REMOTE SENSING AND GIS INTERGRATION FOR TERRAIN EVALUATION AND LAND RESOURCES ASSESSMENT IN NORTH WESTERN VIETNAM

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ABSTRACT

This paper focuses on the study of the terrain and major land features in northwestern Vietnam using remote sensing and Geographical Information System (GIS) to assist in the manipulation and interpretation of spatial data. Representation of the terrain is based on the digital elevation model (DEM) of northwest Vietnam generated from radar interferometry and interpretation of Landsat images. The Landsat TM and ETM+ images of the study area were processed and interpreted to extract information about the major landforms (fault lines, geo-dynamic zones) and land-resources delineation (forest-vegetation cover, water resources, and agricultural and residential areas) in the region. Vegetation cover was characterized by vegetation index (NDVI). The integration of remote sensing methodologies with GIS provides a powerful way of extracting land features inherent in satellite images. The information provided in this study has many areas of application, including in environmental management and planning, hydrological watershed analysis and modeling, landform and natural resource evaluations, geological structural study, and hydropower infrastructure planning and construction.

Keywords: terrain evaluation, digital elevation model, remote sensing, satellite images, spatial data, vegetation, surface land features.

1. INTRODUCTION

Remote sensing (RS) data, including those derived from aerial photographs, are used for terrain evaluation and landform study (Thomas, 1999). RS-images are used for the study of fluvial landform, rock types, geological structures, water bodies and stream networks, and soil erosion. Digital elevation data to conduct such studies are available from the Shuttle Radar Topography Mission (SRTM) provided by the National Aeronautics and Space Administration (NASA), the National Imagery Mapping Agency (NIMA), the German Space Agency (DLR), and Italian Space Agency (ASI). This product with 1 arc-second, 30-m resolution (SRTM-1) or 3 arc-seconds, 90-m resolution (SRTM-3) provides the necessary information to derive elevation models. The multi-spectral Landsat satellite data, including Landsat TM and ETM+, and GIS data (e.g., line and polygon of geological structural features) are used for conducting terrain evaluation and land-resources assessment.

The main objective of this study is to use SRTM products and Landsat TM/ETM+ data integrated with geographical information to evaluate and assess land resources in NW Vietnam. ARC/INFO and ARCVIEW with ARC MACRO LANGUAGE (AML) programming are used to convert the raw SRTM-3 data to construct the DEM. Digital-image interpretation of Landsat TM and ETM+ data in IDRISI was used to extract information concerning vegetation cover, hydrological features (e.g., stream networks and water bodies), and geological features in the area.

2 METHODOLOGY

2.1. The study area

The study area is in NW Vietnam, bounded by China in the north, Laos in the west, the Red River in the east, and the Ma River in the south within the 102-106^{o} E longitude and 20-24^{o} N latitude (Figure 1). The study area is characterized by a humid tropical climate with four distinct seasons, spatially influenced by regional changes in elevation.

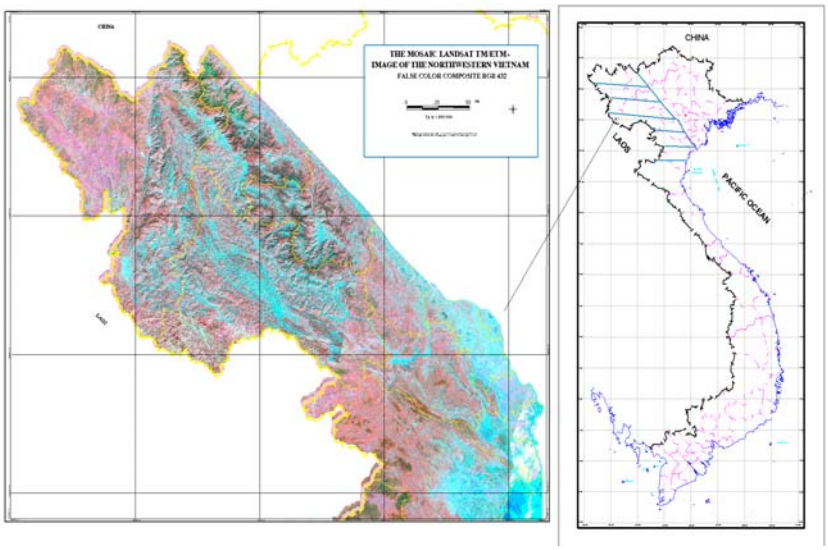


Figure 1. The study area with Landsat TM/ETM^{+} False Color Composite RGB 432 mosaic image

2.2. Data used for the study

RS-data used in this study were Landsat 5 TM and Landsat 7 ETM+ images and SRTM-3 data gathered in January 2000 by the Space-borne Imaging Radar-C (SIR-C). Each SRTM-3 file (34 files in total, with file names n19e102.hgt, n19e103.hgt, n24e108.hgt, n24e109.hgt, …) covered an area of 1^{o} N and 1^{o} E. The Landsat TM/ETM+ mosaic image was constructed from Landsat TM 5 and Landsat ETM+ images with path_row 129_044 (1992) for the TM 5 image and path_rows 129_045, (2000), 128_044 (1999), 128_045 (1999), 128_046 (1999), 127_045 (2000), 127_046 (2000), and 126_047 (2001) for the ETM+ images. GIS information employed in the analysis included a 1:500 000 scale geological map and other spatial data.

2.3. Integrating RS and GIS in terrain & landform analysis

2.3.1 Digital Elevation Model analysis

Raw data from the SRTM-3 product were converted to ARC/INFO grid format using AML. The AML script fixed the negative 16-bit signed DEM values and merged converted files to form a single DEM file. For verification of the DEM, a stream network digitized from a topographic map of the area was placed over the DEM to verify stream-location accuracy with existing DEM landform. The operation was performed in ARCVIEW GIS. The DEM for the study area is shown in Figure 2.

2.3.2 Digital image processing and image interpretation

The Landsat TM and Landsat ETM^{+} data were digitally processed for each scene with spatial geometrical corrections applied in IDRISI. The false color composite (FCC) image with spectral band combination of red (R; band 4), green (G; band 3) and blue (B; band 2) were created for each scene. The color composite image was used to produce a mosaic image of the study area (Figure 1).

The mosaic FCC of the study area was used for image interpretation to extract and evaluate terrain features, including geological faults, stream networks, water bodies, and vegetation cover. Digital-image interpretation was based on a supervised image classification, overlaying of the images, and image rationing.

One of the rationing algorithms for evaluating vegetation characteristic and biomass relationships was based on the Normalized Derived Vegetation Index (NDVI) given as:

$$NDVI = \frac{NIR - R}{NIR - R} \quad ,$$

where NIR and R are the spectral values of the infrared and red wavelength bands of the Landsat TM/ETM+ image.

2.3.3. Spatial analysis

Spatial analysis was performed in GIS to assess terrain features, e.g., water bodies, stream networks, faults, rock type, elevation, land-use classes, and vegetation cover. GIS-RS spatial analysis was used to generate land surface statistics and to assist in the study of spatial relationships between terrain elements for image classification and derivation of the vegetation index.

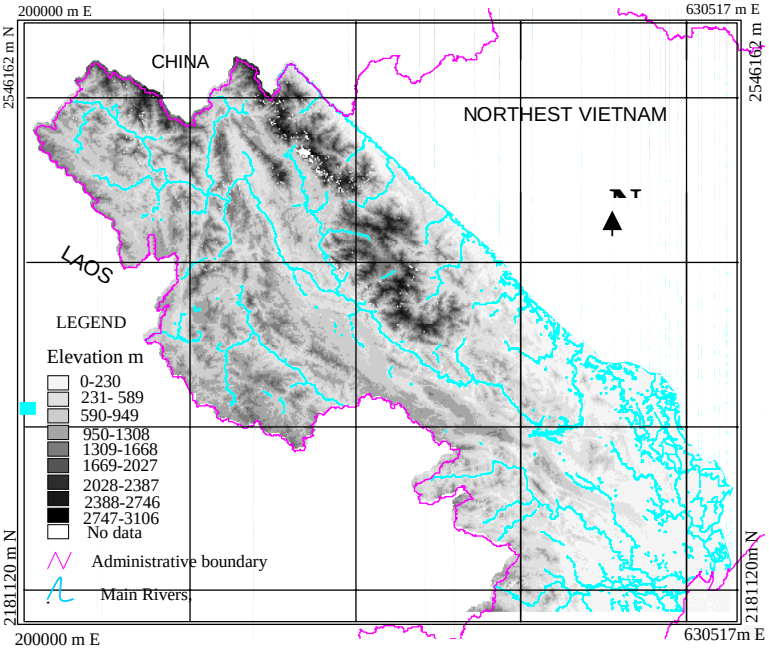


Figure 2. The DEM from SRTM interpheremotry and surface stream network

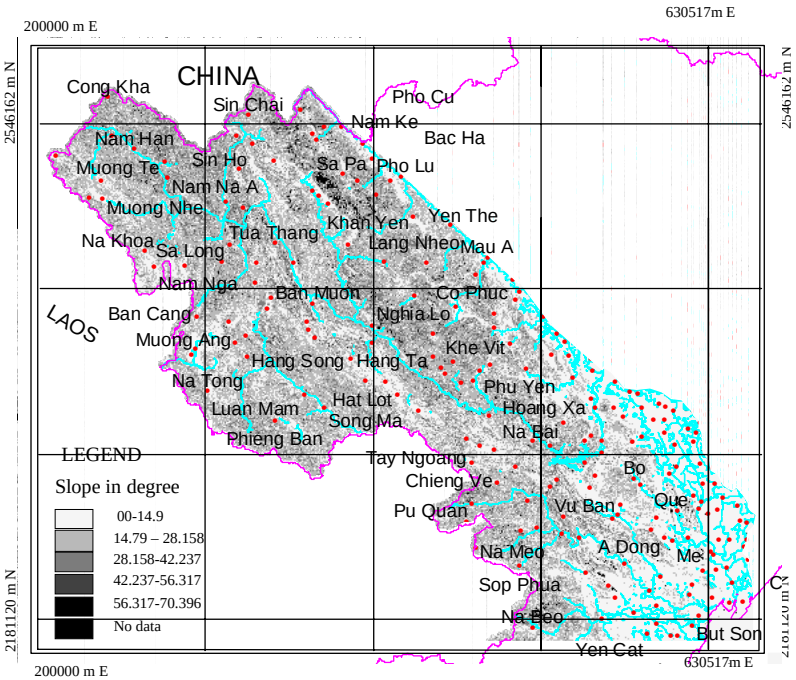


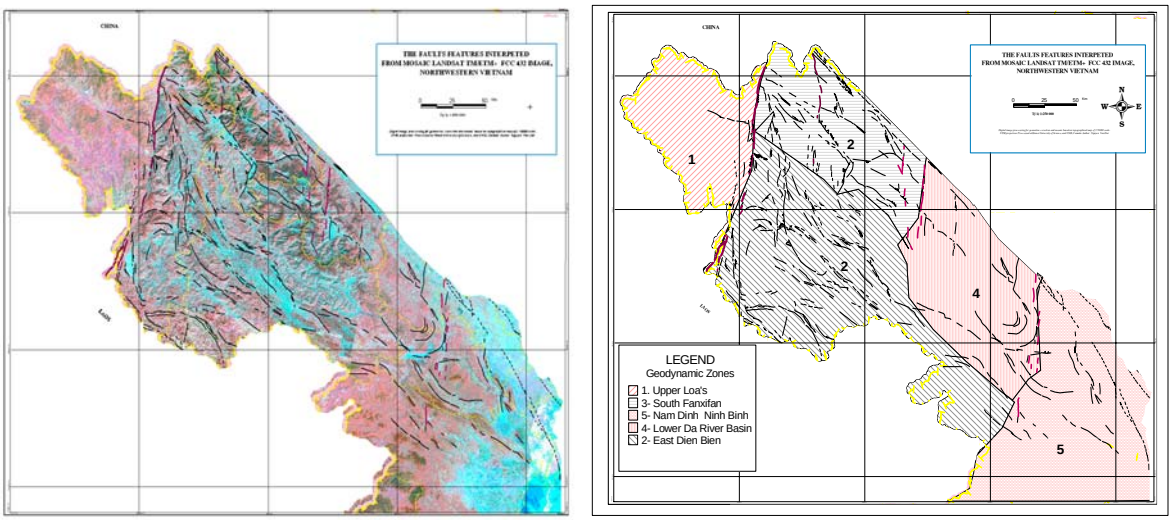
Figure 3. DEM derived slope and stream network.

3. RESULTS AND DISCUSSION

3.1 Evaluating terrain characteristics

1. The elevation in the study area (Figure 2) ranges from 0 m next to the Pacific Ocean to 3106 m in the mountainous region along the NE border of Vietnam. 2. The slopes derived from the DEM (Figure 3) range from ~ 56-70^{o} in a small portion of the study area in the NE, i.e., in Sapa and Hoang Lien Son mountain region, and 0-28^{o} throughout the rest of the region.

3.2. Evaluating hydrological and ecological characteristics



(a) (b)

Figure 4. Faults displayed on FCC 432 Landsat images (a). Image interpretation of fault lines and geodynamic zones (b).

1. The stream network derived from the DEM shows that stream orientation is from the NW to SE. DEM-watershed analysis of the area uncovered four main watersheds, namely the Da River, Mekong River, Thao River, and Hong River watersheds.

2. The ecological setting is expressed by a complex of tree and animal communities defined by local variation in topography. The area can be sub-divided into four ecological zones, namely (i) a low elevation mountain Muong Te zone, (ii) Dien Bien depression zone, (iii) Da Lake shore zone, and (iv) Red River delta zone.

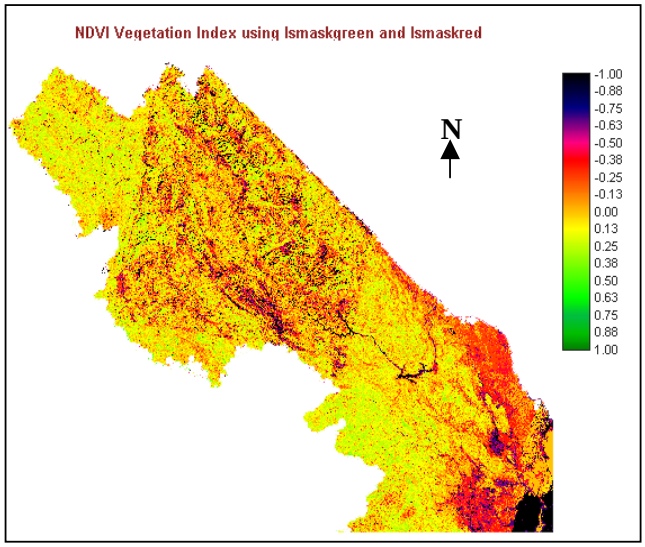


Figure 5. NDVI (1999-2001) map

3.4.1. Evaluating geological faults

The faults appearing in the FCC 432 Landsat TM and ETM+ are shown in Figure 4. There are three kinds of faults displayed: (i) faults with an ~ 5-10^{o} orientation from north (Eocene); (ii) faults with NW-SE direction (Oligocene), and (iii) faults oriented ~ 90^{o} from N (Pliocene - Quaternary). All faults and fault facets are clearly displayed in Figure 4. The three faults types describe the geodynamics since the Eocene era. In view of the geological structure, the study area can be sub-divided into two geodynamic blocks: (i) the Upper Laos tectonic block, and (ii) the North Vietnam block. The North Vietnam block can be further sub-divided into four geodynamic zones: (i) the East Dien Bien, (ii) the South Fanxipan, (iii) the Lower Da River, and (iv) the Ninh Binh- Nam Dinh zones.

3. 5 Land resources assessment

The supervised digital image classification was used to assess land-use classes. The land-use regions are shown in Figure 6. Total land area occupied by the main land-use groups is listed in Table 1.

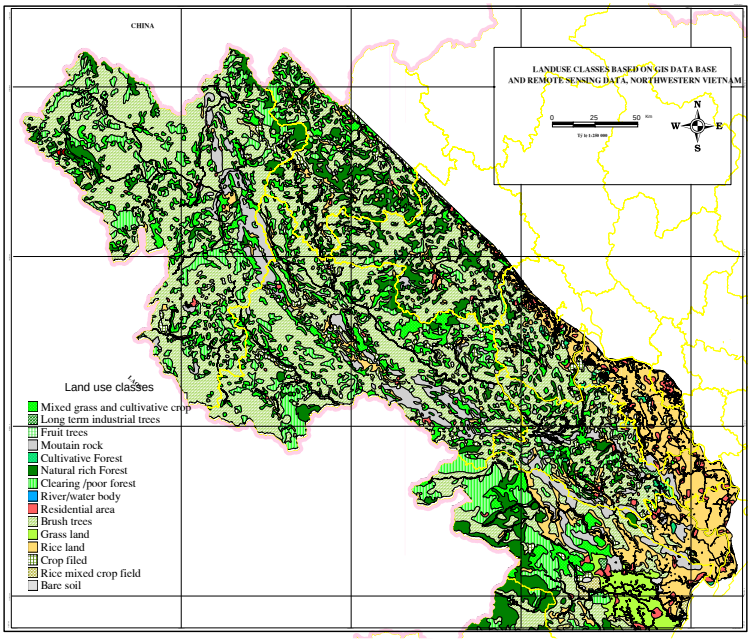


Figure 6. Land use map

3.5.1. Vegetation and forest

Areas with rich, dense vegetation cover have IDVI >0. NDVI map for the study area has values ranging from –1 to 1. NDVI = –1 in Figure 5 (black) describes the areas with no vegetation cover (including water bodies, bare soil, roads). NDVI =1, coincides with areas with dense vegetation cover. These areas are generally located in the mountainous regions of the country. The forest areas (green; Figure 5) form the largest land-use component compared to other land-use types (Table1).

3.5.2. Agricultural land & other land-use classes

Agricultural land consisting of rice fields, crop fields, fruit trees and commercial trees, occupy the second greatest land-use area next to forests. The majority of agricultural land consists of rice fields and rice-crop mixed fields in lower Da River basin and along the Red River flood plain. Total area of agricultural land and land designated to industrial tree growth is given Table 1.

Comments: SRTM products are very good for mountainous areas. Flat areas and undisturbed water surfaces are presented as having no data, because of radar backscattering. SRTM data provide a basis for creating reasonable DEM's for many regions of the world.

4. CONCLUSION

- Remote sensing image interpretation of Landsat TM/ETM+ with GIS is a valuable tool to delineate tectonic faults and geodynamic zones. Radar SRTM products are useful for producing DEM's for conducting terrain stream-network and watershed analysis.

- In this study, four watersheds and four ecological zones were delineated by terrain analysis. The forest area consisted of small natural forests and cultivated forests.

Table 1. Evaluation Land use by

Land use group	Area (sq. m)
Forest	12103235707
Agicultural & industrial trees	10512492538
Residential area	931903634
Water body	866629664
Rock and bare soil	3472073346
Grass land	1094121123
Sparse brush trees	4885840818

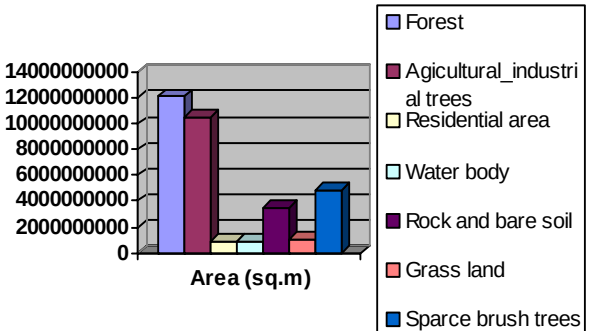


Figure 7. Comparison of land use categories by area

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