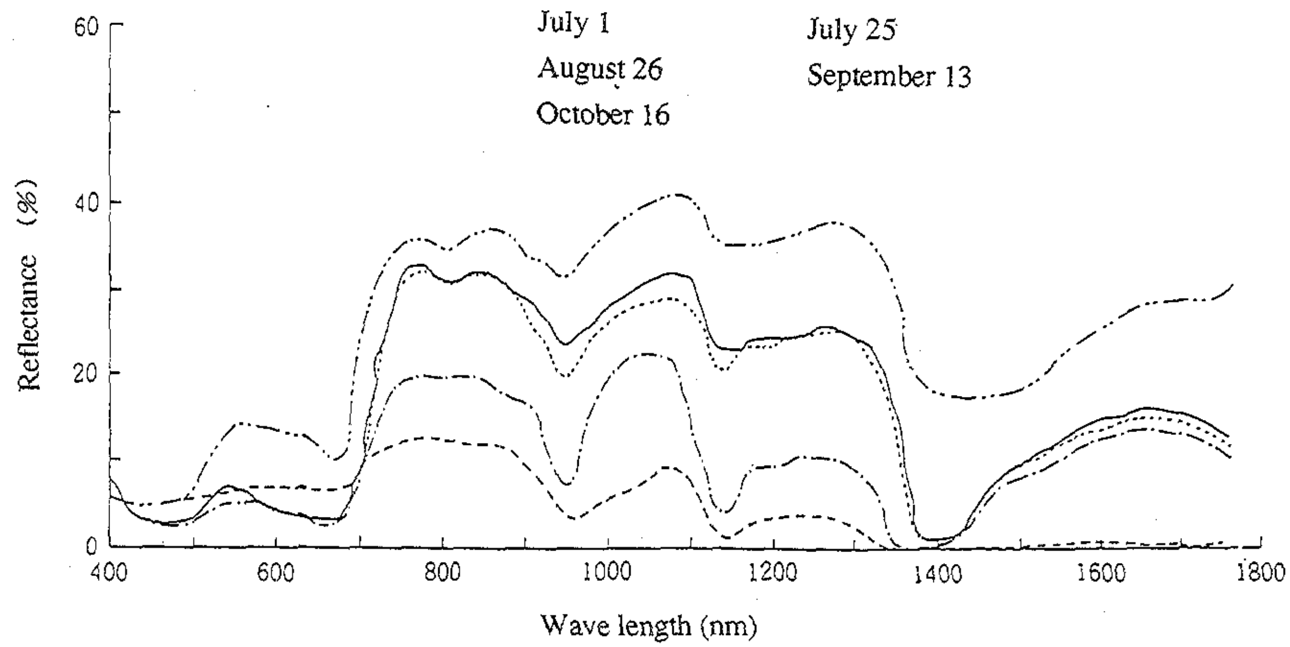


Fig. 2-2-2 Changes in Spectral Reflectance Characteristics of Paddy Rice Species (Akeno-hoshi Planted on June 6) in Accordance with Growth Stages (Akiyama, et. al., 1986)

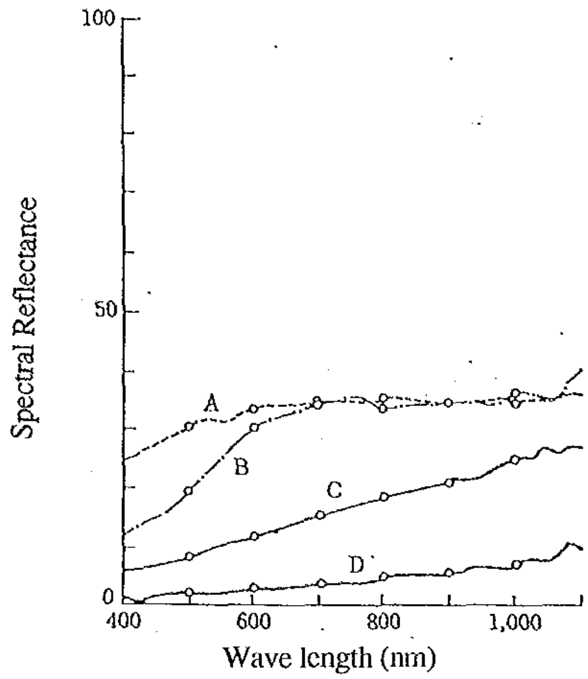


Fig. 2-2-3 Effects of Soil Ingredients on Spectral Reflectance

A : unweathered volcanic ash, B : accumulation of iron oxide

C : accumulation of humus (in brown volcanic soil), D : wet soil

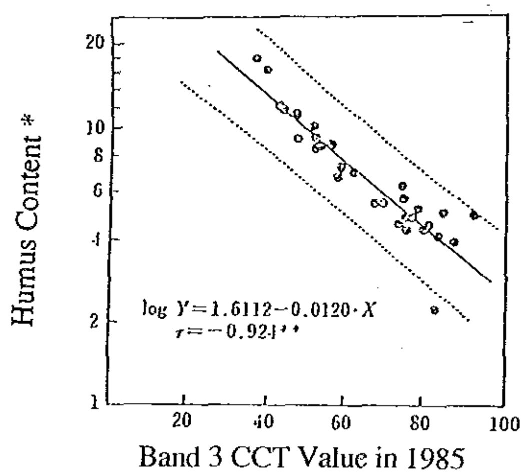
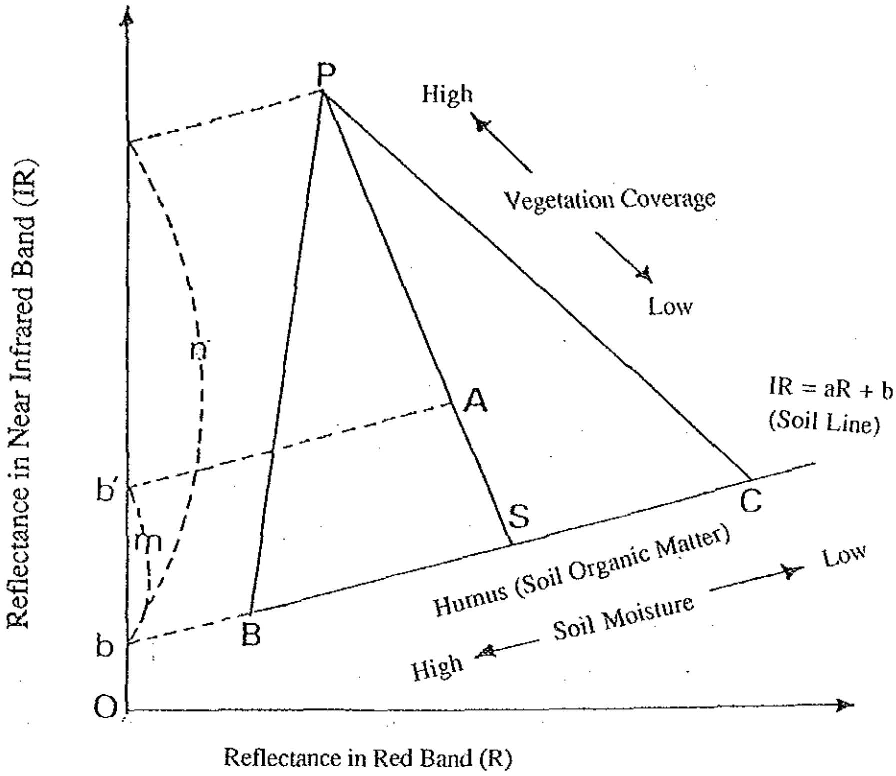


Fig. 2-2-4 Correlation Between Humus Contents and Band 3 CCT Value (1985)

* Weighted average for 25cm thick soil layer at sample boring sites of the Land Fertility Conservation Basic Study.

** Significance Level : 1%

The broken lines determine the area of 1% reliability. Soils outside this area are brown lowland soil.



A : observed value, P : point of 100% vegetation coverage, S : point of 0% vegetation coverage, m/n : coverage ratio (n = 100%)

Fig. 2-2-5 Model to Enhance Soil Reflectance While Removing Effects of Vegetation Cover

Table 2-2-1 Observation Conditions for Agricultural, Forestry and Geological Surveys

	Application Field	Suitable Survey Season	Instantaneous Field of View (m)	Survey Frequency	Altitude
(observation & Analysis by Multiple Altitude)	1. Forest				
	(1) Forest and Non-Forest	winter, early spring,	50~100	every 2.5 years	satellite
	(2) Forest Type	spring, winter,	2~5; 20~30	every 2.5 years	aircraft
	(3) Number of Trees	summer	1 or less	every 5 years	aircraft
	Crown Diameter				
	Species Identification				
	(4) Background Forest Bed				ground
	2. Cultivated Land and Harvest Estimation				
	(1) Cultivated Land and Non-Cultivated Land	crop growing season	50~100	every year	satellite
	(2) Type of Cultivated Land (Crops, Fruit and Grazing Grass, etc.)	crop growing season	5~10	4 times/year	aircraft
	(3) Crop Identification	crop growing season	1 or less	4 times/year	aircraft
	(4) Background Soil Type				ground
	3. Inhabited Areas				
	(1) Inhabited Area and Non-Inhabited Area		50~100	every 5 years	satellite
	(2) Type of Inhabited Area		2~5	every 2.5 years	aircraft
	(3) Classification and Observable Trends of Inhabited Area		1 or less	every 5 years	aircraft
	(4) Infrastructure				ground
(Observation & Analysis by Single Altitude)	1. Forest	early summer	50~100	every 5 years	satellite
	2. Watershed	varies	50~100	twice/year	satellite
	3. Snow Line	winter	50~100	6 times/week	satellite
	4. Desert	varies	50~100	every 5 years	satellite
	5. Distinction Between Grassland and Undeveloped Area	spring and autumn	50~100	every 2.5 years	satellite
	6. Distinction Between Grassland and Forest	spring and autumn	50~100	every 2.5 years	satellite
	7. Distinction Between Undeveloped Area and Forest	spring	50~100	every 2.5 years	satellite
	8. Denuded Land and Vegetation Area	spring and summer	50~100	3 times/year	satellite
	9. Main Roads, Railways and Water Channels	summer and winter	30~505	twice/year	satellite
	10. Cultivated Land and Non-Cultivated Land	crop growing season	50~100	4 times/week	satellite
	11. Plant Detection	crop growing season	2~5; 30~50	4 times/ 5 times	aircraft
	12. Farm	crop growing season	5~10	every year	aircraft
	13. Matured Fruit Tree	crop growing season	2~5	4 times/year	aircraft
	14. Forest Engineering	winter and summer	5~10	twice/year	aircraft
	15. Expansion of Water Surface	summer	5~10	twice/year	aircraft
	16. Classification of Crops	crop growing season	2~5; 30~50	4 times/year	aircraft
	17. Open Area of Farm	crop growing season	2~5	every year	aircraft
	18. Urban Area	varies	50~100	every year	satellite
	19. Changes in Land Use	varies	30~50	6 times/year	satellite
	20. Expansion of Urban Area	varies	30~50	every year	satellite
	21. Urban Functions	winter and summer	5~10	twice/year	aircraft
	22. Detailed Urban Structure	winter and summer	1~5	twice/year	aircraft
	23. Emergency Measures and Disasters	as required	1~5	4 times as required	aircraft

Table 2-2-2 Main Forest Types in the Tropical East Asia in Connection with Site Factors

(Whitmore, 1975)

Climate	Soil moisture	Location	Soils	Altitude	Forest Formation Type *
High moisture in all seasons	Dry land	Inland	Zonal soil	Lowland~1200m Hilly (750) 1200~1500m (600) 1500~3000m (3350m) 3000 (3350m)~to forest limit	1. Tropical lowland evergeen rain forest 2. Tropical low-mountain rain forest 3. Tropical upper-mountain rain forest 4. Tropical sub-alpine forest
			Podzolic sand Limestone Ultrabasic rock	Mainly lowland Mainly lowland Mainly lowland	5. Heath forest 6. Limestone forest 7. Serpentin forest
		Coast			8. Coastal forest
		Salt water swamp			9. Mangrove forest
		Brackish water swamp			10. Brackish water swamp forest
		Fresh water swamp	Poor fertile peat		11. Peat swamp forest
			Fertile soil (Organic and inorganic	Wet Periodically wet	12.a. Fresh water swamp forest 12.b. Seasonal swamp forest
Seasonally dry	Causes moderate water deficit seasonally				13. Tropical semi-evergeen rain forest
	Causes severe water deficit seasonally				14. Tropical moist deciduous forest 15. Other formation types according with the increment of dry season

* 1~13: Tropical rain forests, 14~15: Monsoon forest

Table 2-2-3 Levels of Forest Resources Data

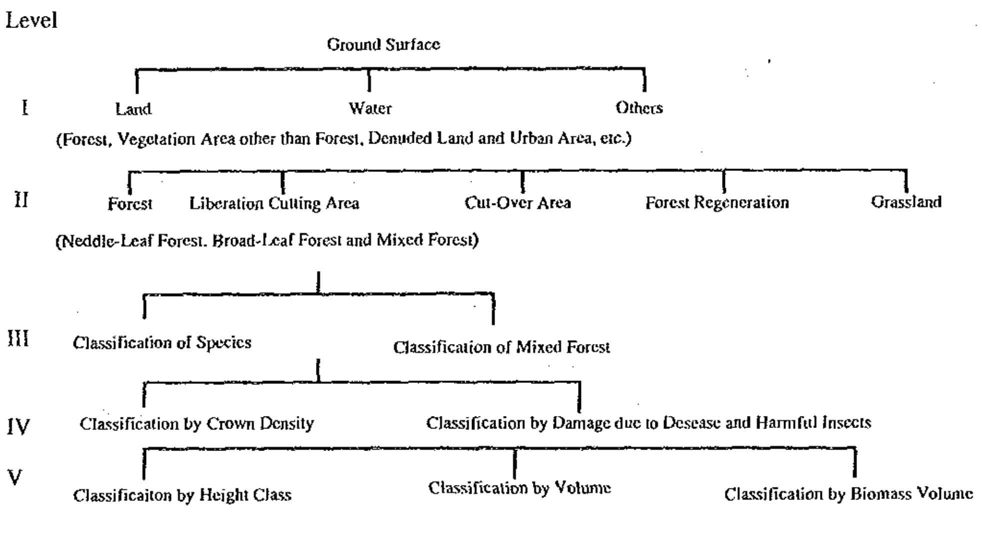


Table 2-2-4 Elements Used in Element Analysis (Vink, 1963)

Category	Element
1. Elements with a positive direct relation to one or more aspects of the soils themselves	1) clearly waterlogged soils 2) patterned ground
2. Elements related to the general morphology of the terrain	3) land type 4) relief form 5) slope 6) drainage pattern 7) watershed pattern 8) rivers and creeks and other patterns
3. Elements related to special aspects of the terrain	9) stratigraphy 10) gully form 11) gully pattern 12) colour of the earth's surface
4. Elements related to the vegetation cover	13) natural vegetation 14) specific trees 15) land use
5. Elements related to specific human aspects	16) ditches and canals 17) dikes 18) parcelling 19) roads 20) patterns and sites of buildings and villages 21) archaeological objects
6. Inferred elements or elements based on "coverging evidence"	22) water and drainage conditions 23) some cases of stratigraphy 24) parent material 25) microrelief

In this order the weight is decreasing from top to bottom of the list.

Table 2-2-5 Comparison of Estimated Latent Heat Flux and Observed Values at Tomakomai Experimental Forest

Year	Month	Day	Time	Latent Heat Flux (W/m^2)	
				Estimated Value	Ground Observation Value
1987	9	4	14:04	362	347
1987	9	23	14:00	317	353
1989	7	22	12:54	525	541
1989	8	2	12:41	522	598

2.3 Utilization of Remote Sensing Data for Land Evaluation

Genya Saito

2.3.1 What is Land Evaluation?

Land evaluation involves a ranking or scoring system to evaluate land properties for a particular use propose. It does not show the absolute value of the land in question and the evaluated land use largely varies depending on a particular land use. For example, soil fertility is not important for industrial land but is a crucial evaluation factor for agricultural land. The requirements of a paddy field differ from those of a upland farming field in that, for example, the former requires good water retention while the latter requires good drainage.

The land evaluation criteria can change depending on the preconditions even if the anticipated land use is the same. In the case of a paddy field for example, the evaluation results may significantly differ depending on whether a farming system using chemical fertilizers is assumed. If chemical fertilizers are not used, land fertility becomes the important evaluation factor. In contrast, the intended use of chemical fertilizers reduces the importance of land fertility. Another example is the use of machinery, including a tractor, for farming. On one hand, if no supporting means other than animals are used, paddy rice cultivation is possible on steep slopes with the introduction of terraces. In view of the relatively weak tilling power, however, tillability is essential. On the other hand, if the use of large machinery is considered, the problem of field tillability can be solved. The mechanical method, however, demands a large field size to justify its use and poses a strong restriction in terms of slope gradient.

Since the present Project aims at the selection of suitable sites for agricultural development, it should suffice to consider the land evaluation process for the use of land as paddy fields or upland farming fields. The clarification of the preconditions for development efforts is still necessary by conducting a general assessment of the farming methods to be employed after the development.

Land evaluation can be conducted in 2 ways as described in 2.3.2, i.e. based on the scoring system or based on the ranking system. In general, land evaluation is an interesting research theme and the Project involves the search for a new evaluation system using remote sensing data. In view of the practicality of an evaluation system, the basic step is to select an appropriate method from the existing methods. However, the simple application of such a system following the set procedure will prove unsatisfactory and some modifications of the analysis procedure will be required to incorporate specific conditions.

Another problem is deciding the unit land size for evaluation. In many cases, a closed area called a drawing figure unit with uniform conditions prevailing within is used as the basic unit. A square grid cell of a certain area has been increasingly used in recent days as the basic unit which is convenient for use in remote sensing application.

The most important question is how to prepare the evaluation criteria rather than the evaluation method and evaluation unit. The quality of the evaluation criteria actually determines the total accuracy of evaluation. The technical report compiled for Phase I lists the agricultural development criteria for Japan. As these criteria were prepared for application in Japan which is a highly industrialized country in the temperate zone, they cannot be directly applied to Indonesia which is undergoing rapid industrialization in the tropical zone. Consequently, the creation of a new set of criteria is necessary.

2.3.2 Examples of Land Evaluation Methods 2), 9), 11), 12), 13)

Land evaluation uses the characteristics of the subject land as evaluation factors and there are 2 methods as described earlier, i.e. the ranking system or scoring system. The ranking system where land is evaluated as being either suitable or unsuitable is called a dichotomy. This dichotomy method is sometimes separated from the ranking system as shown in Fig. 2-3-1. The scoring system is a quantitative evaluation method while the ranking system is a qualitative evaluation method. In general, the quantitative method is understood to be superior to the qualitative method but such understanding is often found to be untrue in the case of land evaluation. It is true that comparison of land of the same rank cannot be made in many cases and the scoring system should be adopted here to enable such comparison. In the case of selecting suitable sites for development, a process to convert score to rank is necessary despite the difficulty of introducing thresholds into numerical continuity. In addition, many data on evaluation factors are qualitative and the calculated score of the land may be called into question. In contrast, the ranking system ranks the evaluation factors and expresses the evaluation result in terms of a rank. Here, the evaluation result directly determines the rank of the land in question.

Both the scoring system and ranking system can be devided into statistical analysis and normative analysis. Statistical analysis means the formulation of a functional equation for evaluation based on the evaluated values of sample areas and the values of evaluation factors using the multiple regression analysis method or the quantification theory. Normative analysis is decides the evaluation criteria and the evaluation system structure based on empirical judgement. A new method where the evaluation criteria values are decided by a statistical method is under consideration for the scoring system as an intermediate method.

Fig. 2-3-1 also lists the names of concrete evaluation methods. These are the basic methods and many other methods are available. A brief description of these methods is given below.

① Multiple Regression Analysis Method

The multiple regression coefficient to be used for evaluation is calculated from the evaluation scores of sample areas and the values of evaluation factors. The evaluation of sample areas is usually conducted by experts who have thorough knowledge of the subject sites.

② Quantification Theory Type I Method

The quantification theory type I method can produce an evaluation function using the scores of sample areas and the values of evaluation factors. While the multiple regression analysis method expresses the value of each factor in terms of a score, the quantification theory type I method expresses it in terms of a rank.

③ Accumulation Method

The evaluation score is given by the values of all the evaluation factors. All the evaluation factors are classified into categories which have their own specific scores. In addition, all the evaluation factors are weighted in view of their relative importance. The evaluation result is given by the following equation (1).

$$\nu i = \Sigma \Sigma \tau j \, . \, \beta jk \, . \, \chi \; i \; (jk) \quad \text{.................................(1)}$$

j : 1, 2, 3 ..... factor
k : 1, 2, 3 ..... category
νi : evaluation point of site i
τj : factor weight of factor j
βjk : category weight of category k for factor j
χi (jk) : dummy variable (1 or 0) relating to site i, factor j and category k

④ Tree Type Method

This is also called the PATTERN (Planning Assistance Through Technical Evaluation of Relevance Numbers) method. A pyramidal relevance tree with the final evaluation value at the top is prepared and the relative importance (relevance number) of factors on one level vis-a-vis a superior level are determined to obtain a final score.

(5) Regression and Accumulation Method

Using the statistical method, the category weight and factor weight are decided for evaluation which is conducted in the following manner.

a) Selection and categorization of evaluation factors.

b) Application of quantification theory type I using the evaluation scores of sample areas where wise evaluation was conducted as dependent variables and the categories of evaluation factors as independent variables.

c) Calculation of the category weight (0 - 1) from the evaluation coefficient obtained in b) above for the purposes of weighting categories using the following equation (2).

$$Cjk = \frac{\alpha jk - \text{Min}(\alpha jk)}{dj} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

dj = Max (ajk) - Min (ajk) : range
ajk : evaluation coefficient
Cjk : category weight

j = 1, 2 .... : (factor)
k = 1, 2, 3 .... : (category)
Max (αjk) : maximum value of evaluation coefficient with factor j
Min (αjk) : minimum value of evaluation coefficient with factor j

d) The resulting partial correlation coefficient is regarded as a relative quantity to indicate the degree of contribution of an individual factor to the evaluation result and the partial correlation coefficient value for each factor is regarded as the factor weight.

e) Multiplication of the category weight and factor weight and integration of the multiplication results to obtain evaluation scores for all sites using equation (1).

(6) Discriminant Function Method

At sample areas, the statistical value is calculated from the evaluation ranks and scores of evaluation factors. The evaluation rank of each subject site is then obtained using the discriminant function of the minimum distance classification method or the maximum likelihood classification method.

⑦ Quantification Theory Type II Method

The quantification theory type II method is applied to the evaluation ranks of sample areas and ranking data on evaluation factors to obtain a functional formula for evaluation.

⑧ Minimum Ranking Method

The lowest of all ranks given to the evaluation factors for each site is considered the representative rank of the site. The concept of this method is shown in Fig. 2-3-2 where the final evaluation result is rank IV which is the lowest of the 3 ranks, i.e. II for factor A, I for factor B and IV for factor C.

⑨ Matrix Method

A matrix of factor a and factor b is prepared to read the value of the crossing point of different ranks. Repetition of this process achieves the final evaluation result. The concept of the matrix method is shown in Fig. 2-3-3 where the synthetic evaluation value is 2 based on the evaluation ranks of factor A and factor B of III and I respectively.

2.3.3 Preparation Method for Land Evaluation Criteria

Land evaluation criteria in the case of the statistical analysis method require the synthetic evaluation values of sample areas and the values of evaluation factors. The values of evaluation factors and norms for ranks are required for the normative analysis method. In either case, the evaluation factors must firstly be determined by means of a literature survey, expert advice and a ground truth survey.

In the case of the statistical analysis method, it is difficult to determine the synthetic evaluation values of sample areas. These can only be determined by a proper field survey by experts. With regard to the evaluation of suitable areas for agricultural development, it is possible to evaluate the real crop yield using developed farmland as sample areas.

The determination of norms for evaluation factors in the normative analysis method is also difficult. These norms should be determined based on a literature survey, expert advice, recommendations of a committee comprising knowledgeable persons to determine norms, a questionnaire survey and a field survey, etc.

Examples of these criteria adopted in Japan are listed in the technical manual for Phase I 1). The guidebook entitled " A Framework for Land Evaluation" published by the FAO should also prove useful for reference purposes.

2.3.4 Application of Remote Sensing Data to Land Evaluation

(1) Direct Application of Remote Sensing Data to Land Evaluation

A regression equation can be formulated by conducting multiple regression between the synthetic evaluation values of samples areas and remote sensing data, such as CCT data, for each band to obtain a total evaluation. In this case, the spectral characteristics must be identical to those of the evaluation subject. Here, the use of developed farmland as sample areas is impossible because of the different spectral characteristics involved. The evaluation area must have the same land use features as the sample areas.

Suitable land for development can also be determined in terms of a supervised classification class. In this case, the relationship with other classification items must be carefully examined. For example, if forest class is made and this class is adaptable to the development area, a large part of the suitable land for development is classified as forest.

As the theoretical background to relate an evaluation score to the spectral characteristics is not clearly determined, it is difficult to use remote sensing data directly for land evaluation. However, as remote sensing data are closely related to water content, vegetation and soil, the future availability of multi-bands (more than 20 bands) should provide a land evaluation method solely depending on remote sensing data.

(2) Preparation of Thematic Maps from Remote Sensing Data and Use of These Maps for Land Evaluation

Land evaluation means the synthetic evaluation of the ranks and/or scores of various factors. Thematic maps prepared from remote sensing data can be used as evaluation factors for such land evaluation.

Evaluation based only on remote sensing data is difficult and may be meaningless for practical purposes. Other geographic information, such as geographic data, must be used to supplement remote sensing data. In other words, remote sensing data should be overlaid on other data within the framework of a geographic information system.

Thematic maps which can be prepared from remote sensing data are described in 1.4 and 2.2 of this report. Thematic maps which are commonly used for land evaluation are land cover maps, vegetation maps, water basin (river system) maps and soil maps.

The elevation of topographical objects can be obtained from SPOT and sensors on board satellites to be launched in the future will make such data readily available. In view of the fact that topographical maps are available for most areas, however, it may be more practical to use a scanner or digitizer to input topographical data from these maps.

Similar examination is necessarily in the case of meteorological data where both satellite data and ground observation data are available.

Even though the preparation of thematic maps directly from remote sensing data is not anticipated, it is important to check the existing geographic information using remote sensing data. Ordinary geographic information often expresses conditions in the past and, therefor, should be updated using remote sensing data. This updating is particularly important for roads, railway tracks, water channels and land use, etc. Moreover, the boundaries on a soil map or surface geological map prepared solely on the basis of field investigation results may not be accurate and their correction using remote sensing data is very important.

2.3.5 Examples of Land Evaluation Using Remote Sensing Data

(1) Examples in Japan 14)

Table 2-3-1 shows examples of land evaluation for wide area agricultural development using remote sensing technologies conducted by Japanese teams, most of which were JICA teams. One exemption is the large project entitled "Agriculture and Village Development Plan in the Niger River Basin" which was promoted by the Ministry of Agriculture, Forestry and Fisheries to prevent desert expansion in Africa.

All the reports listed in Table 2-3-1 have their own characteristics and employ different analysis and evaluation methods and criteria in accordance with the local conditions and collected data. Here, one of the latest surveys, the Survey for Comprehensive

Agricultural Development Plan for Neighboring Areas of Yacyreta Dam in Argentina, is cited to explain the possible use of remote sensing data for land evaluation.

(2) Survey for Comprehensive Agricultural Development Plan for Neighboring Areas of Yacyreta Dam in Argentina

This survey intended the preparation of various thematic maps using remote sensing data to provide basic data for the outline determination of the subject agricultural development area and the preparation of a land use plan as part of the Comprehensive Agricultural Development Plan for Neighboring Areas of Yacyreta Dam in Argentina.

The subject area of the survey is an area of some 200km (east - west) by some 100km (north - south) to the south of the Parana River which flows in the north of Argentina along the border with Paraguay. The data mainly used were Landsat MSS data and 6 scenes representing 2 areas in 3 seasons, i.e. dry season, intermediate season and rainy season, were mainly analyzed. Landsat TM, images and aerial photographs were also used.

The survey employed the multi-stage method and basic maps (1/250,000) and thematic maps (1/50,000) were prepared to obtain evaluation maps (1/50,000). The following 5 types of basic maps were prepared.

① Land Cover Classification Maps (for dry, intermediate and rainy seasons)

A land cover classification map was prepared for each season by the maximum likelihood classification method using Landsat MSS data for the 3 seasons.

② Submerged Area Maps (for dry, intermediate and rainy seasons)

A submerged area map was prepared for each season by the level slicing method using Landsat MSS data for the 3 seasons.

③ Topographical Classification Map

A topographical classification map was prepared by means of reading existing topographical maps, interpreting Land sat false color images and conducting a field investigation.

④ Surface Geological Map

A surface geological map was prepared by means of reading the topographical classification map (3 above) and existing geological maps and conducting a field investigation.

⑤ Soil Map

Based on the topographical classification map (3 above) and the land cover classification maps (1 above), etc., the estimated soil map was firstly prepared which was then perfected by the field investigation results. Existing soil maps for some areas were also used.

Thematic maps (1/50,000) were prepared to obtain a detailed understanding of the current conditions of the subject area and also to provide basic materials for land classification. Topographical maps, Landsat data and aerial photographs were used in the preparation of the thematic maps and complemented by a field investigation. The following 7 types of thematic maps were prepared.

① Land Cover Classification Maps (for dry, intermediate and rainy seasons)

Based on the basic land cover classification maps using Landsat MSS data, a land cover classification map was prepared for each season by means of interpreting aerial photographs and Landsat TM images (1988) and by conducting a field investigation.

② Submerged Area Maps (for dry, intermediate and rainy seasons)

A submerged area map was prepared for each season based on the basic submerged area maps.

③ Topographical Classification Map

Based on the basic topographical classification map (1/250,000), a topographical classification map was prepared by means of reading topographical maps, interpreting aerial photographs and both Landsat MSS and TM images and conducting a field investigation.

④ Surface Geological Map

Based on the basic surface geological map (1/250,000), a surface geological maps was prepared by means of reading topographical maps, interpreting aerial photographs and both Landsat MSS and TM images and conducting a field investigation.

⑤ Soil Map

Based on the basic soil map (1/250,000), a soil map was prepared by means of referring to INTA (Institute Nacional de Technologia Agropecuarja) data and conducting a field investigation.

⑥ Elevation Classification Map

An elevation classification map was prepared by means of extracting contour lines at 10m intervals from topographical maps.

⑦ Slope Classification Map

A slope classification map was prepared by means of interpreting topographical maps.

Land classification, which involves land evaluation based on certain criteria with due consideration paid to various land-related conditions, is an essential part of the agricultural development planning process. In the course of conducting such land classification, it is necessary to determine the land conditions and to examine the classification criteria so that classification can be conducted by a reasonable method which takes the appropriate land conditions into consideration. While it is desirable to include not only the natural conditions but also the socioeconomic conditions in land classification for an agricultural development plan, it was decided in the present case to refer only to the natural conditions to proceed with the land classification in view of convenience. The land classification assumed 3 development aspects, i.e. paddy field development using irrigation water from the Parana River (particularly intake from the Yacyreta Dam), promotion of upland farming and promotion of afforestation. Consequently, the classification was conducted in terms of 1 land productivity, 2 operation difficulty and 3 land security. The classification results were then used to conduct 4 a land capability classification from the viewpoint of the locative conditions of natural resources. Fig. 2-3-4 shows the classification flow.

① Classification of Land Productivity

Land productivity is evaluated in terms of the surface soil conditions and topographical conditions. The suitability of soil for farming depends on the soil texture and water content, etc. As the subject area is extremely flat, the water content is believed to have a large influence on productivity. Here, the soil productivity classification is made for paddy fields, upland farming fields and afforestation areas. The topographical conditions indicating the locative potential are very important in agricultural development. The topography reflects slopes and slope categories can represent the topographical conditions. Consequently, a slope classification map was used when available forland productivity classification. Topographical classification maps were used for those areas for which a slope classification map was unavailable.

② Classification of Operation Difficulty

The classification of operation difficulty mainly deals with topographical conditions which restrict agricultural development. Since the subject area mainly consists of grassland and farmland, the amount of land improvement work, such as uprooting, remains small. As a result, slopes are a crucial factor in developing farmland. The classification of operation difficulty was conducted using both the slope classification and topographical classification results.

③ Classification of Land Security

Land security in the subject area must be considered in terms of security against submergence with floods and security against soil erosion. Land security is mainly determined by the topographical conditions. Here, data on submerged areas and soil conditions provided by Landsat data were also taken into account.

④ Land Capability Classification Based on Locative Conditions of Natural Resources

The evaluation of land capability was conducted on the basis of a thorough understanding of the classification results of 1 - 3 above, agricultural development policies in Argentina and the current land use conditions.

The actual classification was conducted from the viewpoints of a) paddy field suitability, b) upland farming field suitability, c) afforestation suitability and d) drainage improvement suitability. The results of 1 - 3 above and the land cover classification map (land use map) were used in the classification of land capability.

In the preparation of evaluation maps, the images of thematic maps (1/50,000) were created to form an image database. Various evaluation maps were produced by extracting appropriate images from this database and overlaying them.

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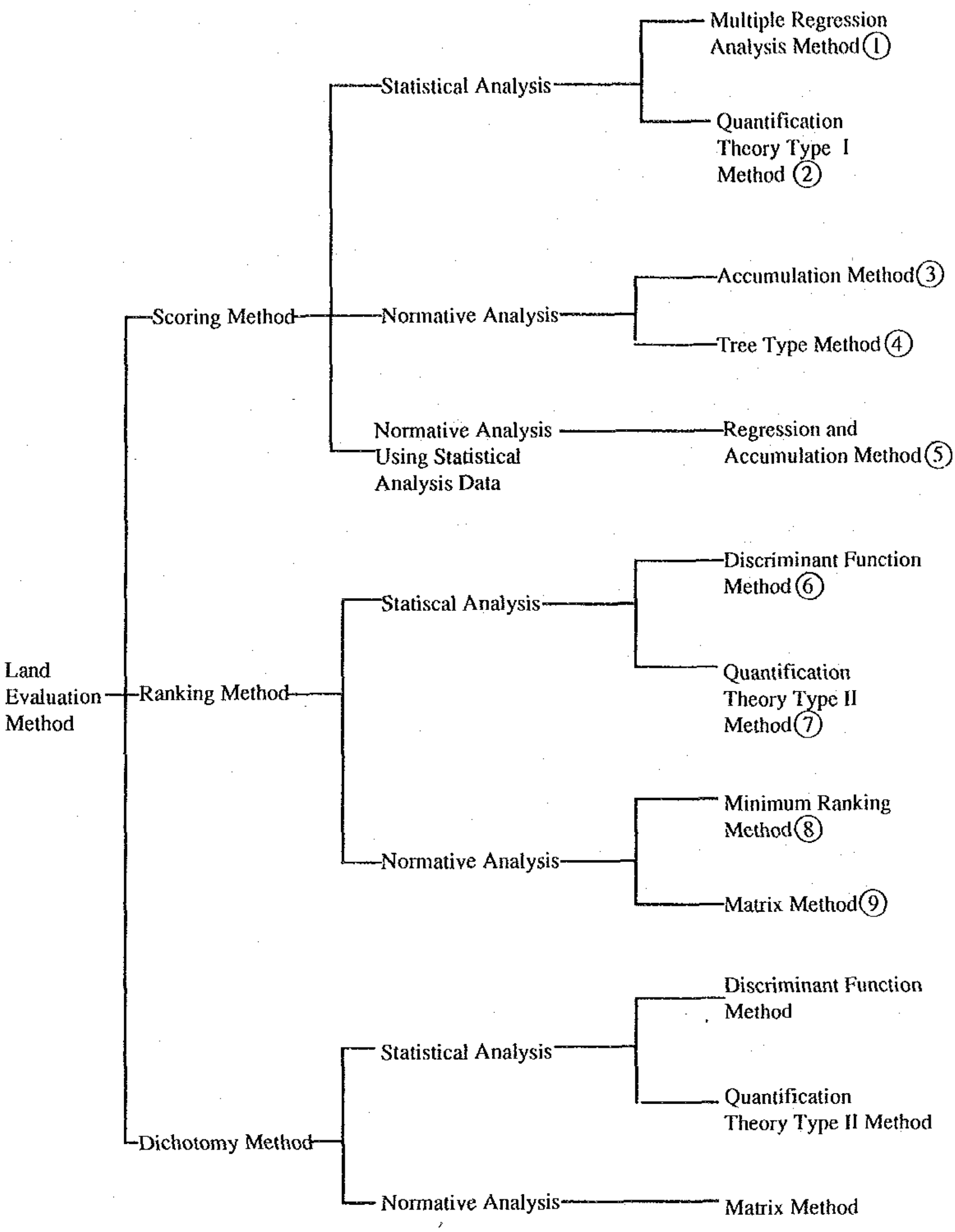

Fig.2-3-1 Tree Map of Land Evaluation Methods

	Rank			
	I	II	III	IV
Factor A		O		
Factor B	O			
Factor C				O

Synthetic Evaluation Rank: IV

Fig. 2-3-2 Concept of Minimum Ranking Method

		Factor A			
		I	II	III	IV
Factor B	I	1	1	2	2
	II	1	2	2	3
	III	2	3	3	4

Factor A: III

Factor B: I

Synthetic Evaluation Rank: 2

Fig. 2-3-3 Concept of Matrix Method

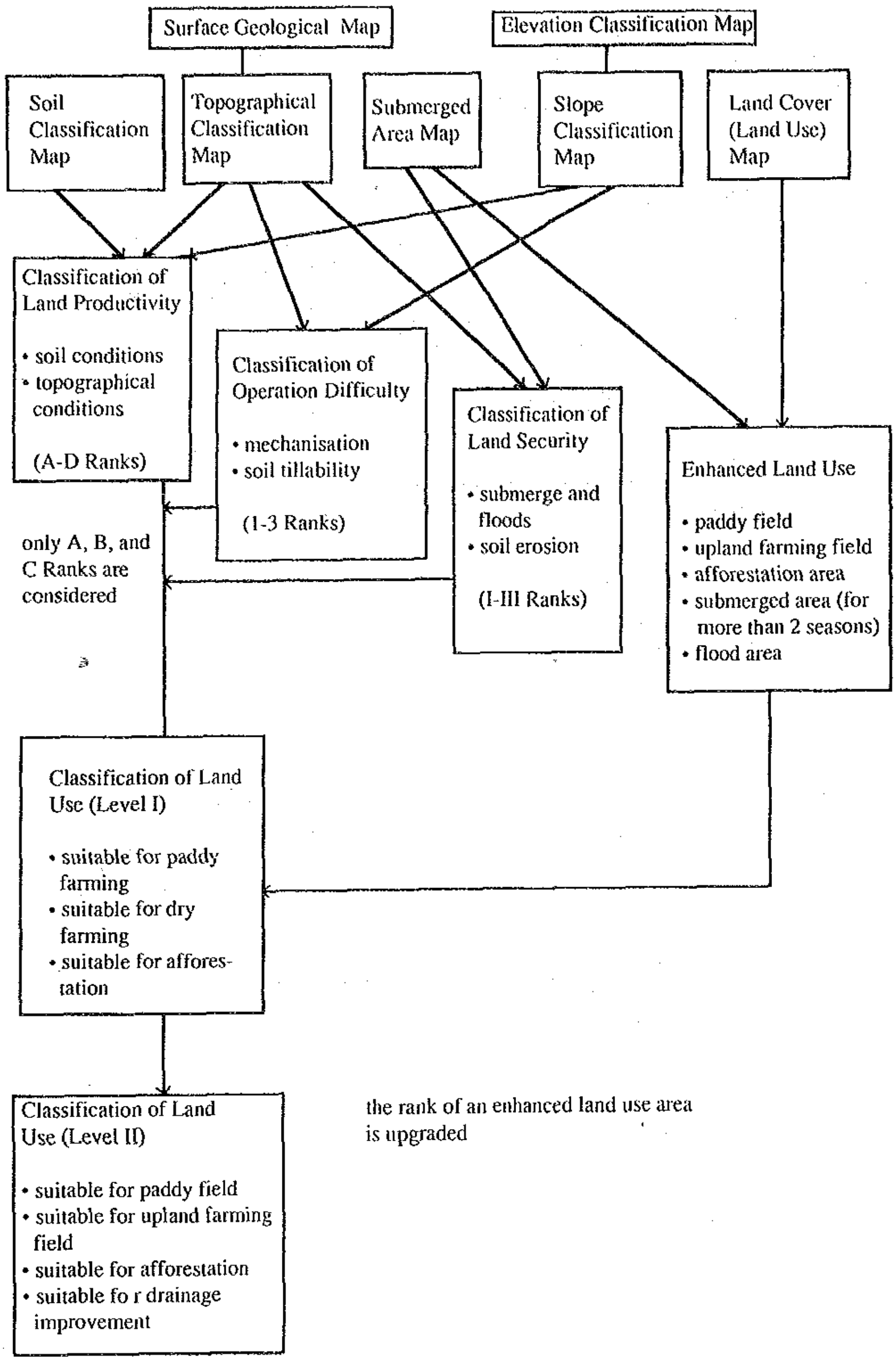

Fig. 2-3-4 Classification Flow Chart

Table 2-3-1 Examples of Land Evaluation for Wide Area Agricultural Development Using Remote Sensing Technologies by Japanese Teams (from reference no. 14 and some additions)

Survey Title	Subject Country	Survey Period	Survey Contents
Comprehensive Agricultural Development Plan in Haja Province: Master Plan	North Yemen	1979	analysis of land use and vegetation distribution
Research Cooperation Project for Brazilian Agriculture	Brazil	1980 - 1983	preparation of vegetation and land use maps and soil maps; analysis of secular changes in agricultural development and planting conditions; analysis of burnt fields and recovery of soil fertility
Second Survey for the Implementation of Agricultural Development Plan in Wajiji Basin	Oman	1981	preparation of vegetation and land use maps, topographical classification maps, basin classification maps, geological maps and soil maps
Agricultural Development Plan in the Northwest of Lake Ypoa	Paraguay	1981 - 1982	interpretation of land use conditions
Agricultural Irrigation Plan Implementation Survey in Nkoma Valley	Tanzania	1982	interpretation of water system and boundaries based on synthetic color maps
Comprehensive Agricultural Development Plan for Neighboring Areas of Yacyreta Dam	Paraguay	1982 - 1984	land cover classification; analysis of changing conditions of submerged areas
Hydrological Observation Survey in Batinah Coast Area	Oman	1982 - 1985	land cover classification; analysis of seasonal changes of vegetation; rainfall distribution forecast based on cloud brightness and labled of earth surface; preparation of geological maps
Survey for Water Resources Development Basic Plan in North Banten	Indonesia	1983	preparation of land cover classification maps, biomass classification maps, water content in soil maps, geological maps, water system maps, topographical classification maps, seasonal changes maps of vegetation and land use and flood risk evaluation maps
Medium Size Irrigation Package Project Implementation Survey in Southern Part of Northeastern Thailand	Thailand	1983	preparation of land use maps and current water utilization maps
Agricultural Development Plan Implementation Survey in North Hosailiya and South Port Said	Egypt	1983	preparation of field survey plan for surveying and plan design by interpreting lake district conditionings
Sanjiang Plain Agricultural Development Plan Survey	China	1983	interpretation of land use conditions, topographical and geological conditions and flood/drainage conditions
Analysis of Crop Growth in Sanjiang Plain	China	1983	examination of wheat yield forecast
Asahan Downstream Agricultural Development Master Plan	Indonesia	1984	preparation of land cover classification maps, soil maps and plant biomass maps
Analysis of Landsat Data on Kosi River	Nepal	1984	analysis of soil moisture (soil water content distribution)
Crop Production Increase Plan Survey in Itapua Province	Paraguay	1985 - 1986	preparation of land cover classification maps; land classification analysis
Comprehensive Development Plan Survey for Surrounding Areas of Lake Victoria	Kenya	1985 - 1986	analysis of seasonal changes of vegetation and land use
Comprehensive Agricultural Development Plan Survey in Niger River Basin	9 West African Countries	1985 - 1989	preparation of geographic information maps; preparation of site selection maps with suitable agricultural development areas based on land classification analysis results
Agricultural Development Study Plan for Northeastern Thailand	Thailand	1986	land classification (soil moisture, salt accumulation) analysis
Medium Size Irrigation Plan Implementation Survey in Masvingo Province	Zimbabwe	1986	selection of dam sites for agricultural irrigation
Comprehensive Agricultural Development Plan Implementation Study in Quindio Basin in Colombia	Colombia	1987	preparation of various thematic maps; preparation of land and land use maps from the viewpoint of development suitability
Survey for Comprehensive Agricultural Development Plan for Neighboring Areas of Yacyreta Dan in Argentina	Argentina	1988	preparation of various thematic maps and land use potential classification maps

2.4 Creation of Hyper Multimedia System for Collection and Utilization of Agricultural Development Data

Takashi Hoshi

The present Agricultural Development Project Phase II anticipates the collection and utilization of the necessary data for the implementation of the Project. The establishment of a database is essential to manage such bulk data as remote sensing data and map data. The basic concept of such a database is discussed in this chapter and the criteria for thematic maps are explained. As additional guidelines for the data supply method are necessary in view of the effective use of these data, the types of data, data extraction and relationship between a computer system and a database are also briefly explained.

With regard to the database system, the target is to create a hyper multimedia system which incorporates both an intelligent retrieval system and a logging function. The logging function in particular appears to be an effective processing function to be taught to the local technicians during the training sessions.

2.4.1 Basic Concept of Database for Agricultural Development

The following 2 types of work are necessary for the creation of the database required for the implementation of Phase II in 5 years and to be installed at the Data Processing and Statistics Center of the Ministry of Public Works (hereinafter referred to as the PU Center).

1) establishment of criteria to develop thematic maps on Indonesia
2) information exchange better the PU Center and regional centers

2.4.2 Establishment of Criteria to Develop Thematic Maps

For the preparation of the thematic maps in question, classified maps prepared based on extracted image data from a multispectral scanner on aboard a satellite and other data are used as original maps. Either unsupervised classification or supervised classification is used for pattern recognition for the preparation of classified maps. Thematic maps are prepared by combining these classified maps with topographical maps, mesh charts and statistical data, etc. For details, refer to the source data groups used for the pattern and ranking methods in Phase I.

The basic scale for thematic maps is 1/50,000. Maps with a scale of 1/100,000 and 1/250,000, etc. are prepared using the thinned-out method or the smoothing method. Therefore, it is necessary here to decide the rules for the preparation of thematic maps with a scale of 1/50,000.

Firstly, the across-the-country latitude and longitude are assumed as standard coordinates and are related to the more practical distance coordinate system (X,Y) and computing coordinate system (I,J). Secondly, Indonesia is divided into 5 regions representing all the main islands. A regional center is located in each region for database operation and local offices are introduced under these regional centers where deemed necessary. Fig. 2-4-1 shows the organization for data supply while the abbreviation of each region is indicated on Fig. 2-4-2. The abbreviations of these 5 regions and the main islands in each region are as follows.

(1) JAVA : Java, Mudara, Bali, Lombok, Sumabawa, Sumba, Flores, Timor and Welar
(2) SUMA : Sumatera, Bangka and Billiton
(3) KALI : Kalimantan and Lant
(4) SULA : Sulawesi, Buru, Seram and Halahera
(5) IRJA : Irian Jaya and Tanimbar

The UP Center acts as the central organization of the data collection network. Each regional center is responsible for data collection is assigned area and its location is expressed in terms of the first order mesh and second order mesh.

- First Order Meshes

The entire land of Indonesia is divided into meshes of 1° (latitude) x 1° (longitude) meshes (approximately 111 x 111.3km). These meshes are called first order meshes. The first order mesh map consists of approximately 18 x 48 unit meshes covering all of Indonesia. The location of a first order mesh is given by a 2 digit latitude code and a 2 digit longitude code, employing decimal notation.

Example: 14 11

- 11 → $J_1 = 11$: longitude code
- 14 → $J_1 = 14$: latitude code

- Second Order Meshes

Second order meshes further divide the unit first order meshes. Each unit first order mesh is divided by 10' for latitude and 15' for longitude, creating 6 units along the latitude direction and 4 units along the longitude direction. The second order mesh codes are expressed by 2 digits, one each for latitude and longitude. As the second order mesh codes are further details of the first order mesh codes, they are shown together with the first order mesh codes. For example, (1411 - 32) means $I_1 + 14$, $J_1 = 11$, $I_2 = 3$ and $J_2 = 2$. Using these mesh codes, an area is determined by the latitudes and longitudes corresponding to the codes.

a) Topographic Map Data

A topographic map contains diverse data. The following items are particularly important for an agricultural development project, taking the map data in a geographic information system into consideration.

(1) elevation, slope inclination, slope direction
(2) administrative boundaries
(3) rivers, lakes, ponds and coastlines
(4) roads and railways
(5) notable buildings (structures) and vegetation
(6) land names, etc.

Items (1) and (2) above are considered as the subjects of data extraction Phase II. The elevation can be extracted from the contour lines on a topographic map while the slope inclination can be calculated from the mesh elevation figures using a specially designed formula. With regard to items (3) and (4), a topographic map is set to a digitizer to extract the selected areas for analysis using their coordinates. The continuity of a line is guaranteed by the chain structure. The structures of point, line and spatial data are separately defined. The extraction unit of data is a square shape of 50m by 50m (called a unit cell). The existing old maps of Indonesia were made using Dutch technology and are based on square units. It must be noted that the mesh standards of the existing maps are different than those proposed for Phase II.

b) Existing Mesh Data

The existing mesh data should firstly be checked to determine whether or not they can be used for the present purposes. Data should then be extracted in the form of the minimum unit cell (50m x 50m). If the mesh size of the existing data is not identical to the above unit cell size, it should be changed to fit the unit cell size using a predetermined equation.

It is advisable to obtain the assistance of the LEMIGAS (oil and Gas Development Technology Center of the Ministry of Industry and Energy) to deal with geological data. The following data can constitute existing data.

(1) geological data
(2) effective soil thickness data
(3) soil data
(4) water system data
(5) vegetation data
(6) atmospheric data (rainfall distribution, sunshine hours and temperature, etc.)

c) Thematic Map Data

Thematic maps are mainly those which can be prepared on the basis of remote sensing image data. The following thematic maps were used in Phase I (Fig. 2-4-6).

(1) land cover map
(2) biomass classification chart
(3) soul color patterns
(4) assessment map
(5) soil moisture chart

Those thematic maps subject to the pattern method and the ranking method are dealt with in Phase II and are items (1) - (4) of b) above and items (1) - (5) of c) above. The anticipated database should, therefore, contain all or at least partial data on these items.

d) Agricultural Development Plan Data

The following plan maps and assessment maps will be created using data relating to the agricultural development plan.

(1) environmental thematic maps
(2) environmental assessment maps
(3) physical plan maps
(4) socioeconomic plan maps
(5) sector plan maps

e) Sector Plan Data

The sector plan maps mentioned in d) above should include the following.

(1) mining facilities and improvement plan maps
(2) agricultural facilities and improvement plan maps
(3) forestry facilities and improvement plan maps
(4) fisheries facilities and improvement plan maps
(5) industrial facilities and improvement plan maps
(6) commerce facilities and improvement plan maps
(7) settlement facilities and improvement plan maps
(8) recreation facilities and improvement plan maps
(9) disaster prevention facilities and improvement plan maps
(10) public facilities and improvement plan maps
(11) roads and transportation facilities and improvement plan maps
(12) water utilization facilities and improvement plan maps
(13) supply and treatment facilities and improvement plans maps

As the provision of all the maps referred to in d) and e) above for all of Indonesia is practically impossible in view of the volume, these maps will simply be prepared for a model area.

2.4.3 Data Exchange Between PU Center and Regional Centers

a) Provision of Data by PU Center to Regional Center

The PU Center will provide 2 types of data to the regional centers. The first type is satellite remote sensing data (Landsat MSS, SPOT XS and MOS-1 MESSR) stored in a separate floppy disk for each cell unit. The data mode will be either BSQ or BIL and the format will be separately decided. The second type is a module for the software to be used for the analysis of agricultural development. The language will be FORTRAN and the size will not be too large to prohibit the use of the software by a personal computer (to be operated by a CPU memory of approximately 1MB). The PU Center will provide each regional center with 1 personal computer set.

b) Provision of Data by Regional Centers to PU Center

The centralized generation of data at the PU Center which can be collected by the regional centers could lead to data inaccuracies. Therefore, the principle of regional data, including field survey data, being locally collected and extracted should be adopted. Based on this principle, the regional centers should collect the following 3 types of data in accordance with the first and second order mesh standards and supply the collected data to the PU Center.

(1) data extractable from topographic maps - to reduce the amount of digitizer imput as much as possible by the introduction of an automated process.

(2) data required for agricultural development planning to include all items listed in 2.4.2 d)

(3) information required for rural agricultural land use planning - to include all items listed in 2.4.2 e)

The concrete items of data to be collected under categories (2) and (3) above will be determined by agricultural experts. The data to be collected under category (1) above will be data on elevation, administrative boundaries, rivers, lakes, ponds coastlines, roads and railways as described in 2.4.1. Elevation data will be prepared by tracing the contour lines on the existing topographic maps to create uninterrupted contour lines and will then be read by the CCD scanner at the PU Center. Digitizer input may be employed if this tracing work is found technically difficult at a regional center.

All the advice data, except those on elevation, are line data which will be extracted as point coordinates by the digitizer at irregular intervals with a departure length (e) within ±1mm. These data will be stored by the hard disk (40 - 200MB) of the personal computer during actual processing. Following correction of the extracted data, they will be copied on a floppy disk (either 5.25 or 3.5 inches) which will then be posted to the PU Center. The key points of this data extraction process are the method of inspecting the extracted data and the manpower quality.

2.4.4 Data Selection and Extraction Criteria

a) Remote Sensing Image Data

The readily available remote sensing image data are SPOT panchromatic data (resolution: 10m), SPOT multispectral data (resolution: 20m), Landsat TM data (resolution: 30m), MOS-1 MESSR data (resolution: 50m), and Landsat MSS data (resolution: 80m). Assuming that the scale for the thematic maps is 1/50,000, the MOS-1 MESSR data provided by the Japanese satellite are the best in terms of resolution and economy. The problem with the MOS-1 is that the receivable area does not cover all of Indonesia.

Landsat MSS data were used for Java and Sumatera etc. (approximately 200 scenes) in Phase I. The continuous use of these data for the thematic maps will result in the optimal scale of 1/250,000. Since Landsat TM image data are the only data to include the thermal infrared band, they are particularly useful for geographic and mining exploitation purposes. However, the high cost will drastically reduce the number of scenes unless the project budget is substantially increased. Therefore, it is a difficult task to select one of these 3 types of data. Here, priority is tentatively given to Landsat MSS data. New data provided by the COSMOS satellites of the USSR (resolution: 5m) and IRS -1A/LISS-II of India (resolution: 36.25m) will need to be separately purchased from the governments involved.

The second priority source of remote sensing image data is Landsat TM data which have 7 bands with fine resolution and the wider scene measurements of which are more economical than those of SPOT XS data and MOS-1 MESSR data.

The third priority source is SPOT XS data, the resolution of which is better than that of MOS-1 MESSRs data and Landsat TM data. SPOT XS data have a fewer number of bands. however, and the subject area of each scene is smaller than in the case of MOS-1 and Landsat data.

There are some additional data, including SPOT P band data which have a high resolution of 10m. Since SPOT P band data are single band data, however their application is limited to specific purposes, such as the extraction of elevation values.

In short, Landsat MSS and TM data are the most appropriate data to create an image database while MOS-1 and SPOT data can be used for the preparation of thematic maps on certain areas.

b) Extraction and Interpolation of Mesh Data

Mesh data can be extracted by selecting the values at the mesh centers or crossing points. If the mesh measurements of the original data differ, they are uninformatized by such interpolation methods as the shortest route method, bilinear method and cubic convolution method.

c) Line Data Structure

Line data are formed by combining point data. Apart from point coordinate data (X, Y), data on diverging points, crossing points, end points and continuous points are used to express line data. Moreover, the names of the polygons on both sides of a point are added to determine the relation between points, lines and planes.

d) The automatic extraction process for line data from a topographic map is described below.

(1) Tracing of contour lines on a topographic map.
(2) Reading of traced contour lines by a CCD scanner at a resolution of 16 lines/mm.
(3) Use of data compression technology to deal with the massive volume of data.
(4) Skeleton extraction of reproduced compressed data using image processing technology.
(5) Conversion of center lines to vector data to obtain point data.
(6) Preparation of elevation data based on center lines.
(7) Data modification using editing function.

e) Data Handling by Digitizer

The menu for the tablet used to extract data by a digitizer must be designed with the assistance of experts as such design work requires a great amount of both technical and empirical know-how.

2.4.5 Computer System Structure

At present (1990), the computer system introduced in Phase I is in operation at the PU Center and this system appears suitable for analysis who covering several local areas. However, as it is necessary to create and agricultural development database in view of its application of all of Indonesia in Phase II, the CPU and auxiliary storage unit of the current system must be renewed. The smooth exchange of data between the PU Center and the regional centers must be ensured and, therefore, a system which is capable of converting data from the host computer level to the EWS level and further to the terminal personal computer level is required. Moreover, in view of the vast volume of data to be utilized in the agricultural development project, a flexible database management system (DBMS) must be introduced to properly sort the data. Based on these requirements, the introduction of a computer system equipped with the hardware units listed in a) below is proposed for Phase II.

With regard to the use of a network system, its application should be delayed until the PU Center has established a LAN network within its building as the present capacity of the telecommunication lines at the PU Center is not sufficient to run a network. It is also recommended that an additional 10 or so terminal units be introduced at the PU Center to maximize the use of the remote sensing data stored by the Center.

a) Hardware List

(1)	CPU Memory Unit	16MByte
(2)	DISK Memory Unit	10GByte
(3)	Magnetic Tape Units	2 (tape density: 6250/1600 BPI)
(4)	Line Printer	1 (10MByte)
(5)	Frame Memory Units	2 (FDP: 5.25", 3.5")
(6)	EWS (4 - 16MB)	5
(7)	Color Graphics Units	2
(8)	Page Printer	1
(9)	Color Hard Copier	1
(10)	Electrostatic Color Plotter	1
(11)	Digitizer	1
(12)	Personal Computer	1
(13)	Terminal Units	10
(14)	Console Unit	1
(15)	Telecommunications Control Unit	1
(16)	Photo Printer	1 (usable on off-line)

b) Distributed Computer System

A centralized processing system using the IBM 4341 host computer (HOST 2-OLD) was introduced in Phase I. For Phase II, the introduction of the distributed processing method using and Ethernet LAN is proposed to enable the processing of remote sensing data for agricultural development purposes.

A LAN system is composed of a LAN, a host computer and a user. There are 3 types of LAN services as shown in Fig. 2-4-5, i.e. host - terminal type, host - host type and processor - server type. The distributed processing system proposed here is the processor - server type.

The system to be established in the 5 year Phase II period should satisfy the following conditions.

i) The host computer for Phase II should be connectable to the host computer PUSDATA of the Ministry of Public works through a LAN.

ii) The host computer of Phase I (PUSDA HOST 2-OLD) should be temporarily used as the host computer for Phase II.

iii) The host computer of Phase I should be detached from the system only when there is a good prospect of the function and data accumulated in Phase I being effectively used in phase II.

iv) The distributed processing in Phase II should be capable of providing the following functions.

a. total system management function
b. local network function
c. intelligent image analysis system development function
d. image and spatial data input/output function
e. image, spatial and character data connection function
f. character data input/output function
g. intelligent retrieval function
h. data conversion function for regional use

An Ethernet LAN system equipped with the above functions is illustrated in Fig. 2-4-7 and Fig. 2-4-8 and the system characteristics are summarized below.

1) Fig. 2-4-8 shows the entire functions of the image database system. A DBMS constitutes part of this system and handles user requests for data retrieval. As a DBMS cannot be installed for the host computer of Phase I due to the inadequate CPU memory capacity, a host computer for Phase II should be installed in the mid-1990's. Differences between the Phase I computer system and the Phase II computer system are shown in Fig. 2-4-9. As the image database requires a large storage capacity, a hard disk capacity of 10GB will be provided.

2) The structure of the spatial database will be based on the concept of topology design. Although the existing routine (programme) can be used, the source list of the programme must be submitted. In the case of this being impossible, a software which can explain the point, line and polygon files of the spatial data to the counterparts at the PU Center must be added to provide the system with a training function. An editing function to process point data and raster data provided by a CCD scanner must also be provided. This function must not be too complicated to deter the understanding of the counterparts at the PU Center as well as at regional centers.

3) With regard to an image analysis system, the image processing system necessary for agricultural development purposes will be developed by combining image and spatial data. The system will incorporate a CPU with a processing capability of 2

- 10 MIPS with the help of EWSs. The image memory capacity will be some 8MB so that all bands of the Landsat TM images can be simultaneously processed.

A spatial data processing software and image data processing software will be used. The former must have an excellent design to facilitate its easy use by long-term experts and the counterparts.

4) While the intelligent image analysis system is being developed, users cannot use the system to avoid the disappointing or even disruptive results of using an inadequate system. Consequently, 2 image analysis system must be provided, i.e. one for users and one for system development. The system contents of these 2 systems can be similar. The important point to remember is that the subject of the image analysis system for users is data under the control of a DBMS.

5) The conceivable output modes are electrostatic color plotter output, image output, photo output and character output. An electrostatic color plotter (A0 size output), color image plotter (A3 size output), drum printer and laser beam printer (A4 size output) will be required. An inexpensive EWS or personal computer will be used to control these devices.

6) 6 sets of EWS or personal computer systems will be distributed to the regional centers and one of them will serve for a LAN to conduct practical tests to rectify any shortcomings of the system. Output programmes and data files may be stored on floppy disks and copies will be posted to the regional centers.

Although the A3 size output is not widely used throughout the world, its selection for color image output is based on the facts that the A4 size is too small to be useful and the Al size is too expensive to run. A unit which is capable of providing color A0 size output is desirable if the budget allows this.

The structure of the new system us outlined next.

c) Subsystem for Regional Centers

Figs. 2-4-10 (a) and (b) show the structure of the personal computer system for the regional centers which includes the following softwares available in the market.

(1) operating system: MS-DOS or OS/2
(2) image processing software

(3) programme to extract data from digitizer
(4) GIS-related programme
(5) basic arithmetic library
(6) basic statistics programme
(7) grid data display software
(8) multi-window
(9) word processing programmes for English and Japanese

d) Memory Capacity to Run Database

The required disk storage volume can be estimated based on the following.

(1)	system area	:	S1 = 0.6GB
(2)	agricultural development plan related data area	:	S2 = 0.8GB
(3)	rural land use plan - related data area	:	S2 = 0.8 GB
(4)	image data area	:	S2 = 1.6 GB
(5)	vector data area	:	S3 = 1.4GB
(6)	existing (mesh) data area	:	S4 = 1.6 GB
(7)	module area	:	S5 = 0.4GB
(8)	study area	:	S6 = 1.2GB
	total disk area	:	$S = (S_1+S_2+S_3+S_4+S_5+S_6) \times 1.2$
			= 10.1 GByte

2.4.6 Establishment of Hyper Multimedia System

A data system for use for agricultural development purposes in association with a rural development plan and a rural land use plan will be increasingly required to be both swift and flexible in its application in the 1990's. Such a system will be required to swiftly and accurately provide the data necessary for decision making in the agricultural development process and also to convey the actual decisions taken to all of Indonesia through a communications network. The relational database to be developed must be capable of quickly developing an agricultural development data system which is versatile enough to absorb environmental changes. The provision of such a database will reduce manpower as well as software development expenses. It will also reduce the end user training cost at the regional centers. In view of these advantages, it should prove extremely useful to develop a hyper multimedia system for the Phase II agricultural development of the Project.

A hyper multimedia system means a system which is capable of making such multi media as remote sensing image data, spatial (map) data and statistical data into separate databases and providing a file transfer function between these databases. The Ethernet LAN system can be used for such file transfer. This system incorporates functions to store intelligent data for each meduim, to retrieve these intelligent data (retrieval of training data and location of clouds on an image, etc.) and to reproduce analysis results (to reproduce the results of data processing conducted by an expert).

a) Trends of Geographic Information System (GIS)

In the U.S., the software developed by the Computer Graphics and Spatial Analysis Laboratory of Harvard University is the basis of the GIS. Harvard developed various programmes in the 1970's, including the POLYVRT, CALFORM, SYMVU, DOTMAP, ASPEX, SYMAP and GRID, some of which have been used by U.S. government agencies for national census database and spatial display purposes. The DIME file is one example of such application programmes. The POLYURT was a data structure conversion programme, the idea of which was inherited by and improved in the later ODYSSEY programme package. Nissho Electronics is the agent in Japan for ODYSSEY and has made it possible to run the ODYSSEY on the OS-F4 developed in Japan. A software called ARC/INFO was also developed in the U.S. by HENCO which combines an ARC module to manage spatial data files and an INFO module to manage attribute data files. In more recent years, PASCO has combined this spatial data processing system, ARC/INFO, with the image processing system ERDAS.

b) Features of Developed Databases

Even after the introduction of an image data system and a GIS, it is still necessary to develop a database for agricultural development purposes under the management of a relational database (for example, Structured Query Language) on the host computer side. For such development, the contents and factors of thematic maps for agricultural development must be clarified. In view of these requirements, it is necessary for the database in question to have the following features.

(1) a database system and DBMS suitable for agricultural development
(2) an intelligent retrieval system emphasizing quick response and flexibility and retrieval capability using TSS terminals
(3) ease of editing and renewing data
(4) connectability of line data, image data and thematic map data
(5) a graphics display, editing and retrieval function

As this database will have a large volume of data, the management of the DBMS and databank will be conducted by the basic system of the host computer. The host computer stipulates the extent of data availability for open access and manages the retrieval system.

2 sets of EWSs (engineering work stations) will be provided, i.e. one for image database development and one for actual use of the database.

In the course of the database development stage, many of the systems are imperfect and are not given open access. These will be available once the system has stabilized. The EWSs will have an image processing function, spatial data processing function and an editing function.

The input/output of the maps required for agricultural development purposes will, in principle, be made on the on-line distributed processing system in order to reduce dependence on the host computer.

The regional personal computer systems will only conduct the collection of regional data and simple editing. Their main objective is the retrieval of necessary data from the data file software supplied by the PU Center.

The data to be handled will be remote sensing image data and both elevation and administrative boundary data indicated on topographic maps. The data format will be the BSQ format for image data and the 1km interval mesh format for elevation data. Administrative boundary data will be created by combining real data and extracted data and will be given a tolerance of ±0.5mm on a scale of 1/50,000.

c) Intelligent Retrieval System

In the actual utilization of an image database, it is firstly necessary of establish an intelligent retrieval system on the SQL/DS data system. The subjects of retrieval are divided into remote sensing image data, map data, geographical data, agricultural development data and others. The guidelines for remote sensing image data are described below.

(1) The retrieval items of the remote sensing image data will include the path number, row number, date of data extraction, approximate cloud coverage (%), radiometric and geometric correction levels, data format, data previously read/written, owner, degree of data accessibility, mission particulars (name of satellite and serial

number) and data sources. The retrieval items of the map data will include the first order mesh number, second order mesh number, type of information (road, administrative boundary or other), scale, date of data extraction and information on the map from which the data is extracted, etc.

(2) Data for retrieval will be arranged under the same format for each image or map. The order of retrieval will be predetermined while the maximum digits for characters or numerals expressing any item will be designated. In a conceptual model, the retrieval system must have a hierarchical structure such as that shown in Fig. 2-4-11 and should be developed on a relational database.

Table 2-4-1 shows the restricted items to be handled by the hierarchical structure to be developed in Phase II. What is important here is that the relationship between Ai (i = 1~n) cannot be obtained by such a hierarchical structure and a retrieval item to relate these two Ai (i = 1~n) must be introduced. This item can be expressed as a position. A retrieval item C is designed for development and editing purposes. The use of a marketed package cannot create an intelligent database and the functions of the package decide the nature of retrieval item C which also depends on the particulars of image processing. For example, the subject data for retrieval can include total band data, band data in processing, ground control point, test area data, training area data, unsupervised image data, supervised image data, normalized data and noise stripping data.

In the case of spatial data processing, the editing function of point, line and polygon data is included in retrieval item C.

A concrete example of intelligent database application is the retrieval of patterns in images. For the database to be established in Phase II, the inclusion of a system which can retrieve cloud locations in satellite images is proposed.

d) Logging Processing

The subject data of the hyper multimedia system in Phase II will be satellite image data, map (spatial) data, character data and statistical data and a series of processing operations will, in most cases, be required for the interactive retrieval and utilization of these multiple data. A logging processing function can be created based on the sampling of these processing cases to make intelligent image data processing and intelligent spatial data processing possible. This development of a logging processing function is an important objective in Phase II and should be conducted by a manufacturer or long-term experts.

The assistance of short-term experts will also be required to develop an intelligent image data processing procedure.

e) Processing Function of Hyper Multimedia System

The entire processing environment of the hyper multimedia system is compiled in Table 2-4-2 taking the contents of 2.1 - 2.3 into consideration.

In the application process of remote sensing image data to agricultural development, color composite images will be created as the first step, followed by the creation of geometrically corrected images as the second step, thematic images as the third step and assessment maps as the fourth and final step. The use of multimedia data is essential at the second step onwards as in the case of the Remote Sensing Project Phase I in Indonesia and the Comprehensive Agricultural Development Plan in Paraguay referred to in 2.3. The establishment of this hyper multimedia system on the basis of experience accumulated in the application of agricultural development system appears important instead of relying solely on the work of computer system experts. Such experience should also prove useful in other application fields.

2.4.7 Conclusion

This chapter describes the basic concept of a hyper multimedia database, the early establishment of which is essential for the completion of Phase II in 5 years. The hyper multimedia database proposed here differs from an ordinary data file system in that in contains image data. As a result, the basic step is the design of an image database. It is also planned that the database in question will deal with map data and statistical data. A database which handles such multiple data cannot be created even in Japan without the skillfull application of the latest technologies and , therefore, it is a pleasure to see the prospect of a hyper multimedia database being designed in Indonesia which has a close relationship with Japan. It is hoped that the database will be established in due course for practical application.

(References)

1) JICA: Minutes of Discussions on Remote Sensing Engineering Project Phase II *for the Development of Agricultural Infrastructure in the Republic of Indonesia*, 1988

2) Hoshi, T.: Database System for Remote Sensing for Agricultural Developing (Rep.1), Report of JICA Short-Term Experts, March, 1989

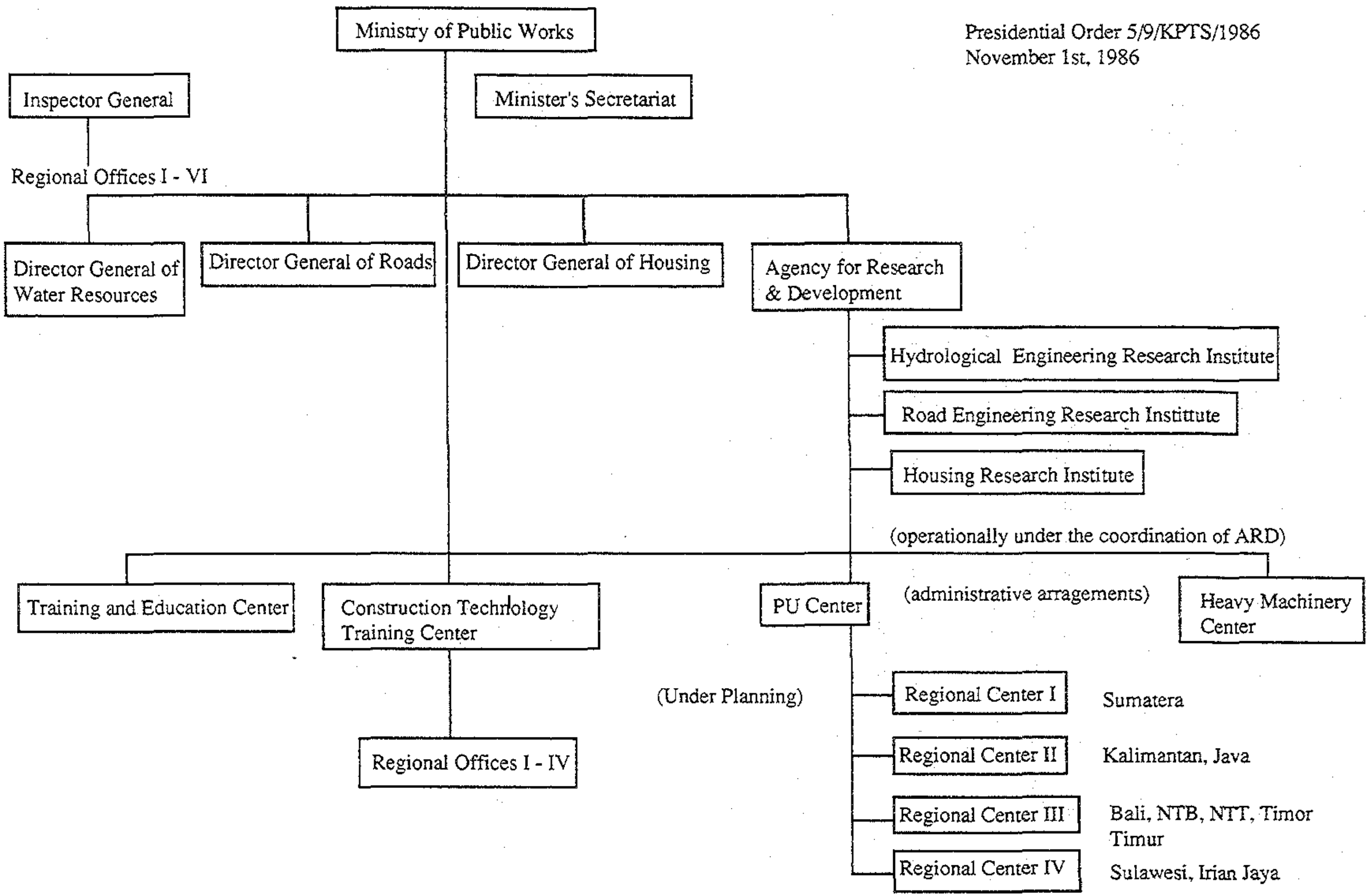

Fig. 2-4-1 (a) Organizational Status of PU Center

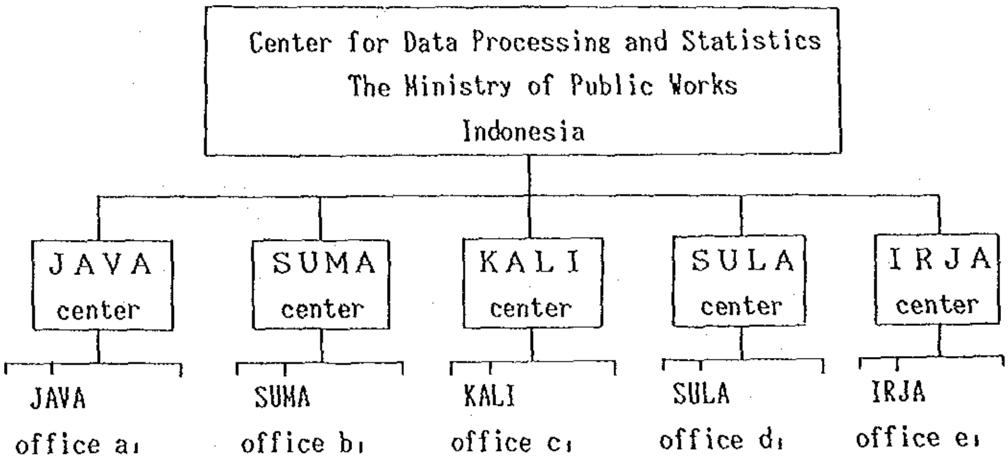

Fig. 2-4-1 (b) Data Supply Organization for Database Establishment

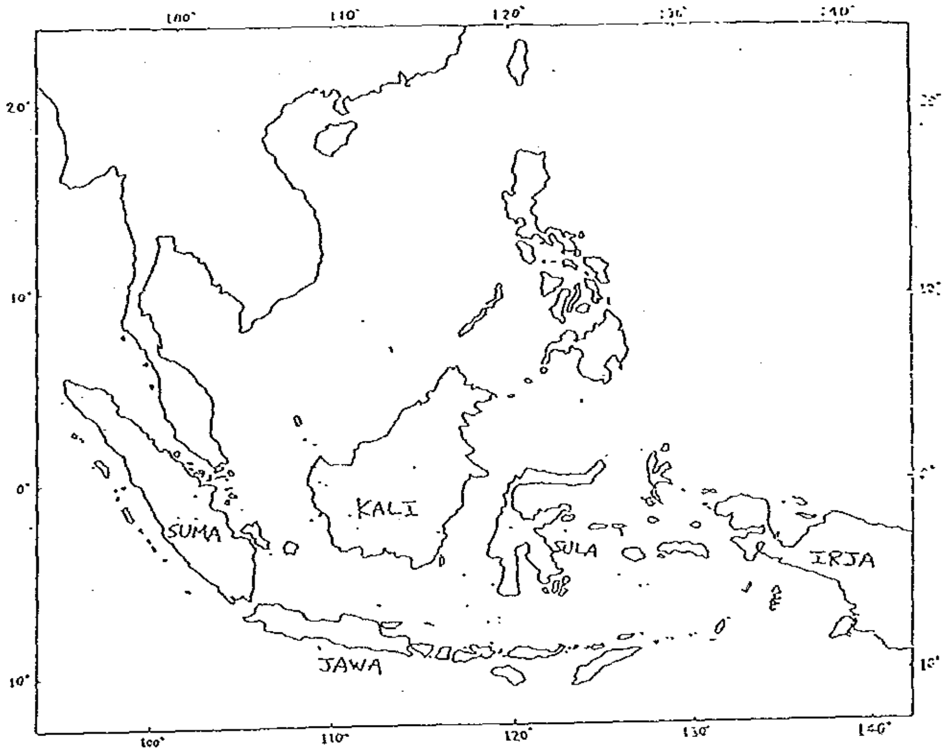

Fig. 2.4.2 Regions in Indonesia

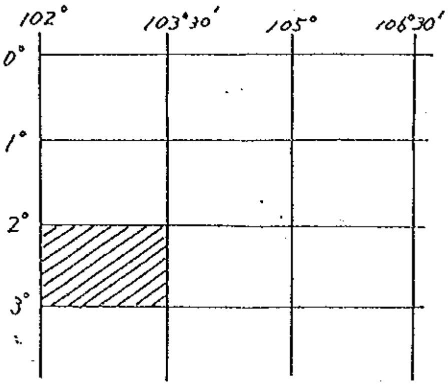

Fig. 2-4-3 First Order Mesh Standards

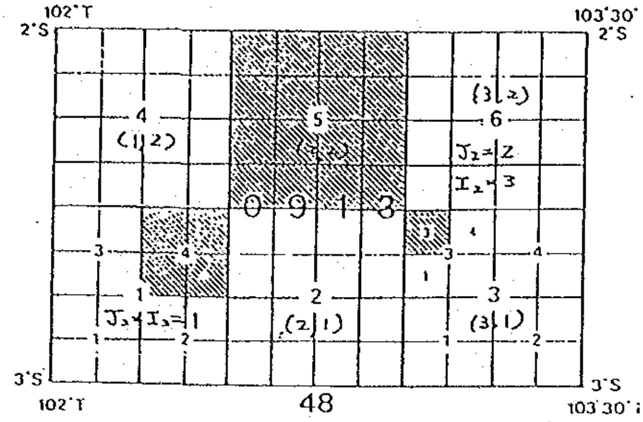

Fig. 2-4-4 Second Order Mesh Standards

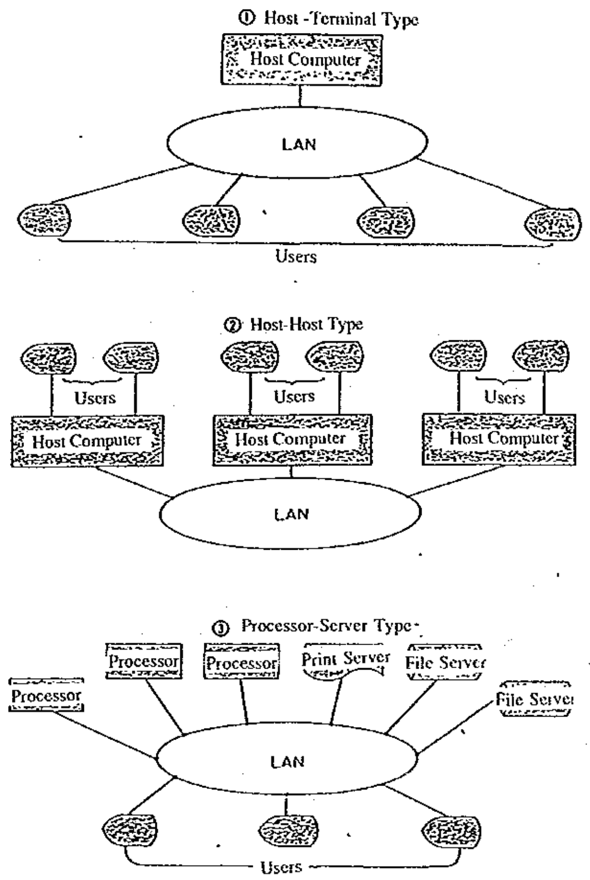

Fig. 2-4-5 LAN Service Types

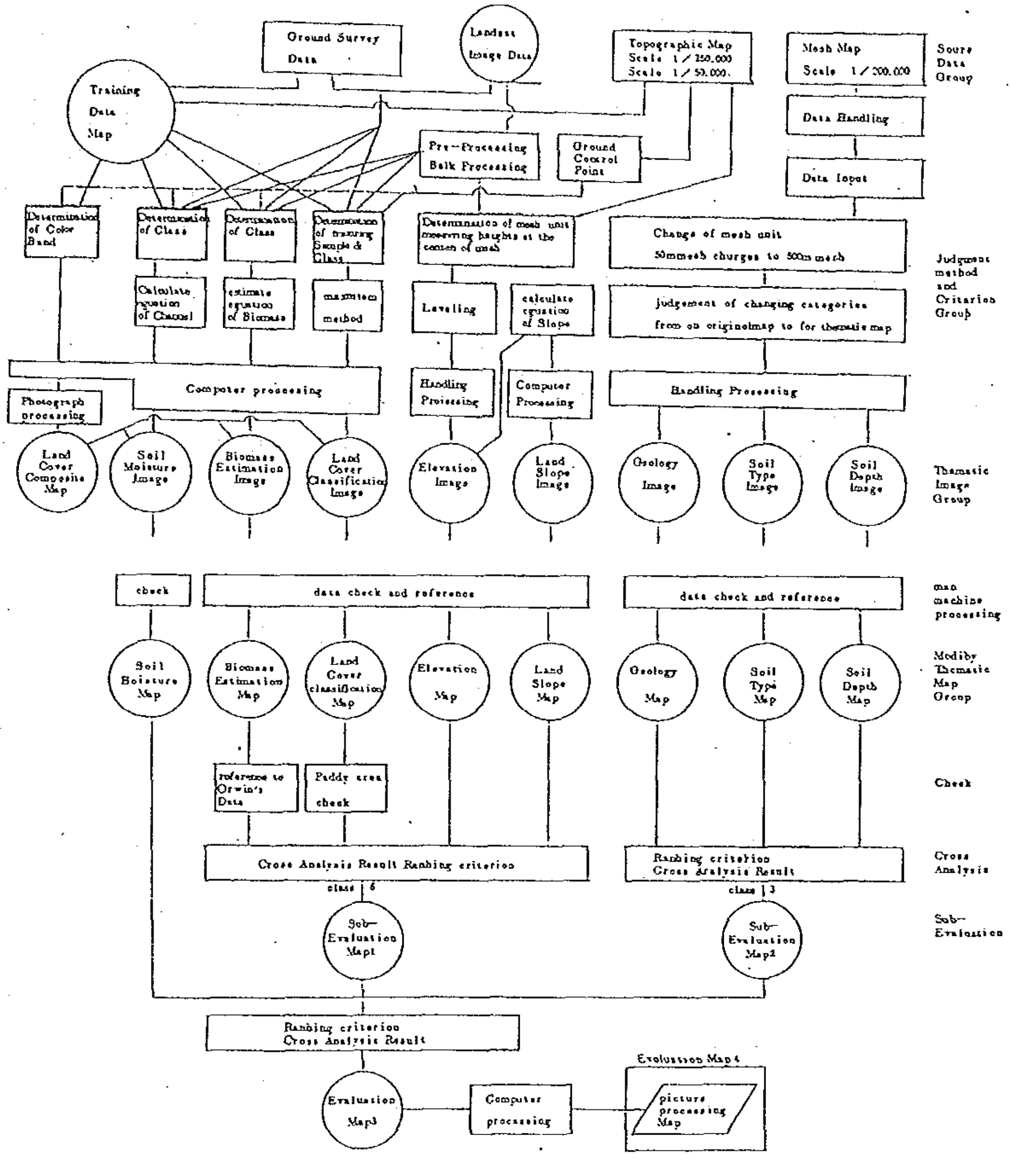

Fig. 2-4-6 Assessment (Evaluation) Mapping System

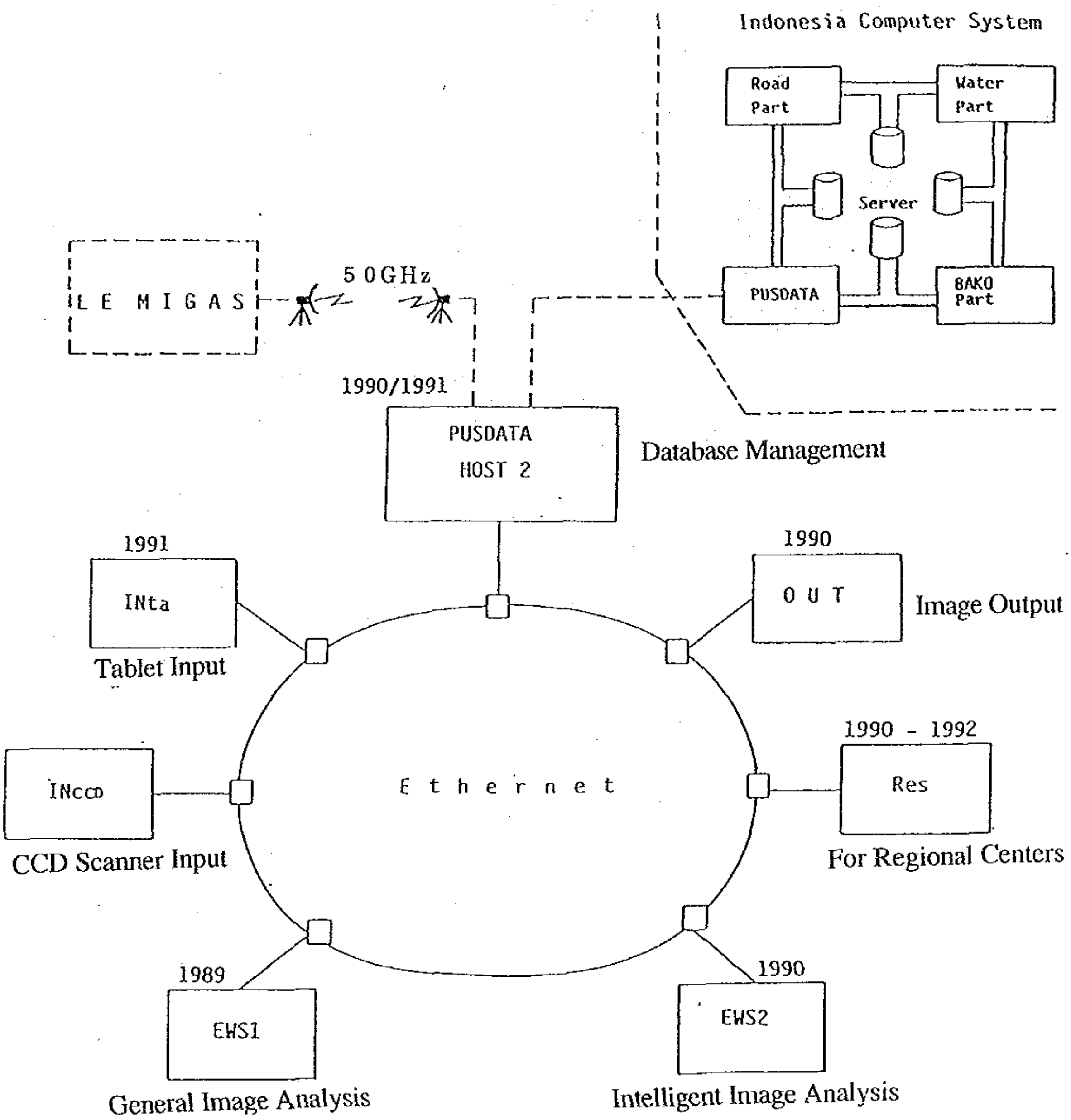

Fig. 2-4-7 Outline of LAN Structure

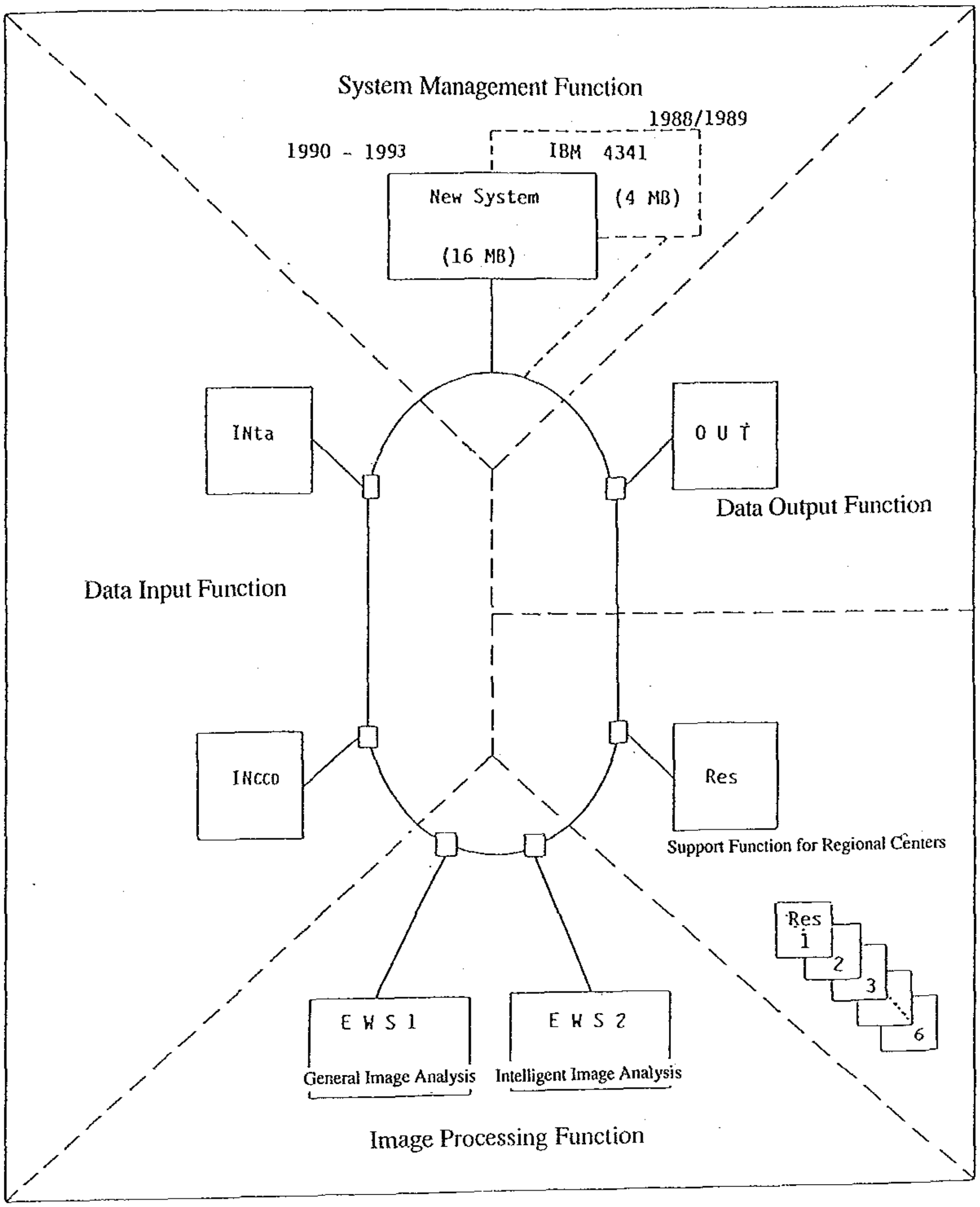

Fig. 2-4-8 Distributed Processing System Envisaged in Phase II

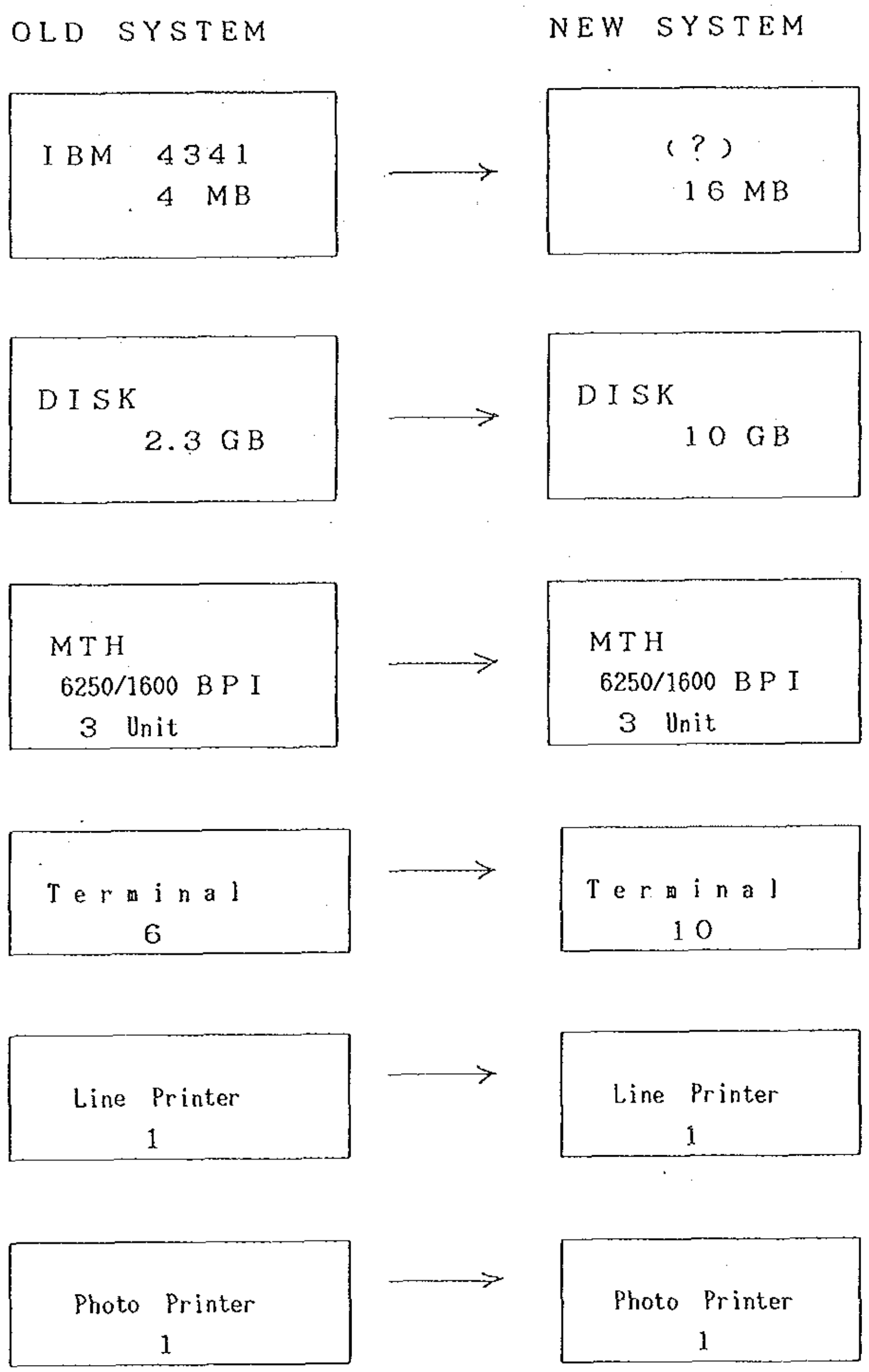

Fig. 2-4-9 Comparison Between Old and New Systems

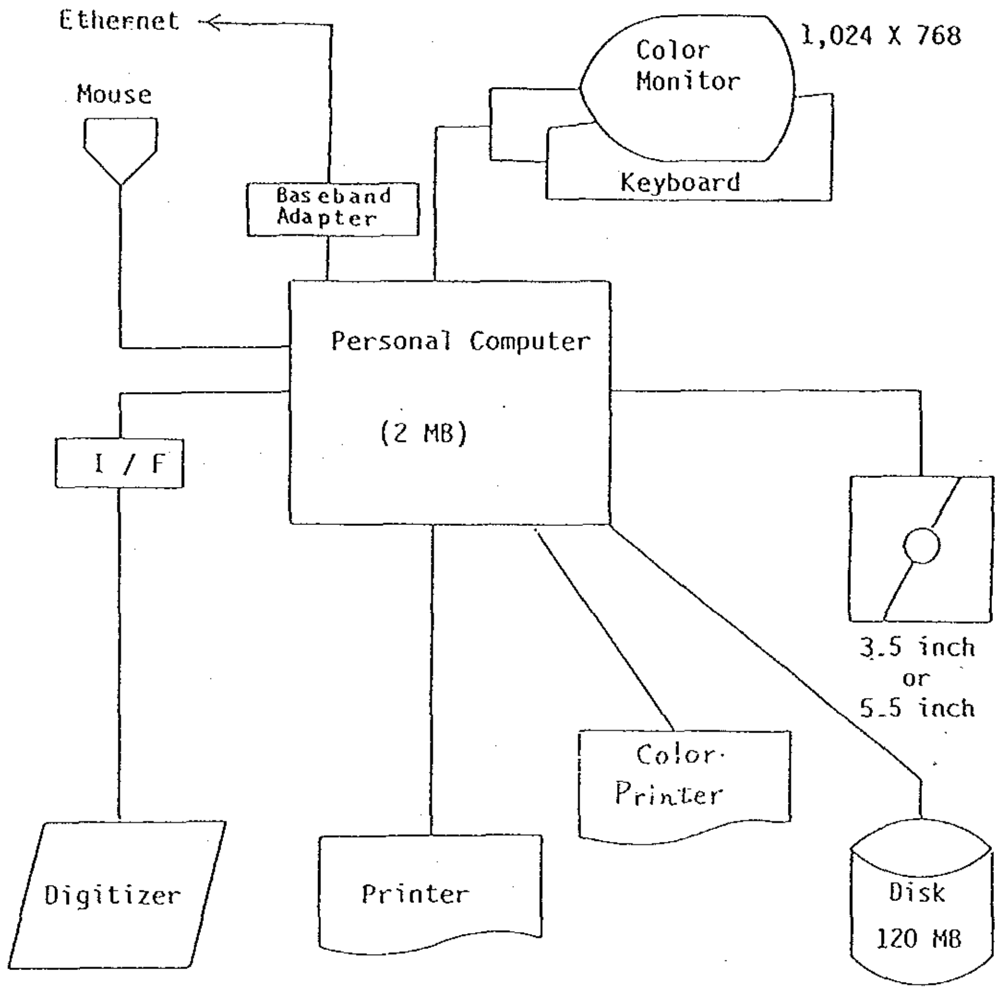

Fig. 2-4-10 (a) Personal Computer System for PUSDATA

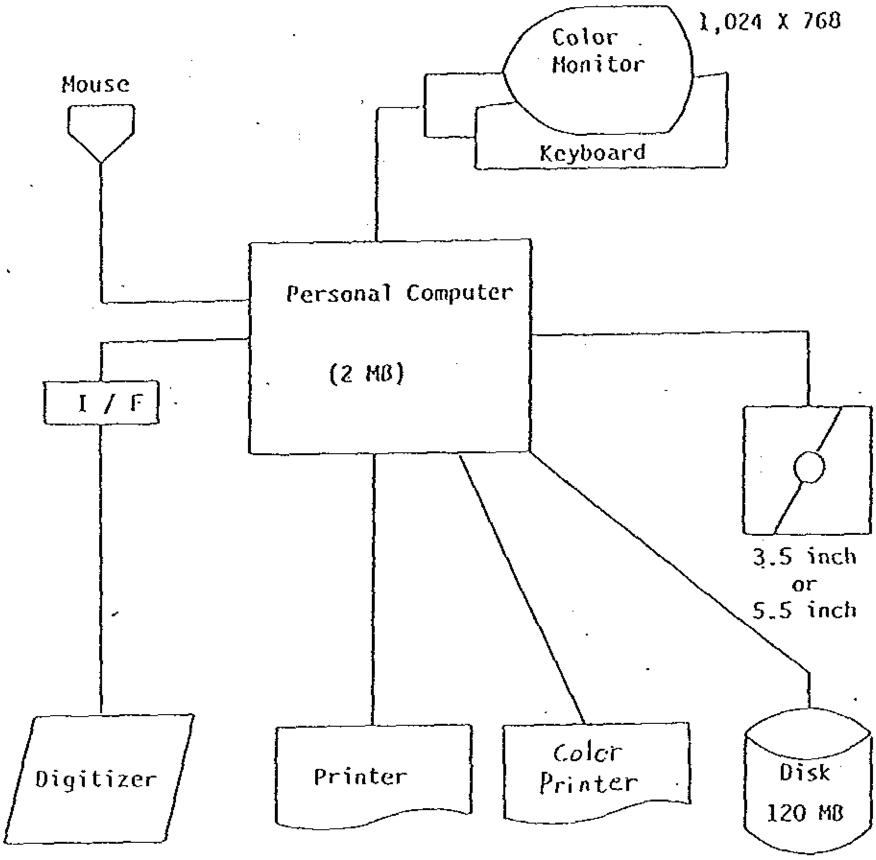

Fig. 2-4-10 (b)   Personal Computer System for Regional Centers

Retrieval Item A1.........................Ai...............................An
Retrieval Item B1...................Bj..........................Bm
Retrieval Item C1...............Ck.......................................C1

Fig. 2-4-11   Concept of Hierarchical Structure

Table 2-4-1 Contents of Retrieval Items

	Image Data	Map Data	Geographic Data	Economic Data
Item A	• Landsat MSS • Landsat TM • SPOT • MOS-1 • GMS • NOAA	• data of 1/50,000 maps • data of 1/50,000 maps • data of 1/25,000 maps	• total population in administrative area • population by sex • population by age • population by industry	• budget of an administrative area • national income
Item B	• land coverage classification data • soil map data • biomass map data • effective soil thickness data	• administrative boundary data • elevation data • road data • railway data • local name data • map symbol data	• number of houses • education • medical care • sport • environment	• individual income • land ownership • house ownership • car ownership • bicycle ownership
Item C	• normalized data • noise stripped data • location data • training data • test data • classification result data	• point data • line data • polygon data • titles • line width	• travelling time to school	• paid income tax • paid commodity tax

* Some of these were prepared in Phase I.

Table 2-4-2 Processing Function of Hyper-Multimedia System

Item	Processing and Manipulation	Description of Subject	Executing Environment
Database Function	• input • structural accumulation • hierarchical structure • indexing • matching • retrieval • editing • renewal • output	• multimedia • data accumulation and storage method • data definition • media definition • data independence • media independence	• multimedia • database • technology
Data Processing Function	• understanding of structure • description method of structure • coding of data • data coordination for general purpose use	• description of multimedia	• distributed processing
	• creation of macroscopic data • data processing method • media conversion • feature extraction • recognition and understanding	• description of model • description of knowledge • creation of model • acquisition of knowledge	• man-machine interaction
	• telecommunication method • coding	• data compression	• wide area network

AFTERWORD

1. Objectives of the Work

Phase II of the Remote Sensing Engineering Project for the Development of Agricultural Infrastructure in the Republic of Indonesia intends to accomplish the following objectives for the preparation of thematic maps and evaluation (assessment) maps required for an agricultural development plan and also for the preparation of agricultural development plan standards, all of which are necessary to conduct appropriate site selection for agricultural development.

(1) compilation and examination of the recent development of the basic remote sensing technology
(2) compilation and examination of the application technologies of remote sensing data for agricultural development planning

2. Progress of the Work

The Remote Sensing Technology Center of Japan was commissioned by JICA to compile a technical manual on the basis of the above objectives and to establish a working group. Each chapter of the report was assigned to an expert in the relevant field and the final report was compiled after 3 meetings to discuss the details of the report. The members of the working group are given in Supplement.

3. Aims of the Technical Manual

This Technical Manual explains the latest technical trends of the application of remote sensing technologies to agricultural development and aims at indirectly assisting Phase II of the Remote Sensing Project in Indonesia as a technical reference book for field workers.

While the contents of this Technical Manual are not directly related to the 4 objectives of the above Engineering Project (Phase II), they have been compiled in such a way that readers can easily relate them to the objectives of the Engineering Project.

This Technical Manual is the successor of the Technical Report on Site Selection System for Agricultural Development (March, 1983) which was compiled during Phase I of the Engineering Project.

4. Conclusion

The Technical Manual was written by leading experts in the relevant fields. It is hoped that it will be found for use of the implementation of the Remote Sensing Engineering Project in Indonesia.

Finally, I would like to express my gratitude to those contributors who kindly accepted the request and spent their valuable time on preparing the Manual.

Toshio Michino
(Secretariat)

SUPPLEMENT

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APPENDIX

Appendix: Major Technical Terms for Remote Sensing

Terms	Descriptions	References (pages)
Active system	A remote sensing system that transmits its own electromagnetic emission at an object(s) and then records the energy reflected or refracted back to the sensor. (Compare passive system.)	
Algorithm	(1) A fixed step-by-step procedure to accomplish a given result; usually a simplified procedure for solving a complex problem; also a full statement of a finite number of steps. (2) A computer-oriented procedure for resolving a problem.	22, 25
Altitude	Height above a datum; the datum is usually mean sea level. (See elevation.)	1,2,7,19~21 25,27,28, 61,62
Analog	A form of data display in which values are shown in graphic form, such as curves. Also a form of computing in which values are represented by directly measurable quantities, such as voltages or resistances. Analog computing methods contrast with digital methods in which values are treated numerically.	25
Aperture	The opening in a lens diaphragm through which light passes.	
Atmospheric windows	Those wavelength ranges in which radiation can pass through the atmosphere with relatively little attenuation; in the optical portion of the spectrum, approximately 0.3-2.5, 3.0-4.0, 4.2-5.0, and 7.0-15.0 μm.	
Band	(1) A selection of wavelengths. (2) Frequency band. (3) Absorption band. (4) A group of tracks on a magnetic drum. (5) A range of radar frequencies, such as X-band, Q-band, etc.	1,3,4,7,12~ 15,60~64, 155,172, 175,180
Bit	(1) An abbreviation of binary digit. (2) A single character of a language employing only two distinct kinds of characters. (See also byte)	85,87,88

Terms	Descriptions	References (pages)
Blackbody, black body	An ideal emitter which radiates energy at the maximum possible rate per unit area at each wavelength for any given temperature. A blackbody also absorbs all the radiant energy incident upon it. No actual substance behaves as a true blackbody.	
Brightness	(1) The attribute of visual perception in accordance with which an area appears to emit more or less light. (2) Luminance. (3) The luminous flux emitted or reflected per unit projected area per unit solid angle. The unit of brightness, the lambert, is defined as brightness of a surface which emits or reflects one/π lumen per square centimeter per steradian.	2,5,6
Brightness temperature	(1) The temperature of a blackbody radiating the same amount of energy per unit area at the wavelengths under consideration as the observed body. Also called effective temperature. (2) The apparent temperature of a nonblackbody determined by measurement with an optical pyrometer or radiometer.	64
Byte	A group of eight bits of digital data. (See also bit)	82,88,91, 174,177
Calibration	The act or process of comparing certain specific measurements in an instrument with a standard.	
Category	Each unit is assumed to be of one and only one given type. The set of types is called the set of "classes" or "categories," each type being a particular category. The categories are chosen specifically by the investigator as being the ones of interest to him.	4,5,13,49, 50,111,113, 136,152, 153,171
Classification	The process of assigning individual pixels of a multispectral image to categories, generally on the basis of spectral reflectance characteristics.	4,~23,40~ 48,58~60, 71,76,109, 112~126, 127,136~ 154~169
Clustering	The analysis of a set of measurement vectors to detect their inherent tendency to form clusters in multi-dimensional measurement space.	

Terms	Descriptions	References (pages)
Color composite (multiband photography)	A color picture produced by assigning a color to a particular spectral band. In Landsat, blue is ordinarily assigned to MSS band 4 (0.5-0.6μm), green to band 5 (0.6-0.7μm), and red to band 7 (0.8-1.1μm), to form a picture closely approximating a color-infrared photograph.	181
Computer-compatible tapes (CCT)	Tapes containing digital Landsat data. These tapes are standard 19-cm (7 1/2-in) wide magnetic tapes in 9-track or 7-track format. Four tapes are required for the four-band multispectral digital data corresponding to one Landsat scene	
Contrast stretching	Improving the contrast of images by digital processing. The original range of digital values is expanded to utilize the full contrast range of the recording film or display device.	2
Data acquisition system	The collection of devices and media that measures physical variables and records them prior to input to the data processing system.	
Data base	A well-defined collection of data, usually of the same general type, that can be accessed by a computer: also called data bank.	52,69,75, 91,92,173
Data processing	Application of procedures mechanical, electrical, computational, or other whereby data are changed from one form into another.	36,41,42,59 68,69,73,74 78,80~88, 166~179, 191
Density (symbol, D)	A measure of the degree of blackening of an exposed film, plate, or paper after development, or of the direct image (in the case of a printout material). It is defined strictly as the logarithm of the optical opacity, where the opacity is the ratio of the incident to the transmitted (or reflected) light or transmissivity, T, as $D = \log(1/T)$.	5,23,24,30, 59,174

Terms	Descriptions	References (pages)
Detector (radiation)	A device providing an electrical output that is a useful measure of incident radiation. It is broadly divisible into two groups: thermal (sensitive to temperature changes), and photodetectors (sensitive to changes in photon flux incident on the detector), or it may also include antennas and film. Typical thermal detectors are thermocouples, thermopiles, and thermistors; the latter is termed a bolometer.	25
Digitization	The process of converting an image recorded originally on photographic material into numerical format.	
Display	An output device that produces a visible representation of a data set for quick visual access; usually the primary hardware component is a cathode ray tube.	4,33~39,44, 47,52,58,59 71,82~90, 176,177
Dynamic range	The ratio of maximum measurable signal to minimum detectable signal.	
Edge enhancement	The use of analytical techniques to emphasize transition in imagery.	2,164
Electromagnetic radiation (EMR)	Energy propagated through space or through material media in the form of an advancing interaction between electric and magnetic fields. The term radiation, alone is commonly used for this type of energy, although it actually has a broader meaning. Also called electromagnetic energy.	
Elevation	(1) Vertical distance from the datum, usually mean sea level, to a point or object on the earth's surface. Not to be confused with altitude, which refers to points or objects above the earth's surface. (2, architectural) An orthographic projection of any object into a vertical plane. (See altitude)	48,50,53,58 61~66,91, 135,136, 156,159, 168,171~ 174,191

Terms	Descriptions	References (pages)
Emissivity	The ratio of the radiation given off by a surface to the radiation given off by a blackbody at the same temperature; a blackbody has an emissivity of 1, other objects between 0 and 1.	
False color	The use of one color to represent another; for example, the use of red emulsion to represent infrared light in color infrared film.	2,61,157
Field of view (FOV)	The solid angle through which an instrument is sensitive to radiation. Owing to various effects, diffractions, etc., the edges are not sharp. In practice they are defined as the "half-power" points, i.e., the angle outwards from the optical axis, at which the energy sensed by the radiometer drops to half its on-axis value.	2
Frequency	Number of oscillations per unit time or number of wavelengths that pass a point per unit time. (See also band) . The frequency bands used by radar (radar frequency bands) were first designated by letters for military secrecy.	24,135
Geometric correction	Satellite images are subjected to different deformations due to the Earth, the satellite, the orbit, and the image projection. These deformations will prevent meaningful comparison among images acquired at different times, by different sources, and with different geometries. The images must be geometrically registered to one another. (Compare radiometric correction)	2~11,43, 179
Ground control point (GCP)	A geographical feature of known location that is recognizable on images and can be used to determine geometrical corrections.	3,11,62
Gray scale	A calibrated sequence of gray tones ranging from black to white.	

Terms	Descriptions	References (pages)
Ground resolution cell	The area on the terrain that is covered by the instantaneous field of view of a detector. The size of the ground resolution cell is determined by the altitude of the remote-sensing system and the instantaneous field of view of the detector. (See IFOV, pixel)	
Ground truth	Term coined for data and information obtained on surface or subsurface features to aid in interpretation of remotely sensed data. Ground data and ground information are prefered terms.	4~7,85,154
Histogram	The graphical display of a set of data which shows the frequency of occurrence (along the vertical axis) of individual measurements or values (along the horizontal axis); a frequency distribution.	2,6
Infrared (IR)	Pertaining to energy in the 0.7-100μm wavelength region of the electromagnetic spectrum. For remote sensing, the infrared wavelengths are often subdivided into near infrared (0.7-1.3μm), middle infrared (1.3-3.0μm), and far infrared (7.0-15.0μm). Far infrared is sometimes referred to as thermal or emissive infrared.	2,7,13~15, 60~64,136~141,172
Instantaneous field of view (IFOV)	A term specifically denoting the narrow field of view designed into detectors, particularly scanning radiometer systems, so that, while as much as 120° may be under scan, only EMR from a small area is being recorded at any one instant. (See ground resolution cell, pixel)	2
Interactive image processing	The use of an operator or analyst at a console that provides the means of assessing, preprocessing, feature extracting, classifying, identifying, and displaying the original imagery or the processed imagery for his subjective evaluations and further interactions.	
Map, thematic	A map designed to demonstrate particular features or concepts. In conventional use this term excludes topographical maps.	1~6,11, 155~172, 178~181

Terms	Descriptions	References (pages)
Microwave	A very short EM wave; any wave between 1 meter and 1 millimeter in wavelength or 300 GHz to 0.3 GHz in frequency. The portion of the electromagnetic spectrum in the millimeter and centimeter wavelengths, bounded on the short wavelength sides by the far infrared (at 1mm) and on the long wavelength side by very high-frequency radio waves. Passive systems operating at these wavelength sometimes are called microwave systems. Active systems are called radar, although the literal definition of radar requires a distance-measuring capability not always included in active systems. The exact limits of the microwave region are not defined.	
Mosaic	An assemblage of overlapping aerial or space photographs or images whose edges have been matched to form a continuous pictorial representation of a portion of the Earth's surface.	
Multispectral (line) scanner (MSS)	A remote sensing device that operates on the same principle as the infrared scanner, except that it is capable of recording data in the ultraviolet and visible portions of the spectrum as well as the infrared.	3~13,59,60, 61,91,140~158,170~172,191
Nadir	(1) That point on the celestial sphere vertically below the observer, or 180° from the zenith. (2) That point on the ground vertically beneath the perspective center of the camera lens.	62
Near Infrared	The preferred term for the shorter wavelengths in the infrared region extending from about 0.7 micrometers (visible red), to around 2 or 3 micrometers (varying with the author). The longer wavelength end grades into the middle infrared. The term really emphasizes the radiation reflected from plant materials, which peaks around 0.85 micrometers. It is also called solar infrared, as it is only available for use during the daylight hours.	2,13~15, 60~63,136, 137,138, 141

Terms	Descriptions	References (pages)
Orbit	(1) The path of a body or particle under the influence of a gravitational or other force. For instance, the orbit of a celestial body is its path relative to another body around which it revolves. (2) To go around the Earth or other body in an orbit.	1
Overlap	The area common to two successive photos along the same flight strip; the amount of overlap is expressed as a percentage of photo area. Also called endlap.	52
Overlay	(1) A transparent sheet giving information to supplement that shown on maps. When the overlay is laid over the map on which it is based, its details will supplement the map. (2) A tracing of selected details on a photograph, mosaic, or map to present the interpreted features and the pertinent detail.	26~28,47, 52~62,71, 84,85,93, 161
Passive system	A sensing system that detects or measures radiation emitted by the target. (Compare active system.)	
Pattern recognition	The automated process through which unidentified patterns can be classified into a limited number of discrete classes through comparison with other class-defining patterns or characteristics.	166
Pixel	(Derived from "picture element.") A data element having both spatial and spectral aspects. The spatial variable defines the apparent size of the resolution cell (i.e., the area on the ground represented by the data values), and the spectral variable defines the intensity of the spectral response for that cell in a particular channel. (See ground resolution cell, IFOV)	1~5,11,20, 25,34,43,44 59,138,139
Polarization	The direction of vibration of the electrical field vector of electromagnetic radiation. In SLAR systems polarization is either horizontal or vertical.	

Terms	Descriptions	References (pages)
Pulse	(1) A variation of a quantity whose value is normally constant; this variation is characterized by a rise and a decay, and has a finite duration. (2) A short burst of EMR transmitted by the radar.	
Radar	Acronym for radio detection and ranging. A method, system or technique, including equipment components, for using beamed, reflected, and timed EMR to detect, locate, and (or) track objects, to measure altitude and to acquire a terrain image. In remote sensing of the Earth's or a planetary surface, it is used for measuring and, often, mapping the scattering properties of the surface.	
Radar, synthetic aperture (SAR)	A radar in which a synthetically long apparent or effective aperture is constructed by integrating multiple returns from the same ground cell, taking advantage of the Doppler effect to produce a phase history film or tape that may be optically or digitally processed to reproduce an image.	91
Radiance	The accepted term for radiant flux in power units (e.g., W) and not for flux density per solid angle (e.g., W cm^{-2} sr^{-1}) as often found in recent publications.	
Radiometer	An instrument for quantitively measuring the intensity of EMR in some band of wavelengths in any part of the EM spectrum. Usually used with a modifier, such as an IR radiometer or a microwave radiometer.	
Radiometric correction	Correcting gain and offset variations in MSS data. Procedure calibrates and corrects the radiation data provided by the sensor detectors. (Compare geometric correction)	

Terms	Descriptions	References (pages)
Registration	The process of geometrically aligning two or more sets of image data such that resolution cells for a single ground area can be digitally or visually superposed. Data being registered may be of the same type, from very different kinds of sensors, or collected at different times.	1,3,5
Resolution cell	The smallest area in a scene considered as a unit of data. For Landsat-1 and -2 the resolution cell approximates a rectangular ground area of 0.44 hectares or 1.1 acres (See pixel, instantaneous field of view).	
Scan line	The narrow strip on the ground that is swept by the instantaneous field of view of a detector in a scanner system.	
Scanner	(1) Any device that scans, and thus produces an image. (2) A radar set incorporating a rotatable antenna, or radiator element, motor drives, mounting, etc. for directing a searching radar beam through space and imparting target information to an indicator.	1,4,25,44, 47,89,156
Scattering	(1) The process by which small particles suspended in a medium of a different index of refraction diffuse a portion of the incident radiation in all directions. (2) The process by which a rough surface reradiates EMR incident upon it.	20
Scene	In a passive remote sensing system, everything occurring spatially or temporally before the sensor, including the Earth's surface, the energy source, and the atmosphere, that the energy passes through as it travels from its source to the Earth and from the Earth to the sensor.	8,10,26,83 91,157,166 171~175

Terms	Descriptions	References (pages)
Sensor	Any device that gathers energy, EMR or other, converts it into a signal and presents it in a form suitable for obtaining information about the environment.	1,2,3,10,13 156
Sidelap	The extent of lateral overlap between images acquired on adjacent flight lines.	
Sidelooking radar	An all weather, day/night remote sensor which is particularly effective in imaging large areas of terrain. It is an active sensor, as it generates its own energy which is transmitted and received to produce a photo-like picture of the ground. Also referred to as sidelooking airborne radar; abbr., SLAR.	
Signature	Any characteristics or series of characteristics by which a material may be recognized in an image, photo, or data set. See also spectral signature.	
Smoothing	The averaging of densities in adjacent areas to produce more gradual transitions.	167
Software	The computer programs that drive the hardware components of a data processing system; includes system monitoring programs, programming language processors, data handling utilities, and data analysis a programs.	34,35,57,63 71,75,82~ 88,106,111, 119~124, 175~179
Stereoscope	A binocular optical instrument for assisting the observer to view two properly oriented photographs or diagrams to obtain the mental impression of a three-dimensional model.	
Sun synchronous	An Earth satellite orbit in which the orbital plane is near polar and the altitude such that the satellite passes over all places on Earth having the same latitude twice daily at the same local sun time.	

Terms	Descriptions	References (pages)
Supervised classification	A computer-implemented process through which each measurement vector is assigned to a class according to a specified decision rule, where the possible classes have been defined on the basis of representative training samples of known identity. (See classification)	4,43,155, 166
Swath width (total field of view)	The overall plane angle or linear ground distance covered by a multispectral scanner in the across-track direction.	13~15
Texture	In a photo image, the frequency of change and arrangement of tones. Some descriptive adjectives for textures are fine, medium or coarse; and stippled or mottled.	25,160
Thermal band	A general term for middle-infrared wavelengths which are transmitted through the atmosphere window at 8-14μm. Occasionally also used for the windows around 3-6μm. (See thermal infrared)	63
Thermal infrared	The preferred term for the middle wavelength range of the IR region,extending roughly from 3μm at the end of the near infrared, to about 15 or 20μm, where the far infrared begins. In practice the limits represent the envelope of energy emitted by the Earth behaving as a gray body with a surface temperature around 290°K (27°C).	7,13~15,63 64,172
Tilt	The angle between the optical axis of the camera and the plump line for a given photo.	
Training samples	The data samples of known identity used to determine decision boundaries in the measurement or feature space prior to classification of the overall set of data vectors from a scene.	
Visible wavelengths (band)	The radiation range in which the human eye is sensitive, approximately 0.4-0.7μm.	

ACRONYMS

AMI	Active Microwave Instrumentation (E•ERS)
AVHRR	Advanced Very High Resolution Radiometer (NOAA)
CCT	Computer Compatible Tape
CPU	Central Processing Unit
CRT	Cathode-Ray Tube
EMR	Electromagnetic Radiation
FOV	Field-of-View
GCP	Ground Control Point
HRV	High Resolution Visible (SPOT)
IFOV	Instantaneous Field-of-View
IR	Infrared
JPL	Jet Propulsion Laboratory (USA)
JSC	Johnson Space Center (USA)
MESSR	Multispectral Electronic Self-Scanning Radiometer (MOS)
MSR	Microwave Scanning Radiometer (MOS)
MSS	Multi-Spectral Scanner (Landsat)
NASA	National Aeronautics and Space Administration (USA)
NASDA	National Space Development Agency of Japan
NOAA	National Oceanic and Atmospheric Administration (USA)
OPS	Optical Sensor (J•ERS)
RBV	Return Beam Vidicon (Landsat)
RESTEC	Remote Sensing Technology Center of Japan
SLAR	Side-Looking Airborne Radar
S/N	Signal-to-Noise Ratio
SWIR	Short Wavelength Infrared Radiometer (J•ERS)
TM	Thematic Mapper (Landsat)
VNIR	Visible and Near Infrared Radiometer (J•ERS)
VTIR	Visible and Thermal Infrared Radiometer (MOS)

JICA