GIS Analyses of the landslides in Japan

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要旨: 最近、わが国には豪雨や地震による表層崩壊や地すべりが数多く発生している。これらの GIS 解析にあたっては、オルソ画像、地質図、地すべりマップ、10mDEM などが必要である。しかし、これらのデジタルデータは最近、いくつかの政府機関から提供されるようになってきた。そこで、私たちは、最近あるいは古い地すべり地形について、上記のデジタルデータを利用して斜面災害の GIS 解析を実施した。さらに、これらのデータやほかのデータを使って四国防災 GIS マップなどを試みている。

キーワード: 斜面災害(landslide)、GIS 解析(GIS analyses)、デジタルデータ(digital data)

Introduction

Japanese Islands are prone to landsliding caused by earthquakes as well as heavy rainfalls due to Asia Monsoon zones. Actually, recent heavy rainfalls triggered many shallow landslides and also intensive earthquakes triggered many shallow- and deep-seated landslides. In this paper, we are using GIS analyzing heavy rainfall-induced failures in 1983 at Hamada, Shimane, those in 2003, at Hidaka, Hokkaido, those in 2004 at Niigata, and in 2004 at Niihama. Further, using GIS we are analyzing deep-seated landslides in Hokkaido and attempting to make Shikoku GIS maps including deep-seated landslides and active faults.

1. GIS using analyses of heavy rainfall-induced landslides in Japan

1.1 Heavy rainfall-induced landslides in 1983 in Hamada area, Chugoku region

1.1.1 Geological and geomorphological setting

Hamada area (Fig.1) is a coastal area of hills and plains with elevations generally lower than 150 m; but some isolated hills have elevations of between 260 m and 400 m. The eastern part is more mountainous, with peaks elevations of up to 700 m. Lithologies consist of (a) Paleozoic to Mesozoic pelitic and psammitic schists, (b) Paleogene diorites and granitic rocks, and (c) Paleogene rhyolitic to dacitic pyroclastic and volcanic rocks. In addition to these rocks, Quaternary deposits form terraces and alluvial plains within valleys. Schists form a low hilly terrain with a relatively higher drainage density than the igneous rock terrain. The regional structural trend of the schistose rocks is NE-SW. Plutonics form isolated high peaks. Volcanic and pyroclastic rocks form a higher mountainous terrain with steep slopes in the northeastern part of the study area.

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addition to precipitation intensity. The highest frequency of failures occurred on 30º to 40º slopes, and the largest slope failures occurred in granitic rock regions.

### 1.1.3 Distribution of slope failures
The slope failure distribution was obtained from the stereoscopic interpretation of 1:8,000 scale black-and-white aerial photographs that were taken just after the rainstorm (Fig. 2). The average size of rupture surface was 1,400 m²; and 40% of all failures had a surface of rupture between 500-1,000 m² (Pimiento and Yokota, 2006).

![Fig. 2 Distribution of slope failures (Pimiento and Yokota, 2006) and elevation from 10 m DEM (Geographical Survey Institute of Japan, 2009). The centers of the source area of the failures are represented as points. Notice that the encircled area is sub-area which is much concentrated failures.](image)

**Fig. 2** Distribution of slope failures (Pimiento and Yokota, 2006) and elevation from 10 m DEM (Geographical Survey Institute of Japan, 2009). The centers of the source area of the failures are represented as points. Notice that the encircled area is sub-area which is much concentrated failures.

### 1.2 Rainfall-induced failure distribution in the Izumozaki, Niigata from 1961 to 2004
On July 13, 2004, heavy rainfalls due to the strong activities of rain front occurred in the Mid Niigata Region, Japan. They are as much as 400 mm in 24 hours, bringing about serious flooding by breaking the river banks. The heavy rainfalls also triggered more than 3350 failures and field research revealed that two types of landslides were inventoried; one is shallow failure and the other is deep failure which is associated with mudflows. The shallow failures are much more abundant by 2004 July rainfalls, and the Izumozaki area was also damaged by the same type of failures in 1961 August, and 1976, 1978. Therefore, using GIS we put all of the failures into polygon data in GIS system, and then analyzed characteristics of particularly shallow failure distribution by the past heavy rainfall as well as 2004 ones.

We have made slope distribution map derived from 10 m DEM, and divided into 5 zones in gradient zones with intervals of 10.8° degree. And then, we have examined the relationship between the slope gradient and slope density of all of the total failures (4,448 sites) from 1961 to 2004 (Number/km²).

We calculated each failure density (Number/km²) within the 10.8° interval zone, and then we suggest that the shallow failure density is linearly increasing up to 43.2-54.0, proportionally to the slope gradients. The fact suggests that failure density mostly depends on the slope degrees (Yamagishi et al., 2008).

### 1.2.1 Geologic lithology and failure distribution
Using GIS, we have plotted all of the failures from 1961 to 2004 into the geologic map which was simply divided into sandstone area and mudstone area. As the results, in any year of 1961, 2004 and 1961 to 2004, the failure density in the mudstone areas is larger than that in the sandstone ones (Yamagishi et al., 2008).

### 1.2.2 Strata dipping and failure distribution
Using GIS, we put all of the vector data of the failures into the raster distribution map of dipping of strata (5 zones) derived from the Neogene sedimentary rocks. As the results, we have obtained that most of the failure density of each strata-dipping zone of 5 zones, are not so much affected by the dipping of the strata (geologic structures of bedrock) (Yamagishi et al., 2008).

### 1.3 Heavy rainfall-induced landslides in 2003 in Hidaka area, Hokkaido
In Hidaka area, Hokkaido, in August 9th to 10th, 2003,
Typhoon No.10 was closing and landing at Hidaka Mountains. The typhoon brought about total more than 400mm precipitation within two days. At maximum, 50mm/hour was recorded. As the results, total 20,000 failures were inventoried along the Sarugawa and Appetsugawa tributaries, Hidaka, Hokkaido (Fig.4).

We are analyzing the failures using GIS and 10m_DEM for clarifying the relationship to slope gradient and slope aspects. As the results, we have obtained the graph and radar chart as shown in Fig.3. The graph (Fig. 5a) indicates that the failure number increases gradually with slope class up to 24-30° degrees, but at more than 30° degrees the number decreases drastically (Fig.5a).

While, the Fig. 5b indicate that failures are concentrated preferably on the northwest slopes rather than eastern slopes.

1.4 Heavy rainfall-induced failures in 2004 October at Niihama, Shikoku

In 2004, total ten typhoons were landing on Japanese Islands. Therefore, many places were affected by heavy winds and rains throughout Japan. Typhoon no. 21 reached the southwest Japan on Sep 27, 2004, and passed Shikoku on September 29-30th, where totally more than 400 mm precipitation was recorded. By the precipitation, Niihama, Ehime Prefecture were seriously damaged by the many shallow failures which were inventoried as total 1300 failures by Ehime Prefecture (Fig. 6).

In the highly affected area closing to Niihama City (Fig. 6), the total number of slope failures was 900 with a total area of 1.2 km². Slope gradient values were reclassified in 10-degree classes and the failure density gradually increased to 9.5% for the 55-65 degree slope class; then it decreased drastically for up to more than 66° degree (Fig.7a). The number (count) of the failures are preferably concentrated to the western original slopes (Fig.7b).

2. GIS analyses of deep-seated landslides

In Japan, there are many deep-seated landslides which were inventoried through airphotographs. Those in Hokkaido island were inventoried by Yamagishi, H.
(1994) and those in Honshu, Kyushou and Shikoku were inventoried by NIED. Some of the landslides are prone to reactivation triggered by heavy rainfall and earthquakes etc. **Hokkaido Island** has more than 12,000 deep-seated landslide sites. GIS analyses of the landslides related to Geology (total 200 legends of GeoDB were reclassified and dissolved into 13 legends) have revealed that most of the landslides are distributed in the Late Cretaceous to Miocene volcanic rock areas (Fig. 8).

**Shikoku Island** has a few plains and most of the island has slope areas (more than 15° in inclination) of 78% which is much more the average of whole Japan. Therefore, the Shikoku island has many landslides some of which are historical landslides from ancient times (Fig.9). In addition, famous active fault called Median Tectonic Line is running in E-W direction throughout the island. Namely, Shikoku Island has high potential of natural hazards likely to the other Japanese islands although it has no active volcanoes.

Thus, we are now preparing Shikoku GIS Disaster Maps for the basic database for detailed hazard maps including such as landslides and active faults, using GIS and variable digital data provided from governmental organizations, such as NIED, Japan etc. In this paper, we are beginning to make susceptibility maps which are preparing for hazard and risk maps for reactivation of deep-seated landslides using GIS technology.

**Conclusions**

We have done GIS analyses of the recent shallow failures caused by heavy rainfalls in Japan. As the results, we have found that the failure density increases with the slope gradients up to certain values although the values are different in places. In addition, we have analyzed the deep-seated landslides in Hokkaido and now attempting to make GIS using susceptibility mapping of deep-seated landslides for reactivation in the future. If we can find more appropriate factors for any triggers, we can improve analytical results and susceptible maps toward the hazard maps.

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**References**


