LANDFORM CLASSIFICATION BY A RULE-BASED APPROACH FOR MONITORING FLOOD INUNDATION IN HANOI AND SURROUNDING AREAS, NORTH VIETNAM

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ABSTRACT

This study aims to describe the adaptation and generalization of the rule-based landform classification method based on moist conditions, local land-surface parameters, and relative position for predicting states of flood inundation. These inputs are derived from multi-temporal Landsat data and Shuttle Radar Topographic Mission Digital Elevation Model (SRTM DEM). A case study was conducted for Hanoi and surrounding areas, the western part of Red River delta, north Vietnam.

Moist condition classification by slicing Modified Normalized Different Water Index (MNDWI) of a flood (rainy)-season image and relative position are principle inputs that can be applicable for most classification scheme of flood plains. Local land-surface parameters calculated from the SRTM DEM are employed flexibly to adapt to each situation, but in general they are local relief, average elevations, and standard deviation of elevations. In this study, average elevations, and standard deviation of elevations are used. To obtain accurate results of the local land-surface parameters, enhancing SRTM DEM mostly by removing the bias of the SRTM DEM is a critical step.

Multi-temporal land cover classifications by the unmixing technique were performed to support for enhancing the SRTM DEM and studying the relationship between recent and original states of landforms. The result of the rule-based landform classification is well explained for flood inundation conditions of the recently severe flood event in 2008. This method is useful for the countries of regions where detail DEMs are not prepared. This study also discusses limitations, versatility, and customization of this rule-based method when applied for two areas (this area and the other one in central Vietnam) with an effort to generalize its application for different flood plains.

1. INTRODUCTION

Although flooding is naturally caused by meteorological and hydrological factors, its behaviors in alluvial flood plains can be understood by studying geomorphologic characteristics of those plains. Study on landform characteristics in flood plains can help to explain and monitor states of flood inundation, and provide proper and valuable information for land use and urban planning (Oya, 2001). Alluvial flood plains are usually ideal locations for human settlement and urbanization. Although land surface is covered largely by artificial land use, flood inundation also tends to act in relation to the structure of original landforms. Study on the interaction between flood inundation, geomorphologic features, and land use/cover can help to comprehend inundation characteristics and influences of human activities to the nature of flooding.

Application of DEMs and satellite images for landform classification has been increasing for the last several decades beside conventional materials (topographic maps and aerial photos) to overcome the shortage of data sources in developing countries. Ho and Umitsu (2011) demonstrated the usefulness of SRTM DEM and Landsat images in locations here topographic and land cover data are insufficient.

Recently, digital landform classifications such as automated, semi-automated, and rule-based methods have been increasingly developed and applied (Gallant et al., 2005, Drăguţ & Eisanka, 2012). The digital approach takes advantage of processing remotely sensed multi-spectral/temporal and digital elevation data. Hence, it is normally more objective, time-saving, and convenient to edit the maps compared to the manual approach by visual interpretation using data of field investigation, aerial photos and topographic maps. Ho, Yamaguchi and Umitsu (2012) developed a rule-based landform classification in small scale for the purpose of flood assessment. The authors demonstrate the feasibility of combination multi-spectral/temporal remotely sensed data and SRTM DEM to classify landforms in a flat alluvial plain using a rule. The interactive use between land cover characteristics and local topography parameters proved the significance of these two factors in landform delineation in alluvial plains. However, these inputs always are the same in different areas due to the different characteristics of those areas. Thus, depending on the characteristics of each plain, types of land-surface parameters and the ways they work are considered.

This study aims to describe the modified rule-based landform classification method to adapt to the local situation and report the results of this adaptation in the western part of Red River delta, surrounding Hanoi city. This study also discusses the principle of versatility and customization when applying this method for different alluvial plains.

2. STUDY AREA

The study area includes Hanoi capital and surrounding areas, in the western part of the Red River delta, north Vietnam, covers approximately 2594.8 km2. Hanoi is located at the confluence of Red River and Thai Binh River, along the right bank of the Red River. The study area is a part of the fluvial-dominated plain beside the wave-dominated plain in the southwestern part and the tidal-dominated one in the northeastern part of the delta. The fluvial flux is relatively strong compared with that of the other two systems (Tanabe et al., 2003). This fluvial-dominated part consists of meandering rivers, meandering levee belts, flood plain, and fluvial terraces. Natural levees are formed along the Red River, Day, Duong River, and along the abandoned river channels with absolute elevation about 5–10 m. Back marshes are formed at 3–5 m between the natural levees (Funabiki et al., 2007).

Hanoi represents the economic, social and urban center of north Vietnam and one of the two biggest cities of Vietnam beside Ho Chi Minh city. The central urban areas of Hanoi have expanded in all directions, but primarily to the South, Southwest, West, and recently to the East. However, a large part or this area is still maintained as crop land that plays an important role to supply food and other agricultural products to Hanoi city. The urbanization of Hanoi has accelerated since the introduction of the Doi Moi (Economic Renovation Policy) in the late 1980s (Ho and Shibayama, 2009).

3. MATERIALS AND METHODS

Table 1. Data used

Data	Date
Landsat MSS	December 29, 1975
TM	December 27, 1993
ETM+	November 11, 2000
ETM+	July 29, 2005
ETM+	August 5, 2007
ETM+	November 8, 2007
ETM+	November 10, 2008
SRTM DEM	February, 2000

Land cover types were classified by an integrated method. The fraction images (high albedo, low albedo, vegetation, soil) by unmixing technique, the supervised classification image, MNDWI (Modified Normalized Different Water Index), and LST (Land Surface Temperature) were combined to produce a land cover image by a decision tree model.

Then, the land cover classification of the Landsat ETM+ November 11, 2000 is used to enhance the SRTM DEM obtained in the same year 2000. The enhancement processes include eliminating the overestimated elevation in the entire plain and removing the bias caused by trees and houses. The second one was carried out within the areas of dense vegetation and urban derived from the land cover classification image.

In general, the scheme of the rule-base landform classification in relation to flood inundation mechanism is based on the method by Ho et al. (2012) conducted in the Vu Gia-Thu Bon alluvial plain, central Vietnam. The main idea for the classification scheme is identifying the moist areas (using MNDWI) that can be relatively low compared to adjacent areas and easily absorb and maintain water and/or moisture (water and moist soil); and classifying the rest areas (non-water) into landform types that are less or not inundated (Ho et al., 2012). However, to adapt with the Hanoi area that is flat and very low relief, local relief was replaced by average elevation and standard deviation of elevation calculated by each non-water object. Standard deviation (SD) of elevation is demonstrated as more stable parameter (Evan, 1998). The purpose of using average elevation and SD of elevation is dividing non-water objects into homogeneous objects in term of topographic variation. The final procedure was designating final-level objects into specific landform types using thresholds of average elevation (absolute and relative), standard deviation of elevation, land cover characteristics and relative position. The moist soil and inundated areas were extracted from the Landsat flood image of November 10, 2008. This flood image was captured three days after the heavy-rain time.

4. RESULTS

The original SRTM DEM before the enhancement shows the bias that is coincident with the pattern of urban and tree cover areas displayed in the land cover classification. After the enhancement, the SRTM DEM is remarkably removed the bias.

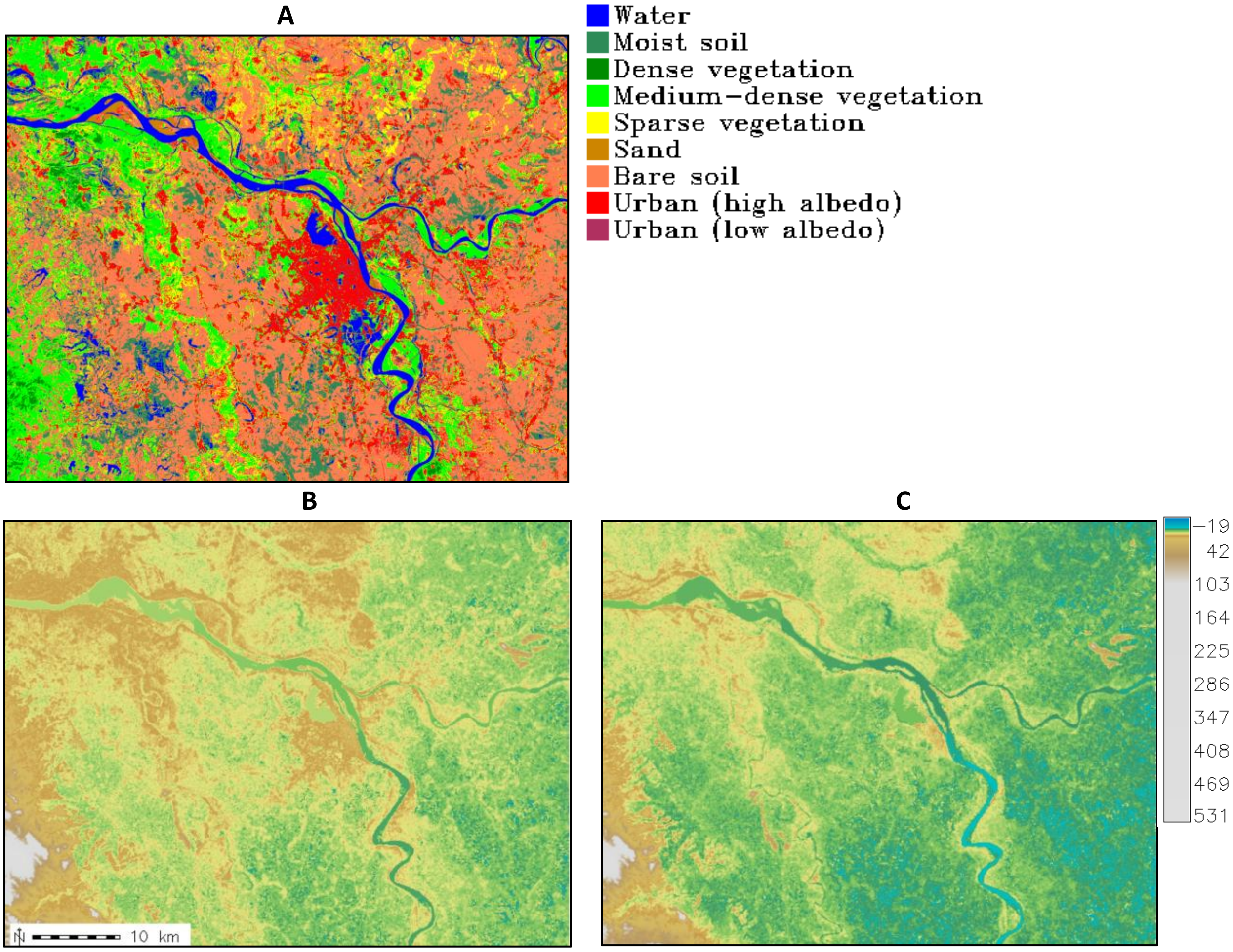

Figure 1. Using the land cover classification image of the year 2000 (A) to enhance the original SRTM DEM with the bias caused by trees and houses (B), and the SRTM DEM after the enhancement (C) with significant removal of the bias.

The result of the modified rule-based landform classification method is displayed in Figure 2A. This map was compared to the landform delineation result of Funabiki et al. (2012) using aerial photographs, satellite images, and geological maps (Fig. 2B). This preliminary verification shows the good fit between the result of this study and the classification result by the manual method. Moreover, this method can classify more detailed levels of natural levees and flood basin based on elevations, and the landform classification is in close relation to flood conditions, so helps to explain the states of flood inundation. In particular, compared to the flood-inundation image in 2008 (Fig. 2C), the landform classification provides more conditions of flood susceptibility. For instance, flood basin is absolutely submerged in and after flood time, higher flood basin is submerged in flood time but partly affected after that. Terraces are not inundated. Natural levees are affected by overbank flow but flood water can drain well. Lower natural levees are occasionally inundated in flood time.

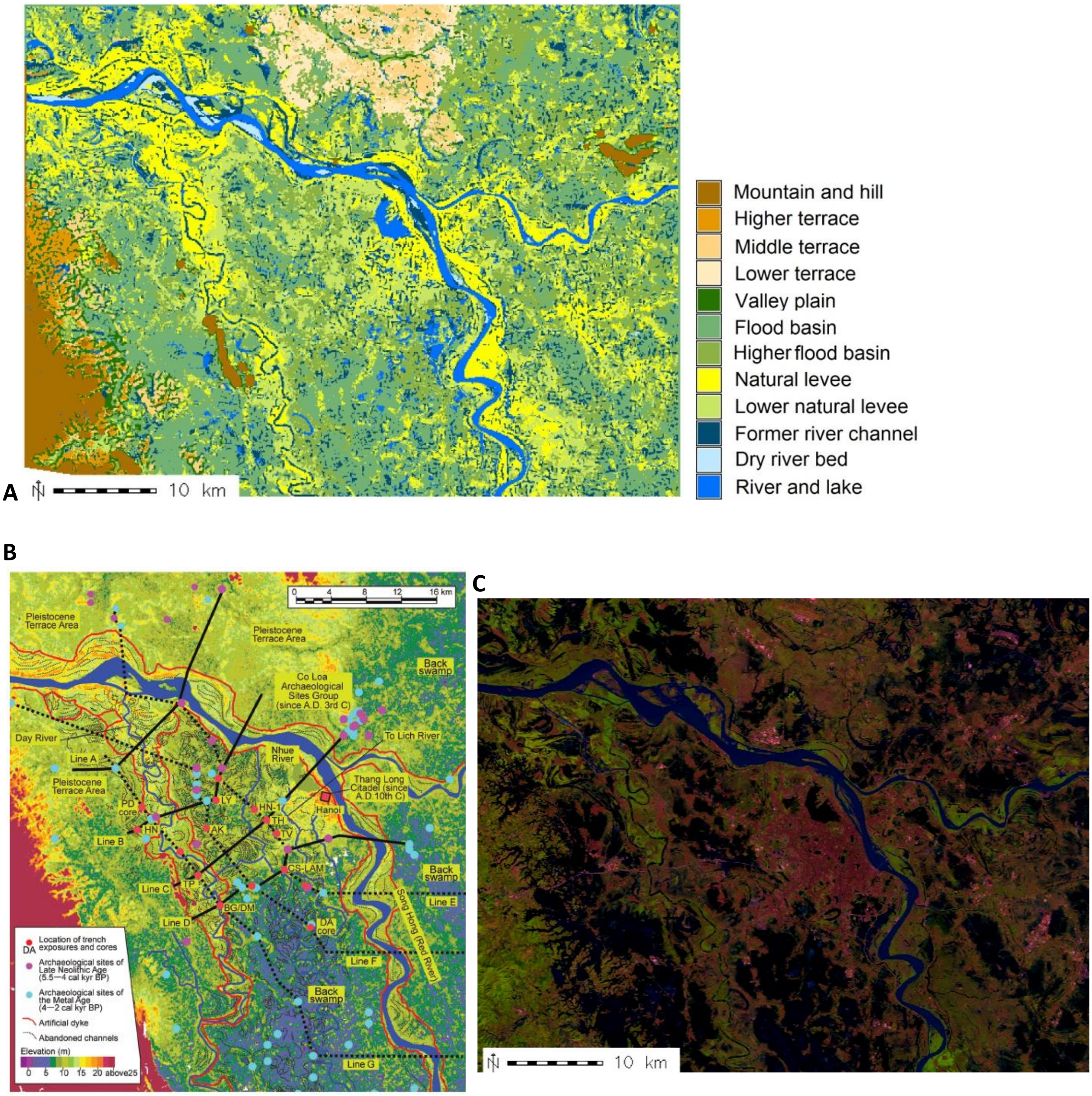

Figure 2. Comparing the landform classification map (A) generated by the modified rule-based method with the landform delineation result (B) of Funabiki et al. (2012) and the Landsat ETM+ November 10, 2008 (three days after flood).

5. DISCUSSIONS AND CONCLUSION

Moist conditions represent groups of landforms in flood plains and are independent of topographic features, surface gradient and absolute elevations. Thus, the procedure of moist classification can apply for all flood plain to classify landforms. In areas where landform boundaries have clear scarp like the case of central Vietnam, local relief is useful to identify elevated landform (terraces, natural levees). Meanwhile, areas with flat and very low-relief characteristics like the Hanoi area in this study, average elevation and standard deviation of elevations is more applicable.

Land cover classification supports significantly for improving the SRTM DEM. Real digital-terrain SRTM is very important for landform classification in small-scale. Moist condition, local land-surface parameters, relative position are key factors for classifying landforms in flood plains. Rules and parameters used in specific cases are quite flexible but closely based on main ideas for classification by understanding natural characteristics of a flood plain.

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