Environmental Studies using the Remote Sensing Data in Civil Engineering Project

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1. Introduction

In construction of large civil Engineering projects,environmental studies before its construction, during construction and after construction are required from both the natural side and human side and their scientific systematic approaches are now being studied from the point of pattern classification using computer analysis.

This paper describes the fundamental environmental studies by means of photographic informations such as natural color, infrared color, multiphotos and thermal images and how to evaluate their elements relating to the construction of civil engineering projects as a system. The latter discusses the environmental evaluation by computer analysis for construction of forest roads and others showing the examples.

2. Purpose and Place

Since the design works of a forest road are important from the point of development and protection of natural resources, natural conditions must be considered from both the long and short-range viewpoint in the total planning system.

The main factors of natural conditions are such items as topography, geology, soil, animal, vegetation and weather conditions. As they include scientific contents, it is difficult to classify the quantitative values. These studies are connected to computer data analysis for evaluating natural environment by correlated analysis using the computer in case of constructing a forest road.

Moreover the moderate processing methods using the many factors relating to construction are examined in connection with the data printing methods, especially important considerations were mostly placed on the relationship between development and protection of natural resources.

The authors selected the test site (area, about 3.71 km^2) in the reservoir along the Oi and Abegawa River in Shizuoka Prefecture situated in the center part of Japan. In the test area, the forest road connecting Toshiro villege, Onezawa-sawa and Kurasawa-sawa (the place of forest cottage) was planned. This road is required for forest planting and hauling the timbers from the forest. Fig.1 shows the automatic drawing of forest roads researched by specifications. Fig.2 shows the specification for construction of a forest road. Fig.3 shows the planning technical factors of the second class road.

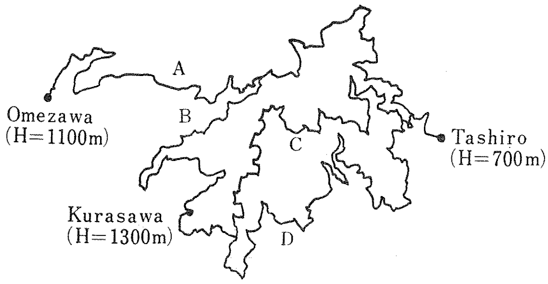


Fig. 1 Automatic drawing of forest roads researched by specifications of forest roads

Item 10. Vehicle velocity for pranning

Class	Velocity for planning (km/h)		
First	40	or	30
Second	30	or	20
Third			20

Item 15. Curve radius

Velocity	Radius (m)	
40	60	40
30	30	20
20	15	12(8)

Item 20. Profile gradient

Velocity	Profile (%)	
40	7	10
30	8	12
20	9	14

Fig. 2 Specification for construction of forest road

1: 25,000	
Vehicle velocity	20km/h
Road class	Second order
Profile gradient	10%
Radius	12m

Fig. 3 Planning factors

3. System and Data Processing

Fig.4 shows the system flow chart used for this study for environmental anlysis for the construction of a forest road.

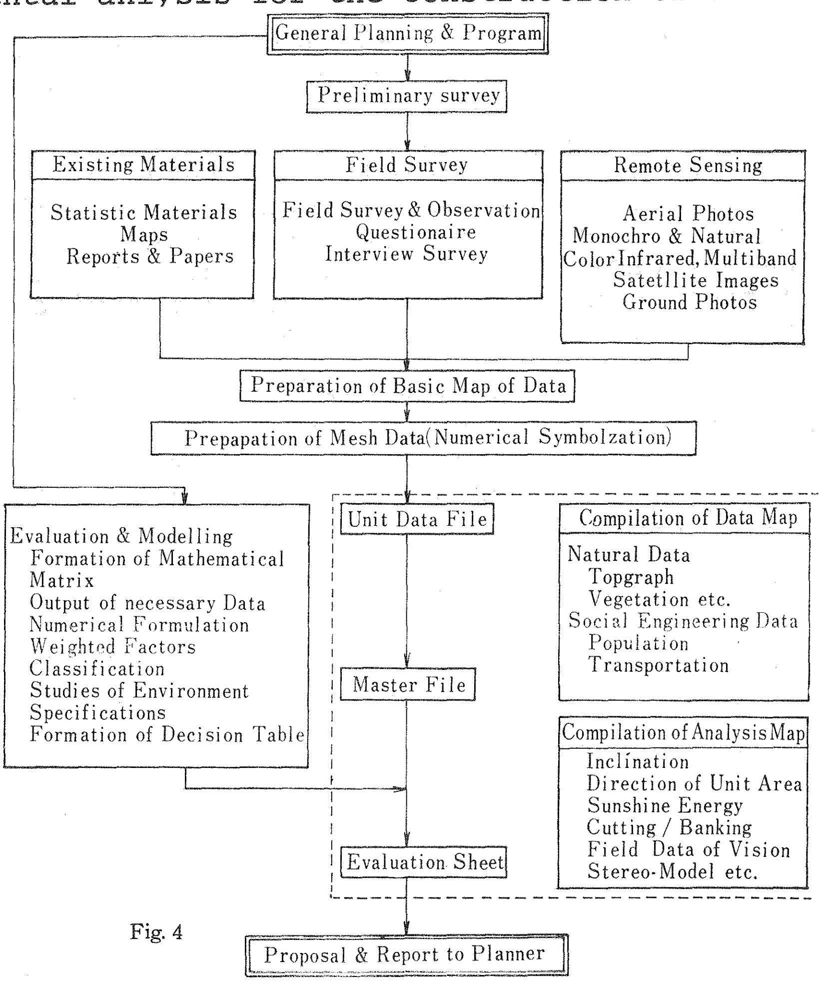


Fig. 4

In the first stage, total general planning, its program and approach are needed. Especially problems which are most likely to be encountered in each practical processing stage must be cleared and related and effective information and materials must at the same time be collected, such as existing statistical data, maps and reports. Adding to the conventional field survry, the photo images of remote sensing techniques from airplane and satellite also provide very useful information. But these data are arranged in a certain fixed list and must be tabled in a numerical inventory which is called the basic map of data.

Secondly the basic map must be converted to a mumerically arranged program for input into a computer which can be stored for processing the next step. For this purpose, the test area is divided into square meshes having fixed intervals and each legend data of the basic map are replaced with a numerical code weighted to the natural conditions. This work is known as the formation of mesh data. Files are prepared for each basic map data. In the first step of mumerical coding, the file number is equivalent to the number of the basic map and each file can be analyzed into the details necessary for inventories under consideration for each relationship. For example, topographical data can be obtained such as data on inclination of topography, direction of unit area and sunshine energy,etc. and the newly formulated data files, which is called a master file, increase during processing of anlysis in proportion to percentages.

The stored information in the master file can be outputted in analogue form which is called a computer map typed out from the line printer and also these drawings can be done by using the automatic drafter. The advantage of this process is that various kinds of statistical information is typed out from the systematized master file and at the dame time select the meshes that are equivalent to natural environmental conditions. In this stage, the necessary data are outputs for mumerical formulation with the mathematical matrix to satisfy certain environmental condition tables, called " Decision Tables ".

Accordingly, the modelling work needs an objective and purpose for the projects and for the formation of the decision tables. Severe and descreet selection of related factors and the relationship of each factor must be throughly considered in a well-systematized process.

4. Processing System of Environment Data

The outline of the processing system ofenvironment data is as follows :

(1) Preparation of basic map
(2) preparation of mesh data
(3) preparation of data file (correlation of master file)
(4) Environmental evaluation

4-1. Preparation of basic map

The materials amd data for analysis of the environment were collected in 1974 and 1975 and the results were arranged in a form of a topographic map, water flow map(river system map), landslide map. vegetation map. soil map and geology map. They are shown in the basic data of the first column in Fig.5.

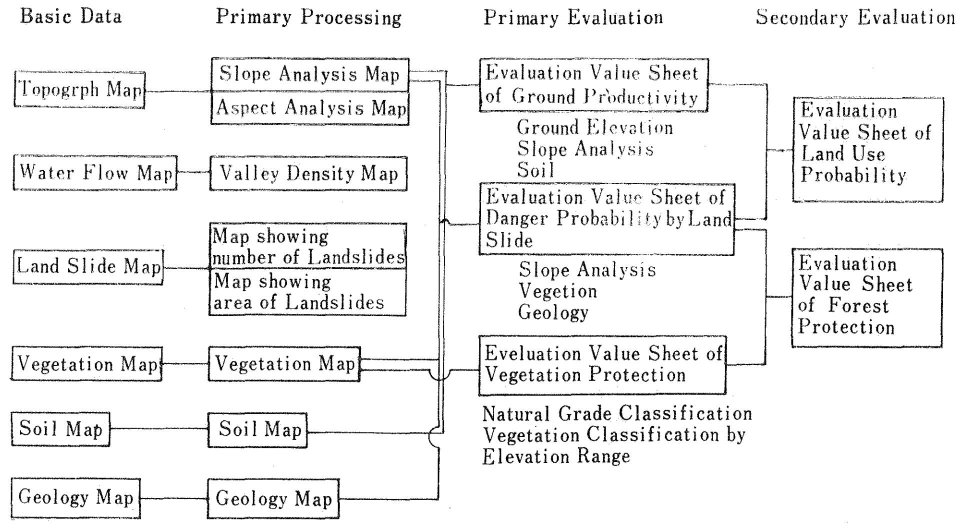


Fig. 5 Environment analysis by computer

Especially, the map showing the number of landslides were completed in 1974 using areial photos at a scale of 1/20,000 and on the aerial photographs at a scale of 1/20,000 taken by the Government Forest Agency, landslide areas occupying more than the 1 mm X 1 mm on the photos were interpreted.

4-2. Preparation of mesh data

To store each type of data in the computer, the test was divided into square meshes consisting of one unit 450 m X 575 m and each legend data of the basic map was read within each area mesh and denoted by numbers.

(1) topographic map -minimum ground elevation reading 10 meters at the center of one unit mesh.
(2) Geology map - from first to third rank in order of geological calssification occupied in one unit mesh.
(3) Landslide frequency map - map showing number and area of landslide.
(4) Vegetation map - from first to third rank in order of area occupied in vegetation classification in one unit area.
(5) Soil map - from first to third rank inorder of area occupied in soil calssifocation .
(6) Water flow map - density of mumber of valleys.(river system map)

4-3. Formation of Data File

Various basic map data can be input into the computer, each file in a matrix-form, known as a unit data file. The drawing by the line printer can be called a computer map as shown in the following figures.

There are inclination slope analysis map, slope direction analysis map, valley density map, map showing number of landslide, vegetation map, soil map and geology map. From this topographic unit file, slope analysis, direction map and sunshine energy map were outputted by the computer.

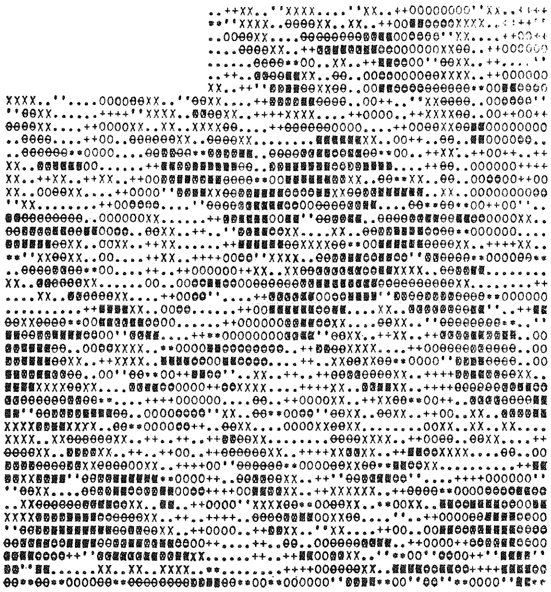


Fig.6 Slope direction analysis map

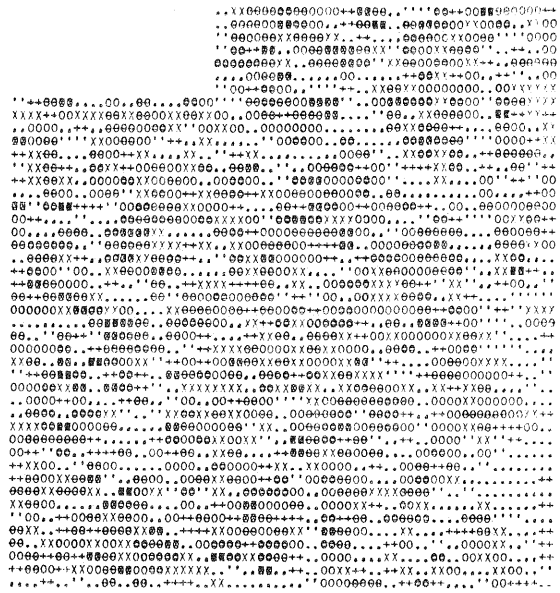


Fig.7 Slope analysis map

Fig. 6 shows slope direction in 8 directions, gray tones show,north the darkest and south the lightest. Westerly directions are shown lighter than easterly directions, since late afternoon sun is a greater attribute than early morning sun for most activity. The following shows the frequency distribution of data in each direction.

LEVELS	1	2	3	4	5	6	7	8	9	10
FREQUENCY	43	171	116	219	171	307	131	184	85	57

Fig.8 Frequency of directions

Level	Direction
2	north
3	northeast
4	east
5	southeast
6	south
7	southwest
8	west
9	northwest

Fig. 7 shows slope analysis in 10 levels with a range of 9.33 each level, X signal is the steepest,lower numbering shows gentle and number 1 is the gentlest. Fig.9 shows frequency distribution of each level.

LEVELS	1	2	3	4	5	6	7	8	9	10
FREQUENCY	172	113	160	154	178	266	236	135	55	12

Fig.9 Frequency of slope level

4-4. Correlation of Unit Data

The computer map file can be used for correlation analysis of each unit data file. The final purpose of environmental evaluation by computer is to determine the potentiality of land use and forest protection which can be shown as primary evaluation in the former figure of envirnmental anlysis by computer.

They are explained in the following divided into three categories.

(1) Evaluation of danger probability of land slide by correlation

(2) Evaluation of ground productivity
(3) Evaluation of Vegetation

The evaluation of (1) can be done from the unit file of toptgraphic slope, geology, vegetation and distribution of landslide frequency which are considered as main factors for landslide occurrence. The evaluation of (2) is related to ground productivity and land use probability which have been done by using the data file on soil, topography, slope grade and ground elevation. The soil classification can be calssified by the calssification standard of the soil product probability and adding the ground elevation grade which is related directly to the air temperature.

The evaluation of (3) was done using files on vegetation, ground elevation and sun shine energy. The vegetation was classified by the natural grade of vegetation regulated by the Environmental Agency of the Government. In case the same kind of vegetation is distributed in several places on the ground elevation, natural grades of the ground elevation considering the statiscal distribution of ground elevation were decided. Moreover, sun shine energy calculated from the inclination and direction of the unit area on the inclination was the essential factor for evaluating the ecological and practical engineering sides of the existing field vegetation during construction and thus the evaluation of forest protection and land use probability were completed in the secondary evaluation process.

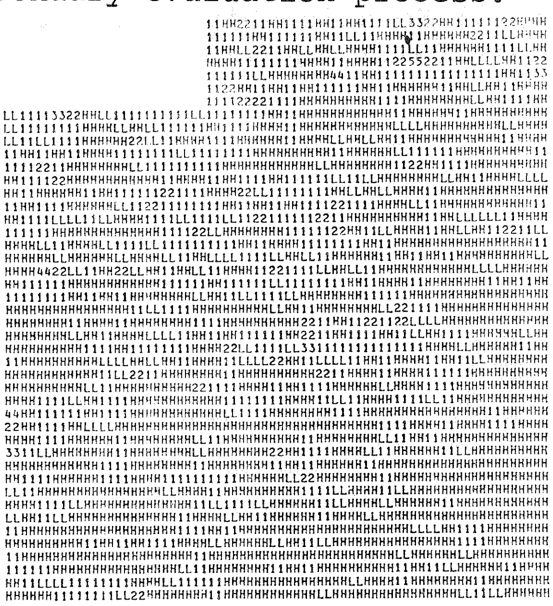


Fig.10 Land slide frequency distribution

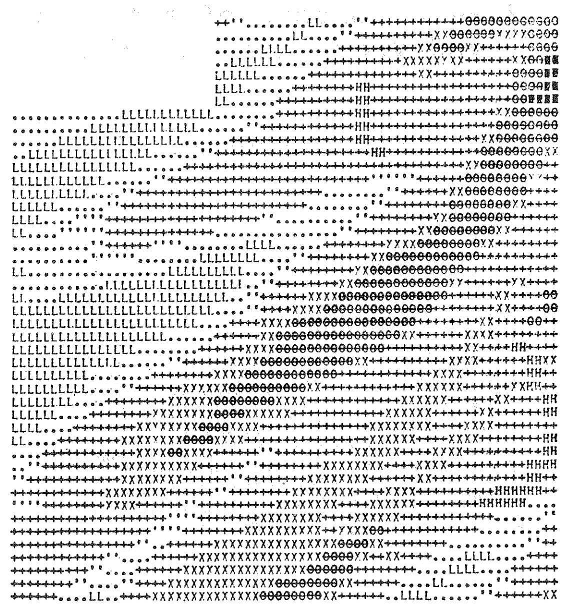


Fig.11 Geological distribution

Fig.10 and fig.11 show the graphical distribution of basic map data like in fig. 6 and 7. These are called the computer mapping which can be used for the total evaluation, the others are vally density map,vegitation and soil map. The evaluations mentioned in 4-3,are analized by combining the basic map data using computer. The basic map data are important for the integrated environmental evaluation to dicide the weight value.

The followings are the graphical distribution of the basic map data that were used for weighing of evaluation.

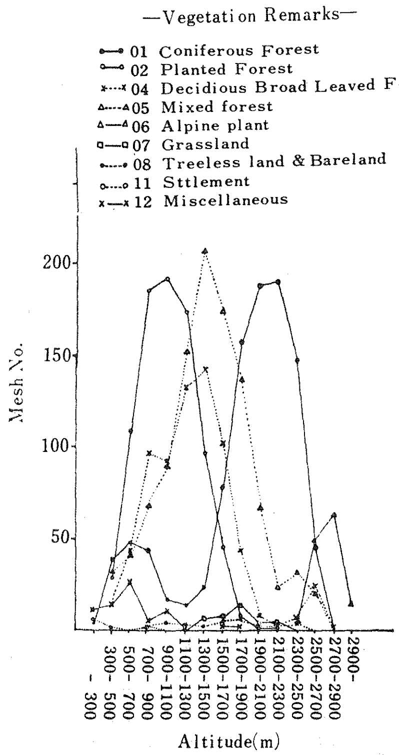


Fig.12 Relationship of altitude and vegetation specimen

Fig. 25 Altitude vegetation

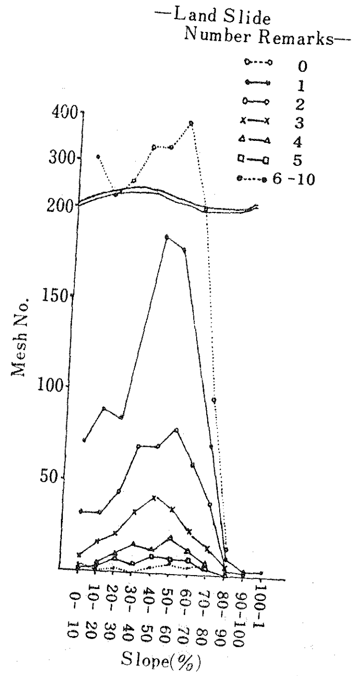


Fig.13 Relationship of slope and landslide occurrence

Fig. 26 Land slide-slope

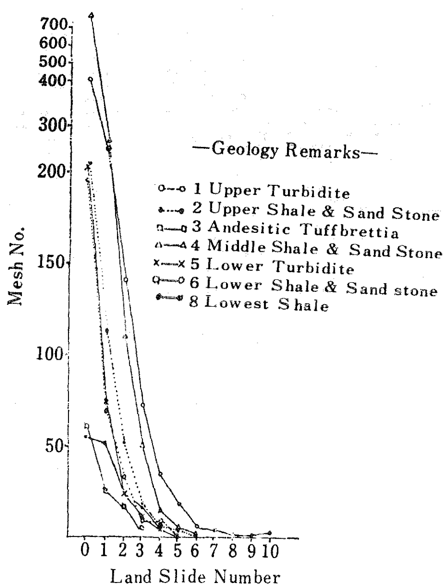


Fig.14 Relationship of geology species and landslide

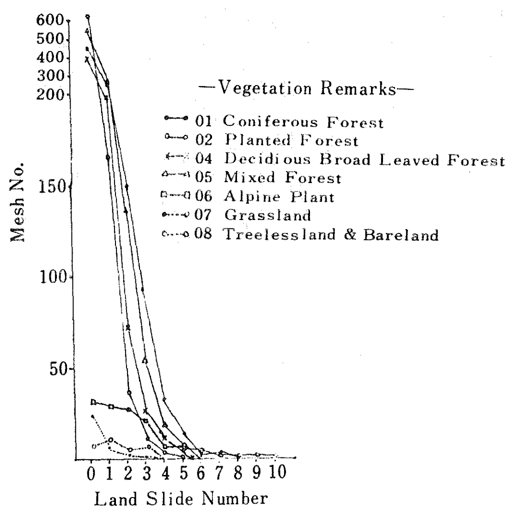


Fig.15 Relationship of vegetation species and landslide

5. Environmental Evaluation for Construction of Roads

As explained before in the former article, mesh maps and the relationship of the related factors of natural conditions are prepared in order to select the best route out of four preliminary selected routes. Four selected routes are compared with the evaluation for danger probability by landslide,vegetation protection and ground productivity. The evaluation vlue multiplied by the mesh number and compared with each route is calculated.

The following figures show landslide frequency and landslide occurrence probability in relation to the slope grade of topography,geology species and vegetation species. From these statitical data, the evaluation of the danger probability by landslide is decided.

In the same way, evaluation of vegetation protection, and ground productivity are calculated with the statistically related data file.

Weight	5	4	3	2	1	0
Slope (%)	40—70	30—40	70<	30>		
Vegetation	6	8	1	4, 5	2, 3, 7	9—12
Geology	8, 6	7	1—4	5		

Fig.16 Superposition of evaluation of danger probability by land slide

Slope grade	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	100-
Landslide frequency	201	229	301	447	557	582	392	230	34	4	2
Number of mesh	427	369	423	589	652	706	426	224	32	4	2
Landslide outbreak probability	0.47	0.62	0.71	0.76	0.85	0.82	0.92	1.03	1.00	1.00	1.00

* Landslide outbreak probability=Landslide frequency/number of mesh

Fig.17 Landslide frequency & landslide outbreak probability

Geology grade	1	2	3	4	5	6	7	8
Landslide frequency	204	324	80	742	175	1,079	1	192
Number of mesh	318	415	109	1,180	332	926	1	154
Landslide outbreak probability	0.64	0.78	0.73	0.63	0.53	1.16	1	1.25

Fig.18 Landslide frequency & landslide outbreak probability

Vegetation grade	1	2	3	4	5	6	7	8	9	10	11	12
Landslide frequency	1,050	290	4	495	825	265	17	40	0	0	0	13
Number of mesh	988	841	2	707	1,041	130	34	28	7	1	7	68
Landslide outbreak probability	1.06	0.34	2	0.70	0.79	2.04	0.50	1.43	0	0	0	0.19

Fig.19 Landslide frequency & vegetation

In these figures, the evaluation value (ranks from 1 to 5) is regulated by each statistical distribution data. For example, in deciding the evaluation value of landslide occurrence probability, the cause factors of landslides such as slope, geology, vegetation etc. are surveyed statistically as discussed in the former articles.

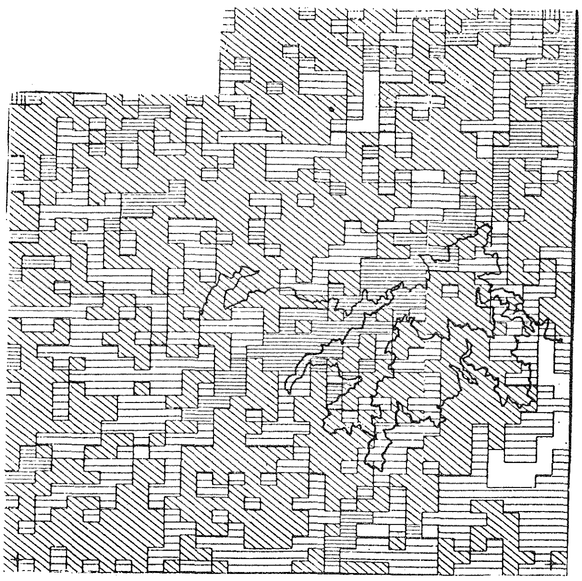


Fig.20 Evaluation value sheet of danger probability by land slide

—Remarks—

- 1 High
- 2 Fairly High
- 3 Medium
- 4 Fairly Law
- 5 Law

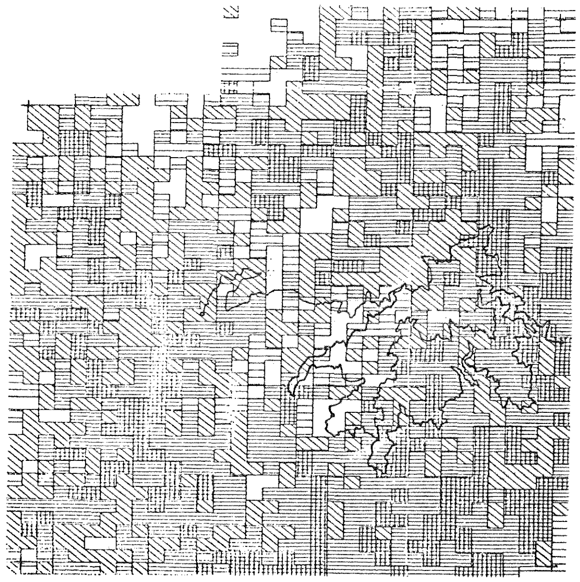


Fig.21 Evaluation value sheet of ground productivity

—Remarks—

- 5 High
- 4 Fairly High
- 3 Medium
- 2 Fairly Law
- 1 Law

Fig.20,Fig.21 and Fig.22 show the result of correlation analysis of basic unit file shown at article 4-4.

From these data, the four selected roads, the correlation values are calculated as shown in Fig. 23 and 24. These were calculated for the total length of each route and total meshes which the preliminary routes expect to pass. There if one unit evaluation value which is closely related to the cost of construction and a little different from the total evaluation value.

From the final grade of integrated evaluation, per unit mesh and per one kilometer, C route is the best followed by A route. From the evaluation value sheet of land use probability and forest protection, the best is C route followed by D route.

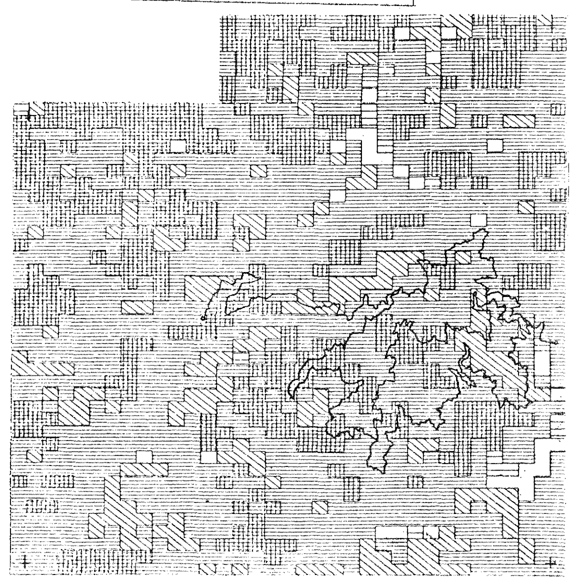


Fig.22 Evaluation value sheet of vegetation protection

—Remarks—

- 1 High
- 2 Fairly
- 3 Medium
- 4 Fairly Law
- 5 Law

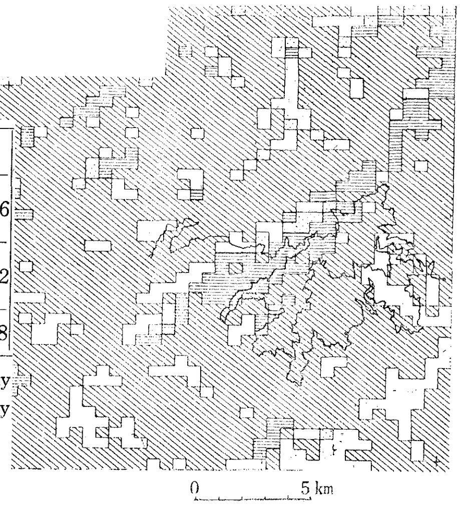
To clarify the local character to generalize this system the evaluation value sheet of land use probability and forest protection were drawn by automatic drafter. These are shown in Fig.25 and 26. The final route selection from anlysis of computer data considering the natural environmental conditions was decided as C route.

6. Conclusion

The pattern classification by computer has played an important role for environmental evaluation of civil engineering projects ad shown in this paper. But there are various problems which must be solved if this method is to be applicable systematically through the final stage of construction using the multispectral data. Since only a fundamental solution for evaluation study by pattern classidivation for evaluating the effect of civil engineering projects has been given, we must perform more research in order to find integrated techniques in considering economical and easily applicable conditions.

Route	A	B	C	D
Evaluation value of ground productivity	246	226	225	246
Evaluation valuf of danger probaoility by land slide	220	207	210	222
Total	466	433	435	468

Fig.23 Evaluation value of ground productivity Evaluation value of danger probability by land slide



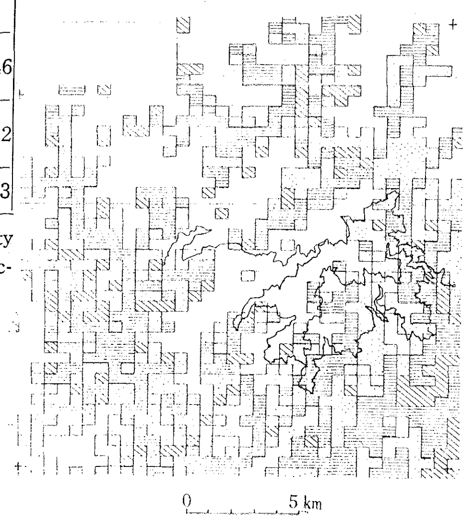
—Remarks—

Value \ Simbol	Evaluation Value for Forest Protection	Vegetation Protection	Danger Probability
(symbol)	A	High (Eva. 1-2)	High (Eva. 1-2)
(symbol)	B	High (Eva. 1-2)	Law (Eva. 3-5)
(symbol)	C	Law (Eva. 3-5)	High (Eva. 1-2)
(symbol)	D	Law (Eva. 3-5)	Law (Eva. 3-5)

Fig.25 Evaluation value sheet of foresy protection

Route	A	B	C	D
Evaluation value of ground productivity	246	226	225	246
Evaluation value of vegetation protection	158	135	126	132
Total	404	361	351	373

Fig.24 Evaluation value of ground productivity Evaluation value of vegetation protection



—Remarks—

Value \ Simbol	Evaluation Value of Land Use Probability	Ground Productivity	Danger Probabiltiy
(symbol)	A	High (Eva. 4-5)	Law (Eva. 4-5)
(symbol)	B	Law (Eva. 1-3)	Law (Eva. 4-5)
(symbol)	C	High (Eva. 4-5)	High (Eva. 1-3)
(symbol)	D	Law (Eva. 1-3)	High (Eva. 1-3)

Fig.26 ; 50 Evalation value sheet of land probability

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