USING LANDSAT IMAGES FOR STUDYING LAND USE DYNAMICS AND SOIL DEGRADATION, CASE STUDY IN TAMDUONG DISTRICT, VINHPHUC PROVINCE, VIETNAM

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Abstract
Tamduong district, Vinhphuc province, is representative for vast areas in the north of Vietnam where soils are strongly degraded and erosion has led to patches of bare soil with exposure of parent material and crop yields on these soils are strongly reduced. The aims of this study are to apply satellite imagery for the assessment of the extent of soil degradation and implementing the results to the whole middle altitude area of North of Vietnam. Satellite images Landsat MSS in 1984 (4 bands), TM 1992, 1996 and 2000 (6 bands) were used for creating maps of the Color Composite and Band Ratios. Bare and degraded soils were identified and extracted from the Color Composite and Band Ratios images. The classified map of Band Ratios of the year 2000 was established on the basis of new soil maps and ground truth data, in combination with laboratory analysis of soil quality. The best band ratio was selected for continuously processing and classification base on its visual interpretation and accuracy. Results showed that the band ratio of Red/Near-Infrared bands was selected and classified map of degraded soils matched well with the soil survey map and the field checks with overall accuracy of 65%. Land use and soil degradation dynamics were delineated for the dates 1984, 1992, 1996 and 2000 and degraded soil area of district in these dates are: 2437, 3282, 2185 and 2576 respectively. Hot spots from the Band Ratio imagery appeared to accurately represent the degraded soil areas in the hilly land and the degraded sandy soils on high terraces, but not the agricultural lowland, because on hilly and sandy terraces soil organic matter and soil moisture content were very low. The study shows that satellite imagery is a very useful tool for soil degradation studies.

1. Introduction

Deforestation, desertification and land degradation have been critical global environmental issues during the past decade. Monitoring and cover conditions and their changes is essential to the management of the environmental problems in both of the local and global scale (Olderman, 1994). Vietnam, with a population of 77 million, covers a total land area of 33,104 Mha (Nhuan, 1996), of which three fourths consists of high mountains with a complex topography and steep slopes. Phong (1995) reported that the forest cover in 1945 was 19 Mha, in 1980 12, in 1985 9.6 and in 1992 9.3 Mha. Non-cultivated land up to 1995 was 13 Mha, including 10.4 Mha bare land distributed over 56 soil units of 12 soil groups, consisting of ferrasols (65%), high mountain humus soils (12.6%), eroded land, partially to rock outcrops (8.6%) and others (13.8%). Degraded land in Vietnam (Siem and Phien, 1999) are 5.5 Mha for strong degradation, 4.6 Mha for intermediate and 4.6 Mha for light degradation. It is, therefore, important to monitor land and water management scenarios causing severe soil degradation. Remote sensing is one of the key tools in monitoring local, regional and global environmental issues. More recently, much attention has been paid to spatial analysis due to merging of Geographic Information System (GIS) and satellite images for environmental research and applications (Hill and Schutt, 2000; Harahsheh and Tateishi, 2000 and Harmsen, 2004). The conventional means are however, not only difficult and time consuming but also laborious due to vagaries of the weather. It is prudent to use such emerging technique with an emphasis to its application. Many studies that using remote sensing and GIS have been done (Tateishi, 2003) for soil degradation and gave essential output for management of natural resource conservation of degraded soil for example Gad (2002) use Remote sensing and GIS to obtain land use, land cover maps with 132 field observations and 65 soil profiles to get a final map of soil degradation, Zeleke and Hurni (2001) alerted that soil degradation in Dembecha, Gojam, Ethiopia is increasing when natural forest declined from 27% in 1957 to 2% in 1982 and to 0.3% in 1995. More detailed, Huete (2002) used EO-1 and air-born AVIRIS with field measurements ASD spectroradiometer to detect types and stages of soil degradation. Nizeyimana and Petersen (1998) distinguished the major difference between bare soil and soil with crop residue are 0.45 – 0.66 μm and 0.83 μm, also used Bright Index (BI) derived from multi-spectral spot images to distinguish soil erosion class. The present paper describes an attempt, where in Landsat digital data for different dates used along with field check data to study land use dynamics and soil degradation in Tamduong, upstream district of Red River Delta in North of Vietnam.

2. **Methodology**

2.1 Study area

Tamduong district in Vietnam is located upstream in the Red River Basin (21^0 18’ to 21^0 27’N, 105^0 36’ to 105^0 38’E), about 60 kilometers northeast of Hanoi. The district is located in the transitional zone between almost flat lowlands and mountainous regions. The southern part (3 communes) is flat and characterized by paddy rice and vegetable cropping systems, whereas the middle part (7 communes) consists of alternating flat land and hilly land at altitudes between 20 and 100 m above sea level (asl). More than half of the district area (7 communes in the Northern part) is mountainous along the Tamdao range from northwest to southeast, at altitudes ranging from 100 to 1400 m asl. The district has a total area of 19,779 ha, with 8,045 ha of agricultural land (including 6,147 ha of annual crops and 1,691 ha of perennial crops), 6,744 ha of forest and 1,628 ha non-cultivated land. Seven soil types can be distinguished: *Acrisols, Cambisols, Gleysols, Fluvisols, Plinthosols, Arenosols* and *Leptosols*.

2.2. Methodology

The data used in this study are LANDSAT-MSS image (MSS84) operating in 4 bands with 60m spatial resolution acquired on 8th May 1984 and four LANDSAT-TM images operating in 6 bands with 30m spatial resolution acquired on 21st October 1992, 18th October 1996 and 11st April 2000 (TM92, TM96 and TM00). All thought the time of acquiring images are difference but land cover status quite similar because October is early of dry season with low land cover, but April and May are late of dry and early of rain seasons, biomass is still very low. Bare soil in this time has very low water content. Color Composites (CC) were generated using band combination of R:G:B = 4:3:2 for MSS84 image and R:G:B = 5:4:3 for TM92, TM96 and TM00 images for better and visual interpretation of temporal change of land use and land cover. Band ratios were generated by dividing the pixels in one band by the corresponding pixels in a second band, in this study two kind of BRs are generated from dividing Red band by Green band (ratio = R/G) and dividing Red band by Nir-Infra Red band (ratio = R/NIR).

BR images in 2000 were supervised classified to differentiate the degraded soil from forest and arable soils and other land use classes. The classified map was adjusted to be matched reality by comparing with degraded soil map derived from soil map of district (Khang et al., 1998) and field checks. The best band ratio imagery will be selected for continuously works base on its well fitted with ground truth. Soil degradation was extracted from supervised classified of selected BRs in each date combined with RGB color combinations to simulate land use dynamics and soil degradation area change in the study area.

3. Results and discussion

3.1. Image preprocessing

Before performing digital processing, all images were radiometrically normalized. To compensate for variations in the sensor radiometric responses over time and for variations in natural conditions of solar irradiance and solar angles, digital numbers were firstly converted into exoatmosphere reflectance values (Markham & Barker, 1985) and then were radiometrically rectified (Hall et al., 1991). After radiometric normalization, images were geometrically corrected. The scene acquired in 2000 was converted to the UTM coordinate system using common control points extracted from a topographic map at the scale of 1:50,000. Using a first-degree polynomial rectification algorithm, this procedure yielded a registration accuracy equal to 0.8 pixel. Following this procedure, the others scenes were registered through image-to-image tie-down algorithm using ILWIS 3.0 for windows.

3.2. Image processing and Band Ratio selection

The reason for using BR (Abdeen et al., 2001; Ren, 2003; Giggs, 2004 and Penn, 2002) is twofold: One is that differences between the spectral reflectance curves of surface types can be brought out. The second is that illumination, and consequently radiance, may vary, the ratio between an illuminated and a not illuminated area of the same surface type will be the same. Base on this principle vegetated soil and bare/degraded soil can be differentiated by using band ratios. For R/G ratio bare and degraded soils have high reflectance in red band but low in green one. For vegetated area, red band has lower reflectance than green one. Hence, the ratio of R/G will give high Digital Number (DN) for bare/degraded soils and low for vegetated area. When ratio R/NIR is depicted so that features such as water and roads which reflect highly in the red band and little in near-infrared band. Features such as vegetation has relatively low reflectance in the red band and high reflectance in the near-infrared band (Lillesand and Kiefer, 1994). Therefore, ratio between R/NIR gives high DN value for water, bare soils, and low DN value for vegetation (Figure 1).

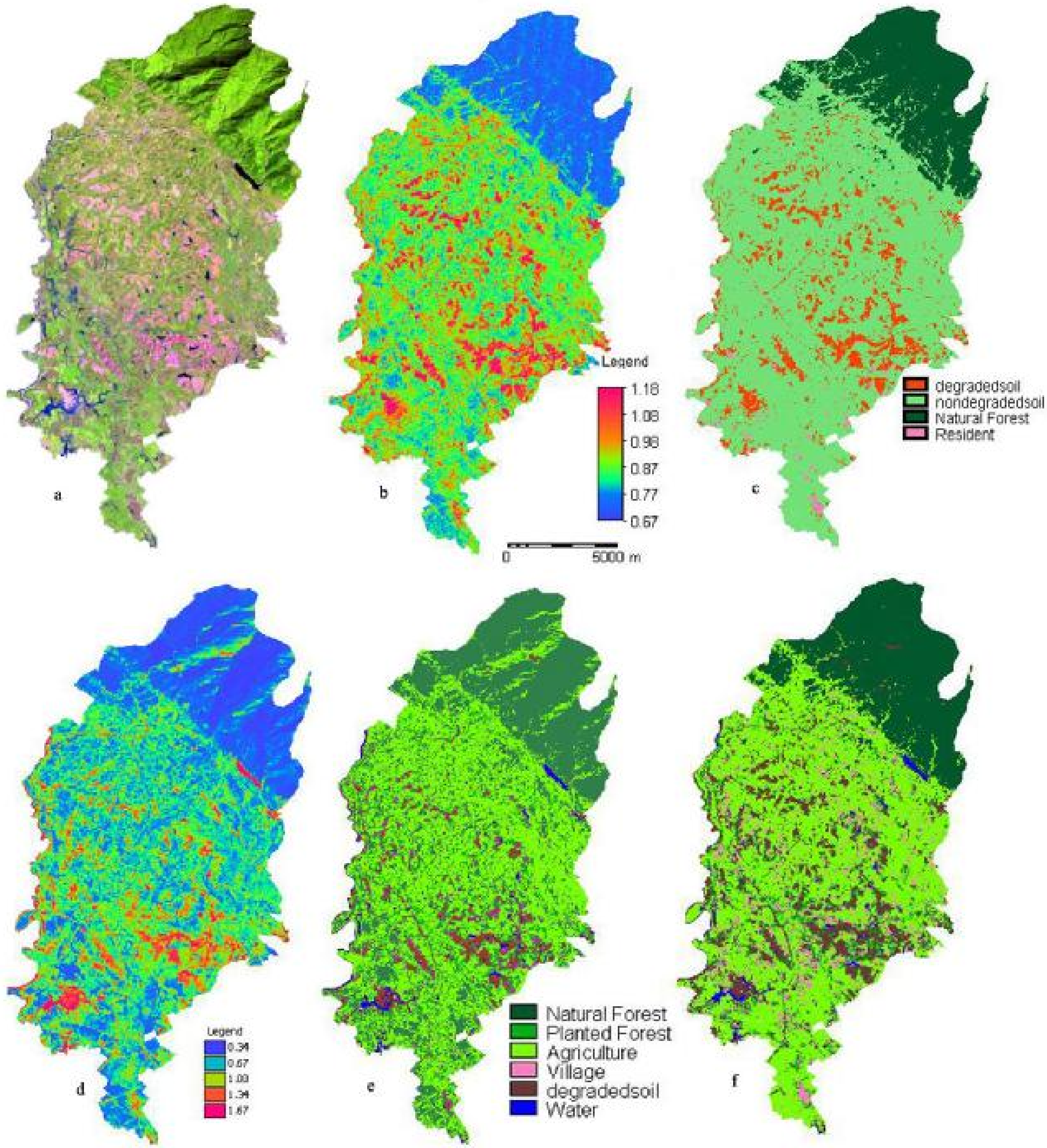

Figure 1: Result maps from Landsat TM 2000 (a) Color Composite RGB 5:4:3, (b) Band ratio R/G (c) supervised classified map from band ratio R/G, (d) Band ratio R/NIR (e) Sliced classified map from band ratio N/NIR and (f) supervised classified map from band ratio R/NIR.

Both BRs images (Figure 1) showed distinction of natural forest (low DN value, blue color) and bare/degraded soils (high DN value, red color) and we can easily differentiate these features. But the differences between two ratio is that in band ratio R/G the DN value is very close between degraded soil and village and between planted forest and agriculture land while these features can be distinguished in band ratio R/NIR image with strongly red color representative for water class, light blue representative for agriculture, green orange for planted forest and red orange for villages. Result in four classes obtained in classified map from BR R/G and 6 classes obtained from BR R/NIR with maintaining of features geometric. In addition, BR R/NIR showed high correlation trend of DN value for different features, that why slicing classified (figure 1e) work well with this BR and gave comparable result with supervised classified map (figure 1f). Base on all advantages mentioned above, the band ratio of Red/Near-Infrared (R/NIR) will be used for next image processing and classification.

3.3. Soil degradation

Soil degradation map in the area was derived from soil map (Khang, 1998) in combination with field checks for each soil unit base on the guideline of Olderman (1994) that soil degradation was classified into different types, cause, degree, rate and extent. According to this reference, the dominated soil degradation in the area is water erosion caused by forest cutting, agriculture production on slopping land with very low/no fertilizer and without soil conservation. Most soil is sandy with very low organic carbon, nutrient content as well as Cation Exchange Capacity.

3. 4. Field observations

Twenty one ground check points were determined degradation in type, state and degree and the result showed a comparable to the classified map (R/NIR band ratio) with 9 points of strong degraded soil, that are bare soil and poor eucalyptus plantation and sandy soil on terraces. Three points of upland soil with cassava and fruit tree plantation have intermediate soil degradation but only two of them lay in the domain of degraded soil in classified map.

The classified map was compared to degraded soil map derived from soil map and field check. It showed most degraded soil in classified map lay in the domain of degraded soil map but not full coverage. This can be explained that in classified map most strongly degraded soil can be extract where the soils were dried, low water content, organic matter and high sand content and also poor land cover. In fact, in one word many degraded soils have been reclaimed by reforestation, applying high organic matter for crops or farm with productive fruit tree, high land cover and biomass. In other word degraded sandy soils located on terraces was cultivated agriculture and its reflectance in red band reduced by crop cover as beans and rice.

5. Soil degradation dynamics

For classification, degraded soil was extracted by classifying BRs between Red and Near-Infrared bands in each date of 1984, 1992, 1996 and 2000. According to classified results (Figure 2), the extent of soil degradation in Tamduong was fluctuated with 2437 ha in 1984, 3282 ha in 1992, 2185 ha in 1996 and 2576 ha in 2000. This trend is reasonable and can be explained by real human activities in Tamduong district, when forest was cut, soil start degraded and get worse until 1992. During 1990-1992 reforestation has started (most was eucalyptus for supplying to paper mill), forest increased with higher land cover and biomass to reduce soil erosion and soil degradation. The productive forest has been massive harvesting since 1996 resulting in bare soil area increased and soil degradation was increased subsequently.

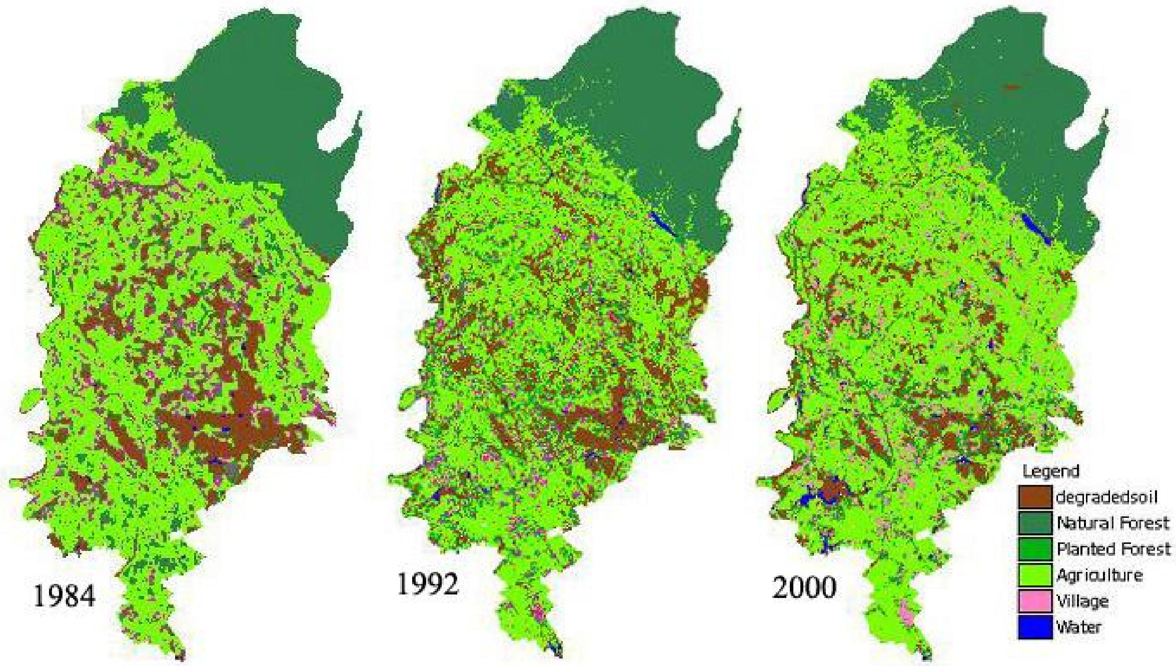

Figure 2: Classified maps derived from Band Ratio R/NIR in 1984, 1992 and 2000 in Tamduong

6. Conclusion

Band ratio of Red/Near-Infrared gave better result than band ratio Red/Green because it showed different DN range for different land use classes. Color Composite and unsupervised classified images of Red/Near-Infrared Band ratio showed that most of degraded soils are located on the hilly land and high-levelled sandy terraces in Tamduong district especially for strong degraded soils and bare soils with very high reflectance and distinguished color. Classified images from dates 1984, 1992, 1996 and 2000 showed very well trend of soil degradation extent in time with 2437 ha in 1984, 3282 ha in 1992, 2185 ha in 1996 and 2576 ha in 2000 that closely related to land use dynamics in the district, especially the forest cover and agricultural activities in upland soil. The results opened an idea to use satellite images for recognition of degraded soil in event types, causes and degrees of soil degradation by testing more satellite images with different resolution and functions in combination with more field check with detail soil properties.

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