TXT-tool 1.081-2.1 Landslide Mapping Through the Interpretation of Aerial Photographs

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Abstract

Topography created by landslides is widely distributed. Landslide risk evaluation is very important for mitigating or preventing these natural disasters, and finding facts can be very difficult. We here describe the techniques for aerial photo interpretation and explain the results. Sometimes, we "can't see the forest for the trees." This manual will clearly and practically explain the following: (1) why stereo pair interpretation is necessary; (2) how to perform stereo pair interpretation with aerial photos etc. to determine the landslide area; (3) what can be learned using this method of interpretation; (4) how landslide motion characteristics can be ascertained once interpretation of landslide micro-topography is performed; (5) once this is ascertained, how to rationalize landslide surveys and countermeasures.

Keywords

Landslide dynamics · Aerial photo interpretation · Micro topography Risk · Reactivation

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1 The Significance of Mapping Based on Photo Interpretation

First we wish to discuss the necessity of ascertaining landslide topography using stereo pair interpretation, such as aerial photo interpretation.

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Sometimes, it is said, we "can't see the forest for the trees". This proverb is applicable to landslides. For example, cut slopes frequently collapse when building roads. If one supervises in the field, the engineer is sure to see such accidents. In order to find countermeasures, we must first consider why such surface landslides occur.

By investigating the causes of surface landslides, we can also investigate the dynamic characteristics of rock. If it rained heavily before the surface landslide, we should also take an account into consideration. By resolving issues of material characteristics related to rock deformation, an understanding of dynamic characteristics can lead to solutions to problems. Taking rainfall into consideration can lead to a lower evaluation of a site's safety as a rise in pore water pressure can trigger landslides. Of course, such perspectives are necessary in responding to surface landslides on site. However, from the perspective of landslide topography mapping, it should be emphasized that it is necessary to rank the reasons why the surface landslide occurred where it dose on the road slope.

In many cases it is difficult to accurately ascertain the overall form of massive landslides from field observation alone. It is impossible to know if the surface landslide occurring before one's eyes the toe of a large-scale landslide, spreading out across a huge slope behind it, or a small phenomenon occurring only in that location. These small surface landslides also sometimes occur due to fissures caused by large landslides.

This manual will clearly and practically explain the following: (1) why stereo pair interpretation is necessary; (2) how to perform stereo pair interpretation with aerial photos etc. to determine the landslide area; (3) what can be learned using this method of interpretation; (4) how landslide motion characteristics can be ascertained by interpretation of landslide micro topography; (5) After it is ascertained, how to rationalize landslide surveys and countermeasures.

For those with no experience in stereo pair interpretation, the relevance of these tasks may be difficult to do. The ability to observe and analyze topography can be developed through adequate methods, but the study of civil engineering alone imparts only a mechanical understanding and material properties; normally it does not prompt one to question why failures occur where they do. This is analogous to bandaging a cut on an arm, without realizing that the arm is actually broken. However, although mapping of landslide topography can be performed by interpretation of aerial photos, the research on using it for risk evaluation is still very much work in progress. In other words, this method is not yet in some respects. Thus, the development of this risk evaluation method and its application suitable to regional characteristics are also goals of this research. Below, the significance and weaknesses of aerial photo interpretation will be listed (Fig. 1).

2 Why Is Stereo Pair Interpretation Necessary?

It is necessary to ascertain the actual shape of the landslide breakdown region. Landslides occur when the landslide block slides over a portion of slope bounded by a contact surface, called the slip surface, while this landslide block remains on the slope. This landslide block is referred to as the landslide body. Its size can vary from a few meters on the extremely small size, up to several kilometers.

Much research and many reports exist about the evaluation of landslide hazard potential. In general, such research combines data from detailed geological maps, land gradient, and estimated weight of rainfall, and focuses on areas where much of the information overlaps, to render evaluations such as "landslides probably have a high chance of occurring here." Needless to say, such analysis and evaluations are important. However, each landslide is unique. Put another way, the largest characteristic of the slope fluctuations referred to as landslides is that the area of deformation caused by the landslide is clearly distinguished from the surrounding, immobile area. This being the case, if we are

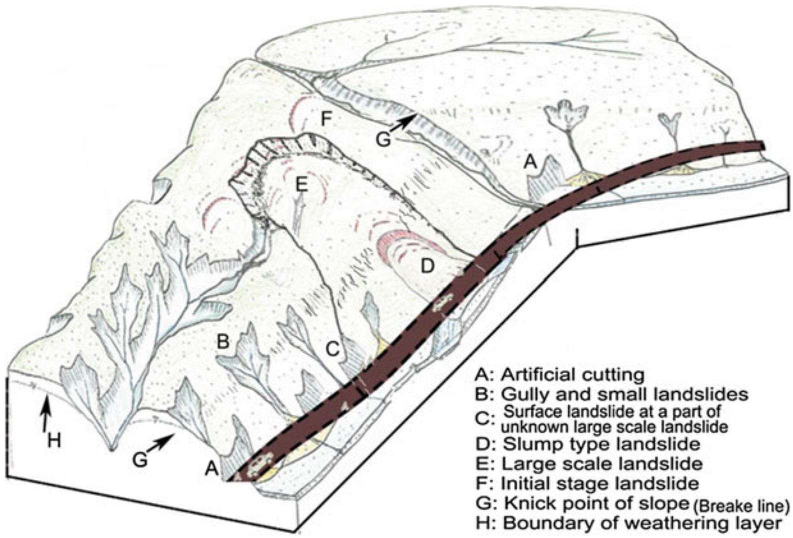

Fig. 1 Schematic illustration of the relationship between the trees (the surface landslide before one's eyes) and the forest (large-scale landslide, incorporating the surface landslides)

unable to determine the extent of the area deformed by the landslide, disaster countermeasures, and judgment of the probability of future disasters, will be impossible. Another characteristic of landslides is that even after the landslide has triggered fluctuations, the landslide body, causing failures within the landslide area, still remains, and has the potential to cause further failures. By ascertaining the actual shape of the landslide body, a host of disaster prevention measures, such as evaluations, countermeasures, and monitoring, can undertakes. Through photo interpretation, a distribution map of the landslide topography can be created, allowing the main scarp, which constitutes the actual shape of the generation area, to be realistically interpreted and illustrated. This in turn enables making contours of the landslide body, i.e. the area that broke free from the main scarp and moved, to be realistically illustrated, thus allowing to the determine the landslide topography.

Whole landslide topography cannot be ascertained from field investigation alone. The scale of landslide phenomena range from a few meters to several kilometers, and have drastic relief and depth. Thus, the visible phenomenon conceals the underlying phenomena. It is also usual for the cases in which we are unable to accurately ascertain the overall picture of the landslide fluctuation zone in the field, and for the positioning the phenomena which we are observing within the landslide overall. Before heading to the field, it is advisable to get a whole picture of the landslide from the air, and objectively ascertain the characteristics of its topography using vertical, somehow exaggerated, and relief images. Ascertaining the landslide's actual shape using photographic interpretation, and considering what part of the whole landslide the site constitutes, will lead to a rational understanding of it.

Ascertaining the micro topography of the landslide generation area: lead to performing risk evaluation of landslide topography using AHP (Analytic Hierarchy Process (Saaty 1980)), and to distinguishing from the non-landslide area. By ascertaining micro characteristics of the landslide area, indicators of the mode of movement, extent of crushing, and localized atypical deformation, can be discerned. Understanding the landslide's minor structures requires the use of high resolution data such as photos, and precise interpretation by an experienced technician.

3 Difficulties with Direct Sensing of Images and Their Solutions

Difficulty in confirming the landslide area: In surfaces covered with vegetation, such as tall trees, it will be difficult to confirm the area of landslide topography and micro-topography. If vegetation is scant or devastated, interpretation of the topography will be simple. On the other hand, if the surface is densely covered with a forest of tall trees, such as a tropical rain forest, interpretation will be difficult. This point is likely to be reviewed during the current Vietnam project.

Difficulty in understanding topography due to artificial land deformation: Landslide-prone areas tend to have abundant water, and often minor flatlands. Since such land is often used for habitation and agriculture, it tends to be subject to artificial land deformation. Artificial land deformation often produces topography similar to landslide micro topography. Therefore, caution is required (Fig. 2).

Difficulty in understanding landslide topography due to the motion characteristics of the landslide itself: depending on the characteristics of the rock and style of failure, a clear range of movement and main scarp might not be formed. When landslides occur particularly in schist regions of Japan, the entire slope often moves, therefore no clear landslide topography is established.

4 How Is Stereo Pair Interpretation of Aerial Photos for Determining the Landslide Area?

Taking aerial photographs: A camera is brought on board an aircraft, and consecutive elevated vertical photographs are taken. About 60% of the consecutive photographs should overlap. These

Fig. 2 Aerial photo interpretation performed using aerial photographs with a stereoscope of mirror type, using simple stereoscope, topography map, geological map, writing materials etc. The series of aerial photographs should be arranged as shown above, and examined from directly above. The gap between photos differs depending on the person; appropriate adjusting the image by moving the photos while a time leads to clearly seeing

overlapping portions will be used for suitable views. In a pair of two images, the images should be taken from slightly different perspectives; they should not be exactly the same. The difference in viewing angle between the two photos is what enables stereoscopic interpretation. The aerial photographs can be taken on roll negative film of 20 cm or 24 cm width, or with a digital camera. Due to the nature of cameras, which use central projection, because the image will be distorted around the edge. However, despite this distortion, interpretation can be performed adequately.

On the other hand, ortho images are central projection images to which processing has been applied to remove the distortions, recreating them as orthogonal projections. Consequently, they do not appear stereoscopic, even if two side-by-side orthogonal projection photographs are arranged and observed.

5 What Can Be Learned Through Aerial Photo Interpretation?

(1) A whole picture of the land can be observed. The images capture the whole land conditions at the time the aerial photograph was taken. You can observe land utility, the survey route, and of course the object of interpretation.

(2) Landform classification, land cover classification, and vegetation classification can be determined. This will be explained later, but land comprises a combination of the surface and the break line of the slope profile. Such topography is most easily observed in aerial photo interpretation.

(3) The area of land deformed by the landslide can be clearly observed. The main scarp as well as the landslide body can be ascertained by clearly determining the contours of the landslide topography. If this is unclear, it suggests that the landslide is inactive or suspended.

(4) Interpretation enables topography mapping. A landslide distribution map can be completed by transcribing the interpreted information into a topography map.

Moreover, you can estimate

(5) how landslide motion characteristics can be ascertained by that interpretation of landslide micro-topography is performed, and

(6) how to rationalize landslide surveys and countermeasures.

6 Examples of Landslide Topography and Distribution Maps

See Figs. 3, 4, 5, 6, 7, 8 and 9.

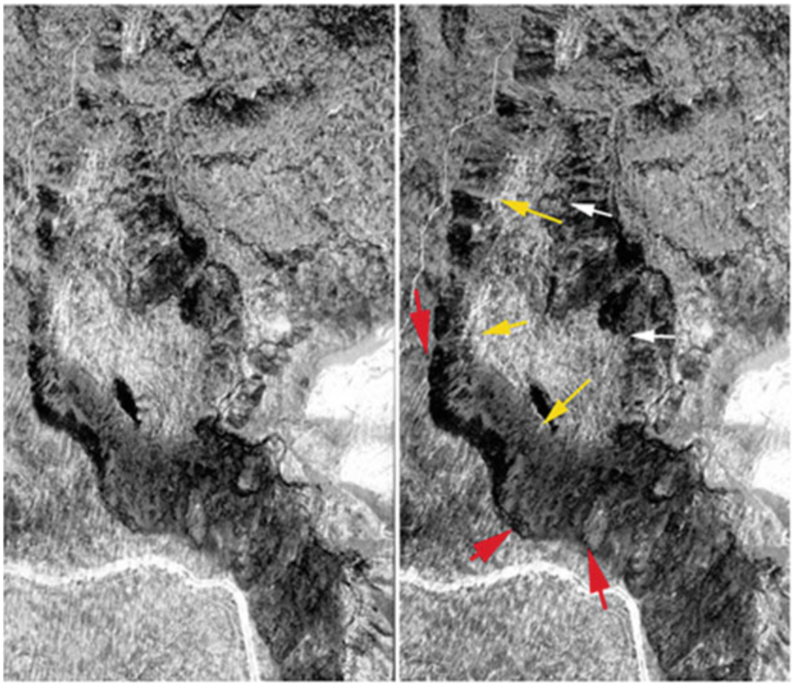

Fig. 3 An example of the appearance of a large-scale landslide topography by stereo pair aerial photographs. This is a typical large-scale block slump landslide (300 by 600 m and the AHP score: 85). *Red* main scarp; *yellow* boundary area of landslide body between main scarp (gentle slope created by talus accumulation is almost invisible), tip of landslide body (numerous small-scale surface landslides occurring) (Miyagi et al. 2004)

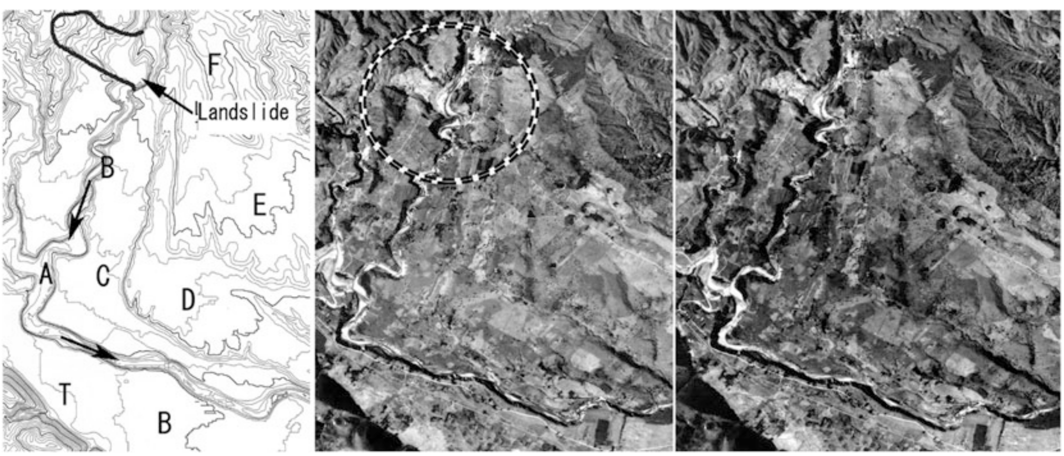

Fig. 4 Example of stereo pair image and the topo map (*left*). *A* river, *B–F* river terraces, *T* alluvial cone. A landslide is visible at the *upper part*. The landslide cut the river terraces (Miyagi et al. 2004)

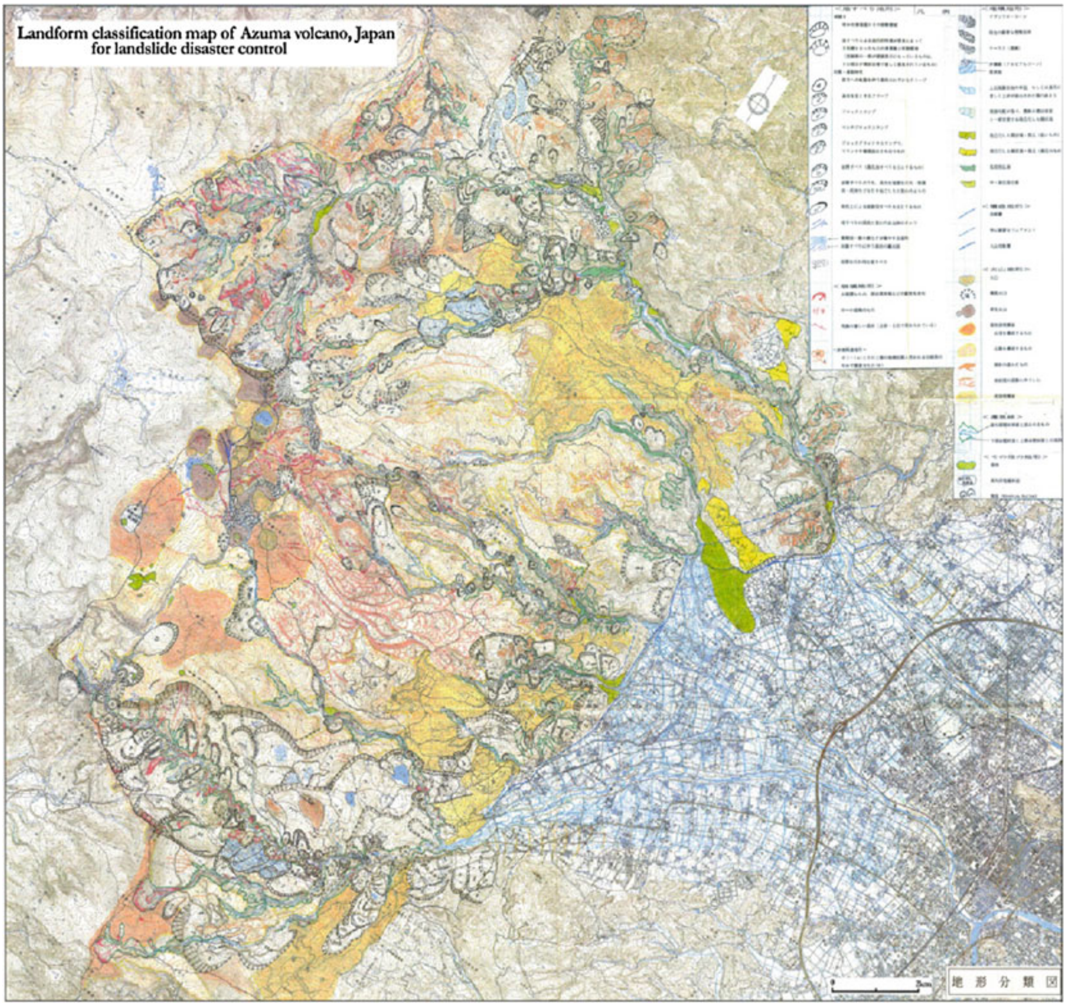

Fig. 5 Azuma volcanic region landform classification map (*top*) rendered as a 1:25,000 scale topography map. It depicts the landslide topography (the type of movement is also classified), volcanic slope, accumulation topography of the mountain foot, and a convex break line (corrosion line), allowing estimation of the landslide topography distribution, as well as the relationship between the landslide area and volcanic slope, and potential sediment yield per watershed. Aerial photograph: 1:20,000 scale monochrome adhesive photo (drawn by T. Miyagi)

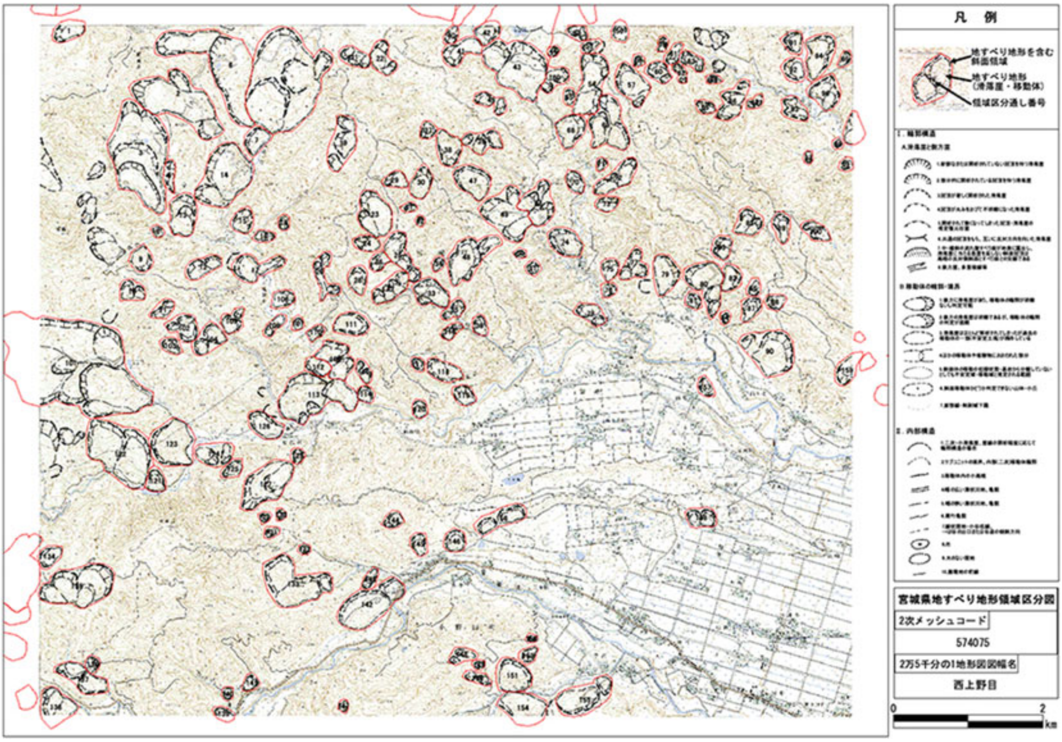

Fig. 6 Landslide topography distribution map (created at the request of the Japan Landslide Society). Depicts landslide topography derived from aerial photo interpretation in a 1:25,000 scale topography map. Here, maps are annotated as per the legend on the right. The minimum landslide fluctuation range has been determined, and the main scarp is indicated by *heavy lines* and *hatch marks*. The actual shape of the landslide body is indicated with *thin lines*. If large-scale internal structures, on a scale that permits interpretation, and if the landslide body are confirmed, these too are noted. The main scarp and its surroundings, the height difference at the top part of the slope, and fissures, probably suggest instability. They are noted with extreme caution. The aerial photographs used were 1:20,000 scale monochrome adhesive photos from the Nishikaminome region of northwestern Miyagi Prefecture. Each landslide topography map is assigned an ID number linked to relevant information (Japan Landslide Society and Miyagi Prefectural Office 2002). The creation of this distribution data began in the 1980s, and comprises a 1:50,000 scale map of recent information covering all of Japan (NIED 2015)

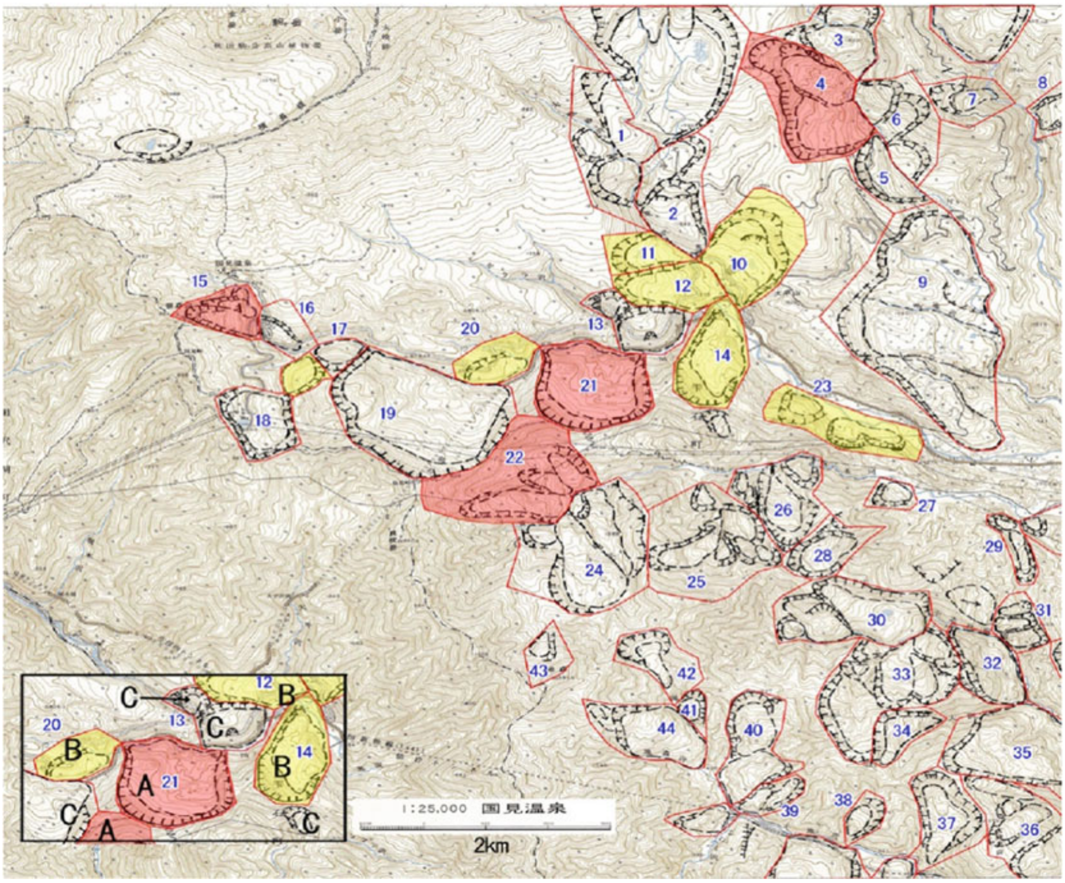

Fig. 7 Landslide topography distribution and risk level chart (stereo pair interpretation) was performed on the distribution map from Fig. 5 and the images recorded in the interpretation evaluation chart; landslide risk was evaluated using AHP. Hamasaki provides an explanation of this. The evaluation points obtained through interpretation do not constitute a rigorous scale (e.g., there is not a significant difference between a score of 60 and 65), and are divided into three general ranks. *A-rank areas*, which have an AHP score of 80 or higher, if synthesized with AHP evaluations in actual disaster countermeasure case studies, can be judged to be essentially active. *B-rank areas* have a score of 60 or higher; caution is necessary when surveying them. *C-rank areas* have been judged to be essentially unmoving, but caution is necessary as the landslide body itself has sustained damage from the landslide, and actions such as tearing might lower the landslide body's stability. Evaluation of this is done using aerial photo interpretation alone; use of estimated values is legitimate. It is very useful as a draft map for various plans, and is the basis for assigning priority to the implementation of field surveys (Miyagi et al. 2004)

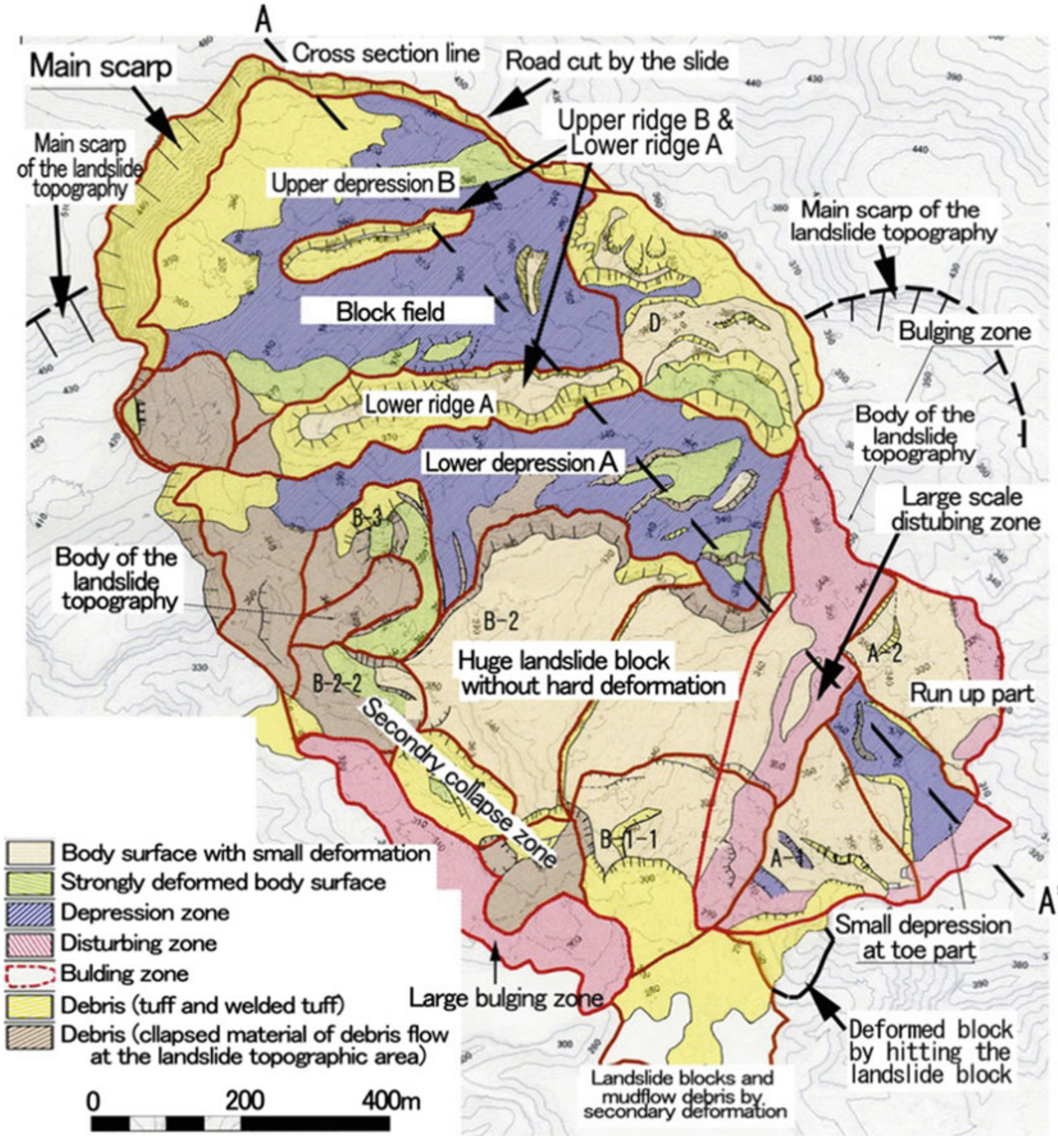

Fig. 8 Micro-topography landform classification map showing the internal state of the landslide topography. Land deformation caused by landslide action creates new micro-topographies. These or their adjacent topographies move together, giving rise to the possibility of new fluctuations. Aerial photograph scale: 1:8000, real color photograph (Miyagi et al. 2011)

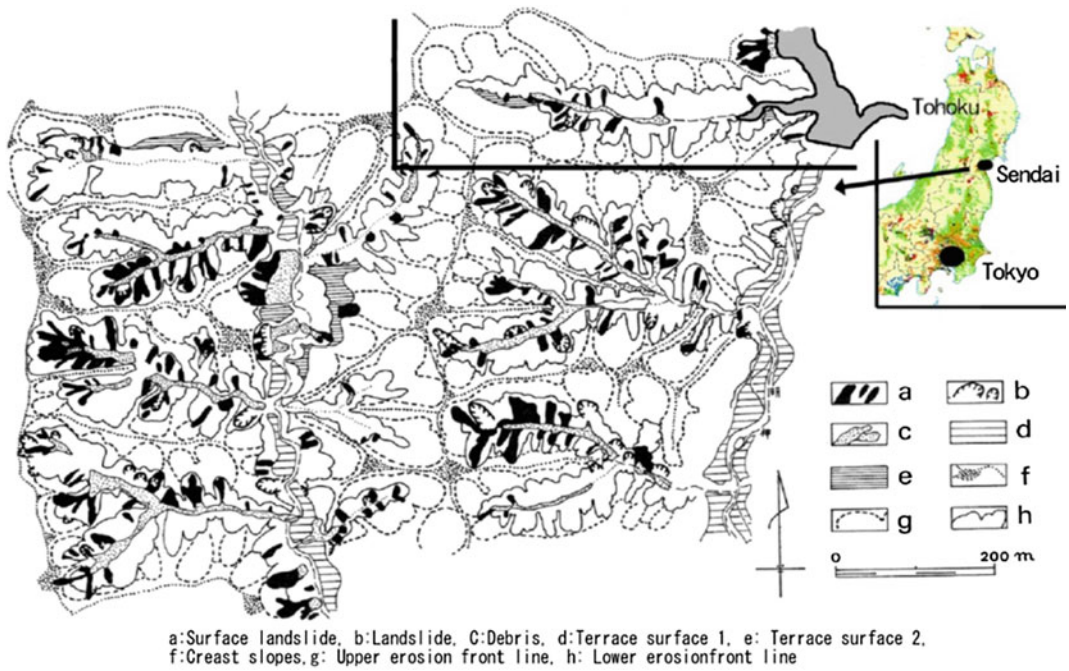

Fig. 9 Distribution map showing small-scale surface failures occurring in dissected valleys on hilly terrain, and distribution and convex break lines (corrosion line) of superficial landslides. Aerial photograph scale (1:10,000 adhesive); 91% of topographical sites of landslide occurrence were near the lower convex break line (Miyagi et al. 2004)

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