

# DIGITAL TERRAIN ANALYSIS USING AIRBORNE LASER SCANNER (LIDAR) DATA FOR NATURAL HAZARD ASSESSMENT

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## ABSTRACT:

The airborne laser scanner (LiDAR) adopted recently permits creation of a more high resolution digital elevation model (DEM). Since the airborne laser scanner can measure the elevation under vegetation, the topographic information is more detailed than the information obtained from maps drawn by aerial survey mapping. We have developed a new method of representation to permit topographic reading. The ELSAMAP (Elevation and Slope Angle Map) is a new topographic analysis method developed by our company to permit easy understanding of topography. The ELSAMAP is drawn by transmission synthesis of the “elevation information” represented by color phase and the “slope information” represented by gray scale images. It permits intuitive and correct understanding of the relative positions and the scale of the topography, offering an effective terrain representation tool that will support topographic readers. Topographic analysis using a high resolution DEM obtained by an airborne laser scanner permits creation of a more detailed topography classification map, as well numerical simulation. Quantitative estimation of topographical change by repeated measurement using an airborne laser scanner is also possible. Since examination of wide-ranging hazard only by ground survey is inefficient, the qualitative and quantitative survey by an airborne laser scanner will be efficient in terms of cost-benefit performance as well.

## 1. INTRODUCTION

Topographic map reading and stereoscopic vision of aerial photographs have been used for topographic survey for assessment of natural hazard. However, topographic maps drawn by aerial survey mapping do not always represent the topography in detail occasionally. Meanwhile, aerial photographs do not allow easy reading of the topography occasionally because of vegetation, buildings, and other obstacles.

An airborne laser scanner adopted recently permits creation of a more high resolution digital elevation model (hereinafter referred to as a “DEM”). Since the airborne laser scanner can measure the elevation under vegetation, the topographic information is more detailed than the information obtained from maps drawn by aerial survey mapping. Therefore, more detailed topographic reading and natural hazard assessment are expected.

This paper introduces some examples of the use of an airborne laser scanner for natural hazard assessment.

## 2. FEATURES OF AIRBORNE LASER SCANNER

The land is divided into 50 m meshes throughout Japan, and analysis of topography in 50 m-mesh or smaller patterns is impossible. An airborne laser scanner can make a DEM with mesh intervals of several meters, which is close to the actual

topography. The comparison of the two will easily show the difference in the fine topography of mountainous regions, terraces, and low lands, as well as in the way of representing artificial structures (roads and embankments) (Figure 1).

The DEM made by an airborne laser scanner excels in the following points:

- The density of measurement points is high and fine topography is represented well.
- The topographical shape under vegetation is measured directly.
- The data is two-dimensionally uniform.
- The resolution is high and the topography can be reproduced on a personal computer as well.

Furthermore, digital topographic analysis using a DEM has the following merits when understanding the topography.

- Both persons with and without expertise can have identical recognition.
- In addition to the contour information, detailed topographic feature quantity data is obtainable.

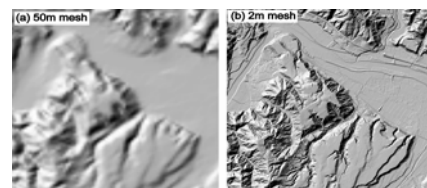


Figure 1. Comparison of DEM

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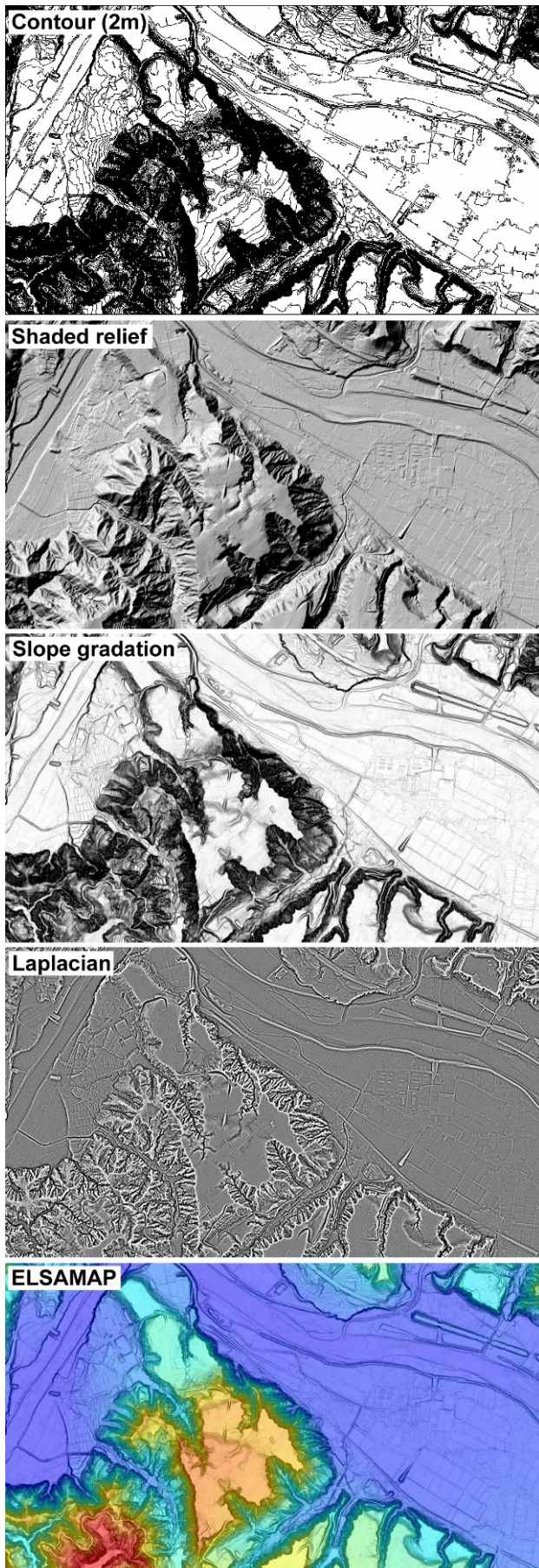


Figure 2. Comparison of various terrain representation methods

### 3. TERRAIN REPRESENTATION METHOD USING AIRBORNE LASER SCANNER DEM

#### 3.1 Conventional terrain representation method

Topographic reading with a DEM requires visualization of data. The following maps were drawn based on a DEM drawn by using an airborne laser scanner DEM: Contour map, shaded relief map, slope gradation map, laplacian (Figure 2).

Contour maps and shaded relief map are the most common maps. When the slope is gentle, the intervals of contour lines are large, and the fine topography will not be represented. The shaded relief map will not represent the topography of the shaded part. Therefore, we have developed a new method of representation to permit topographic reading.

#### 3.2 New terrain representation method (ELSAMAP)

The ELSAMAP (Elevation and Slope Angle Map) is a new topographic analysis method developed by our company to permit easy understanding of topography. The ELSAMAP is drawn by transmission synthesis of the “elevation information” represented by color phase and the “slope information” represented by gray scale images (Figure 3). It permits intuitive and correct understanding of the relative positions and the scale of the topography, offering an effective terrain representation tool that will support topographic readers.

For example, the steep slope of a valley is represented by a dark image, while the gentle slope is represented by a bright image. When the elevation information is added to such slope information, the ridge and valley will not be reversed, permitting easy topographic reading. Furthermore, the visual highlighting of the topography can be changed according to the purpose by adjusting the elevation indicating colors and the shading of the slope according to the elevation zone and the range of slope.

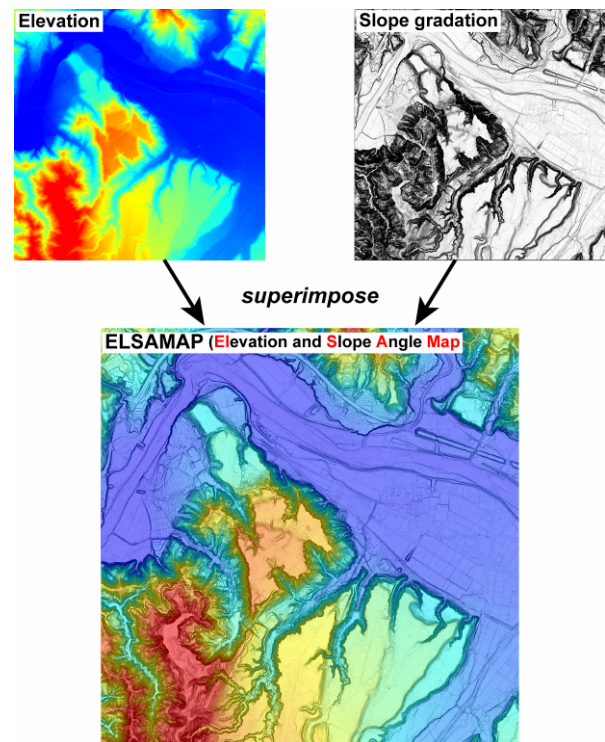


Figure 3. Outline of ELSAMAP

#### 4. TOPOGRAPHIC READING WITH AIRBORNE LASER SCANNER DEM

##### 4.1 Low land and terrace

When a contour map is used for topographic classification of low land, terrace surfaces, microtopography of low land, and other fine ups and downs cannot be represented, because the information about the space between contour lines is missing. Meanwhile, the ELSAMAP permits easy recognition of terrace cliffs, terrace plains, natural levees, meander scars, and other types of topography. Adjustment of elevation indicating colors, while attention is being paid to the fine topography of low land, will permit simplified flood assessment (Figure 4).

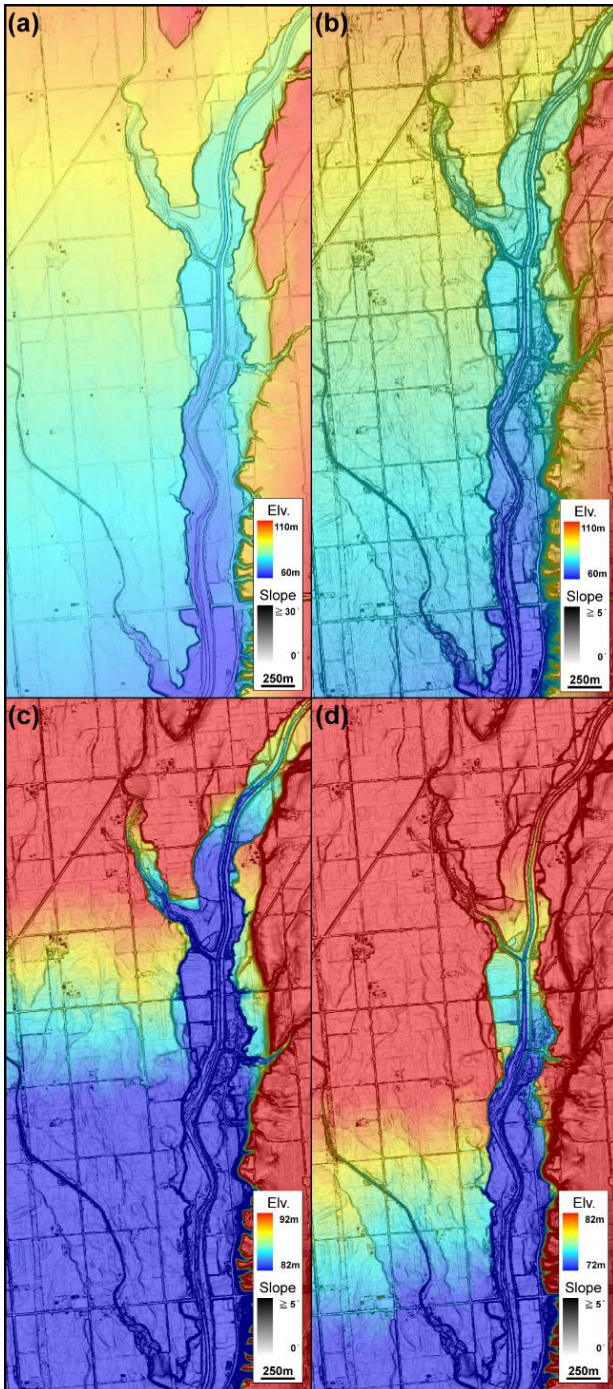


Figure 4. ELSAMAP of shihoro river, Hokkaido, Japan

##### 4.2 Mountainous region

A contour map of a mountainous region drawn by using an airborne laser scanner DEM represents the topography under vegetation, permitting more detailed map reading than a topographic map drawn by aerial survey mapping. The ELSAMAP that highlights break of slopes permit easy reading of the erosion front, collapsed topography, landslide topography (slip scarp, slide block, etc.), alluvial cone, and other types of topography (Figure 5).

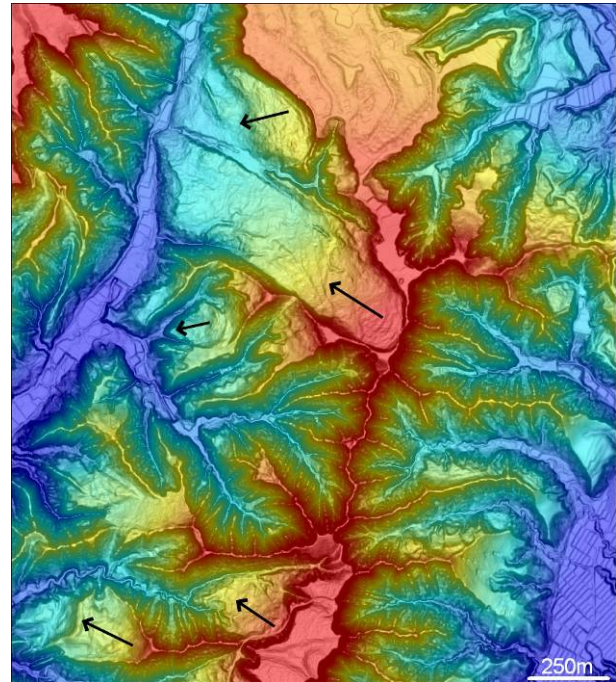


Figure 5. Landslide topography of Chuetsu-district in Niigata

##### 4.3 Active fault in urban area

Active faults in urban areas in general do not clearly show the fault topography because of the influence of the artificial topographical change. Therefore, reading of aerial photographs and the ordinary terrain representation method will hardly permit extraction of the tectonic landform. However, a shaded-relief map that highlights the direction of elevation sometimes permits representation of flexure scarp with a long wavelength and small amplitude (Figure 6).

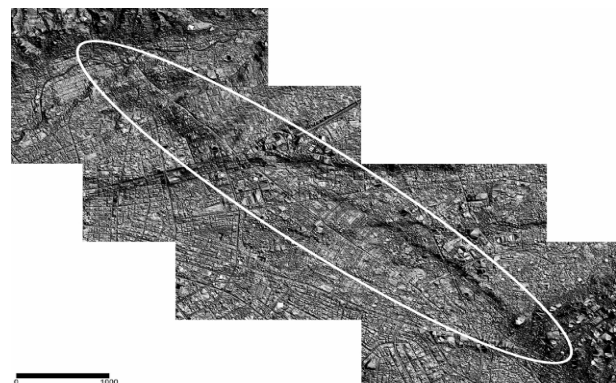


Figure 6. Flexure scarp of active fault passing through urban area

## 5. UTILIZATION AS THREE-DIMENSIONAL DATA

Chapter 4 introduced some examples of topographical reading that is qualitative assessment. This chapter introduces some examples of quantitative assessment (numerical analysis).

### 5.1 Utilization of data collected through multiple periods

Accumulation of airborne laser scanner data collected through multiple periods will permit understanding of topographical change. When a heavy rain or an earthquake collapses the land, a difference map of DEMs before and after the collapse will permit extraction of the location of collapse and the collapse volume.

Figure 7 shows an example of the understanding the change in the channel bed using the airborne laser scanner DEMs before and after a flood. The quantity of change in the channel bed was calculated by the difference using the airborne laser scanner DEMs obtained in August before the flood and in November after the flood. Use of an airborne laser scanner permits understanding of the two-dimensional change in quantity, and comparison with the quantity of change found by the conventional cross-sectional surveying will permit acquisition of a higher-accuracy value. Furthermore, periodical data collection will permit interannual understanding of the change in sand-banks and scoured places, as well as detailed confirmation of channel bed situation.

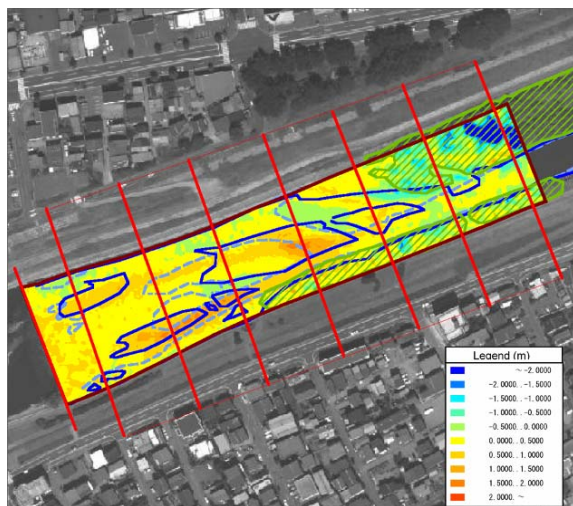


Figure 7. Quantity of change in channel bed due to flooding

### 5.2 Utilization for numerical analysis

The number of cases where data in meshes of less than several meters are used for numerical simulation of floods and debris flow is increasing recently, and calculation that takes into consideration the embankments and sediment control dams is possible (Figure 8). In the example of simulation of flooding due to debris flow, for which an airborne laser scanner DEM is used, fine topography is faithfully reproduced, representing the way the flood flows down along roads and depressions. For confirmation of the effect of sediment control dams and embankments, it is possible to run a simulation using a high resolution DEM prepared in accordance with the scale of the sabo facilities.

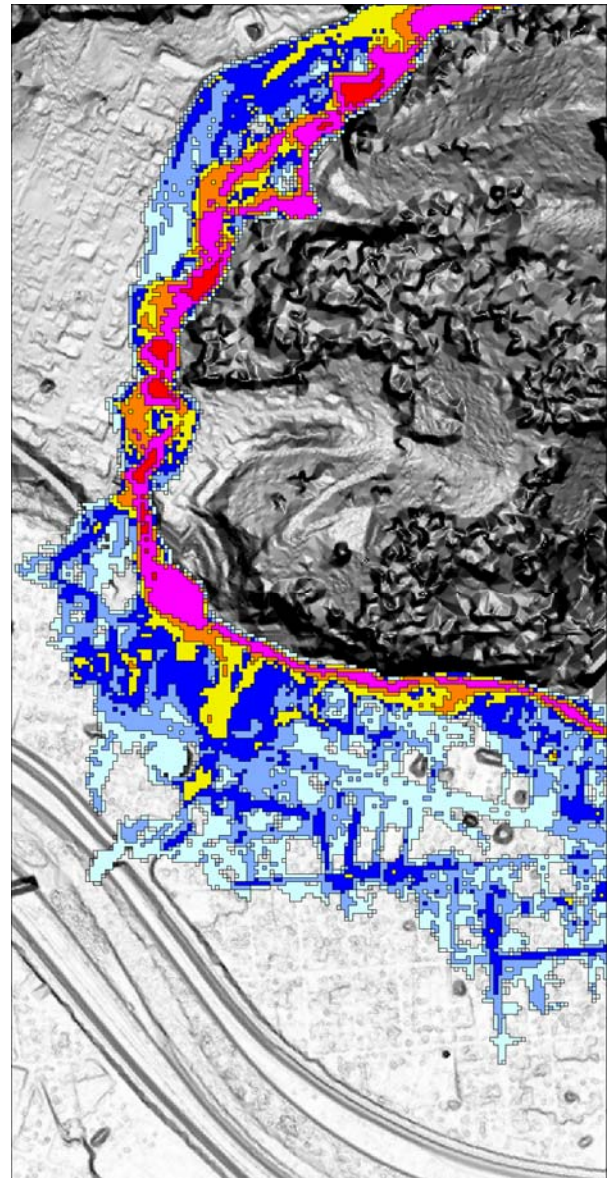


Figure 8. Result of numerical simulation of debris flow

## 6. CONCLUSION

Topographic analysis using a high resolution DEM obtained by an airborne laser scanner permits creation of a more detailed topography classification map, as well numerical simulation. Quantitative estimation of topographical change by repeated measurement using an airborne laser scanner is also possible. Since examination of wide-ranging hazard only by ground survey is inefficient, the qualitative and quantitative survey by an airborne laser scanner will be efficient in terms of cost-benefit performance as well. Especially the detailed topographic classification using an ELSAMAP is considered to provide important information for assessment of natural hazard.

## REFERENCES

Sasaki, H. and Mukoyama, S., 2007. The Development of ELSAMAP (Elevation and Slope Angle Map) for Geographical Features Interpretation. *APA*, 93, pp.8-16.