APPLICATION OF GIS AND REMOTE SENSING TO EXTRACTION OF LANDSLIDE AREAS

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ABSTRACT

The objective of this study is to find areas where landslide may occur in the near future by using satellite remote sensing data and thematic-map data related to landslide areas with GIS (Geographic Information system) techniques. We considered that remote sensing data combine thematic map data with Geographical Information System (GIS) may greatly facilitate for assessment and estimation of regional landslide hazards.To get dangerous areas of landslides we introduced watershed based on elevation data. Because Geographic Survey Institute of Japan published DEM in the pilot areas at 1st July in 1995.

We researched that the relationship among remote sensing data ,geological type ,inclination angle and shape factor F in each watershed areas at pilot areas. In pilot areas we got the interested results: (1) We can divide pilot areas into watershed areas by using GIS technique. (2) The virtual rivers were made automatically by GIS and then we confirmed it correspond with the true rivers. (3) GIS is able to extract small rivers where we did not confirm on the map. (4) As the proportion of landslide area increase band6 CCT data decreases. (5) When the proportion of landslide area was over 70 % the shape factor F increases sharply. We started the study only 2 sheets of 1/25000 scale maps. In this paper we extended the investigation areas to 6 sheets of 1/25000 scale maps.

1. INTRODUCTION

Remote Sensing has been used to clarify characteristics properties of ground surface by the advantage of broad area observation and periodicity. We consider that the remote sensing data from space gives us useful advice on natural hazard. We have already been conducted the analysis using remote sensing data and thematic map data respectively. Estimation of landslide areas , however, has been considered very difficult because the principal factor of landslide complexly relate with some phenomena. The objective of this study is to find areas where landslide may occur in the near future by using satellite remote sensing data and thematic-map data related to landslide areas with GIS (Geographic Information system) techniques.

We considered that remote sensing data combine thematic map data with Geographical Information System (GIS) may greatly facilitate for assessment and estimation of regional landslide hazards.

2. PILOT AREA

In the Noto peninsula in Hokuriku district of Japan where we have investigated, most of landslide hazards occur near the stream in the valley. The area of the study site is about 600 km2 and altitude is lower than 600m. Figure 1 shows the areas of Hokuriku district of Japan. Dotted point in the Figure shows that the landslide occurred in the past. This area is well-known as landslide areas in the Japan. Figure 2 shows the north district of Noto peninsula where we mainly conducted researches. The rectangular areas in the figure correspond to 1/25000 scale map about 10km wide to 10km long.

3. THEMATIC MAPS AND SATELLITE DATA

3.1 ELEVATION DATA

Used data shows Table 1. Thematic maps are the monitored map of landslide area,geological map of Ishikawa prefecture and elevation data. In this

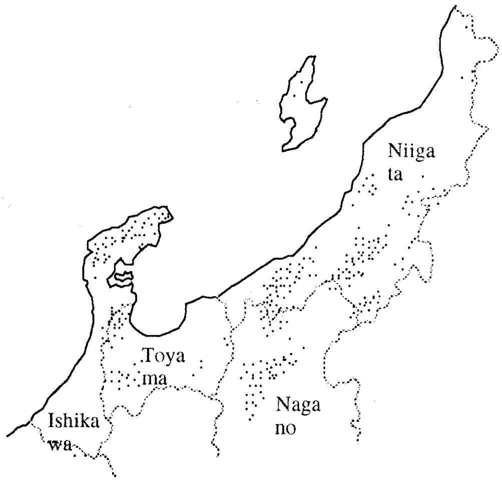

Fig.1 Landslide areas in Hokuriku District
Dotted symbols in the figure is landslide areas

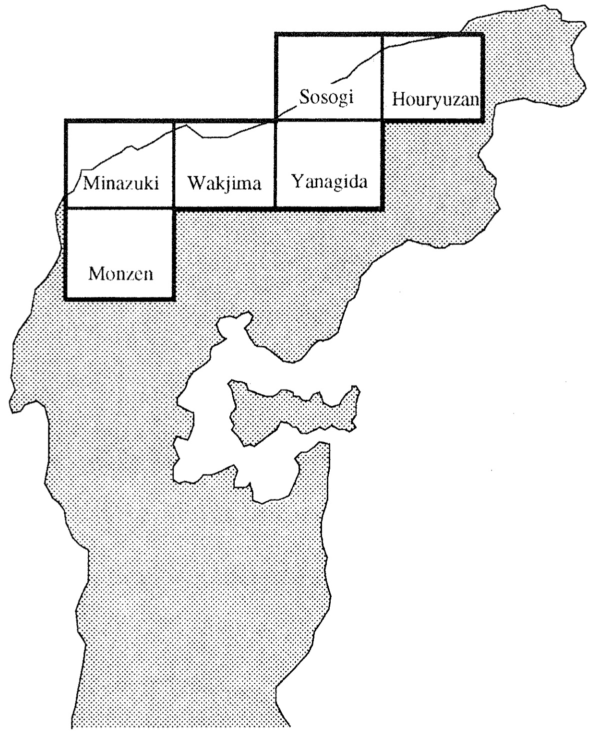

Fig.2 Investigation areas for landslide.
Each square is about 10km long
by 10km wide

study elevation data is key data to evaluate the landslide areas. In the past study we had made the elevation data from 1/25000 scale maps with a lot of works. For example elevation data of 30m*30m mesh size for a sheet of 1/25000 scale map was made by four or five persons with two weeks. The 1st July in 1995,however, Geographic Survey Institute of Japan published DEM of 50m*50m mesh size for the pilot areas. We adopted DEM data instead of hand made elevation data. Figure 3 shows the map of elevation originally made by us. Mesh size is 30m * 30m. Figure 4 shows the map of elevation made from DEM which has 50m * 50m mesh size. Two figures have similar condition. It is shown that DEM of 50m * 50m mesh size data is able to extract watershed areas. We convert DEM of 50m * 50m mesh size to 30m * 30m mesh size by using bi-linear interpolation method. Inclination angle was computed from interpolated elevation data.

3.2 SATELLITE DATA

Ground surface temperature and NVI was used to evaluate Landsat TM data. It is well known that Landsat TM band 6 data (we call it thermal band

Table.1 Thematic maps and Landsat TM data

Thematic Maps	Landslide Map Geological Map of Ishikawa Elevation Data
Landsat TM Data	Observed Date (Rainfall of a week before)
	6 April 1989 (0.0mm) 24 May 1989 (3.5mm) 9 April 1990 (70.0mm) 6 Nov. 1991 (34.5mm) 21 May 1991 (-----mm) night-time

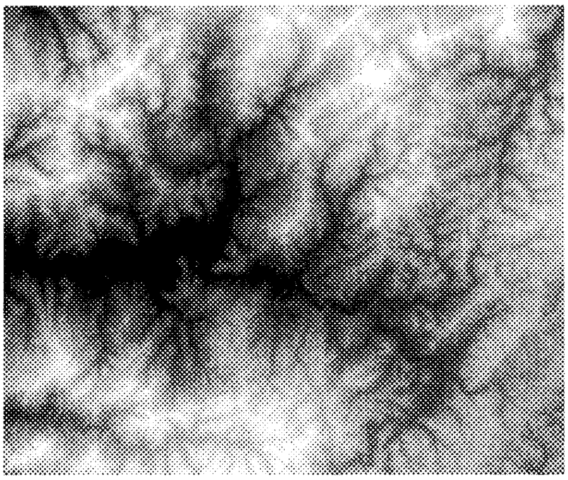

Fig.3 Imaged elevation data by 30m mesh size (Monzen district)
This data was made by us on handiwork

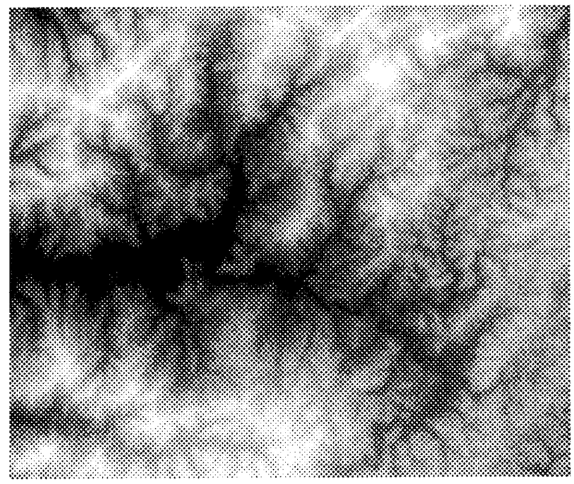

Fig.4 Imaged elvation data by 50m mesh size (Monzen district) . Elevation data was made from DEM.
DEM was establised by Geographic Survey Institute of Japan.

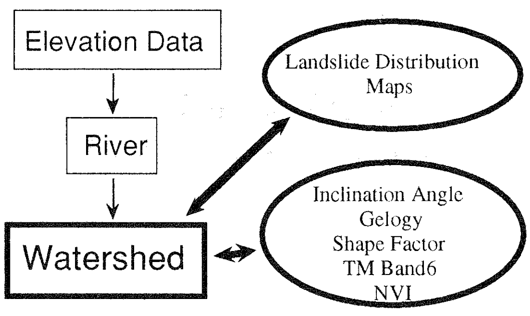

Fig.5 Flow of study

data) has the information of temperature. It is shown that TM band 6 data represent temperature of ground surface. Landslide closely relates under ground water. Generally speaking, water contents in landslide area has higher than that of non-landslide areas.In other words,temperature of ground surface in landslide areas has lower than that of non-landslide areas. TM band 6 data was used to estimate indirectly landslide areas.

3.3 NVI DATA

It is well known that the NVI data shows vitality of vegetation. Calculation of NVI is as follows.

$$NVI=(NIR-VIS)/(NIR+VIS) \qquad (1)$$

In this equation , NIR is the near infrared band data and VIS is visible band data . The reason why we use NIR band data is because it reacts to the amount of chlorophyll in vegetation. Generally speaking, as NVI increases , mass of vegetation or the vitality of that vegetation also increase. There are many index to represent the condition of vegetation by using satellite data. We adopted equation (1) to analyze the relation between the vegetation index and occurrence of landslides. We used band 4 as NIR and band 3 as VIS in the equation (1). NVI data calculated from the above equation is greater than or equal to -1 and less than or equal to +1. Data of equation (1) needs to be changed to an integer. Equation (2) was used to change a decimal NVI value to an integer value.

$$NVI1=\{(NIR-VIS)/(NIR+VIS)\}*100+100.5 \qquad (2)$$

4. METHOD AND TECHNIQUES

4.1 FLOW OF ANALYSIS

Figure 5 shows the outline of analysis.There are five major part in this study. They are generation of elevation data (in this paper we adopted DEM data which was made by Geographic Survey Institute of Japan),generation of virtual river from elevation data , generation of watershed from virtual river and extraction of characteristics of landslide areas in each watershed. In this paper we describe the characteristics of inclination angle , geology, shape factor F ,TM thermal band data and NVI data within watershed.
Major data of the research is the elevation data. GIS gives us virtual rivers from elevation data. We used GIS software of ARC/INFO ,however, algorithm to extract rivers from elevation data does not open to users. Our object is not evalua-

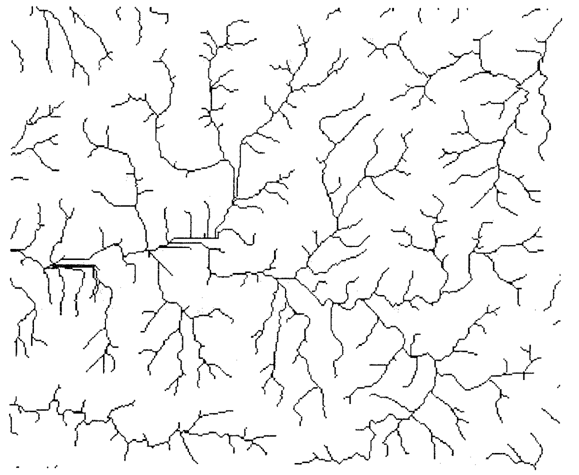

Fig.6 Virtual river which was made by elevation data

Fig.7 Real river on the map

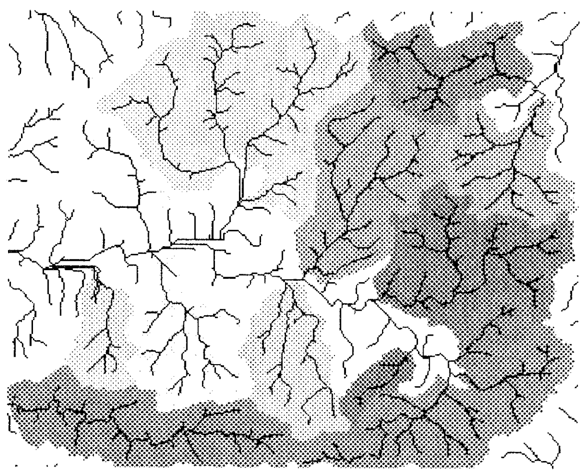

Fig.8 Wtershed areas which was made from elevation data and virtual river by using GIS

tion of the algorithm for generation of rivers and watershed. Then we extract watershed areas from the virtual rivers. Many analysis were performed by us. For example, relationship between landslide areas and inclination angle, geology, temperature of ground surface ,NVI were analyzed based on the each watershed areas.

4.2 EXTRACTION OF VIRTUAL RIVER AND LARGE WATERSHED

Figure 6 shows the virtual river extracted by elevation data. Figure 7 shows the digitized rivers made from 1/25000 scale maps by map digitize. We confirmed that the rivers on two figures corresponded. The result proved that the rivers made by elevation data and GIS were computed correctly. Then we extracted watershed areas from figure 6. On the GIS software we point out the cross section of mail river and tributary on manual operation. Figure 8 shows the watershed areas of Monzen district.

5. RESULTS AND DISCUSSIONS

5.1 ANALYSIS OF INCLINATION ANGLE

Figure 9 shows the relationship between proportion of landslide area to total area in each watershed and inclination angle on the Minazuki district. This figure shows that as the proportion of landslide area increase inclination angle decreases. We realized that landslide has been occurred on areas of gentle slope.

5.2 ANALYSIS OF GEOLOGY

Figure 10 shows the relationship between proportion of landslide area to total area in each watershed and geology. Symbols on the horizontal axis shows the geological types. Frequency diagram on the figure 10 shows the total areas of the geologies which is correspond to right side axis. On the other hand , the solid line which correspond to the left side axis shows proportion of landslide area to each geology. This value represent the proportion of landslide area to total area in each watershed. The geology which has high values on the left side axis shows geology of the tertiary era. It is well known that the geology for the period of tertiary era easily occurs landslide. Figure 11 shows the relationship between proportion of landslide area to total area in each watershed and geology on Yanagida district. The values of left side axis shows the sequence of dangerous geology . In this district, we realized landslide depend on geology.

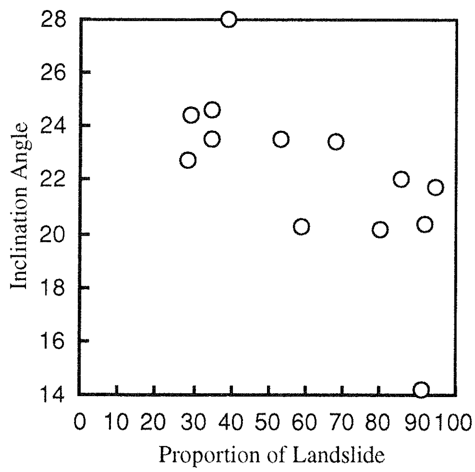

Fig.9 Relationship between proportion of landslide areas to total area in each watershed and inclination angle on Minazuki district

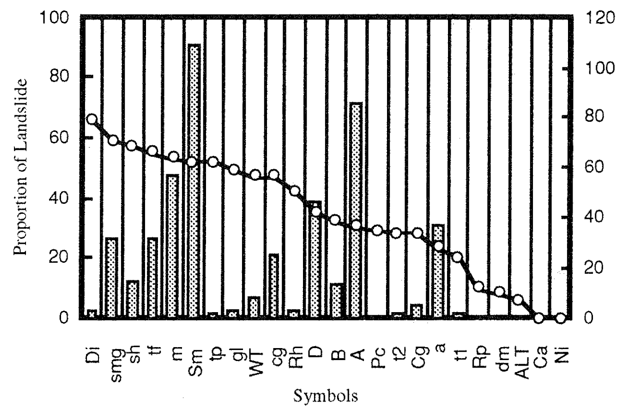

Fig.10 Relationship between proportion of landslide areas to total area in each watershed and geology

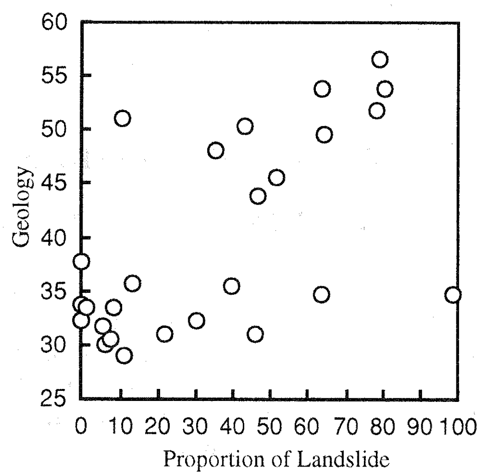

Fig.11 Relationship between proportion of landslide areas to total area in each watershed and geology on Yanagida district

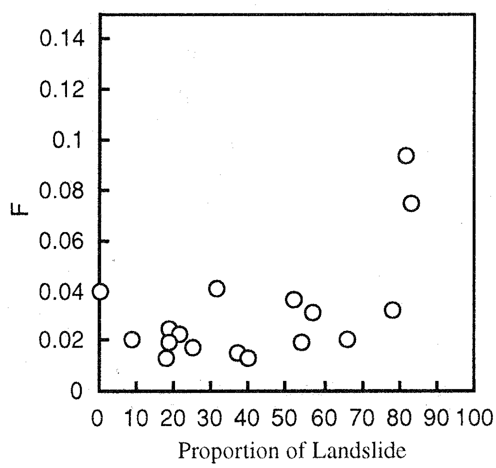

Fig.12 Relationship between shape factor F and proportion of landslide areas to total area in each watershed

5.3 SHAPE FACTOR AND LANDSLIDE

To access characteristics of each watershed , we introduced the factor F. F is the shape factor (A/L)/L. A and L represent the area of watershed and length of the main river in watershed respectively.

A/L represents averaged width of watershed . A/L divided by L represents shape factor F.

Figure 12 shows the relationship between shape factor F and proportion of landslide area to total area in each watershed. Figure 12 has very interesting results which did not realize in the past. When the proportion of landslide was over 70 % in the watershed the shape factor F increased sharply.

5.4 THERMAL BAND DATA AND LANDSLIDE

Figure 13 and figure 14 shows the relationship between Band6 CCT data and the proportion of landslide area to total area in each watershed. Vertical axis of figure 13 shows CCT data of daytime. On the other hand, figure 14 shows Band6 CCT data of nighttime. Same district were selected on this analysis. These two figures has very interesting results because of opposite tendency appears clearly. We considered that the soils of landslide areas at near the ground surface has more water than that of non-landslide areas. At the daytime, the water in the ground keeps soil temperature at the low level. On the other hand, at the nighttime the water in the ground keeps soil temperature at high level. As a

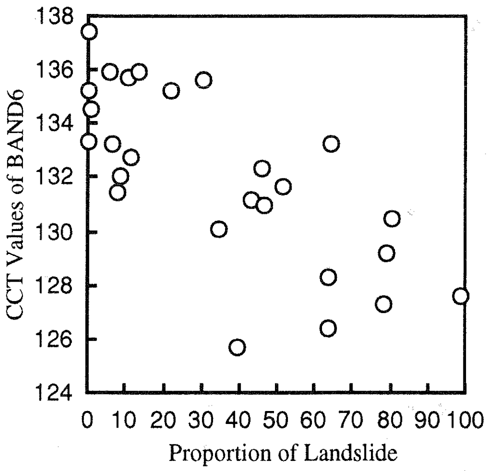

Fig.13 Relationship between Band 6 CCT data and the proportion of landslide areas to total area in each watershed on daytime

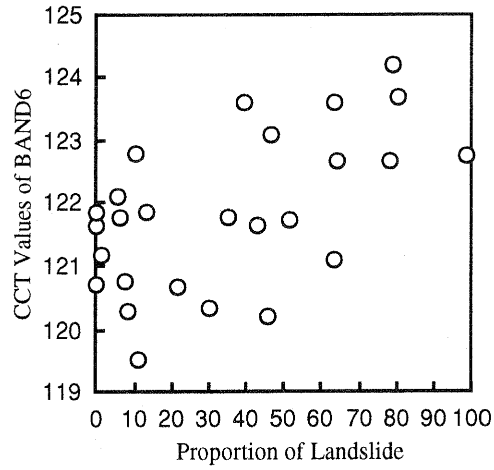

Fig.14 Relationship between Band 6 CCT data and the proportion of landslide areas to total area in each watershed on nighttime

result, the landslide areas has constant ground temperature. Figures 13 and 14 establish above phenomena.

6. CONCLUSIONS

We have been conducted the procedure mentioned above in the pilot area located north district of Noto Peninsula in the central district of Japan. These pilot areas are correspond to 2 sheets of 1/25000 scale map.In this paper we expand the pilot area to 6 sheets of 1/25000 scale map. On the expanded pilot area we got the new informations. For example , thermal band data for daytime and night time shows very interested results. These conclusions indicate that combining thematic maps and satellite data using GIS techniques is successful estimating and zoning landslide areas.

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