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Spatio-temporal Land Cover Change Detection in the Lake Bosomtwe Catchment

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ABSTRACT

This study investigates the spatio-temporal land cover changes within 6 km of Lake Bosomtwe catchment in Ghana. In this study, Landsat images acquired on February 1, 2008 and January 13, 2013 were used. Ground Control Points (GCPs) were taken with a handheld Juno SB GPS receiver at strategic locations to verify land cover types. Unsupervised and Supervised (hybridized) classifications were performed to generate land cover maps of the study area. Three land cover classes were distinguished. They were water, vegetated and non-vegetated areas. The vegetation cover map of 2008 and 2013 obtained from the hybridized classification were then analyzed to determine the change in land cover over the period. In addition, the Normalized Difference Vegetation Index (NDVI) was applied to identify areas of vegetation and non-vegetation cover. The study revealed decrease in vegetation cover of the study area. For example, between 2008 and 2013 vegetation cover decreased by 4.65 km^2. The research therefore recommends that management intensifies the Lake Bosomtwe reforestation project.

Keywords: Lake Bosomtwe, NDVI, Vegetation, spatio-temporal, land cover, Ghana

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I. INTRODUCTION

Land cover is a basic variable that impacts on the human and physical environments. Land cover change is also regarded as the most important variable of global change affecting ecological systems (Vitousek, 1994; Skole, 1994). Globally, land cover is altered mostly by direct human activities (Nagendra *et al*., 2003). There are also impacts from acid rain and from automobile exhaust (Meyer, 1995). Significant land cover changes have been reported during the last century both on spatial and temporal scales (Mitch, 1993). Lake Bosomtwe is situated about 30km south-east of Kumasi and is a popular recreational area. The lake is also the only significant natural lake in Ghana and therefore attracts a lot of tourists and other human activities. Management of the lake area, over the years, has found it difficult to protect and preserve the lake. Extensive and repeated farming activities have altered and degraded the original vegetation. Since vegetation influences air quality and human health (Wagrowski and Hites, 1997) and also provides a useful means for recognising changes in other environmental factors (Mantey *et al*., 2011), the aim of this research was to determine the land cover change pattern of the Lake Bosomtwe catchment.

II. MATERIALS AND METHODS

2.1 Study area

Lake Bosomtwe is sited within an age-old meteorite impact crater and is approximately 8 km across and is the only natural lake in Ghana (Anon., 2006), as shown in Figure 1. The Lake is 10.5 km in diameter and is estimated to be 1.07 million years old. The crater has been partly eroded, and is situated in dense rainforest, making it difficult to study and confirm its origin by meteorite impact. It is situated about 30 km south – east of Kumasi and is a popular recreational area. There are about 30 villages near this Crater Lake, with a combined population of about 70 000 people.

Bosomtwe District is located at the central portion of the Ashanti Region. It lies within latitudes 6° 43′ North and longitudes 1° 46′ West. It spreads over a land area of 718 (sq.km). The District is bounded on the North by Atwima Nwabiagya and Kumasi Metropolis and on the East by Ejisu-Juaben Municipal. The southern section is bounded by Amansie West and East Districts. Kuntinase is the District Capital (Anon., 2006).

This study investigates only areas within 6 km of the catchment of the lake and some of the communities located within the study area include Abono, Pepiakuma, Kuntanse, Dadiasi, Ochereso and Beposo Achiasi. The lake is bounded by two districts which are Bosomtwe – Kwanwoma District and Amansie East District.

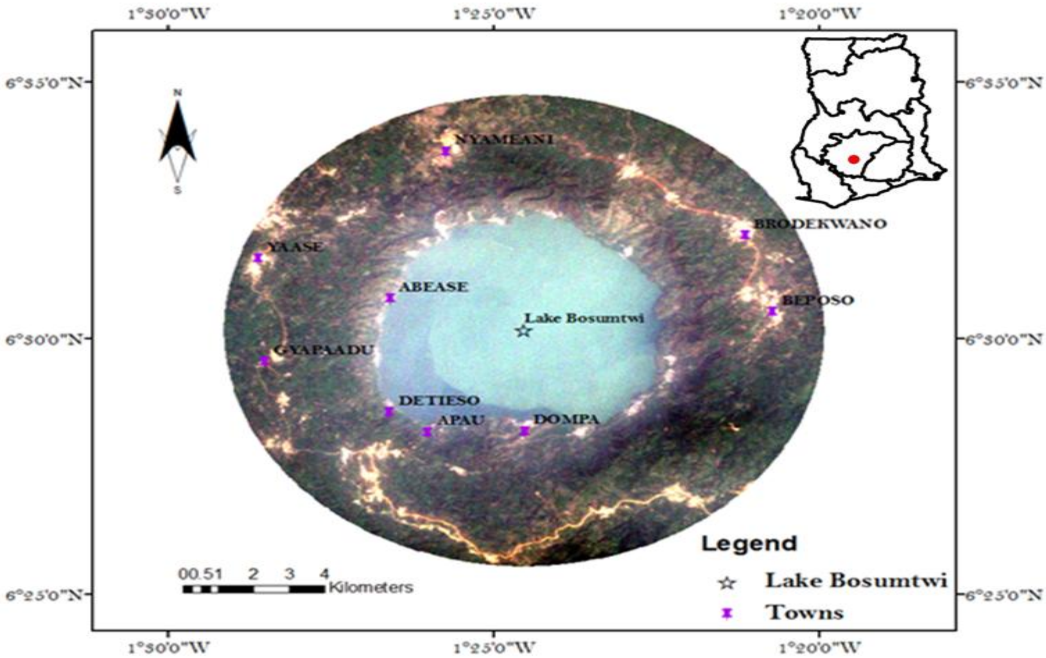


Figure 1: Map of Study Area

2.2 Research Data

Landsat images of different dates and were used. The characteristics of the data are shown in Table 1. Landsat images (Jensen, 2000; Campbell, 2002; Skidmore, 2002) were used due to two main reasons: (1) previous studies using Landsat images in similar environments were successful (Sandholt*et. al*., 2003; Toyra *et al.*, 2002) and (2) Landsat data were readily availabl eand have relatively high spatial resolution.

Table 1: Data Used

Data of Acquisition	Satellite	Spatial Resolution	Satellite Instrument	Number of Bands	Source of Data
1th February, 2008	LANDSAT 7	30m	ETM	7	U.S Geological Survey
13th January, 2013	LANDSAT 7	30m	ETM	7	U.S Geological Survey

2.3 Georeferencing and Co-registration

The Landsat images used in this study had been accurately rectified to Universal Transverse Mercator UTM 30N based on WGS84 projection. For this reason, there was no need for georeferencing; however the shapefile of the Lake Bosomtwe was co-registered to the satellite images to conform to the same projection (Dai and Khorram, 1998).

2.4 Radiometric Calibration

In comparative analysis of multi-temporal images acquired on different dates and by different sensors, radiometric calibration is very important (Markham and Barker, 1987; Singh, 1985; Tilton *et al*., 1985). Every sensor has its own calibration parameters in recording digital numbers and therefore the same digital numbers recorded by different sensors will represent different radiance and reflectance values. Since this study aims at comparing multi-temporal satellite images to detect change, the equations presented by Chander *et al*., (2009) for converting calibrated Digital Numbers (DNs) to absolute units of At-sensor spectral radiance and Top-Of-Atmosphere (TOA) reflectance were applied. Calibrated Digital Numbers (DNs) of both the TM and ETM+ images were converted to absolute units of At-sensor spectral radiance using Equation 1. To minimize scene variability and correct for difference in the Earth–Sun distance between different Landsat image acquisition dates, At-sensor spectral radiance values (L_λ) were subsequently converted to Top-Of-Atmosphere (TOA) reflectance ($\rho\lambda$) using Equation 2.

$$L_\lambda = G_{rescale} * Q_{cal} + B_{rescale} \quad (Equation\ 1)$$

$$\rho\lambda = \frac{\pi * L_\lambda * d^2}{ESUN\lambda * \cos\theta_s} \qquad (Equation\ 2)$$

Where:

- L_λ is the spectral radiance
- $G_{rescale}$ is Band-specific rescaling gain factor
- $B_{rescale}$ is Band-specific rescaling bias factor
- $QCAL$ is the quantized calibrated pixel value in digital number for each band
- $\rho\lambda$ is the Top-of-atmosphere reflectance
- d is the distance from the earth to the sun in astronomical units (AU)
- $ESUN\lambda$ is the mean solar exoatmospheric irradiance
- θs is the solar zenith angle.

2.5 Visual interpretations of land cover changes

Prior to image classification, true colour composite of bands 321 RGB images and false colour composite of bands 432 RGB images of the study area were composed to visually analyse the land cover types of the study area. Figure 2 shows both the true and false colour composite of 2013 Landsat images. Vegetated areas appeared as shades of green, in the true colour composite as opposed to shades of red in false colour composite. Water bodies on the other hand appear as shades of blue in both true and false colour composite (see Figure 2).

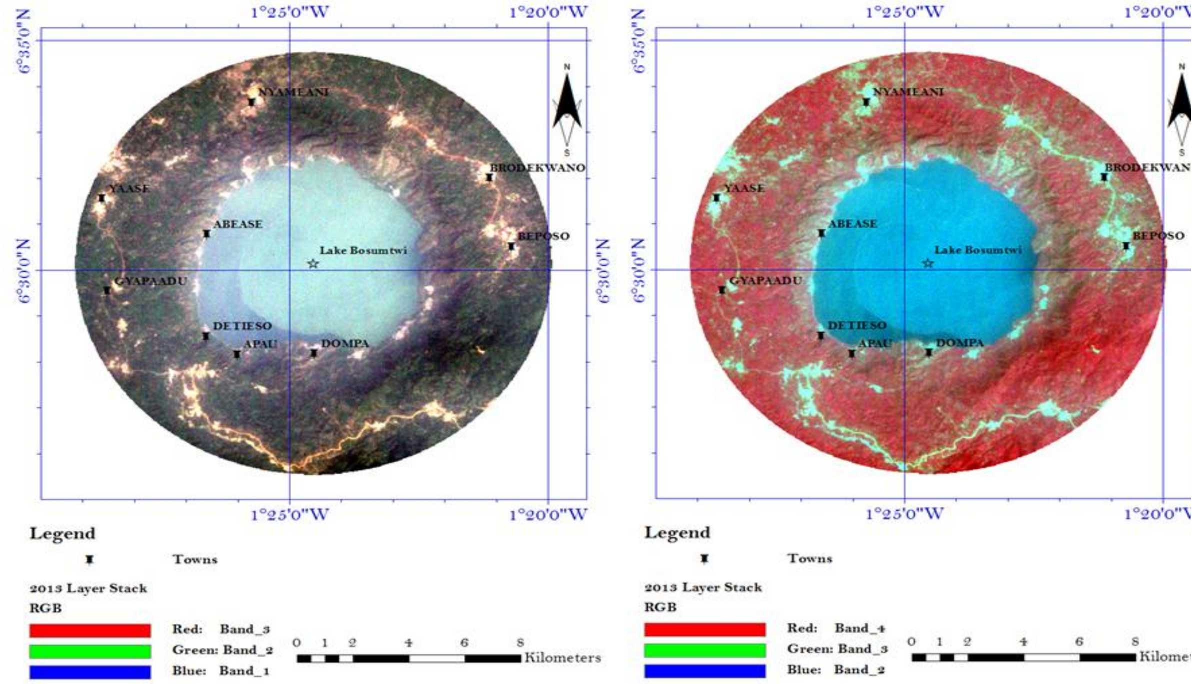


Figure 2: True Colour Composite (Left)/False Colour Composite (Right)

2.6 Normalized Difference Vegetation Index (NDVI)

NDVI is a robust technique for quantifying vegetated and non-vegetated areas based on absorbing features in the red portion of the electromagnetic spectrum and high reflectance in the Near Infrared (NIR) portion of the electromagnetic spectrum. NDVI values range from -1.0 to 1.0 (Lillesand and Kiefer, 1994). To assist in image classification, NDVI was computed for both 2008 and 2013 using Equation 3.

$$NDVI = \frac{NIR - Red}{NIR + Red} \qquad Equation\ 3$$

Where:

- Red is the Reflectanceof Landsat Band 3
- NIR is the Reflectance of Landsat Band 4

High NDVI is an indicator of vegetation abundance while negative and low NDVI values indicate the absence of vegetation. Negative values were mainly recorded in the Lake Bosomtwe while low values were generated from built-up areas, bare land and wetland. Moderate to high NDVI values (0.2 to 0.534911) represented vegetated areas (grassland, farmlands, shrub and forest) (see Figure 3).

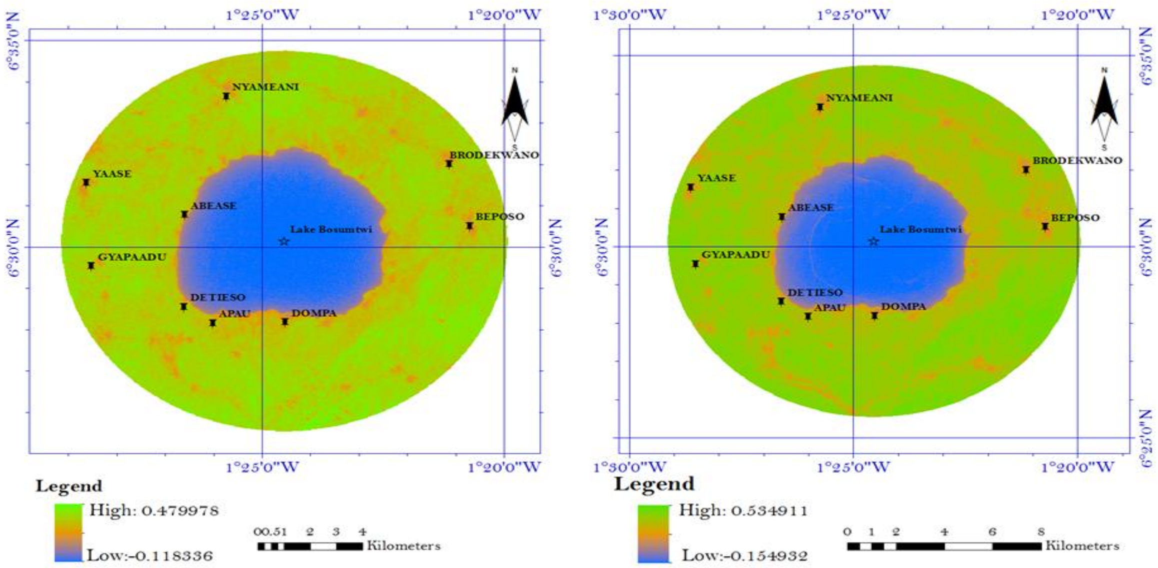


Figure 3: NDVI for 2008 (Left)/ NDVI for 2013 (Right)

2.7 Image classification

A hybrid classification approach was adopted. Training signatures were selected based on unsupervised classification, NDVI calculation and visual interpretation of the true/false colour composites of Landsat images as well as local knowledge of the study area (Glasser and Reinartz, 2005). A land cover map with three broad classes; water, vegetated and non-vegetated were generated. Table 2, briefly describes the constituent of the four land cover classes. Finally, assuming that the reflectance pixels forming the training signatures were normally distributed, the stacked reflectance bands (Landsat band 1-5 and 7) were reclassified using the well-known supervised classification algorithm - maximum likelihood algorithm (Jensen, 2000).

Table 2: Description of land cover types

Class	Description
Water	Lake, river and reservoirs
Vegetated	Grassland, farmlandsshrubs and forest
Non-Vegetated	Bareland and built-up area

2.8 Accuracy Assessment

Accuracy assessment was carried out after classification of each image. The land cover map of the study area was pre-loaded onto a Juno SB handheld GPS receiver. The map was then geo-referenced for ground-truth delineation of land cover classes of the classified images. Readings were taken for thirty five (35) geographical positions and corresponding classes of vegetation for estimating classification accuracy. Accuracy reports were generated after each image classification. The results of the accuracy assessment in this study were reported in the form of error matrix as presented in a lay-out by Story and Congalton (1986) in their description of the error matrix.

The overall accuracies obtained were 82.21% and 87.43% for 2008 and 2013 respectively. Anderson *et al*., (2001) stated that accuracies of 85% are required for land-use data for resource management. The accuracy obtained for the 2008 image was less than 85% as the ground truthing was only done in February 2013. The accuracy results for the classifications can therefore be described as reliable for further analysis.

III. RESULTS AND DISCUSSION

From Figures4 and 5, results show that the major land covers in the study area were water, vegetation (dense shrubs and forest), and non-vegetation (bare land, built-up area and wetland). The water class dominates the landscape while the non-vegetation class constitutes the smallest land cover.

Referring to Figures 4 and 5, the study revealed an increase in the surface area of the water class (Lake Bosomtwe) from 47.84 km^2 in 2008 to 48.16 km^2 in 2013. A decrease in vegetation from 143.00 km^2 in 2008 to 138.34 km^2 in 2013 was also revealed. Areas with virtually no evidence of vegetation (bare land, built-up areas and wetland) increased from 34.99 km^2 in 2008 to 39.34 km^2 in 2013.

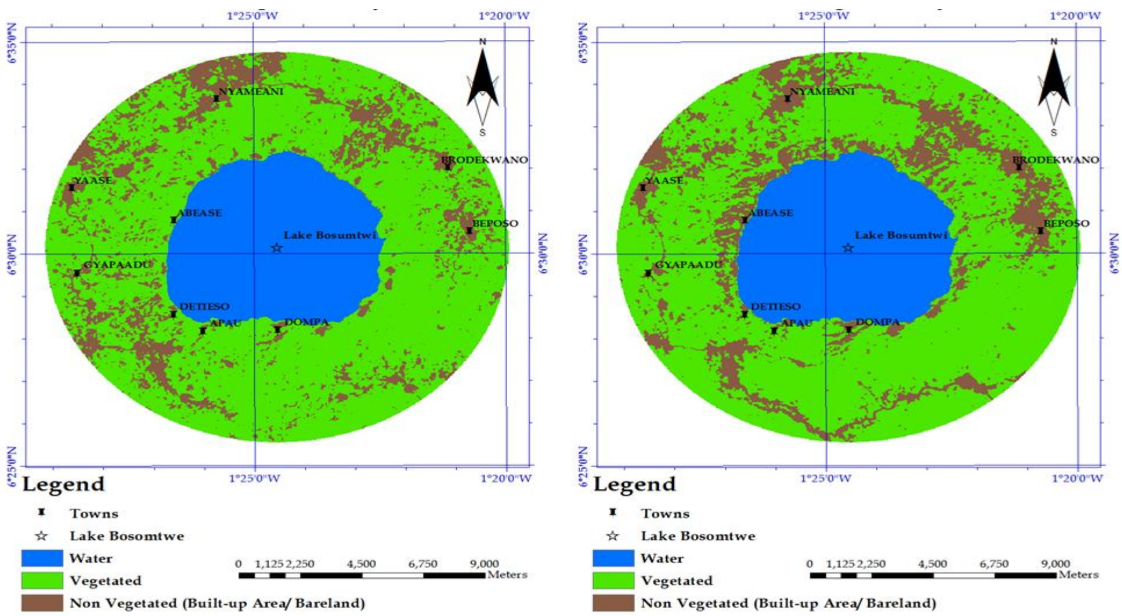
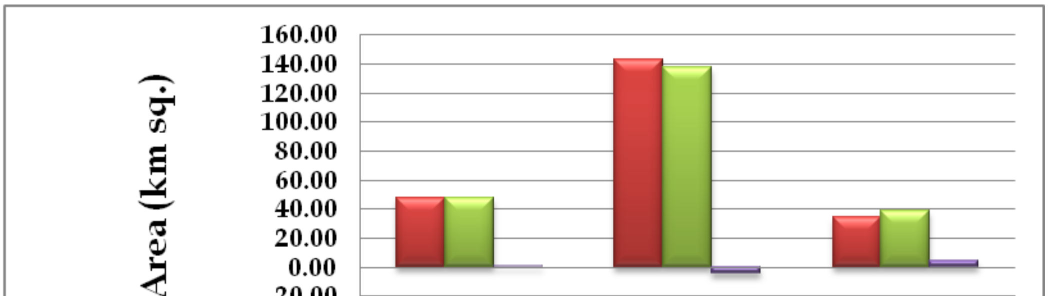


Figure 4: Land cover maps for 2008 (Left) and 2013 (Right) based on 4 Classes



	Water	Vegetated	Non vegetated
Year 2008	47.84	143.00	34.99
Year 2013	48.16	138.34	39.32
Change (2008 - 2013)	0.33	-4.65	4.33

Figure5: Land Cover Statistics for 2008 and 2013

IV. CONCLUSIONS AND RECOMMENDATIONS

This study has demonstrated the suitability of satellite remote sensing of vegetation as a means to better understand land cover change (Galford *et al*., 2008; Lunetta *et al*., 2006). In this study, there was a decrease of vegetation cover between 2008 and 2013 and a corresponding increase in non-vegetated areas within the same period. The decrease in vegetation was a result of negative human activities within the catchment area. It must be noted that, but for the proper management of the lake Bosomtwe catchment, vegetation would have decreased by higher extents. Management should therefore continue to implement reforestation project and also establish a task force which will prevent encroachment on the buffer zone. Existing regulations should also be enforced to enhance the protection of the Lake.

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REFERENCES

[1.] Anderson, J. R., Hardy, E. E., Roach, J. T., and Witmer, R. E., (2001).“A Land Use and Land Cover Classification System for Use with Remote Sensor Data”, *Geological Survey Professional Paper 964*, United States Government Printing Office, Washington: 1976, 40 pp.

[2.] Anon.,(2006). “BosomtweDistrict”, http://www.ghanadistricts.gov.gh, Last modified on 2006, Accessed on February 17, 2013.

[3.] Campbell, J. B. (2002), “Introduction to Remote Sensing”, 3rd Edition, London: Taylor and Francis.

[4.] Chander, G., Markham, B.L., Helder, D.L., (2009). "Summary of Current Radiometric Calibration Coefficients for Landsat MSS, TM, ETM+, and EO-1 ALI Sensors", *Remote Sensing of Environment*, 113, pp. 893 – 903.

[5.] Dai, X.L., Khorram, S., (1998).“The effects of image misregistration on the accuracy of remotely sensed change detection”,***IEEE Transaction on Geoscience and Remote Sensing***, 36, pp. 1566-1577.

[6.] Galford, G. L.; Mustard, J. F.; Melillo, J.; Gendrin, A.; Cerri, C. C. and Cerri, C. E., (2008),“Wavelet analysis of MODIS time series to detect expansion and intensification of row-crop agriculture in Brazil”,*Remote Sensing of Environment*, 112, pp. 576-587

[7.] Glasser, C. and Reinartz, P. (2005), “Multitemporal and multispectral remote sensing approach for flood detection in the Elbe-Mulde Region”, *Acta Hydrochimica* et Hydrobiologica, 33, 5, pp. 395−403.

[8.] Jensen, J.R., (2000).“Remote sensing of the environment: An earth resource perspective”, Prentice-Hall, New Jersey, pp: 181-243, 333-529.

[9.] Lillesand, T.M. and R.W. Kiefer, (1994).“Remote Sensing and Image Interpretation”, John Wiley & Sons, Chichester.

[10.] Lunetta, R. S.; Knight, J. F.; Ediriwickrema, J.; Lyon, J. G. and Worthy, L. D., (2006). “Land-cover change detection using multi-temporal MODIS NDVI data”,*Remote Sensing of Environment*, 105, pp. 142-154.

[11.] Mantey, S., Tagoe, N. D. and Aduah, M. S. (2011), “Detecting areas of vegetation change in the Densu River Basin, Ghana”, *River Basin Management VI, WIT Transactions on Ecology and the Environment*, vol. 146, pp. 37-48.

[12.] Markham, B.L., and J.L. Barker, (1987). “Radiometric properties of U.S. processed Landsat MSS data”, *Remote Sensing of Environment*, 22:39-71.

[13.] Meyer, W. B. (1995). “Past and Present Land – use and Land cover in the U. S. A. consequences approach”, *Environmental International Journal*, Vol. 2, 9, pp. 27-32.

[14.] Mitch, Gosselink, (1993).“Landscape Ecological Planning Through a multi-scale characterization of pattern: Studies in Western Ghats, South India”,*Environmental Monitoring and Assessment*, pp. 215-233.

[15.] Nagendra H, Southworth, J., Tucker, C., (2003). “Assessibility as a determinant of landscape transformation in Western Honduras, *Linking Pattern and Process*”, *Landscape Ecololgy*,18, pp. 141-158.

[16.] Sandholt, I., Nyborg, L., Fog, B., Lô, M., Bocoum, O. and Rasmussen, K. (2003), “Remote sensing techniques for flood monitoring in the Senegal River Valley”, *Danish Journal of Geography*, 103, 1, pp. 71-81.

[17.] Singh, A., (1985). “Thematic Mapper radiometric correction research and development results and performance”, *Photogrammetric Engineering and Remote Sensing*, 51, pp. 1379-1384.

[18.] Skidmore, A. (2002), “Environmental Modelling with GIS and remote sensing”, London: *Taylor and Francis*, 260pp.

[19.] Skole, D. L., (1994).“Data on global land-cover change: acquisition, assessment and analysis”, In: W. B. Meyer, B. L. Turner II (Eds.), *Changes in land use and land cover: a global perspective*, Cambridge: *Cambridge University Press*, pp. 437– 471.

[20.] Story, M. and R. G. Congalton, (1986). “Accuracy assessment, a user's perspective”, *Photogrammetric Engineering and Remote Sensing*, 52(3), pp. 397-399.

[21.] Tilton, J. C., B. L. Markham, and W. L. Alford, (1985).“Landsat-4 and Landsat-5 MSS coherent noise: characterization and removal, *Photogrammetric Engineering & Remote Sensing*, 51: pp. 1263-1280.

[22.] Toyra, J., Pietroniro, A., Martz, L. W. and Prowse,T. D. (2002), “A multi-sensor approach to wetlandflood monitoring”, *Hydrological processes*,16, pp. 1569-1581.

[23.] Vitousek, P. M., (1994). “Beyond Global Warming: Ecology and Global Change”, *Ecology*, 75, pp.1861– 1876.

[24.] Wagrowski, D. M., and Hites, R. A.,(1997), “Polycyclic aromatic hydrocarbon accumulation in urban, suburban and rural vegetation”, *Environmental Science & Technology*, 31, 1, pp. 279-282.