

STUDY OF GEOGRAPHICAL INFORMATION SYSTEM TO RENEW THE LANDSLIDE DISTRIBUTION

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ABSTRACT:

Geographical Information System (G.I.S.) is good for renewing the information of landslide distribution. In Most cases, Land slides are caused by geological and geographical factors. Furthermore, in Japan, landslides often affect vegetation and landuse. Therefore, in renewing distribution of landslides, it is necessary to manage, analyze and evaluate these kinds of information. A map that describe above results can support the renewal of landslides distribution. This study examines the use of G.I.S. for the renewal of landslide distribution.

KEYWORDS: Extraction, GIS, Landslide, Overlay, Renew

1. Introduction

In Japan, landslide disasters have exerted significant influences on the livelihood of people, because landslides have occurred in large scale. The landslide which occurred at Mt. Zizuki, Nagano City, Nagano Pref. is a good example of large scaled disaster in recent years in Japan. The western region of Joetsu City of Niigata Pref. which we selected as the object area of our present study is a place where the landslides occur frequently, and therefore, it is necessary to always grasp the up-to-date information concerning the landslide distribution in this area.

The information concerning the landslide distribution has been so far acquired as a result of air photograph interpretation and exploration/observation at actual sites. However, much time and labor are necessary to grasp the distribution of landslide because it expands over a wide area. In addition, the skill of high level is required for acquiring the information of landslide distribution such as in, for an example, air photograph interpretation. This was the reason why much time and labor have been necessitated for collecting the landslide distribution information over a wide area at the same level of accuracy.

Under such circumstances, the authors have been discussing the application of Geographical Information System (GIS) to the acquisition and renewing landslide distribution information (Setojima et al., 1991). Especially noteworthy is the utilization of GIS taking advantage of overlay function, etc. in order to improve the efficiency and uniformity of accuracy which have been major concerns in acquiring of landslide distribution in the past.

The distribution of landslide is considered to be deeply related to the factors such as the geological feature and the soil mechanics feature. In many cases, on the other hand, the landslide have exerted an influence on the various phenomena on land such as land use and vegetation. Therefore, it is necessary to discuss these pieces information one by one in order to renew the distribution information of landslide. But the efficiency of analysis will be enhanced integrating other various factors and making judgment basing thereon. GIS has various kinds of information in its database. Also, it is possible for us to utilize the analysis function and spatial operation function of GIS for supporting the intended analysis. Therefore, it is considered effective to use the GIS for renewing the distribution information of landslide.

We select the area at the western part of Joetsu City, Niigata Pref. (Fig. 1) as our study area. This is a region where landslide took place

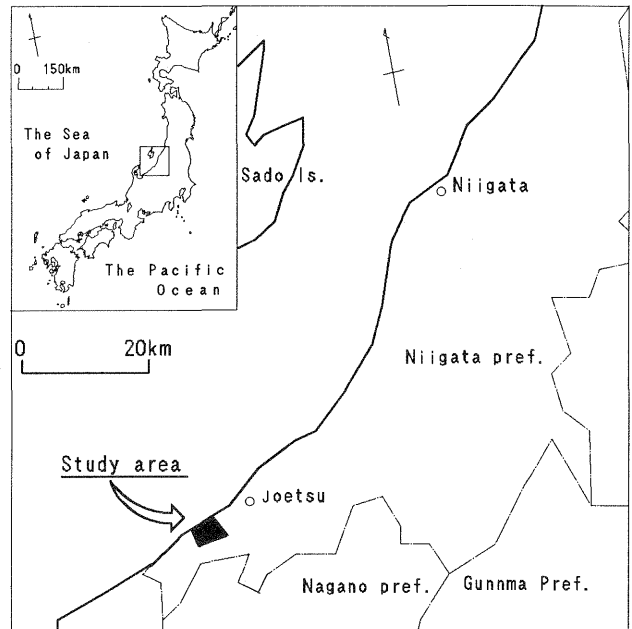


Fig.1 Study area

frequently from the olden times (Akahane et al., 1989). In 1963, railway disaster occurred in this region due to a landslide. It can be said, therefore, that this is the region where up-to-date information of landslide distribution should be grasped correctly. However, only the available information source of landslide distribution for this area is the landslide distribution map (at a scale 1:50000) which was made in 1969, and it is required, for this reason, to renew the information of landslide information in this region.

In this study, we make analysis by using only the information which has been arranged as the plane information as much as possible in supporting the renewal of landslide distribution information (in case of the analysis on landslide, the existence of plane of slip and soil mechanics factors such as $c\phi$ are important; these are detailed and point information, but we did not use them because they are not arranged as the plane information). Now therefore, the authors constructed a database using planely arranged geographical information such as the distribution of landslides occurred already, topography (digital terrain model, DTM), geology and land use. Next, the authors overlaid the landslide distribution and geographical information and analyzed the relationship between them. Basing on this analysis result, the authors attempted the extraction of landslide areas, and used the information obtained therefrom as the basic information for supporting the renewal of landslide distribution information to be done on later stages.

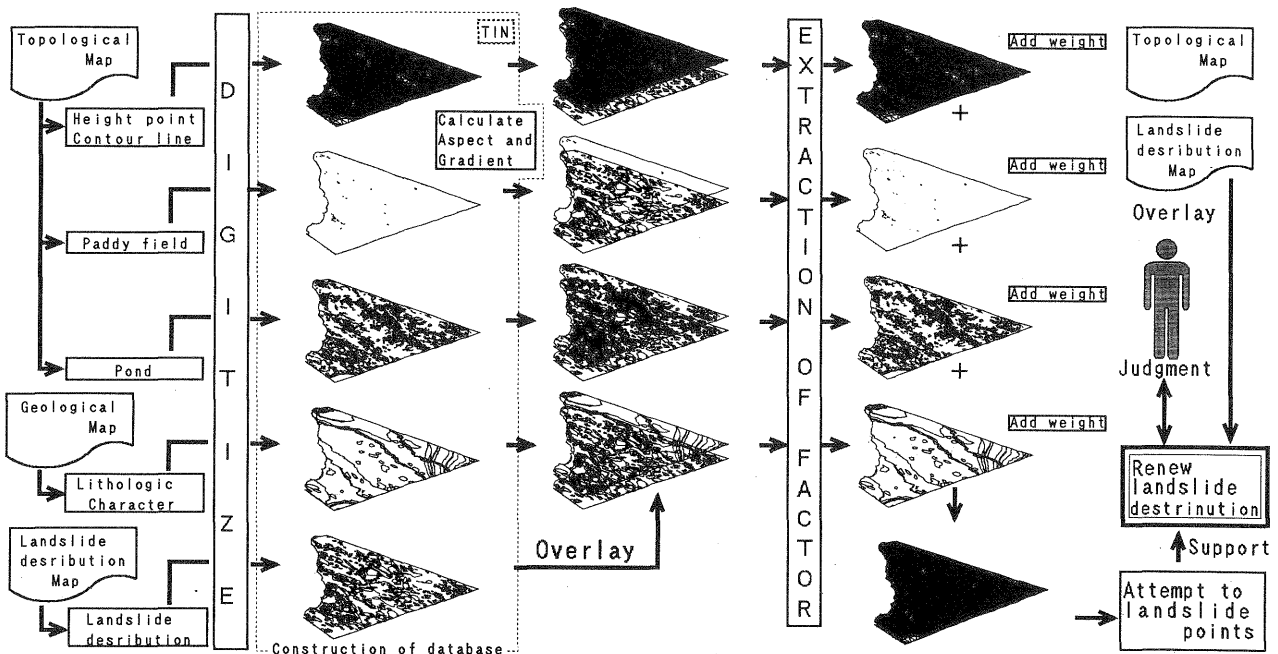


Fig.2 Flow chart of this study

2. Study method

This study is carried out following the procedures shown in Fig. 2.

2.1 Construction of database

Since there is no digitized geographical information available for the study area, we constructed the database from the topographic map and geological map using a digitizer. The digitized geographical information is as follows:

2.1.1 Landslide distribution: As for the distribution of landslides occurred already, we use the landslide distribution map at a scale 1:50000 (The Public Works Research Institution, 1969) made in 1969. As for the landslide distribution information, the shape of landslide is digitized and converted into polygon data.

2.1.2 Digital terrain model (DTM): DTM is constructed by digitizing contour lines and altitude points from topographic map at a scale 1:25000. And then DTM is converted into TIN (Triangulated Irregular Network). Topographical information is made from TIN, and gradient and aspect are calculated therefrom. The TIN is converted into polygon data, and the topographical information is added to TIN polygon data.

2.1.3 Land information: Landslide exerts influences on the various phenomena on land. Especially in many cases, ponds and paddy fields are located on the gentle slope land of landslide area. In case of this study area too, there are many paddy fields and ponds on the area where landslide already occurred. In this study, therefore, land information of the shape of paddy field and pond is digitized from topographic map at a scale 1:25000 and is converted into polygon data.

2.1.4 Lithologic character: In many cases, the geological age is used as an indicator and stratigraphic classification is indicated on the geological map. However, in considering the relation between landslide and geology, we place our focus not on the stratigraphic classification

but on what kinds of lithologic character the stratigraphic classification is composed of. Also, there are some cases where different stratigraphic classification may have the same lithologic character. Therefore, we digitize the stratigraphic classification to the database from geological map at a scale 1:50000. After the digitized data is converted into polygon data, main lithologic character of each stratigraphic classification is added to the data as attribute information.

2.2 Extraction of factor information

Each of geographic information compiled as a database following the procedures as stated above is overlaid with the distribution information of landslides occurred already. Overlay is carried out in an aim to study the relation between landslide and each kind of geographical information. As a method to study the relationship, we compare the area ratios which are occupied by each category contained in the geographical information within the study area with those area ratios within the landslide area. As a result of comparison, the geographical information which recognized difference in the ratio between the landslide area and the total study area is used for the analysis as an effective factor.

We used to use much time and labor to quantitatively analyze the factor information of landslide in the past, but it is now possible to do this analysis far more effectively by using GIS.

2.3 Attempt to extract landslide points

The factor information to be used for analysis is created in an output layer by overlay. As a result, the information organized in one layer is added with the score obtained by the area ratio of each category of factor information within the landslide area. Finally, we attempt to extract landslide area by picking up the areas which have higher scores.

2.4 Attempt to renew the landslide distribution information

The information extracted through the above

procedures are considered to indicate an area which has high potential of landslide. Also, in most cases, the landslide shows a topographical unique shape. For example, the landslide shows horse-shoe-shaped land form as a whole, or the landslide is composed of cliff of steep slope called main scarp and gentle slope called slide block. This composition creates the unique topographic pattern. It is better at present to leave the recognition of pattern to the judgment of experts. In this study, therefore, we select the areas which have a high possibility of landslide distribution excluding the areas where landslide actually occurred. The selection results are used as supporting information for the renewal of landslide distribution information.

3. Results

3.1 Extraction of factor information

Table 1 shows the area ratio of category among each factor information at the landslide area and within the study area. The findings we obtained here are as follows:

3.1.1 Topographical information: As for the gradient and aspect calculated from DTM, the gradient is classified into 10 grades at the interval of 5°, and the aspect into 8 directions. The ratio of areas with the gradient 5° or more but less than 25° occupy 71% of the total study area, while the ratio of it is 80% at the landslide areas. No significant difference is observed as for the aspect.

3.1.1 Lithological character: We compared the area ratio of "colluvial and debris" and "sand stone and mud stone" within the total study area and landslide area. The ratio of "colluvial and debris" is 5.3% (total) against 11.0% (landslide area), while that of "sand stone and mud stone" is 56.2% (total) against 64.3% (landslide area). Namely, it means that the landslide area contains more quantity of these two categories of lithologic character than other categories. Therefore, these two categories of lithologic character have higher potential of landslide distributions.

On the contrary, the ratio of area occupied by "gravel, sand and silt," "mud stone" and "sand stone" is lower at the landslide areas comparing with those ratios in the total study area. In other words, it means that these categories have lower potential of landslide distribution.

3.1.3 Ponds: There are 44 ponds in the total study area, of which 30 ponds are located at the landslide area (including the ponds only a part of which is located at landslide area).

3.1.4 Paddy field: There are 644 paddy fields in the total study area of which 458 paddy fields are located at the landslide area (including the fields only a part of which is at the landslide area).

As a result, we decide to use four factors of (1) gradient, (2) lithologic character, (3) distribution of ponds and (4) distribution of paddy field for the analysis.

Table.1 The area ratio of factor information

(1) Topographical factor

(%)

G r a d i e n t			A s p e c t		
C a t e g o r y	Study area	Landslide	Category	Study area	Landslide
less than 5°	9.1	5.4	N	13.1	13.0
5° or more less than 10°	11.0	13.3	NE	14.0	14.4
10° or more less than 15°	20.0	24.5	E	13.2	15.5
15° or more less than 20°	23.2	26.2	SE	8.7	10.1
20° or more less than 25°	17.4	17.0	S	8.6	7.8
25° or more less than 30°	10.3	8.4	SW	10.3	9.0
30° or more less than 35°	5.7	3.4	W	12.6	12.2
35° or more less than 40°	2.2	1.3	NW	14.5	14.2
40° or more less than 45°	0.6	0.3			
45° or more	0.5	0.3			

(2) Geological factor

(%)

L i t h o l o g i c c h a r a c t e r		
C a t e g o r y	Study area	Landslide
Conglomerate	1.7	0.5
Colluvial and Debris	5.3	11.0
Gravel, sand and silt	6.3	2.2
Mud stone	10.9	6.6
Mud stone and sand stone	56.2	64.3
Sandstone	0.1	0.0
Sand stone and mud stone	0.5	0.2
Sand stone	18.2	14.3
Silt, sand and gravel	0.1	0
Tuff	0.7	0.7
Volcanic rock	0.1	0.0

(3) Land information factor

P o n d	
Study area	Landslide
56857 m ² (100.0%)	33074 m ² (55.3%)
P a d d y f i e l d	
Study area	Landslide
20452672 m ² (100.0%)	9925485 m ² (48.5%)

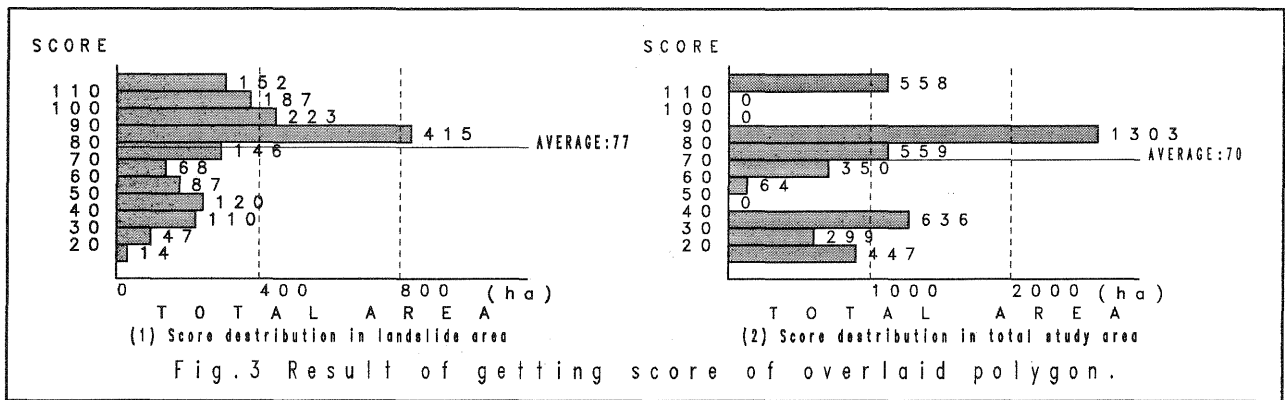


Fig.3 Result of getting score of overlaid polygon.

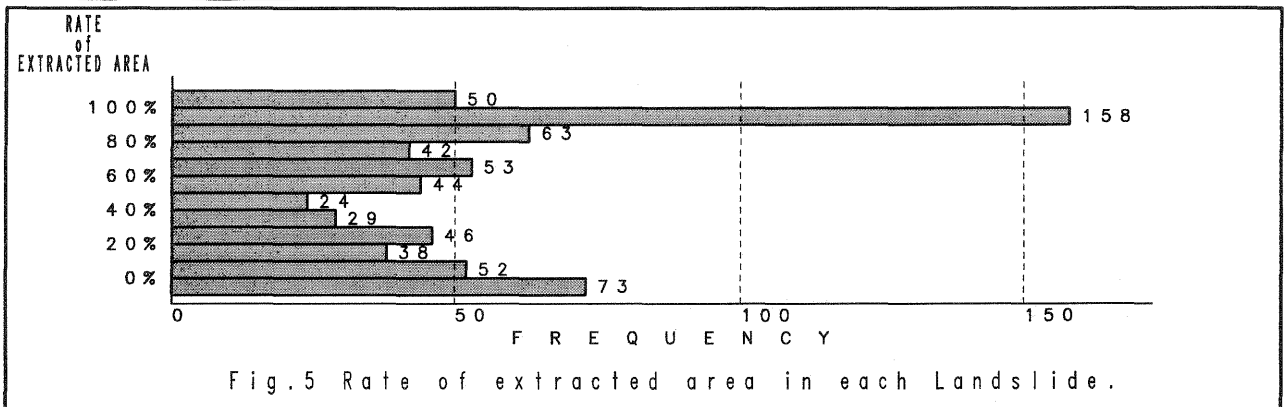


Fig.5 Rate of extracted area in each Landslide.

3.2 Attempt to extract landslide areas

The factor information used for the analysis of 3.1 was organized into one layer by polygon overlay. The polygon created as a result of polygon overlay was added with the score worked out for each factor from its relationship with the landslide. The extraction of landslide areas is carried out basing on these score. The extracted results are discussed from the viewpoint of coordination with the already-occurred landslide areas.

3.2.1 Establishment of threshold: It is necessary to give a score for each category and add weight to the factor information organized into one layer. At present, however, there is no effective method to do so which is both objective and quantitative. In this study, therefore, we worked out the ratio of area occupied by each category within the landslide area and discussed thereon the relationship between the factor and landslide. Namely, the difference of area ratio within the landslide area can be considered as the difference of weight among the categories. For example, lithologic character at the total area of landslide shows that approximately 11% of "colluvial and debris" and approximately 2% of "gravel, sand and silt" are distributed on the already occurred landslide areas. Within the total study area, on the other hand, the share of "colluvial and debris" is approximately 5% and that of "gravel, sand and silt" is approximately 6%. Thus, if the area ratio of categories related to the landslide, the area ratio changed between the landslide area and the total study area. Therefore, the value of percent of each category at the landslide area can be used as the weight. This way of weighting is considered to be more coinciding with the actual state.

Also, it is impossible to ignore the relation between landslide and ponds/paddy fields. However, the database of ponds and paddy fields was not the one created as the result of classification made to

the total study area, but it is a result of extraction the land information. Therefore, as the method to add weight to the ponds and paddy fields, we decide to calculate the ratio of area occupied by each factor within the landslide area against the area of each factor within the total study area, and to add the percent value as a score.

Also, these scores are used as the threshold value in extracting the landslide areas. The information to which the weight addition was completed is overlaid with the landslide distribution information. Fig. 3 shows the distribution of scores within the total study area and at the landslide areas. The average score in the already occurred landslide areas is 77 points, while the average score of total study area was 70. Now, the difference of score distribution between the total study area and landslide area is that the score distribution at the landslide area is lower than that in the total study area below the average. Namely, the landslide areas are distributing at the high score areas within the total study area. Basing on this result, we extracted the polygons which have the score of 77 or higher, which is shown in Fig. 4.

3.2.2 Analysis result: Here, we will evaluate the information extracted through the above-mentioned process. Fig. 5 shows the ratio of region with the score 77 or higher against each landslide area. There are 672 landslide points in the study area. Out of which, the landslide points which are located within the extracted area are 599 (including the point only a part of which is included in the extracted area). Namely, the landslide points in the extracted area is 88% of all the landslide points in the total study area. Also, the landslide points 60% or more of which is occupied by the score 77 or higher are 366. Namely, the landslide points 60% or more of which is occupied by the score 77 or higher is 54% of all the landslide points within the total study area.

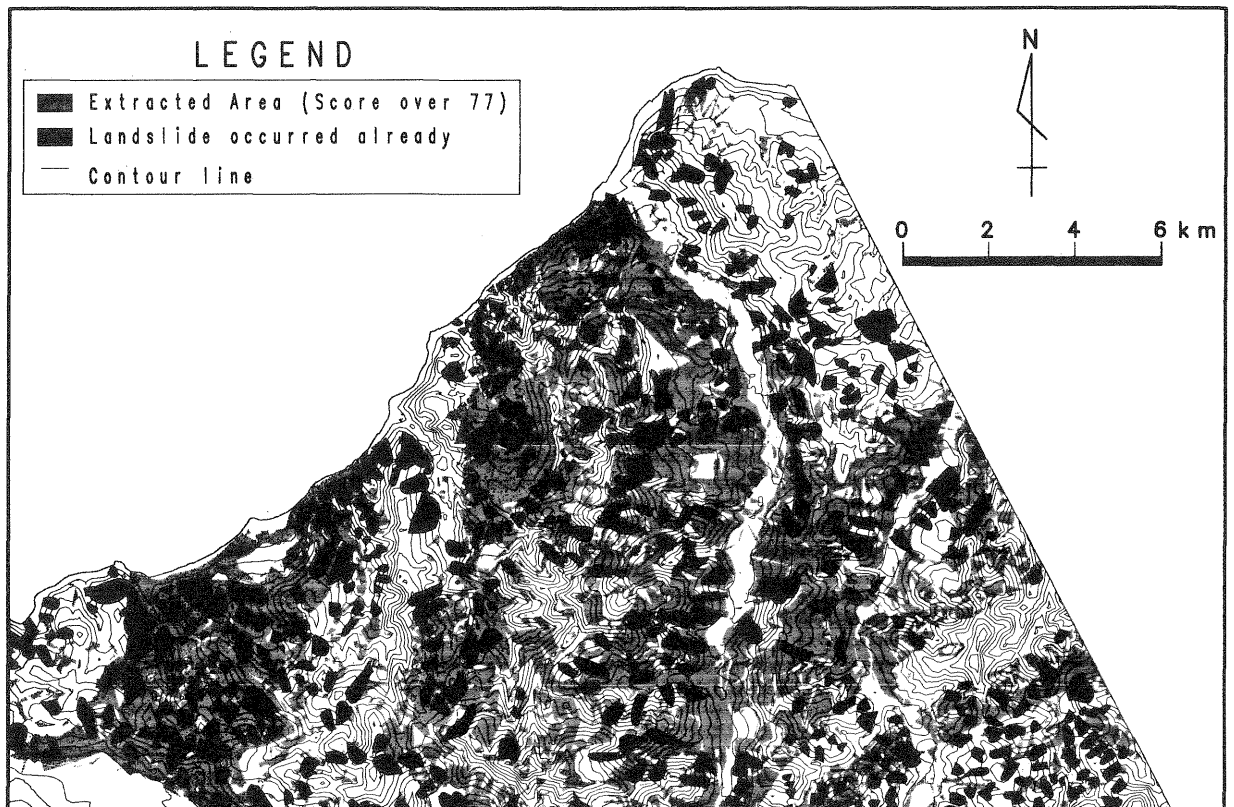


Fig.4 Distribution of extraction area.

Gray area is area of getting score over 77. It is a great possible to find new landslide points in gray area.

3.3 Attempt to renew the landslide distribution information

Fig. 4 shows the results of 3.2 including those of already occurred landslide areas. But the possibility that new landslide may occur is considered at other than the areas where landslide occurred already. Therefore, in extracting new areas of landslide, we overlaid the landslide point information extracted by the analysis mentioned in the above with raster data of topographical information (information in the form of image), and extracted the areas on the display by visual interpretation. We attempted to renew the landslide point information by overlaying the new landslide points thus extracted onto the already occurred landslide areas.

4. Conclusion

We obtain the following findings through this study.

(1) It is useful to introduce GIS to support the renew of landslide distribution information which needed much time and labor in the past, for the following reasons.

- 1) Simultaneous evaluation of factor information
 - 2) Free retrieval of geographical information
 - 3) Quantitative and rapid grasp of complicated polygons.
- (2) To add weight to factor information in evaluating the overlay result means to establish a quantitative judgment standard.
- (3) In this study, we used only the information which has been arranged as plane information. Even by using the plane information, it is possible for us to obtain support information to specify the landslide area by utilizing the various function of GIS.

5. Epilogue

In this study, we discussed the application of GIS to the extraction of landslide points and to the renewal of landslide distribution information. GIS is effective for quantitatively analyze the geographical information which expands over a wide area and which has complicated shape. The effectiveness of GIS will become higher as there will be more advancement in the study of spatial analysis method such as pattern recognition. Lastly, the following matters are pointed out as the future problems:

- (1) It is necessary to introduce objective and quantitative method in making judgment for attribute information. For this purpose, it is desirable to establish the analysis method jointly using the statistical method such as quantity theory.
- (2) It takes much time and labor to construct the database. When the future of GIS is considered, it should be urgent to improve the efficiency of data acquisition.

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