Eco-environmental vulnerability evaluation and land use/land cover changes through Landsat time series data

Anh Kim **NGUYEN**, Yuei-An **LIOU**[*], and Ming-Hsu **LI**

Abstract: Eco-environmental vulnerability changes are assessed and classified into six vulnerability levels consisting of *potential, slight, light, medium, heavy,* and *very heavy* vulnerabilities. Patterns of *heavy* and *very heavy* vulnerability levels exhibit an increasing trend in both magnitude and spatial size over the time frames of concern in 1989-2003 and 2003-2014. The evolving pattern of urban thermal anomalies is highly associated with sprawl of developed land and tightly correlated with higher eco-environmental vulnerable levels, namely *medium, heavy*, and *very heavy*. It is concluded that increased human activities have intensified the vulnerability of eco-environment in the study area, the Thua Thien - Hue Province of Vietnam.

Keywords: Vulnerability; Eco-environment; Landsat data;

1. Introduction

Anthropogenic activities alter natural systems and lead to eco-environmental vulnerabilities. It is vital to improve understanding of human influences on eco-environment and evaluate the trend of eco-environment changes driven by land surface parameters in the past decades. In this study, we investigate the trend and regions where tend to experience vulnerability through an assessment framework that groups variables based on remote sensing data alone. We focus on the Thua Thien - Hue Province because it has been experiencing environmental problems (triggering water, soil, and air pollution) devastatingly with rapid urbanization, deforestation, and natural disasters, which tend to damage the eco-environment. In the previous work (Nguyen et al., 2016), we proposed an assessment framework with involvement of 16 variables including those extracted from Landsat 8 OLI, digital maps, and in situ-measurement data to evaluate the eco-environmental vulnerability in the Thua Thien – Hue

Province. However, insufficient historical in situ-measurement data and relevant maps often cause a barrier for long-term eco-environmental monitoring. Thus, we extend the previous work by proposing an improved assessment framework with the use of variables derived from satellite data alone to monitor the eco-environmental changes in both spatial distribution and vulnerable magnitude over the past 20 years (1989-2014). Landsat data imagery in the same summer season capturing dynamics of land surface properties is utilized. The relationship between land cover changes and urban thermal anomalies is also investigated.

2. Methodology

There are three major steps for data processing (Fig. 1):

Yuei-An Liou
Professor
Center for Space and Remote Sensing Research, National Central University, No. 300, Jhongda Rd., Jhongli District, Taoyuan City 32001, Taiwan, ROC. Tel.: +886 3 4227151x57631.
yueian@csrsr.ncu.edu.tw

(i) Preprocessing Landsat data images and calculation of environmental variables),

(ii) Calculating the weight for every variable/factor/layer, and class, and

(iii) According to variable's weight, applying algebra computations in ArcGIS to produce maps of four group variables as well as the synthesis map.
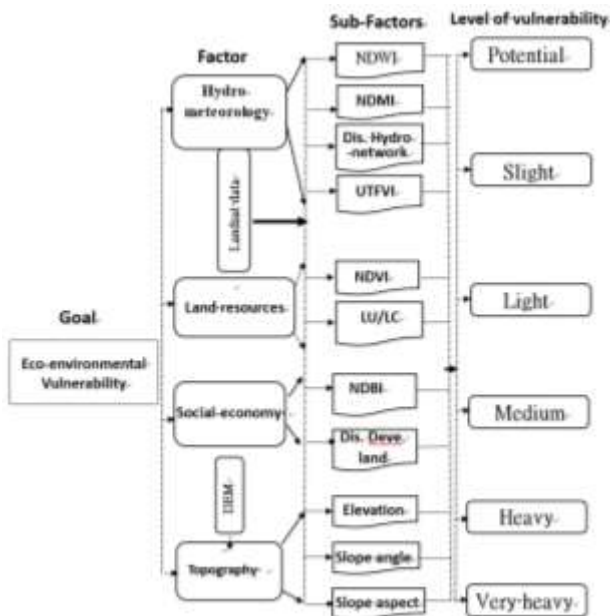

Figure 1. Eco-environmental vulnerability assessment framework.

3. Case study

The Thua Thien - Hue Province covers an area of 5,054 km^2 in the north central coastal region of Vietnam with coordinates of 15° 59'-16° 48'N and 106° 25'-107° 51'E, comprising two basins of four rivers and Hue city, the provincial capital (Fig. 1). Due to its location in the tropical monsoon basin, the average annual temperature ranges from 21° C to 26° C. The highest temperature (approximately 41.3 ^{o} C) normally occurs in June, July, and August, while the lowest temperature (12 ^{o} C) occurs in November, December, and January. The average relative humidity is around 84-85%. Annual average precipitation may reach 2,500-3,500 mm in the plains and 3,000-4,500 mm in the mountains. In general, the Thua Thien - Hue Province is the most vulnerable to tropical cyclones in Vietnam and experienced with urbanization and fast economic development. Thus it is a good example for this study.
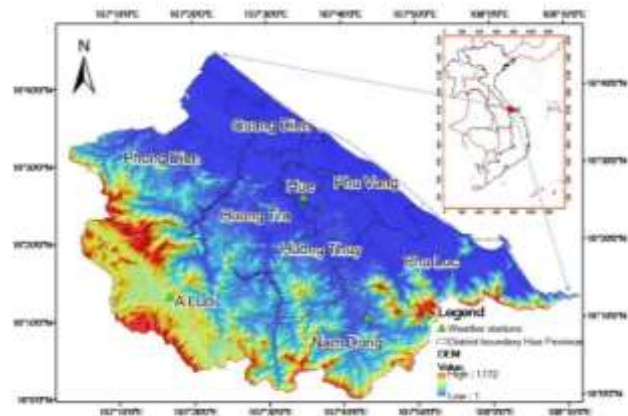

Figure 2. Study area

3.1. Study materials

(1) Remotely sensed Landsat time series images include Landsat 5 TM images (acquired on 08 May 1989; 03 December 1990), Landsat 7 ETM+ images (acquired on 21 April 2003; 06 November 2000), and Landsat 8 OLI & TIRS images (acquired on 27 April 2014; 04 October 2014). Those images acquired in summer months are used to examine the LST and land cover changes with supporting seasonal vegetation features by using those images acquired in winter months.

(2) Digital elevation model (DEM) with resolution of 20 meters provided by Vietnam Publishing House of Natural Resources, Environment, and Cartography, and

(3) Meteorological data of three stations, Hue, A Luoi, and Nam Dong (Fig. 2).

3. Results

3.1 Variables and group variables analysis

Yuei-An Liou
Professor
Center for Space and Remote Sensing Research, National Central University, No. 300, Jhongda Rd., Jhongli District, Taoyuan City 32001, Taiwan, ROC. Tel.: +886 3 4227151x57631.
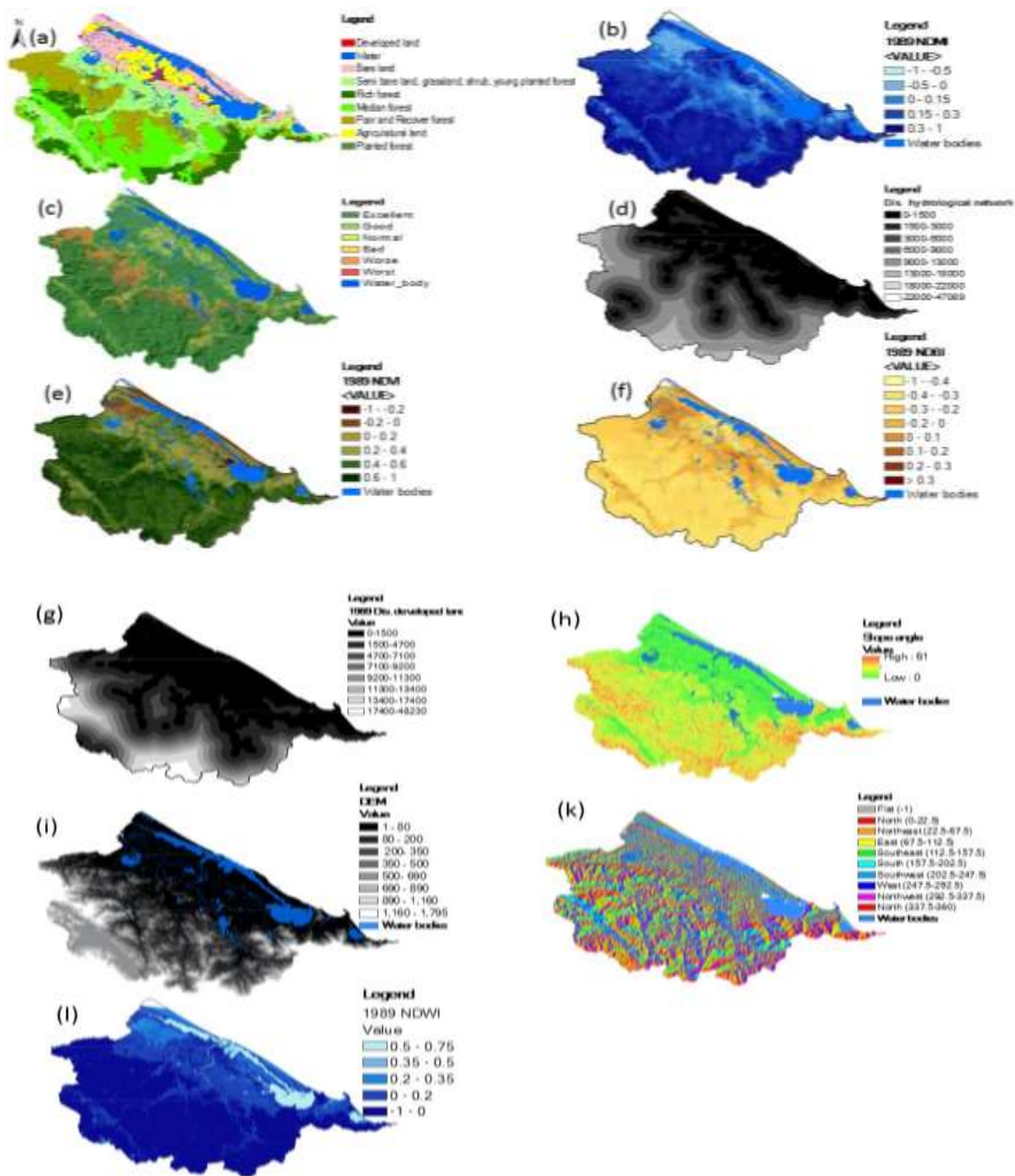yueian@csrsr.ncu.edu.tw

Figure 3. 11 Variables extracted from Landsat data and DEM over the the Thua Thien-Hue Province in 1989. (a) Land use/Land cover; (b) Normalized Difference Moisture Index (NDMI); (c) Urban Thermal Field Variance Index (UTFVI); (d) Distances from hydrological network; (e) Normalized Difference Vegetation Index (NDVI); (f) Normalized Difference Built-up Index (NDBI); (g) Distances from developed land; (h) Slope angle; (i) DEM; (k) Slope aspects; (l) Normalized Difference Water Index (NDWI). (The same method for the years in 2003 and 2014).

Yuei-An Liou
Professor
Center for Space and Remote Sensing Research, National Central University, No. 300, Jhongda Rd., Jhongli District, Taoyuan City 32001, Taiwan, ROC. Tel.: +886 3 4227151x57631.
yueian@csrsr.ncu.edu.tw
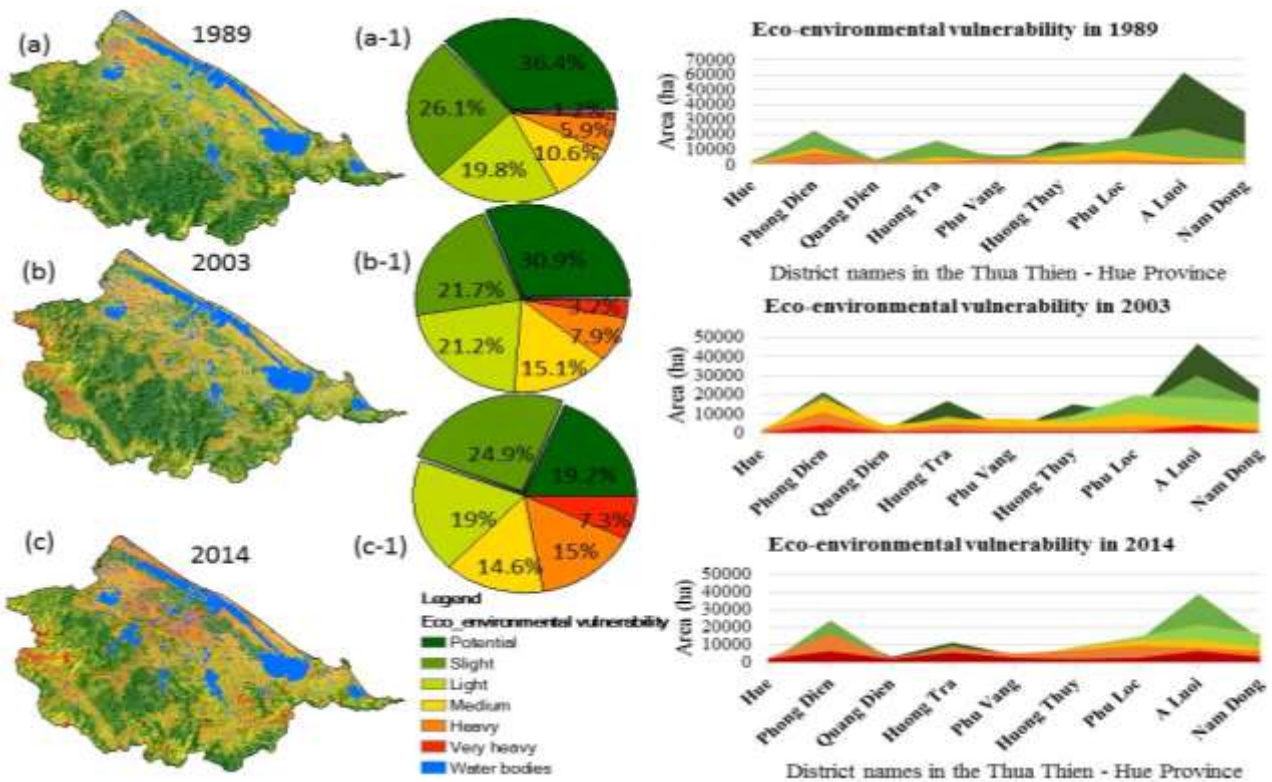
3.2 Eco-environmental vulnerability analysis

Figure 4. The maps of eco-environmental vulnerability in the Thua Thien – Hue Province in 1989, 2003, and 2014.

4. Discussions and Conclusions

Fig.4 presents eco-environment vulnerability patterns in the Thua Thien - Hue Province during the period of timeframes from 1989-2003 to 2003-2014 generated from four determinants including hydrometeorology, land resources, topography, and social economics. An overall perspective, eco-environmental vulnerability had an increasing trend and the contribution of *heavy,* and *very heavy* vulnerability levels show evolving patterns (for *heavy* vulnerability level raised from 5.9% in 1989 to 7.9% in 2003 and 15% in 2014; for very *heavy* vulnerability level climbed from 1.2% in 1989, to 3.2% in 2003, and 7.3% in 2014). In contrast, there was a significant decline in *potential* vulnerability level (36.4% in 1989, 30.9% in 2003, and 19.2% in 2014. The remaining vulnerability levels include *slight, light, medium* fluctuated slightly by increasing in 2003 and decreasing in 2014. The driving factors of eco-environmental vulnerability were increased in *heavy* and *very heavy* levels and declined in *potential* levels throughout the period 1989, 2003, and 2014 mainly caused by expansion of developed land, developing cultivation, and narrowing natural forest land.

References

Nguyen, A.K., Y.A. Liou, M.H. Li, and T.A. Tran., 2016. Zoning eco-environmental vulnerability for environmental management and protection, *Ecol. Indic.* Vol 69, 100–117. *doi:10.1016/j.ecolind.2016.03.026. (SCI, IF:* 3.649*).*

Yuei-An Liou
Professor
Center for Space and Remote Sensing Research, National Central University, No. 300, Jhongda Rd., Jhongli District, Taoyuan City 32001, Taiwan, ROC. Tel.: +886 3 4227151x57631.
yueian@csrsr.ncu.edu.tw