Significance of combining SRTM DEM and satellite images for generating automated micro-landform map

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Abstract—**This study outlines a method for generating an automated micro-landform map of an alluvial plain for further flood hazard assessment by combining Shuttle Radar Topographic Mission Digital Elevation Model (SRTM DEM) and satellite images. Average elevation and channel features extracted from DEM are associated with soil moist condition (thresholds of Modified Normalized Difference Water Index – MNDWI) from remotely sensed images based on a logic rule. This process is conducted in GRASS GIS. SRTM DEM is known as consistent and useful data for landform mapping by digital terrain analyses. However, because of its limitation in spatial resolution, satellite images are combined to isolate micro-landforms in alluvial plains (flat and low relief). Another merit of this automated method in comparison of a manual method is time-saving, objective and simple for editing. Although, theoretically, manual mapping by aerial photos and topographic maps combined with field survey is definitely more accurate; in fact it subjectively relies on human interpretation. Meanwhile the automated mapping process is rather objective, as a result create more accurate boundaries of landform objects of large-size units such as terraces, sand dunes but less detailed in small-size units such as natural levees. A case study is conducted in the alluvial plain of the Vu Gia-Thu Bon River, central Vietnam.**

I. INTRODUCTION

A. Importance of a micro-landform map

A landform map plays an important role to study the nature of many natural phenomena since relationship between landforms and those phenomena occur at micro-landform level. A micro-landform maps are is useful for many other purposes, such as land use planning, land degradation predicting (Speight, 1990). In particular, it is useful for predicting flood-prone areas because evidences formed by past flood events are preserved and remained in term of micro-landform. According to Oya (2002), a geomorphological map can help to study the extent of inundated areas, the direction of flood flow, and changes in river channels through examination of remnant flood evidence, relief features, and sediment deposits formed by repeated previous flooding. The geomorphological approach to flood investigation is effective in the case where a channel system and the associated floodplain morphology experience dynamic changes resulting in highly erosive potential and substantial sediment supply (Lastra et al., 2008). And the fact that the Vu Gia – Thu Bon alluvial plain in central Vietnam is such a dynamic and high sediment supply plain. Therefore, this approach is suitable to the study of flooding in this alluvial plain. In particular, geomorphological method is effective in developing countries where hydro-meteorological data for generating flood models are usually restricted.

B. Mapping micro-landforms by a manual approach

For the reasons mentioned above, Ho and Umitsu (2011) developed an integrated method for classifying micro-landforms in relation to flood inundation by visual interpretation utilizing Shuttle Radar Topographic Mission Digital Elevation Model (SRTM DEM) and Landsat Enhanced Thematic Mapper plus (ETM+) data combined with field investigation. Micro-landform units on an alluvial plain were classified in relation to flood conditions by integrating an SRTM DEM with spectral characteristics from a pair of Landsat images from dry and flood seasons. Micro-landform categories included mountains and hills, terraces (higher, middle and lower), valley plain, flood basin, deltaic lowland, natural levee, former river channel, dry river bed, sand dunes, inter-dune marsh, and water. Then, three-dimensional (3D) diagrams of the composed maps were produced using GRASS 6.3 to visualize the geomorphology and flood risk. The results were validated by field surveys, topographic maps and past inundation images.

The findings of this study revealed a close interaction between the geomorphological characteristics and flood conditions of this region. Flooding and sedimentation mechanisms cause dynamic formations of fluvial and coastal landforms, and these geomorphological features in turn affect flood hazard. The landform classification map was applied to predict flood hazard degrees effectively. The methodology employed here for mapping landforms using satellite data (SRTM and LANDSAT) as primary material has demonstrated usefulness of these data in places where topographic and land cover data are insufficient. SRTM DEM provides valuable, consistent topographic data, and Landsat images provide land cover information.

C. Mapping micro-landforms by an automated approach

Although conventional landform maps by visual interpretation theoretically have more detail and high accuracy, they subjectively relies on human interpretation. Mapping landform using DEM and satellite images is more time-saving and objective than traditional method. Combining land-surface parameters (LSPs) extracted from DEM and land cover condition from remotely sensed images to generate automated landform map is more objective based on a logic rule (Speight, 1974 and 1990).

However, in fact, most studies to date have classified small-scale geomorphological features (e.g., mountains, terraces, plateaus, floodplains, etc.) using SRTM DEM. There are few studies taking advantage of such data to extract micro-landforms; or focusing on mountainous or high land areas where topographic differences are distinct and evident, thus micro-landforms there can be identified advantageously (e.g., Iwahashi et al., 2007; Saadat et al., 2008). This study aims to classify micro-landforms in an alluvial plain using SRTM DEM and GRASS GIS software. Nevertheless, because of flatness and low relief features of micro-landforms in a plain, it is difficult to classify micro-landforms solely by SRTM DEM. For this reason, satellite images are employed to obtain land surface characteristics associated with LSPs from SRTM DEM.

II. STUDY AREAS

The Vu Gia and Thu Bon river originates from the Ngoc Linh Mountain (2,598 m) of the Truong Son range belonging to Kon Tum province, then, goes through a part of Quang Ngai province, almost whole Quang Nam province and Da Nang city in central Vietnam. The channel of this river shows braided and/or anastomosing pattern indicated by meandering and anabranching. Sandy sediment supply dominates in river load and governs flow mechanism of the river and the drainage as well. This alluvial plain is belonging to the central part of Vietnam which has the highest rainfall in the whole country. The rainy season is from September to December and the rest is dry season. An average annual rainfall in upland areas of the basin is approximately 3000-4000 mm that is much higher than the annual rainfall in the coastal areas (approx 2000 mm per year). Maximum monthly rainfall concentrates in rainy season from September to December with 60 – 76% (75 – 76% at coastal areas) and resulted from storms and typhoons causing flooding. The elevations of this plain are not higher than 30 m.

III. METHODOLOGY

We develop a method to generate an automated micro-landform map of an alluvial plain by combining LSPs calculated from SRTM DEM and land cover features from satellite images for further flood hazard assessment. The SRTM DEM used in this study is a World Reference System tile of path 124 / row 49 with 90 m resolution, and fill-finished B version in GeoTIFF format.

The micro-landform units are defined in relation to flood conditions, including terraces (higher, middle and lower), natural levee, sand dune, flood basin, former river channel, dry river bed, and valley plain. Since landforms are determined based on elevation, relief, shape, size, orientation, contextual position, moist regimes, etc. (Speight, 1974); average elevation, local relief, and slope from SRTM DEM are designated as LSPs to classify micro-landforms in an alluvial plain. However, this step we used average elevation as a main LSP for micro-landform classification. In addition, channels are also detected by a GRASS GIS function r.param.scale which calculates and classifies terrain features including planar, pit, channel, pass, ridge, and peak (Wood, 1996). Among them, the channel feature s are extracted and represented for former river channel, dry river bed, and valley plain areas.

On the other hand, Modified Normalized Difference Water Index (MNDWI = (Green – MIR)/(Green+MIR)=(B2-B5)/(B2+B5)) of Xu (2006) calculated from Landsat ETM+ image in rainy season (2007 December 21) can help to separate non water areas from water and moist soil areas by determining thresholds. Ho et al. (2010) demonstrated the effectiveness of MNDWI for separating moist surface states by thresholds as follows: $1 \geq MNDWI_{water} \geq threshold > MNDWI_{moist\ soil} > 0 \geq MNDWI_{non\ water} \geq -1$. Furthermore, moist soil areas had good relationship with flood basin and valley plain which are commonly submerged during flood time, non water areas indicated well levees, sand dunes, and terraces (Fig. 1).

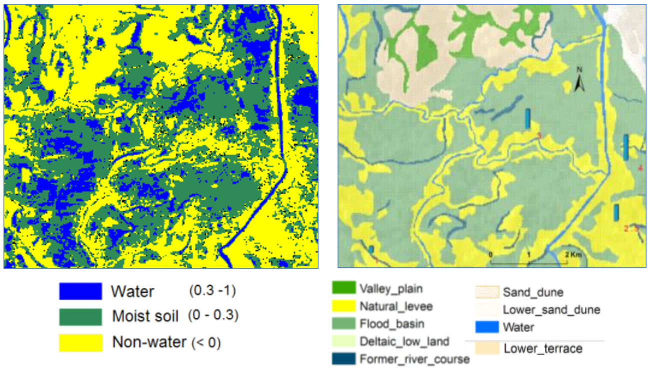

Figure 1. The left hand side is MNDWI after classified into three classes and the right hand side is manual landform map. Except permanent water as rivers and channel, we can see temporal water among moist soil areas. Blue (temporal water) and green parts (moist soil) of MNDWI image coincide well with flood basin in landform map. The yellow areas (non-water) of the left one have similar pattern with natural levees and terraces of the right one.

Average elevations are calculated within objects of non water, moist soil, and water attributes based on SRTM DEM; and then classified by elevation thresholds for each landform unit. Moreover, these objects are also classified by land cover characteristics obtained from ASTER VNIR 2003 January 31 such as sand dune dominated by sand, natural levee covered by houses and trees, flood basin usually covered by paddy field.

IV. Result and Discussions

The automated micro-landform map produced by this method has a scale about 1:50,000. Then the automated micro-landform map is compared with the manual interpretation map (Fig. 2).

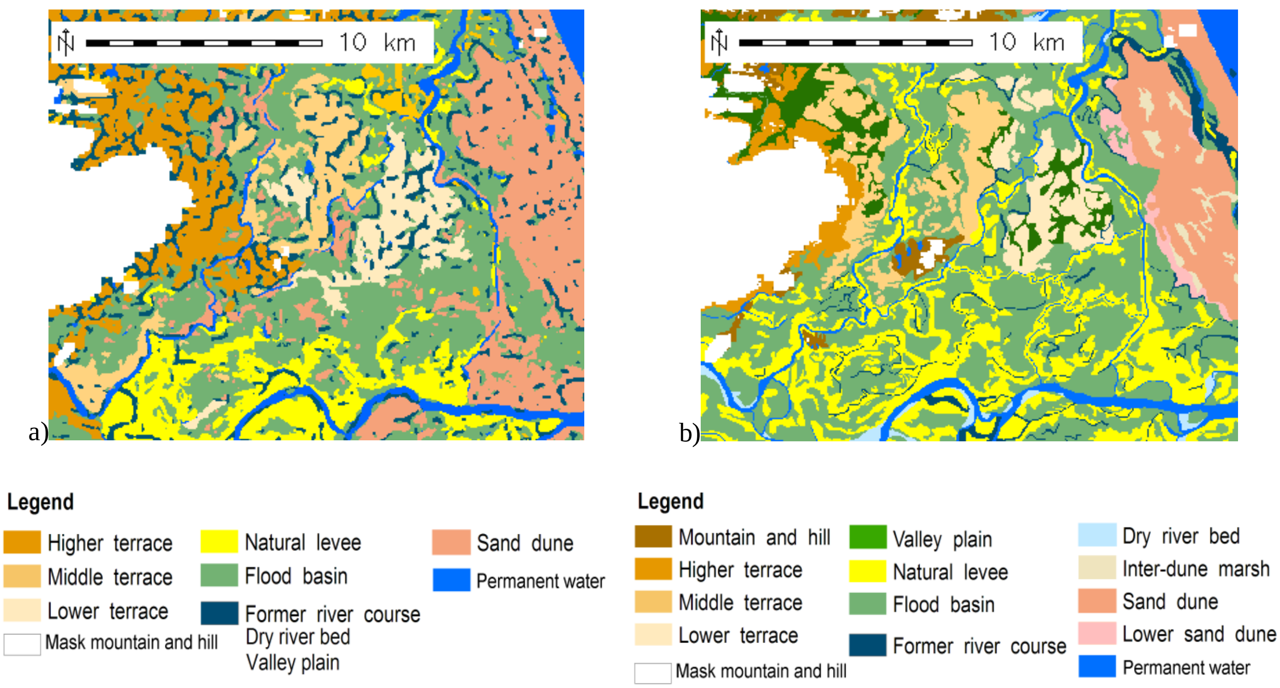

Figure 2. Automated micro-landform classification map (a) compared to manual one (b)

Micro-landform features of the automated map are compared to those of the manual map. The statistics of each unit are calculated to evaluate similarities and unsimilarities between these two maps. The unsimilarities indicate limitations of the automated method, but on the contrary reveal the subjectiveness of the manual one.

The comparison shows that flood basin areas are quite similar in both maps (64%). Most terrace areas (middle and lower) surrounded by flood basin of automated map are well fit with those of manual one (about 70%). However, on the west side the manual map dominates with middle terraces while the automated one dominates with higher terraces because of classification based on average elevation. The higher terraces showed in automated one seems to be more reasonable due to elevation and pattern. This confusion may be caused by the subjective interpretation in the manual map. Natural levees of the right one is more detailed than the left one, the percentage of similarity between the automated map and the manual map is about 60%. However, the boundaries of large levees in the left one are more reliable. Some levees are misclassified with sand dune because their average elevations are equal to sand dune. Manual map has more categories of micro-landform and more detail of small-area landform objects such as narrow natural levee, former river channel; while automated method specify more accurate boundaries of large-area landforms such as terraces and sand dunes. The channel parts in automated map indicate quite well areas of former river channel, dry river bed, and valley plain in manual one.

In general, the result reveals that various moist conditions extracted from MNDWI are closely related to micro-landforms, thus assist to separate them. Average elevations are pretty useful for micro-landform classification. However, it is more appropriate to sort different levels of terraces (higher, middle and lower). These evidences demonstrate that it is possible to generate automated micro-landform map by combination of SRTM DEM and satellite images. Nevertheless, due to limitation on resolution and bias caused by trees and houses in some areas of SRTM DEM, the result is restricted somewhat. It is necessary to improve the result by associating more parameters. For further processes, local relief and relative landform position combined with MNDWI and average elevation are expected to give a higher accurate result.

V. CONCLUSION

The proposed method for generating an automated micro-landform map by combining SRTM DEM and satellite images is effective and promising to produce landform maps that have similar quality with landform maps by visual interpretation and field survey. Furthermore, the map by this approach is objective, simpe for editing, and much time-saving than that by the manual approach. However, because of limitation on resolution and bias of SRTM DEM, other parameters need to be used to create a better automated micro-landform map.

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REFERENCES

[1] Iwahashi, J. and Pike, R. J., 2007. "Automated classifications of topography from DEMs by an unsupervised nested-means algorithm and a three-part geometric signature", Geomorphology, vol.86, pp. 409 – 440.

[2] Ho, T. K. L ., Umitsu, M and Yamaguchi, Y., 2010. "Flood hazard mapping by satellite images and SRTM DEM in the Vu Gia – Thu Bon alluvial plain, central Vietnam". International Archives of the Photogrammetry, Remote Sensing and Spatial Information Science, Volume XXXVIII, Part 8, Kyoto Japan 2010, pp. 275-280.

[3] Ho, T. K. L .and Umitsu, M., 2011. "Micro-landform classification and flood hazard assessment of the Thu Bon alluvial plain, central Vietnam via an integrated method utilizing remotely sensed data", Applied Geography vol. 31, doi:10.1016/j.apgeog.2011.01.005, pp. 1082-1093.

[4] Lastra, J., Fernández, E., Díez-Herrero, A., and Marquínez, J., 2008. "Flood hazard delineation combining geomorphological and hydrological methods: an example in the Northern Iberian Peninsula", Natural Hazards vol. 45, pp. 277–293.

[5] Oya, M., 2001. "Applied geomorphology for mitigation of natural hazards". Boston: Kluwer Academic Publishers in Dordrecht, 167p.

[6] Saadat, H., Bonnell, R., Sharifi, F., Mehuys, G., Namdar, M., Ale-Ebrahim, S., 2008. "Landform classification from a digital elevation model and satellite imagery", ScienceDirect, Geomorphology, vol. 100, pp. 453 – 464.

[7] Speight, J.G., 1974. "A parametric approach to landform regions". In: Progress in Geomorphology, Special Publication, vol. 7, Institute of British Geographers, Alden & Mowbray Ltd at the Alden Press, Oxford, pp. 213–230.

[8] Speight, J.G., 1990. "Landform". In: McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J., Hop, M.S.(Eds.), Australian Soil and Land Survey Field Handbook. Inkata Press, Melbourne, pp. 9–57.

[9] Wood, J., 1996. "The geomorphological characterisation of digital elevation models". Ph.D. Thesis. Department of Geography, University of Leicester, Leicester, UK, 185 pp.

[10] Xu, H., 2006. "Modification of normalised difference water index (NDWI) to enhance open water features in remotely sensed imagery", International Journal of Remote sensing, vol. 27, no. 14, pp. 3025-3033.