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

Mai Van. Trinh[1] , Nguyen. Dinh. Duong[2], Herman. Van. Keulen[1]
[1]Plant Production Systems Group, Wageningen University and Research centre, P.O. Box 430, 6700 AK, Wageningen, The Netherlands
Email:trinh.mai@wur.nl; maivantrinh@yahoo.com
[2] Department of Environmental Information Study and Analysis, Institute of Geography, Hanoi, Vietnam, Tel: 84-4-7562417 Fax: 84-4-8361192
Email: duong.nd@hn.vnn.vn
[1]Plant Production Systems Group, Wageningen University and Research centre, P.O. Box 430, 6700 AK, Wageningen, The Netherlands
Email: herman.vankeulen@wur.nl

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 73.29%. 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 of cover conditions and their changes is essential to the identification of environmental problems at both the local and global scale (Oldeman, 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 steep mountains with a complex topography. Forest cover in 1945 was 19 Mha, gradually declining to 9.3 Mha in 1992 (Phong, 1995). Non-cultivated land comprised 13 Mha up to 1995, including 10.4 Mha bare land, distributed over 56 soil units of 12 soil groups, including ferrasols (65%), high mountain humus soils (12.6%), eroded land, partially rock outcrops (8.6%) and others

(13.8%). A total of 5.5 Mha are strongly degraded. 4.6 Mha intermediately and 4.6 Mha slightly (Siem and Phien, 1999). It is, therefore, important to monitor land and water management practices causing severe soil degradation. Remote sensing is one of the key tools in monitoring local, regional and global environmental issues. Recently, attention has been paid to spatial analysis via combinations of Geographic Information Systems (GIS) and satellite images for environmental research and applications (Hill and Schütt, 2000; Harahsheh and Tateishi, 2000; Harmsen, 2004). Examples of such studies are that of Tateishi (2003) for soil degradation, which yielded essential information for management of natural resources, that of Gad (2002) for obtaining land use and land cover maps on the basis of 132 field observations and 65 soil profiles to finally arrive at a map of soil degradation, and that of Zeleke and Hurni (2001) indicating the increase in soil degradation in Dembecha, Gojam, Ethiopia with declining cover of natural forest from 27% in 1957 to 2% in 1982 and to 0.3% in 1995. At a more detailed level, Huete et al. (2002) combined EO-1 and air-born AVIRIS with field measurements of an ASD spectroradiometer to identify types and stages of soil degradation. Nizeyimana and Petersen (1998) identified the major difference between bare soil and soil with crop residue as between 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. In the present paper a study is described in which Landsat digital data for different dates are used in combination with ground truth data to study land use dynamics and soil degradation in Tamduong, an upstream district in the Red River Delta in the 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 km northeast of Hanoi, in the transitional zone between almost flat lowlands and the mountainous regions. The flat southern part (3 communes) is characterized by paddy rice and vegetable cropping systems; the middle part (7 communes) consists of alternating flat and hilly land at altitudes between 20 and 100 m above sea level (asl). More than half of the district (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 one LANDSAT-MSS image (MSS84) operating in 4 bands with 80m 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). Al though the images are acquired at difference dates, the land cover status is quite similar, because October is the early dry season with low land cover, while April and May are late dry and early rainy seasons, respectively, when biomass is still very low, as is soil water content. Color Composites (CC) were generated using band combination of RGB = 4:3:2 for the MSS84 image and RGB = 5:4:3 for the TM92, TM96 and TM00 images for visual interpretation of temporal changes in land use and land cover. Use of band ratios (BRs), generated by dividing the pixels in one band by the corresponding pixels in a second band, to suppress illumination differences attributable to surface albedo, incidence angle and topographic effects, has long history of successful applications to multispectral data. In this study two kinds of BR are generated by dividing the

Red band by the Green band (ratio = R/G) and dividing the Red band by the Nir-Infra Red band (ratio = R/NIR). The 2000 image was supervised classified to differentiate degraded soil from forest and arable soils and other land use classes. The classified map was adjusted to match reality by comparison with the map of degraded soils derived from the district soil map (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 deduced from the supervised classified of selected BRs at each date combined with the RGB color combinations to simulate land use dynamics and soil degradation area changes in the study area.

3 RESULT 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 first converted into exo-atmosphere reflectance values (Markham and Barker, 1985) and subsequently radiometrically corrected (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 other images were registered through an image-to-image tie-down algorithm using ILWIS 3.0 for Windows.Second order headings like the one above are in 12 pt bold face, 2 lines (12 pt) below the preceding paragraph and one line (12 pt) above the succeeding text.

3.2 Image processing and Band Ratio selection

There are two reasons for using BR (Abdeen et al., 2001; Penn, 2002, Ren and Abdelsalam, 2003; Giggs, 2004): (i) differences between the spectral reflectance curves of surface types can be brought out. (ii) Illumination, and consequently radiance, may vary, the ratio between an illuminated and a non-illuminated area of the same surface type will be the same. Based on this principle, vegetated soil and bare/degraded soil can be differentiated by using the band ratios. For R/G ratio bare and degraded soils show high reflectance in the red band but low in the green one, while the vegetated soils shows lower reflectance in the red band. Hence, the ratio of R/G will give high Digital Numbers (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).

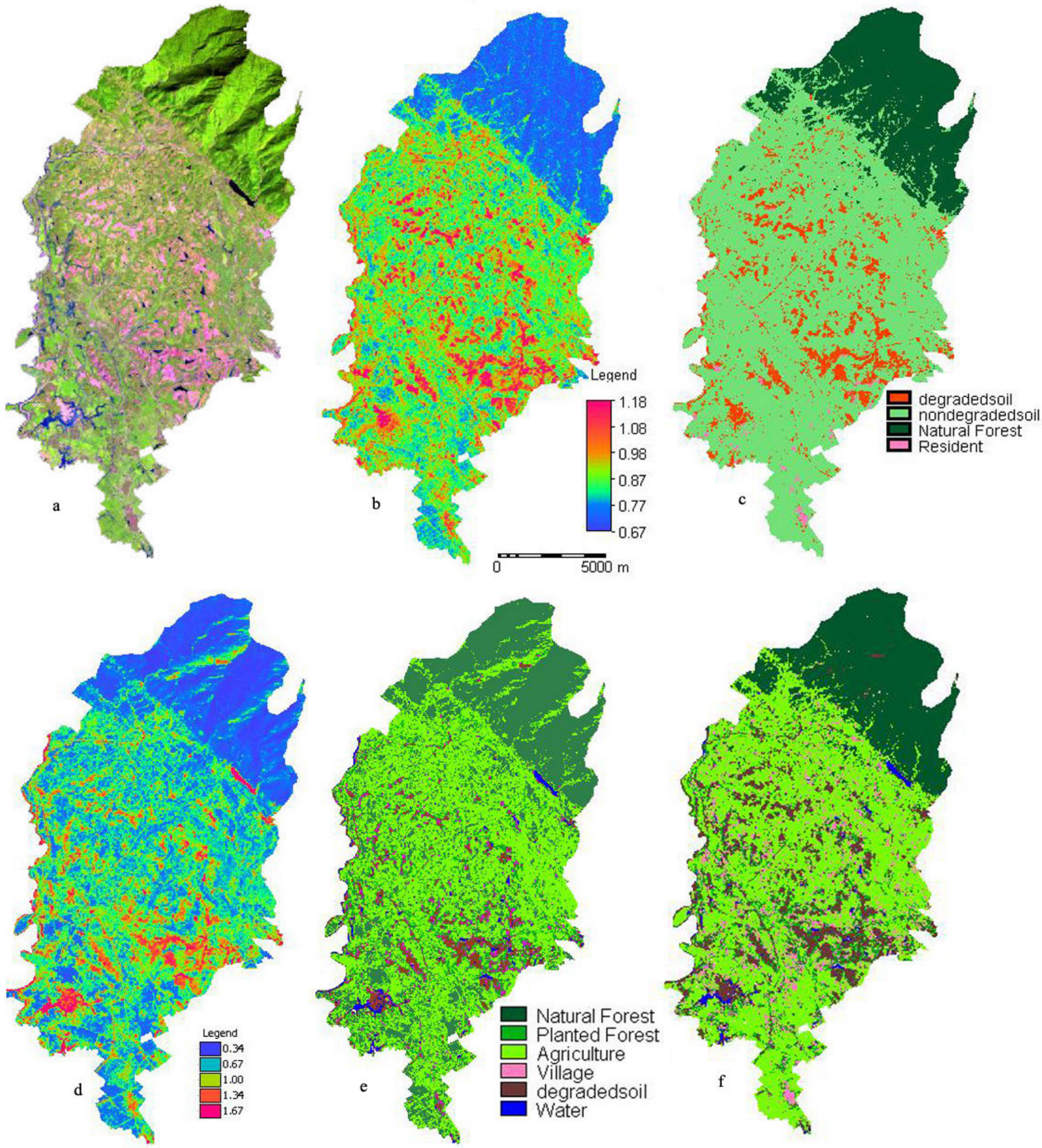

Figure 1. Result maps from Landsat TM 2000 (a) Color Composite RGB 5:4:3, (b) Band ratio red/green (c) supervised classified map from band ratio red/green, (d) Band ratio red/near-infrared (e) Sliced classified map from band ratio red/near-infrared and (f) supervised classified map from band ratio red/near-infrared.

On both BRs images (Figure 1), natural forest (low DN value, blue color) and bare/degraded soils (high DN value, red color) can easily distinguished visually. 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 imagery 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) would be used for next image processing and classification.

3.3 Soil degradation

The soil degradation map for the area was derived from the soil map (Khang *et al.*, 1998) in combination with field checks for each soil unit based on the guidelines of Oldeman (1994) where soil degradation was classified into different types, causes, degrees, rates 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

For each of twenty one ground truth points we determined type, state and degree of degradation and the results showed satisfactory agreement with the classified map (R/NIR band ratio), with 9 strongly degraded observations, on bare soil, poor eucalyptus plantations and sandy soil on terraces. Three points on upland soil with cassava and fruit tree plantations have intermediate levels of soil degradation, but while only two were part of the degraded domain on the classified map.

The classified map was compared to the soil degradation map derived from the soil map and ground truth data showing that most soil classified as degraded on the classified map was located in the degraded domain of the soil degradation map, but not completely. The reason is that on the classified map the most strongly degraded soils were identified where soils were dry, with low organic matter content, high sand content and poor land cover. However, as explained before, part of the degraded soils have been reclaimed through reforestation, application of high organic matter doses for crops or through planting of productive fruit trees, with high land cover and biomass. In other words degraded sandy soils located on terraces are being cultivated, and their reflectance is thus reduced, as they are covered by crops, such as beans and rice.

3.5 Soil degradation dynamics

For classification, degraded soil was identified by classifying BRs between the red and near-infrared bands for all dates in 1984, 1992, 1996 and 2000. The results (Figure 2) yielded an attractive picture of soil degradation dynamics since 1984. The extent of soil degradation in Tamduong fluctuated from 2437 ha in 1984 via 3282 ha in 1992 to 2185 ha in 1996 and 2576 ha in 2000. This trend is reasonable and can be associated with real human activities in Tamduong district: when forest was cut, soil degradation started and aggravated till 1992. During the years 1990-1992, large-scale reforestation took place (mostly Eucalyptus for supply to the paper mill), with the associated higher land cover and biomass, reducing erosion and soil degradation. The productive forest has been harvested since 1996, resulting in larger bare soil areas and increased soil degradation.

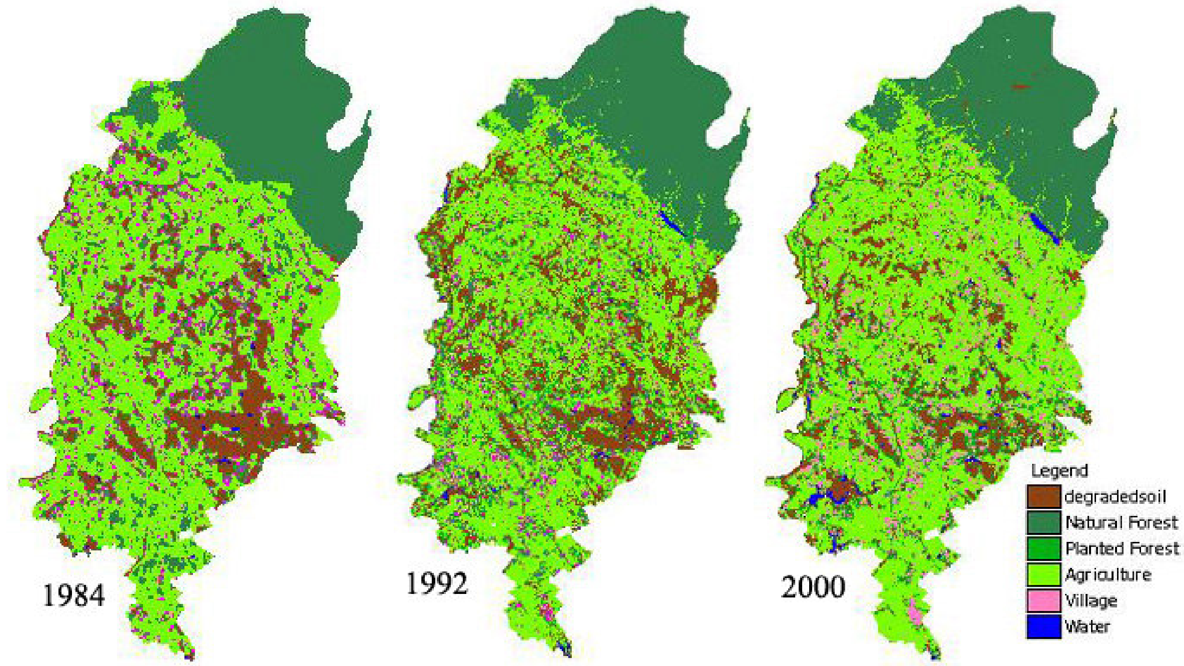

Figure 2: Classified maps derived from Band Ratio R/NIR in 1984, 1992 and 2000 in Tamduong.

4 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 supervised classified images of red/near-infrared band ratio showed that in Tamduong district in Vietnam, most degraded soils, especially the strongly degraded and bare soils, with very high reflectance and distinct colours, are located on the hilly land and high-levelled sandy terraces. Classified images from 1984, 1992, 1996 and 2000 very clearly show the trends in the extent of soil degradation with 2437 ha in 1984, 3282 ha in 1992, 2185 ha in 1996 and 2576 ha in 2000, a trend that is closely related to land use dynamics in the district, especially the forest cover and agricultural activities in the upland soils. These results illustrate the possibilities for use of satellite images for identification of degraded soils. Moreover, types, causes and degrees of soil degradation could possibly be identified by testing more satellite images with different resolution and functions in combination with more ground truth data, including detailed soil properties.

REFERENCES

Abdeen, M. M., Thurmond, A. K., Abdelsalam, M. G. and Stern, R. J., 2001. Application of ASTER Band-Ratio images for geological mapping in arid regions: the Neoproterozoic Allaqi Suture, Egypt. GSA (The Geological Society of America) Annual Meeting, November 5-8, 2001 Boston, Massachusetts

Gad, A., 2002. Characterizing the environmental conditions of land use/land cover classes towards the assessment of desertification: case study in NorthWestern coast of Egypt. *Paper no 2114, Symposium no 46, 17th World Congress of Soil Science*, 14-21 August 2002, Bankok, Thailand.

Hall, F. G., Strebel, D. E., Nickeson, J. E. and Goetz, S. J., 1991. Radiometric rectification: Toward a common radiometric response among multidate, multisensor images. *Remote Sensing of the Environment* 35, 11-27.

Harahsheh, H. and R. Tateishi, 2000. Desertification Mapping Of West Asia -A GIS and Remote Sensing Application. http://www.gisdevelopment.net/aars/acrs/2000/ts11/glc001b.shtml.

Harmsen, K., 2004. Assessment of the use of RS and GIS in India. http://www.gisdevelopment.net/magazine/gisdev/2004/april/assessment5.shtml.

Higgs, G. K., 2004. Supervised classification of TM band ratio images and radar for geological interpretations of central Madagascar. *Geological Society of America Abstracts with Programs* 36, 7.

Huete, A., X. Gao, H. J. Kim, T. Miura, C. Borghi and R. Ojeda, 2002. Characterization of land degradation in Central Argentina with hyperspectral AVIRIS and EO-1 data. *Paper no 987, Symposium no 46, 17th World Congress of Soil Science*, 14-21 August 2002, Bangkok.

Khang, N., Tan, N. V., Pho, N. C., Liem, T. V., Anh, N. T., Hai, N. V., Toan, N. D., Tu, V. A., Hai, T. T., 1998. *Soil map of Vinhphuc province.*

Markham, B. L. and J. L. Barker, 1985. Spectral charaterization of Landsat Thematic Mapper Sensors. *International Journal of Remote Sensing* 5, 679-716.

Lillesand, T. M. and R. W. Kiefer, 1994. *Remote sensing and image interpretation*. John Wiley & Sons, Inc., London.

Nhuan, C. T., 1996. Agricultural and forestry land allocation in Vietnam. *Vietnam Soil Science* 7, 35-41.

Nizeyimana, E. and G. W. Petersen, 1998. Remote sensing application to soil degradation assessment. Method for assessment of soil degradation. *Advances in Soil Science* XX, 393-405.

Penn, B. S., 2002. Applying band ratios to hyperspectral imagery data. *Remote Sensing and Geographic Information Systems in the New Millennium: Their Use in Environmental and Engineering Geology*. Colorado Convention Center, October 30, 2002.

Phong, T.A., 1995. Open and bare land in Vietnam. *Vietnam Soil Science* 5: 67 - 69.

Ren, D. and Abdelsalam, M. G., 2003. ASTER band-ratio images for geological mapping in arid regions: the Neoproterozoic Allaqi-Heiani Suture, southern Egypt. South-Central Section (37th) and Southeastern Section (52nd). GSA (The Geological Society of America) Joint Annual Meeting (March 12–14, 2003), Memphis.

Siem, N. T. and T. Phien, 1999. *Upland soils in Vietnam - Degradation and rehabilitation*. Agriculture Publishing House, Hanoi.

Statistical Publishing House, 2000. *Statistical data of Vietnam Agriculture, Forestry and Fishery 1975-2000.* Statistical Publishing House, Hanoi.

Oldeman, L. R., 1994. An International Methodology for an Assessment of Soil Degradation: Land Georeferenced Soils and Terrain Database. In: *The collection and analysis of land degradation data*. Report of the Expert consultation of the Asian Network on Problem soils, Bangkok, Thailand, 25 to 29 October, 1993. pp. 35-60.

Tateishi, R., 2003. Land Cover Data and Desertification Data of Asia. http://www.arsrin.net/contents/mar2003/p69.htm.

Zeleke, G. and H. Hurni, 2001. Implication of land use and land cover for mountain resource degradation in the Northwestern Ethiopian highlands. *Mountain Research and Development* 21: 184-191.