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Classification of topography in artificially modified alluvial plains using DEMs

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Abstract— **We developed classification schemes for topography in the artificially modified alluvial plains. In order to determine the ground conditions in such areas, it is important to define the distributions of low rises such as natural levees and gentle fans. We searched for geometric signatures which did not over-emphasize the influences of artificial unevenness and were thus useful for revealing low rises on alluvial plains. Based on our findings using the highly accurate DEM for the Nobi plain, we concluded that Height Above Nearest Drainage (HAND) was most useful for detecting natural levees and gentle fans. Then we used HAND and slope gradient to produce terrain classification data for the Central Plain of Thailand using MERIT DEM in consideration to future development of global data.**

I. INTRODUCTION

Geomorphological maps are produced by delineating ranges showing homogeneous landforms. They can be used to identify areas susceptible to floods or landslides or to plan infrastructure. In addition, they can be used to estimate soil types [1] or earthquake shaking [2], because terrain types can be good indicators of bedrock erosion resistance and ground conditions under the same climatic and/or geological provinces.

Iwahashi et al. [3] developed polygon data for global terrain classification using a combination of slope gradient, surface texture, and local convexity of the 280 m DEM interpolated from the Multi-Error-Removed Improved-Terrain (MERIT) DEM [4]. The results were generally suitable for distinguishing bedrock mountains, hills, large highland slopes, intermediate landforms (plateaus, terraces, and large lowland slopes), and plains. However, we found that this data could not detect narrow valley bottom plains, metropolitan areas, and slight rises in gentle plains. As the majority of the population is concentrated in plains, it is necessary to classify these areas accurately to better estimation of their vulnerability to natural disasters and plan land development.

For example, in order to determine the ground conditions for alluvial plains in monsoon areas such as Japan and Thailand, it is important to define the distributions of low rises such as natural levees and gentle fans. Although choosing accurate and high-resolution DEMs can accomplish this, these can also cause a problem: artificial unevenness in urban areas may disrupt the terrain classification of natural landforms. Therefore, we experimented with classification schemes suitable for terrain classification of alluvial plains in complex terrains of urban areas.

II. METHOD AND STUDY AREAS

We focused on the Central Plain of Thailand and the Nobi Plain of Japan, where (1) manually created geomorphological maps depicting detailed landforms within alluvial plains are available, (2) GIS data for rivers and water channels are available, and (3) urbanized areas are predominant. For the Central Plain of Thailand, we used the 3 arc-second MERIT DEM, for which the data source is mainly SRTM（NASA/JPL）and AW3D (JAXA）. For the Nobi plain, where is the first test field, we used the Fundamental Geospatial Data of Geospatial Information Authority of Japan (GSI), for which the data source is mainly LiDAR along with DEMs created by photogrammetry or topographic map contours. The resolution of the DEMs after projection transformation was 90 m, corresponding to 3 arc-seconds.

The Central Plain of Thailand is composed of the Chaophraya River delta, flood plain, lagoons, sand bars and gentle fans [5]. The southern part of the Central Plain includes Bangkok metropolitan region. In the countryside, the Central Plain is filled by rice fields and many artificial channels. The Nobi Plain lies in the central part of Honshu Island. The eastern part is mainly composed of alluvial fans and low terraces, and includes urbanized and filled or embanked lands of the Nagoya metropolitan region. The western part is composed of the Kiso and Ibi River deltas, and is bordered by active faults within the Yoro Mountains [6]. Both plains are highly urbanized and cultivated, with significant observable artificial unevenness and banks.

At first, we compared the manually created geomorphological maps (1:25,000 Land Condition Maps from the GSI) with the geometric signatures calculated from DEMs in the Nobi Plain where high-quality DEMs and GIS data of the geomorphological maps had been obtained. Elevation itself, the primary information, does not indicate the height above the standard plane of erosion. We considered Height Above Nearest Drainage (HAND), developed by Rennó et al. [7]. The D-infinity toolset of TauDEM [8] was used for hydrological analyses. We used drainages drawn on topographic maps (Thailand rivers and streams: Marc Souris, IRD; Japan: National Land Numerical Information by the MLIT) as well as drainages calculated from DEMs. We examined the three geometric signatures: slope gradient, local convexity, and surface texture [9] as the secondary derivatives. The latter two derivatives are evidently useful for terrain classification of mountains and extraction of terraces [3][9]. Finally, we created a prototype classification of the Central Plain using the geometric signatures calculated from the global MERIT DEM.

III. Results

The mapped drainages (rivers and water channels) and those calculated from the DEMs were different with regards to gentle slopes. We could not obtain a HAND image that was sufficiently usable for terrain classification based on mapped drainages. This was caused by the many excavated water channels traversing the alluvial fans (both plains) and water channels drawn on the map for raised-bed rivers (the Nobi Plain). However, the deltas, natural levees, and alluvial fans which are aggregates of natural levees could be sufficiently discriminated by the HAND image when using the DEM drainages (Fig. 1). Spatial distributions of low rises in HAND imagery differed depending on the thresholds. Both river- and stream-level drainages were needed to obtain sufficient HAND data for terrain classification. Appropriate thresholds may vary from region to region, and it seems that in Japan, with more undulations, higher-order drainages are needed to properly depict low rises.

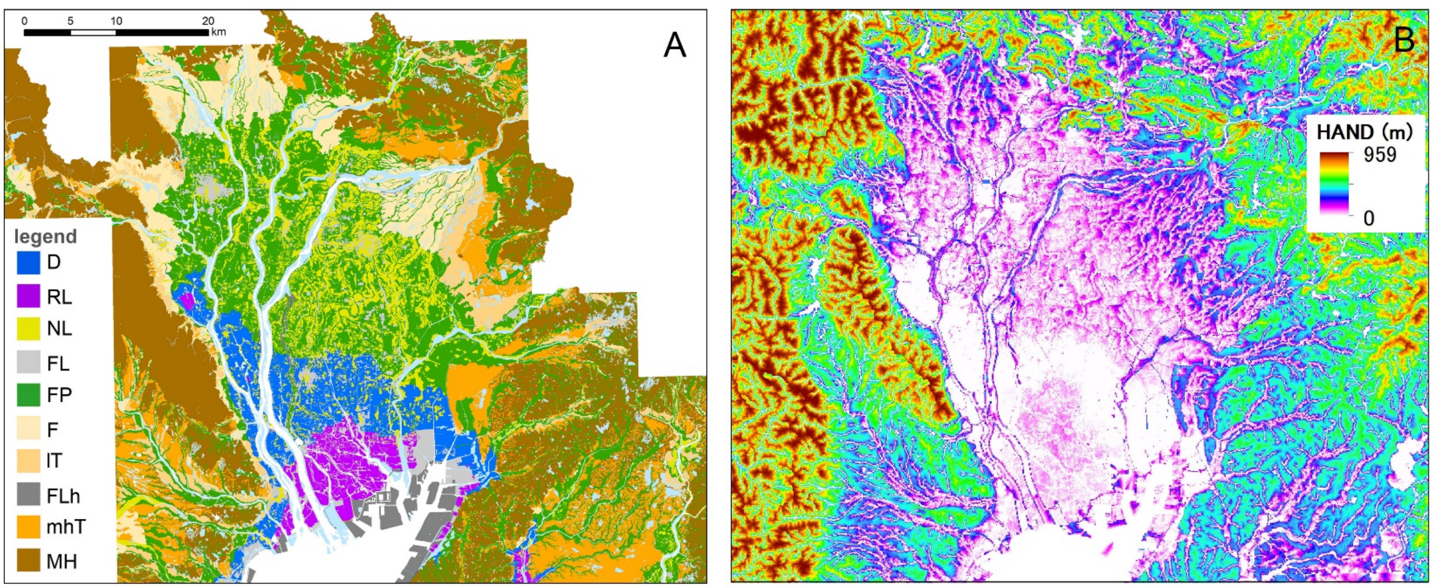

Figure 1. (A) Geomorphological map of the Nobi Plain created by observation of aerial photographs and geological survey, aggregated from the 1:25,000 Land Condition Map of the GSI. Classifications are D: delta; RL: reclaimed land; NL: natural levee; FL: filled land; FP: flood plain; F: alluvial fan; lT: low terrace; FLh: high filled land; mhT: middle to high terrace; MH: mountains and hills. (B) HAND calculated from 90 m DEMs which was interpolated from the Fundamental Geospatial Data of the GSI. The color of elevation was adjusted by histogram equalization.

Fig. 2 shows the box-and-whisker plots and mean values of the geometric signatures for each category in the Nobi Plain on logarithmic axes. Some box-and-whisker plots, i.e. non-mountainous areas of HAND and high filled lands of the slope gradient, indicate that the frequency distributions of them are far from normal distributions. With using the high-accuracy DEM derived from LiDAR, the mean values from HAND are sufficiently divergent, indicating that HAND is a good detector for low rises on alluvial plains. The disadvantage of HAND is that alluvial fans (F) and low terraces (lT) may not be distinguished. Flood plains (FP) with many artificial levees by rice fields have mean slope gradient values close to those of low terraces (lT) and fans (F). With regards to local convexity and surface texture, the mean values of low terraces (lT) and fans (F) show clear differences, so they remedy the defects of the HAND method. However, flood plains (FP) may be more easily confused with terraces (lT, mhT), so we anticipated that the use of surface texture and local convexity for sub-divisions of gentle plains may be difficult. We expected that the extraction of mountains and hills (MH) would be easy. The high filled land (FLh) along the coast is also difficult to classify automatically, because the influence of artificial unevenness is large in both MERIT and the Fundamental Geospatial Data. We feel that manual correction by visual inspection is necessary.

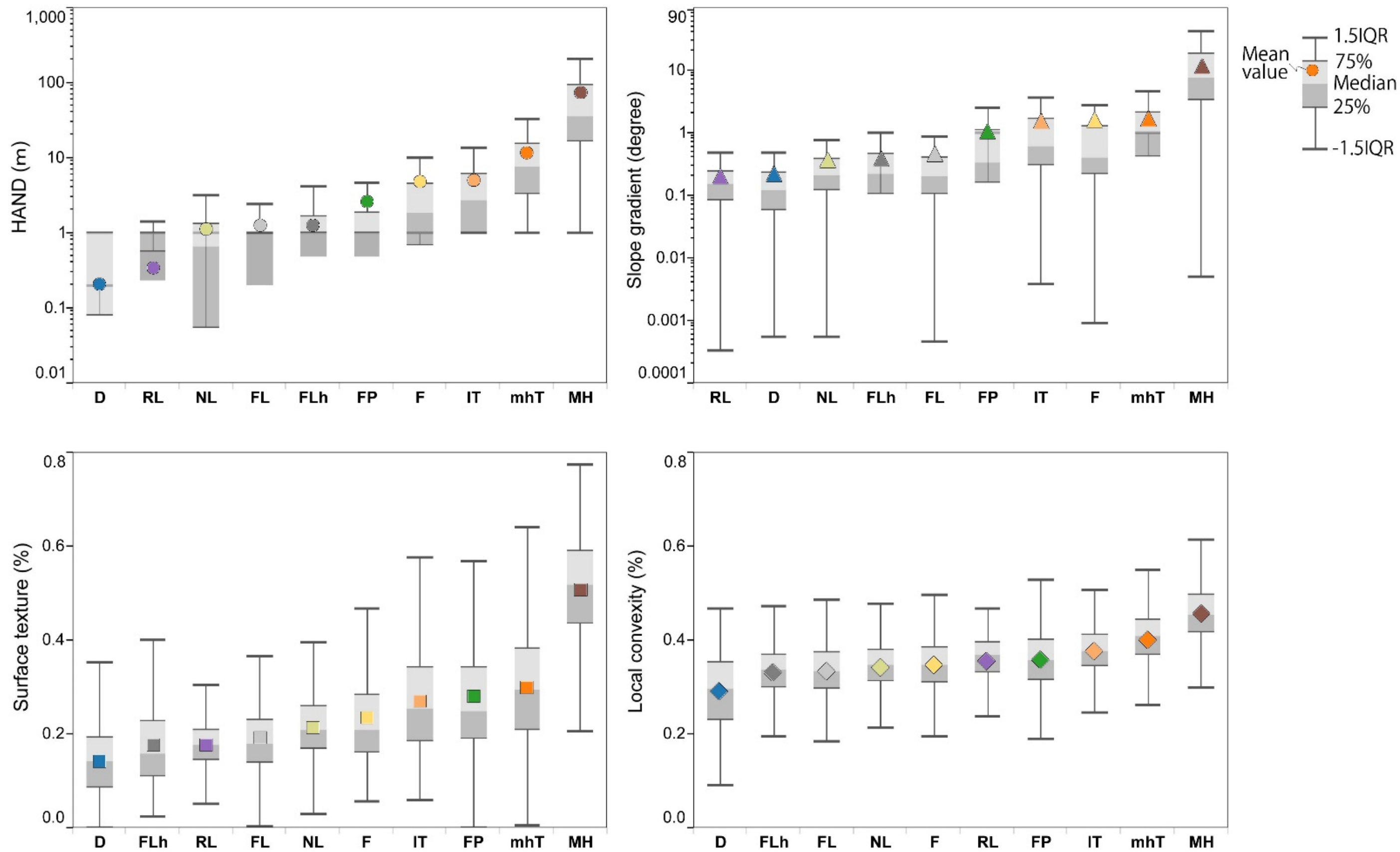

Figure 2. Box-and-whisker plots and mean values of the geometric signatures calculated from the Fundamental Geospatial Data for each category of the manually created geomorphological map of the Nobi Plain (Fig. 1 left). Color definitions are given in Fig. 1. The vertical accuracy of the Fundamental Geospatial Data is regulated by the standard deviation within 0.3 m.

Based on our findings using the highly accurate DEM for the Nobi plain, HAND and slope gradient were chosen for topographical classification. Then we used them to produce terrain classification data for the Central Plain of Thailand using MERIT DEM in consideration to future development of global data. In the Central Plain, there are no obvious terraces, so it is suitable for classification without local convexity and surface texture. We obtained sufficient area segmentation using multiresolution segmentation [10] with the logarithmic values of HAND and slope gradient.

Using the mean value of HAND and slope gradient for each polygon, we first extracted the mountains and hills by thresholding, then used k-means clustering [11] in the remaining area to prepare terrain classification data (Fig. 3). For riverbeds and natural levees, manual correction was necessary due to data noise in these areas. In the intertidal zone, we found abundant unevenness due to artificial water channels, and found that it was necessary to use elevation to determine the intertidal zone.

IV. CONCLUSION

HAND proved to be a good detector of gentle alluvial fans and deltas in alluvial plains even in urban areas with significant artificial unevenness. By segmenting the area using HAND and slope gradient images, it was possible to create terrain classification data that separate low rises and low lands. This classification method seems applicable to global alluvial plains using 3 arc-second MERIT DEMs.

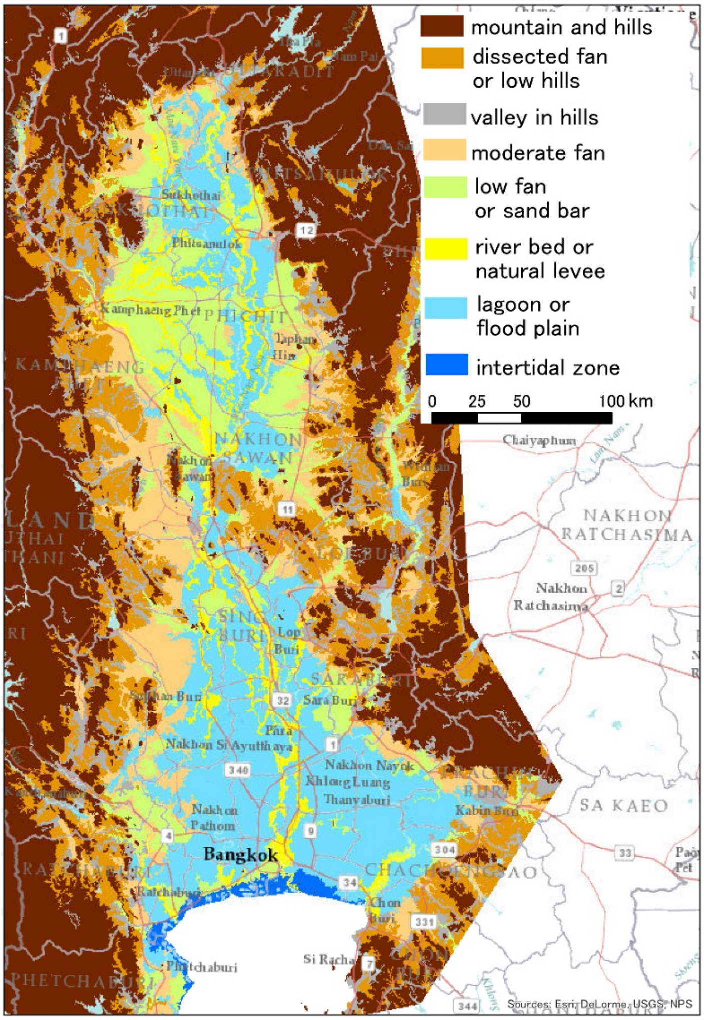

Figure 3. Terrain classification of the Central Plain of Thailand using HAND and slope gradient calculated using a 90 m DEM interpolated from MERIT. The legend was designed according to the existing manual geomorphological map [5].

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