Applied Geography 31 (2011) 1082–1093

Contents lists available at ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Micro-landform classification and flood hazard assessment of the Thu Bon alluvial plain, central Vietnam via an integrated method utilizing remotely sensed data

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Keywords:
Landform classification
Flood hazard mapping
Alluvial plain
SRTM
LANDSAT
GRASS GIS

A B S T R A C T

In this study, we developed an integrated method for classifying micro-landforms and flood hazard zones based on a geomorphological approach utilizing Shuttle Radar Topographic Mission (SRTM) and LANDSAT ETM + (Enhanced Thematic Mapper Plus) data combined with field investigation. Micro-landform units on an alluvial plain were classified in relation to flood conditions by integrating an SRTM digital elevation model (DEM) with spectral characteristics from a pair of LANDSAT images from dry and flood seasons. In addition, the LANDSAT ETM + band4-band3 of the flood season image was calculated to identify moist surfaces. Next, a flood hazard zonation map was generated by categorizing geomorphological features and the average elevation of each landform into flood hazard classes. Then, three-dimensional (3D) diagrams of the composed maps were produced using GRASS 6.3 to visualize the geomorphology and flooding risk. The results were validated using field surveys, topographic maps and past inundation images. This case study was undertaken for the Thu Bon alluvial plain, central Vietnam. The findings of this study revealed a close interaction between the geomorphological characteristics of this region and flood conditions. Flooding and sedimentation mechanisms cause dynamic formations of fluvial and coastal landforms, and these geomorphological features in turn affect flood hazard. Furthermore, 43.34% of the area of this plain is classified as having a very high or high flood hazard in lowland areas and a flash flood hazard in higher areas.

Introduction

Floods are the most catastrophic natural disaster that occurs in Vietnam; they result from the typical tropical monsoon climatic features exacerbated by topographic characteristics, and recent climate change (CCFSC, 2006). In particular, the coastal alluvial plains in central Vietnam are vulnerable to flooding due to high rainfall, narrow coastal plain, short steep rivers, and high population density due to good living conditions in these areas. Flood hazard maps are therefore crucial tools for monitoring the flood risk in this region.

There are several methods for flood mapping that are based primarily on hydrological, meteorological, and geomorphological approaches. In developing countries, where hydro-meteorological data are commonly insufficient, thus limiting the generation of flood models, the geomorphological method is most effective and appropriate (Lastra, Fernández, Díez-Herrero, & Marquínez, 2008; Wolman, 1971). This method uses aerial photo interpretation and field investigations of flood evidence to study geomorphological characteristics in relation to historical flood events (Baker, Kochel, & Patton, 1988). A geomorphological map can assist with studying 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 flooding. Such maps can also reveal the nature of former floods and the probable characteristics of floods occurring in the future (Oya, 2001). This approach to flood investigation has been verified 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). It may therefore be suitable to the study of flooding in the Thu Bon alluvial plain in central Vietnam. Additionally, a method for flood hazard zonation based on the geomorphological approach was developed.

Combining LANDSAT and Shuttle Radar Topographic Mission Digital Elevation Model (SRTM DEM) data is an economical and efficient method for mapping flood hazards and overcoming inadequate data sources in developing countries (Wang, Colby, & Mulcahy, 2002).

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doi:10.1016/j.apgeog.2011.01.005

Supervised land cover classifications from LANDSAT and SRTM DEM data can be combined for coastal flood risk (Demirkesen, Evrendilek, Berberoglu, & Kilic, 2006; Willige, 2007) and digital terrain analysis (Demirkesen, 2008). Three-dimensional (3D) DEM models clearly show the relief, which can indicate the characteristics of landforms (Badura & Przybylski, 2005). Shaikh, Nayak, Shah, and Jambusaria (1989) confirmed the applicability of LANDSAT Thematic Mapper (TM) for alluvial and coastal landform mapping by visual interpretation associated with field surveys and aerial photos. A variety of alluvial and coastal landforms, such as floodplain features, including natural levees, flood basins, paleo-channels, paleo-meanders, oxbow lakes, and coastal landforms, such as estuaries, mudflats, shorelines, dunes, and sand bars could be delineated using this approach. Umitsu, Hiramatsu, and Tanavud (2006) demonstrated the utility of SRTM incorporated with GIS data for studies on flooding and micro-landforms. Ground surface height data from SRTM contributes to the investigation of the relationship between flood-affected areas and flood height.

However, most studies to date have used SRTM and medium resolution LANDSAT data to classify large-scale geomorphological features (e.g., mountains, terraces, plateaus, floodplains); very few studies have made use of such data to extract micro-landforms. This aim of this study was to classify micro-landforms on an alluvial plain and map flood hazard zones using SRTM and LANDSAT images and GRASS GIS software.

GRASS (Geographical Resources Analysis Support System) is open-source general-purpose GIS software for the management, image processing, analysis, modeling, and visualization of many kinds of vector and raster data. In particular, 3D visualization using NVIZ function and extruding from 2D to 3D vectors in GRASS can generate 3D diagrams from 2D raster and vector data, which supports interpretation and visualization of data (Hofierka, Mitášová, & Neteler, 2008; Neteler & Mitasova, 2007). Therefore, this study utilized GRASS as an efficient tool to enhance and support the interpretation and visualization of the data.

Study area

The Thu Bon alluvial plain is formed by the Thu Bon River and the Vu Gia River (Fig. 1). The Thu Bon River, which is approximately 205 km in length, originates from Ngoc Linh Mountain (2598 m) in the Truong Son range in Kon Tum province and then flows through a portion of Quang Ngai province and most of Quang Nam province in central Vietnam. It first runs south, changes its course to a northeasterly direction and finally flows east down to the Thu Bon alluvial plain, where it drains into the South China Sea via the Dai River. The Thu Bon River lacks a distinct alluvial fan (Kubo, 2002). The river channel exhibits a braided and/or anastomosing pattern, which is associated with meandering and anabranching. The alluvial plain is not only governed by fluvial processes due to frequent flooding but also by coastal processes, such as wave, longshore or/and aeolian processes. Therefore, the plain is dominated by levees, meanders, channel bars, and flood basins in inland areas and by sand dunes in the coastal zone.

Sandy sediment dominates the river load and also governs the flow mechanisms and drainage of the river. The bed load of the Vu Gia-Thu Bon basin has increased over the last century due to upstream deforestation resulting in unconsolidated soil, as well as exploitation of high slopes for settlement and cultivation (Centre for Hydro-meteorology Quang Nam, 2001). The average volume of the sediment supply measured at Thanh My gauge station on the Vu Gia River is 460,000 tons per year. Consequently, the delta front is progressively elevated and shifted seaward by sediment deposition, and flood levels have tended to be increasing in recent years (Fig. 2) (CCFSC, 2006; Nguyen, 2007).

This alluvial plain in the central part of Vietnam is characterized by the highest rainfall in the country. The rainy season spans from September to December. The average annual rainfall in upland areas of the basin is approximately 3000–4000 mm, which is much higher than in coastal areas (approx. 2000 mm per year). Approximately 60–76% (75–76% in coastal areas) of the annual rainfall is received in the rainy season and results from storms and typhoons that cause flooding. The major flood events that occurred in this area in 1964, 1999, 2007, and 2009 were caused by complex meteorological phenomena (storms, typhoons, and tropical low pressure) causing torrential rain in most provinces in the central and southern regions of central Vietnam.

Data sources and processing

SRTM DEM characteristics and processing

The Shuttle Radar Topography Mission (SRTM) successfully collected Interferometric Synthetic Aperture Radar (IFSAR) data

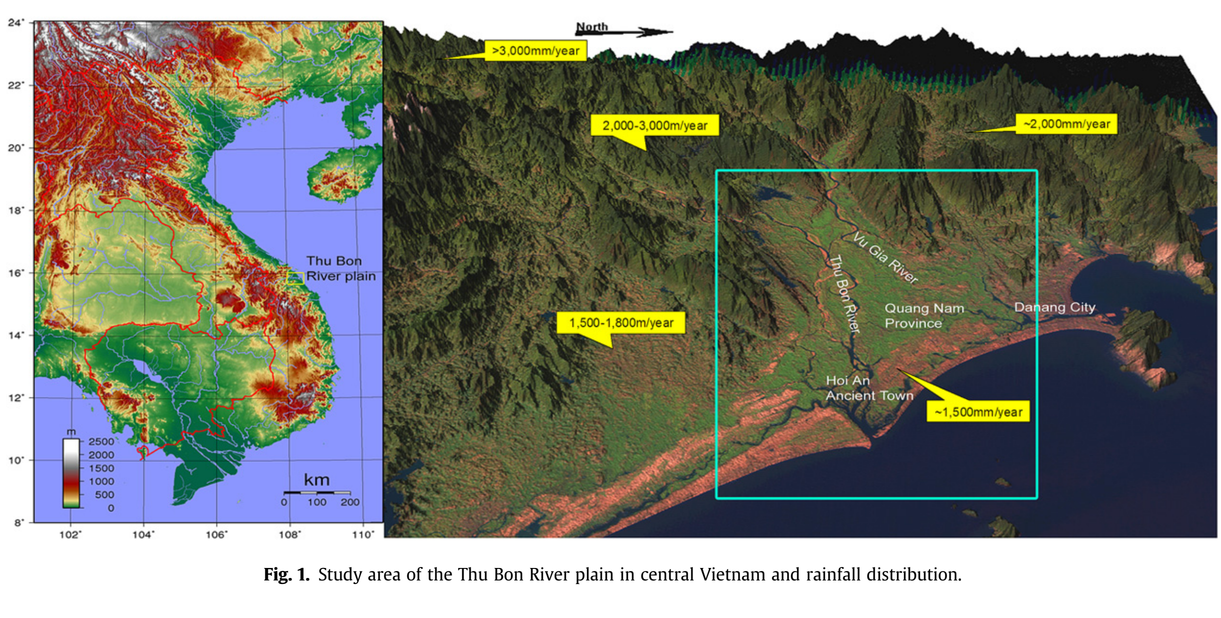

Fig. 1. Study area of the Thu Bon River plain in central Vietnam and rainfall distribution.