OPTIMUM SPATIAL RESOLUTION OF DIGITAL ELEVATION MODEL
FOR TOPOGRAPHICAL ANALYSIS

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ABSTRACT:

An influence of spatial resolution for topographic analysis using DEM is evaluated. In classification of landform, number of category and spatial resolution was compared. And the possibility of 50m grid DEM for topographic feature extraction was mentioned. Moreover, very high resolution DEM was prepared using photogrammetry and laser range finder. The accuracy of DEM was intended to generate 1m in spatial resolution. Finally, required spatial resolution of DEM was discussed using auto-correlation.

In landform classification, the results showed number of category must set depending on spatial resolution. In case of 400m grid DEM, number of category should be less than 3 to 6. In case of 50m grid DEM, number of category should be less than 6 to 8. The optimum number of category for landform classification was existence depending on spatial resolution. Therefore, very high spatial resolution was required for detail analysis. Nowadays, 50m grid DEM is very popular and published by many institutes. We must recognise limitation of analysis by using 50m grid DEM.

In this study, 1m grid DEM was generated. Digital photogrammetry was used in mountainous area and laser range finder was used in glass land. An auto-correlation function of generated DEM was calculated. The results showed 8m spatial resolution was required to keep 0.9 of auto-correlation coefficient in mountainous area, 16m spatial resolution was required in case of hill area. In the present situation, meaning of auto-correlation coefficient in DEM is not understood clearly. However the auto-correlation coefficient would make one kind of index for complexity of landform.

1. BACKGROUND

Digital Elevation Model (DEM) is indispensable for many analyses such as topographic feature extraction, runoff analysis, slope stability analysis and so on. Those analyses require generally a high accurate DEM. The accuracy of DEM is usually represented by spatial resolution and height accuracy. The accuracy influences results in those analyses. Therefore, optimum accuracy of DEM for each analysis must be found.

In Japan, 50m grid DEM was published throughout the country. The DEM has been widely applied in many GIS users. However, there have not been many discussions about influence of DEM accuracy for each analysis. Now one question arose "Does 50m grid base DEM have enough accuracy for topographic analysis?"

On the other hand, high accurate DEM can be generated by digital photogrammetry, airborne SAR, laser scanner and so on. These methods have an ability to measure in 1cm accuracy. Therefore, optimum spatial resolution can be evaluated in the current condition. And finding optimum spatial resolution will make improve efficiency for measurement, computing time and data storage.

2. OBJECTIVES

In this study, an influence of spatial resolution for topographic analysis using DEM was evaluated. In classification of landform, number of category and spatial resolution was evaluated. And the possibility of 50m grid DEM for topographic feature extraction was mentioned. Next, very high resolution DEM was prepared using photogrammetry and laser range finder. The accuracy of DEM was intended to generate

1m in spatial resolution. Finally, required spatial resolution in some topographic conditions was discussed.

3. SPACIAL RESOLUTION AND TOPOGRAPHIC FEATURE EXTRACTION

3.1 Materials

In this chapter, 50m grid DEM was used, which provided by geological survey institute, Japan. From the DEM, many low spatial resolution DEM were generated which are 100m, 200m and 400m resolution by the nearest neighbor resampling. And, DEM in various topographic conditions was prepared for evaluation. Because, the topographic analysis will make unique results in each topographic condition.
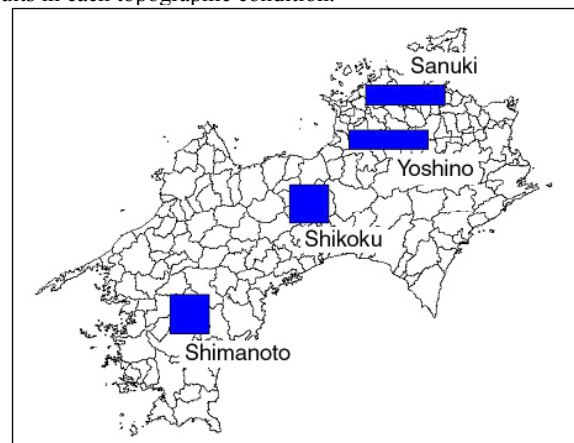

Figure 1. Test Area in Japan

As test area, three typical topographies were selected which are mountainous area pan (Shikoku and Shimanto), hill area (Sanuki) and terraced area (Yoshino). Figure 1 shows location of selected test area.

3.2 Landform Classification

Using those DEM, landform was extracted by classification with image processing. Three items of classification are an inclination, a concave-convex and a ridge-valley. The classification method was carried out following a paper by Iwahasi and Kamiya(1995)[1].

Inclination: The inclination was classified into two categories those are gentle slope and steep slope. The threshold value was calculated mean value in the test area.

Concave and Convex: For extracting concave and convex, Laplacian filtering was applied. Laplacian filter can calculate differential coefficient of second order, which can extract concave and convex.

Ridge and Valley: For extracting ridge and valley, Median filtering was applied. Median filter means one kind of smoothing. When the DEM after median filtering subtracted from original DEM, ridge indicates positive value, flat land indicates zero, valley indicates negative value.

The classified images have many noises come from detail undulation of ground surface. So, uniform linear transformation in 10 pixels radius was applied in all classified images.

The generated three images of classification were overlaid each other. Totally 12 categories are generated, which are consisted with steep or gentle, concave or convex and ridge, valley or flat. The classification results were compared each other according to spatial resolution.

3.3 Results

A relative frequency of each 12 categories according to spatial resolution was shown in Figure 2. The spatial resolution influenced seriously on concave-convex extraction. The concave area increased remarkably depending on increasing grid size.
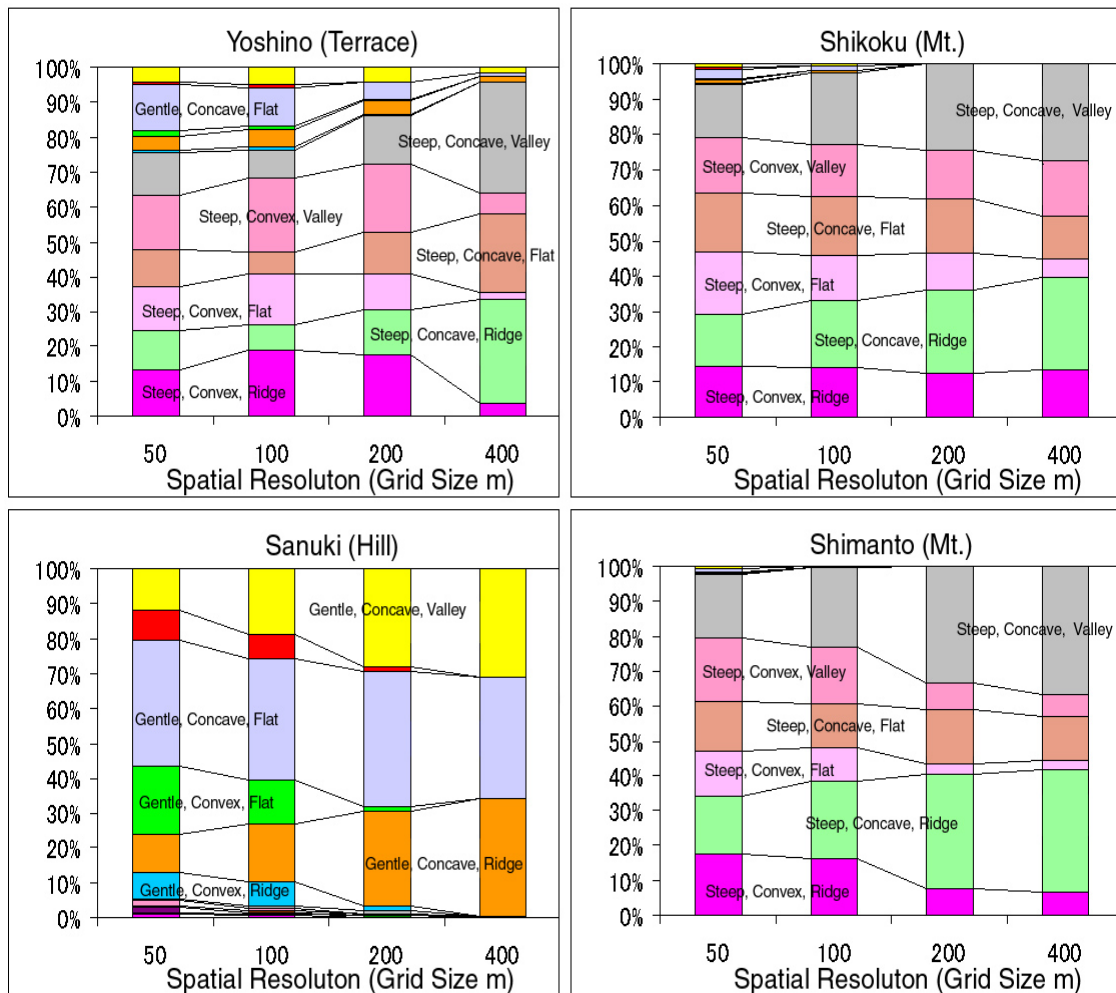

Figure 2. Classification Results in each Test Area

In the terraced area and the hill area, number of category decreased remarkably depending on increasing grid size. These areas have so many undulations on the ground surface that wide spatial resolution erased the small undulations.

The results showed optimum number of category was depending on spatial resolution. In case of 400m grid DEM, number of category should be less than 3 to 6. In case of 50m grid DEM, number of category should be less than 6 to 8. Those

results meant that very high spatial resolution was required for detail topographic analysis. In this study, 12 categories were used for landform classification. However, even 50m grid DEM didn't have enough resolution.

Figure 3 showed auto-correlation function of 50m grid DEM in each test area. The auto-correlation is generally used in signal processing for extracting periodicity. When the auto-correlation is applied to DEM, complexity of landform might be extracted. The results showed auto-correlation coefficients fall remarkably in mountainous area. Terraced area kept high auto-correlation coefficients because of continuous same size of terrace. The hill

4. REQUIRED RESOLUTION OF DEM

4.1 Data Acquisition

In previous chapter, possibility of 50m grid DEM was mentioned. 50m grid DEM didn't have enough resolution for landform classification in 12 categories. So, higher spatial resolution must be used.

Firstly, very high accurate DEM was prepared for detail evaluation on accuracy. Digital photogrammetry and laser range finder was used for DEM generation in this study. Selected test area was mountainous area in Shikoku, Japan as high undulated mountain. For comparison, Mongolian grassland also selected
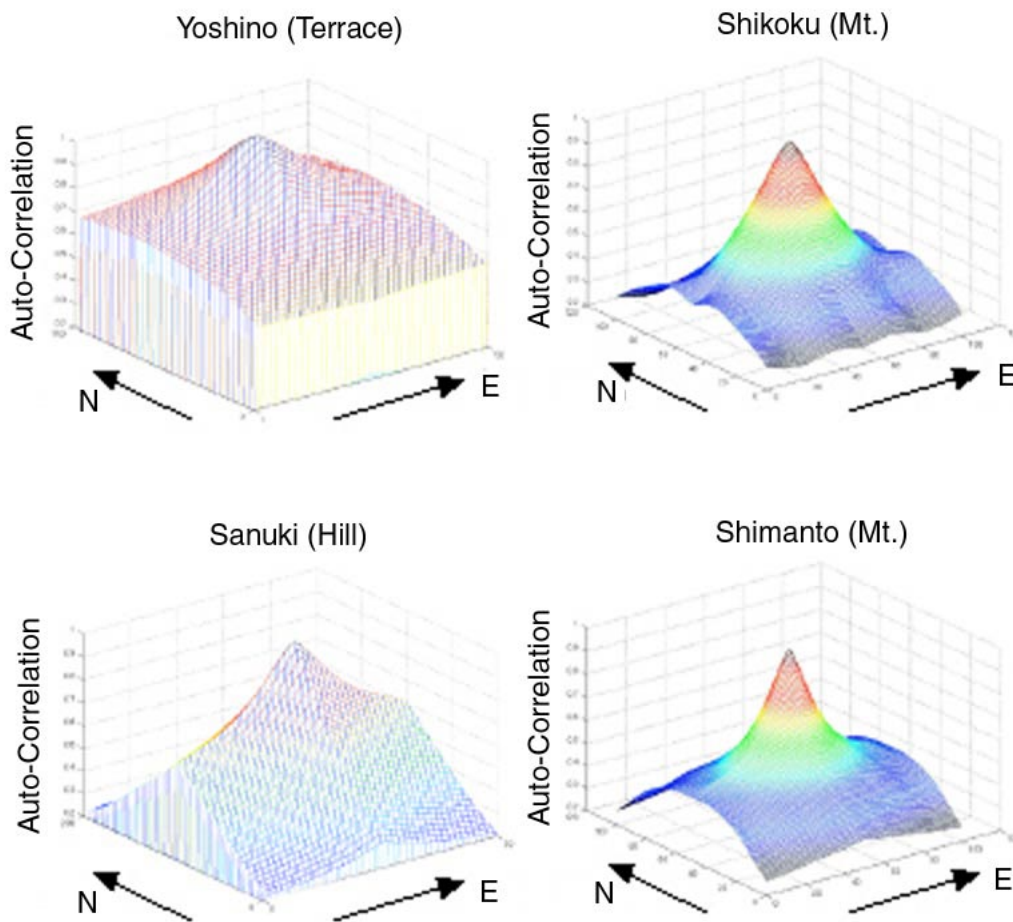

Figure 3. Auto-Correlation of Each DEM

area had anisotropic shape of auto-correlation function depending on direction because one big lineament crosses the test area. Anyway, landform in pointed shape of the auto-correlation function should need high resolution DEM. Therefore, the auto-correlation function of DEM could be represented topographic feature and optimum resolution of DEM might be shown.

as gentle hill area. In the mountainous area, digital photogrammetry can be applied because of easy for stereo matching. In the hill area, laser range finder must be applied because of difficult for stereo matching. The accuracy of DEM was intended to generate 1m in spatial resolution.

4.1.1 DEM generation in mountainous area

For generating mountainous DEM, general digital camera with 4 million pixels was used. This digital camera has an ability to generate DEM in about 4cm accuracy in case of 30m distance from object points.

The test area was landslide prevention zone in Shikoku, Japan where is very steep area. Ten ground control points in the test area equipped, which were surveyed ground coordination by using GPS in static measurement. In the test area, 3 scenes were taken on the ground to look out over whole test area and almost ground control points. And stereo matching was succeeded with getting 1,116 corresponding points. By using these corresponding points, DEM was generated in 1m accuracy. Figure 4 shows generated DEM by shading. The mean value of inclination was indicated 18.9 degree.

4.1.2   DEM generation in grassland area

For generating DEM in grassland, laser range finder with 10cm accuracy was used. The laser range finder was mounted on telescope that can control attitude in 1 minute accuracy.

Test area was grassland in Mongolia. The laser range finder was set on ground control points where surveyed by GPS. And 511 points were measured ground coordination. By using these measurement points, DEM was generated in 1m accuracy. Figure 5 shows generated DEM. The mean value of inclination was indicated 3.2 degree.

4.2 Evaluation using Auto-correlation

Generated DEM was firstly evaluated by auto-correlation function. The auto-correlation function was efficient to evaluate topographic feature in previous chapter. Complicated landform makes auto-correlation coefficients fall remarkably. When the auto-correlation function keeps high value, low spatial resolution of DEM can used for analyse. However, when the shape of auto-correlation coefficients fall rapidly, DEM must be
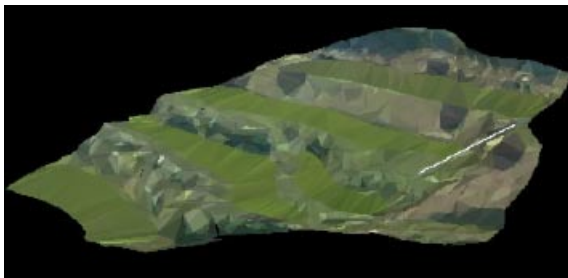

Figure 4. Generated DEM in Mountainous Area

generated in high spatial resolution.

Figure 6 shows each auto-correlation function in one profile. The results showed inside of 4m from origin point indicate to keep 0.9 of auto-correlation coefficient in mountainous area. On the other hand, inside of 8m from origin point can keep 0.9 of auto-correlation coefficient in hill area. The distance can be expressed 8m and 16m resolution each in spatial resolution.

5. CONCLUSIONS

In landform classification, influence of spatial resolution was mentioned. The results showed number of category must set depending on spatial resolution. In case of 400m grid DEM, number of category should be less than 3 to 6. In case of 50m grid DEM, number of category should be less than 6 to 8. The optimum number of category for landform classification was existence depending on spatial resolution. The results meant that very high spatial resolution was required for detail analysis.

Nowadays, 50m grid DEM is very popular and published by many institutes. We must recognise limitation of analysis by using 50m grid DEM.

Next, 1m grid DEM was generated. Digital photogrammetry was used in mountainous area and laser range finder was used in glass land. And an auto-correlation of generated DEM was calculated. The results showed at least 8m spatial resolution is required to keep 0.9 of auto-correlation coefficient in steep mountainous area, 16m spatial resolution was required in case of gentle hill area. In the present situation, meaning of auto-correlation coefficient in DEM is not understood clearly. However the auto-correlation coefficient would make one kind of index for complexity of landform. The shape of auto-correlation function in each test area showed unique. It means there is possibility for classification of landform by using auto-correlation function. For definition of topography by using auto-correlation function, many experiments should carry out.
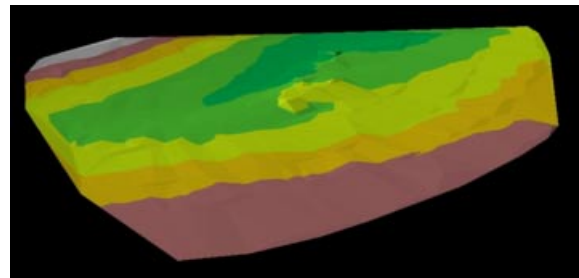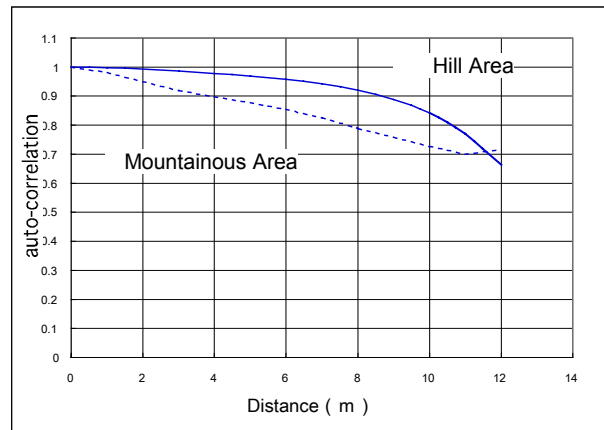

Figure 5. Generated DEM in Hill Area

Figure 6. Auto-correlation Function

References:

[1] Junko Iwahashi and Izumi Kamiya, (1995), "Landform Classification using Digital Elevation Model by the Skills of Image Processing (In Japanese)", Geoinformatics, Vol.6 No.2, pp.97-108

[2] Masataka Takagi, (1998), "*Accuracy of Digital Elevation Model according to Spatial Resolution*", International Archives of Photogrammetry and Remote Sensing, Vol.32 Part 4, pp.613-617.

[3] Masataka Takagi (2000), "*Relationship between Spatial Resolution and Terrain Feature in DEM Accuracy*", International Archives of Photogrammetry and Remote Sensing, Vol.33 Part B4, pp.1038-1045

[4] F. Ackermann (1994), "*Digital Elevation Models - Techniques and Application, Quality Standards, Development*", International Archives of Photogrammetry and Remote Sensing, Vol.30 Part 4, pp.421 - 432

[5] P. A. Burrough (1986), "Principles of Geographical Information Systems for Land Resources Assessment", Oxford University Press.