

STUDY ON MICRO-SCALE LANDFORM ANALYZING METHOD BY USING LARGE-SCALE DEM DERIVED FROM AIRBORNE LIDAR DATA

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ABSTRACT:

This study proposed a method for micro-scale landform analysis using large-scale digital terrain model (DEM), which was derived from airborne LIDAR data. Other than common topography and watershed analysis using DEM, new method of cross-section curve analysis was developed and tested in this study, which aims to extract convex break and concave break points on the surface of large-scale of DEM. With extracted convex slope break lines and concave slope break lines, micro-scale landform units of study area, including crest slope, the upper side-slope, lower side-slope, head hollow, foot slope and channel-way, etc., were identified and classified successfully, which proved adaptation of the proposed method for micro-scale landform analysis over a large extent.

1. INTRODUCTION

In the field of nature regeneration research, analysis on the relations among various geographical factors and local environmental factors is important. Up to now, in the field of micro-scale landform research, field survey and measurement method have been used to classify and identify micro-scale landform units (Ronald.Z 1965, Tamura 1969). Due to the lack of the large scale DEM, very limited achievements have been made in the quantitative and automatic analysis in this field.

As new technique of remote sensing, the airborne laser imaging detection and ranging (LIDAR) technology provides a revolutionizing way to acquire large-scale DEM by allowing rapid and inexpensive measurements of topography over a large area (Sato, H.P2002, Mckean.J.,2004, Mio.KASAI, Fan 2010).

In this study, with aim of developing automatic interpretation model for the mountainous area, quantitative analysis method of micro-scale landform identification was discussed, which used large-scale DEM data divided from airborne LIDAR data.

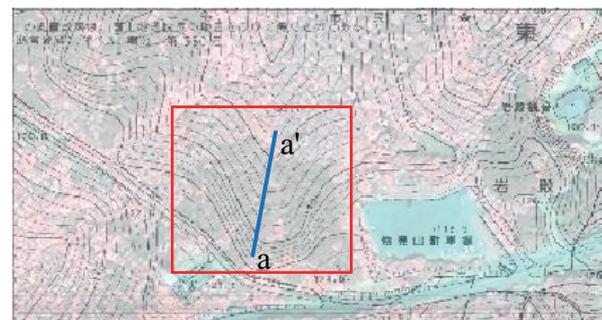
2. STUDY AREA AND DATA

2.1 STUDY AREA

This paper's study area is located in undulating hill (HIKI Hill) covered by second-growth forest, which is mainly composed of *Quercus serrata* (deciduous broad-leaf), *Pinus densiflora* (conifer). Within the study area, terrain slope varies between 0~60 degrees, with elevation variation up to 75.51 meters. In this study, watershed area was selected as test site, which is shown in Figure 1.

2.2 LIDAR DATA

The LIDAR data of study area was collected by an airborne LIDAR mapping system mounted to a Cessna 404 aircraft at December 25, 2006. Collected LIDAR data includes two returns for each laser pulse, which were assigned with name of "first pulse" and "last pulse" according to reception sequence. Each measurement contains attributes of its 3D location (x, y, z). Sample of LIDAR data is shown in Figure 2.



* Composition of Terrain Map and IKONOS colour Image
Legend Study area Cross-section line

Figure 1. Overview of study area (Iwadono Forest Park, Higashi-matsuyama City, Saitama Pref.)

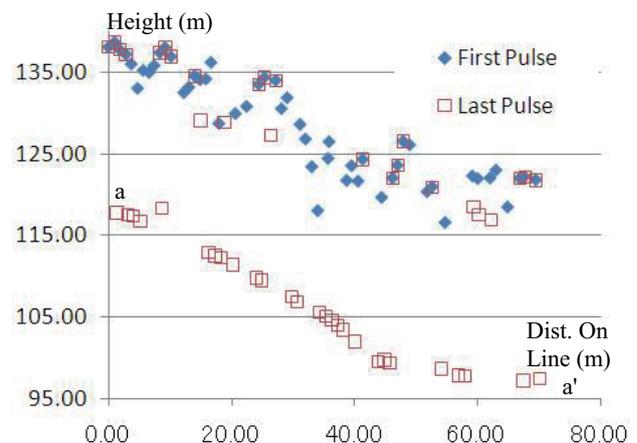
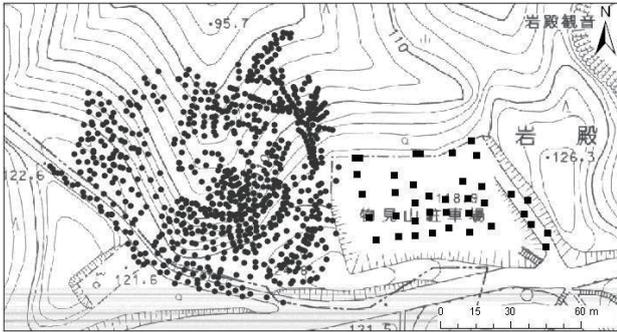


Figure2. Cross-section sample of LIDAR data

2.3 TS measurement

In this study, total station (TS) was used to collect reference data for assessing the accuracy of the LIDAR-derived DEM. Collected terrain survey data (587 points) is shown in Figure 3.



● TS points (within woods) ■ TS points (within park)

Figure 3. Distribution of TS measurements

2.4 DEM derived from LIDAR data

By using TS measurement (587 points) as reference data, (altitude) error of DEM (grid size = 1m), which was generated from LIDAR data, was summarized. The error histogram is shown in Figure 9.

With RMSE(Z) of 0.413m and STD(Z) of 0.396m, derived DEM can meet the requirements of national cartography standard on large-scale terrain mapping. For example, the national standard for terrain map with scale of 1/2500 is $STD_z \in [-0.66m, 0.66m]$, which means that it is possible to generate DEM with large scale (up to 1/2500) by using airborne LIDAR data. And such large-scale DEM can meet requirements for micro-scale landform analysis.

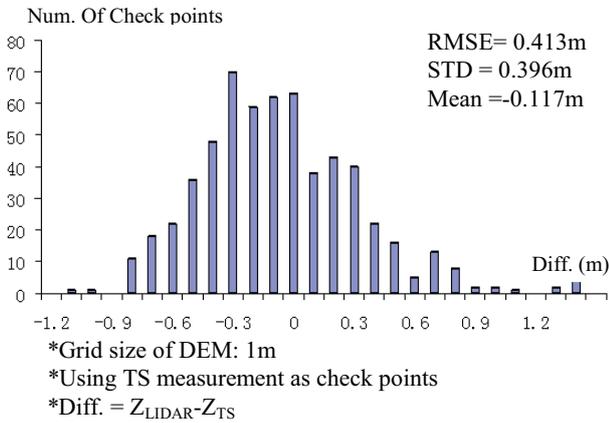


Figure 4. Error Histogram of DEM

3. METHOD OF MICRO-SCALE LANDFORM ANALYSIS

Flow-chart of micro-scale landform analysis using DEM is shown in Figure 5. Key procedures of data processing are as follows.

- (1) Generation of intersection curves of terrain elements, which include elevation, slope angle and moving-slope-difference (MSD, discussed in more detail later in this paper).
- (2) Detection of topographic changing points.

- (3) Identification of micro-scale landform.

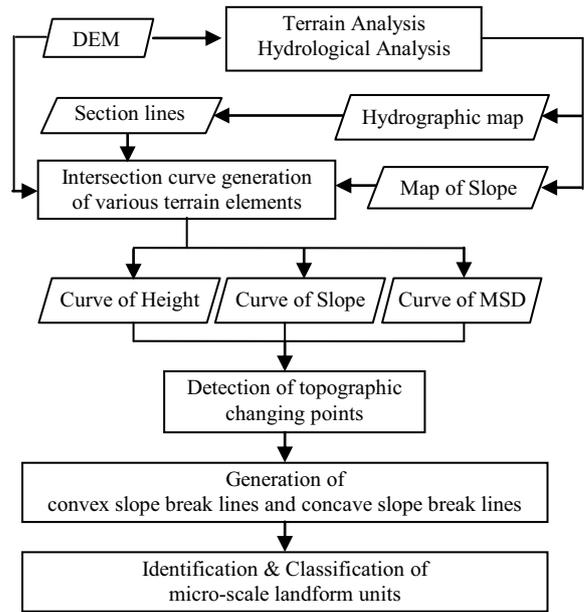


Figure 5. Flow-chart of data processing

The details of the main processing steps shown in Figure 5 are described as follows.

3.1 Generation of section lines

Firstly, by utilizing GIS software’s hydrological analysis function, channel ways within target area were generated. Secondly, radial section lines were drawn with channel ways as central lines (see Figure 6), with the range from the bottom of the valley to the ridge.

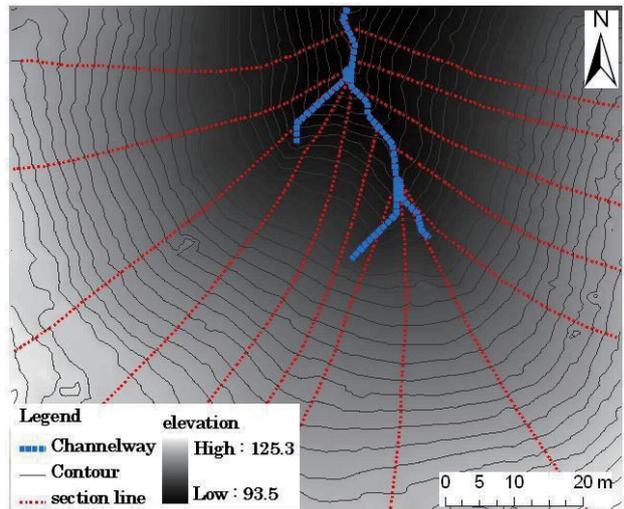
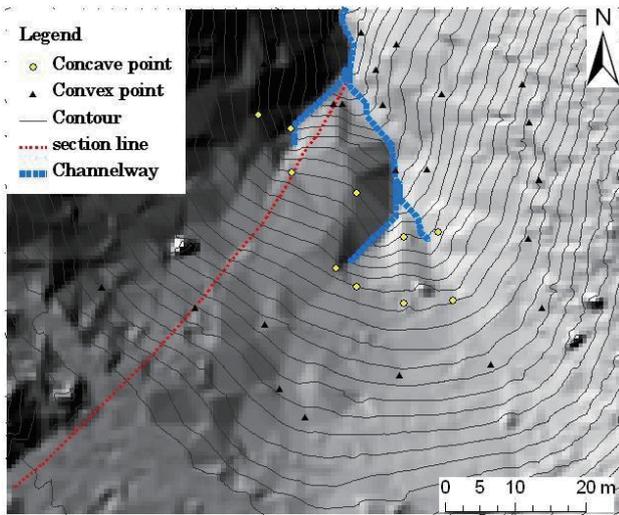


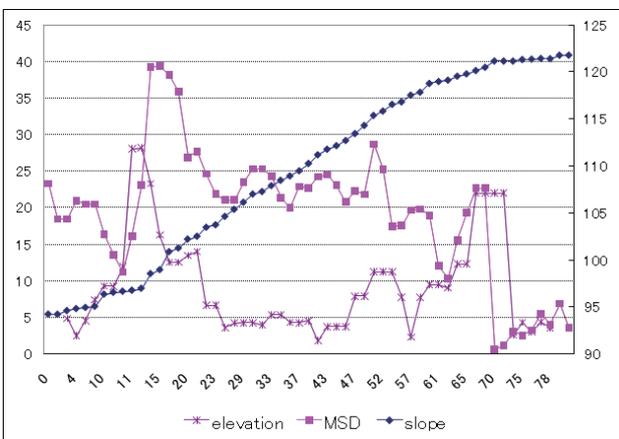
Figure 6. Section lines along slope’s inclining direction

3.2 Intersection curves of terrain elements

As shown in Figure 7, intersection lines of various terrain elements, which include elevations, slopes and MSD, were derived along the above defined section lines upon terrain surface.



(a) Section line



(b) Intersection curves along section line

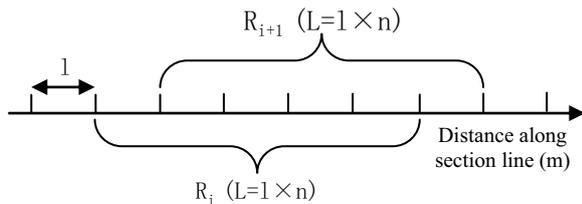
Figure 7. Intersection lines of elevation, slope and MSD

Concerning the definition of “moving-slope-difference (MSD)”, description on this terrain parameter is as follows.

MSD is calculated as the difference between maximum slope and minimum slope within certain range along section line. Formula of MSD is as below.

$$D_{R_i} = \text{Max}(S_{R_i}) - \text{Min}(S_{R_i}) \quad (1)$$

Range R_i in above formula is defined in Figure 8. In each range, $\text{Max}(S_{R_i})$ and $\text{Min}(S_{R_i})$, which stand for maximum and minimum slope within range R_i respectively, are derived for calculating D_{R_i} , the maximum difference of slope within range R_i . sample of derived MSD curve is shown In Figure 7.



* Length of range (L): 3-6 meters

Figure 8. Definition of moving range along section line

3.3 Detection of topographic changing point

In this study, as a key step toward micro-scale landform classification, topographic changing points along each section line, which include convex points and concave points, were identified by referring to intersection curves of previously defined terrain elements (including elevation, slope and MSD, see Figure 7).

The convex points are the locations between the mountain ridge and the mountain root, where slope changes remarkably. On the other hand, those locations with near-zero curvature are taken as concave points.

In this study, following methods are proposed for extracting topographic changing points along section line.

(a) Method for identifying topographic changing points

First of all, topographic changing points are extracted by following conditions.

$$MSC_p \geq T_{MSD}$$

By applying above condition, locations with their MSD value more than specified threshold value (T_{MSD}) are extracted as topographic changing points (P_{TC}), which will be further classified as follows.

(b) Method for identifying convex points

Topographic changing points (P_{TC}) which meet below conditions are identified as convex points.

$$T_{slope_convex_max} \geq Slope_p \geq T_{slope_convex_min}$$

(c) Method for identifying concave points

On the other hand, topographic changing points (P_{TC}) which meet below conditions are labelled with concave points.

$$Slope_p \leq T_{slope_concave}$$

Sample of extracted convex points and concave points is shown in Figure 9.

3.4 Convex break line and concave break line

By joining convex points and concave points (see Figure 9) within same elevation zone respectively, convex break lines and concave break lines in study area were generated. See Figure 12.

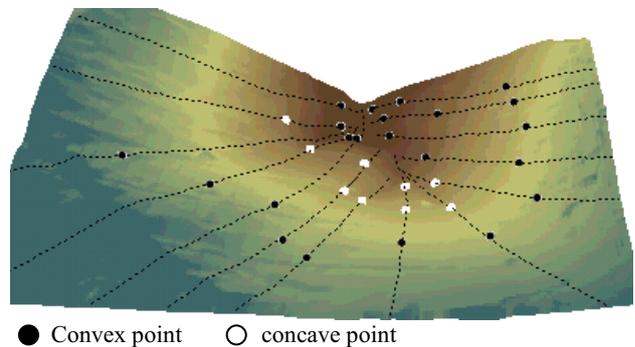


Figure 9. convex points and concave points on the section lines

With the aid of above convex break line and concave break line, which were derived from large-scale DEM, it is possible to classify and identify micro-scale landform units in study area.

Concerning applicability of above proposed micro-scale landform analysis method, detailed discussions were carried out as follows.

4. DISCUSSIONS AND RESULTS

4.1 Landform classification based on DEM-grid analysis

Based on Tamura’s landform classification method, which takes elevation, slop and channel way as key elements (see Table 1), auto-classification method using DEM were developed in this study.

Micro-scale landform unit	Elevation range	Slope range	Channel way
Crest falt (A)	$\geq 110m$	$[0^\circ, 10^\circ)$	No reference
Crest slope (B)	$\geq 110m$	$[10^\circ, 20^\circ)$	No reference
Upper side slope (C)	$[100\sim 110m)$	$[20^\circ, 30^\circ)$	No reference
Lower side slope (D)	$\leq 100m$	$[30^\circ, 90^\circ)$	No reference
Head hollow (E)	$\leq 110m$	$\geq 20^\circ$	Referenced
Channel way (F)	$\leq 110m$	$\geq 20^\circ$	Referenced

Table 1. Specifications of micro-scale landform units in study area

According to the definitions of micro-scale landform units in Table 1, grid-based statistic was performed using GIS soft. As shown in Figure 10, zone statistic (unit size = $l*n$, l:size of DEM unit, n:size of zone in DEM unit) was carried out on the topographic parameters listed in Table 1, and landform classification was performed within each “big” grid unit (See Figure 10) with outcome shown in Figure 11.

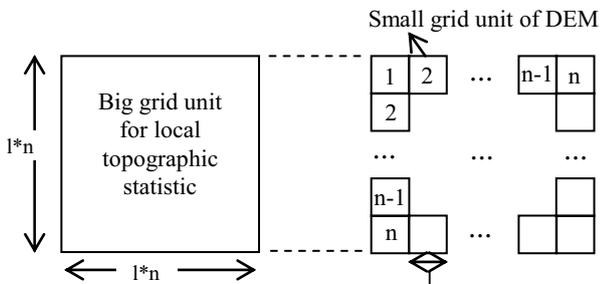


Figure 10. Method of local topographic statistic

4.2 Landform analysis by convex & concave break line

By referring to convex break lines and concave break lines , which are combination of convex points and concave points derived from large-scale DEM along section line, large-scale landform in study area was identified with following units: Crest flat (B), Upper side slope (upper part, c1), Upper side slope(lower part, c2), Lower side slope(d), Head hollow (e) and Foot slope (F). See Figure 12.

4.3 Compare of landform analysis methods

Compare of above two landform analysis methods, DEM-grid-based classification and convex-concave-break-line-based analysis shows that, there exists certain correspondence between them to some degree.

On the other hand, within outcome of zone statistic, i.e. DEM-grid-based analysis, boundaries of landform units cannot be distinguished, which shows its lack of applicability in auto-analysis by taking advantage of large-scale DEM.

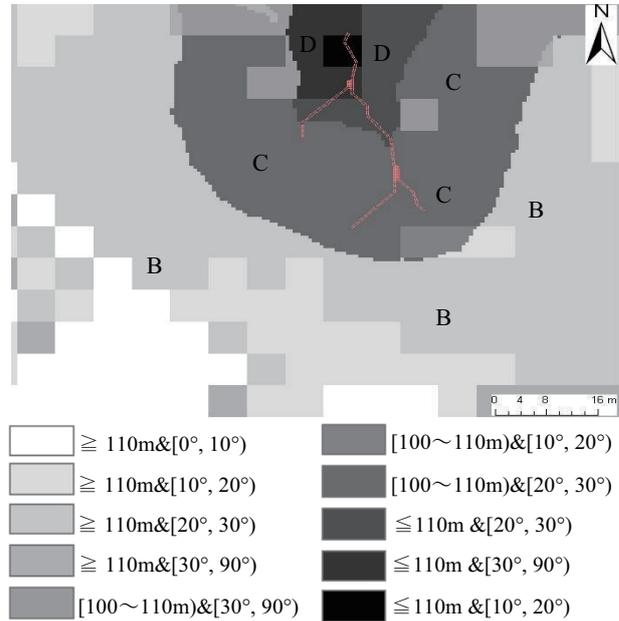


Figure 11. Landform classification outcomes from DEM-grid analysis

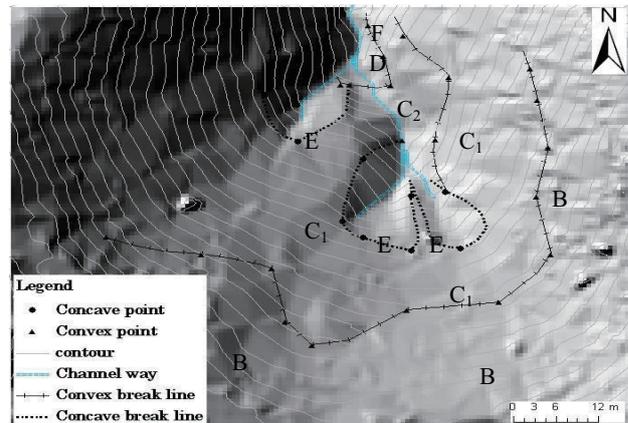


Figure 12. Landform analysis by convex & concave break line

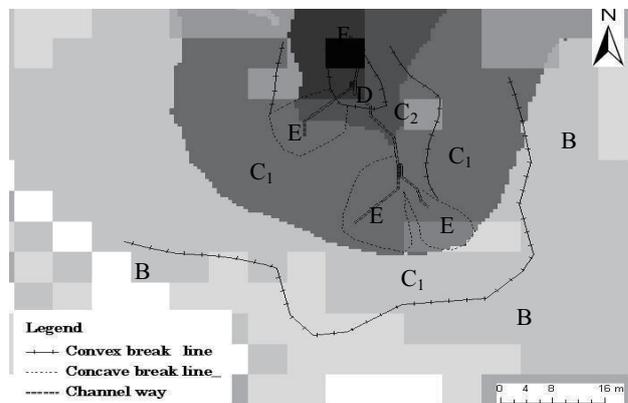


Figure 13. Compare of different landform analysis methods

5. SUMMARY

In this study, large-scale DEM derived from airborne LIDAR data was firstly used for micro-scale landform analysis, with the aim to developing auto-analyzing algorithm and processing model for micro-landform survey. And, new method for extracting convex & concave break lines, the key topographic features for micro-scale landform, were developed by taking advantage of large-scale DEM.

By comparing outcomes from DEM-grid-based classification, which adopted conventional field-survey algorithm, and convex-concave-break-line-based analyzing method proposed in this paper, good possibility was verified for its application in micro-scale landform analysis over a large extent.

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