GIS analysis on slash and burn cultivation in Indonesia

Shinobu Sakai
Tohoku Regional Agricultural Administration Office
Ministry of Agriculture, Forestry and Fisheries
2-1, Sakaimatsu, Kuroishi-shi, Aomori 036-0389

Abstract

A GIS analysis system for monitoring of " slash & burn" cultivation has developed at the RSP (Remote Sensing Project), DPU (Department of Public Works) in Indonesia, which had been assisted by the JICA (Japan International Cooperation Agency). In this system, those elements (①decrease of vegetation between two period, ②size of plot, ③ shape of plot) are considered for detection of accurate "slash & burn" cultivation plots.

Outputs of this analysis are distribution map of "slash & burn" cultivation plot, area estimation table, dimension table of each "slash & burn" plot.This analysis system had applied on three areas in Indonesia.

1. Background and research areas

In recent years, amongst the growing awareness on environmental issues globally, slash & burn in tropical forest zone is regarded as one of the major factors in deforestation and considered to be a problem.
Information related to slash & burn in a region is not only important as a main indicator of environmental monitoring but also as basic information for conducting various investigation on forest conservation and agricultural development.

This slash & burn plot analysis was carried out at the Remote Sensing Project (RSP), Department of Public Works (DPU), in Indonesia as a project type technical cooperation assisted by Japan International Cooperation Agency (JICA). This paper deals with three application examples and introduces the methodology used and results of the analysis. The application areas are the upper reaches area of Negara River basin in South Kalimantan Province , the Wailalem Dam basin in Lampung Province, and the upper reaches area of Kampar River basin in Riau Province of Sumatra. (see Figure 1).

2. Method for detection of slash & burn plots

2. 1 Elements of detection method for slash & burn plots

It is difficult to detect slash & burn plots directly by spectral classification from satellite imagery data. Main factors that prevent detection is the existence of similar spectral characteristics to slash & burn, such as old logging site, site of forest fire, site of landslide and debris flow, site of factory or housing development, facility area like trial digging bore, road, and riverbed. Thus spectral information by itself cannot distinguish the land use of slash & burn from others.

Figure 1 Locations of analyzed slash & burn plots

In order to improve the accuracy of slash & burn detection avoiding these errors, a method focusing on the following three elements was developed and applied.

(1) Decrease of vegetation
In this slash & burn model, an assumption is made that before the burning of the site, the area has vegetation density of a natural/secondary forest. After the burning, there are M years of cultivation, followed by N years of fallow period and in this period will recover to the same vegetation level again. In this case, between after the two

images of M years interval two images, the slash & burn site should be detected as a section in which the vegetation decreases from a natural/secondary forest to a bare/bush land. If the interval of two images is more than or below M, there might be cases where the slash & burn sites cannot be detected as decrease of vegetation; or land already with fallow land is misinterpreted as estimated slash & burn. In reality, the cultivation period of slash & burn is not uniform but has variation, therefore there are elements that cause errors. However, considerable improvement in its accuracy can be expected compared with classification from a single image.

shape with five grids in single horizontal line is 2.6 (see Fig. 2).

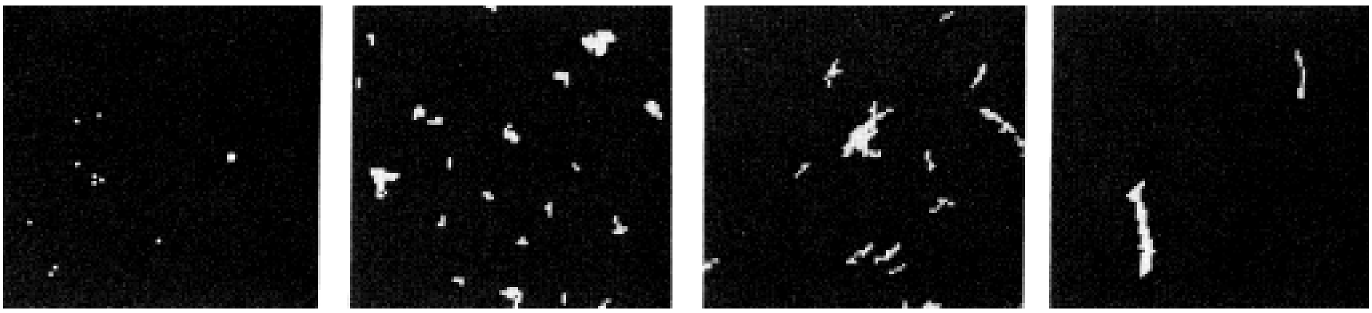
$$AI = (D1^2 + Dc^2) / 2A \qquad (1)$$

where AI: Aspect Index

D1: North-south width of plot (m)

Dc: East-west width (m)

A: Plot area (m^2)



1.0 1.5 ～ 2.0 3.0 ～ 4.0 5.0 ～ 7.0

Figure 2 Examples of AI of slash & burn plots

(2) Size of plot

Given that a certain grid itself is estimated to be a slash & burn site and any of the eight surrounding grids are defined as to form a plot. The neighbouring relationships between all the grids is examined and sorted for analysis.

Classification of plots is made by their sizes. Plots up to a certain size are considered to be the estimated slash & burn site. If the size exceeds this certain size, they are considered much more likely to be the sites other than slash & burn, such as forest fire sites or large-scale land reclamation areas and are excluded from estimated slash & bum.

(3) Shape of plot

Discrimination/Classification of cultivated land from road/rivers etc. is carried out by the shape of estimated slash & burn plot. Aspect index (AI) for the plot is defined by the following formula. If a site has a small AI number and a rectangular/round shape, it is regarded as cultivated land. In case a site has a big AI number and extreme linear shape, it is regarded not likely to be cultivated land and excluded through processing. Following this formula, AI is obtained easily based on the ratio of length and width regardless of its direction. For example, AI number of a square is 1, and AI number of a

Detection method of estimated slash & burn site is applied in the following order. (see Figure 3)

(1) From the two satellite images taken at different periods, respective land cover maps are prepared by classifying the data supervised by ground truth data obtained from the field survey.

(2)Apply classification method using vegetation decrease, namely, to select the grids in the land cover maps which show remarkable decrease of vegetation between the two periods and estimate them as the primary estimated slash & burn plots. “Remarkable decrease of vegetation” is based on the following definition. At first, the land cover of the two periods is classified into four classes depending on the vegetation density as shown in Table 1. Next, “remarkable decrease of vegetation” is defined by the change in the decrease of two or more vegetation classes in the two periods. In other words, changes from Ⅰ to Ⅳ, Ⅰ to Ⅲ, and Ⅱ to Ⅳ correspond to this.

Table .1 Vegetation density classes

Level	Class of vegetation	Land cover classification
I	Dense ve getation	Dense vegetation forest (natural forest)
II	Moderate vegetation	Forest with less density (secondary forest) Mixed forest with trees and crops
III	Grass/bus h	Grassland, Bush, Growin g stage paddy field
IV	Bare land	Paddy field without veg etation, Naked land

(3) In the case only one image data is available, there is no choice but to apply the site classified as bare land or equivalent to the primary estimated slash & burn. If the condition is good such as having few bare land other than slash & burn, a good result may be obtained.

(4) Apply classification method by plot size. Carry out plot size classification on the primary estimated slash & burn site and regard the area of up to 5ha, which is about the size of a cooperative farm of several families, as the secondary estimated slash & burn site. However in the mountain ridges, in the raw image data there are many cases where there are nosie-like bright points and shades, and slash & burn sites in single grids are excluded as it lacks reliability.

(5) Apply classification method by plot shape.
Classify the sites into cultivated land with small AI number and road/riverbed with large AI number, and allocate as tertiary (final) estimated slash & burn for analysis. Threshold value of the classification is aimed at AI number 5.

(6) Numerical sorting and image processing of the final estimated slash & burn sites are obtained by the above processes. From this procedure, the following results are obtained.

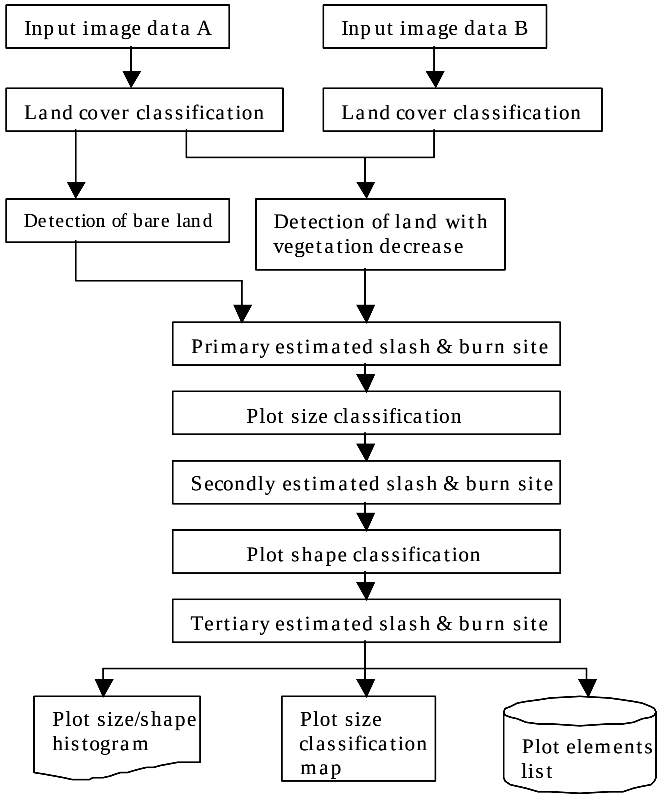


Figure 3 Flow chart of detection process of estimated slash & burn site

1) Histogram of slash & burn plot size

2) Histogram of slash & burn plot shape

3) Distribution map of slash & burn plot by size

4) Plot elements list (Serial number, coordinate value, area and AI number for all plots)

3. Applied examples

3.1 The upper reaches of Negara River basin, South Kalimantan Province

Using one SPOT (20m grid) image, the bare land obtained by classification as the estimated slash & burn site, plot size classification was applied. In this example, classification by AI number is not applied (see Photo 1 and 2).

Target area is about 10km square, where slash & burn sites are scattered in rubber woods.
Many rubber trees are not for harvest, therefore the area looks like an extremely extensive plantation or fallow land. There are not many permanent farm lands and most bare land are presumed to be slash & burn.

Therefore, the relisbility of classification from a single image is rather high. In the field survey, sites classified as estimated slash & burn were confirmed to actually bear the state of slash & burn.

Table 2 illustrates the processing results. Area proportion ratio shows that the plot size is concentrated from 0.4ha to 1.0ha. This implies that there are slash & burn sites of one family to several families per unit but due to the gentle peak from 0.4 to 1.0ha, 0.5ha is estimated to be the minimum unit for one family.

Field survey result shows that areas with old rubber trees are apt to be changed into slash & burn. Therefore, slash & burn cycle is assumed to be harmonized with re-plantation of rubber trees. Given that the area of present slash & burn to be 286ha, of the total area between 0.08ha to 4.0ha in Table-2, (assuming that all the estimated site to be real slash & burn), and the area was cultivated for three years after slash & burn, the life of rubber tree to be between 20 to 30 years, a land of $286 \div 3 \times 30 = 2,860$ha for slash & burn becomes necessary. On the other hand, the total size of the target area is approximately 10,000 ha, and even if the area available for slash & burn may be approximately one third of the total due to topographic condition and land ownership, it is estimated that slash & burn cycle of this area can be feasible.

Table 2 Counting list of estimated slash & burn in Negara area by plot size

Plot size (ha)	Number of plots	Area (ha)	Ratio of area c omposition (%)
0.00 - 0.08	585	32	8.99
0.08 - 0.20	255	39	11.04
0.2 - 0.4	148	55	15.54
0.4 - 1.0	107	71	20.18
1.0 - 2.0	37	53	15.13
2.0 - 4.0	24	67	19.10
4.0 - 8.0	3	17	4.85
8.0 <	2	18	5.17
Total	11,161	353	100.00
Total dimension of area		10,347	

3.2 Wailalem Dam basin of Lampung Province, Sumatra

An area of approximately 36,000ha of Wailalem Dam basin was analyzed by applying classification of vegetation decrease and plot size using Landsat MSS image data (resampled 50m grid) of two periods, 1978 and 1989. Classification by plot shape is not applied. The interval of the two data is 11 years and is not desirable interval. However, these data were used because of the limited availability of the images.

In this area, illegal settlement in the dam basin has been accelerating due to the improvement of traffic circumstances brought by the dam construction. Newly cultivated lands are conspicuous around the dam lake because of easily available irrigation water leading to acceleration of mud flow and water pollution to the dam lake. In the field survey, due to the lack of land and the existence of large numbers of illegal settlers, slash & burn was thought to be difficult and therefore permanent farms were expected to exist. However, as new field reclamation is being carried out in the form of slash & burn, the information on its characteristics have been organized and used as a material for considering the method of selecting the estimated slash & burn sites.

In accordance with the vegetation density class shown on Table 1, plots which showed decrease of vegetation between two periods were detected according to the decrease pattern. Then, it was identified as to which decrease pattern showed the characteristics of estimated slash & burn plot. Figure 4 is the graph denoting the processed result. According to the graph, decrease pattern Ⅰ to Ⅲ and Ⅰ to Ⅳ have remarkable peaks around 0.2 to 1.0ha, and also Ⅲto Ⅳ and Ⅱ to Ⅳ have gentle rise from 0.2 to 2.0ha. This shows that the area which have characteristics of a plot is detected. This fact is the basis for the adoption of the "vegetation decrease of two or more classes" as the standard to select primary estimated slash & burn site.

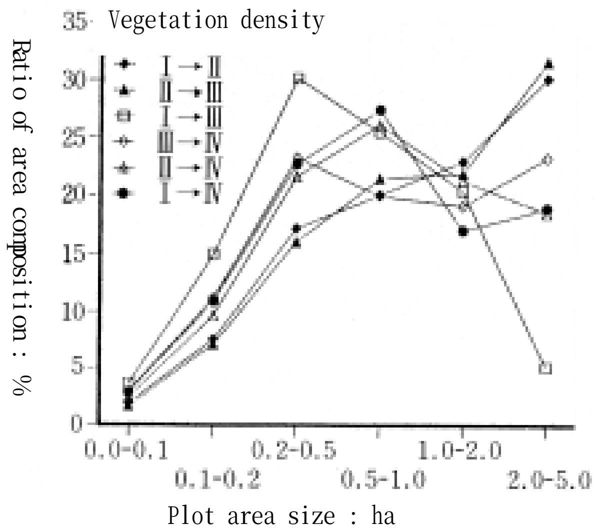


Figure 4 Ratio of area composition of estimated slash & burn site by plot size in Wailalem area

3.3 Upper reaches of Kampar River basin in Riau Province of Sumatra

This area has remarkable characteristics of slash & burn pattern out of many places in Sumatra. By using two images, Landsat MSS (resampled 30m grid) of 1985 and Landsat TM (30m grid) of 1992, approximately 330,000ha were processed collectively by applying classification by vegetation decrease, plot size and plot shape. Based on the impression of the field survey, it can be said that flat areas were relatively occupied by paddy field and rubber plantation, while food crops seemed to be planted on the side of the mountain. Although there are sites for shifting cultivation, there are many which seem to be permanent fields.

Besides the entire area, partial analysis and comparison were made in remote areas in the mountain, steep mountain sides near the village and mountain hill sides slightly far away from the villages with particular characteristics. (see Picture 3, 4 and 5: red plots are sizes of 2 to 5ha, and areas in khaki are the sites primary estimated but excluded for classification due to plot size and AI number.)

The size of estimated slash & burn plots in this area are generally large. Except for the steep side of the mountain which shows the peak from 1.0 to 2.0ha where large area cannot be occupied, size of the plot is larger both in the hill on the side of the mountain and remote place in the mountain. These larger plots seem to be cultivated by groups of several families.

The plots in the remote mountains, where people's access is not easy, have slightly irregular shape. Figure 5 is a graph that shows the area proportion in different AI classes. The graph shows that AI number of the plots tends to incline in the order of steep side of the mountain, hill on the side of the mountain and remote places in the mountain.

These phenomena could be caused by the following factors. Steep side of the mountain with limited land resources located near to the village is strongly influenced by the norms of the society, therefore the farm is in a regular shape. On the other hand, in the remote mountains, although they are designated as reserved forest by the government, they are reclaimed by unbridled slash & burn by illegal settlers, and the fields tend to be irregular in shape due to the spread of the fire. Correlation between the shape of the slash & burn plot and physical/social conditions of a location is a noteworthy issue.

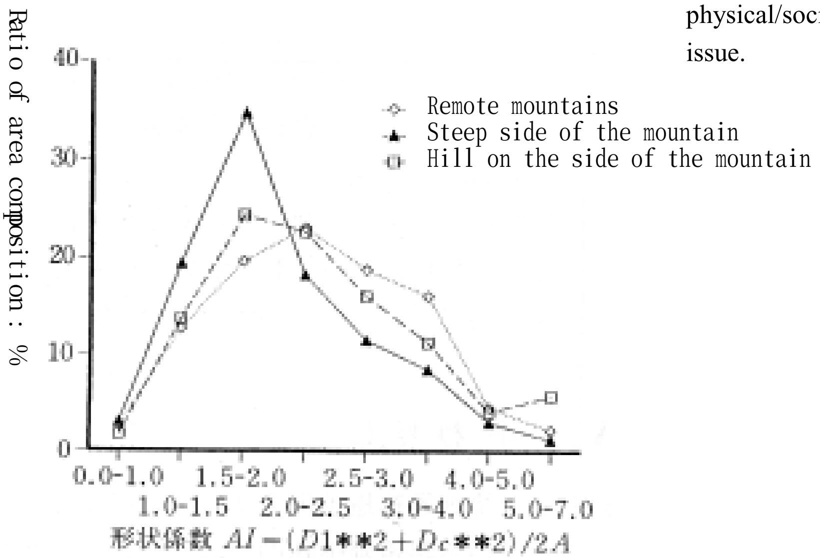
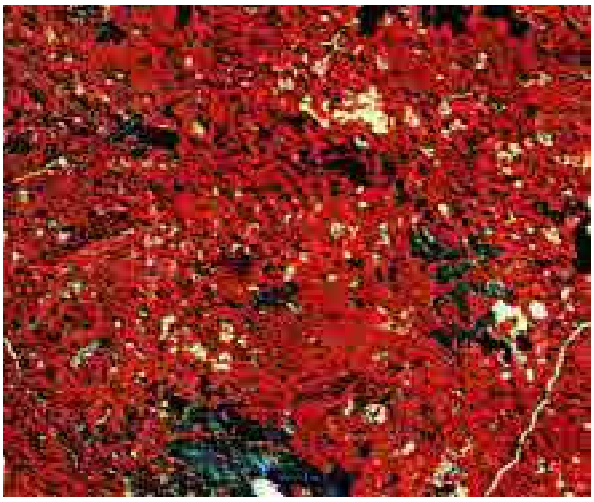
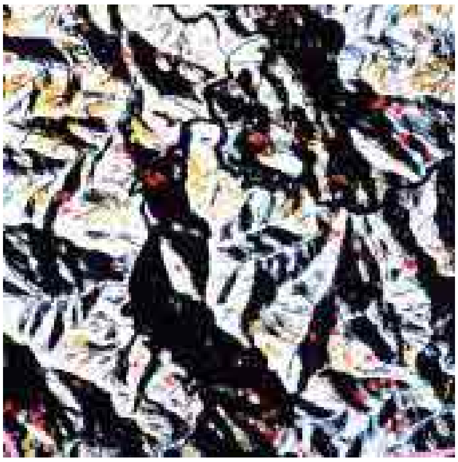


Figure5 Ratio of area composition estimated slash & burn site by plot AI class in upper reaches of Kampar River area



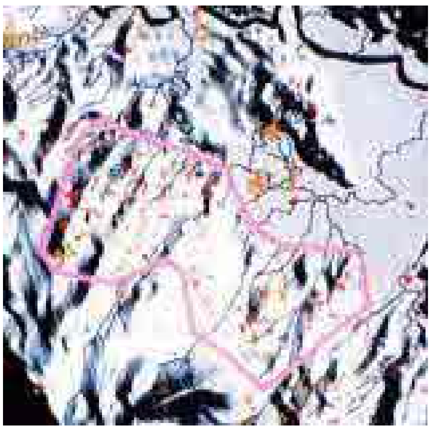
Picture 1　SPOT image on slash & burn distribution in Negara area
－Slash & burn sites are seen as white patches in red rubber plantation　－



Picture 3　Upper reaches area of Kampar River
（Slash & burn in remote mountain）

Picture 2　Picture of the slash & burn scene in Negara area
－ Upland rice, maize and young rubber trees are mixed.－

Picture 4　Upper reaches area of Kampar River



Picture 5　Upper reaches of Kampar River

4. Consideration and Deduction

The following facts were obtained from the three examples introduced.

(1) It is apparent that detection accuracy of slash & burn is improved with the introduction of a new classification method. However, it is difficult to make quantitative analysis on each of the three examples because the field survey is limited in areas along the roads only and lack of adequate materials for accuracy validation. These are issues for future consideration.

(2) If the regional total area, estimated slash & burn area and location are considered, it may be possible to estimate sustainable slash & burn cycle or to decide forest maintenance/recovery function .

(3) The size of the estimated slash & burn plots often has its peak below 5ha. Long and narrow plots exceeding AI number 5 have small possibility of being slash & burn.

(4) In an area where slash & burn is common, the plot size is generally small (not more than 2ha). On the other hand, plot size is large (several ha) in areas where permanent farms are thought to exist.

(5) Plots in the unbridled slash & burn area are irregular in shape. Those in the area where social norm functions, there is a tendency for the shape to be regular with a difference in AI number.

Application of GIS Technique on Basin Irrigation Water Balance in Indonesia

Shinobu SAKAI
Tohoku Regional Agricultural Administration Office
Ministry of Agriculture, Forestry and Fisheries
2-1, Sakaimatsu, Kuroishi-shi, Aomori 036-03891

A river basin simulation system for estimation of irrigation water balance has developed at the RSP (Remote Sensing Project), DPU (Department of Public Works) in Indonesia, which had been assisted by JICA (Japan International Cooperation Agency).

Input data are digital elevation, drainage pattern, rainfall distribution, and land cover analyzed from satellite image. Data process includes correction of depression on digital elevation, tracing of rainwater runoff, estimation of evapo-transpiration, and estimation of annual average discharge. Output are a discharge map which shows estimated discharge of every grid coordinate points and a table for selected ground points. This simulation system had applied on the 350,000ha Jeratensuluna river basin area, Central Jawa.

1. Background and Target Area

his paper introduces a river basin simulation system utilizing GIS along with a case to which this method was applied. The system introduced here has following functions. First, tracing of rain runoff channel by using the existing information such as digital elevation models, existing river systems, rainfall distribution and the land cover classification analyzed from satellite image data. Second, simulation on catchment area for a small sectional basin and for any selected ground points in a basin, or calculation of annual mean runoff discharge, etc., can be performed. Lastly, the data processed in this way can be output in the form of figures, diagrams and tabulated lists.

This simulation was carried out at the RSP (Remote Sensing Project), DPU (Department of Public Works) of Indonesia, which was assisted by JICA (Japan International Cooperation Agency). A target area includes approximately 350,000 ha of Jeratensuluna river basin that extends from 110 ° 15’ E to 111 ° 30’ E Long. and from 6 ° 15’ S to 7 ° 30’ S Lat. in Central Java (See Figure 1) .

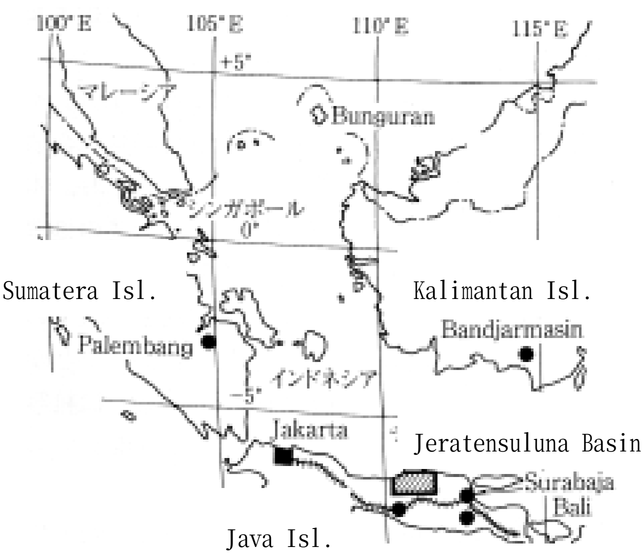


Figure 1 Location of Case Area

Figure 2 shows a basin pattern diagram of a target area. Lusi River, the main stream, has two head works and Serang River, a tributary river, has a dam and two head works. Construction of some of these facilities was completed and others are still in the planning stage. In this paper, the condition without these facilities is termed as “present” and the condition in which all these facilities have been completed is termed as “designed” for the purpose of arranging the results of basin elements calculation.

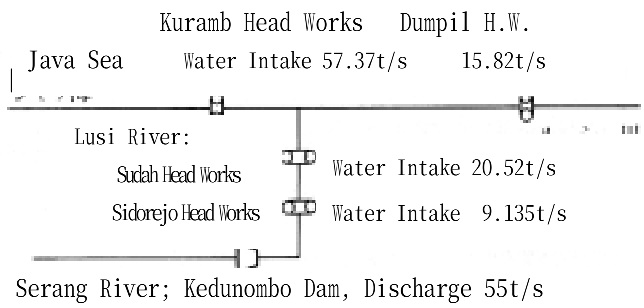


Figure 2 Pattern Diagram of Jeratensuluna Basin

2. Outline of the Process

2.1 Flow of the Whole Process

Figure 3 shows a flow of the process of this system. The process can be roughly classified into 4 stages.

(1) Adjustment of digital elevation model
Removing depressions to satisfy the rainwater runoff conditions
(2) Tracing of rainwater runoff
Production of rainwater runoff direction map
(3) Calculation of catchment area
(4) Calculation of runoff discharge

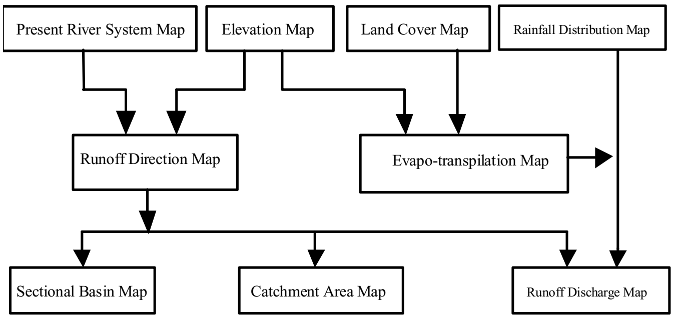


Figure 3 Flow Chart for the Whole Proce

2.2 Input Data

The following 4 kinds of data are input in a digital format.

(1) Digital Elevation Model

Digital elevation model was created from a 1:250,000 scale topographical map. A background image in Picture 4 is the one created in this way.

(2) River System Map

This map was produced by digitizing a 1:250,000 scale topographical map. The rivers drawn in this map have priority over other runoff channels in the output of river channels. It is also used for correcting depressions in the digital elevation model. This map is not indispensable and, therefore, a series of processing can be performed without it. Nonetheless, this map is helpful to avoid false results caused by the fact that quasi-rivers in a flat land, in particular, generated from digital elevation model do not always coincide with the true river channel. Main part of the river channels output in Picture 4 was created from this data.

(3) Land Cover Classification Map (see Picture 1)

This map was produced by classifying satellite image data (a mosaic of the Landsat TM images taken in June, 1991 and August, 1991).

(4) Rainfall Distribution Map

This map was produced by digitizing the existing maps. In actual application, rainfall distribution patterns were smoothened by applying a processing technique similar to the one that was used in producing a digital elevation model from contour data.

3. Processing Method

3.1 Removal of Depression in Digital Elevation Data

Many depressions are generally found in a digital elevation model. For example, when a valley stripe with steep cliffs on its both sides is represented with a large-size grid, a depression tends to be produced in the back of a valley. Size of a depression can be as big as one grid, or sometimes it can stretch out up to huge number of grids.

Such depressions were removed with the following two steps.

The elevation of a grid is compared with those of 8 surrounding grids. When the elevations of all surrounding 8 grids are the same height as the center grid or higher, a depression may be produced there. In such a case, the following examinations and process are performed.

ａ） First, define the coordinates and the elevation of a center grid as a searching center and the basic elevation, respectively.

ｂ）Among 8 grids around the searching center, look for a grid whose elevation is lower than the standard elevation (runoff point).

ｃ）When no runoff point is found, record in the memory the coordinates and elevations of all the grids that have been examined.

ｄ) Select a grid with the lowest elevation among those that have been recorded, and newly define its coordinates and elevation as a searching center and the basic elevation, respectively.

ｅ）Repeat the process from (b) to (d) on each grid except those that have been already examined or previously defined as a searching center until a runoff point is found.

ｆ）When a runoff point is found, the elevations of the grids that have been recorded in the memory are raised to the basic elevation if their heights are lower than the basic elevation.

ｇ）Next, shift a searching center to a new grid which has not been examined yet, and again the process from (a) to (f) mentioned above is repeated on every grid.

In case of the grid that has been previously defined as a runoff point is, in fact, found to be a part of a much larger depression, the following process is performed to remove a depression. Every time when shift a searching center to a new grid in process (g), clear the history "already examined or previously defined as a searching center" which is mentioned in the process (e).

In this way, regardless of the shape and the size of depressions, filling up process can be correctly performed. The maximum number of grids that can be processed in this system is dependent on the capacity of a computer. The system that was used in our study was able to fill up as many depressions as 1 million grids.

3.2 Tracing of Rainwater Runoff

For tracing rainwater runoff, there are presently two methods available, i.e. a quasi-river system method and a method that gives priority to the data of an existing river system if it is available. In the quasi-river system method, angle between the center grid and every one of the 8 surrounding grids was checked and the direction in the one with steepest gradient was defined as the rainwater runoff direction.

(1) Procedure for Creating a Quasi-River System

The following are the procedure to create a quasi-river system.

ａ）Select any point to start tracing and define it as the tracing center.

b）Examine the surrounding 8 grids to find the one whose elevation is the lowest of all and lower than the tracing center as well. Then, this grid is defined as a runoff point and runoff direction. However, if there is particular grid in the 8 surrounding grids which has been defined runoff direction already, the direction toward the particular grid should prevail as the runoff direction.

c）When the elevations of all 8 surrounding grids are same or higher than the tracing center, a tracing area should be extended as explained in (d) to (g) below to find a runoff point.

d）Among 8 grids around the tracing center, the coordinates of the one having the same height as the searching center and the direction connecting with the searching center should be recorded. The grid with same height should exist if removal of depression is previously processed.

e）Among the recorded grids, the one that was most recently recorded, except those that have already been defined as the tracing center, should be defined a new tracing center.

f）Repeat the step from (d) to (e) until the runoff point can be found.

g）When the runoff point is found, a sequent connection among the recorded grids can be traced back from the runoff point to the original tracing center defined in (a). The route thus traced back is determined as the runoff direction in that section.

h）Select a grid that has no runoff direction, set new tracing center there and perform the process from (b) to (g) again until the runoff direction can been determined for every grid. The results are arranged in a runoff direction file, which has direction numbers from 1 to 8 that points to the one of the 8 surrounding grids. This file can be used in calculation of catchment areas and the volume of runoff discharge.

(2) Priority Process of Existing River System

By recording runoff directions of the existing river system in an output runoff direction file, in advance, of a quasi-river system process mentioned in (1), the priority process stated in the above (1)-(b), i.e. "However, if there is particular grid in the 8 surrounding grids which has been defined runoff direction already, the direction toward the particular grid should prevail as the runoff direction." becomes effective and the results that reflect the priority process of the existing river system over a quasi-river system are produced. If any grid without the existing river system is found, it is filled with a quasi-river system and thus no contradiction is produced.

In determining the runoff direction of the existing river system, the rainwater tracing method mentioned in (1) can be directly applied. Digital data of the existing river system has no elevation information and it is, therefore, expressed as a flat area. In such a case, tracing of rainwater runoff can be performed by placing at least one grid at the river mouth (or at the end of a target river basin) and setting its elevation lower than the area of the existing river system. Runoff direction can be also determined in the same process. In this case, complicated tributary streams or their size, for example, some of the tributaries may occupy only one grid width, or others may form a delta and thus occupy many grids width, cause no problem in creation of river system data.

3.3 Calculation of Catchment Area

If catchment area of any given point in a target area is calculated, it will be helpful in irrigation planning and other plannings. In fact, calculation of a catchment is easily done. In the course of previous operation for tracing rainwater runoff explained in 3.2, a runoff channel has been already known. Therefore, summing up all the grids where a runoff channel lies and then multiplying the sum by unit area will give a catchment area. Cumulative catchment area from a dividing ridge to a given point and a sectional catchment area between any sections demarcated by main facilities as well can be utilized for planning. In this system, cumulative catchment area as well as sectional catchment area in every grid in a target area have been calculated. Therefore, they can be recorded in a disk file and the data of all the grids can be freely output in graphic forms or tabulated lists. "Sectional Catchment Area" and "Cumurative Catchment Area" in table 2 show some of these examples.

3.4 Calculation of Runoff Discharge

Our system calculate runoff discharge of a basin. This kind of method belongs to a distributed runoff model. In this system, the runoff depth of a grid is obtained by subtracting the percolation to deep underground and the evapo-transpiration from the amount of rainfall. Then, runoff discharge is calculated by cumulating the runoff depth of every grid along the runoff direction. Since this system uses annual data, the results are expressed in the form of annual average runoff discharge.

(1) Calculation of Runoff Depth of Each Grid

The following formula is used for calculation.

$$Pi = Ri * (1 - Bi) - Ei \qquad (1)$$

where

Pi ：Annual runoff depth of grid "i"（mm）

Ri ：Amount of annual rainfall of grid "i"（mm）

Bi ：Percolation rate to deep underground of grid "i"

Due to the fact that no effective data was available, percolation rate was uniformly set as 10% of annual rainfall of a grid.

Ei ：Annual evapo-transpiration of grid "i"（mm）

Further, Ei is expressed in the following formula as a function of elevation and vegetation.

$$Ei = ei * fi \quad (2)$$

where

$$ei = F(hi) = -0.30*hi + 1560 \quad (3)$$

ei ： Annual evapo-transpiration capacity of grid “i” (mm/year)

hi ： Elevation of grid “i” (m)

Estimated evapo-transpiration capacity at the dozens of points in Central Java was calculated by Penman method. It is highly correlated with elevation, which is a major determining factor for temperature in a tropical region. Therefore, evapo-transpiration capacity of each grid is set by the above regression equation in which elevation is used as a parameter (see Figure 4).

fi ： Vegetation coefficient (see Table 1) to obtain the amount of evapo-transpiration from evaotranspiration capacity of grid “i”.

Annual amount of evapo-transpiration obtained by formula (2) is shown in Picture 3.

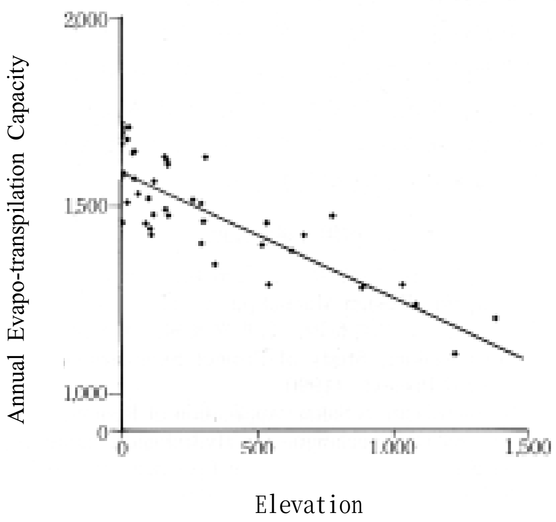


Figure 4 Correlation between Evapo-transpiration Capacity and Elevation

Table 1 Vegetation Coefficient for Evapo-transpiration

	Bare Land	Paddy Field	Upland Field/ Bush	Water Body	Plantation/ Forests
Vegetation Coefficient	0.45	0.85	0.95	1.10	1.20

(Coefficients were set by referring to the irrigation planning standards of the Ministry of Public Works)

(2) Calculation of Runoff Discharge

Runoff discharge at any given point can be calculated by, first, integrating runoff depth of each grid along the runoff direction obtained in 3.2, then multiplying the result by unit area of grid.

The following is the formula for calculation.

$$Q_C = \sum_{i \in C} Pi * A * k \quad (4)$$

where

Q_C ：Discharge (t/s) at the end of basin C (t/s)

C ：Target basin

Pi ：Annual runoff depth of grid “i” (mm)

A ：Unit area of grid “i” (ha)

k ：Conversion factor 10/(3600*24*365)

After this process is performed, annual mean discharge of each grid is obtained. The discharge at major points is shown in “Estimated Annual Mean Discharge ” in Table 2.

(3) Comparison with the Observed Discharge

“Observed Annual Mean Discharge (reference)” in Table 2 shows the values actually observed at the same points whereas the estimated runoff discharge is calculated by the above method. Due to the facts that the observed values of only 2 points are available and also percolation rate to deep underground is hypothetical, it is risky to draw a final evaluation, however, tendency toward low specific discharge rate in Dumpil basin, where arid climate prevails, can be found. Therefore, it can be safely concluded that, though a model introduced in this paper is very simple, our model has been proved effective.

(4) Displaying Water Balance Reflecting Water Utilization Plan

In addition to displaying annual mean runoff discharge, this system is able to simulate comprehensive discharge conditions when artificial operations such as water intake and water discharge were intervened at the midstream of a river, in accordance with plans such as River Basin Development Plan and so on. “Designed water intake/discharge” in Table 2 shows artificial operations, if any, and the results are shown in “designed discharge after operations”. Although there are contradictory values in our case between the annual mean values and the values limited to an irrigation period, this function allows us to compare and evaluate various water utilizations in a river basin. Picture 4 shows design discharge for all the grids. It also shows the balance of discharge resulted from discharge from a dam or water intake at head works.

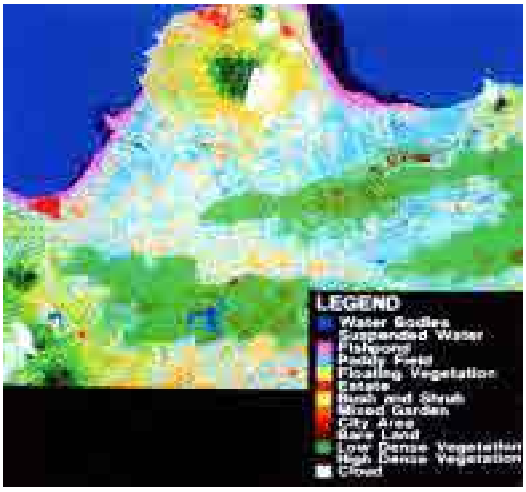
4. Farther target for Runoff Analysis by GIS

The method introduced in this paper has the advantages of utilizing updated information by remote sensing technique and high geographic resolution by GIS. Since this method does not require so many sort of information in application, it will be a powerful tool in the assessment of development plans in a developing country where limited information is available

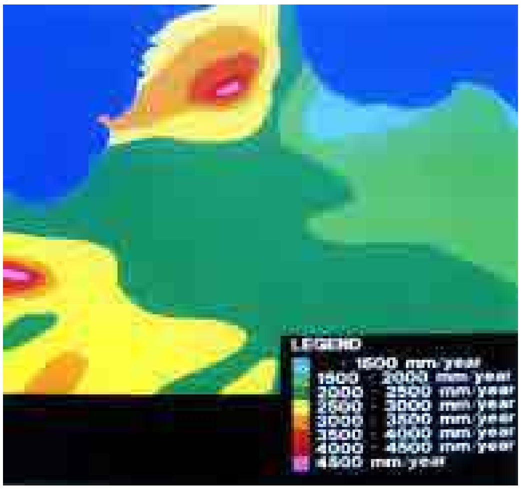
In this paper we treated hydrologic process with the distributed runoff analysis that utilizes a system of small size grids. This kind of approach has just started and, therefore, it is still in developing stage. It is expected that efforts be focused on the development of runoff model so that the model can adequately explain such phenomena as surface runoff, percolation behavior, hydrological transition of runoff, etc. by fully utilizing the advantages of GIS so as to produce fruitful results in the future.

Table 2 Basin Elements

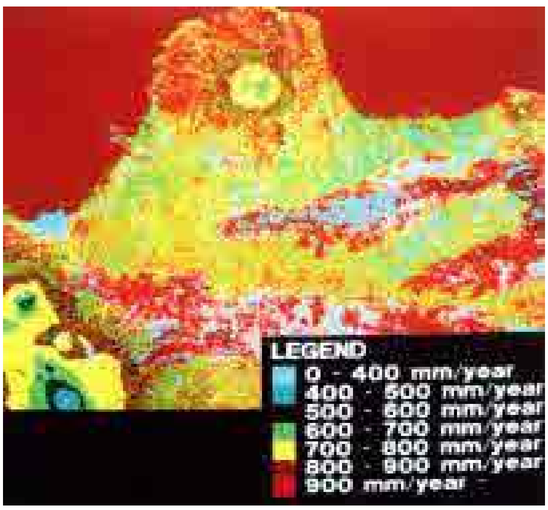
Watershed Outlet No.	Point Name	Sectional Catchment Area km²	Total Catchment Area km²	Estimated Annual Mean Discharge m³/s	Observed Annual Mean Discharge (reference) m³/s	Designed Water Intake/ Discharge m³/s	Designed Discharge After Operation m³/s
27	Dumpil Head Works	390	842	17.05	17.70	Water Intake 15.82	1.23
11	Kedunombo Dam	652	652	26.67		Dam Discharge 55.00	55.00
25	Sidorejo Head Works	24	676	27.46		Water Intake 9.14	46.65
26	Sudhadi Head Works	221	897	34.79	30.86	Water Intake 20.52	33.46
12	Kuramb Head Works	31	3,070	87.58		Water Intake 57.37	13.06
1	River Mouth	223	3,476	104.11			29.59



Picture 1 Present Land Cover (input)



Picture 2 Annual Rainfall Distribution (input)



Picture 3 Annual Evapo-transpilation (intermediate output)

Picture 4 Annual mean runoff drainage (out put)

GIS Application on Selection of Suitable Area for Agricultural Development in Indonesia

Shinobu SAKAI
Tohoku Regional Agricultural Administration Office
Ministry of Agriculture, Forestry and Fisheries
2-1, Sakaimatsu, Kuroishi-shi, Aomori 036-03891
Hiroshi YAMAMOTO
Asia Air Survey Co., Ltd.
2-18, Shinjuku-4, Shinjuku-ku, Tokyo 160-0022

Abstract

A GIS land evaluation system has developed at the RSP (Remote Sensing Project), DPU (Department of Public Works) in Indonesia, which had been assisted by the JICA (Japan International Cooperation Agency).

This paper describes some introduces a GIS applications on land evaluation for agricultural development in Indonesia. Collected raw data are existing soil map, geology map, rainfall distribution map, elevation map, slope map, and land cover map analyzed from satellite image data. Applied evaluation methods are the "Ranking method" which is based on the combination of categories in each thematic map and the "PATTERN" method which is based on the total of score correspondent to categories in each thematic map.

1. Background

Indonesia is the largest archipelago country in the world, which consists of 13,667 islands scattered in an area of 5,113km running east/west and 1,820km north/south. Around 60% of 195 million, the total population of Indonesia, is concentrated in Java Island with a population density of 800 persons/km^2, whilst on the outer islands (islands other than Java) it is 100 persons/ km^2. This remarkable regional difference in population distribution has been a problem. In order to solve the problem, the government of Indonesia has planned to develop agricultural infrastructure in the outer islands, aiming the promotion of transmigration from Java to the outer islands as well as the increase in food crop production.

For the effective selection of suitable areas for agriculture from the vast land on the outer islands, Remote Sensing and GIS was planned to be introduced as a tool for data collection and processing and analysis. In 1980, the Remote Sensing Project for the Development of Agricultural Infrastructure was established in the Ministry of Public Works in Indonesia as a project-type technical cooperation by the government of Japan through the JICA.

The project was completed in 1993 after going through phase I and II. Part of the project results are introduced here.

2. Target area for the study

In order to develop the method to select suitable areas for agricultural development in the outer islands, North Banten, the region situated in the northwestern edge of Java of approximately 400,000 ha (Figure 1) was selected as a test site to prepare an evaluation map. As shown on the LANDSAT image (Photograph 1), North Banten consists of an alluvial plain in the northeast, hilly land in the southeast and a mountainous area in the west. The plain is mainly used for rice paddy fields and the hilly land for plantations of coconuts, bananas, etc. The mountainous area including three volcanoes such as Mt. Karang is covered with forests. The distinction of dry and rainy seasons is clear. In addition, the rainfall distribution varies widely depending on topographic conditions (1,555mm/year in the northern coast and 4,500mm/year in the mountainous area). In the rainy season, the alluvial plain in the northeast is subject to constant flood damages.

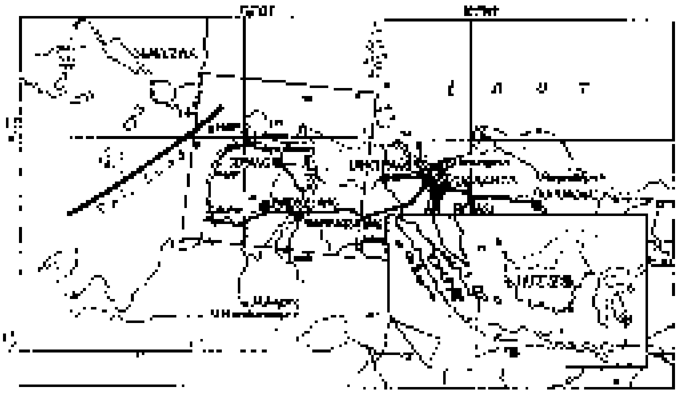


Figure 1 North Banten region location map

LANDSAT

Color composite image

- Blue parts on the mountainous area and low land areas are rice paddy fields.
- Bright yellowish white areas are arid areas.
- The blueish black belt along the coast is a group of fish ponds.
- The river slightly right to the center is River Ci Ujung.
- The peak covered with clouds is Mt. Karang (1,778m).

Photograph 1 ; LANDSAT Color composite image

Table 1 Thematic map production

Natural Factor	Thematic map	Main source of data	Production method	used to select suitable areas for agricultural development	
				Ranking evaluation method	PATTERN method
Land use	Land cover classification map	LANDSAT MSS	classify digital data with maximum likelihood method[1]	○	
Vegetation	Biomass classification map	LANDSAT MSS	compute vegetation index[2] by Rouse et.al model (1975) from digital data	○	
Geology/Geomorphology	Geology/geomorphology map	LANDSAT MSS	digitize the results of color composite image interpretation and prepare grid codes	○	○
Landform	Elevation classification map	Existing topographic map	read elevation on each grid	○	○
	Slope classification map	Existing topographic map	compute slope steepness and angles from elevation data	○	○
Soil	Soil map	Existing soil map[3]	convert the map into grid codes	○	○
	Soil depth map	Existing soil depth map[4]	convert the map into grid codes	○	○
	Soil moisture condition map	LANDSAT MSS	compute soil index[5] by Fukuhara model (1980) from digital data	○	
Precipitation	Precipitation classification map	Existing rainfall data[6]	convert the map into grid codes		○
Disasters	Flood potential map[7]	Various thematic maps	use various thematic maps to evaluate with the Typ2 Quantification Method developed by C. Hayashi (1961)		○

1) Maximum likelihood classification method: The results of field surveys and interpretation of infrared color aerial photos (scale 1/30,000) are used for classification as training data.

2) Vegetation index by Rouse et.al : the index to represent the quantity of living green plants.
VI= √(MSS7-MSS5)/(MSS7+MSS5), where, VI: vegetation index, MSS5, MSS7 : computed values of LANDSAT MSS bands 5 and 7 in the target area

3),4),6) Existing soil map, existing soil depth map, existing precipitation data : [Proyek A.P.B.D. Propinci Daerah Tingkat I Jawa Barat. (1977/1978); Perencanaan Tata Guna Tanah, Wilayah Pembangunan Banten.], precipitation data for 1931-1960

5) Soil index by Fukuhara et.al : This indicates the spectrum property on the soil surface which can be the index of soil moisture condition because of the generally strong influence by the surface moisture condition. SI=(PMSS7－MSS7)(MSS5－PMSS5), where, SI : soil index, PMSS5, PMSS7 : the values of LANDSAT MSS bands 5 and 7 related to vegetation, MSS5, MSS7 : the values of LANDSAT MSS bands 5 and 7 in the target area

7) Flood potential map : The flood potential is evaluated using 6-year flood frequency experiment data as external criteria and land cover, biomass classification, soil moisture condition, elevation, slope, distance from river, precipitation, geology/geomorphology, etc. as explaining variables.

3. Thematic map production

In order to evaluate suitability for agricultural development, it is essential to properly understand the distribution of regional resources. The information on such resources is mainly related to land and water resources. Regarding land resources, the evaluation on land stability (tolerance for disasters such as erosions, collapses and floods), productivity (efficiency of agricultural production) and workability (difficulty of land cultivation and possibility of mechanization) need to be considered. Table 1 is a list of the items of regional resources for evaluation selected under the above preconditions and the thematic maps to represent those items.

4. Evaluation map production

An evaluation map for the selection of suitable areas is obtained through comprehensive evaluation of various thematic maps. There are various kinds of evaluation methods, but they are roughly divided into two groups. One group is done by combining categories from each thematic map, and in the other by aggregating scores corresponding to each category. Both methods, Ranking evaluation method and PATTERN method, which are the representative methods of two groups are introduced in this paper. Since rice production is the most important in agriculture in Indonesia, the suitability for agricultural development here focuses on that of rice paddy fields.

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4.1 Evaluation with Ranking evaluation method

In Ranking evaluation method, a category group for each factor representing land characteristic (thematic map) is prepared and a comprehensive evaluation on specific land is done according to response combinations of those categories. For example, let the category in the thematic map A which corresponds to the comprehensive evaluation class i be Ai ; the category in the thematic map B be Bi, and so forth. If characteristics of certain land respond to all of Ai, Bi,・・・, the land is evaluated as class i. This means that Ai, Bi,・・・can be combined using AND circuit.

Eight kinds of thematic maps shown on Figure 2 were used for the evaluation. Intermediate (1^{st} stage) evaluation is carried out to avoid complication of planner's decisions and the final (2^{nd} stage) evaluation to be more realistic. One part of the intermediate evaluation is a land condition map which shows land workability and the other part is a map which shows land productivity. These intermediate evaluation maps and a soil moisture condition map showing possible soil moisture content are overlaid and the suitability of land for agricultural development is evaluated.

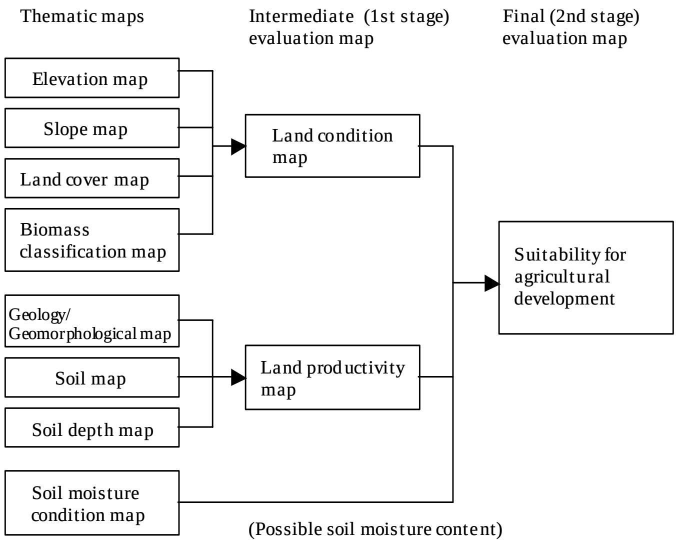

Figure 2 Evaluation of suitability for agricultural development by Ranking method

This method was applied using the following procedure:

(1) Cross aggregation of training data and thematic grid map

To know the relationship between each category of thematic map and suitability for agricultural development, cross aggregation of training data and thematic maps were done at target area. The area where suitability for development is already known through field surveys, etc. is used as training data. By investigating the characteristics of thematic map categories included in the zones according to the degree of suitability, it becomes clear what characteristics of categories combination suitable areas should possess, and at the same time, a guideline for utilizing the areas for agricultural development can be obtained.

(2) Establishing the evaluation criteria

Based on the relation between suitability for development and thematic map categories obtained by cross aggregation, opinions of agronomist and specific regional situations are taken into account to establish evaluation criteria. Table 2 shows the evaluation criteria for land condition, Table 3 illustrates those for land productivity and Table 4 shows the final comprehensive evaluation criteria which gives the suitability for agricultural development.

(3) Evaluation map production

Following the given evaluation criteria, each area unit data are classified into evaluation classes corresponding to response combination against each thematic map category. Figure 3 is a suitability evaluation map for agricultural development produced based on Ranking method.

Table 2 Evaluation criteria for land conditions, first stage evaluation (Ranking method)

		Thematic maps			
		Elevation	Slope	Land cover	Biomass
Land conditions	1. Best for paddy fields (Ideal conditions)	0－200 m	0－2%	Paddy (wet) Paddy (dry) Bushes	0－31 kg/m^2
	2. Moderate for paddy fields (Lack of workability)	25－200 m	0－15%	Bushes Garden crops	2－31 kg/m^2
	3. Moderate for paddy fields (Lack of irrigation)	0－200 m	0－15%	Paddy (dry) Grass Bushes	0－14 kg/m^2
	4. Moderate for paddy fields (Lack of drainage)	0－100 m	0－2%	Fish ponds Paddy (wet) Wetlands	0－6 kg/m^2
	5. Difficult for paddy fields (Upland plantations only)	25－1,000 m	2－40%	Paddy (dry) Grass Bushes Garden crops Forests	2－31 kg/m^2
	6. Useless for agriculture	1,000 m－	0 %－	All classes	0 kg/m^2－
		0 m－	40 %－	All classes	6 kg/m^2－

Table 3 Evaluation criteria for land productivity, first stage evaluation (Ranking method)

		Thematic maps		
		Geology	Soil	Soil depth
Land productivity	1. Good productivity	Alluvium Volcanic products Pliocene sedimentary	Alluvial Podosol Grey humus	60 cm－
	2. Normal productivity	Alluvium Volcanic products Pliocene sedimentary	Latosol Regosol Brown forest soil	60 cm－
		Alluvium Volcanic products Pliocene sedimentary	All categories Except grey-yellow Regosol	0－60 cm
		Miocene sedimentary	All categories Except grey-yellow Regosol	0 cm－
	3. Poor productivity	All categories	All categories	Rock
		All categories	Grey-yellow regosol	0 cm
		Miocene limestone Andesite Basalt Diabase	All categories	0 cm

Table 4 Evaluation criteria for suitability of paddy field development, second stage evaluation (Ranking method)

		First stage evaluation		
		Land conditions	Land productivity	Soil moisture conditions
Suitability for paddy fields	1. Best for paddy fields (Ideal conditions)	1. Best	1. Good	Wet Dry
	2. Moderate for paddy fields (Lack of workability)	1. Best	2. Normal	Wet Dry
		2. Moderate (Lack of workability)	1. Good 2. Normal	Wet Dry
	3. Moderate for paddy fields (Lack of irrigation)	3. Moderate (Lack of irrigation)	1. Good 2. Normal	Dry Extremely dry
		1. Best 2. Moderate (Lack of workability)	1. Good 2. Normal	Extremely dry

	4. Moderate for paddy fields (Lack of drainage)	4. Moderate (Lack of drainage)	1. Good 2. Normal	Extremely wet Wet
		1. Best 2. Moderate (Lack of workability)	1. Good 2. Normal	Extremely wet
	5. Difficult for paddy fields (Upland plantations only)	5. Difficult for paddy fields	1. Good 2. Normal	Wet Dry Extremely dry
	6. Useless for agriculture	6. Useless for agriculture	All categories	All categories
		All categories	3. Poor	All categories

(Notes)

・Lack of workability : The land cannot be highly efficient paddy fields due to the inclined land surface.

・Lack of irrigation : Though the land surface is currently dry, the land has a possibility to be good paddy fields with irrigation facilities.

・Lack of drainage : Though it is currently wet land, the land has a possibility to be good paddy fields with the drainage improved.

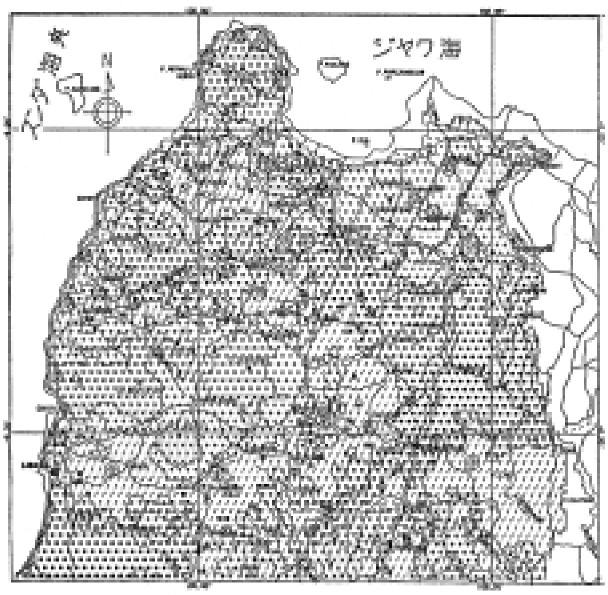

Figure 3 Evaluation map produced with Ranking method

1: Best for paddy fields, 2: Moderate for paddy fields (Lack of workability), 3: Moderate for paddy fields (Lack of irrigation), 4: Moderate for paddy fields (Lack of drainage), 5: Difficult for paddy fields (Upland plantations only), 6: Useless for agriculture

4.2 Evaluation with PATTERN method

(1) Characteristics of PATTERN method

The selection of suitable area for agricultural development is difficult to be dealt with a quantitative model because regional resources used for evaluation such as geography, geology/geomorphology and soil have qualitative characteristics. The PATTERN method described here quantifies the issues and has a different characteristic from a qualitative model described by the former Ranking method. In suitable area selection using the PATTERN method, evaluation is done on how much various resources in the region can be utilized with the objective for regional agricultural use. In other words, it is a method to numerically express the regional potentiality for agricultural use, an effective method for determining priority in regional development. PATTERN (Planning Assistance Through Technical Evaluation of Relevance Numbers) method is a method developed by the US company Honeywel in 1963 for planning a long-term project in the space section. In the Apollo Project, PATTERN method was used for selecting an observation system mounted on a rocket sufficient enough for accomplishing their objectives.

(2) Evaluation with PATTERN method

The evaluation using PATTERN method creates a pyramid shaped relevance dendrogram having the agricultural development suitability at the top and regional resource factors at the bottom of the pyramid, based on the importance of each regional resource factors' objectives. Following this, the total score is obtained for each regional grid to be used as development suitability evaluation value.

The relevance dendrogram in this project is shown in Figure 4 as an actual example.

If the final objective is the suitability for agricultural development, the relative weight of land capability and land limitation are 70% and 30% respectively. Land condition, land productivity and water resources are elements which influence land capability in the lower level and their relative weights are 20%, 40% and 40%. Moreover, elevation and slope elements are related to land condition with relative weight of 60% and 40%. Amongst the regional resource items, slope contributes to the final objective with an absolute degree of $0.4 \times 0.2 \times 0.7 = 5.6\%$. Thus, a target area unit of 'slope 2-15%' has a total score of 1.68, which is obtained by multiplying the category score of 30 by 5.6%. In the same manner scores of every land resources factor are computed, and the sum of the final scores is regarded as the potential of a target area for agricultural use.

Based on a relevance dendrogram in Figure 4, the suitability results evaluated using the PATTERN method is shown in Figure 5.

improve land conditions for development can be obtained from the Ranking method because every evaluation class is shown in a qualitative manner and includes explanations of the hand characteristics. On the other land, the order for agricultural development can be obtained from PATTERN because the land potential is denoted in quantity.

Accordingly, it is suggested that PATTERN be applied to determine the order of development after the selection of suitable areas by the Ranking method.

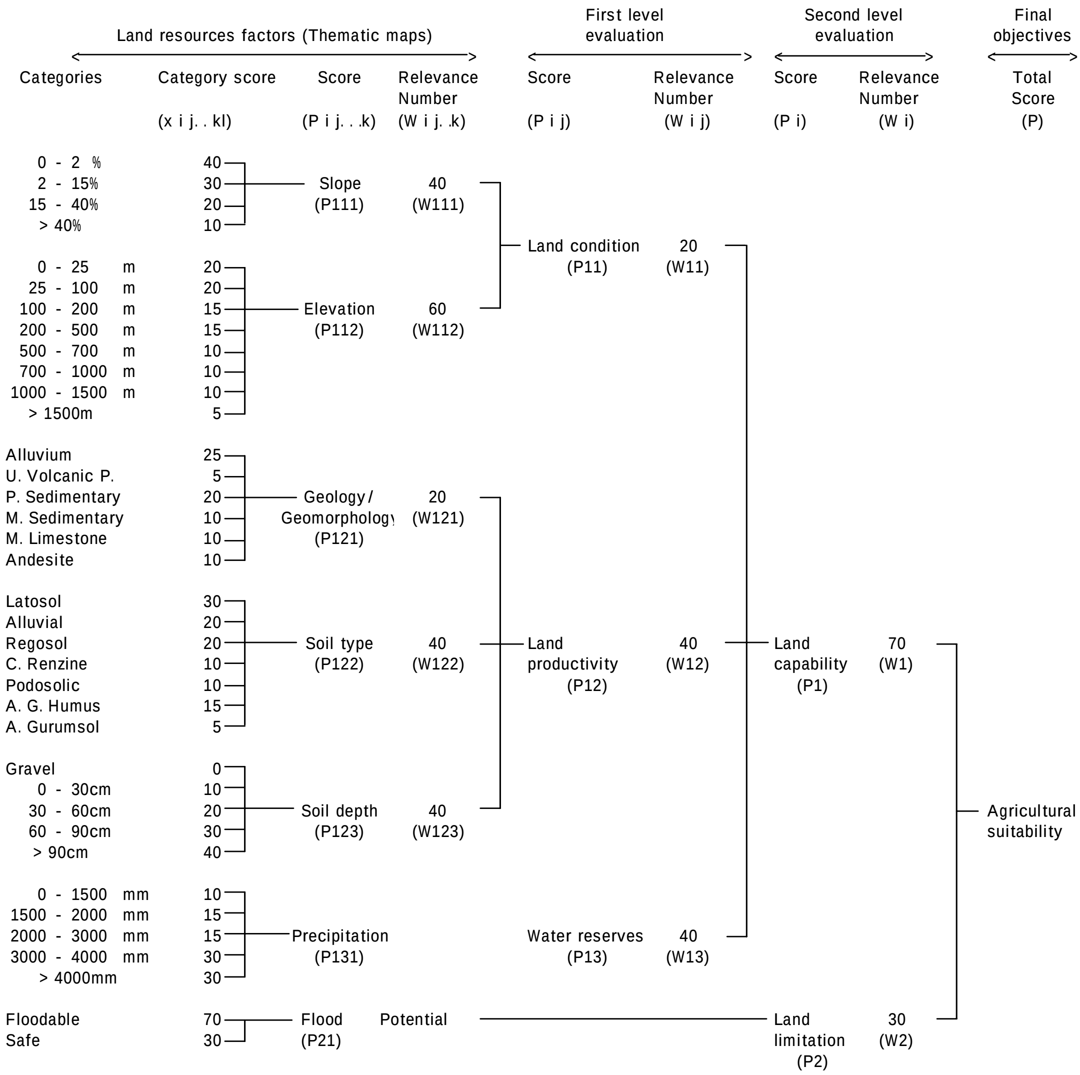

Figure 4 Evaluation model by PATTERN method (Nasu et. al, 1983)

5. Comparison of the two methods

Both the Ranking method and the PATTERN method are useful for understanding the land condition. They are able to evaluate suitability with enough accuracy for practical planning, as confirmed by field checks. However, each method has different characteristics. Effective guidance to

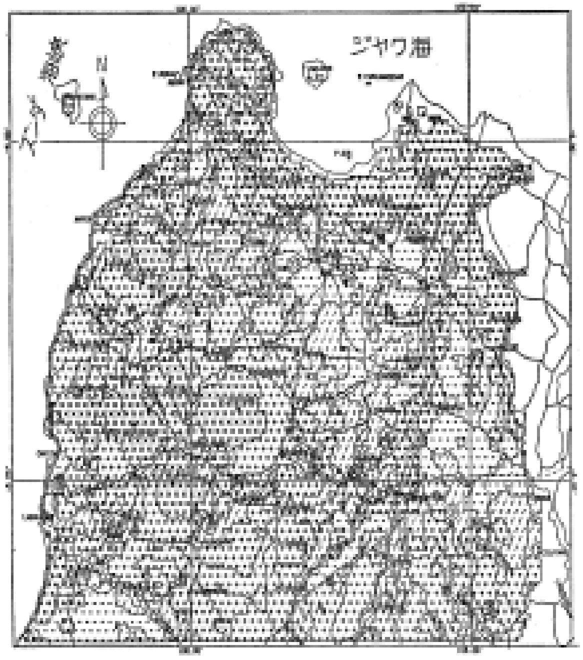

Figure 5　Evaluation with PATTERN method
1: Best,　2: Good, 3: Good – Moderate,　4 Moderate – Poor,　5: Poor,　6: Not good

Integration of GIS and Multivariate Statistical Analysis in Master Plan Study on Integrated Agricultural Development in Laos

Makoto ISHIZUKA*, Shigeya OTSUKA**, and Yukiyasu SUMI***
Nihonkouei Co.,ltd.　Overseas Consulting Administration
* Agriculture Development Division
** Irrigation and Rural Development Department
*** Environmental Science & Engineering Department
3-1 Koujimachi, Chiyodaku, Tokyo 102-0083 Japan

Abstract

The authors established the advanced analytical methodology for decision-making, using GIS and multivariate analysis (Principal Components Analysis and Cluster Analysis) in master plan study on integrated agricultural development in Laos. As GIS is increasingly used for overseas projects, GIS is naturally used for geospatial analysis while it is very important to be identified to use GIS as a function of database and the way of application and GIS is integrated as one of fundamental technologies in decision-making process. This method has become an outstanding attention from other development assistant organizations as well as the Ministry of Agriculture and Forest in Laos. In addition, all 141 districts are divided into 10 groups according to its grouping method based on the scientific and objective interpretation of these data set and derived a present condition of agriculture, constrains prevented development, and specific targets to tackle the constrains found in each district. Strategic development planning will work out effectively in a specified area when human and financial resources are invested in specific targets for development. This methodology will be highly applied for **strategic development planning** in other various fields as well as agricultural development and points out that GIS is an essential technology for the formation of a master plan.

1. Introduction and Objectives

The government of Japan had decided to conduct master plan study on integrated agricultural development in Laos after received a request of the Government of Laos. Japan International Cooperation Agency (JICA) dispatched a study team, which was included members of Nippon Koei Co.,Ltd., to Laos between November and Octorber 2001.

The methodology using GIS and multivariate analysis was applied to the identification of the agricultural conditions in each district of Laos. It is intended to use the results of analysis for **strategic development planning** to make realistic and area-specific projects/programs based on the scientific methodology applied here. The effectiveness of GIS was optimized by the combination of GIS and statistical analyses, which integrates agricultural, social, topographical, and natural environmental data, and by making decisions based on the scientific and objective interpretation of these data sets. It should be pointed out that GIS should not be an isolated technology but a part of an integrated methodology of analysis.

2. Methodology

2.1 Integration of GIS and Statistical Analyses

GIS derives digital data sets from an existing database and adds meaningful information to the integrated analysis. Essential data sets stemmed by GIS are topographical data sets including elevation, slope, the total length of roads, land use data derived from the satellite image analysis. On the other hand, the statistical analysis makes plenty of data sets (in this project about 20,000 data were used) easily readable and comprehensive.

The advantage of this methodology is derived from the fact that strategic development planning, which leads to appropriate decision making for planners, bureaucrats and politicians in both developed and developing countries, can be accomplished through the combination of GIS and multivariate analysis (in this project principal components analysis and cluster analysis were applied).

2.2 Flow of Analysis

Firstly, existing agriculture census 1998/99 and population census 1995 data and GIS data (both raster and vector data) were collected in Laos. The compilation of topographical data was conducted using ESRI ArcView Spatial Analyst.

After the data compilation using GIS, principal components analysis (PCA), one of the multivariate statistical analysis techniques, was carried out. PCA derives a number of principal components (five of which were extracted in this project) that explain the main factors related to the present conditions of agriculture in Laos. Then, all the 141 districts were classified into 10 groups based on the principal component (PC) scores of the five principal components by applying the technique of cluster analysis.

Then, the present characteristics of each group are identified in terms of various aspects of agricultural conditions, and then constraints, which prevent sustainable agricultural and rural development, were found out for each group. Finally, targets and appropriate policies were clarified to tackle the constraints found for each group of districts. Strategic planning of area-based agricultural and rural development can be made possible following the methodology applied here.

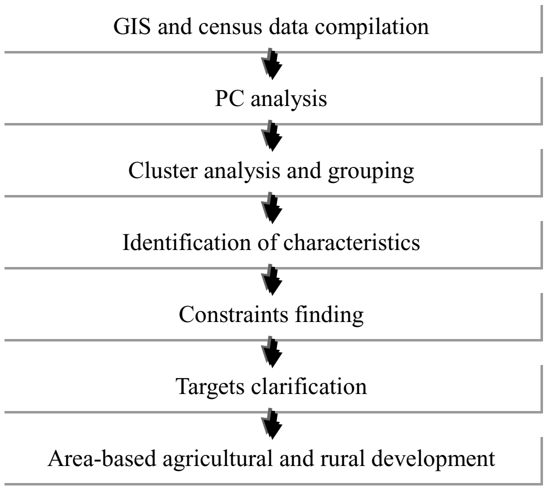

Figure 1. Flow Chart of Analysis

2.3 Principal Components Analysis (PCA) and Data used

PCA was applied to plural sets of variables to discover similarities and positioning of the variables. PCA involves a mathematical procedure that transforms a number of (possibly) correlated variables into a (smaller) number of uncorrelated variables called principal components. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible.

Since the possible number of PC should be the total number of variables (equal to 141 districts in this analysis) minus 1 according to the principle of PC analysis, about 140 data sets were selected as meaningful data to be applied to principal components analysis. The list of the data used in this project is presented below.

Existing GIS data was obtained from the National Agriculture and Forest Research Institute (NAFRI) in Vientiane that has conducted a number of GIS projects in cooperation with the Mekong River Commission to derive 50 m and 250 m grid digital elevation model (DEM) and other essential data for the analysis.

2.4 Cluster Analysis and grouping

After the identification of the five PC, cluster analysis was applied to the grouping of the 141 districts based on the PC scores of each district. Cluster analysis is also one of the

Table 1. Data Compiled and Used

Data Type	Description of Data	Data Format
Topographic data	·Roads in 4 classifications	GIS polyline data
Elevation and slope	·Digital Elevation Model (DEM) of 50 and 250 m grid in all Laos ·Slope of 50 and 250 m grid in all Laos	GIS grid data
Administrative boundary of provinces and districts	·District boundary containing 141 districts ·Provincial boundary containing 18 provinces	GIS polygon data
District level digital data from 1998/99 agriculture census	·Average area of holding and number of parcels, land use and land tenure conditions Cropping pattern and major crops cultivated ·Purpose of production ·Use of production inputs ·Average number of livestock raised by livestock type · Number of holdings with aquaculture ·Others	DBF
District level digital data from 1995 population census	·Population density ·Percent distribution of population by sex ·Urban and rural population ·Percent distribution by place of birth ·Household size by urban and rural ·Population by education level and literacy rate ·Economically active population by occupational classification and unemployment rate ·Children born and deceased persons ·Electricity and domestic water supply ·Conditions and availability ·Others	DBF

multivariate analysis techniques that seeks to organize information about variables so that relatively homogeneous groups, or "clusters," are formed based on the Mahalanobis distance which determines the "similarity" of a set of values from an unknown sample to a set of values measured from a collection of known samples. The number of groups is determined on the trial-and-error basis, which finally comes up with the meaningful division of districts in terms of agricultural conditions over the country.

3. Results

3.1 Derived Principal Components

The five sets of principal components identified as a result of PCA include: 1) Transitional Farming, 2) Market Orientation, 3) Water Resource Utilization, 4) Farm Intensity, and 5) Degree of

The characteristics of Groups 1 and 5 are described in the following table based on the averaged score of each group's PC. The difference between the two groups is huge in terms of their agricultural settings. Group 1 is representative for the region where shifting cultivation and traditional agriculture are popular among the farmers, while Group 5 practices the modernized and market-oriented agriculture.

Table 4. Description of Agricultural Setting

Group	Principal Components: Components	Principal Components: Evaluation	Describe Characteristics
Group 1	Transitional Farming	Low	• Shifting cultivation is widely practiced on sloping land for production of upland paddy. • In order to supplement a lower productivity, non-paddy products (including livestock and home manufacturing products) are produced and marketed to a certain extent. • Expansion of irrigation area mainly for lowland paddy production is at mid to low level. • Resource management is poor and depletion is high. • Farming intensity is at mid to low level, and diversification is at mid to high level.
	Market Orientation	Mid. to High	
	Water Resource Utilization	Mid. to Low	
	Farm Intensity	Mid. to Low	
	Degree of Diversification	Mid. to High	
Group 5	Transitional Farming	High	• Districts that belong to this group are located near to Vientiane city, and production of market oriented crops are considerably well developed. • Irrigation system is also well developed and supports crop diversification. However, farm intensity is relatively low. • Floods occur frequently in the wet season along the Namgum River due to its topographic condition.
	Market Orientation	High	
	Water Resource Utilization	High	
	Farm Intensity	Low	
	Degree of Diversification	Mid.	

As shown in the next table, the constraints, rooted in the described characteristics, are found out, and the targets to be achieved are clarified. The comparison between the two groups exemplifies the necessity of strategic development policies to tackle the constraints focusing on some regions.

Table 5. Constraints and Targets Identified

Group	Found Constraints	Clarified Targets
Group 1	(1) Domination of unsustainable shifting cultivation which is a cause of forest cover reduction, soil erosion, etc. (2) Food crops are insufficiently produced. (3) Productivity of non-paddy crops is low, although they are important for cash income source. (4) Production and marketing infrastructure is poorly developed. (5) Degree of market orientation is still at mid. level.	**(1) To prevent expansion of shifting cultivation.** **(2) To develop adequate production systems for sustainable use of upland.** **(3) To promote production of cash crops to increase farmers' income both in upland and lowland areas.** **(4) To provide production and marketing infrastructure.** **(5) To improve productivity of lowland paddy.**
Group 5	(1) Further expansion of market oriented crops are becoming difficult due to small domestic market. (2) Quality of marketing crops is still at a low level for export. (3) Paddy productivity is still at a low level. (4) Flood damages are considerable in the eastern part of Vientiane municipality, although the largest market is close by.	**(1) To develop and introduce proper cropping pattern and production technologies so as to produce high value crops throughout the year.** **(2) To improve the quality of products so as to increase their competitiveness.** **(3) To assist farmers in marketing development.** **(4) To improve productivity of paddy by use of proper level of inputs taking economic return into account.** **(5) Some flood mitigation measures in the mid- to long-term are thus needed.**

3.4 Area-based agricultural and rural development

After clarifying all the necessary information on the agricultural setting of each group, the planning of area-based agricultural and rural development was conducted.

Group 1

Shifting cultivation, having a considerable negative impact on the land and forest, is widely practiced in the mountainous areas of Group 1. It is expected that such a negative impact may expand in future as a result of increased population pressure. Fundamental measures to stabilize shifting cultivation include the development of alternative production systems through the strengthening of research efforts and the dissemination of such systems to farmers through extension services.

In addition, the expansion of road networks is promising to promote infrastructure and marketing possibility in remote areas. For the lowland areas, the distribution of improved seed, and the improvement of cultivation techniques and existing irrigation systems are required.

Group 2

A part of Vientiane municipality and its suburbs are classified into Group 5 where vegetables for the largest market in Laos, Vientiane City, are intensively produced particularly in dry season. In this area, however, flooding due to its topographic conditions is one of the largest constraints to agricultural development. Flood mitigation measures in the mid- or long-term are thus needed for the promotion of wet season agricultural production, although this analysis is independent of the statistical results.

In addition, the introduction of new vegetable crops and varieties, cheaper plant management and quality control technologies and appropriate technologies for all-year-round crop production is indispensable to facilitate vegetable production in non-flooded areas.

4. conclusion

Necessity and urgency of agricultural and rural development projects/programs can be derived from the full understanding of the present conditions of agriculture, and prospective projects/programs are to be designed to fulfill the targets identified for each group.

4.1 advantages

The application of this methodology to the formulation of the integrated agricultural development plan derives the following advantages:

- Strategic development policies can be derived, which is to efficiently and effectively concentrate limited human and financial resources on a specific target and in a specific area (through grouping) to tackle poverty and promote agricultural production.
- It is possible for decision-makers to clearly prioritize both development targets for each group and geographical regions that should be addressed first, based on the principal component scores of each district.

4.2 limitations

- The quality of original data is of the utmost importance. In other words, the quality of this methodology heavily relies on the reliability of original data sets. Therefore, the importance of both data collection and data selection cannot be overemphasized.
- This methodology is not independent of other additional information, particularly, of field surveys. For a group of analysts applying this methodology, experienced experts who are familiar with the actual conditions should work on the analysis together. Otherwise, the analysis will not be sufficiently reliable at all.
- Political considerations should not be ignored at the time of final decision making. Priority actions or areas might be shifted from the results of the analysis due to the local politics.

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The Feasibility Study on the Forest Management Plan In The Central Highland In the Socialist Republic of Viet Nam

Kei Satoh
PASCO corporation
1-1-2 Higashiyama, Meguro-ku, Tokyo 153-0043, Japan

Abstract:

The Feasibility Study on the Forest Management Plan in the Central Highland in Socialist Republic of Viet Nam was decided to be conducted by the Government of Japan in response to a request of the Government of Socialist Republic of Viet Nam. Japan International Cooperation Agency (JICA) dispatched a study team that included Japan Overseas Forestry Consultants Association and Pasco International Inc. to Viet Nam between February 2000 and May 2001. Digital data of topographic data, land-use/vegetation image data, forest type boundaries, communes, forestry enterprise boundaries of the study area were created. Using the GIS database potentiality/problem/constraint of forestry development was evaluated by geographical analysis. Furthermore, suitability analysis/evaluation of the existing surrounding villages were carried out in order to support the local inhabitants.

1. Study Objectives

The purpose of The Feasibility Study on the Forest Management Plan in the Central Highland in Socialist Republic of Vietnam (hereinafter referred to as the Study) is to prepare plans to realise long term Sustainable Forest Management. As a short-term plan, a forest management plan was to be developed in the most important forest of the region, Kon Plong County, Kontum province in the Central Highland. The survey area is located in Kon Plong county, Kontum province (some 233,000ha) in the Central Highland. The model area is 24,000ha in area and a district administered by Mangura forestry public corporation.

The purposes of the use of GIS in this Study are to investigate forestry potentiality (area etc.) and evaluate land suitability etc. for the formulation of forest management plans.

2. Data in Use

The data used in the Study are as follows.

2.1 1:50,000 Topographic Maps

GIS data were prepared from the topographic maps using a digitizer. The GIS data created consists of study area boundaries (polygon), rivers (line), roads (line), villages (point), contours (line), and elevation points (point).

2.2 1:10,000 Topographic Maps

GIS data of Mangura district were prepared using digitizer the topographic maps. The GIS data created consists of vegetation boundaries (polygon), buildings (line), rivers (line), roads (line) and contours (line).

2.3 Landsat/TM Image Data

Landsat/TM Image data, when given the same projection system (geographic coordinate) as that of topographic maps, are able to be handled in the same way as GIS data in the same computer system. Image data with this kind of projection are called Raster GIS data. In this Study, land use・forest type image data were prepared by image processing Raster GIS data. Raster GIS data were converted to GIS data.

2.4 1:20,000 Monochrome Aerial Photographs

They were used as reference materials to classify land use and forest types. Principal point position data in the photographs were converted to GIS data.

2.5 Other Thematic Maps

Forest type boundaries (polygon), communes (polygon), forestry corporation boundaries (polygon) were created in GIS database using each thematic maps. From land-use・forest type images, slash and burn field distribution maps were prepared and stored in the GIS database. Analytical maps of topography etc. were compiled by parting into grids (1cm×1cm) and by analysing topography and water system using a 1:50,000 topographic map as a base map. Analytic grids of topography etc. (polygon) were stored in GIS database as well as various thematic maps. Details of analytical grids of topography etc. consist of local topographic features, relative relief, river systems, and elevation classes.

The advantage of storing digitised data in GIS format from topographic maps is that information of text, numerical values and images can be processed simultaneously on the basis of position information on the computer. Thus it is characterised by integrated management of maps, field records, site photographs and analysis of various map data information in the same system.

Furthermore, different from paper maps, it is possible to reduce or enlarge the map sizes on the computer but it is important to keep in mind that the accuracy is heavily dependent on source materials, in this case the paper maps.

Figure 1 shows an example of commune boundaries and compartments displayed in layers against the background of contours, roads and rivers digitally inputted from 1:50,000 topographic map. Figure 2 shows land use・forest type image data referred to as Raster GIS. The boundaries of communes and compartments are overlaid as shown in Figure 1 and illustrates that land use・forest type image data and boundaries of compartments etc. data can be handled simultaneously on the basis of position information.

Figure 1: 1: 50,000 Topographic Map, commune boundaries and forest boundaries

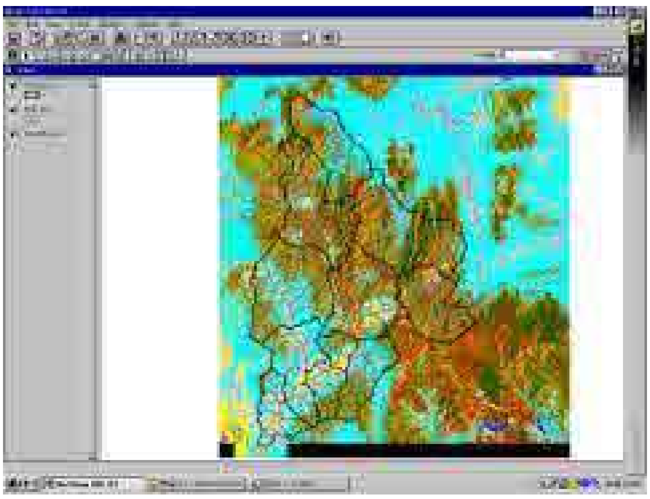

Figure 2: Land Use/Forest Type Image Data

3. Role of GIS and examples of its application

An example of GIS application in the field of forestry is forest planning information management system in which forest/forest survey inventories are added to a forest planning map as attributive information. This system enables users to comprehend existing forest conditions visually and systematically, to set up various plans (forest management plans, such as administration plans and implementation plans), and to calculate forest area and wood supply capabilities. By using GIS, it is possible to adopt other evaluation factors such as geology and topography other than forestry and carry out forestry capacity evaluation of water conservation, mountain disaster prevention, conservation of living environment, health culture, etc.

In this Study, evaluation of forest malfunction warning levels was carried out by applying GIS through comprehending forestry potentiality in each compartments/forest administration areas and evaluating various functions (water conservation, soil conservation, landslide prevention, outflow prevention) by using analysed results of topography etc. and forest type data. Furthermore, land suitability evaluation study of the existing peripheral villages was also implemented to support local inhabitants.

Figure 3 illustrates the results of topographic analysis stored as GIS data of the grid data and commune/forest boundary overlays. Both figure 3 and 2 shows that various data, such as area calculation of local topography evaluation in each forest boundary can be analysed on the same system. Figure 4 shows selected land use/forest type data of the periphery of villages, a part of the land suitability evaluation to support inhabitants. It is possible from this to identify land cover conditions within 1 km radius of existing villages and to prepare suitability analysis to support local inhabitants.

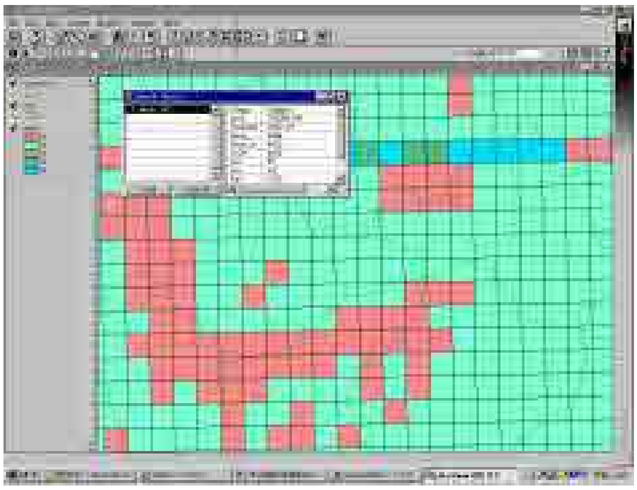

Figure 3: Results of topographic analysis stored as GIS grid data

Various collected map data and analysed results have been handled separately so far, but in this Study they were unified by the use of GIS. If GIS analytical technology transferred, it will be possible not only to implement forestry management, evaluation and planning in field offices whenever need arises, but also to apply all the process of evaluation methods and forest management planning adopted in this Study to other regions.

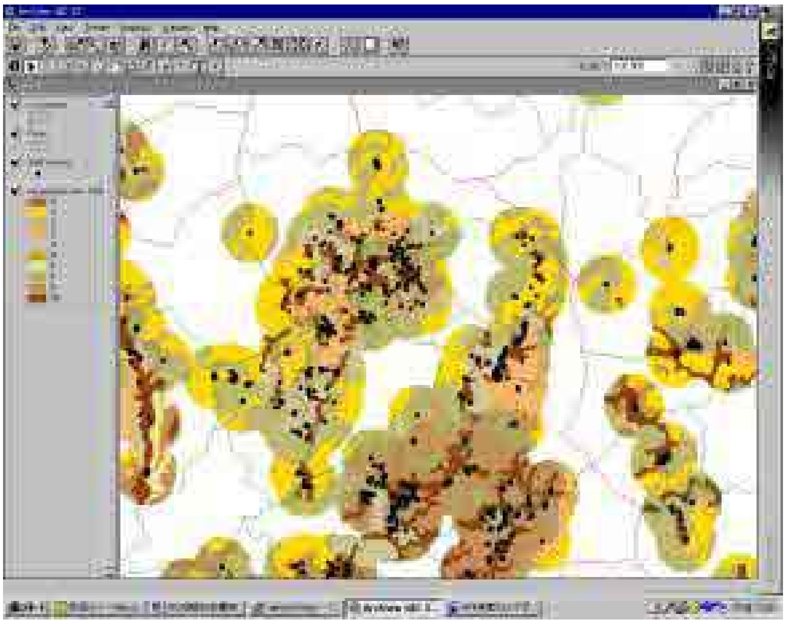

Figure 4: Land covering status within 1-km radius of villages