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Development of the Automatic D.T.M. Generation System and its Application for Pre-surveying of Water resourses Development

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Abstract

This study describes the Pre-survery which the authors used to generate and analyze the numerical altitude data or D.T.M data for project management of water resource development in the mountain district.

First, conditions such as topography, geology, vegetation and water resources of the projected area are analyzed together with D.T.M data. Secondly, using the first step data, the estimation mapping for grade of weatherd granite and degree of landslide danger are analyzed by the "Maximum-Likelihood method" and "Similarity analysis". Further, the sites proposed for re-development around the dam reservoir are selected and listed according to the classified grade.

§ 1. SPECIFICATION

1.1 Using data

Digital terrain data :

Data intervals 25m×25m, Data origin 1 : 10,000 scale map

Data input ; Digital dramscanner

Aero photo Black & White :

Scale 1 : 12,500 Taken in 1974

Aero photo color :

Scale 1 : 10,000 Taken in 1981

1.2 Methodogy

Heat condition index, Cluster analysis, Maximum likelihood, Similarity analysis, DTM analysis, Principal component analysis.

1.3 Test site

The basins of the Kaze nad Jobaru rivers. Those areas are located in Kyushu Island in Japan.

1.4 Structure of Research

This research consists of 4 units.

a. Basic data obtaind

b. Basic analysis

c. Application analysis

d. Assessement

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§ 2. D.T.M. DATA GENERATION

2.1 DTM data preparration

Digital terrain model or DTM data is converted from a 1 : 10,000 topogrphic map. At first a color drum scanner system was used to read map-images and A/D conversion and input data to the computer. Second, images processing made X,Y,Z vector data from a lustor image map, and the procedure is line-normalize, luster/vector conversion, addtion of attribute (example ; altitude data). Third was arrangement of grid point data at intervals of 25m×25m.

2.2 Hardware Components

Hardware components of the system are shown in figure 1 ; they include a drum scannear, a mainframe computer, micro CAD units, and an electrostatic plotter. With the exception of the mainframe computer all of the components are moderately priced. Considering that the mainframe computer supports many other functions the system can be seen as a low priced, high volumn system for performing raster-to vector conversion.

The drum scanner as well as the micro CAD units are stand alone systems. Magnetic tapes are used to deliver raster data from the drum scanner to the mainframe computer. Floppy disks are used to transfer data between the mainframe and the micro CAD units. The drum scanner and mainframe computer can out pace the micro CAD units therefore, the capacity of the system depends on the number of micro CAD units available. Functioning as stand alone units, micro CAD units can be added to build a mass production raster-to-vector assembly line.

Drum Scanner

The drum has a diameter of 38 cm and a length of 128 cm, giving the scanner the capability of digitizing map sheets up to 128cm by 128cm. The resolution of the scanner is variable between 1 and 10 points per millimeter. Light reflected from the map sheet is detected and split into three colors (red, green, and blue). The sheets are digitized at a speed of 100 revolutions per minute, allowing the typical 1 : 25,000 topographic quadrangle sheet to be digitized in less than 1 hour.

Computer

The computer used for processing the raster-to-vector conversion is a medium sized Japanese model (Fujitsu, M-340). The main memory is 8 M bytes with an additional 5.3 G bytes of storage on disk. The raster-to-vector processing requires a large amount of CPU time so the system is mainly operated at night.

Electrostatic Plotter

An electrostatic plotter is connected directly to the mainframe computer as an output device. At any of several steps during the processing vector data can be transferred to the plotter for checking the form of the topographic contours.

Micro CAD Units

It has configured a micro CAD unit to edit vector data and to tag an elevation to each contour. line. The unit is composed of a desk top computer, a digitizing tablet with a cursor and a CRT. The desk top computer has 512 KB of memory, a 8 MHz control clock and two floppy disk drive units. The floppy disk provides a means of communication between the micro CAD and the mainframe computer. The cursor attached to the digitizer tablet has three function buttons ; the first is used to select a command ; the second is used for zooming in and out on the CRT ; and the third is used to perform edits.

Vector editing and elevation tagging are performed interactively on the micro CAD. All commands to edit, vector and to tag on elevations are shown on the CRT. The operator invokes commands on the CRT. Programs in assembler language make interactive operations perform rapidly.

2.3 Data Processing

The raster-to-vector conversion process is composed of nine steps ; shown as a flow chart in figure 2. Briefly, the process begins by digitizing the topographic sheets using the drum scanner. The data are passed to the mainframe computer by magnetic type, here two batch processing programs are run to thin the data and to convert raster to vector format. The raster-to-vector conversion process first divides the data into 1024×960 pixel blocks and then converts the pixels into vectors. Batch processing here minimizes computer time and keeps costs moderate. After the batch processing has been completed the data are passed to the micro CAD using a floppy disk and the vector data is edited. This editing is time consuming but use of stand alone micro CAD units helps to reduce the cost.

The edited vector data are transferred back to the mainframe using floppy disk and all of the blocks are reconnected. Because of the massive amount of vector data it is necessary to divide the data into new blocks then transfer them back to the micro CAD unit using floppy disk again and do a second more refined edit. Following the second edit the elevation value are tagged to the contour lines in an interactive process. Finally the fully edited and tagged contours are transferred back to the mainframe computer where they are converted to a mesh elevation data set for analytical display.

STEP 1 Scanning (raster data aquisition)

Raster data is aquired by using a drum scanner following the proceedure outlined here ; 1) the topographic contour sheet is attached to the drum ; 2) the area to be scanned is set by entering the lower left and upper right points into the scanners coordinate system ; 3) the pixel size is set on the scanner's pannel ; 4) the scanning pitch is set ; 5) threshold values for red, green, and blue light are set ; 6) the drum is stared and data aquisition commences. Most map sheet separates range in size from 40cm×40cm to 100cm×100 cm with a resolution of about 8 points per milimeter. Colors are monitored on a color CRT with white as a background (eight colors are recognized ; red, green, blue, yellow, light blue, purple, black and white) the assigned color codes are recorded in digital form on a magnetic tape. (all colors combined as black or white)

STEP 2 Thinning

The thinning program is based on an algorithm developed by Deutsch (Deutsch, 1972). The algorithm makes use of a smaller (3 × 3) window, and does not change the connectivity properties of the raster contour lines. After the process is completed, each raster contour line is thinned down to its medial line with a single pixel thickness. Figure 1 shows examples of pre-and post-processing by the thinning program.

STEP 3 Raster To Vector Conversion

Conversion of raster data to vector data is illustrated in figure 2. A string of raster data registered as black pixels is recognized as forming a continuous line, the coordinates of points located on the line are calculated at short fixed intervals and recorded by the computer.

On maps of complex hilly terrain or mountainous areas the contours are very crenulated and close to each other. Raster contours for these areas are often connected to other contours. Under this condition this raster-to-vector conversion program will identify the contours as linked, a connecting point between two raster contours is recognized as a branching point. The branching points will be removed during the next process (vector data editing). In instances where a short line is identified with both ends recogniqed as branching points the line is automatically deleted by the program.

Another very important feature of the raster-to-vector conversion program identifies gaps caused by scanning from finely drawn contours. White gaps are often produced when scanning very fine lines, these gaps show up breaks in the contour line. When the program identifies a line break it searches for the end of the other line to which it should connect. When the line to be connected is found, both line numbers are registered in a directory of connections stored by the program. The connections can then be easily checked during the vector data edit step. In addition the program divides the data into blocks of 1024×960 pixels. A typical raster-to vector product from this system is shown in figure 3.

STEP 4 Vector Data Editing

The vectorized data is transferred from the mainframe to the micro CAD using a floppy disk. Vector data editing is performed using the Micro CAD as a standalone work station. In this step the contours are either seperated or connected interactively.

Five simple commands control all interactive operations ; 1) delete a connection made previously in the raster-to-vector conversion step ; 2) divide one line into two lines ; 3) delete a line ; 4) produce a new line ; and 5) connect two lines to form one line. First the command to be performed is selected, and then the line to be edited is hit. If an edit is made by made by mistake, the cancel button is pushed and the edit is deleted

The Micro CAD unit is capable of zooming in or out allowing greatly magnifyed views of complicated areas.

STEP 5 Block Connecting

After finishing the vector editing work in Step 4 all of the blocks of vector data are reconnected using a battch process program to produce a vector data set which matches the topographic quadrangle sheet.

The thinning step is performed on the entire raster data set at one time. The raster-to-vector conversion program divides the data into 1024×690 pixel blocks and then converts the data for each block into vectors. Vector editing is done on the Micro CAD unit in 1024 × 690 pixel blocks. The blocks are re-connected during this step to from a 7200×5920 pixel data set which is then re- divided into 2500×2000 pixel sets in the following step.

STEP 6 Dividing

A few contour lines are inevitably mis-connected in the area around the block boundaries during the process of reconnecting (Step 5). In order to conduct further editing it is necessary to divide the data set again and transfer it back to the Micro CAD unit. The block size for this second data division is 2500× 2000 pixels allowing each block to fit into the Micro CAD's smaller memory. Each block will contain 80 to 100 thousand vector data points.

STEP 7 Second Vector Data Editing

The contour lines mis-connected in Step 5 are edited interactively using the Micro CAD unit. Edit commands are essentially the same as for step 5 although the program accesses the somewhat larger data sets differently.

STEP 8 Tagging An Elevation

Contour line value tagging is done as an interactive process on the Micro CAD unit after all of the contours have been completely edited.

The locally highest and lowest contours are assigned their proper elevation values interactively ; and then the intermediate contours are calculated by the Micro CAD unit by inputting the contour interval. The Micro CAD unit automatically assigns the proper elevation to all contours. As processing proceeds the contour lines are changed from green to red as the line are assigned thir elevations. There are sometimes supplemental contours on the maps which cannot be automatically assigned, these untagged contours are then tagged with their proper elevation values interactively.

STEP 9 Contour-To-Mesh Conversion

It has a program to convert contour lines to mesh elevation data. The program first produces a cross section by parallel cutting the X-axis or the Y-axis.

Next the program interpolates the elevation of the mesh points from the elevations of the neighboring two contours in the cross section.

The contour elevation values are verified by checking the elevation values of the neighboring contours in the cross section. If the elevation tags are wrong, the processing of vector contour data is repeated as in Step 8.

§ 3. BASIC SURVEY AND ANALYSIS

3.1 Topographycal Analysis

Subject Map Preparation

Using DTM data, several kinds of subject map were prepared by topographical analysis, as follows.

Altitude contour map Slope direction map
Summit level map Slope gradient map
River level map Unevenness map
Difference between summit and river map
Erosion situation map (Remaining area)
Erosion situation map(Lost area)
Undulation map

3.2 Photo-interpretation

The land-slide areas were extracted by photo-interpretation with 1 : 10,000 color and 1 : 12,500 black & white areo-photos. The result was plotted on 1：10,000 torographycal map, and classfied the geographical type of each extracted area amounts to 519 points. and the locations of these areas were input to the computer. The surveyed points amount to 444 areas.

3.3 Ground Investigation

On the spot, the land-slide areas were cheched, and the grade of weathered granit was observed along the road side slope. Then the weathering grade was classfied into three type, A. B, C. Ais a perfectly weathered area B is weathered a little. C is not much weathered. These three types and their locations were input to the computer. The surveyed points amount to 444 ares.

§ 4. APPLICATION ANALYSIS

4.1 Principal component analysis

Topographical analysis data originated as altitude data. So each topographical result data has some correlation to another result, and no result is independent . Principal component analysis (PCA) has some effct of extracting new variables and condensing the variable. Then the results of topographical analysis were condensed with PCA operation.

4.2 Cluster Analysis

This analis is unsuperviced classfication, and classfies the PCA data and remote sensed data. the results produce a geographical type map and some kind of vegitation condition map.

4.3 Maximum Likelihood Method

The training area of superviced area was selected from ground inventigation data and photo interpretation results, and classfied as to weathered granite type distribution on the image. It shows fine results compared with ground truth data.

4.4 Similarity Analysis

The training area of superviced area was selected from ground investigation data and photo-interpretation result. The similarity graded which is compared condition of land slide area, was analysed.

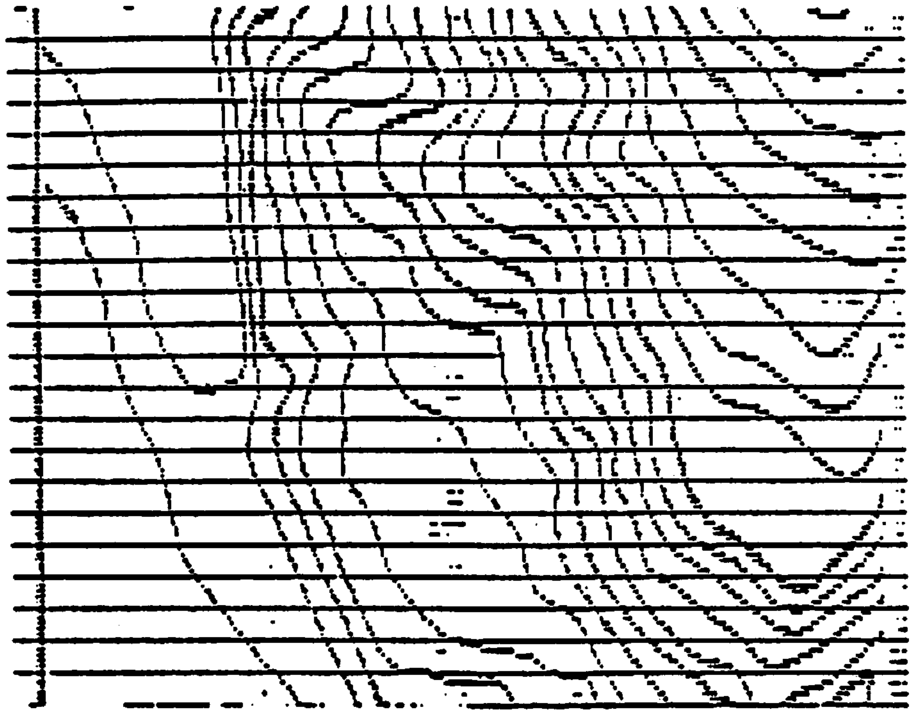
4.5 Redevelopment Planning

The people, who lived in dam reservoir planning area, must move to a redevelopment area, until the dam site construction is started. Then it must be simulated to find the optimum area for redevelopment and removal. The results of this study were used. And also the soil volume to construct a flat plane was estimated, for some flat level area: For example how much for a 250m×250m×250m, or 150m×150m flat plane ? After that, other kind data were overlapped for example, altitude, weathered area map and so on.

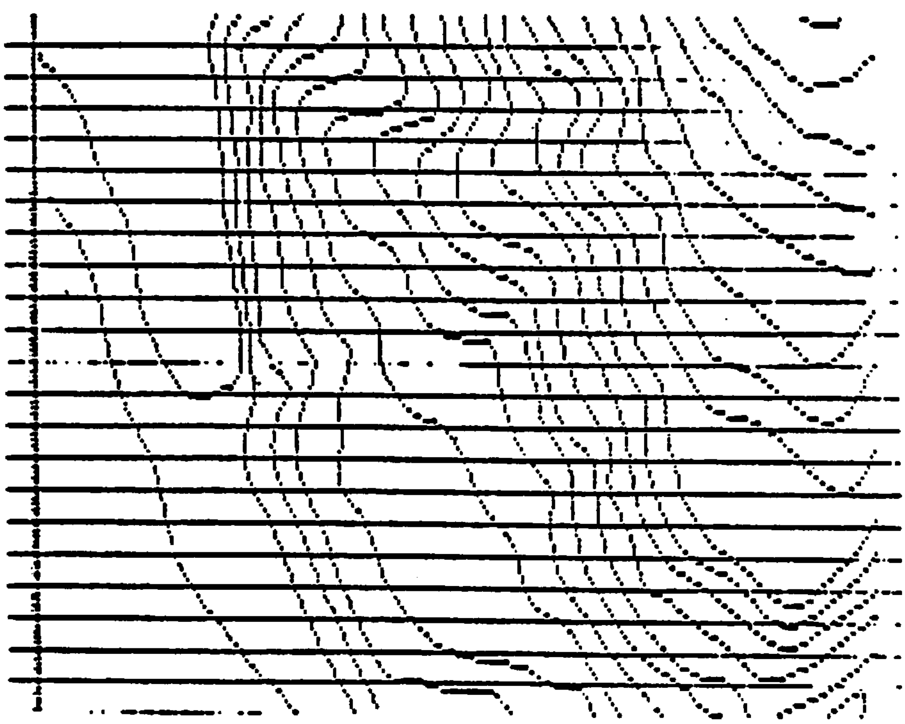
§ 5. CONCLUSION

D.T.M data is very useful for civil engineering project. When digital contour information is put into a computer it presents many opportunities for it's use. It is possible to extract clearly the land slide danger area. It was possible to identify the grade of weathered granite. It was available to make use of simulation for extract optimum redevelopment area.

In the future, it is expected to be able to apply the large scale civil engineering field much more.



AN EXAMPLE BEFORE THINNING



AN EXAMPLE AFTER THINNING

Fig. 1 Examples of pre- and post-
processing of thinning.

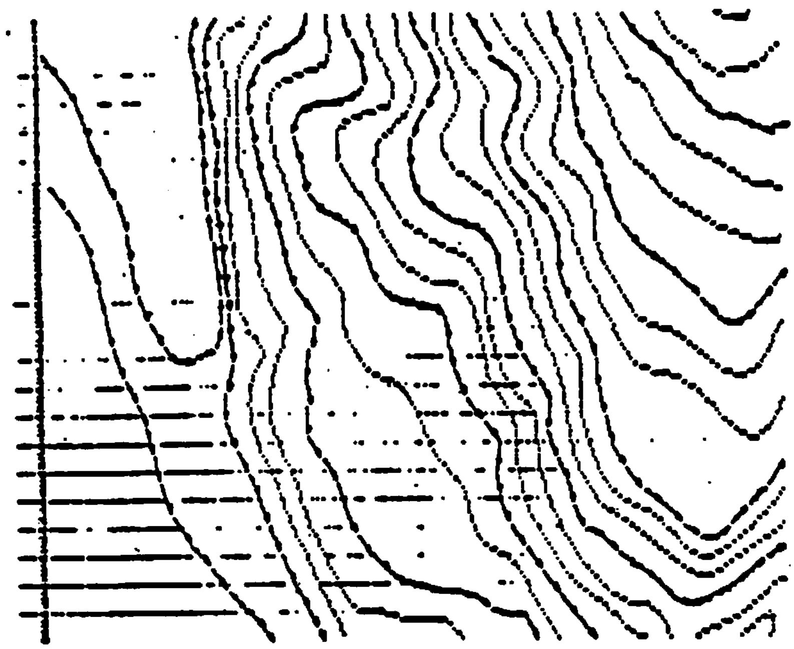


Fig. 2　Method how to convert raster contour to vector contour.

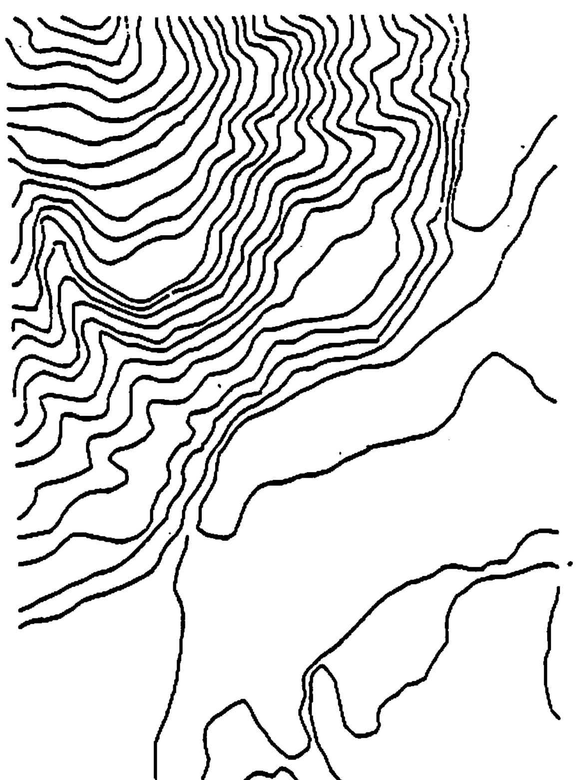


Fig. 3　Result obtained by raster to vector conversion processing.

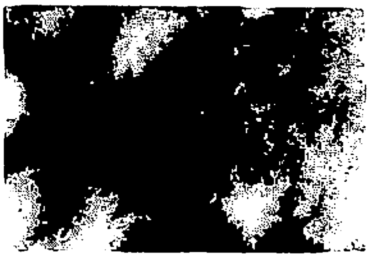


Image-1 Altitude image map

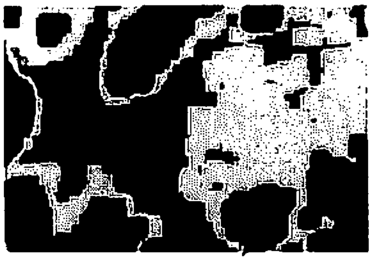


Image-2 Summit level′map

Image-3 River level map

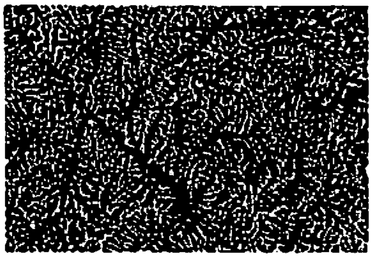


Image-4 Unevenness map

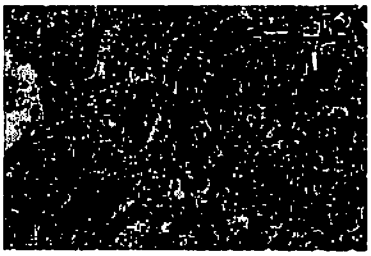


Image-5 Erosion map (lost area)

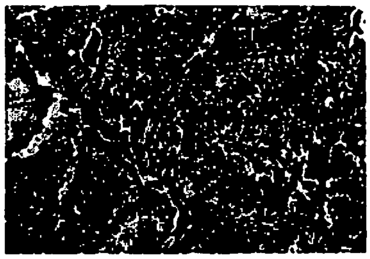


Image-6 Erosion map (remain area)

Image-7 Slope direction map

Image-8 Slope gradient map

Image-9 Undulation map

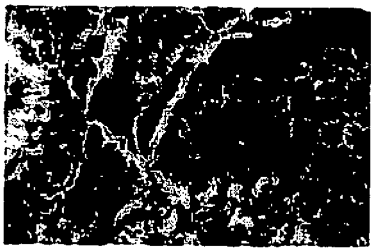


Image-10 PCA result image (All term)

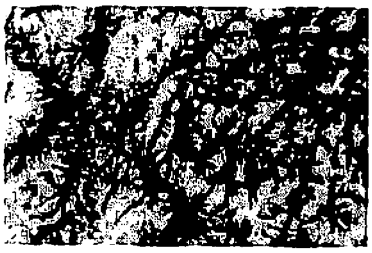


Image-11 PCA result image (partial)

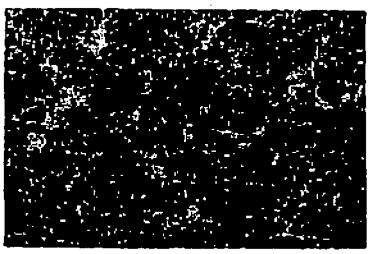


Image-12 LANDSAT PCA image

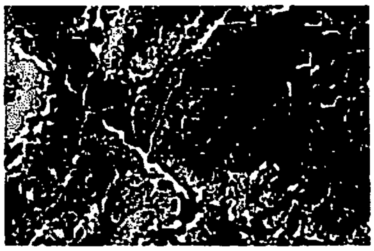


Image-13 Cluster image (DTM)

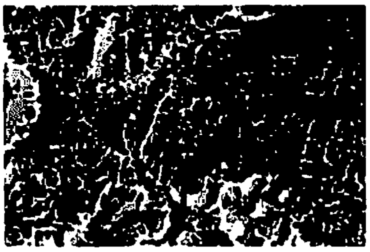


Image-14 Cluster image (DTM + MSS)

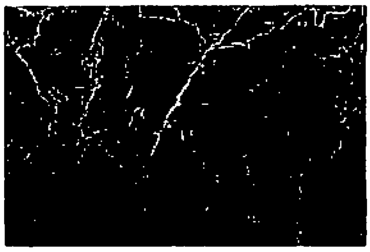


Image-15 Landslide spot on spot

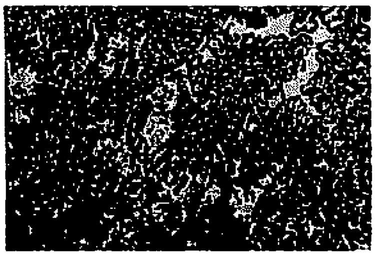


Image-16 Landslide danger (Concave)

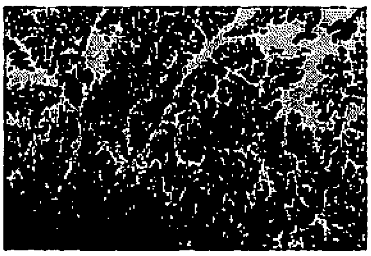


Image-17 Landslide danger (Convex)

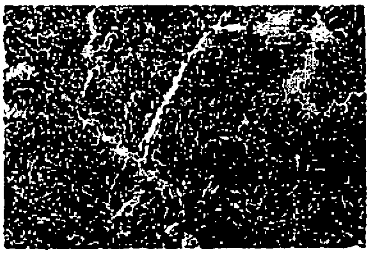


Image-18 Landslide danger (All term)

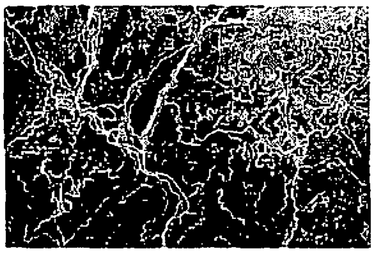


Image-19 Erosion + Slope map

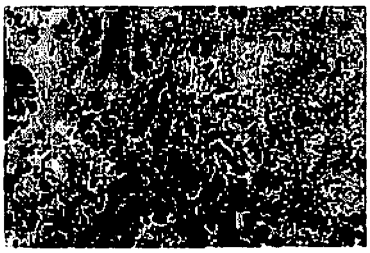


Image-20 Erosion + Vegetation

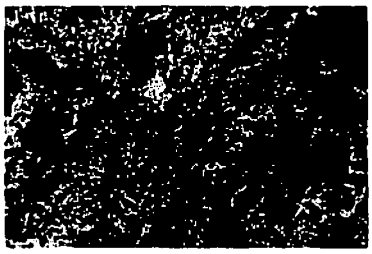


Image-21 Landslide +Heat index map

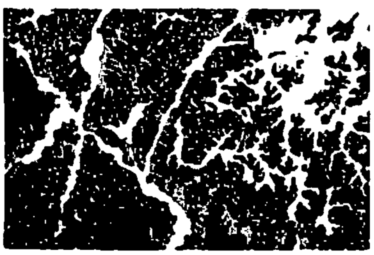


Image-22 Weathering granit map

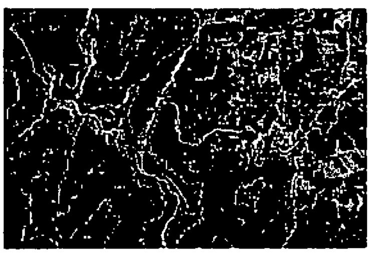


Image-23 Redevelop. plan map (Flat)

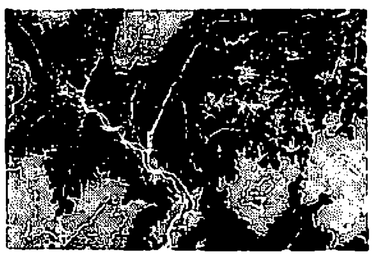


Image-24 Redevelop. plan (Flat + Alti)