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Environmental Studies by Pattern Classification for Evaluating the Effect of Civil Engineering Project under Construction

Taichi OSHIMA*

Abstract

In constructtion 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 evaluation environmental evaluation by computer analysis for construction of forest roads.

§ 1. Environmental evaluation by computer analysis for construction of a forest road

1. 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 and 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 connetion with the data printing methods, especially important considerations were mostly placed on the relationship between development and protection of natural resources.

The author selected the test site (area, about 3.71 km²) in the reservoir along the Oi and Abegawa River in Shizuoka Prefecture situated in the center part of Japan.

The reason in selecting this test area is that area is that this district includes various kinds of typical social engineering factors and natural conditions which can be solved by an integrated system and related data is easily available.

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

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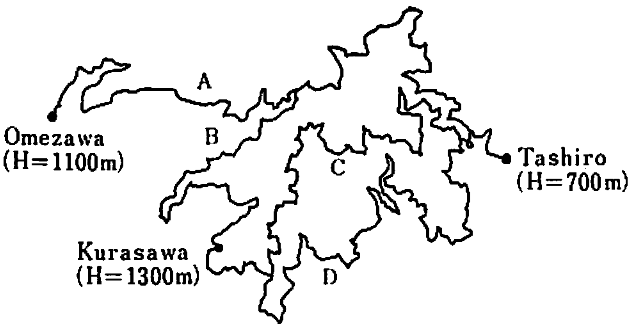


Fig. 1 Automatic drawing of forest roads researched by specifications of forest roads

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

planting and hauling the timbers from the forest.

Fig. 1 shows the automatic drawing of forest roads researched by specifications shown as follows.

Fig. 2 shows the specification for construction of a forest road. Fig. 3 shows the planning technical factors of the second class road.

2. System of Data Processing

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

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 survey, 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 numerically 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 numerical 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,

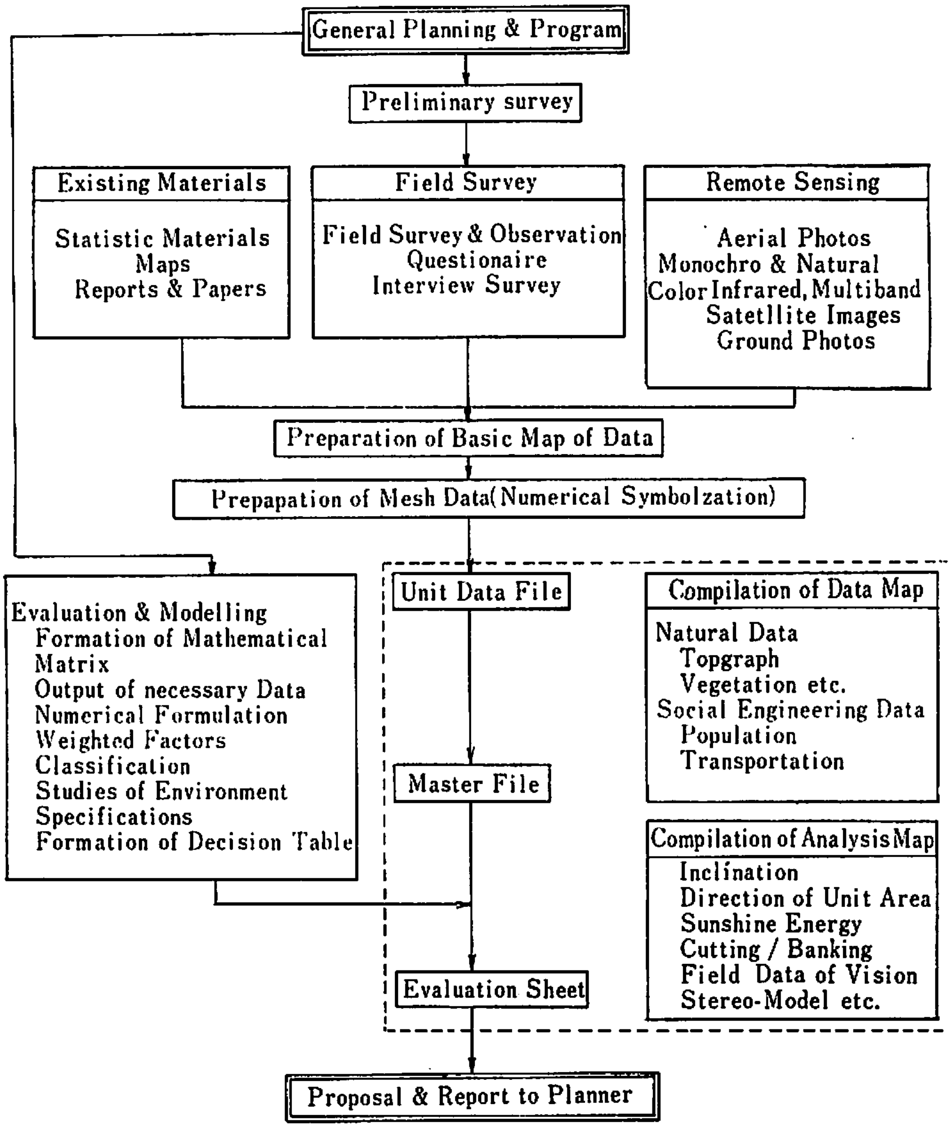


Fig. 4

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 analysis 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 drafters.

The advantage of this process is that various kinds of statistical information is typed out from the systematized master file and at the same time select the meshes that are equivalent to natural environmental conditions. In this stage, the necessary data are outputs for numerical 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.

3. Processing system of Environment Data

The outline of the processing system of environment 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

3.1. Preparation of basic map

The materials and 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.

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

3.2. 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×575 m and each legend data of the basic map was read

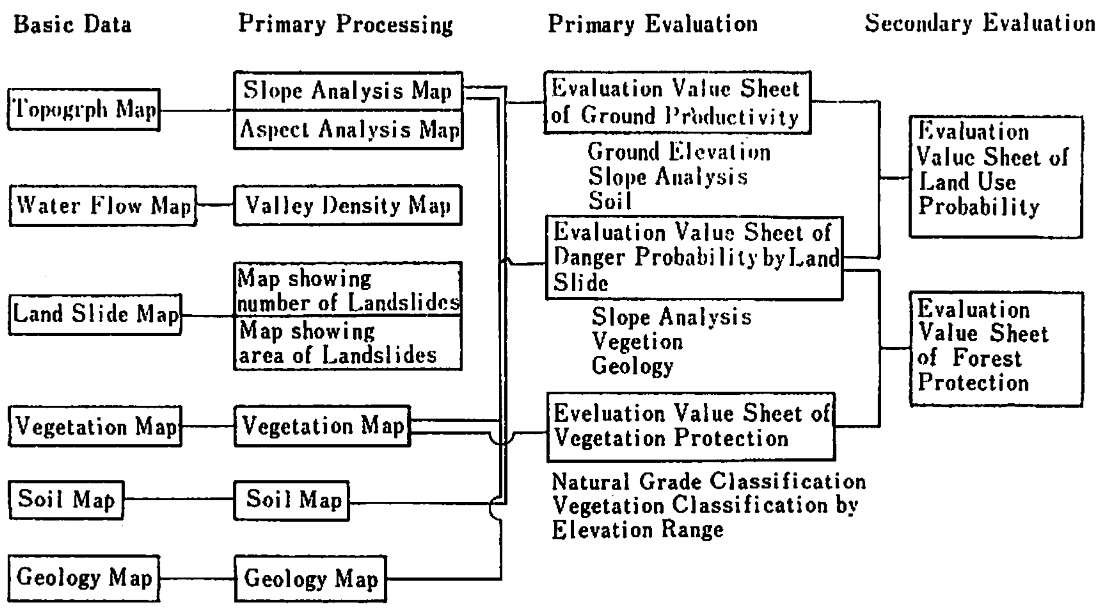
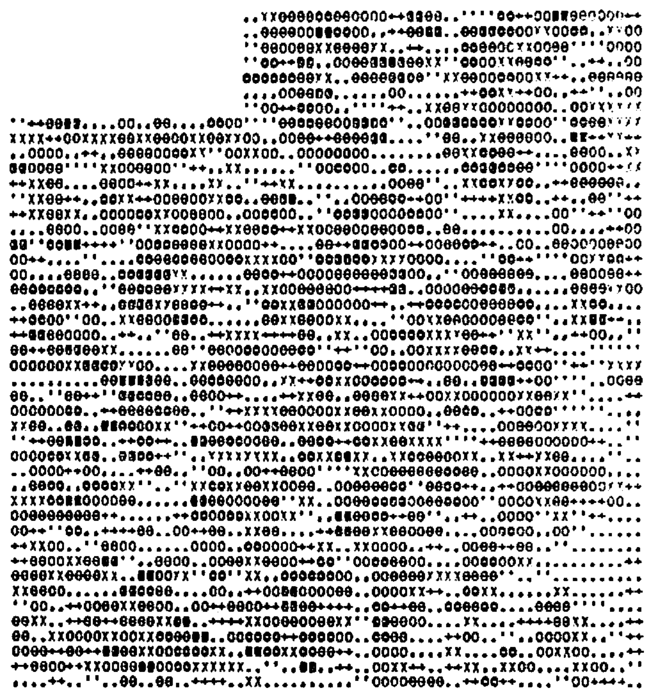


Fig. 5 Environment analysis by computer

within each unit 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 classification 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



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SLOPE ANALYSIS

1976.9.20

DATA MAPPED IN 10 LEVELS BETWEEN EXTREME VALUES OF 0. AND 93.33

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

MINIMUM	0.	9.33	18.67	28.00	37.33	46.67	56.00	65.33	74.67	84.?
MAXIMUM	9.33	18.67	28.00	37.33	46.67	56.00	65.33	74.67	84.00	93.3?

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.0

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	....1....	''''2''''	....3....	++++4++++	XXXX5XXXX	000060000	000070000	000080000	[illegible]	[illegible]
FREQUENCY	172	113	160	154	178	266	236	139	55	12

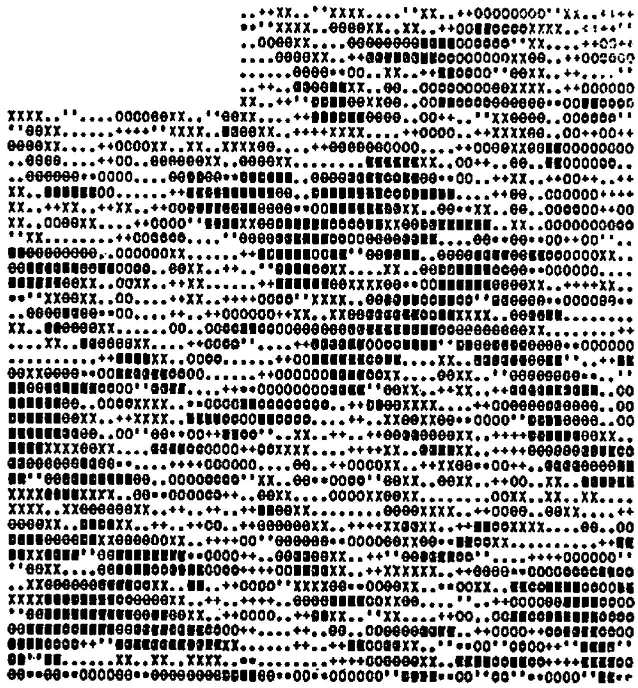
Fig. 6

classification in one unit area.

5. Soil map—from first to third rank in order of area occupied in soil classification.
6. Water flow map—density of number of valleys. (river system map)

3.3. 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. (Fig. 6~Fig. 13)



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ASPECT ANALYSIS

1976.9.27

LEGEND

LEVEL		DESCRIPTION
1	PIT	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 ACTIVITIES.
2	NORTH	
3	NORTHEAST	
4	EAST	
5	SOUTHEAST	
6	SOUTH	
7	SOUTHWEST	
8	WEST	
9	NORTHWEST	
10	PEAK	

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	••••1••••	■■■■2■■■■	@@@@3@@@@	@@@@4@@@@	XXXX5XXXX	....6....	++++7++++	0000R0000	@@@@9@@@@	''''0''''
FREQUENCY	43	171	116	219	171	307	131	184	85	57

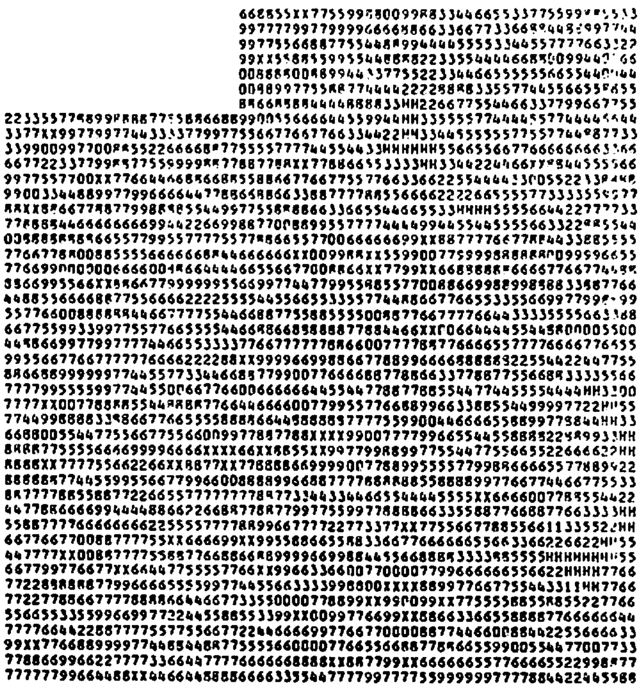
Fig. 7

There are inclination slope analysis map, slope direction analysis map, valley density map, map showing number of landslides, map showing area of landslides, vegetation map, soil map and geology map.

From this topographic unit file, slope analysis, direction map and sunshine energy map were outputted by the compter.

3.4. Correlation of unit data

The computer map file can be used for correlation analysis of each unit data file.



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VALLEY DENSITY

1976.9.10

                        MEAN -   7.98     STANDARD DEVIATION -  11.86

DATA MAPPED IN 10 LEVELS BETWEEN EXTREME VALUES OF     1.50 AND    98.50

APSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
 MINIMUM            1.50    2.50    3.50    4.50    5.50    6.50    7.50    8.50    9.50   10.50
 MAXIMUM            2.50    3.50    4.50    5.50    6.50    7.50    8.50    9.50   10.50   98.50

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
                    1.03    1.03    1.03    1.03    1.03    1.03    1.03    1.03    1.03   90.72

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
           LOW VALUES                                                                                HIGH VALUES
 LEVELS       0         1         2         3         4         5         6         7         8         9        10        11
          ==========================================================================================================================
           111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 999999999 000000000 XXXXXXXXX HHHHHHHHH
           111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 999999999 000000000 XXXXXXXXX HHHHHHHHH
 SYMBOLS   1111 1111 2222 2222 3333 3333 4444 4444 5555 5555 6666 6666 7777 7777 8888 8888 9999 9999 0000 0000 XXXX XXXX HHHHHHHHH
           111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 999999999 000000000 XXXXXXXXX HHHHHHHHH
           111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 999999999 000000000 XXXXXXXXX HHHHHHHHH
          ==========================================================================================================================
 FREQUENCY    2        49        82       124       203       265       263       231       136        63        42        24
```

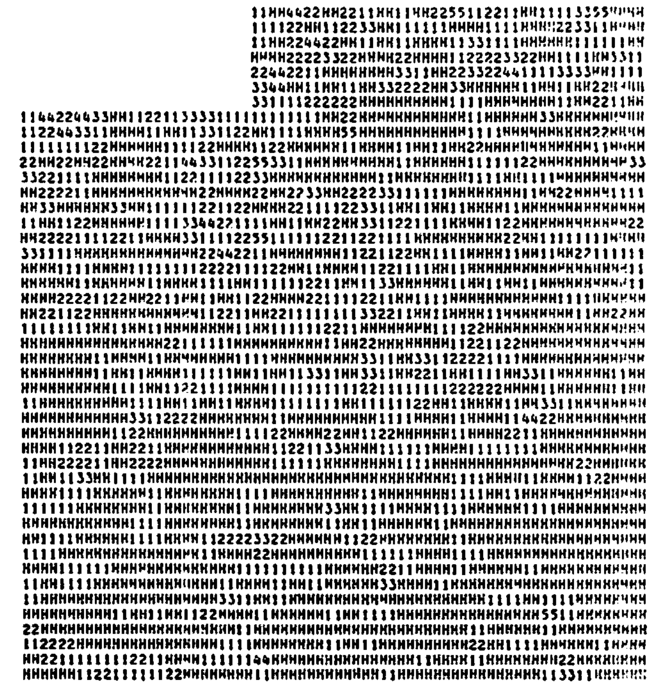
Fig. 8

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 environmental analysis by computer mentioned above.

They are explained in the following divided into three categories.

1) Evaluation of Danger probability of landslide by correlation

This evaluation can be done from the unit file of topographic slope, geology, vegetation and distribution of landslide frequency which are considered as main factors for



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NUMBER OF LAND SLIDE

1976.9.10

                                MEAN -    5.85     STANDARD DEVIATION -    3.74

DATA MAPPED IN  7 LEVELS BETWEEN EXTREME VALUES OF      1.50 AND      8.50

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
 MINIMUM              1.50      2.50      3.50      4.50      5.50      6.50      7.50
 MAXIMUM              2.50      3.50      4.50      5.50      6.50      7.50      8.50

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
                     14.29     14.29     14.29     14.29     14.29     14.29     14.29

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
         LOW VALUES                                                             HIGH VALUES
 LEVELS      0         1         2         3         4         5         6         7         8
         ==========================================================================================
          111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 HHHHHHHHH
          111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 HHHHHHHHH
 SYMBOLS  1111L1111 2222 2222 3333 3333 4444 4444 5555 5555 6666 6666 7777 7777 8888 8888 HHHHHHHHH
          111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 HHHHHHHHH
          111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 HHHHHHHHH
         ==========================================================================================
 FREQUENCY   410       142       51        13        6         0         0         0         862
```

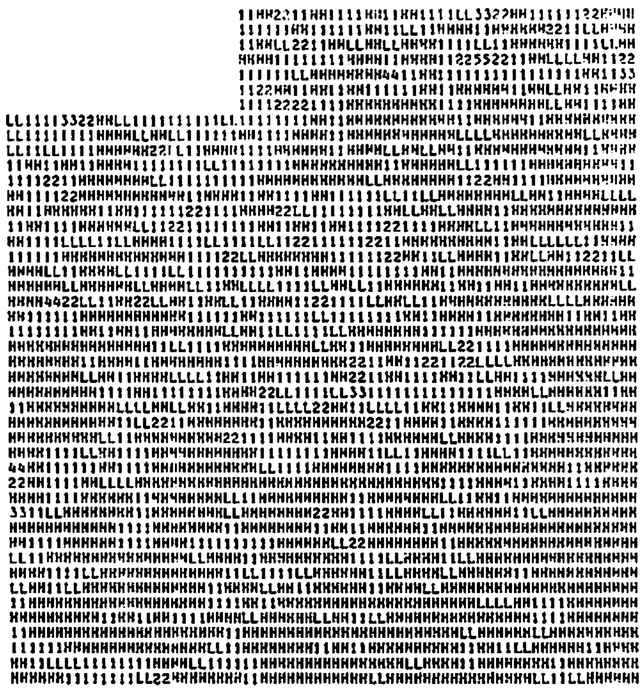
Fig. 9

landslide occurrence.

As the reinfall condition is not included, these are mainly primary causes.

2) Evaluation of ground productivity

Not only the evaluation of ground productivity but land use probability has been done by using the data file on soil, topography, slope grade and ground elevation. The soil classification can be classified by the classification standard of the soil product probability and adding the ground elevation grade which is related directly to the air temperature.



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AREA OF LAND SLIDE

1976.9.10

                              MEAN -  59.69     STANDARD DEVIATION -  46.49

DATA MAPPED IN  8 LEVELS BETWEEN EXTREME VALUES OF       1.50 AND     90.50

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
 MINIMUM                 1.50     12.63     23.75     34.88     46.00     57.13     68.25     79.38
 MAXIMUM                12.63     23.75     34.88     46.00     57.13     68.25     79.38     90.50

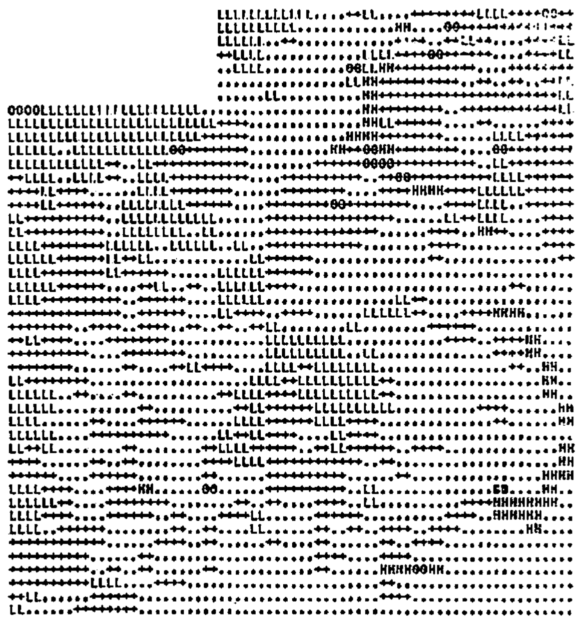
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
                        12.50     12.50     12.50     12.50     12.50     12.50     12.50     12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
          LOW VALUES                                                                          HIGH VALUES
 LEVELS      0         1         2         3         4         5         6         7         8         9
          ==========================================================================================
           LLLLLLLLL 111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 HHHHHHHHH
           LLLLLLLLL 111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 HHHHHHHHH
 SYMBOLS   LLLLLLLLL 1111 1111 2222 2222 3333 3333 4444 4444 5555 5555 6666 6666 7777 7777 8888 8888 HHHHHHHHH
           LLLLLLLLL 111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 HHHHHHHHH
           LLLLLLLLL 111111111 222222222 333333333 444444444 555555555 666666666 777777777 888888888 HHHHHHHHH
          ==========================================================================================
 FREQUENCY   142       428       42        5         3         1         0         0         0         863
```

Fig. 10

3) Evaluation of Vegetation

This was evaluated 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 statistcal distribution of ground elevation were decided. Moreover, sun shine energy calculated from the inclination and direction of the unit area on the inclination



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VEGETATION

1976.9.10

MEAN - 354.91 STANDARD DEVIATION - 211.60

DATA MAPPED IN 10 LEVELS BETWEEN EXTREME VALUES OF 150.00 AND 1150.00

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

MINIMUM	150.00	250.00	350.00	450.00	550.00	650.00	750.00	850.00	950.0	1050.00
MAXIMUM	250.00	350.00	450.00	550.00	650.00	750.00	850.00	950.00	1050.0	1150.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.0	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVELS	LOW VALUES 0	1	2	3	4	5	6	7	8	9	10	HIGH VALUES 11
SYMBOLS	LLLLLLLLL	....1....	''''2''''	....3....	++++4++++	XXXX5XXXX	000060000	000070000	000080000	000090000	[illegible]	HHHHHHHHH
FREQUENCY	246	356	0	330	697	0	3	12	0	1	0	39

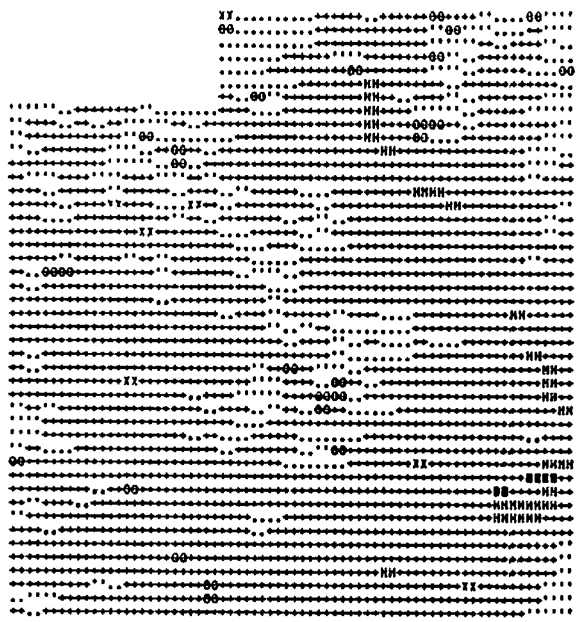
Fig. 11

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.

4. Result of studies

4.1. Computer map

This study aims to evaluate the natural grade conditions by the pattern classification using computer in the test area.



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SOIL

1973.9.10

MEAN = 451.15　　STANDARD DEVIATION = 164.74

DATA MAPPED IN 10 LEVELS BETWEEN EXTREME VALUES OF 100.50 AND 1299.50

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

MINIMUM	100.50	209.50	318.50	427.50	536.50	754.50	863.50	972.50	1081.50	1190.50
MAXIMUM	209.50	318.50	427.50	536.50	754.50	863.50	972.50	1081.50	1190.50	1299.50

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

9.09	9.09	9.09	9.09	18.18	9.09	9.09	9.09	9.09	9.09

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVELS	0 (LOW VALUES)	1	2	3	4	5	6	7	8	9	10	11 (HIGH VALUES)
SYMBOLS	LLLLLLLLL	....1....	''''2''''	....3....	++++4++++	XXXX5XXXX	OOOO6OOOO	OOOO7OOOO	OOOO8OOOO	OOOO9OOOO	████•████	HHHHHHHH
FREQUENCY	0	155	112	5	1146	7	0	27	[illegible]	0	3	26

Fig. 12

At first, the basic maps were formed from each file of factors relating to the construction of forest road. These files were printed out as computer map for clarifying the existing natural conditions.

4.2. Slope Analysis Map

The slope was calculated from the difference of ground elevation between the center of one mesh and the next mesh. The result was classified into 10 ranks as shown in fig. 17. The slope distributing between 37.3~65.3% (20°~32°) occupies one half of the total test

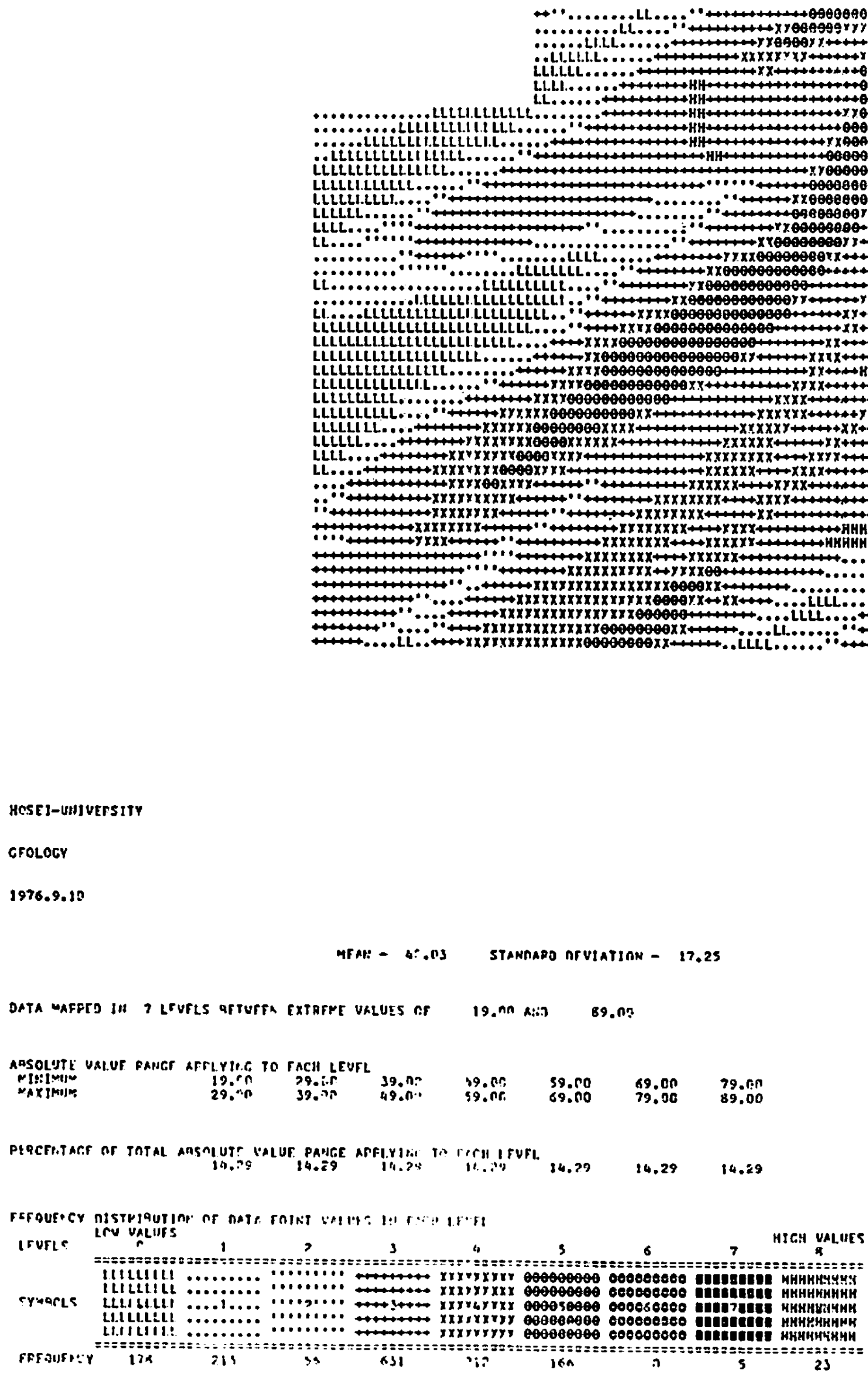


Fig. 13

area. And it is said that this district is relatively steep and has severe natural conditions.

4. 3. Slope direction Analysis

The slope direction was classified into 10 classes as shown in figure 18. The slope facing south is 20% occupying 76 km² (20% of total area). The next faces east and southeast, west and north occupying half of the total area and the three directions except east occupy each 12% of the total area.

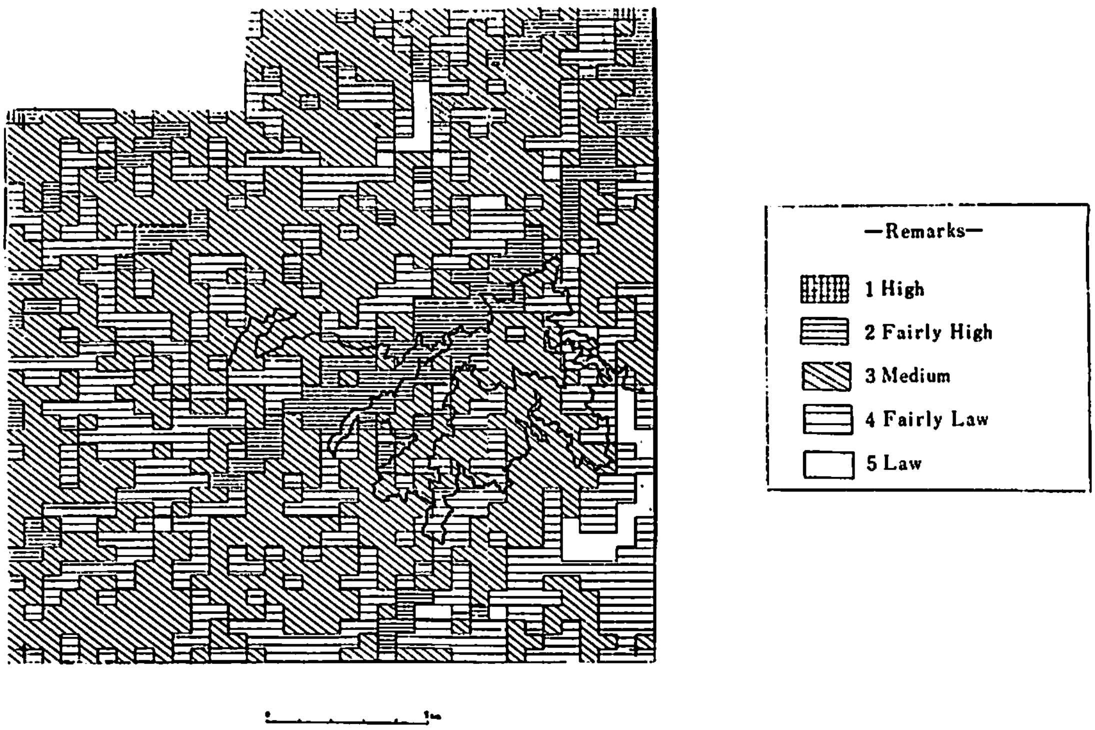


Fig. 14 Evaluation value sheet of danger probability by land slide

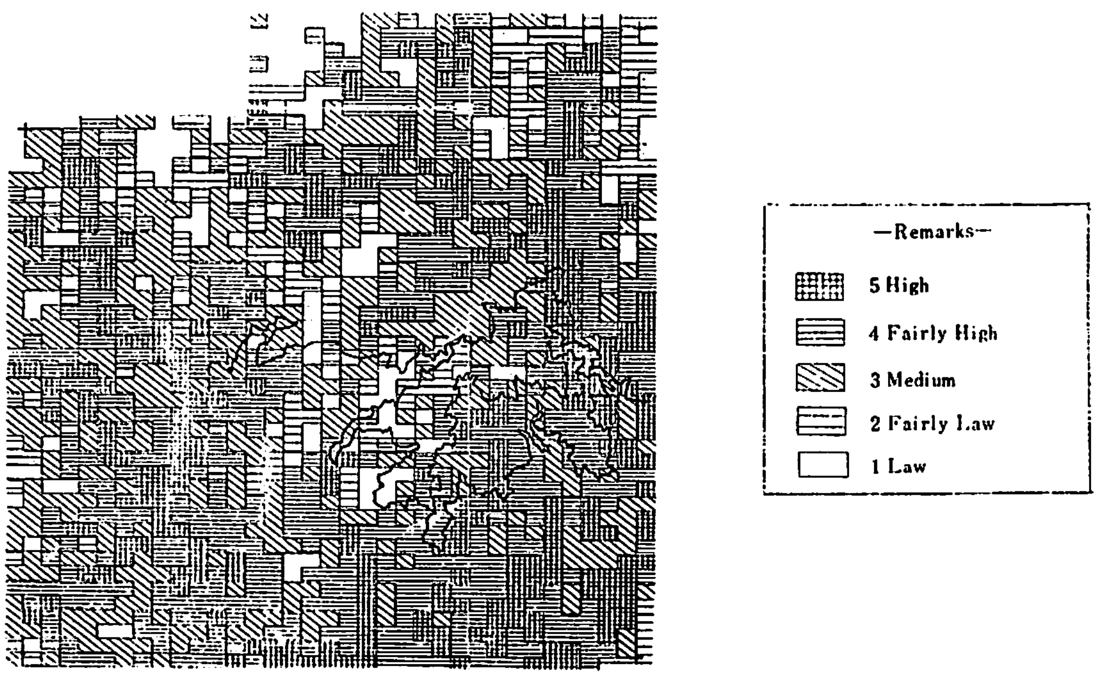


Fig. 15 Evaluation value sheet of ground productivity

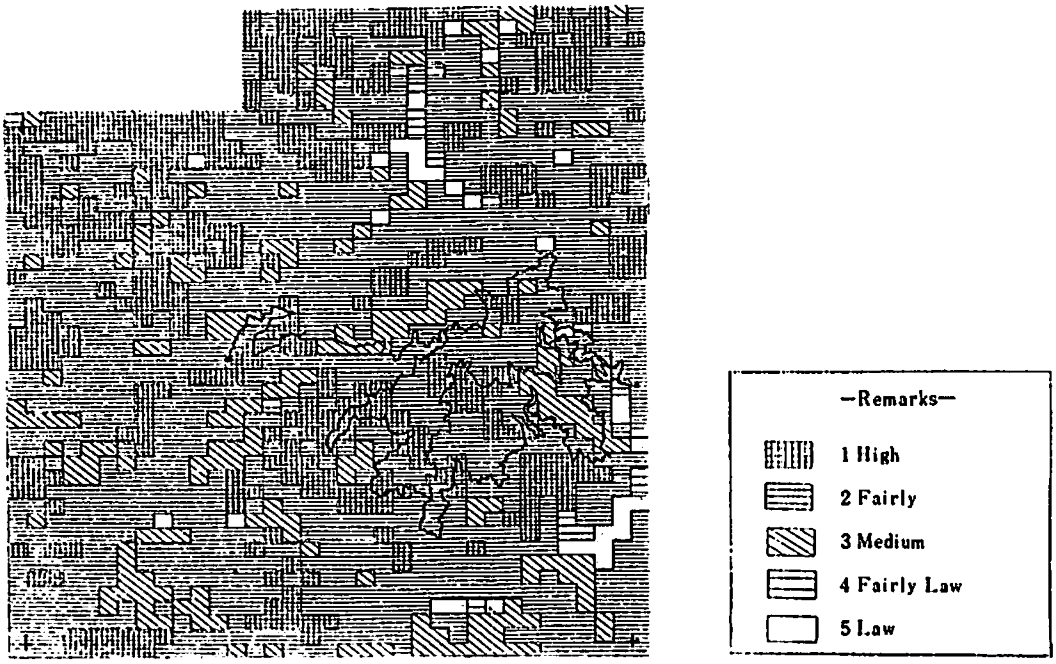


Fig. 16 Evaluation value sheet of vegetation protection

Level	Slope (%)	Mesh No.	Percent (%)	Area (km²)
1	0.0— 9.3	172	12	43
2	9.3—18.7	113	3	28
3	18.7—28.0	160	11	40
4	23.0—37.3	154	10	39
5	37.3—46.7	173	12	45
6	46.7—56.0	266	17	66
7	56.0—65.3	236	16	58
8	65.3—74.7	138	9	35
9	74.7—84.0	55	4	14
10	94.0—93.3	12	1	3

Fig. 17 Slope analysis

Level	Direction	Mesh No.	Percent (%)	Area (km²)
1	Pit	43	3	11
2	North	171	12	43
3	North east	116	8	29
4	east	219	14	55
5	south east	171	12	43
6	South	307	20	76
7	South west	131	9	33
8	west	194	12	46
9	north west	95	6	21
10	Peak	57	4	14

Fig. 18 Aspect analysis

Level	Number/unit mesh	Mesh No.	Percent (%)
1	0	862	58
2	1	410	28
3	2	142	10
4	3	51	3
5	4	13	1
6	5	6	0

Fig. 19 Land slide number

Level	Area/unit mesh (ha)	Mesh No.	Pecent (%)
1	0	863	58
2	— 0.25	142	10
3	0.25— 3.00	428	29
4	3.00— 5.75	42	3
5	5.75— 8.50	5	0
6	8.50—11.50	3	0
7	11.50—14.25	1	0
8	14.25—	1	0

Fig. 20 Land slide area

Level	Number	Mesh No.	Percent (%)
1	0	24	2
2	1— 3	133	9
3	4— 6	592	40
4	7— 9	630	42
5	10—13	105	7

Fig. 21 Valley density

	Remarks	Mesh No.	Percent (%)
1	Upper tiurbidite	178	12
2	Upper shale & sand stone	213	14
3	Andesitic tuffbrettia	56	4
4	Middle shale & sand stone	631	43
5	Lower turbidite	212	14
6	Lower shale & sand stone	166	11
7	Metabasalt	0	0
8	Lowest shale	5	0
9	Lake	23	0

Fig. 22 Geology (dominant species by the mest occupied area)

	Remarks	Mesh No.	Percent
01	Coniferous forest	246	17
02	Planted forest	356	24
03	Decidious coniferous forest	0	0
04	Decidious broad leaved forest	330	22
05	Mixed forest	497	33
06	Alpine plant	0	0
07	Grassland	3	0
08	Treeless land & bareland	12	1
09	Plouwed field, orchard	0	0
10	Puddy	1	0
11	Settlement	0	0
12	Miscellaneous	39	3

Fig. 23 Vegetation (dominant species by the most occupied area)

	Remarks	Mesh No.	Percent (%)
01	Alpine lithosol Alpine meatow	25	2
	Alpine Grass land Alpine podzol		
02	Slightly podzolic soil	130	9
03	Dark brown forest soil	112	8
04	Dry brown forest soil	8	1
05	Moderately moist forest soil	1, 146	76
06	Wet drown forest soil	7	0
07	Block soil	0	0
08	Regosol	0	0
09	Rocky land	27	2
10	Field soil	0	0
11	Puddy soil	0	0
12	Settlement	3	0
13	River reservation Dam Reservoir	26	2

Fig. 24 Soil (dominant species by the most occupied area)

4.4. *Land slide ferquency*

The figure 19 and 20 show the number and area of landslide frequency in one mesh. The number between 4—6 has the most landslides and the next area is between 4—6. Therefore, there are relatively many landslides in this district compared with the other districts. This must be considered very carefully for planning road construction.

4.5. *Valley, Density*

The number of Valleys was counted by computer from the river systems crossing the four sides of the unit mesh. The figure 21 shows, number of valleys distributing between 4—9 occupies almost 80% of the total meshes.

4.6. *Geology, Vegetation and Soil*

5. Statistical analysis of basic data

The contents of the computer map with the natural factors such as topographic vegetation, soil, geology etc. were already explained, but it is required for the integrated environmental evaluation with the correlation system to clarify each relationship of natural factors.

In this article, combined relationship of the two fators of natural conditions of the computer input data is discussed as follows.

1) relationship between ground elevation and vegetation
2) relationship between landslide of geology
3) relationship between landslide and slope
4) relationship between landslide and vegetation

It is clear from figure 25 that the distribution of vegetation species differ from each ground elevation zone. This result can be used for the integrated evaluation to weigh each vegetation species. Each

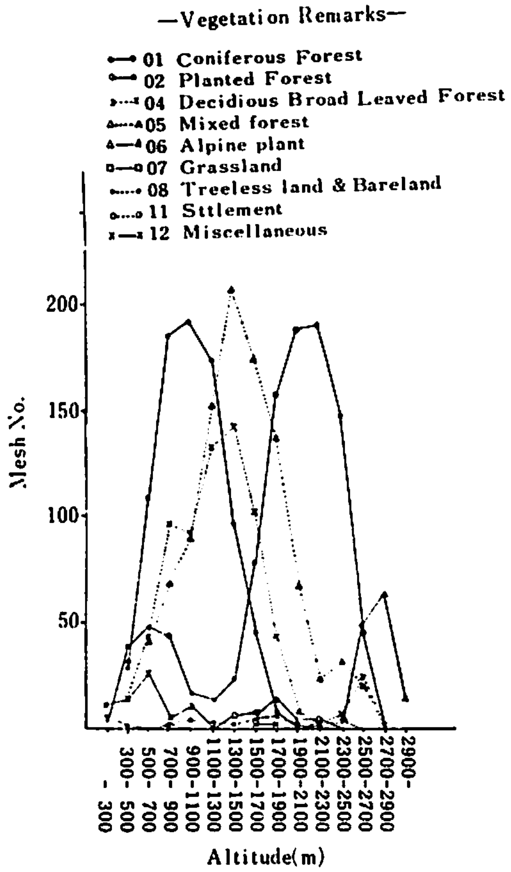


Fig. 25 Altitude vegetation

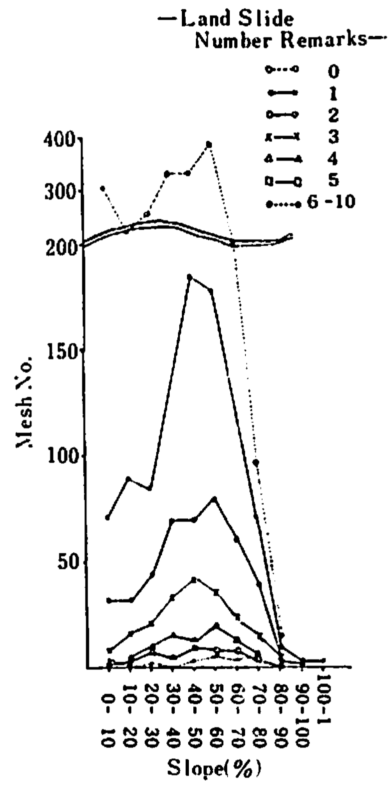


Fig. 26 Land slide-slope

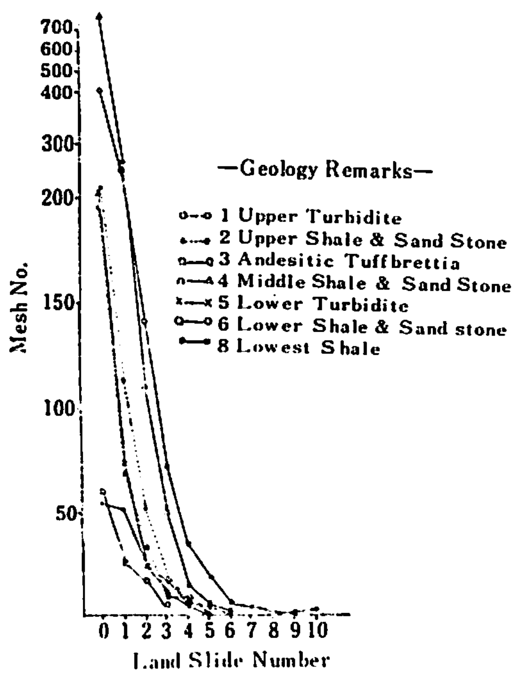


Fig. 27 Land slide-geology

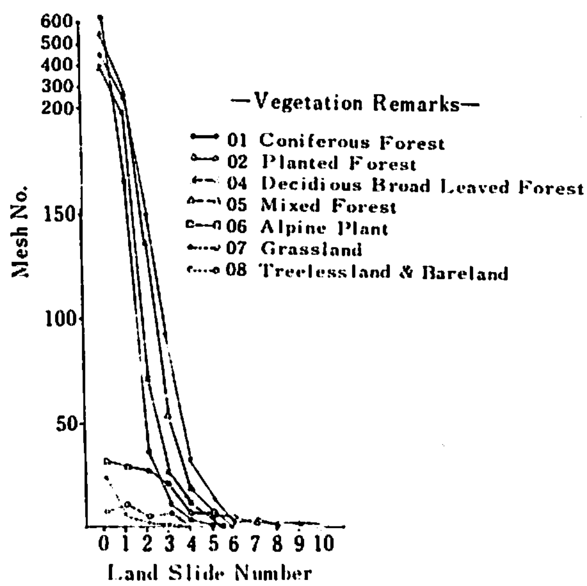


Fig. 28 Land slide-vegetation

vegetation has a peak at a certain elevation point and has a different normal distribution pattern in each vegetation species.

To clarify the occurrence tendency of landslides with the combination of species of geology, vegetation and slope is very important for planning forest roads in mountanious districts in Japan.

Landslides generally occur very often at the grade angle of about 30—50 degrees. But in scopes with grades less than that, the number of landslide occurrence decreases.

Landslides in connection with geology and vegetation species, occur often in the middle and lower shale and sandstone districts. In the districts of Alpine plants and Treeless

Route	A		B		C		D	
Value	Mesh No.	Value× mesh No.	Mesh No.	Value× mesh No.	Mesh No.	Value× mesh No.	Mesh No.	Value× mesh No.
5 Law	6	30	6	30	4	20	3	15
4 Fairly law	13	52	17	68	23	92	21	84
3 Medium	32	96	17	51	32	96	41	123
2 Fairly migh	21	42	29	58	1	2	0	0
1 High	0	0	0	0	0	0	0	0
Total	72	220	69	207	60	210	65	222

Fig. 29 Evaluation value of danger probability by land slide

Route	A		B		C		D	
Value	Mesh No.	Value× mesh No.	Mesh No.	Value× mesh No.	Mesh No.	Value× mesh No.	Mesh No.	Value× mesh No.
5 High	19	95	20	100	19	95	15	75
4 Falrly High	13	52	10	40	22	88	29	116
3 Medium	25	75	17	51	11	33	17	51
2 Fairly law	9	18	13	26	1	2	0	0
1 law	6	6	9	9	7	7	4	4
Total	72	246	69	226	60	225	65	246

Fig. 30 Evaluation value of ground productivity

Route	A		B		C		D	
Value	Mesh No.	Value× mesh No.	Mesh No.	Value× mesh No.	Mesh No.	Value× mesh No.	Mesh No.	Value× mesh No.
5 Law	3	15	3	15	3	15	2	10
4 Fairly law	3	12	3	12	3	12	2	8
3 Medium	9	27	3	9	8	24	6	18
2 Fairly High	47	94	39	78	29	58	41	82
1 High	10	10	21	21	17	17	14	14
Total	72	158	69	135	60	126	65	132

Fig. 31 Evaluation value of vegetation protection

land and Bare land, the occurrence of landsldes are most frequent, followed by coniferous districts.

6. Environmental Evaluation for construction of forest roads

In this article, an actual example of environment evaluation for construction of forest roads is discussed. As explained before in the former articles, 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 landside, vegetation protection and ground productivity. The evoluation value multiplied by the mesh number and compared with each route is shown in figure 29, 30 and 31.

In this figure, 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 article.

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. 32 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	ε01	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. 33 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. 34 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. 35 Landslide frequency & vegetation

Factors \ Weight	5	4	3	2	1	0
Vegetation (natural grade)	01, 06 (9), (10)	04, 05 (8), (8)	02, 03 (6), (6)	07 (5)	09, 10 (2), (2)	08, 11, 12 (1), (1), (1)
Vegetation by elevation range	5	4	3	2	1	0
Sunshine energy	5 (7.1—)	4 (6.6—7.0)	3 (6.1—6.5)	2 (5.6—6.1)	1 (—5.5)	

Fig. 36 Superposition of evaluation of vegetation protection

Factors \ Weight	5	4	3	2	1	0
Soil	05 06		04 07	02 03	01 08 09	10, 11 12, 13
Slope	0—15% (0—8°)	15—27% (8—15°)	27—28% (15—30°)	58—84% (30—40°)	84%— (40—)	
Alutitude	500m |	500m | 1,000m	1,000m | 1,500m	1,500m | 2,000m	2,000m |	

Fig. 37 Superposition of evaluation of ground propuctivity

	Remarks	Grade of probability of soil productivity
01	Alpine lithosol Alpine meatow Alpine grass land Alpine podzol	5
02	Slightly podzolic soil	5
03	Dark brown forest soil	5
04	Dry brown forest Soil	4
05	Moderately moist forest soil	1
06	Wet brown forest soil	1
07	Block soil	3
08	Regosol	5
09	Rocky land	5
10	Field soil	—
11	Puddy soil	—
12	Settlement	—
13	River reservation Dan reservoir	—

Fig. 38 Grade of probability of soil productivity table

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. 39 Evaluation value of ground productivity Evaluation value of danger probability by land slide

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. 40 Evaluation value of ground productivity Evaluation value of vegetation protection

In figures 32, 33, 34 and 35, landslide frequency and landslide occurrence probability in relation to the slope grade of topography, geology species and vegetation species are shown. From these statistical 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.

In this evaluation value table for the danger probability by landslide and vegetation protection, it should be noted that the bigger the number becomes, the lower the value. For the evaluation value of ground productivity, the lower the number, the lower the value.

Route	A	B	C	D
Evaluation value of danger probability by land slide	220	207	210	222
Evaluation value of vegetation protection	158	135	126	132
Total	378	342	326	354

Fig. 41 Evaluation value of danger probability by land slide Evaluation value of vegetation protection

Route	A	B	C	D
Evaluation value of ground productivity	246	226	225	246
Evaluation value of damger probability by land slide	220	207	210	222
Evaluation value of vegetation protection	158	135	126	132
Total	624	568	561	600

Fig. 42 Evaluation value of ground productivity Evaluation value of danger probability by land slide Evaluation value of vegetation protection

Eva. factors \ Route		A	B	C	D
(1)	Evaluation value of ground productivity	3.417	3.275	3.750	3.785
(2)	Evaluation value of danger Probability by land slide	3.056	3.000	3.500	3.415
(3)	Evaluation value of vegetation protection	2.194	1.957	2.100	2.031
(4)	Evaluation value of ground productivity Evaluation value of danger Probability by land slide	3.236	3.138	3.625	3.600
(5)	Evaluation value of danger Probability by land slide Evaluation value of vegetation protection	2.625	2.478	2.717	2.723
(6)	Evaluation value of vegetation protection Evaluation value of ground productivity	2.802	2.616	2.925	2.908
(7)	Evaluation value of ground productivity Evaluation value of danger Probability by land slide Evaluation value of vegetation protection	2.889	2.744	3.117	3.077

Fig. 43 Evaluation value per one mesh area (Eva. va./mesh No.)

Eva. factors \ Route		A	B	C	D
(1)	Evaluation value of ground productivity	8.519	8.256	9.474	8.410
(2)	Evaluation value of danger Probability land slide	7.619	7.562	8.842	7.590
(3)	Evaluation value of vegetation protection	5.472	4.932	5.305	4.513
(4)	Evaluation value of ground productivity Evaluation value of danger Probability by land slide	8.069	7.909	9.158	6.000
(5)	Evaluation value of danger Probability by land slide Evaluation value of vegetation protection	6.545	6.247	6.863	6.051
(6)	Evaluation value of vegetation protection Evaluation value of ground productivity	6.996	6.594	7.389	6.462
(7)	Evaluation value of ground productivity Evaluation value of danger Probability by land slide Evaluation value of vegetation protection	7.203	6.916	7.874	6.838

Fig. 44　Evaluation value per ome km length (Eva. va./total length)

Eva. factors \ Grade	1	2	3	4
(1)	D	C	A	B
(2)	C	D	A	B
(3)	A	C	D	B
(4)	C	D	A	B
(5)	D	C	A	B
(6)	C	D	A	B
(7)	C	D	A	B

Fig. 45　Final grade of integrated evaluation (Eva. va./mesh No.)

Eva. factors \ Grade	1	2	3	4
(1)	C	A	D	B
(2)	C	A	D	B
(3)	A	C	B	D
(4)	C	A	D	B
(5)	C	A	B	D
(6)	C	A	B	D
(7)	C	A	B	D

Fig. 46　Final grade of Integrated evaluation (Eva. va./km)

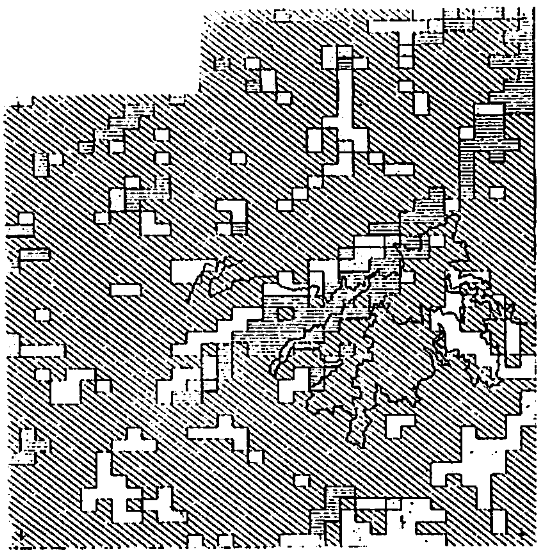
Route	Total length(km)
A	28,875
B	27,375
C	23,750
D	29,250

Eva. \ Route	Ground productivity	Danger probability	A (%)	B (%)	C (%)	D (%)
A	High (Eva. 4—5)	Law (Eva. 4—5)	15(21)	17(24)	25(41)	21(32)
B	Law (Eva. 1—3)	Law (Eva. 4—5)	4(5)	6(9)	3(5)	3(5)
C	High (Eva. 1—3)	High (Eva. 1—3)	17(24)	13(19)	16(27)	23(35)
D	Law (Eva. 1—3)	High (Eva. 1—3)	36(50)	33(48)	16(27)	18(28)
Total			72(100)	69(100)	60(100)	65(100)

Fig. 47　Evaluation value of land use probability (Mesh No.)

Route / Eva.	Vegetation protection	Danger probability	A (%)	B (%)	C (%)	D (%)
A	High (Eva. 1—2)	High (Eva. 1—2)	17(24)	28(41)	1(2)	0(0)
B	High (Eva. 1—2)	Law (Eva. 3—5)	40(35)	32(46)	45(75)	55(85)
C	Law (Eva. 3—5)	High (Eva. 1—2)	2(3)	1(1)	0(0)	0(0)
D	Law (Eva. 3—5)	Law (Eva. 3—5)	13(18)	8(11)	14(23)	10(15)
Total			72(100)	69(100)	60(100)	65(100)

Fig. 48 Evaluation value for forest protection (Mesh No.)

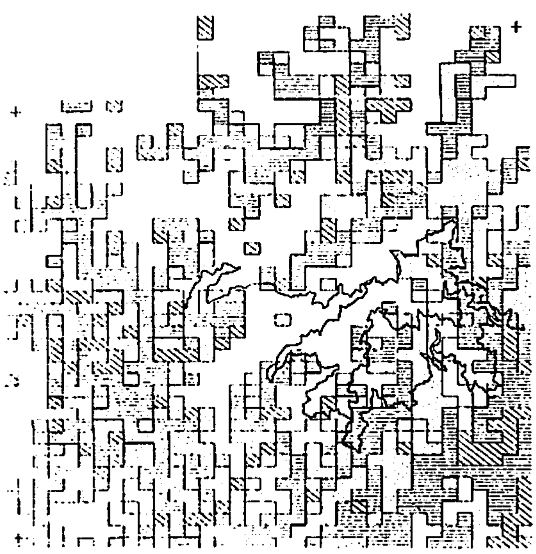


—Remarks—

Value / Simbol	Evaluation Value for Forest Protection	Vegetation Protection	Danger Probability
▤	A	High (Eva. 1-2)	High (Eva. 1-2)
▧	B	High (Eva. 1-2)	Law (Eva. 3-5)
⬚	C	Law (Eva. 3-5)	High (Eva. 1-2)
□	D	Law (Eva. 3-5)	Law (Eva. 3-5)

0 5 km

Fig. 49 Evaluation value sheet of foresy protection



—Remarks—

Value / Simbol	Evaluation Value of Land Use Probability	Ground Productivity	Danger Probabiltiy
▤	A	High (Eva. 4-5)	Law (Eva. 4-5)
▧	B	Law (Eva. 1-3)	Law (Eva. 4-5)
⬚	C	High (Eva. 4-5)	High (Eva. 1-3)
□	D	Law (Eva. 1-3)	High (Eva. 1-3)

0 5 km

Fig. 50 Evalation value sheet of land probability

To clarify the relationship of these two and three related factors, correlated evaluations are calculated as shown in figures 36, 37 and 38.

For the four selected roads, correlation of two and three related factors was calculated as shown in figures 39, 40, 41 and 42.

These were calculated for the total length of each route and total meshes which the preliminary routes expect to pass. Therefore, the figures 43 and 44 show the evaluation value for one unit mesh per one km. of the total route length and the final grade of integrated evaluation is shown in figures 45 and 46.

There is 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.

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. Ihese are shown in fig. 49 and 50.

The final route selection from analysis of computer data considering the natural environmental conditions was desided as C route.

Conclusion

The pattern classification by computer has played an important role for environmental evaluation of civil engineering projects as 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 classification 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 applcable conditions.

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