TECHNICAL REPORT ON SITE SELECTION SYSTEM FOR AGRICULTURAL DEVELOPMENT

THE REMOTE SENSING ENGINEERING PROJECT FOR THE DEVELOPMENT OF AGRICULTURAL INFRASTRUCTURE IN THE REPUBLIC OF INDONESIA

MARCH 1983

JAPAN INTERNATIONAL COOPERATION AGENCY

CONTENTS

INTRODUCTION

The Remote Sensing Engineering Project for the Development of Agricultural Infrastructure in the Republic of Indonesia sponsored by the Technical Cooperation Project, Japan International Cooperation Agency has been started since 1981. Since then the project has made great progress successfully. In 1982 installation of the digital image processing facilities which were transported from Japan as supplying equipment was completed. At the present technical transfer is almost fulfilled. Various thematic maps have been produced with Landsat data by using the facilities.

Remote sensing technology involves a lot of interdisciplinary factors as well as possibility of operational utilization. The utilization of remote sensing data is expanding from international view point in many countries. Especially in developing countries technical cooperation has been requested because remote sensing technology is recognized to be useful for management of natural resources.

Though studies on remote sensing have been made in Japan into world famous level, requirement for operational remote sensing in the management of natural resources and land development seems to be less. This is why other technolgies than remote sensing are available for the management of natural resources and land development in Japan.

To solve a practical problem such as site selection for agricultural development by remote sensing as discussed in this project may be the first experience. However the problem should be solved in order to promote operational remote sensing. Strong request for operational remote sensing comes from many developing countries in spite of less request in Japan.

The research project of " Study on Site Selection System for Agricultural Development " has been contracted between the Japan Society of Photogrammetry and Remote Sensing and Japan International Cooperation Agency. The project is tremendously interesting to the Society that is supported by many reseachers and remote sensing scientists in Japan.

Since the project offers a good opportunity to show the experiences and the efforts of the Society, the Committee for Indonesia Agricultural Development by Remote Sensing has been established with those experts of remote sensing and agriculture in order to develop the best technical system. The report is a result obtained from the works by the Committee.

Chapter 1 GENERAL

This report was made for a technical study on site selection system for agricultural development in relation to " the Remote Sensing Engineering Project for the Development of the Agricultural Infrastructure in Indonesia" under the contract between the Japan International Cooperation Agency and the Japan Society of Photogrammetry and Remote Sensing.

1.1 OBJECTIVE OF STUDY

The objective of the study is to establish a methodology of overall evaluation by physical planning conditions and its procedure in order to promote effectively the development of remote sensing technology for site selection for agricultural development, which is being carried on in "the Remote Sensing Engineering Project for the Development of the Agricultural Infrastructure in Indonesia".

To fulfill the objective, the following items are to be studied.

(1) Concept of multi-stage investigation and its application by analogue and digital image analysis,

(2) Land use mapping and thematic mapping for inventory of physical planning condition,

(3) Thematic mapping for evaluating stability of the land (land slide, soil erosion, danger due to flood, etc.),

(4) Thematic mapping for evaluating productivity of the land (land slope, soil texture, drainage, etc.) and workability (reclamation, possibility of mechanization, etc.).

1.2 ORGANIZATION

The study was done by the Committee for Indonesia Agricultural Development by Remote Sensing.

Chairman:	Yasubumi Emori	Professor, Chiba University
Members:	Tsuyoshi Akiyama	National Grassland Experiment Station
	Motoya Saito	National Grassland Experiment Station
	Ryutaro Tateishi	Chiba University
	Ryuji Matsuoka	Institute of Industrial Science, Univ. of Tokyo
	Kazuya Miyama	Hokkaido National Agricultural Experiment Station
	Kazuaki Miyamoto	Depart. of Civil Engineering, Univ.of Tokyo
	Shunji Murai	Institute of Industrial Science, Univ. of Tokyo
	Yoshizumi Yasuda	Chiba University

Chapter 2 CONCEPT OF MULTISTAGE SCREENING PROCESS AND ITS APPLICATION

2.1 General

Remote sensing is a new information source, and it has an excellent capability of aquiring data over large area. By applying the low altitude survey, it is possible to examine definitely a particular local area.

On the other hand, recent development of the computer has not only enhanced the capability of handling data, but also given us a powerful information system.

Accordingly, by integrating remote sensing data, such as landuse, vegetation, drainage, etc., with already aquired data such as geology, topography, climate and soil, fine analysis and accurate assessment for agricultural development could be accomplished.

How to combine remote sensing technology with computer information system and how to apply this combined new technology for agricultural development are to be important subject of this project. In this chapter, fundamental and basic concept of the integrated technology necessary for agricultural development is firstly presented and secondly practical process for selecting the suitable agricultural land by the screening method is proposed.

2.2 Information system for agricultural development

Agricultural development program is designed and performed by assessing natural land conditions and agro-economical conditions.

However, this agricultural development project in North Smatra is limited only to assessment of natural land conditions.

As fundamental items necessary for assessment of natural land conditions, topography, geology, drainage, landuse, hydrography, vegetation, climate condition...etc., are designated. Data aquisition necessary for these items and their assessments are carried out by the following three steps.

Step 1: Establishment of data base for existing data.

Existing data concerning natural disasters, climate temperature, rainfall, sunshine, topography etc., are collected as computer based information system.

In order to realize the screening process for selecting agricultural suitable land, it is necessary to covert map level data to files of grid cell data, as described later.

Step 2: Establishment of data base for remote sensing data

Up-to-date are detail data concerning landuse, natural vegetation, drainage and etc. and aquired by remote sensing technique and filed in computer based information system in term of grid cell data file as same as in Step 1.

Step 3: Establishment of assessment system

By integrating the data obtained in Step 1 and step 2, analysis and assessment of natural land condition and agro-economical condition which are necessary for agricultural development are carried out.

2.3 Assessment system for agricultural development

Three inventory items of resource base, production base and management base are necessary for assessment of natural land condition and agro-economical condition as shown in Fig. 2.1. Resource base items are topography, geology, soil climate, natural vegetation, etc. Production base items are landuse, yield etc. Management base items are production technology, production cost, development cost, distance to market and transportation.

Data files of the information system necessary for assessing natural land condition consist of inventory items of resourse base and production base. In addition, data files for assessment system for agro-economical condition consist of items of production base and management base.

From data files of the information system, production potential, suitability index and production index are computed. From remote sensing data, vegetation index or biomass index are obtained. By using these assessment data, it is possible to classify the unutilized land into production potential area, units of agricultural development plan and agricultural land use district.

Items required for agricultural landuse classification, that is, slope, soil texture, depth of soil and gravel content are definitely described in chapter 4.

In the case when detail information about soil condition, climate condition, fertile condition and etc., cannot be aquired, it is necessary to introduced new biological factors which enable to evaluate the suitability of agricultural land.

In the developing country as Indonesia, it is impossible to obtain all of required data, because of lack of data.

Accordingly, an assessment system which effectively makes use of remote sensing data, must be developed. This is one of the important reasons to apply the remote sensing technique for assessment of agricultural development plan in the developing country.

2.4 Multistage screening process for site selection for agricultural development

2.4.1 Multistage screening process

As described before, it is very important to develop a new evaluating system by combining Landsat data and other spatial information. In the developing countries, it is difficult to say all part of the land are thoughly investigated. So it is desired to apply the mutistage screening process.

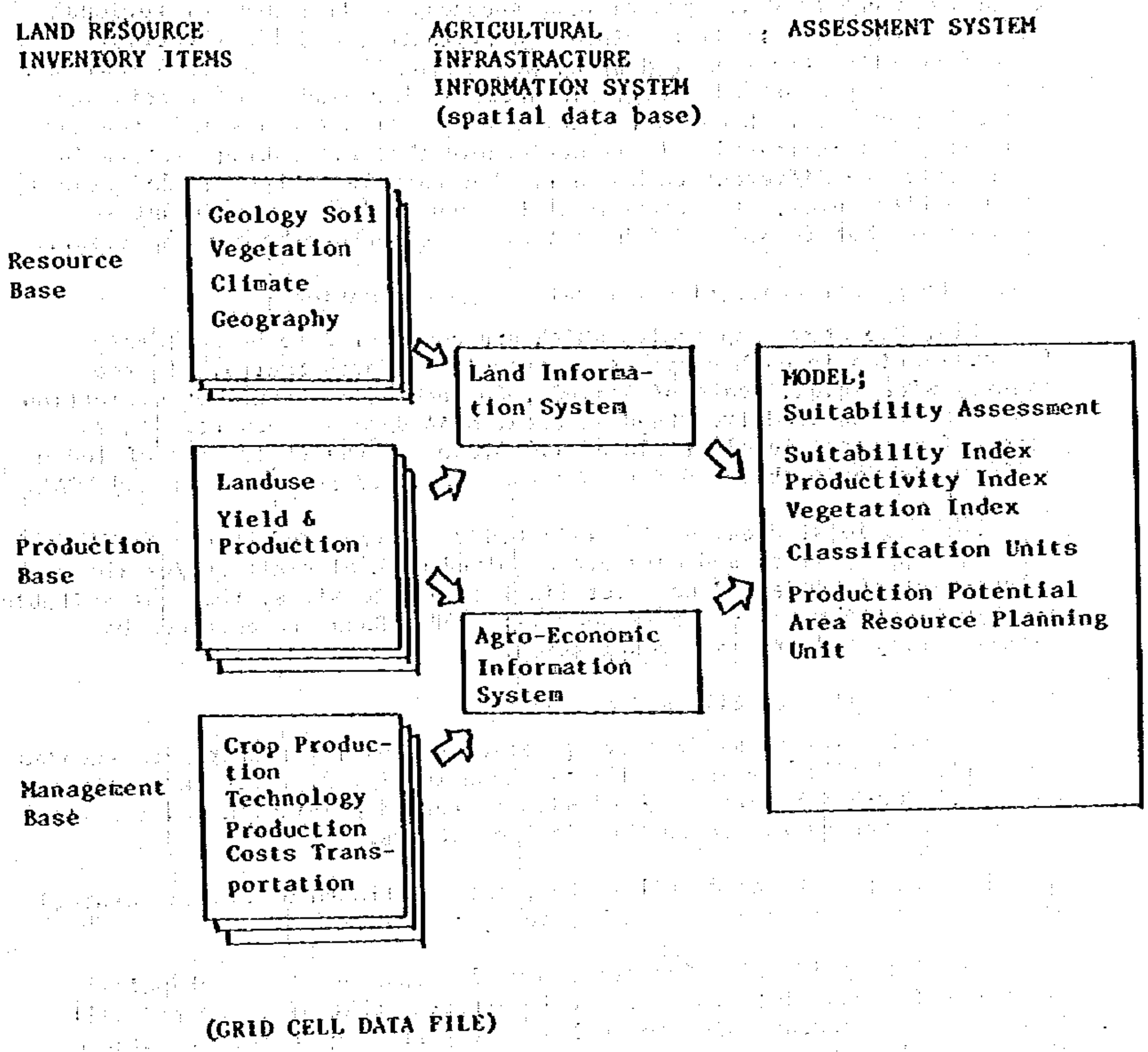


Fig. 2.1 Agricultural Infrastructure Evaluation System and The Major Factors

Large area of country wide level is firstly examined whether any part of these area can be developed or not, secondly smaller area of regional level is more definitely examined and evaluated, and finally final candidate sites are selected after evaluating their agro-economical and natural site properties. Fig. 2.2 shows a flow diagram of multistage screening process. Necessary spatial information factors and thematic maps are also indicated. It is noticeable that evaluating factors in each stage are different each other. For example in 1st and 2nd stages of sattelite level, agro-economical factors are not so important for assessment, but in 3rd and 4th stages, these factors become important.

2.4.2 Data characteristics for multistage evaluation

Fig. 2.3 shows map scales which are considered to be necessary for evaluation in each stage as an example of North Smatra. In the country wide level, scale of 1:1,000,000 becomes a measure of evaluation and data are aquired from Landsat data, NOAA data and others. In 2nd stage of regional level, scale of 1:250,000 and the study area of 100km x 100km are reasonable and data are also obtained from Landsat and NOAA.

For the local area, scale of 1:50,000 and the study area of 20km x 20km are appropriate, and data are acquired with aircraft and/or the enlargement of Landsat data. For final condidate sites, the most suitable area is 4km x 4km and scale is about 1:5,000. Data are obtained by aerial survey and ground investigation.

2.4.3 Grid cell data file and evaluation

Thematic maps classified by specified evaluating factors are encoded digitally and filed by grid cells as shown in Fig. 2.4. If necessary, these grid cell data are weighted with factors depending on contribution of each evaluating factor to the final objective.

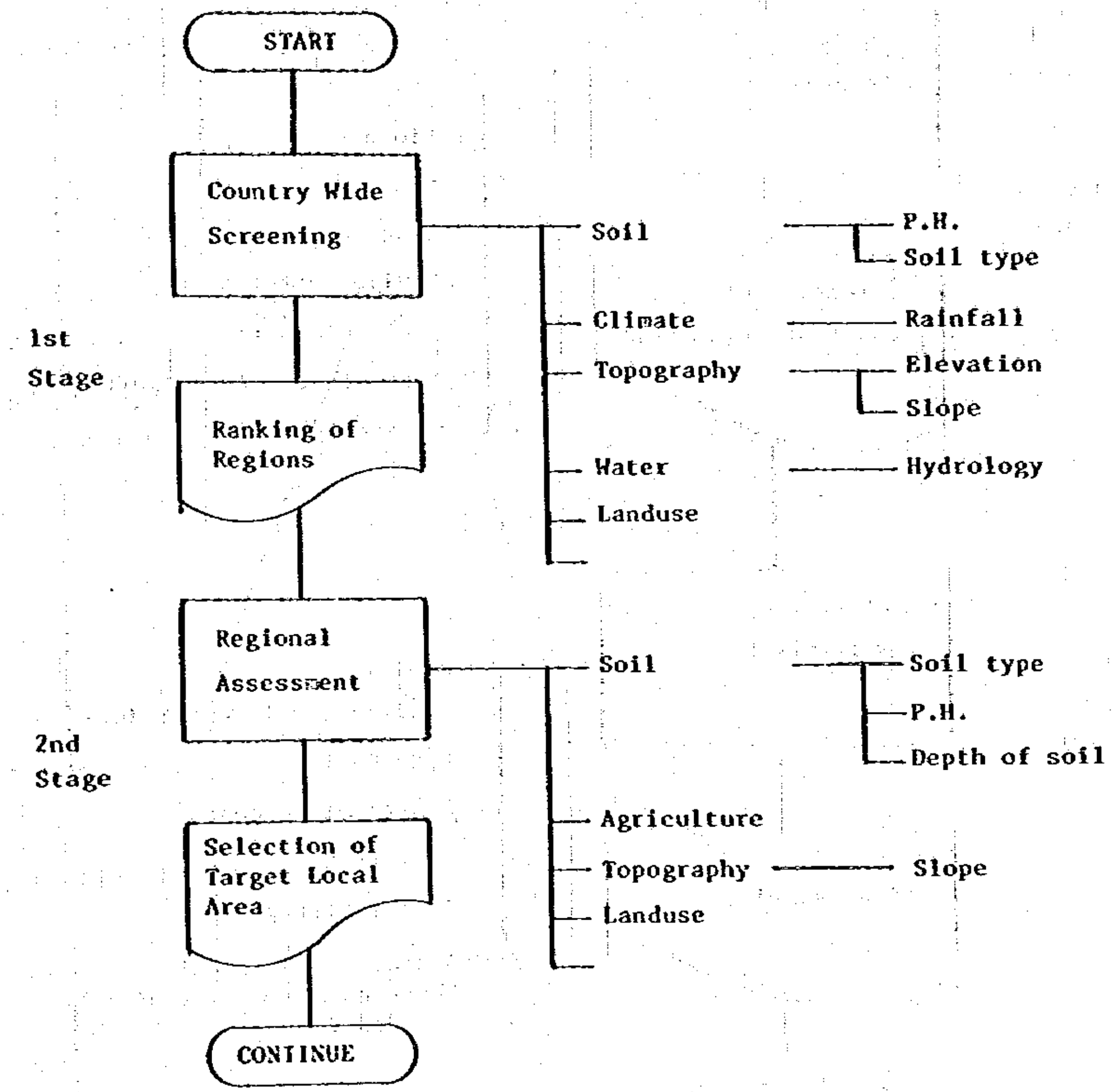
In applying the grid cell system, the relationship between resolution size and size of each grid cell has to be noticed.

A smaller grid cell size as 10 m would minimize the geographical error but increase data volume. It is expected that size of grid cell is determined corresponding to scales of topographic features. size of 500 m cell is appropriate for regional assessment. In Fig. 2.3 required resolution in the term of size of grid cell are indicated in each stage. Grid cell data file is enough to cover only the necessary area in line with primary objectives. For regional assessment, grid cell data file of mountain area are not necessary but limited to the objective study area.

2.4.4 Classification and total assessment of site selection system for agricultural development

It is necessary to totally evaluate all of evaluating factors such as soil condition, topography, landcover...etc., as well as other spatial information for selection of agricultural suitable land.

Fig. 2.2 Flow of Screening Process (1)



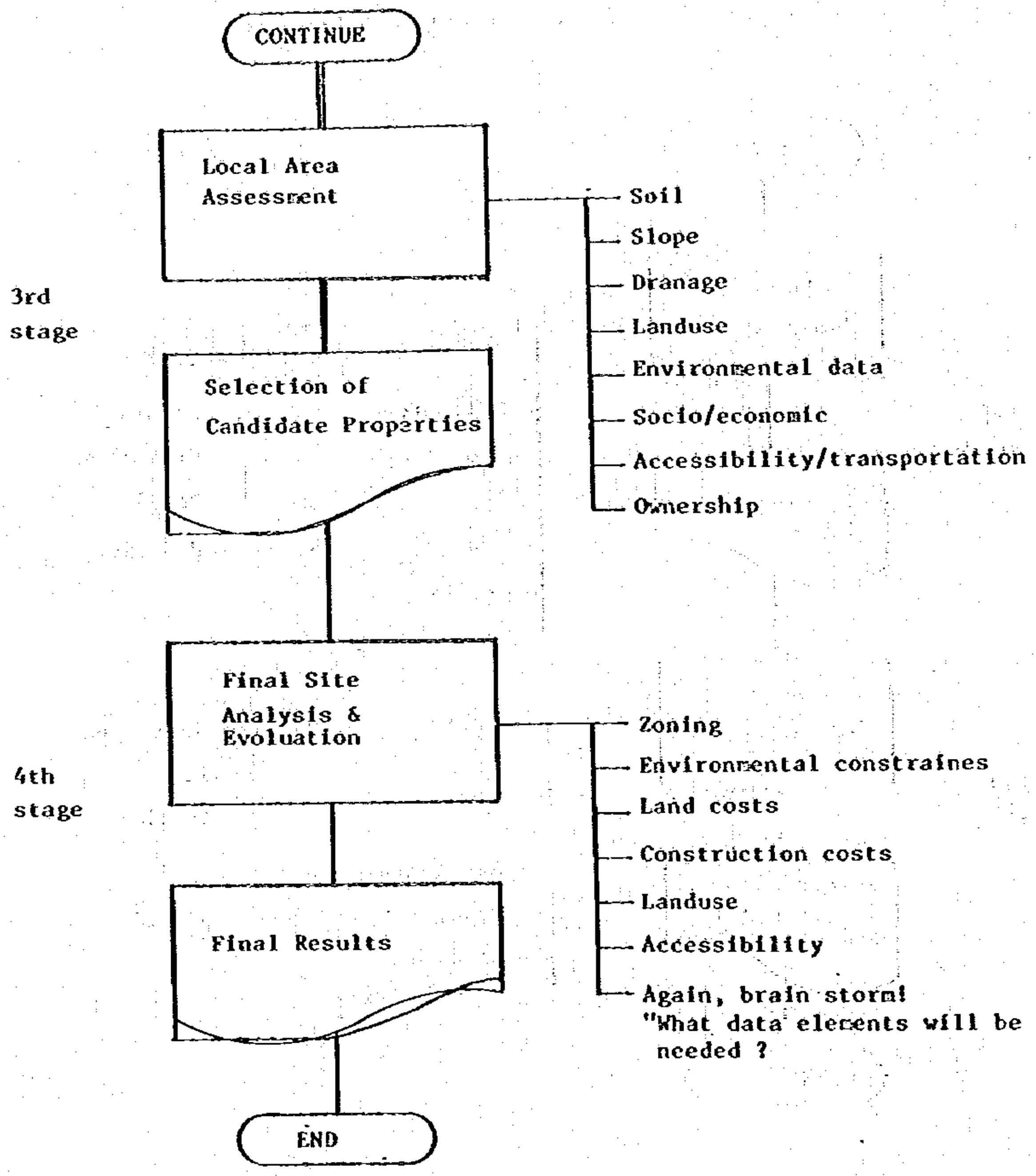
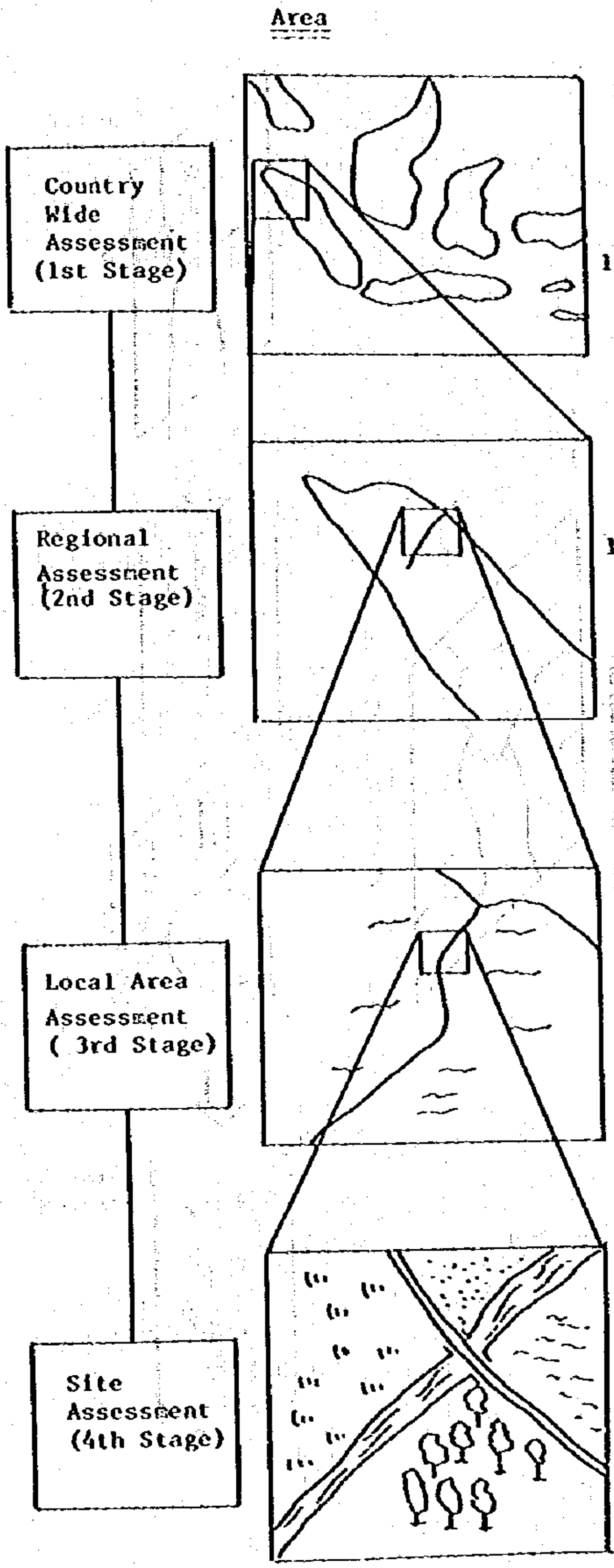


Fig. 2.2 Flow of Screening Process (2)

Fig. 2.3 Data Characteristic for Multi-Stage Evaluation



	Size & Scale	Resolution (Mesh or Grid Cell Size)	Data Acquisition Level
Country Wide Assessment (1st Stage)	TOTAL COUNTRY (NATIONAL) 1:1,000,000	2km x 2km	LANDSAT NOAA HIMAWARI
Regional Assessment (2nd Stage)	100km x 100km 1:250,000	4 - 8 ha 250m x 250m	LANDSAT NOAA
Local Area Assessment (3rd Stage)	20km x 20km 1:50,000	0.2 - 0.4ha 50m x 50m	LANDSAT AIRPLANE
Site Assessment (4th Stage)	4km x 4km 1:5,000	10m x 10m	AIRPLANE NEAR SURFACE AND GROUND

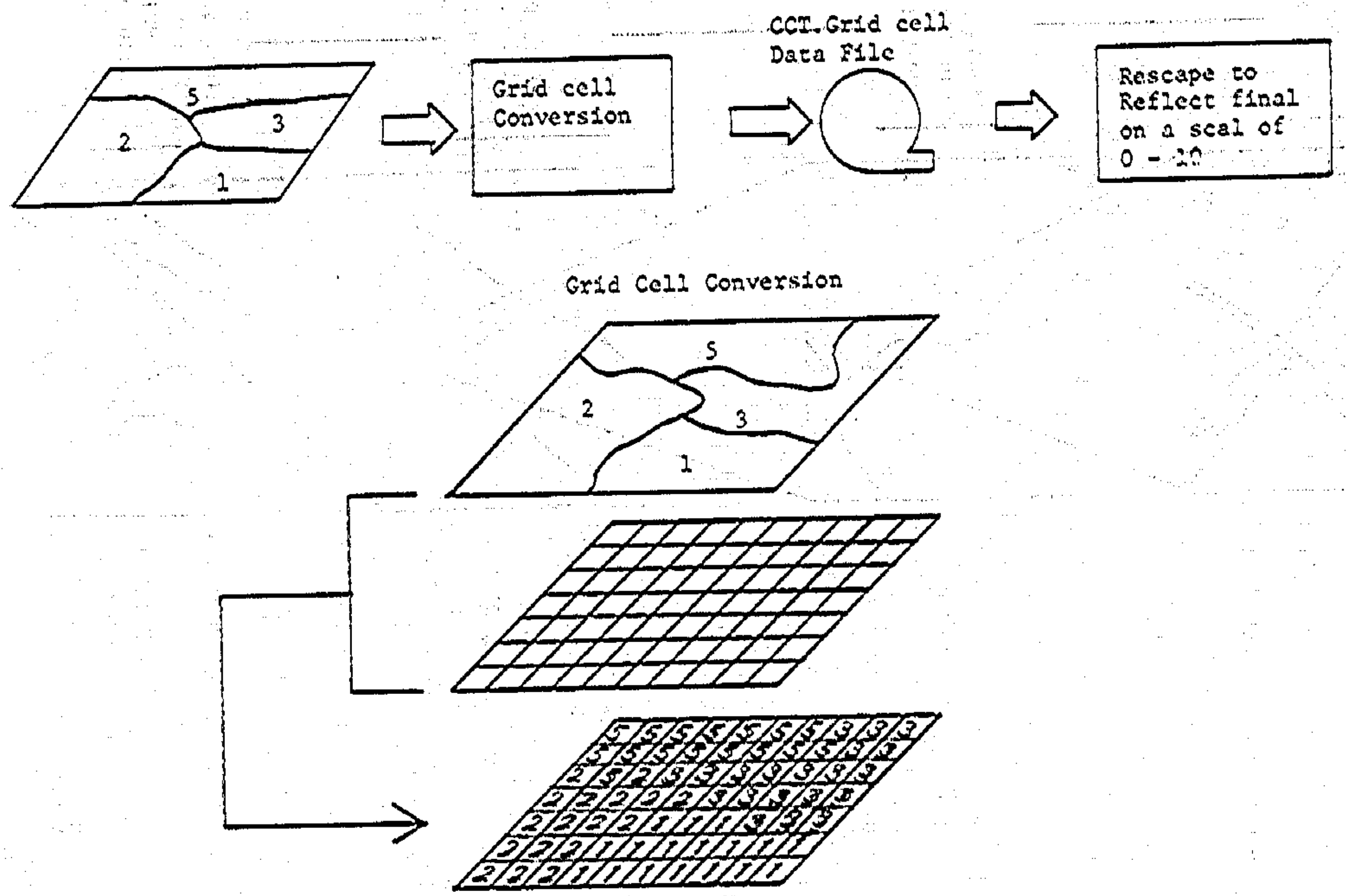


Fig. 2.4 Conversion of X.Y. Coordinate Data into Grid Cell Data File

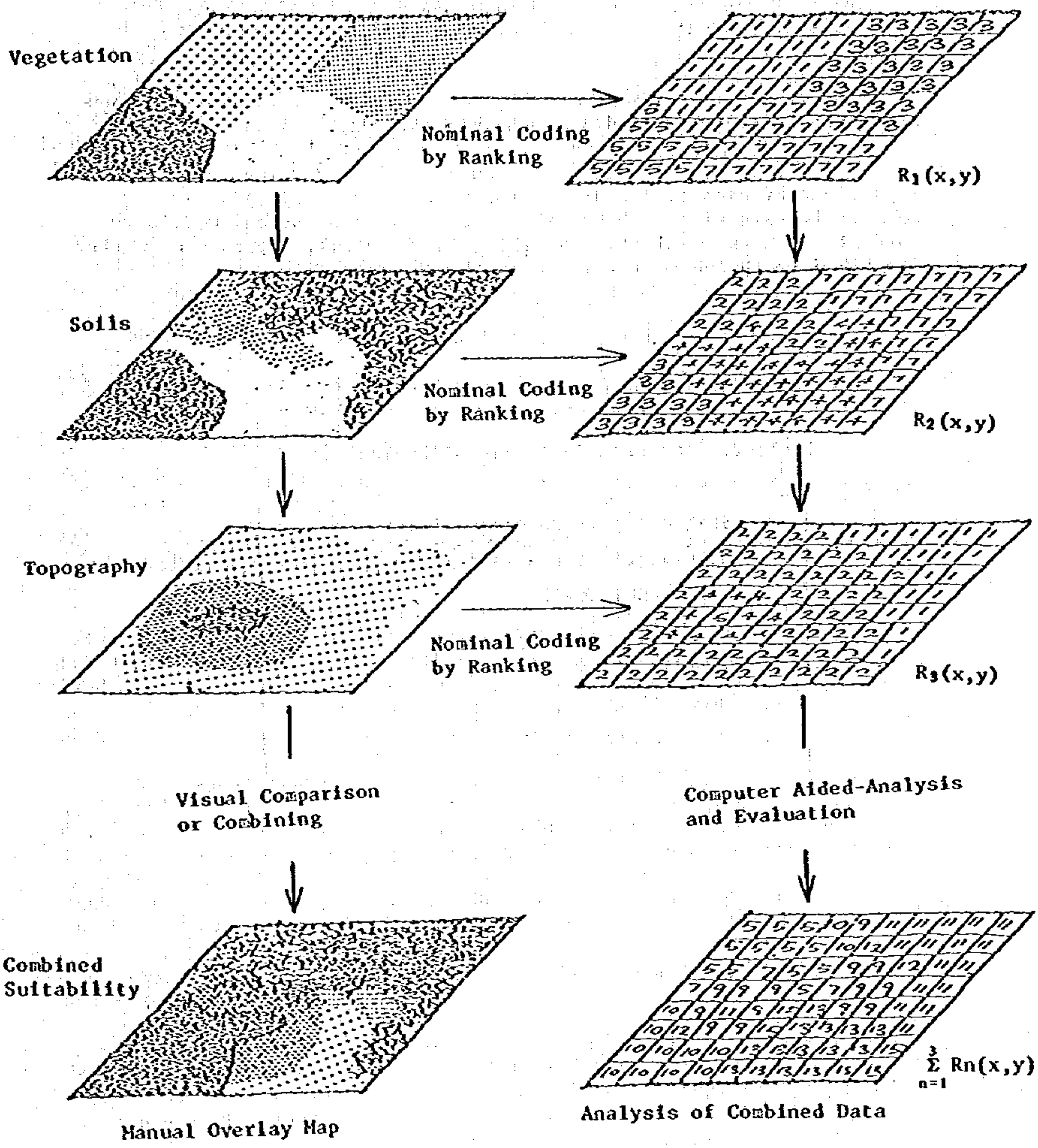


Fig. 2.5 A Simple Example of Integrated Analysis of Spatial Data (concept)

As shown in Fig. 2.5, total evaluation can be visually attained by overlaying thematic maps which are deduced from evaluating each factor.

Numerical evaluation is accomplished by summing evaluated values of corresponding grid cell in each grid cell data files.

In some case, weighted summation of evaluated values depending on importance of each evaluating factor to the final objective is used for total evaluation. Though there are many mathematical models to fulfill the total evaluation as shown in Table 2.1, the ranking method described in the chapter 4 is recommended.

Table 2.1 Mathematic for Total Evaluation

- Statical pattern classification
- Multi-variate analysis
- AND/OR/NOT Logic
- Weighting
- Screening
- Thresholding
- . . . . etc
- Filtering

Chapter 3 PROCESS OF THEMATIC MAPPING FOR SITE SELECTION FOR AGRICULTURAL DEVELOPMENT

3.1 Introduction

This report proposes a site selection system for agricultural development in Indonesia on the basic consideration of the multi-stage concept as stated in the chapter 2 and the evaluation model shown in the chapter 4.

The chapter 3 gives the process how to make thematic map which is important to grasp or estimate ① the present state of land use ② land stability ③ land productivity ④ land workability, which show physical location factors stated in the chapter 4.

The meanings of above mentioned 4 items are as follows.

① land use : land utilization type from the social point of view, for example, residential area or agricultural area

② land stability : possibility of erosion, land slide or flood

③ land productivity : degree of the difficulty to produce agricultural products

④ land workability : degree of the difficulty of land reclamation, or possibility of the mechanization of agriculture

Land stability, productivity and workability are estimated by the data such as vegetation, drainage system, elevation, slope gradient terrain, soil, geology and weather. The detail points how to estimate land stability, productivity and workability are stated in the chapter 4. Table 3.1 shows from what information source the data to estimate the above mentioned 4 items are mainly obtained.

This report proposes, as stated in the chapter 2, to use mesh data (grid cell data) of various information for site selection for agricultural development in digital analysis. Therefore, various information should be represented in not only thematic map but also in mesh data. It is easy to produce thematic map from mesh data by assigning color to each data. Therefore, the process of thematic mapping has the same meaning as the process of mesh data generation.

The paragraph 3.2 gives the process of land use mapping by remote sensing.

The paragraph 3.3 gives the process of thematic mapping and mesh data generation to estimate land stability, productivity and workability, from 3 main information sources such as remote sensing, topographical map and existing materials.

3.2 Land use map

3.2.1 Land use mapping

Land use map is a typical example of the thematic maps which can be produced by remote sensing technology. The important point is that the information directly collected by remote sensing is not the social classification, that is, land use, but the physical classification, that is, land cover.

Land use map can be produced from land cover map by other information or human judgement. The paragraph 3.2.2 and 3.2.3 give the process of land cover mapping by remote sensing.

The process of vegetation mapping is basically the same as the one of land cover mapping. Because different vegetations are considered physically to be different land cover.

3.2.2 Land cover mapping by satellite data

a. Available satellite data

Most suitable satellite data which are available for 5 years plan from April 1, 1980, Remote Sensing Technical Cooperation for Indonesia Agricultural Development, are LANDSAT MSS data. Table 3.2 shows available satellite data including the ones available after the 5 year plan.

MSS data of LANDSAT-3 and-4 are now available. Thematic Mapper (TM) data of LANDSAT 4 are already available experimental in a part of United States, but the ones of Indonesia are not yet available. Since the ground receiving stations in Indonesia and Thailand do not have the ability to receive TM data, TDRS(Tracking and Data Relay Satellite) is necessary to receive TM data of Indonesia at the ground receiving station in the United States. TDRS will launch twice in 1983. Therefore, if TDRS will function normally, TM data may be available in the 5 years plan. Since TM has 7 bands from visible to thermal infrared and has good ground resolution of 30 meters, TM data will be hopeful data for this plan.

NOAA-6 and-7 have low ground resolution of 1,100 meters, but have short observation period. Since NOAA-6 and NOAA-7 have the same sensor of AVHRR, observations every 6 hours are possible by both satellites. Seasonal change of grassland was investigated in the United States by AVHRR data.[1]

b. Process of land cover mapping by LANDSAT MSS data

Land cover map is produced by the following flow shown in Figure 3.1. Each step of the flow is described in the following items.

(1) Determination of season for LANDSAT MSS data

Select one or more seasons in order that different vegetation or agricultural site are easily distinguished by using LANDSAT MSS data.

(2) Data acquisition of LANDSAT MSS data

Obtain cloud free LANDSAT MSS data of the season determined in the step (1).

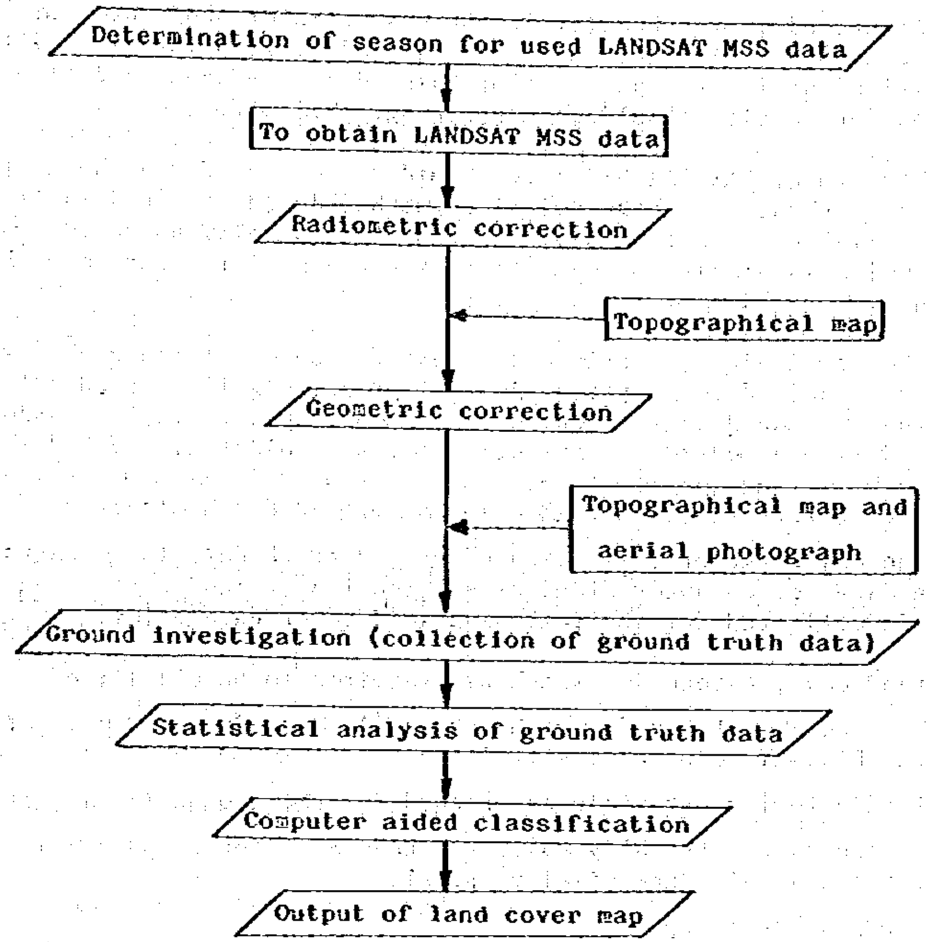


Figure 3.1 Flow of land cover map making by LANDSAT MSS data

(3) Radiometric correction

LANDSAT MSS has 6 detectors each band, collecting data on 6 lines simultaneously by one scan. Since the characteristics of these 6 detectors are slitely different, horizontal stripes appear every 6 lines on the LANDSAT MSS image. This is refered as scan line noise. Since the scan line noise causes bad effect to a computer aided classification, it must be removed by preprocessing.

Radiometric correction refered here is to remove scan line noise and it is carried out by computer processing.[2) 3)]

(4) Geometric correction

As stated in the chapter 2, the mesh data of land cover or land use are combined with the ones of other information for site selection for agricultural development. For this reason, ecah mesh data of various information should coincide geographically.

Therefore, LANDSAT MSS data should be rearranged to the national standard mesh system which coincides with the one of other information. The interval of mesh for LANDSAT MSS data is usually about 80 m or 100 m which is almost the same size as the ground resolution of LANDSAT MSS data.

The geometric correction refered here is to rearrange data to national standard mesh system and this processing is carried out by computer.5) The geometric correction needs topographical map from which about 10 ground control points per scene are selected.

(5) Ground investigation(collection of ground truth data)

The objective of collection of ground truth data is to extract sample data for computer aided classification of land cover. Sample data are collected for the following land cover categories.

① Land cover categories which are required to be classified

② Land cover categories which are easily discriminated each other on the LANDSAT color composite image

The following materials are needed for the ground investigation.

① Enlarged geometrically collected LANDSAT color composite image to extract sample data pixel by pixel

② Topographical map

③ Aerial photograph which is taken coincidentally with LANDSAT data

In the ground investigation, the above 3 materials are related with checking the state of land cover with sample data for each land cover categories which are marked on the material ①.

(6) Statistical analysis of ground truth data

Calculate mean, standard deviation and histogram for each band of each land cover categories and variance covariance matrix for each land cover categories and Mahalanobis distance between land cover categories by using sample data collected acoording the above step (5).

After statistical analysis, land cover categories are redesigned by seperation or integration for obtaining higher seperability by computer. And also misclassified data will be checked in this step.

(7) Computer aided classification

Maximum likelihood, texture analysis and tree type classificasion are frequently used as computer aided classification.5) The adopted method is selected by the characteristics of the image of the object area. That is, it is selected after statistical analysis of ground truth data and visual observation of the image. Multiple methods can be applied simultaneously.

Maximum likelihood method is recommendable in the case that Mahalanobis distances between land cover categories are large. Texture analysis is recommendable in the case that visual patterns on the image are different between land cover categories. Tree type classification is recommendable in the case that land cover categories are distinguished by some logical discrimination. This logical discrimination should be established by characteristics of sample data of each land cover categories.

Texture analysis is carried out only for a single image, but maximum liklihood method and tree type classification can be applied for multi-temporal images. When maximum likelihood method is applied to 2 seasonal LANDSAT MSS data, 4 x 2 = 8 dimentional data need much computing time. Therefore, in this case, Principal Component Analysis is frequently used for dimensional reduction. When vegetation or agricultural site are classified by seasonal difference of LANDSAT MSS data, tree type classification with logical discrimination by seasonal data difference can be applied.

Any classification method can not give a good result through only one trial. It is needed to try classification method repeatedly with changing land cover categories or parameters of classification method until getting a good result.

The number of land cover categories classified by LANDSAT MSS data in Japan is about 10 to 20.

Mesh size of land cover data got is eaqual size of geometrically corrected LANDSAT MSS data generated in the step (4), which is about 80 m to 100 m.

(8) Output of land cover map

Produce land cover map from land cover mesh data obtained in the step (7).

3.2.3 Land cover mapping by aerial photographic data

a. On-board sensor and ground resolution

Fine land cover is investigated by a scanner on an aircraft after comparatively rough land cover mapping by satellite data.

The typical sensor is multispectral scanner or aerial camera. Since multispectral scanner on an aircraft has large geometric distortion, aerial camera is better than multispectral scanner. Color infrared film is most recommendable, because it has effective information for land cover classification and that it is less subject to atmospheric scattering.

Aerial photographic film image should be digitized by AD conversion in order to classify land cover by computer. The resolution of color infrared film is about 30 linepairs/mm with a contrast of 1:10. That is, black line and white line with a width of 16 micrometers can be distinguished. On the other hand, aperture size of digitizer is about 25 to 200 micrometers at the present state of the technology. Therefore, pixel size on the ground of the data digitized from aerial photographic film is determined by a scale of photographic film and an aperture size of digitizer. For example, digitization of the film with a scale of

1:50,000 with an aperture size of 100 micrometers makes ground resolution of 5 m.

b. Process of land cover mapping by aerial photographic data

Land cover map is produced by the following flow shown in Figure 3.2. Since the flow shown in Figure 3.2 is almost same as the one in Figure 3.1 of LANDSAT MSS data, only the different steps are explained below.

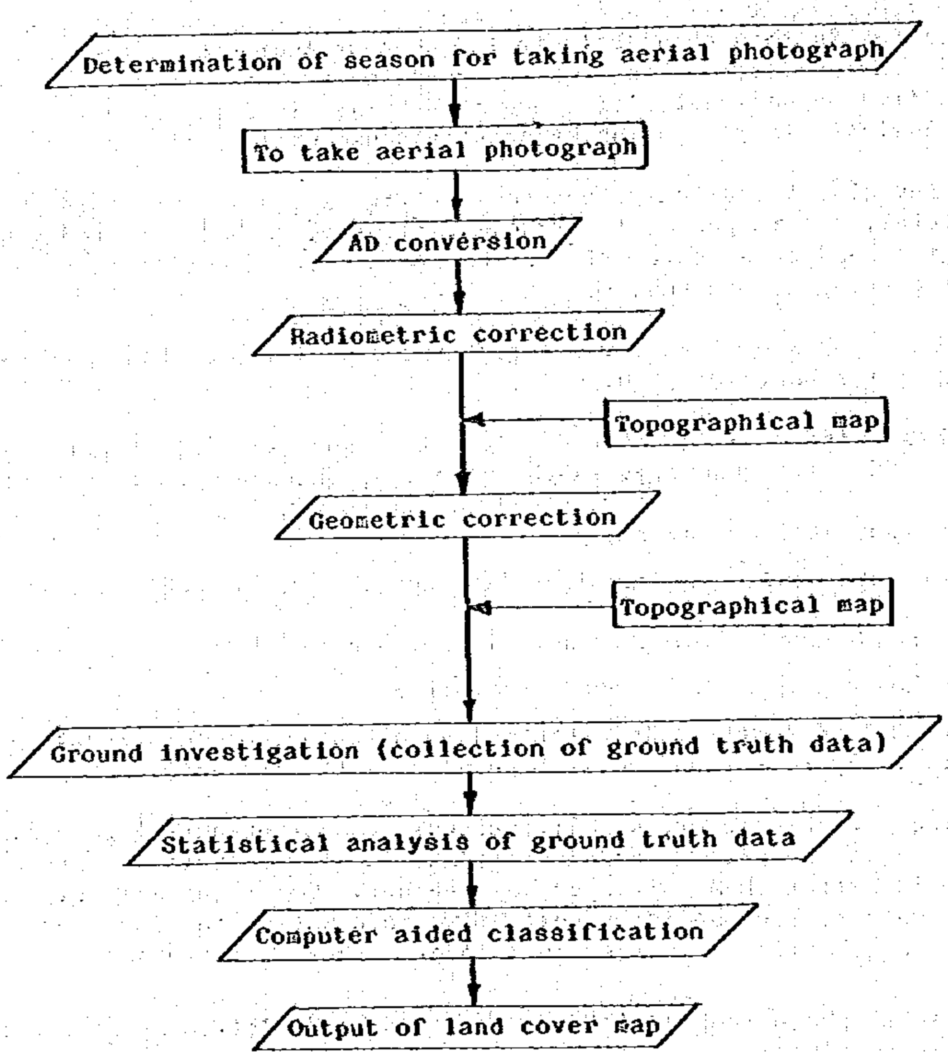


Figure 3.2 Flow of land cover map making by aerial photographic data

(1) AD conversion

Digitize color infrared film through three filters of red, green and blue by AD conversion.

(2) Radiometric correction

Aerial photographic film has radiometric distortions called shading. For example, circumference reduction of illumination by lense system is one of these distortions and it is usually removed by cosine correction. Radiometric correction should be carried out to get good result by computer aided classification.

(3) Geometric correction

Data digitized from photographic film should be rearranged to national standard mesh system which coincide the one of other information. For this geometric correction, coordinate transformation consists of two coordinate transformations as described below using photographic coordinate which is difined by fiducial marks at the four corner of photographic film.

(i) Image coordinate and photographic coordinate

Coordinate transformation is determined by using image coordinates of four fiducial marks on a film. Affine transformation is usually enough to this coordinate transformation.

(ii) Photographic coordinate and ground coordinate

Coordinate transformation is determined by photogrammetric colinearity equations with three or more ground control points whose ground coordinates and photographic coordinates are known. The photographic coordinates of ground control points are determined from their image coordinates by coordinate transformation of (i).

3.3 Thematic maps to estimate land stability, productivity and workability

3.3.1 Thematic mapping by remote sensing

Among thematic maps to estimate land stability, productivity and workability, vegetation map and drainage map are easily produced by remote sensing as shown in Table 3.1.

a. Vegetation map

Since vegetation can be classified as the difference of land cover, vegetation map can be produced by the same process as land cover map as stated in the paragraph 3.2. While LANDSAT MSS data give comparatively rough classification result, photographic film gives finer classification result. There are two methods for vegetation classification that is a method by a computer and a method by a human interpretation. A method by a computer has a merit of short processing time and a demerit of lower classification accuracy. The one by human interpretation is vice versa. Therefore, one of these two methods should be selected from the view point of vegetation categories to be classified and area of object site.

Table 3.1 Source of data to estimate natural location factor

Natural location factor	Data to estimate (Thematic map)	Main source to get data		
		Remote sensing	Topographical map	Available materials
Land use	Land use	○		
Land stability productivity workability	Vegetation	○		
	Water system	○		
	Elevation		○	
	Slope inclination		○	
	Terrain		○	
	Siol			○
	Geology			○
	Weather			○

b. Drainage map

Since water absorbs near infrared well, it is easily detected by remote sensing. Drainage mapping by remote sensing has the following two problems

(i) Water area covered by vegetation can not be detected. Therefore such area should be surveyed by topographic map or other existing materials.

(ii) Water area smaller than a pixel size of remote sensing image can not be detected.

Drainage mesh data has two types with respect to a pixel size of remote sensing image. When the pixel size is the same size as a mesh, produced mesh data is 0-1 data which show whether the mesh includes water body or not. On the other hand, when a mesh includes multiple pixels, produced mesh data show water are included in each mesh.

3.3.2 Thematic mapping of terrain information

Terrain information is the information about terrain features such as elevation, slope gradient and slope aspect. Terrain information can be calculated from elevation mesh data. Elevation mesh data is refered as Digital Elevation Model (DEM). DEM can be generated from one of the following three materials.

① Stereo image from satellite

② Stereo aerial photograph

③ Topographc map

The method ① is now in planning stage and does not realize yet. The method ② is the only one method in the case that topographic map is not available. The method ③ is the easiest one.

In this paragraph, firstly, the method to produce DEM from topographic maps is described and, secondly, the method to calculate other terrain informations from DEM is described.

a. Production of DEM from topographical maps

There are the following three methods to produce DEM from topographical maps.

① To collect elevation data by a human

② To measure coordinate by a digitizer

③ To digitize a map by a scanner

The method ① is the one to overlay mesh on a topographical map and to read elevation data on the mesh node by a human. This method needs much time and efforts.

The method ② is the one to measure planimetric coordinates of the points on contours of a topographic map. Elevation mesh data are produced from measured points by interpolation processing.

The method ③ is the one to generate 0-1 data in the form of fine grid by scanning a contour map with small aperture and AD conversion. Elevation mesh data are produced from digitized 0-1 data and elevation value on each contour by interpolation processing. Since a topographical map includes many symbols and characters besides contours, it is difficult to extract only contours from a topographic map. Therefore, an original contour map from which a topographical map are produced or a contour map which is extracted from a topographical map by human hand are used.

Mesh size of elevation data is important since other terrain informations are extracted with the same mesh size as the one of elevation data. For example, mesh size of 5 mm on a topographical map with a scale of 1:50,000 corresponds to 250 m on the ground. In order to produce 20 m - 30 m mesh data, a topographical map with more large scale, for example 1:5,000, is needed.

b. Production of thematic maps from DEM

Terrain information such as slope gradient and slope aspect can be calculated from elevation mesh data stated above by the following simple formula.$^{5)}$

(i) Slope gradient

α : Slope gradient at the point o

$$\alpha = \tan^{-1}\sqrt{\left(\frac{z_E - z_W}{2d}\right)^2 + \left(\frac{z_N - z_S}{2d}\right)^2}$$

where d : interval of mesh (meter)

z_E, z_W, z_n, z_S : elevation data of 4 points neighboring the point o(meter) (See Figure 3.3)

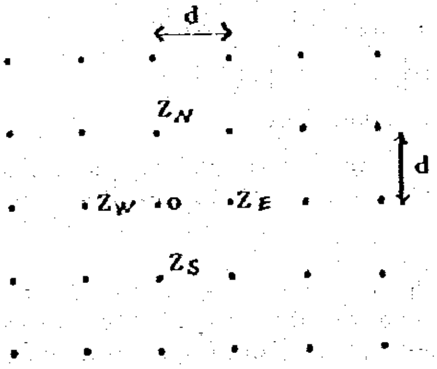


Figure 3.3 Elevation mesh data

(ii) Slope aspect

θ : Slope aspect angle measured clockwise from the north

if $x<0$ $\theta = 90° - \tan^{-1}(\frac{Y}{X})$
if $x=0$ and $Y<0$ $\theta = 0°$
if $x=0$ and $Y=0$ horizontal plane
if $x=0$ and $Y>0$ $\theta = 180°$
if $x>0$ $\theta = 270° - \tan^{-1}(\frac{Y}{X})$

where $X = \frac{Z_E - Z_W}{2d}$

$Y = \frac{Z_N - Z_S}{2d}$ (see Figure 3.3)

Terrain information can be calculated from elevation data easily by the above formula. Mesh size of produced data is the same as the one of elevation data.

3.3.3 Utilization of existing materials

It is impossible to collect enough information about soil or geology by only remote sensing. One reason is that some information about soil or geology such as phosphoric acid absorption coefficient can not be collected directly by remote sensing. The other reason is that almost all parts of terrain surface are covered by vegetation and that they can not be observed directly by remote sensor.

By utilizing the second reason conversely, the information about soil or geology can be collected indirectly. That is, the relationship between vegetation and soil or geology helps to know about soil or geology indirectly by remote sensing. This method is refered in the paragraph 4.1.3.

Since this method can not supply enough information, it is useful only when there is not any other materials about soil or geology in the object area. When there is some existing materials about soil or geology, it is better to use them. The existing materials refered here means thematic maps.

Main types of thematic maps are represented in area map and line map. A thematic map of area map type shows an area of segments by color or closed region. A thematic map of line map type shows line features on the ground such as river or road. Below is the explanation of the method to convert from a thematic map of both types to mesh data.

a. Conversion of area map to mesh data

There are the following two methods to produce mesh data from a region thematic map.

① To measure coordinates by a digitizer (See Figure 3.4)

② To discriminate color by a scanner (See Figure 3.5)

The method ① is the one to approximate area of each item on a thematic map as closed polygons. Mesh data are produced by searching which polygon each mesh are included by computer.

The method ② is the one to discriminate color on a thematic map by a scanner after putting color on each region.

b. Conversion of a line map to mesh data

There are the following two methods to produce mesh data from a line map similarly to an area map.

① To measure coordinates by a digitizer (See Figure 3.6)

② To digitize a line map by a scanner (See Figure 3.7)

Table 3.2 Available satellite data

Satellite	Country	Sensor	Band	Ground Resolution	Observation period
LANDSAT-3	U.S.A.	MSS (Multispectral scanner)	5	80 m	18 days
LANDSAT-4	U.S.A.	MSS	4	80 m	16 days
ditto	ditto	TM (Thematic mapper)	7	30 m	16 days
NOAA-6	U.S.A.	AVHRR (Advanced very high resolution radiometer)	5	1100 m	12 hours
NOAA-7	ditto	ditto	ditto	ditto	ditto
SPOT	France (launch 1984)	Linear array	3	20 m	26 days

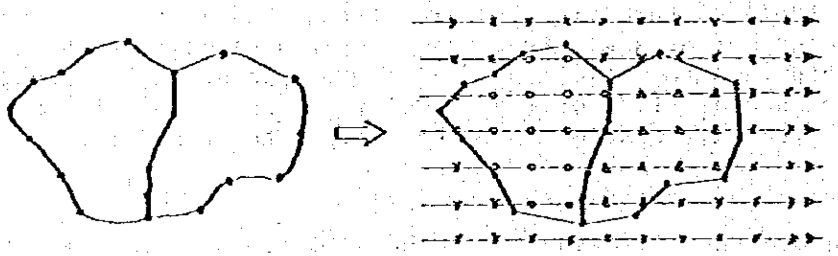


Figure 3.4 Method by a digitizer

The method ① is the one to approximate lines on a thematic map as polygonal lines and to measure nodes of polygonal lines by a digitizer. When to produce mesh data with 0-1 value which shows whether a mesh includes line or not, small mesh is generated by computer. When to produce mesh data which shows the length of lines within a mesh, large mesh is generated. The length of lines is calculated as the length between nodes of a polygonal line.

The method ② is the one to digitize lines on a thematic map to 0-1 data by a scanner, where 0-1 data shows whether a mesh includes line or not. In order to produce data which shows the length of lines within a mesh, large mesh is produced by integrating small meshes. The length of lines is calculated by counting small meshes with value 1.

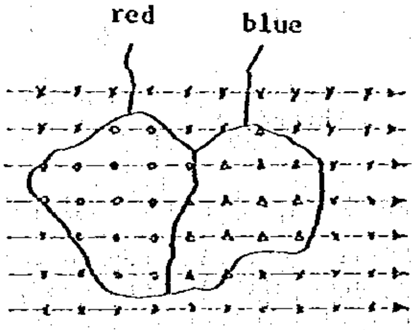


Figure 3.5 Method by a scanner

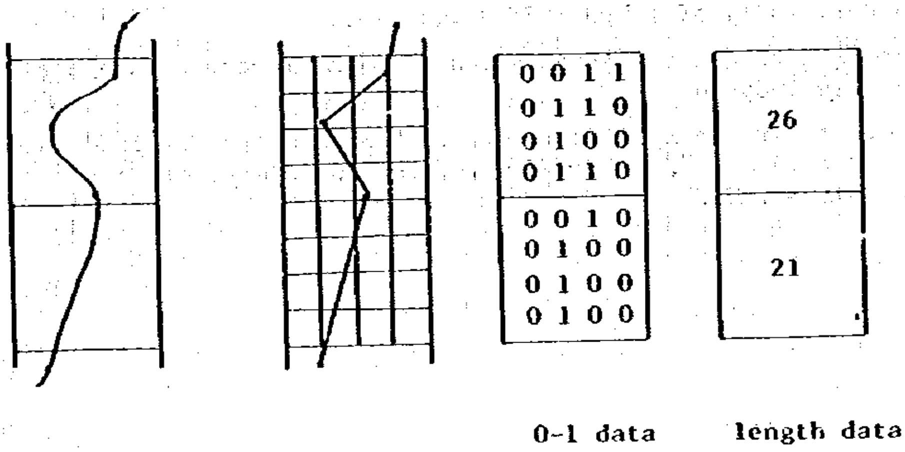


Figure 3.6 Method by a digitizer

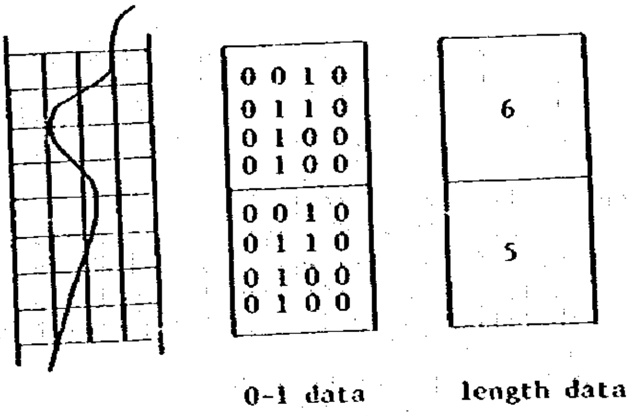


Figure 3.7 Method by a scanner

REFERENCE

1) Landsat Data Users Notes, NOAA, December 1982

2) Hiroshi Maeda, Shunji Murai etc., "A study on radiometric cooreection for LANDSAT MSS by using accumulated histogram", Journal of the Japan Society of Photogrammetry 1980 Vol.19 No.4

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Chapter 4 MODEL FOR DEVELOPMENT OF AGRICULTURAL INFRASTRUCTURE

4.1 Total evaluating technique considered from physical factors

In evaluating the suitability for agricultural lands, it is very important to consider what kind of manufacturing techniques are utilized. For example, in the primitive agriculture in burn field, where human power is mainly used. the most important evaluating factor is production power of farm soil. However in modern agriculture where animal power and machine power are utilized, soil fertility and slope which restrict the application of machine power and animal power, become the most definitive factors. This chapter will be predicated considering on mechanized farming of high technical level, which are widely used in the world and expected to be adapted in near future in Indonesia.

4.1.1 Physical factors for evaluating agricultural land

In Japan slope, depth of soil, soil texture and gravel content are utilized as physical factors for land classification. These four factors are deduced from various surface investigation as climate, drainage, water quality, and geography and soil. Those four factors affect on soil fertility, workability, soil erosion. Classification by these four factors is performed on the premise that Japan is situated in the temperate monsoon climate zone. Therefore, if applied to any other countries where climate, soil and geology are different, some modifications and corrections are necessary. However, these four factors are considered as fundamental in any country.

Fig. 4.1 indicates an evaluating procedure in Japan for the land reclamation project.

(a) Slope

The working efficiency and operating accuracy of farm machineries decreas as the slope becomes steeper. Beyond some limit of slope the farm machines cannot be utilized. This limit is about 10-15 degree depending on vegetation and content of the field workings.

Danger of soil erosion increases as the slope becomes steeper.

Fig. 4.2 shows an example of the relation between the slope and workability. As the slope becomes steeper than 15 to 18 degree, the danger of soil erosion critically increases which is also influenced by rain fall, soil texture and land coverage.

Table 4.1 indicates the relationship between slope and quantity of soil erosion at typical area of Japan. From this table it is concluded that slope of less than 8 degree is optimum for the reclamation into the dry fields and that slope of more than 30-35 degree is not suitable from the view of utilizing the farm machine and prevending soil erosion.

Table 4.2 presents a standard for land classification by slope and their ranking orders, which are used in Japan.

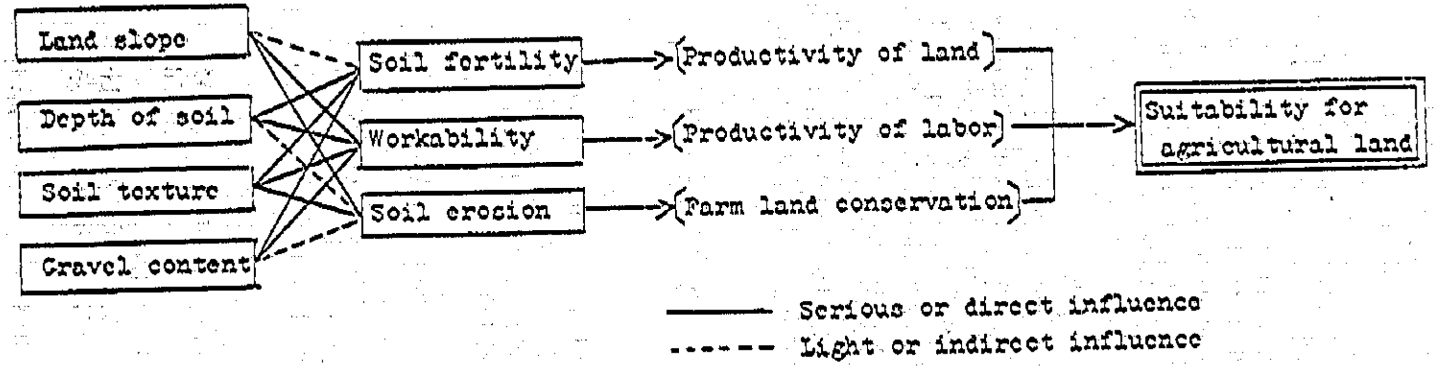


Figure 4.1 Procedure of land-evaluation for the land-reclamation-project in Japan.

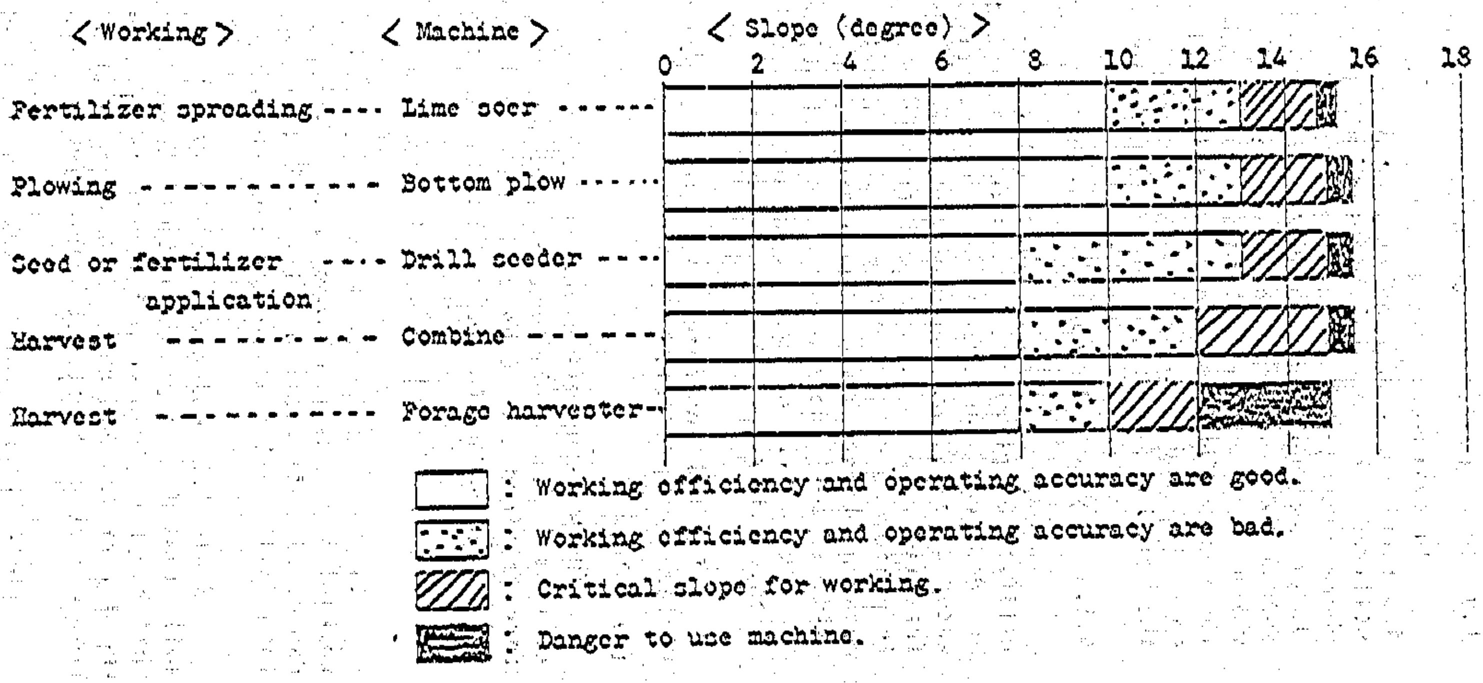


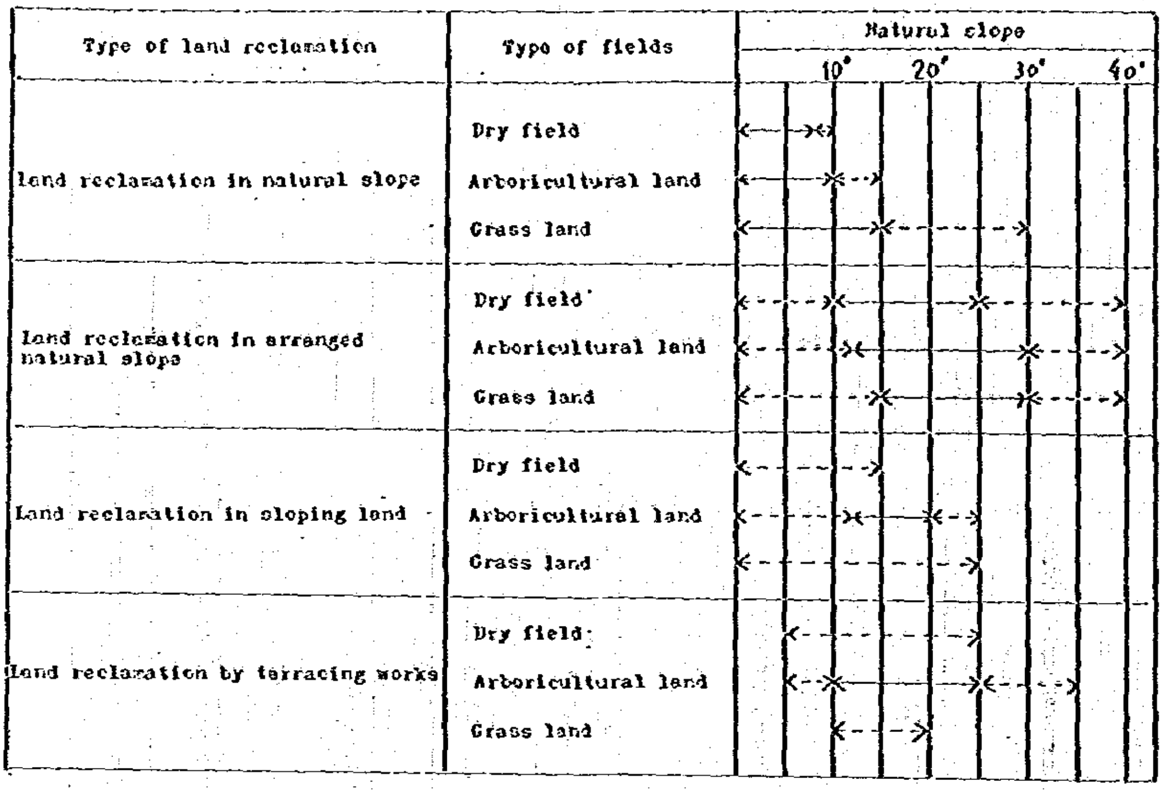
Figure 4.2 Critical slope for farm machinery.

Table 4.1 Correlation between erosion and slope.

Site	Soil	Gradient of slope	Runoff (mm)	Soil loss (kg/10a)	Crop
MORIOKA	Volcanic soil	10°	1.2	6.6	Corn-wheat-turnip
		15	1.6	6.6	
		20	2.1	30.0	
NAGANO	Soil from shale	10	9.6	74.5	Soybean
		19	9.2	200.5	
		28	7.7	2509.5	
		33	14.7	3747.0	
KAGAWA	Soil from granite	3	51.6	12.9	Sweet potato
		10	28.0	70.9	
		14	21.9	176.3	
		23	83.4	956.3	

Table 4.2 Standard of land classification by slope. (for reclaiming to dry field)

Rank	Slope	Evaluation	
1	Less than 3°	Farming mechanization is possible.	There is no erosion.
2a	3 ~ 8°	Farming mechanization is almost possible.	Danger of erosion is slight or moderate.
2b	8 ~ 12°	Farming mechanization is partly possible.	
2c	12 ~ 15°	Some type of farm machine can not be used.	
3	15 ~ 30°	Farm machine can be partly used, but working efficiency will be bad.	Danger of erosion is moderate or severe.
4a	30 ~ 35°	Critical slope for land reclamation.	Danger of erosion is severe.
4b	More than 35°	Land reclamation is not suitable.	



←——→ Suitable

←- - -→ . Possible in special case

* Land reclamation in arranged natural slope ;

When the land slope is steep, land reclamation in natural slope will be impossible. In this case, you arrange the slope gently or flatten the ground by machine power, and reclaim the land to sloping fields.

* Land reclamation in sloping land ;

Farm road will be laied out along the contour line, and inclined plane is used as fields.

Fig. 4.3 Type of Land Reclamation According to Natural Slope

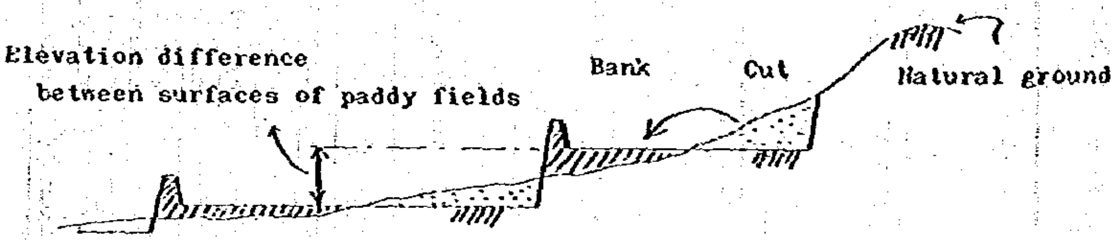


Figure 4.4 Reclaming to paddy field in sloping land

Table 4.3 Standard of land classification by slope. (for reclaiming to paddy field)

Rank	Slope	Evaluation
1	Less than 1/100(35')	Rectangular block size(30a) of paddy field is possible and elevation difference is less than 1 meter.
2a	1/100∼1/35 (35'∼1°40')	Rectangular block size(30a) is possible and elevation difference is less than 1 meter.
2b	1/35∼1/20 (1°40'∼3°)	Rectangular block size(30a∼20a) is possible but elevation difference is 1 meter or so.
3a	1/20∼1/10 (3°∼6°)	Distorted block size(30a∼20a) is possible but elevation difference is more than 1 meter.
3b	1/10∼1/7 (6°∼8°)	
4a	8°∼10°	Critical slope of land reclamation to paddy field.
4b	More than 10°	Land reclamation to paddy field is not suitable.

Elevation difference —— It means a height difference of surface between a paddy field and next ones.

Block size 30a ———— 30m x 100m

Table 4.4 Standard of land classification by depth of soil(for reclaiming to dry field)

Rank	Depth of soil	Evaluation
1	More than 100cm	Reasonable yield will be expected and ordinary farm working is possible.
2	100 ~ 70cm	In the case of terracing works, there will be a little restriction of works. Land reclamation in natural slope is suitable.
3	70 ~ 40cm	In the case of terracing works, there will be considerable restriction of works according to land slope. Land reclamation in natural slope is almost suitable.
4	Less than 40cm	Terracing works is not suitable. Land reclamation in natural slope is possible but resonable yield is not expected and ordinary farm working is impossible.

Table 4.5 Standard of land classification by depth of soil. (for reclaiming to paddy field)

Rank	Depth of soil	Evaluation
1	More than 100cm	There is no restricution of land reclaiming works accordings to land slope
2	100 ~ 70cm	There is considerable restriction of land reclaiming works according to land slope
3	70 ~ 40cm	There is a little restriction of land reclaiming works according to land slope
4a	40 ~ 25cm	Land reclamation is impossible according to land slope.
4b	Less than 25cm	Land reclamation to paddy field is not suitable.

Fig. 4.3 shows types of land reclamation and their effective slope angles for various kinds of field.

For paddy fields, the slope angles of reclamation land are mainly limited by the size of the paddy field and the elevation difference between each paddy field. Fig. 4.4 illustrates an reclamation technique for the paddy field, where surface of the paddy field must be kept horizontal. In reclamation of the paddy field, slope of less than 3 degree is prefered. In case of more than 3 degree, reclamation cost extraordinally increases and more than 8 degree is not suitable for the paddy field.

Table 4.3 indicates a slope classification standard for reclamation of field.

(b) Depth of soil

Depth of soil is very important for management of farm land such as plowing and land grading and also for reclamation of farm land. The optimum depth of soil for the reclamation is more than 70 cm. Depth of less than 40 cm is not suitable for farm land. Table 4.4 and 4.5 indicate land classification standards by the depth of soil for dry field and paddy field respectively.

(c) Soil texture

Soil particles contained in the soil are classified by their particle sizes into four classes ; sand, gravel, silt and clay. Soil texture is defined by the mixture ratio of three components, that is, sand, silt and clay, excluding gravel. Fundamental properties of soil such as retentivity of water and nutrient, and permeability of water and air depend on this texture.

Table 4.6 Soil texture and grain size formation.

	Soil texture	Sign	Clay(%)	Silt(%)	Sand(%)
Sand	Sand	S	0~5	0~15	85~100
	Loamy sand	LS	0~15	0~15	85~95
Loam	Sandy loam	SL	0~15	0~35	65~85
	Loam	L	0~15	20~45	40~65
	Silty loam	SiL	0~15	45~100	0~55
Clay loam	Sandy clay loam	SCL	15~25	0~20	55~85
	Clay loam	CL	15~25	20~45	30~65
	Silty clay loam	SiCL	15~25	45~85	0~40
Clay	Sandy clay	SC	25~45	0~20	55~75
	Light clay	LiC	25~45	0~45	10~55
	Silty clay	SiC	25~45	45~75	0~30
	Heavy clay	HC	45~100	0~55	0~55

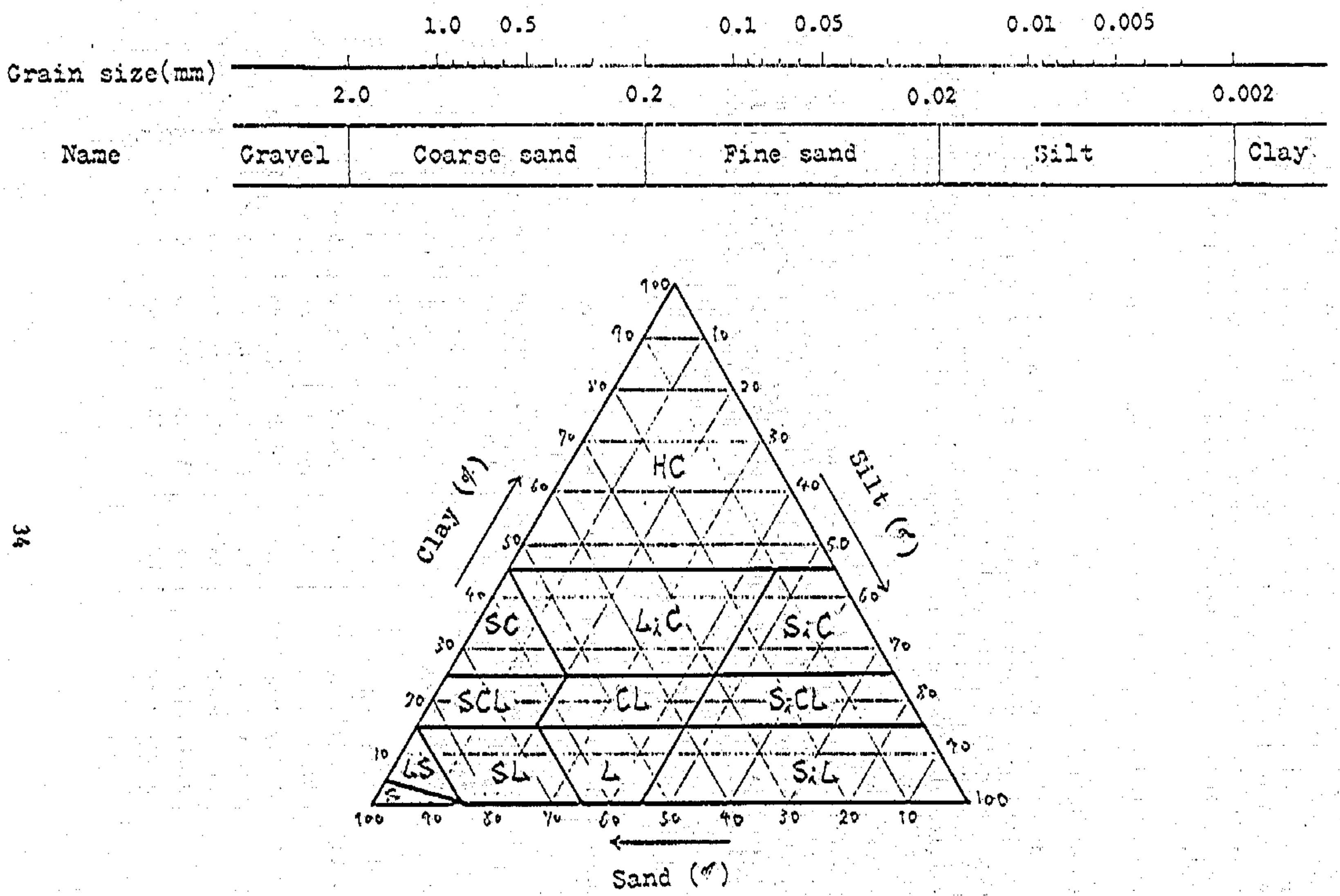


Figure 4.5 Grain size classification and triangular diagram for soil texture.

Fig. 4.5 shows an internationally accepted grain size distribution of soil texture and triangle presentation of soil texture. In Table 4.6 names and symbols of soil texture and their compositions are presented.

Soil texture is an important factor, which influences on the soil power, workability and soil erosion. For example, water retentivity which is necessary for the growth of crops becomes higher as the contained amount of silt and clay becomes larger, as shown in Table 4.7. The infiltration capacity of soil which affects the drainage and irrigation method for the farm land depends on the soil texture as shown in Fig. 4.6.

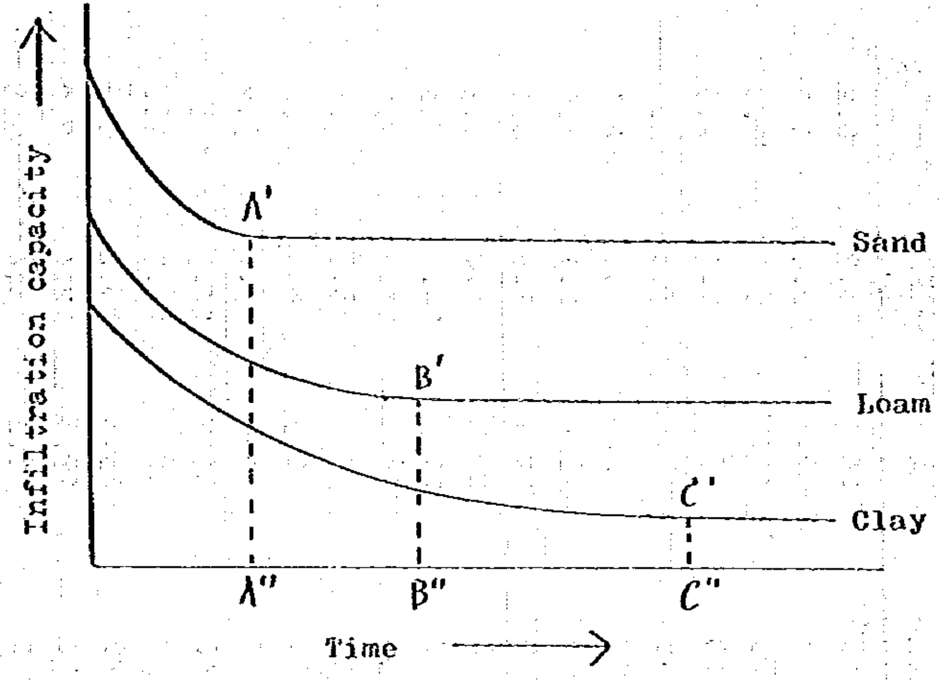


Figure 4.6 Soil texture and infiltration capacity.

Suitable soil texture for the agricultural land is generally sandy loam, loam or clay loam rich in water retentivity, air permeability and ability of drainage. The suitability of soil texture depends on crops of course. Land classification standards by soil texture for the dry field and the paddy fields are presented respectively in Table 4.8 and Table 4.9.

Table 4.7 Water retentivity of soil

Soil	Grain size formation		Field capacity ⓐ	Wilting point ⓑ	Water retentivity ⓐ – ⓑ
	Silt	Clay			
Diluvial soil	16%	45%	24.4%	18.2%	6.2%
	12	35	16.8	12.8	4.0
	9	25	11.7	9.1	2.6
	7	20	10.0	7.1	2.9
	5	15	7.9	5.8	2.1
	4	10	5.6	3.5	2.1
	2	5	3.6	2.1	1.5
	0*	0*	2.1	1.5	0.6
Diluvial soil	25	50	26.3	18.0	8.3
	25	40	21.3	14.1	7.2
	25	30	18.5	11.5	7.0
	25	20	15.4	8.8	6.6
	25	10	12.5	6.5	6.0
	25	0	8.6	3.4	5.2
Volcanic soil	25	40	34.7	24.3	10.4
	25	30	28.6	21.0	7.6
	25	20	23.8	16.2	7.6
	25	10	19.6	12.4	7.2
	25	0	16.2	8.4	7.8

* Sand 100%

Table 4.8 Standard of Land Classification by Soil Texture
(for Reclaiming to Dry Field)

Rank	Soil texture	Evaluation
1	Loam, Clay loam, Clay, Sandy loam, Volcanic loam, Volcanic clay loam	Reasonable yield will be expected and ordinary farm working is possible.
2	Sand, Volcanic sandy loam, Heavy clay, Low-moor peat, Transitional-moor peat	There are considerable restrictive factors for reasonable yield or ordinary farm working. In some cases, land improvement works will be nec~~c~~essary
3	Gravel, Volcanic sand, Volcanic gravel, High-moor peat	There are large restrictive factors for reasonable yield or ordinary farm working. Land improvement works are nec~~c~~essary.

Table 4.9 Standard of Land Classification by Soil
(for Reclaiming to Paddy Field)

Rank	Soil texture	Evaluation
1	Loam, Clay loam, Clay	Reasonable yield will be expected and ordinary farm working is possible.
2	Sandy loam, Volcanic loam, Volcanic clay loam	There will be a little restrictive factors for reasonable yield or ordinary farm working. In the reclaming works, special consideration is nec~~c~~essary.
3	Sand, Volcanic sandy loam, Heavy clay, Low-moor peat, Transitional-moor peat	There are considerable restrictive factors for reasonable yield or ordinary farm working. Land improvement is always nec~~c~~essary.
4	Gravel, Volcanic sand, Volcanic gravel, High-moor peat	Land reclamation to paddy field is not suitable, because there are large restrictive factors for reasonable yield or ordinary farm working.

(d) Gravel content

Gravels contained in the soil are not only obstacles for the growth of crops but also impedients to various farm works such as reduction of farm work efficiency and destruction of farm machine. It is prefered to keep gravel content of the soil below 5 % (volume percent). Table 4.10 shows land classification standard by gravel content and their ranking orders for dry field and paddy field.

(e) Other factors

Four factors of slope, depth of soil, soil texture and gravel content described above are the most important factors for assessment of the agricultural suitability of factors which affect the quality of the reclaimed farm land. These factors must be always adopted for evaluating the reclamed land regardless of the study area and the farming pattern. Baside these four factors, the following factors may be adopted.

Topographic condition	pattern, length and aspect of the slope location, terrain relief etc.
Soil condition	soil moisture, cohesion of surface soil, water permeability, cation exchange capacity phosphate absorption, etc.
Water supply condition	facilities of irrigation and drainage water channels, distances from rivers and lakes, etc.
Climate condition	air temperature, rainfall, snow fall meteorological disasters.

With these many factors, the assessment becomes more concrete and more accurate. However, the weights of these factors on the assessment seem to be relatively lower than those of previously mentioned four factors, because the assessment fluctuates heavily by other causes. For example, topographic condition factors such as aspect of slope and location, water pormeability and pH which have close relations with the growth of crops, can be modified and improved by the modern culutivation technique and the land improvement technique.

Water supply condition are very important for supplying the agriculutural water, but their assessment standards also undergo a change by building dams and constructing irrigation and darainage water channels. In addition, climate condition may become affecting factor for large study area, but not for small area less then 100 km^2. Their assessment standards also vary depending on the selection of crop type cultivation techniques. Accordingly, all factors except slope, depth of soil, soil texture and gravel content must be selected so as to accomodate to the actual situation in the study area.

(f) Selection of evaluating factors in the multistage screen process

In order to evaluate site selection of agricultural land by physical factors, it is necessary to select the most effective and important factors after examining technical level of reclamation and land improvement, crop

Table 4.10 Standard of Land Classification by Gravel Content
(for Reclailing to Paddy Field or Dry Field)

Rank	Gravel content	Evaluation
1	Less than 5%	Reasonable yield will be expected and ordinary farm working is possible.
2	5 ~ 10%	According to some crop, there will be a little restriction of reasonable yield or ordinary farm working. Removal of gravel is unnecessary.
3	10 ~ 30%	There is large restriction of reasonable yield or ordinary farm working. Removal of gravel is always necessary.
4a	More than 30%	Land reclamation is not suitable but some crop may be able to grow.
4b	Rock or large gravel	Land reclamation is not suitable.

Table 4.12 Standard of Land Classification (for Land Reclamation to Dry Field)

Factor \ Rank	I	II	III	IV
Slope	0 ~ 3°	3 ~ 15°	15 ~ 30°	More than 30°
Depth of soil	More than 100cm	100 ~ 70cm	70 ~ 40cm	Less than 40cm
Soil texture	SL, L, SiL, SCL, CL, SiCL, SC, LiC, SiC, Volcanic L, Volcanic CL	S, LS, HC, Volcanic SL, Low-moor peat, Transitional-moor peat	Gravel Volcanic S, High-moor peat	—
Gravel content	Less than 5%	5 ~ 10%	10 ~ 30%	More than 30%

Table 4.11 Evaluation Factors of Natural Condition in Multistage Assessment

	Regional assessment	Local assessment	Site assessment
Weather condition	Climatic zone Temperature Precipitation Snow Frostless period Meteorological disasters	Temperature Precipitation Solar radiation Wind direction Wind velocity Meteorological disasters	Micro-climate
Water use and Water quality	River basin Discharge Danger of flood	Distance from river Distance from canal Discharge Water quality Danger of flood	Discharge Water quality
Topography and Geology	Topography (rough grouping) Geology of top soil	Topography (fine grouping) Geology of top soil Land-slope	Land-slope Direction of slope Shape or length of slope Location in slope Undulation
Soil	Soil type	Soil type Soil texture Soil moisture pH	Depth of soil Gravel content Water permeability pH Cohesion Cation exchange capacity Phosphate absorption coefficient
Vegetation	Natural vegetation Forest type	Vegetation cover Forest type Crown density	Crown density Diameter of tree Number of trees

type, productivity level, area of reclaimed land and climate characteristics in the study area.

Table 4.11 presents the factors in each stage of the multistage screen process described in the chapter 2. In a few case, some factors are not available because of lack of data. In such case, it is advisable to find out the similar or substitutive factors.

4.1.2 Total evaluation method for selecting suitable farm land.

Several evaluating and ranking methods are utilized to select suitable farm land in reclamation project in Japan.

(a) Ranking method

This method is mainly applied to classify farm lands which have similar productivities. Reclaimed areas are classified and ranked as class 1, class 2, ... etc., in the term of prescribed factors. In Japan, four factors of slope, depth of soil, soil texture and gravel content are utilized. Each class designates following evaluation value.

class 1	most suitable
class 2	moderate suitable with some risk of soil erosion and some obstacles for farm works
class 3	less suitable with danger of soil erosion
class 4	unsuitable

Table 4.12 and Table 4.13 present land classification standard for dry field and paddy field respectively. Evaluation should be done by the lowest class among evaluated values for four factors.

For example, if depth of soil, soil texture and gravel content are judged as class 1, and slope as class 3, evaluated class of the land is ranked as class 3.

Since these tables can be applied only to Japan, some modifications are necessary, when this method is applied to any other country.

Hiwatashi(1977) proposed a standard as indicated in Table 4.14 to utilize aerial photographs for land use classification in South East Asia. As stated in Table 4.14, six factors of slope, terrace, soil erosion, depth of soil, soil texture and soil moisture are utilized. Ranks and categories of those factors are classified as follows. However, this standard should be modified if used in Indonesia.

(1) Slope

Rank		
1	Flat	0 - 3°
2	Rolling	3 - 10°
3	Meandering	10 - 25°
4	Steep or terrace	25 - 35°
5	Very steep or mountaneous	over 35°

Table 4.13 Standard of land classification.

(for land reclamation to paddy field)

Factor \ Rank	I	II	III	IV
Slope	0 ~ 35′	35′ ~ 3°	3° ~ 8°	More than 8
Depth of soil	More than 100cm	100 ~ 70cm	70 ~ 40cm	Less than 40cm
Soil texture	L, SiL, SCL, CL, SiCL, SC, LiC, SiC	SL, Volcanic L, Volcanic CL	S, LS, Volcanic SL, HC, Low-moor peat, Transitional-moor peat	Gravel Volcanic S, Volcanic gravel, High-moor peat
Gravel content	Less than 5%	5 ~ 10%	10 ~ 30%	More than 30%

Table 4.14 Standard index for land-use classification (Hiwatashi,1977)

Rank	Items for land-use-capability classification						Explanation
	Inclination	Terrace	Erosion	Soil depth	Soil texture	Soil Moisture	
Grade I	1	1	1	1,2	2	2,1	No need for soil conservation
Grade II	1,2	1	1	1,2	2,1	2,1	Occasionally flood. Need drainage.
Grade III	1,2	1,2	1	2,3	1,2	1,2,3	Need powerful facility for drain and soil conservation.
Grade IV	1,2	1,2	1,2	3,4	2,4	2,3	Swampy soil. occasionally washed by salty water.
Grade V	1,2,3	1,3	1,2	3,4	2,3,4	1	Need facility for drainage even for plantation or forestland.
Grade VI	1	1	1	1	1,2	4,5	Plain but easily flood with salt water.
	2,4	1,3	1,2	4,5	1,2	1	Relatively steeply sloping with shallow soil horizon.
Grade VII	4,5	1,3	3	5	1,4	1	Steeply sloping or severe erosion area.
	1	1	1	1,2	1,2	3,4,5	Swamp or young and poor soil areas.

(2) Terrace

Rank	
1	No terrace
2	Good conditioned terrace
3	Ill conditioned terrace

(3) Soil erosion

Rank	
1	Not or very little eroded
2	Little eroded with bare soil
3	Heavily eroded with exposed rock

(4) Depth of soil

Rank		
1	Very deep	over 100 cm
2	Deep	75 - 100 cm
3	Moderate	50 - 75 cm
4	Shallow	25 - 50 cm
5	Very shallow	below 25 cm

(5) Soil texture

Rank	
1	Soft (Clay silt or loam)
2	Moderate(Sandy clay or sandy loam)
3	Coarse(Sand)
4	Very coarse(Gravel)

(6) Soil moisture

Rank	
1	Dry
2	Little wet
3	Wet
4	Lake or pond
5	Salty wet land
6	Salt land

Since depth of soil, soil moisture and soil texture are highly correlated with vegetation, those three factors would be estimated by vegetation(Funada 1979) when soil map is not available. Land classification in the term of seven classes which can be obtained from Table 4.14 as combinations of the above mentioned six factors, are classified and recognized as follows.

A. Suitable land for agriculture

class 1	Very suitable for agriculture. Not necessary for soil protection works.
class 2	Suitable for agriculture. Necessary for simple soil protection works.
class 3	Possible for agriculture. Necessary for proper soil protection works.

B Not suitable for agriculture but for estate farm or forestry

class 4 Not suitable for agriculture but for meadow, estate farm or forestry. Not necessary for soil protection.

class 5 Suitable for estate farm or forestry. Necessary for drainage or other soil protection works.

class 6 Not suitable and unstable for estate farm. Necessary for strict control for forestry.

C Not suitable for any human activity but for wild life

class 7 Not suitable for any human activity because of danger of flood or soil erosion and/or wetland. Only possible for wild life.

(b) Score method

In this method, each factors are evaluated as score and total evaluation value is computed as weighted summation of each score. Weighting is determined by the dependency of each factors on the objective.

Table 4.15 shows an application example of this score method to dry fiend. This table can be applied to Japanese dry field, where heavy weight is given to enable agriculture in the frostless period, which is most important for agriculture in winter. In application of this score method to South Asia countries it is necessary to select most effective factors and weights.

(c) Mixed method of rank method and score method

This method is a combination of the rank method the sore method in consideration with the characteristic of each factors. Fig 4.7 shows a procedure of applying this method to evaluation of dry field.

Evaluations of 1st and 2nd steps are carried out by rank method, while 3rd and 4th steps by score method. For example, the item of "condition of rhizosphere" in the 2nd step is evaluated by three factors of "depth of soil", "soil moisture" and "gravel content" in the term of six ranks from 0 to 5, as indicated in Table 4.16.

The item of "growth condition" in the 3rd step is evaluated by two factors "condition in rhizosphere" and "assimilation" in the term of score 0 to 10 as shown in Table 4.17. In the final step "suitability for farm land" is classified by two items of "growth condition" and "workability" in the term of total score between 0 - 10, as shown in Table 4.18.

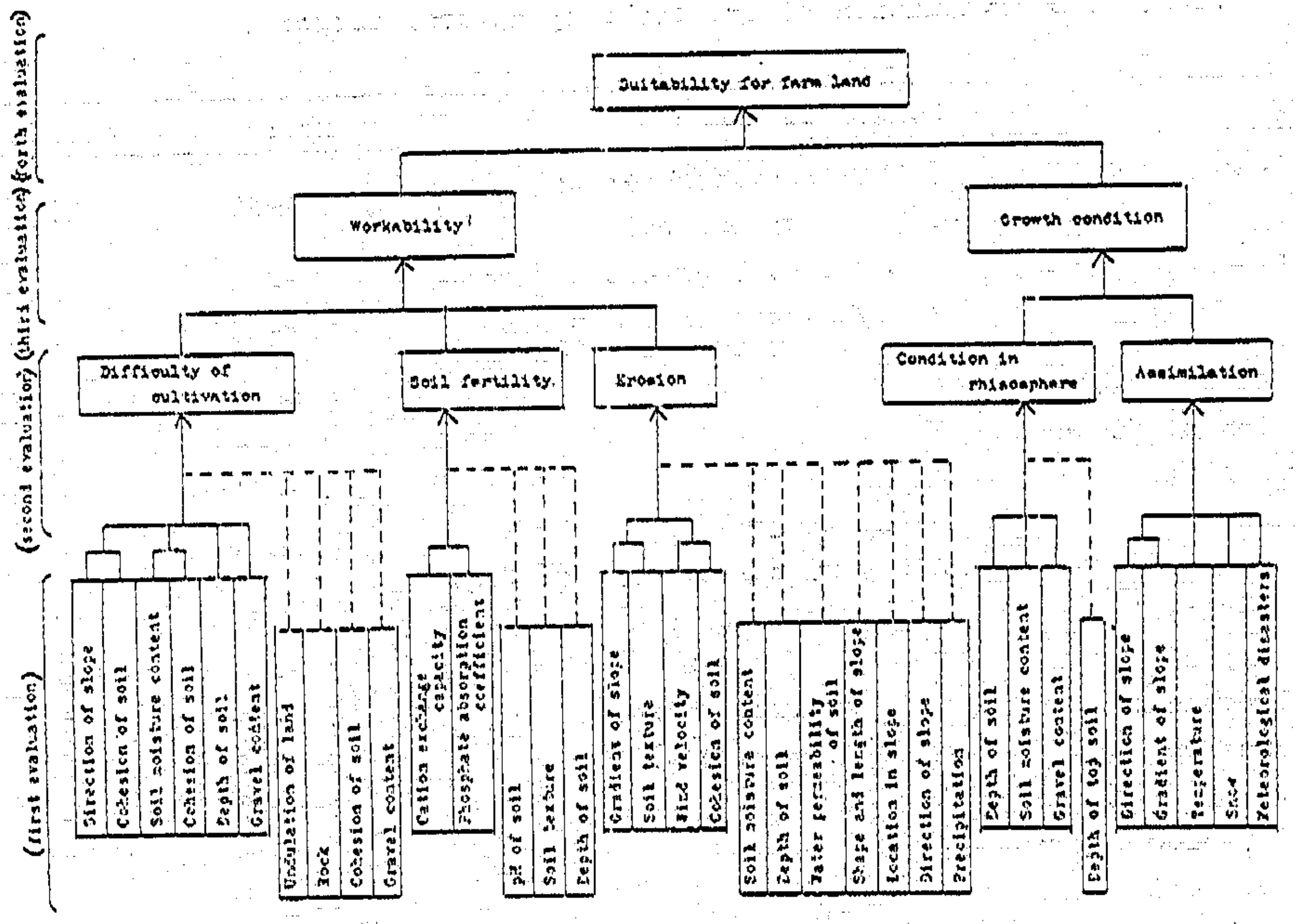
(d) Considerations about a total evaluation method.

Evaluation and assessment method described in the section of (a) to (c) has been established under the particular situation of Japan, on the premise that Japan is geographically located in the temperate monsoon climate zone and has her unique soil, topography and avanced technique for agriculture.

These evaluating methods can not be directly applied to South Asian countries and some modifications are necessary.

Table 4.15 Evaluation of dry field by natural factors.

Factors	Number of class	Score	Weight
Frostless period	7 (by frostless period) 6 (by snow period)	0 ~25	25
Precipitation	4 (by annual precipitation)	0 ~ 3	3
Typhoon	3 (by number of times in the late 25 years)	0 ~ 3	3
Slope of dry field	4	0 ~ 5	5
Direction of field	8	0 ~ 5	5
Natural slope	4	0 ~ 4	4
Sunshine	6 (by shadow) 4 (by number of days of fog)	0 ~ 8	8
Peat in plow layer	2 (by exist or not)	0 ~ 5	5
Soil texture	8	0 ~ 6	6
Gravel content	4 (by volume ratio)	0 ~ 5	5
Wind erosion	3 (by its extent)	0 ~ 2	2
Dranage	5	0 ~ 8	8
Color of plow layer	4	1 ~ 5	5
Depth of soil	4	0 ~ 8	8
Poor soil in 1 meter layer from surface	7 (by exist or not and extent)	1 ~ 8	8
Total		2 100	100



※ Factors combined with straight line are standard factors.
Factors combined with broken line are correct factors.

Figure 4.7 Procedure of land classification for reclamation to dry field, using factors of natural condition.

Table 4. 16 Classification table of condition in rhizosphere.

Rank (Score)	Standard factors		
	Depth of soil	Soil moisture	Gravel content
5	More than 100cm	Moist	—
4	75 ~ 100cm	Moderately dry or wet	5 ~ 10%
3	50 ~ 75cm	dry or wet	10 ~ 20%
2	30 ~ 50cm	Very wet	More than 20%
1	15 ~ 30cm		—
0	Less than 15cm		—

Correct factor	Correct method
Depth of top soil	If the data of standard factor is part of boundary and the depth of top soil is more than 30cm, the rank should be promoted to a higher rank. In this case, if the depth of top soil is less than 30cm, the rank should be degraded.

Table 4. 17 Classification table of growth condition.

Rank (Score)		Condition in rhizosphere					
		5	4	3	2	1	0
Assimilation	5	10	8	5	3	2	0
	4	9	7	4	2	1	0
	3	7	6	3	1	1	0
	2	5	4	2	1	0	0
	1	3	2	1	0	0	0
	0	0	0	0	0	0	0

The following procedure is recommended to decide the total evaluation method.

(1) Selection of effective factors for agricultural infrastructure.

1 Choice of crop types
2 Technical level of agricultural production
3 Technical level of land development
4 Total area of land
5 Physical conditions (topography, climate, vegetation, soil, land cover and so on)

(2) Examination of classification standards

In Japan, slope classification standard is divided into four classes as shown in Table 4.12. The 1st class is 0-3 degree and the 2nd class is 3-15 degree.

These criteria of slope angles are rather bigger than those of other countries. In Japan, most of flat and plane areas have been developed so that hilly area must be developed. Therefore rather bigger angles are chosen as the criteria. In undeveloped district such as North Sumatra, soil erosion seems to occur frequently due to heavy rainfall in the rainy season. Accordingly slope classification standard should be modified. In the same manner the classification standard of soil texture also should be modified to meet the different characteristics resulted from heavy weathering and strong eluviation in the tropical rain forest climate zone.

(3) Total evaluation method

In assessing the suitability of farm land, it is very reasonable to utilize the lowest rank method because all factors independently take park in total evaluation method.

For instance, lands of which slopes is more than 30 degrees are not suitable farm lands, even if they are under good soil condition, where soil texture is clay loam, depth of soil is more than 1 m, and there is no gravel. However, it is more effective to use the score method to classify definitely the selected area and to determine the order of priority for development of farm lands.

Total evaluation method must be established by considering objectives of evaluation and utilization of obtained results.

4.1.3 Concept and applicability of plant indicator to site selection for agricultural development

a. Concept of plant indicator

Up to this time, environment of the earth surface have been measured by physical units such as temperature, amount of radiatiation, gradient and aspect of slope or by chemical units such as soil acidity or nutritive salts. However, the environment can not be measured by only physical and chemical methods. Since agriculture itself is based on biological production, especially in the process of site selection for agricultural development, the environmental condition should be discussed through biological reactions.

Table 4.18 Classification table of suitability for farm land

Rank		Workability										
(Score)		10	9	8	7	6	5	4	3	2	1	0
Growth condition	10	10	10	9	8	8	8	7	6	5	5	0
	9	9	8	8	7	7	6	6	5	4	4	0
	8	8	8	7	7	6	5	4	4	3	3	0
	7	7	6	6	5	5	4	3	3	2	2	0
	6	6	6	5	5	4	3	3	2	2	2	0
	5	5	4	4	3	3	2	2	2	1	1	0
	4	4	4	3	3	2	2	2	1	1	1	0
	3	3	2	2	2	1	1	1	1	0	0	0
	2	2	2	2	1	1	1	1	0	0	0	0
	1	1	1	1	1	1	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0

Physical chemical observations have such weak points as big fluctuations depending on sampling site and occasion, and lack of spatial and temporal continuities.

On the contrary, biological phenomena themselves have such good point that the whole characteristics can be easely grasped at a glance, because integrated results from the past to the present are simulated in the biological phenomena in wide range of space.

The vegetative distribution in a certain area is also an appearance of natural environmental factors such as climate, soil and topology of the site. In addition, the present vegetation can be considered as a comprehensive state resulted from interrelations between surrounding vegetation units. That is to say, environmental factors may be reflected in plant. Therefore, it becomes possible to diagnoze land conditions through plant reaction. However, through biological reaction, one can not expect the precision of environmental factors in p.p.m. order. So, the envronment factors should be measured more precisely with the aids of physical and chemical techniques in addition to biological measurement. Moreover, even if the pattern of biological reaction against the environmental factors possesses an universal validity on the earth, the phenotype such as botanical composition and biomass varies in accordance with the site and the season. Consequently, it is strongly requested to establish a respective standard to meet the objective before deciding the pratical biological indicator.

b. Applicability of remote sensing technology to vegetation survey

In Indonesia, possessing immense land area which includes a region where no human beings have ever penetrated, it is impossible to carry out precise soil examination in a short time which is most important for selecting suitable land for agricultural development.

Since the land surface blessed with abundant precipitation and high temperature in all seasons is covered by vegetation through the year in Indonesia, it is impossible to examine soil condition from space. If one can identify the vegetation from remote sensing data which the total assessment of site factors will be done, more useful information for agricultural development can be extracted.

In order to detect the vegetation on vast area in a short time under same condition, remote sensing technique will not only promise to save cost and time, but also to give valid information for assessment of land development, because remote sensing data provide much information about topography, drainage system and land use besides vegetation. It can be said possible to accomplish overall assessment of agricultural development with the aid of meteorological and soil data, as well as the results obtained from remote sensing data.

The recognized objects may change in response to the height of the sensor platform. The types of vegetation in large area can be detected from Landsat imagery. By these vegetation types, the climate nature, soil texture, soil moisture are estimated. With the assistance of these information, it becomes possible to carry out preliminary land classification.

For investgating special region, such as training area, high altitude airborn MSS data may be helpful. By combining MSS data with the existing data or ground trouth data, precise analysis on vegetation and soil becomes feasible.

By this step, a concrete area suitable for agricultural development is brought into full relief. Low altitude aerial photograph is utilized to detect tree species, and to decide the suitable crop to plant.

c. Level of vegetation and natural environmental factors

Many studies on the relationship between vegetation and environment, have been carried out in the field of ecology.

These studies range from the climate zone classification of large area by geographical distribution of one plant species, to the limitted small regional information about depth of soil and height of water table. Discussion should be made clear about which level of classification is to be extracted by the biological information.

For instance, in Japan which is located widely from north to south with large differences in altitude, country wide distribution of species is determined by the lowest temperature while local distribution of a species is influenced by wind direction or amount of rainfall. The distribution of individual plant in a micro area may be restricted by soil depth, drainage, or the exposure of afternoon sunshine.

In the tropical district where temperature does not work as a limiting factor for plant growth, amount of rainfall will become the primary factor. Existing analysis concerning the relationship between vegetation and environment in tropical area are not sufficient ever since. Some of them will be introduced in later chapter. This type of researches shall be started in Indonesia in near future to create original standard for environment study.

b. Relation between vegetation and location condition

i) Regional classification index

Forest and scrub in the tropical and sub tropical zone, can be classified into five types with respect to climate type as follows.

forest type	climate type
tropical rain forest	tropical rain forest climate
monsoon forest	monsoon forest climate
savanna forest	tropical savanna climate
thorn forest	sub-tropical arid climate
sub-tropical rain forest	sub-tropical monsoon climate

Features of these forest types are defined by Okutomi(1977) as follows.

(1) tropical rain forest

Ever-green leaves forest covered large area with high temperature and much rainfall through the year. Most trees are tall and rich in flora and have buttresses and large edge leaves with many climing plants and epiphytes.

(2) monsoon forest

Forest of multilayers, grown in tropical and sub-tropical zone with dry season and consisted of tall trees, with the leaves fallen in the dry season.

(3) savanna forest

Sparse forest grown in rainy zone with longer dry season as compared with monsoon forest. Its discontinous crown has small ever-green braod leaves, and tropical grasses are grown with preference in its forest bed.

(4) thorn forest and scrub

Forest in the tropical arid zone which mainly consists of short trees or small but tall trees which have thorn leaves and many succulent plants and annual plants are found as forest floor vegetation. Distributed in tropical and dry area.

As forest types are easely classified from Landsat data, this method is applied to forestry development in several countries. For instance, in Paraguai, forest types are roughly classfied fron Landsat imageries and then definitely interpretated by aerial photograph for forestry development of 5,000,000 ha.

In other countries as Brasil and Colombia, interpretation of vegetation from Landsat data plays an important role in selecting agricultural land.

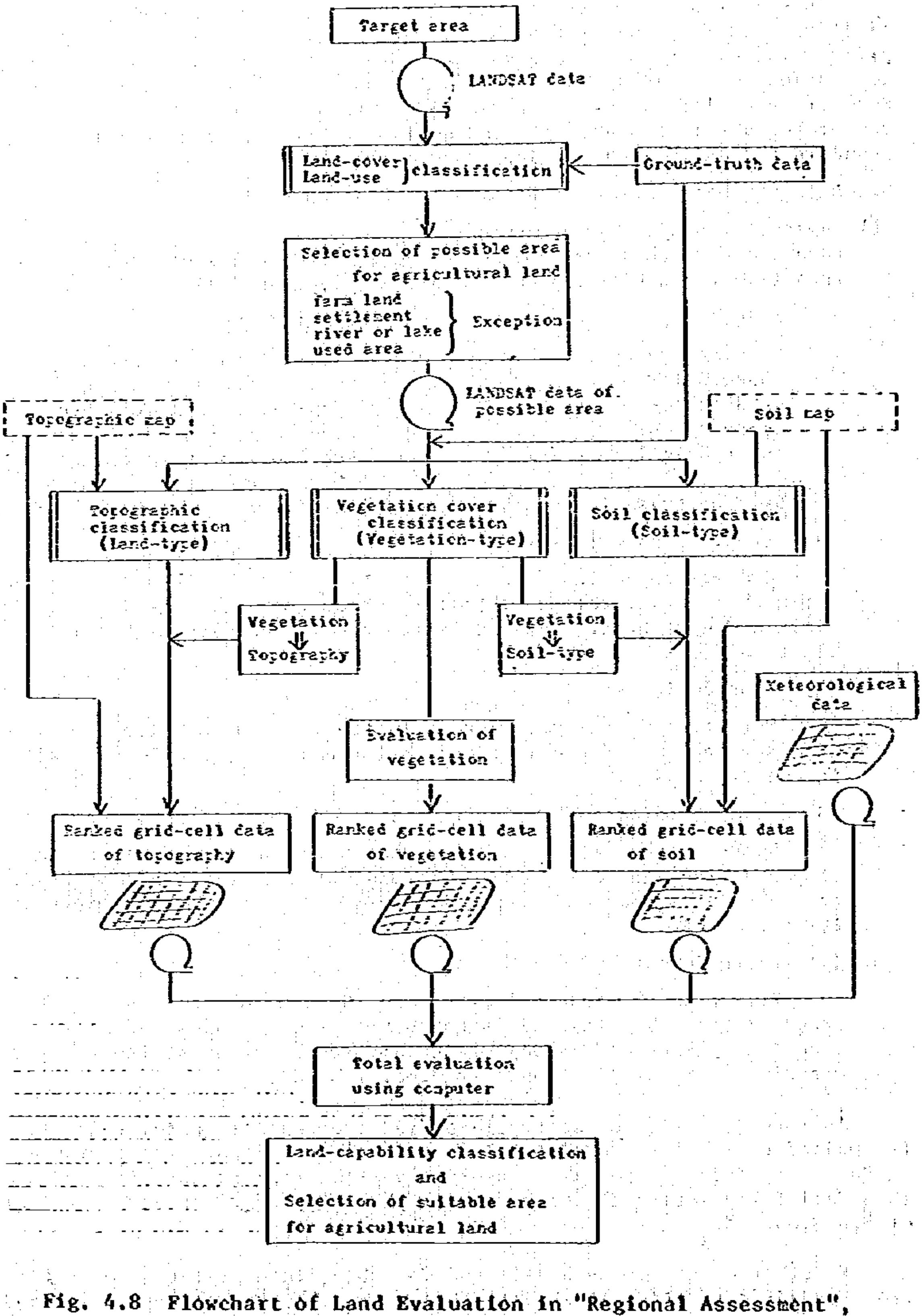


Fig. 4.8 Flowchart of Land Evaluation in "Regional Assessment", Mainly Using Landsat MSS Data.

In Africa as Sudan and North Yemen, classification of forest types by using Landsat data is adopted as a technical method for agricultural development in large area.

ii) Local classification index

Though Landsat data are very useful for regional classification, more detail information of larger scale, such as aerial photograph, is necessary for site selection for agricultural development to arrange plantations and paddy fields.

Table 4.15 shows some relationship between main forest types in tropical East Asia and environmental factors collected by Whitmore(1979). Tropical rain forest and monsoon forest which occupy most area of Indonesia are divided into 15 types in relation to water content of soil, properties of mother rock and sea level. Interpretation of forest types in smaller area can be done by Landsat data, but more convinlently by aerial photograph.

Main scrub of Burma was also classified into 12 climax forest types from tropical rain forest to very dry thorn forest through monsoon forest and savanna forest as shown in Fig. 4.9. Each forest type with specified name was related with rainfall and soil texture.

Table 4.19 and Fig. 4.10 give useful indecies of regional assessment for selecting agricultural farm land.

iii) Detail classification index

In order to design site selection for route location, planning of agricultural facility, selection of proper cultivate crop and construction of water way and fence, more detail information is required.

A plant indicator at the level of species is to be established for this purpose. In most case tree species and plant species can be interpreted by low altitude aerial photograph. Information connected directly to agricultural productivity, such as depth of soil, pH and aspect of slope, can be acquired from tree species and/or grass species with high probability.

Photointerpretation of tree species in tropical forest and practical examples are presented by Hiwatari(1972,1973), Wittgenstein and Corner.

At the present, tables of adaptability or tolerance of each plant species with respect to soil condition(humidity, pH, mother rock etc.) have not yet been published in Indonesia. However, in order to accept plant indicator as an important parameter for selecting agricultural suitable land, it is necessary to integrate data into a new information source.

Table 4.20 indicates climate and soil condition expressed as a function of weed plant in mountain area in Hakkoda, north part of Japan. Land area where Lactuca dentata and Hydrocotyle sibthorpioides dominate implies the existence of low organic matter and cool climate. On the contrary, apperances of Polygonum Blumei and Polygonum Thunbergii suggest that soil of the area is acid and rich in organic matters.

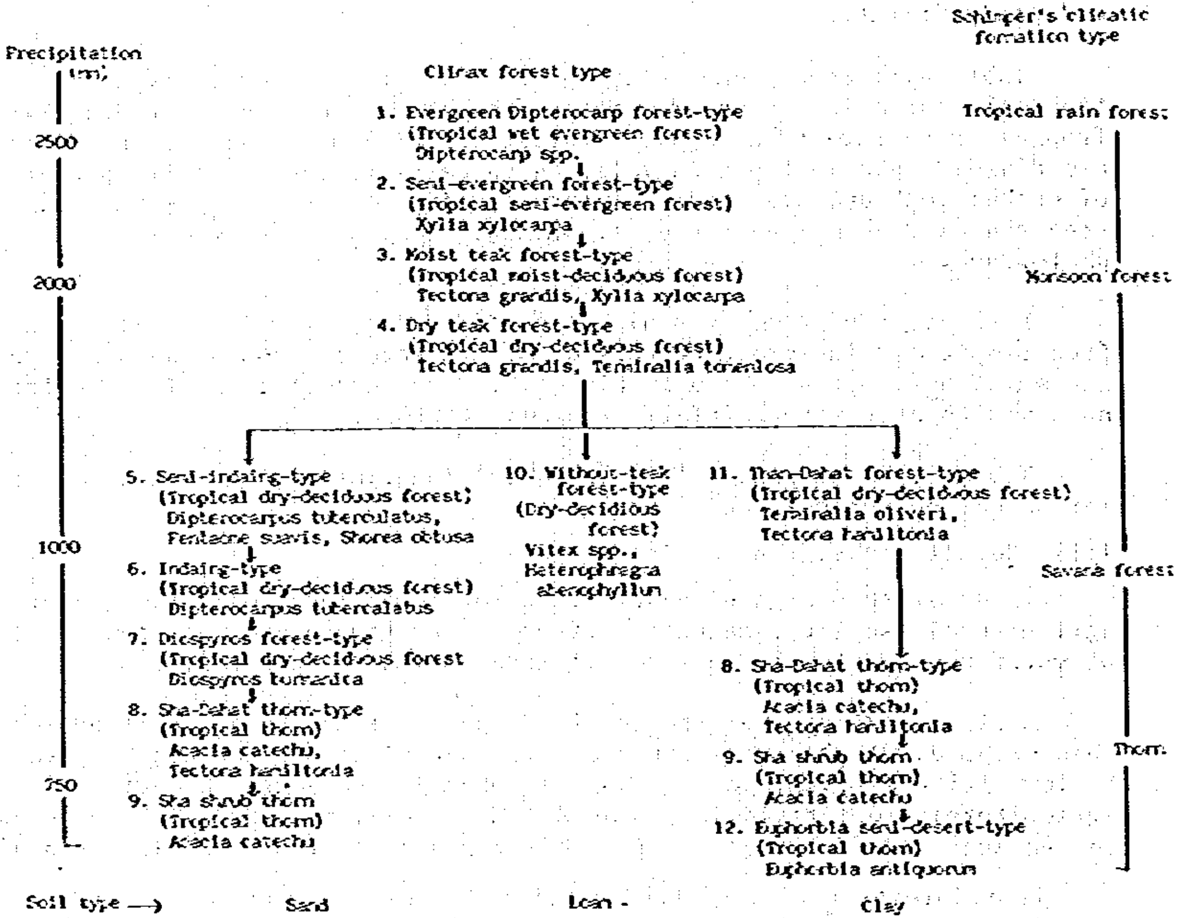


Fig. 4.9 Lowland Climax Forest Types in Burma in Relation to Precipitation and Soil Type (Okutomi, 1977)

Table 4.19 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 -1200 m	1 Tropical lowland evergreen rain forest
				Hilly (750) 1200-1500 m	2 Tropical low-mountain rain forest
				(600) 1500-3000 m	3 Tropical upper-mountain rain forest
				(3000) 3500 m to forest limit	4 Tropical sub-alpine forest
			Podzolic sand	Mainly lowland	5 Heath forest
			Limestone	Mainly lowland	6 Limestone forest
			Ultrabasic rock	Mainly lowland	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	12a Fresh water swamp forest
				Periodically wet	12b Seasonal swamp forest
Seasonally dry	Causes moderate water deficit seasonally				13 Tropical semi-evergreen 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 forests.

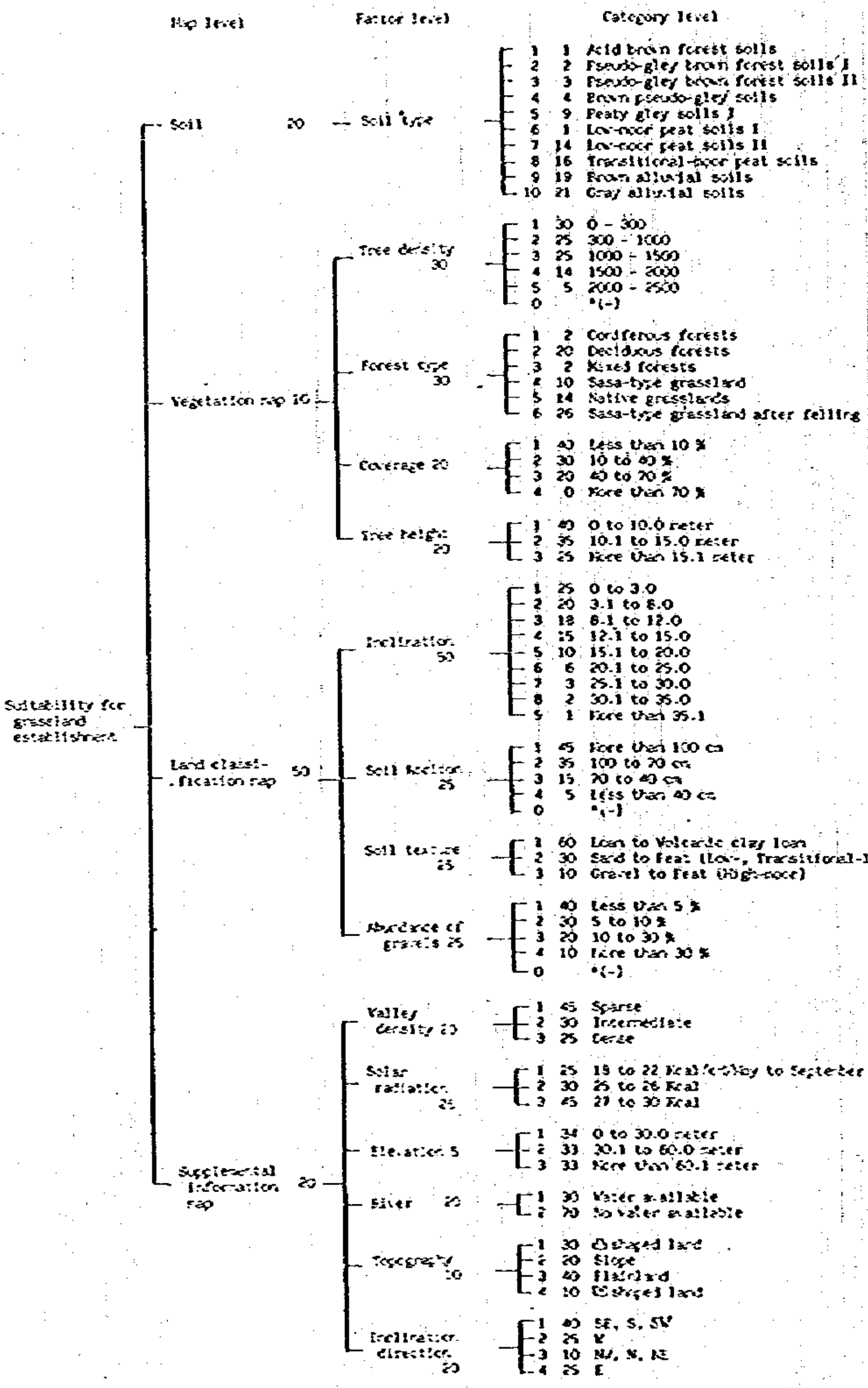


Fig. 4.10 Relevance Tree of Suitability for Grassland Establishment in Japan by Pattern Method (Takahata et al. 1976)

Table 4.20 Weed-plant Ecological Groups Observed in the Hakkohda Mountain System in Japan (Tachibana, 1968)

Species	PH-value	Organic matter content	Climate
Plantago asiatica	1	1	1
Poa annua L.	1	1	1
Trifolium repens L.	1	2	2
Poa pratensis L.	1	2	2
Carex albata Boott	1	1	2
Petasites japonicus var. giganteus	1	1	2
Equisetum arvense L.	1	3	2
Lactuca dentata Makino	2	2	3
Hydrocotyle sibthorpioides Lamk.	2	2	3
Zoysia japonica Steud.	2	2	3
Pteridium aquilinum Kuhn	2	2	3
Miscanthus sinensis Anderss.	2	2	3
Halorrhagis micrantha R. Br.	2	2	3
Rumex acetosella L.	2	3	2
Rumex obtusifolius	3	3	2
Chenopodium album L. var. centrorubrum Makino	3	3	2
Stellaria media Cyr	3	3	2
Viola grypoceras A. Gray	3	3	2
Polygonum Blumei Meisn.	3	3	3
Polygonum Thunbergii Sieb. et Zucc.	3	3	3

Note: Classification criteria

PH-value
1 Species grow in wide soil acidity range between PH 3.9 to 7.0.
2 Species grow only between PH 5.4 to 6.3.
3 Species grow only between PH 3.9 to 5.4.
Organic matter content
1 Species grow in wide range from rich to poor soil.
2 Species can grow on poor to intermediate soil.
3 Species can grow only on rich soil.
Climate
1 Species adapt broad zone among hilly, sub-alpine and alpine zones.
2 Species grow only on hilly or sub-alpine zones.
3 Species grow only on hilly zones.

Table 4.21 Indicator Plants in Mid-Europe Grassland Ecological Groups (Extracted from Ellenberg,1952)

Species	Light	Temperature	Soil		
			Moisture	Acidity	Nitrogen
Calamagrostis Epigeios Roth	3	2	2^{W}	0	2
Dactylis glomerata L.	4	0	3	4	4
Deschampsia flexuosa Trin.	4	0	2	1	2
Festuca ovina L.	4	0	2	$\underline{0}$	1
Holcus lanatus L.	$\underline{3}$	3	3	0	$\underline{4}$
Lolium multiflorum Lam.	5	4	3	4	4
Lolium perenne	$\underline{5}$	3	3	0	4
Phalaris arundinacea L.	4	2	5^{u}	4	5
Phleum pratense L.	4	0	3	0	4
Poa annua L.	3	0	5^{u}	0	5
Juncus effusus L. var. decipiens Buchen.	4	3	3	$\underline{2}$	3
Luzula multiflora Lej.	3	0	4^{W}	$\underline{3}$	2
Inula salicina L.	4	4	4^{W}	5	2
Picris hieracioides L. var. japonica Regel	5	3	2^{W}	4	3
Hemistepta carthamoides O. Kuntze.	3	4	2	4	$\underline{1}$
Parnassia palustris L.	4	0	3^{W}	4	2
Sanguisorba officinalis L.	4	3	4^{W}	0	2
Trifolium pratensis L.	$\underline{4}$	0	4	0	2
Medicago lupulina L.	3	3	0	4	2
Lotus corniculatus L. var. japonicus Regel	4	0	2	0	2
Dianthus superbus L.	4	1	0	$\underline{5}$	1
Rumex obtusifolius	4	3	$\underline{4}$	0	5

Note: Numbers in the Table indicate the grade of tolerance to environmental factors, from 1 (shade tolerance, frost hardiness, drought resistance, acid tolerance and poor nitrogen tolerance) to 5 (not tolerable to each factor). Number 0 indicates no relationship was observed to the factor. Underlined numbers are not cirtain because of few observation. Species with letter w shows strong tolerance under temporally high moisture condition, and letter u shows hydrophilous plants.

Table 4.21 indicates an example of ecological groupes of grass land in Europe which can be expressed as plant indicators.

In the table, the five factors of light, temperature, soil moisture, soil acidity and soil nitrogen are evaluated as the grade of tolerence to environment from 0 to 5 with respect to species.

The number 0 means no relationship. The number 1 indicates high tolerance to the factor (telerable to low light, low temperature, low moisture, low acidity and low nitrogen) while the number 5 indicates high preference to the factor (preference to high light, high temperature, high moisture, high acidity and high nitrogen).

Soil classification will be more easier, if plants which can be utilized as plant indicator for each evaluation factor can be found out in Indonesia.

4.1.4 Uitlization of remote sensing data for land assessment

a. Utilization of Landsat data

In order to aquire physical factors which are useful to evaluate soil condition, ground investigation has been a powerful role.

However, for investigating undeveloped land of large area, data acquisition by remote sensing is most effective. All of necessary data cannot be aquired by the present technical level of remote sensing. Following three problems shall be discussed in utilizing remote sensing data.

(1) Data aquisition remote sensing by technique which are useful for land assessment.

(2) Integrated evaluation with use of remote sensing data, existing supplimentary data and ground truth data.

(3) Computer technique for land assessment.

However, for investigating undeveloped land of large area, data acquisition by remote sensing is most effective. All of necessary data cannot be aquired by the present technical level of remote sensing. Following three problems shall be discussed in utilizing remote sensing data.

(1) Data aquisition remote sensing by technique which are useful for land assessment.

(2) Integrated evaluation with use of remote sensing data, existing supplimentary data and ground truth data.

(3) Computer technique for land assessment.

In the stage of regional assessment, Fig.4.2 shows a proposed procedure for selecting agricultural suitable land by means of Landsat data, topographic map soil map and climate data. In the undeveloped area, such as North Sumatra, existing data are only auxiliary because of relatively low accuracy.

Slope, which is one of most important factors be substituted by land form classification because accurate topographic map is not available.

For regional assessment, land form classification gives enough accuracy. More accurate slope data which are obtained by interpreting aerial photograph taken from lower altitude are required for local and site assessment. The proposal shown in Fig. 4.8 is drawn on base of vegetative classification derived from Landsat data. Land in tropical rain forest climate zone may be covered with natural vegetation which reflects physical planning condition of this land.

If the relatin between vegetation and physical planning condition in the land of interest can be made clear, vegetation classification by means of Landsat data may include implicit information other than vegetation.

b. Utilization of plant indicator for total assessment

Biological method by which vegetation is used to estimate soil chracteristics and site condition for selecting agricultural suitable land has been investigated ever since. However, there is no example of method.

Especially in tropical forest area, detail soil map is very difficult to produce by ground investigation and also soil classification by remote sensing technique is limited only on bare soil area.

Combination of the concept of plant indicator and remote sensing technique is necessary to investigate soil condition and finally to select agricultural suitable land.

Planning Assistance through Technical Evaluation which has been proposed by Takahata for selection of grass land is presented in Fig. 4.10. This table is a relevance tree table where final objective is situated on the top of pyramid and evaluating factors of second order are located over the next level.

By determining relevance number of each evaluating factor up to the upper level and by summing them at the grid cell, total value is determined. Relevance number of each evaluating factors varies by climate, site condition, objective and categories. Some modification will be required if applied in Indonesia.

4.2 Overall Evaluation Method Including Social and Economic Evaluation

4.2.1 Introduction

In site selection for agricultural development, it is not sufficient to evaluate the land with natural location factors such as productivity and workability of the land.

Considering that agriculture is one of the most important industries in Indonesia, it would be important to evaluate social and economic factors in view of the industry location.

Social factors include possibility of settlement of farmers, education, culture and so on, while economic factors include accessbility to markets, possibility of locations of food industries and so on.

However in Indonesia it is difficult to obtain enough data to evaluate all of factors. In this situation an evaluation method only using available data should be developed. The evaluation method proposed in this section is an overall evaluation method, with a combination of physical factors, social factors and economic factors.

This evaluation method is based on the method which was used in analysis of land use potentiality in coastal area of Okinawa Island, Japan.

4.2.2 Social and Economic Factors

Social and econonic factors for agriculture development are as follows.

a. Social factors

(1) possibility of development of village

(2) standard of education

(3) standard of culture

(4) standard of living

(5) medical level

(6) public security

(7) sanitation level

(8) safety from harmful animals and insects

(9) impact on landscape

(10) impact on ruins

(11) others

b. Economic factors

(1) accessibility to markets

(2) possibility of development of allied industries for example food industry

(3) income level

(4) labor

(5) others

It is not necessary to consider all of these factors at every stage in the multi-stage evaluation, but only those factors which could be recognized as significant value in the indivisual stage.

Some of factors may be evaluated by different evaluation index depending on the stage. Accessibility to markets for example, is evaluated by the transportation time computed with a principul road network in the stage of regional assessment, while it is evaluated by the distance to a principal road in the stage of local assessment.

From this view, the evaluation indices in the multistage, are shown in Table 4.22 .

4.2.3 Proposal of Overall Evaluation Method

a. Multi-step Evaluation Method

Overall evaluated value is obtained by multi-step evaluation as shown in Figure 4.10 using evaluation factors and indices as previously stated. Figure 4.10 shows a part of the evaluation tree for the regional assessment. The evaluation trees for the local assessment and the site assessment can be constructed in the same manner as for the regional assessment. In Figure 4.10, numerical values in □ and ○ correspond to evaluated value and weight respectively for example, which will be determined by the method as stated hereafter.

Evaluation is done from right to left in Figure 1, that is, by summing up weighted evaluated values. Evaluated values of all indices as described in ○ are normalized into the value with a range of between 5 for the best condition and 1 for the worst condition. The normalization will be done by brainstorming of experts. Weights as described in □ are also normalized so that sum of weights makes 1.0. Evaluated values for the next step are computed by summing up weighted evaluated values. In the same manner, final overall evaluated value is obtained by summing up three factors that is, physical factors, social factors and economic factors.

In the example of Figure 4.10 overall evaluated value (3.19) is obtained by summing up $\boxed{0.7}$(3.12) for physical factors $\boxed{0.1}$(3.55) for social factors and $\boxed{0.2}$(3.28) for economic factors.

[Explanation of Figure 4.10]

The overall evaluation will be done as follows.

Step 1. Assignment of evaluated values to all indices of the first step.

Each evaluated value should be between 5 for the best condition and 1 for the worst condition.

e.g. evaluate value of water supply is 5 (the best).
evaluate value of drainage is 1 (the worst).

Step 2. Calculation of evaluated values for all evaluation factors.

An evaluated value for a evaluation factor is obtained by summing up all weighted valuated values of indices. At that time weights are

Table 4.22. Examples of evaluation indices in the multi-stage

	evaluation indices			
	evaluation factors	for regional assessment	for local assessment	for site assessment
social	possibility of development of Village	•population of region	•area of flatland •distance to neighbor village •distance to regional center	
	standard of education		•distance to a primary school	
	standard of culture		•distance to a cultural facility	
	standard of living		•water supply •drainage •electric power supply	
	medical level		•distance to a medical facility	
	public security		•number of a crime occurrences •number of policemen	
	sanitation level		•number of epidemic occurrences •number of parasitic disease occurrences	
	safety from harmful animals and insects	•number of harmful animals	•density of harmful insects	
	impact on landscape		•quality of landscape	
	impact on ruins			•importance of ruin
economic	accessibility to markets	•distance to port •distance to airport •distance to major city	•distance to trunk road	•distance to access road
	possibility of development of allied industries	•location of allied industries	•area of flatland •water supply •energy supply	
	income level	•average income		
	labor	•ratio of the unemployed		

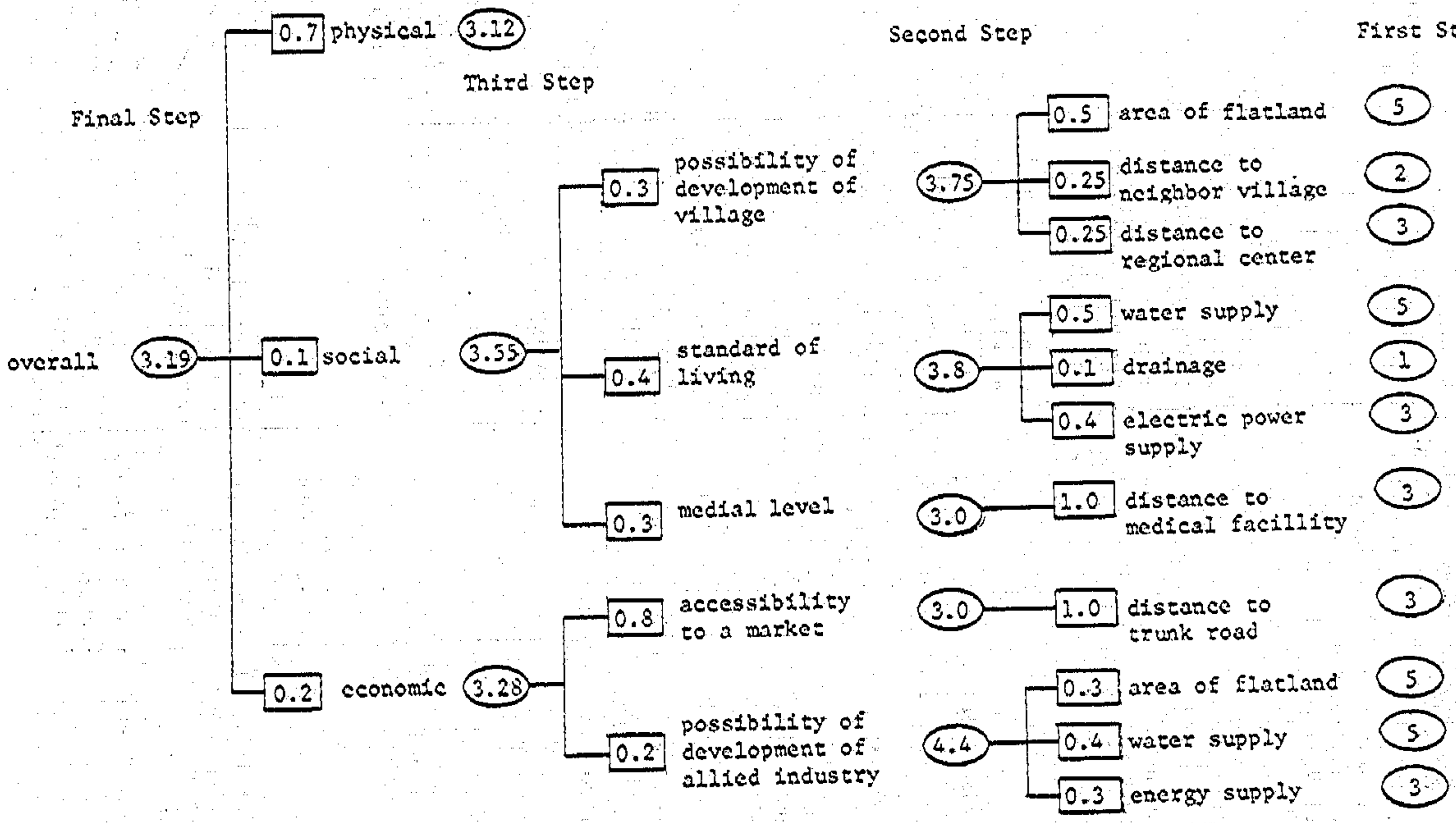


Figure 4.10 A part of the evaluation tree for the overall evaluation at the regional assessment

normalized so that sum of weights is 1.0. Therefore all evaluation values are also computed between 1.0 and 5.0.

e.g. [evaluated value for standard of living]
=[weight for water supply]
x[evaluated value for water supply]
+[weight for drainage]
x[evaluated value for drainage]
+[weight for electric power supply]
x[evaluated value for electric power supply]
$= \boxed{0.5} \times \textcircled{5} + \boxed{0.1} \times \textcircled{1} + \boxed{0.4} \times \textcircled{3}$
$= \textcircled{3.8}$ (sum of weights $= \boxed{0.5} + \boxed{0.1} + \boxed{0.4} = 1.0$)

Step 3. Social Evaluation and Economic Evaluation

A social evaluated value and an economic evaluated value are obtained by summing up all weighted evaluated values of evaluation factor as same as step 2.

e.g. [social evaluated value]
=[weight for possibility of development of willage]
x[evaluated value for possibility of development of village]
+[weight for standard of living]
x[evaluated value for standard of living]
+[weight for medical level]
x[evaluated value for medical level]
$= \boxed{0.3} \times \textcircled{3.75} + \boxed{0.4} \times \textcircled{3.8} + \boxed{0.3} \times \textcircled{3.0}$
$= \textcircled{3.55}$ (sum of weights $= \boxed{0.3} + \boxed{0.4} + \boxed{0.3} = 1.0$)

Step 4. Overall Evaluation

An overall evaluation value is obtained by summing up the weighted evaluated values of physical, social and economic factors as same as Step 2 and Step 3.

e.g. [overall evaluated value]
=[weight for physical evaluation]
x[evaluated value for physical evaluation]
+[weight for social evaluation]
x[evaluated value for social evaluation]
+[weight for economic evaluation]
x[evaluated value for economic evaluation]
$= \boxed{0.7} \times \textcircled{3.12} + \boxed{0.1} \times \textcircled{3.55} + \boxed{0.2} \times \textcircled{3.28}$
$= \textcircled{3.19}$ (sum of weights $= \boxed{0.7} + \boxed{0.1} + \boxed{0.2} = 1.0$)

b. Weights

Generally speaking, weighting is based on the evaluation by experts which may be different each other because of different viewpoint.

One of the most practical method to determine weight is brainstorming by government officiers in charge of agricultural development.

There are psychological methods to determine weight. One of those psychologic methods is Thurstone's method which is a sort of law of comparative judgement.[1] Another is a method using the utility function of multiple objectives.[2]

4.2.4 Applicability of the Proposed Method

In Indonesia, data of indices as indicated in Table 1 are not always available. For that reason, overall evaluation might be impractical. It is indispensable to study importance of social and economic evaluation factors for agriculture development in Indonesia, and to begin with data acquisition of indices with higher priority.

SUMMARY

Remote sensing has short history but is very hopeful technology. Remote sensing is an advanced technique for data aquisition as well as interdisciplinary technique on computer basis. The Committee is coposed of young and outstanding remote scientists, who contributed much to complete the report. The results and materials brought to the Committee have been prepared by those young experts with their flexible and superior ideas. It can be said that this report could not be accomplished without these experts.

The report gives a fundamental orientation for site selection for agriculrural development by remote sensing. Chapter 1 presents the objective of the study. In Chapter 2 an integrated information system connected with remote sensing and spatial information technique was proposed to improve the multi-stage investigation system, and concept of grid cell data file was introduced. Chapter 3 explains about the procedures of thematic mapping for selecting suitable land for agricultural development.

In Chapter 4 procedures for evaluating physical factors for agricultural development and their applicability of remote sensing were introduced. Concept and applicability of plant indicator to site selection for agricultural development was also described. In the later part of Chapter 4, overall evaluation method including social and economic evaluation was proposed in the assumption when the agricutural development will have been improved.

The multi-stage method described in this report must be an useful technique for site selection for agricultural development.

Finally all members of the Committee would like to acknowledge all of the related organizations and staffs. The Committee would like to express the deepest thanks to the Ministry of Foreign Affairs, the Ministry of Agriculture, Forestry and Fishery and the Japan International Agency.