論 文 の 内 容 の 要 旨

論文題目　Spatial distribution and formation of fluvial knickzones in central Japan extracted using multi-resolution Digital Elevation Models (DEMs) and GIS-based tools
（多解像度のデジタル標高モデルとGISのツールを用いて抽出した中部日本の河川遷急区間の分布と形成）

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Extraction of knickpoints or knickzones from a Digital Elevation Model (DEM) has gained immense significance owing to the increasing implications of knickzones on landform development. However, existing methods for knickzone extraction tend to be subjective or require time-intensive data processing. This study uses a newly proposed Knickzone Extraction Tool (KET) and the Semi-Automatic Knickzone Extraction (SAKE) method for the extraction of knickzones. KET, deployed in the form of an ArcGIS toolset, automates the process of knickzone extraction and is both fast and more user-friendly. A comparative analysis of the KET, SAKE and other contemporary knickzone identification techniques was also conducted. The results from a 10-m and a 50-m grid DEM of two geologically different case study areas (mountainous watersheds of the northern Japanese Alps in Gifuand and the Kii Peninsula, respectively) were examined to determine the influence of grid resolution and scale on the extraction of knickzones. In addition, the geologically different study areas determine the transferability of the KET in the extraction of prominent knickzones. Finally, through the results of case studies of the mountainous watersheds in central Japan, the relationship between knickzone distribution and its morphometric characteristics are also examined.

Three contemporary tools namely, the Stream Profiler Tool (SPT), the GIS Knickfinder (GKF) tool and the Semi-Automatic Knickzone Extraction (SAKE) method used to identify or extract knickzones from a 10-m DEM (SAKE10) of a mountainous watershed in Gifu individually resulted in 113, 16 and 141 knickzones. KET, a new tool was conceptualized and applied to the same study area that identified 189 knickzones using the threshold value 1.42×10-5 m-1 (KET1) from Hayakawa and Oguchi (2006, 2009). Another threshold value of 1.92×10-4 m-1, calculated for the SAKE method using the mean and standard deviation of relative steepness (Rd) for all the bedrock reaches in the study area, following the guideline of Hayakawa and Oguchi was also used. This resulted in 20 knickzones (KET2). The results from the four methods using a 10-m DEM are also compared with the knickzones identified by Hayakawa and Oguchi (2006, 20009) who used the SAKE method and a 50-m DEM (SAKE50) since the study contains field validated knickzones. The transferability of the KET was tested on a 10-m and a 50-m DEM of a mountainous watershed of Kii peninsula that successfully resulted in 99 and 80 knickzones, respectively using the SAKE method, while, 13 and 46 knickzones, respectively using the KET. The study also analyzed the locational intersection between knickzones. In other words, an analysis of the intersection of knickzones within a certain distance is conducted. For the intersection distance, six values are used: 15, 30, 45, 60, 75, and 90 m. The degree of intersection is highest for distances of 90 m, considerably good results are also found at 45 m. The rates of increase of the percentage of intersection from 45 to 60 m, 60 to 75 m, and 75 to 90 m distance are approximately 1.15%, 0.39%, and 0.77%, respectively. The results indicate that KET is useful for extracting knickzones by detecting anomalies in the stream length gradient. The KET performs

well in detecting prominent knickzones in the upstream areas, although it is dependent on the applied threshold values, as is the case for the SAKE method.

Finally, the analysis of the frequency of knickzones computed for each class of elevation, distance from the watershed outlet, drainage area and stream gradient for all the rivers reveals high frequency in two elevation zones in Gifu: moderate elevations of 1600–2000 m and the other at higher elevations of 2200–2400 m (Figure 5a). The high elevation region lies within approximately 10–15 km of the river head and a local maxima at about 50–70 km distance from the watershed outlet for all the methods. The frequency of knickzones for most methods reveals an abundance of knickzones in the smallest drainage area (10 km2), although SAKE10 gives the most abundant knickzones between 10–20 km2, and KET2 does not give a clear trend because the number of knickzones is small. Whereas, for Kii the frequency of knickzones computed for each class of elevation, normalized distance upstream and drainage area for all the rivers reveals high frequency in elevations between 1000–1600 m that consist of 20% of the upstream areas of the rivers. Frequency of knickzones are abundant in small drainage areas of 10–30 km2 with higher drainage areas associated with 50-m DEM. In both study areas knickzones are abundant in the upstream reaches which can be attributed to strong hydraulic action in steep reaches. Although, the average watershed slope and hypsometry are very similar for both the areas the river gradient differs, 0.036 m m-1 for Gifu and 0.011m m-1 for Kii for d = 750 m. This is suggestive that despite the dominance of similar V-shaped valleys, the lower river gradient in Kii leads to reduced hydraulic action, resulting in much less knickzones.

Knickzone characteristics in terms of underlying rock types was also analyzed individually for Gifu and Kii. Abundance of knickzones in the upper reaches of the river is influenced by irregular relief and slope of the dominant volcanic rock in Gifu. The average river gradient at d = 750 m, for volcanic, accretionary, sedimentary and plutonic rocks are 4.80×10-2 m m-1, 2.90×10-2 m m-1, 1.05×10-2 m m-1 and 1.18×10-2 m m-1, respectively. The plutonic and sedimentary rocks have high frequency here owing to a short river stretches of 5 km in the former with few knickzones and a longer draining river of 230. 6 km in the latter but with few knickzones. The river action with the combined influence of its coastal location and accretionary rock complex is actively contributing to abundance of knickzones in the upstream reaches in Kii. But compared to simple hillslope forms river profiles are more complex with abundant knickzones. This has been vivid by the knickzone frequency of 0.2 km-1 in Gifu while that of 0.03 km-1 in Kii. The abundance of knickzones are mainly influenced by the irregular relief and slope characteristics that correlate well with hydraulic action in upstream reaches in Japan (Fujiwara et al., 1999; Wakamatsu et al., 2005; Hasegawa et al., 2005).