GIS Analyses of the Landslides in 2004, Mid Niigata, Japan

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Abstract: In 2004, heavy rainfalls and intensive earthquakes triggered numberless landslides in Mid Niigata, Japan. Using ArcInfo9.1, we have analyzed and compared in distribution, related to geology and geomorphology, between the two events. As the results, we have found that the landslide density, and geologic facies where the landslides are concentrated, are remarkably different.

Keywords: Landslides, heavy rainfalls, intensive earthquakes, GIS

Introduction

In 2004, Mid Niigata region (Fig. 1a) was damaged by July 13th heavy rainfalls (Fig. 1b), followed by Oct 23th intensive earthquakes (Fig. 1b). The heavy rainfalls claimed the lives of 13 peoples by flooding of the two rivers such as Kariyata-gawa and Ikarashi-gawa, both of which are branch tributaries of the Shinano-gawa (the longest river in Japan). They also claimed two human lives by the landslides which are counted at more than 3300 landslides. Three months later, intensive earthquakes attacked the southern area of the heavy-rainfall areas. Totally more than 40 persons were killed directly and indirectly by the earthquakes. It was outstanding characteristic that very strong shaking attacked the hilly mountainous areas which are characteristic of Japan. Therefore, both of the heavy rainfalls and earthquakes caused serious landslides in the similar geologic and geomorphologic conditions. In this paper we are discussing the comparison in the landslide distribution related to geology and geomorphology between the two events using GIS.

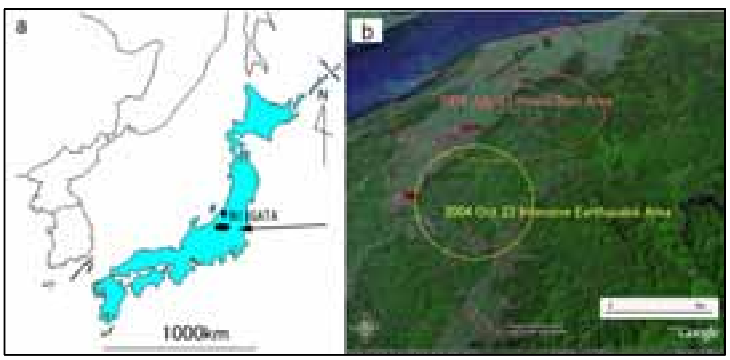


Fig.1a: location maps of the Mid Niigata area, b: affected areas by the 2004 July 13 heavy rainfalls and by the 2004 Oct 23 intensive earthquake(Background of b is from Google Earth)

1. Precipitation conditions of heavy rainfalls on July 13, 2004

According to Ushiyama (2004), the rainfall began in the evening of July 12, 2004 and reached its peak in the early morning of July 13. Fig. 2 presents the precipitation contour map on July 13, showing the areas where flooding and landsliding. Within 1250 km^2 area, the Tochio and Kariyatagawa area obtained the maximum rainfalls of the one day. The one day rainfall of AMEDAS station in Tochio City was recorded to be 421mm.

2. Landslide distribution by heavy rainfalls on July 13, 2004

Many landslides have been inventoried through aerial photographs of Asia Aerial Service. Particularly, Izumozaki area and Tochio areas were characteristic of many shallow landslides, totally recorded as 3300 landslides. In particular, the Yoita of the Izumozaki area was known as more than 500 landslides recorded. Within these areas, we have been checking the sites of the landslides and associated mudflows using the researching cards. As the results, most of the landslides are several meters wide and thick, and some of them are several tens of meters wide and up to 100 m long. They are associated with long-run mudflows up to several hundreds of meters long (Yamagishi and Ayalew, 2005).

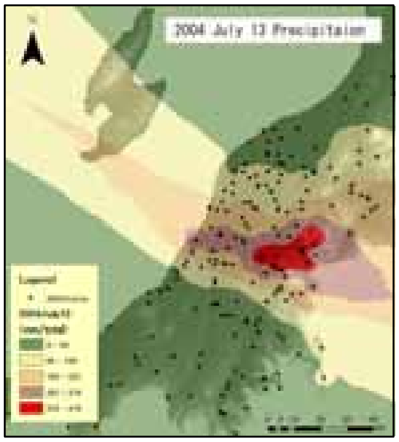


Fig. 2 Using GIS precipitation contour map of 2004 July 13 in Mid-Niigata region.

3. GIS analyses of the landslides by the 7.13 heavy rainfalls

We have made basic data by converting to the vector data models from the inventory maps of the landslides by 7.13 heavy rainfalls. As the basic digital map, we used the GISMAP (Hokkaido Chizu Co. Ltd.) which is DEM of 10m grid. In addition, we

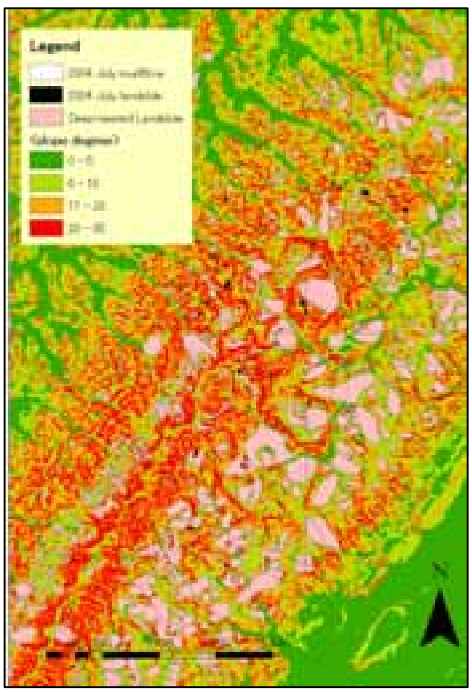


Fig. 3 Map showing the distribution of the 7.13 rainfall-induced landslides and deep-seated landslides showing the Landslide Database of NIED on GIS Slope map.

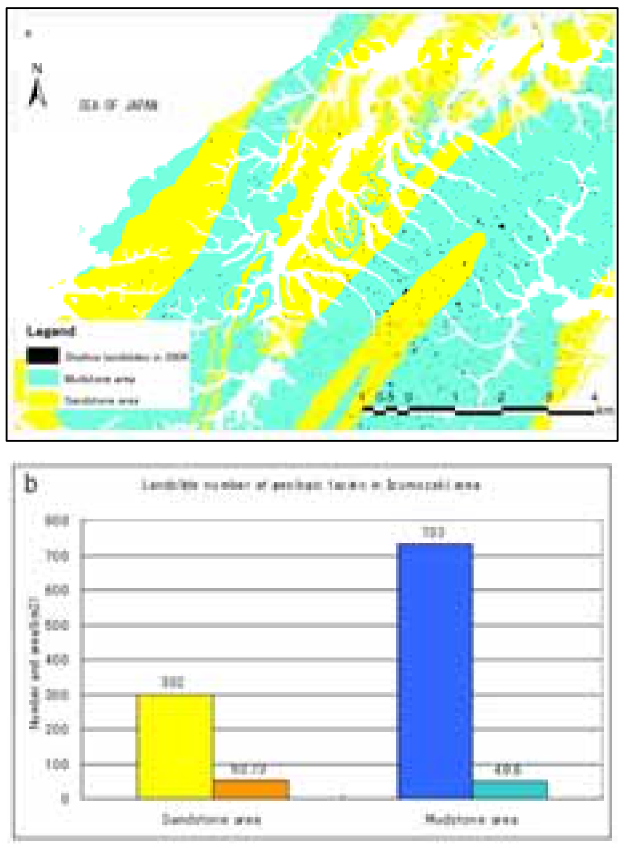


Fig. 4. a: July 13 landslide distribution on the outline geologic map, b: bar graph showing the landslide numbers in the sandstone and mudstone area (modified from Kobayashi et al., 1993, using GIS), and areas of the sandstone and mudstone.

used digital geologic maps of “Izumozaki” (Kobayashi et al., 1993), and “Sanjo” (Kobayashi et al., 2002) of 1: 50,000 in scale, and “Nagaoka” and “Ojiya” of 1: 50,000 in scale , respectively (Geological Survey of Japan, 2004). Further, we used the landslide distribution maps (1:50,000) of ”Nagaoka and “Takada” provide by National Research Institute for Earth Science and Disaster Prevention (NIED) which we did download from the website (http://www.bosai.go.jp/e/dosya.htm).

Mid Niigata Region is composed of hilly mountains of 200-600 m in elevation. On the whole, many straight ridges (for instances, Nishiyama hills in the west and Higashiyama hills in the east) are arranged in directions of NNE-SSW. These ridges are controlled by geological folds and faults in the same directions. Geological lithofacies are composed of Cenozoic mudstone and sandstones (Fig.4a) both of which make up relatively hard Teradomari Formation of Miocene in the lower, and soft mudstone and siltstones of Pliocene to Pleistocene. In addition, old deep-seated landslides are abundantly distributed in the gentle dipping stratum areas (Fig. 3). Relationship between the recent landslides and geology, has revealed that, in Izumozaki area, most of them are concentrated in steep slopes which are diagnostic of quadrangle-patterned drainage systems along the NNE-SSW trending ridges (Fig. 3). Most of the landslides are concentrated in the mudstone-rich zone rather than sandstone- rich zone in the Nishiyama hills (Izumozaki area; Fig. 4a, b) although the areas occupied by the sandstone and mudstone are nearly the same (Fig. 4b).

4. The 10.23 Intensive Earthquakes and landslides

In the evening on October 23th intensive earthquake mostly attacked the Yamokoshi area, and the hypocenter was located in 37^{o} 17’ 4” N in latitude, 138^{o} 52’2” E in longitude with a depth of 13 kilometers, and displayed the magnitude of 6.8 on the Richter Scale. In Kawaguchi town, south of Yamakoshi town, the earthquake marked seismic intensity of 7 of the Japanese Meteorological Agency scale, which is the maximum of this scale in Japan. The main shock was followed by a number of large aftershocks within two hours. The maximum acceleration exceeded 1000 gal, 7 km far from the epicenter. These earthquakes are related to geologic folds and faults in NNE-SSW directions, some of which are associated with active faulting and folding (Active Fault Research Center (AFRC) http://unit.aist.go.jp/actfault/english/activef.html,). AFRC reported that a new active fault appeared in the Tokamachi Town (AFRC, 2004) although there are many debates on this problem.

These main shocks and associated aftershocks triggered many landslides (Chigira and Miyagi, 2006) which are counted to be more than 4400 sites (Sekiguchi and Sato, 2006). They include variable type of landslides. Our aerial photograph interpretation and field researching have revealed that the landslides are classified into the following three types, 1)deep-seated landslides, 2)flow-type landslides, and 3)shallow-seated landslides (Yamagishi et al., 2005). The deep-seated landslides totally ten landslide dams particularly along the Imogawa River which run in the central part of the Yamakoshi Area (Fig. 5a).

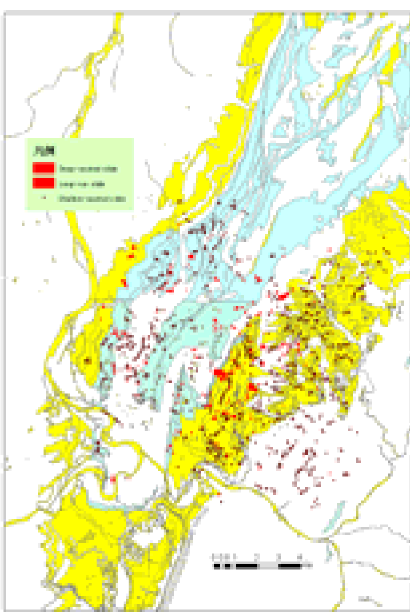


Fig. 5: Map showing the distribution of the landslides by the 10.23 earthquakes, mudstone-rich zone(Yamakoshi area)

5. GIS analyses of the distribution the landslides by the intensive earthquakes.

By the earthquakes, many landslides were induced (Fig.5), because the earthquake area are characteristic of variable slopes in the hills and mountains, and of many paddy fields and ponds.

GIS analyses have revealed that geologically most of the landslides took place in the sandstone-rich zone rather than mudstone-rich zones (Figs. 5, 6; Yamagishi et al., 2005), and that as shown in Fig. 7, relationship exists between the distribution of the landslides, and topographic and geological features of the Yamakoshi area. Namely, Fig. 7 map shows that most of the landslides are distributed more or less steep slopes, geomorphologically, but large-scale ones are concentrated in more gentle dipping strata area.

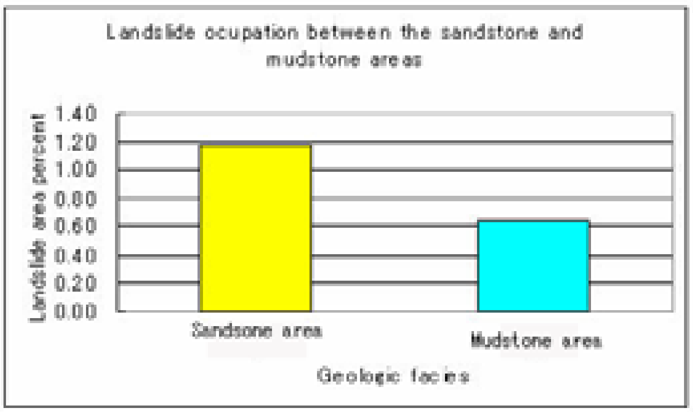
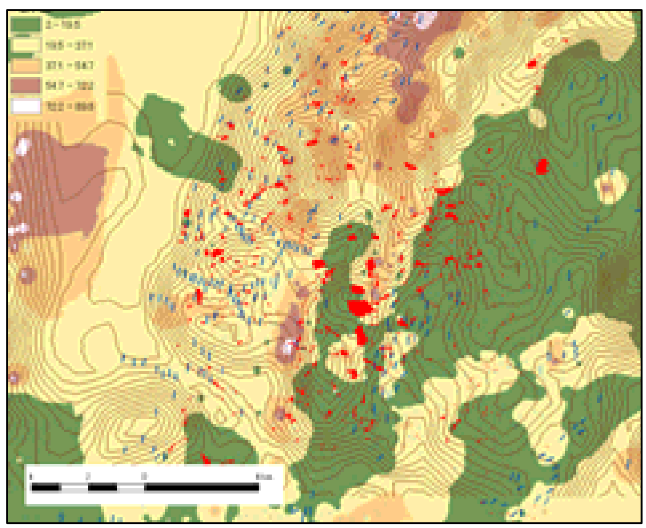


Fig.6: Bar graph of comparison in landslide occupation rate between sandstone area and mudstone area. This graph was made from Fig. 5 using GIS.

Fig.7 Using GIS map showing seismic landslide on the topographic contour line map and geologic stratum dipping contour map. Note that the digits are equal dipping zones.



6. Damage patterns of the patty fields by the10.23 landsliding

The Yamakoshi areas which was devastated by the earthquakes has been occupied by many paddy fields. Since 1970th most of the patty fields have been changed into ponds for feeding for ornamental carps. Therefore, many ponds are distributed in the areas, and

Fig. 8 Stereo-paired photograph showing cracking patterns due to the earthquake. Notice that one (a) is crossing the ponds and the other is arranged

in 2004 many ponds as well as the paddy fields were broken by the earthquakes as shown in Figs. 8 and 9. In particular, the cracking and landsliding of the ponds are believed to be accelerating the damages due to flowing by mixing with water. Therefore, in order to confirm it, we have been analyzing the landslides /cracking on the ponds/paddy fields. We classify the patty fields and ponds using DMC images taken by Asia Air Survey Co. Ltd. The criteria of the recognition are mostly shapes and coloring due to reflection patterns, and cracking and landsliding through the DMC images (25 cm resolution).

The cracking of the patty fields are showing variable patterns. One is crossing vertically or obliquely the elliptical or polygonal shape of the fields as shown in Fig. 8a and the other is arranged along the ponds and paddy fields (Fig. 8b). Most of them are regarded as tensional cracks due to gravitational slipping during the shaking. Some of the landslide did not moved long probably due to scarcity of water (Fig.8b). However, the other landslide moved long with fluidity due to much water mixing from ponds (Fig. 9).

Fig. 9 Flow-type landslides from the ponds probably due to mixing with much water from ponds.

7. Comparison between the two triggering landslides using GIS

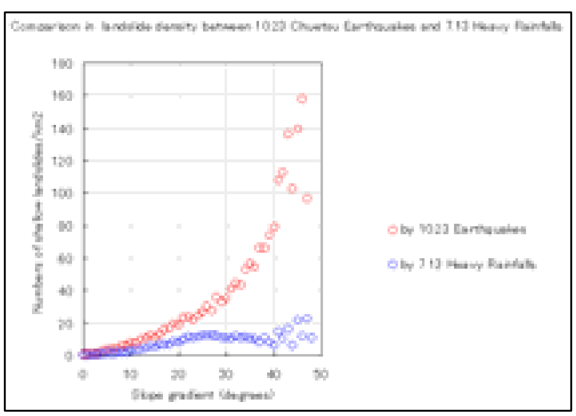


Fig. 10 Comparison in landslide density (landslide number /km^2) with the slope gradients between the 10.23 Earthquake landslides and 7.13 rainfall landslides.

We are discussing the comparison between the two events as the following ; 1) The 7.13 landslides do not necessarily coincide with the old deep-seated landslides provided from Web Site of NIED (http://www.bosai.go.jp/e/earth/earth.html). Most of the 7.13 landslides are small in scale and shallow-seating characteristics. They are distributed in steep slopes geomorphologically and in steep dipping areas of the strata of the sediments (Fig. 3). In addition, they are lithologically found in the mudstone-rich zone rather than sandstone-rich zone (Fig. 4a, b). 2) The distribution of the 10.23 landslides coincided with the old deep-seated

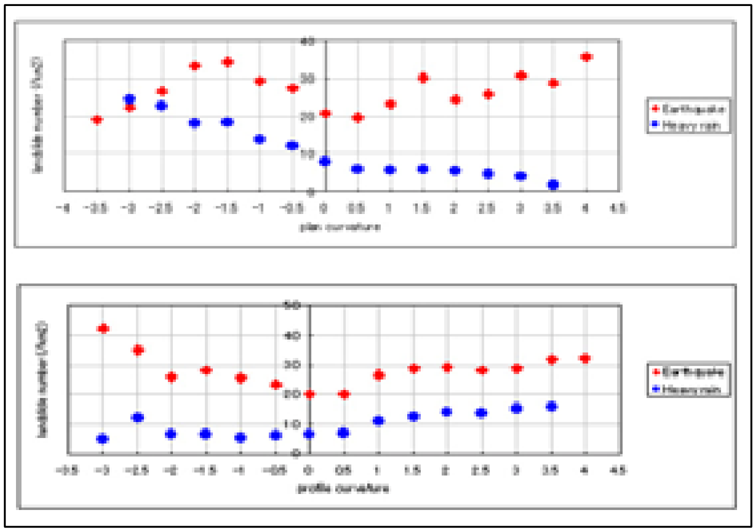


Fig. 11. Graphs showing the comparison in landslide numbers against curvatures between heavy rainfalls and intensive earthquake.

landslides shown by NIED. Most of the deep-seated earthquake-induced landslides are distributed in the gentle slope geomorphologically, and gentle dipping strata area geologically (Fig. 7). In addition, they are mostly distributed in the sandstone-rich zone rather than mudstone-rich zone (Figs. 5 and 6). However, most of the shallow-seated landslides are also the steep slopes (Fig. 7).

Finally, particularly on shallow-seated landslides, we have compared using GIS in the landslide density against slope gradients (Fig. 10) and relationship to curvatures between the two events (Fig.11). As the results, in case of the landslide density (numbers of the landslides/ km^2) of the 10.23 landslides, increases with the slope gradient, while, the density of the 7.13 landslides keep almost constant with the slope gradient (Fig. 10). The relationship of landslide density to slope curvatures has been revealed as that the density at any curvatures induced by the earthquakes, are larger that by the heavy rainfalls (Fig. 11).

Summary and Conclusion

In 2004, two big triggers brought about variable mass movements; one is heavy-rainfall landslides on July 13, 2004, most of which are shallow-seated, but some of which are deep-seated an associated with long-run mudflows. The other is intensive earthquake-induced landslides on October 23, 2004, which are classified into deep-seated landslides, flow-type landslides and shallow-seated landslides. We are compared in such landslide distribution related to geology and geomorphology between the two events using GIS.

As the results, we have revealed that the distribution of landslides caused by the different triggers depends on geologic lithology and slope gradients; the landslides by the heavy rainfalls are more concentrated in mudstone-rich zone rather than sandstone-rich zone particularly in Izumozaki area. On the other hand, those by the earthquakes are distributed in the sandstone-rich zone rather than mudstone-rich zone along Imogawa river in Yamakoshi area.

The most important factors affecting the both of the landslides are geomorphic slopes, and the shallow landslide density against slope gradients and curvatures are larger by the earthquakes than heavy rainfalls (Figs. 10 and 11).

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