Bulletin of the *Transilvania* University of Braşov
Series II: Forestry • Wood Industry • Agricultural Food Engineering • Vol. 7 (56) No. 1 - 2014

ASSESSMENT OF NDVI FOR DIFFERENT LAND COVERS BEFORE AND AFTER ATMOSPHERIC CORRECTIONS

Iosif VOROVENCII[1]

Abstract: *The use of satellite images in order to obtain vegetation indices, namely the Normalized Difference Vegetation Index (NDVI), involves applying corrections to eliminate the atmospheric effects. This paper assesses NDVI for different land covers before and after atmospheric corrections on the basis of Landsat 5 Thematic Mapper (TM) satellite images. The wide variations of the NDVI, highlighted by the mean and standard deviation, show that the atmospheric effects are variable and significant. The results reveal that the mean difference among NDVI values ranges from 1% to 64% before and after the atmospheric corrections for different land cover classes.*

Key words: *NDVI, atmospheric corrections, satellite images, mean, standard deviation.*

1. Introduction

Multispectral images acquired at different dates are widely used in detecting the changes in time. In order to obtain the maximum benefit, the detection of changes must be performed automatically and the results must be correlated with physical ground units. For this purpose, radiometric corrections are applied both to the sensor and to the atmospheric effects. Various methods are used to convert digital numbers (DN) to reflectance. The strongest method converts DN to the so-called apparent or at-satellite reflectances by correcting for sensor gains, offsets, solar irradiance, and solar zenith angle [4], [5], [7-11]. However, the method fails to correct the atmospheric effects which can be substantial [5]. These atmospheric effects are wavelength dependent, are both additive and multiplicative in nature and include scattering, absorption, and refraction of light [6], [13], [14]. To this end, different methods were developed to remove the scattering and absorption component caused by path radiance like the Dark Object Subtraction (DOS) model [1-4], [15] the Cos (t) model, the Apparent Reflectance model and others. The Cos(t) model was developed by Chavez [5] as a technique for approximation that works well in these instances. It incorporates all of the elements of the DOS model (for haze removal) plus a procedure for estimating the effects of absorption by atmospheric gases and Rayleigh scattering. It requires no additional parameters over

[1] Forest Engineering, Forest Management Planning and Terrestrial Measurements Dept., *Transilvania* University of Braşov.

the DOS model and estimates these additional elements based on the cosine of the solar zenith angle (90 – solar elevation) [17].

The most widely spread methods in remote sensing include those that refer to using NDVI with time series of satellite images. For this purpose, satellite images require atmospheric corrections in order to remove its effects. The main aim of this paper is the assessment of NDVI values for different land covers before and after atmospheric correction using Landsat 5 TM satellite images.

2. Study area

The study area is located between 45°70'47" – 45°88'57" north latitude and 25°10'23" – 25°48'27" east longitude. Its surface of 77221 ha includes different land cover classes: forests, hay and pastures, cropland, water bodies, towns, roads (Figure 1). The forest consists of the following species: beech (*Fagus sylvatica*), oak (*Quercus petraea*), hornbeam (*Carpinus betulus*), spruce (*Picea abies*), fir (*Abies alba*), larch (*Larix decidua*). Some parts of the agricultural land are cultivated, others are not. The studied area includes the Dumbravita natural reserve. The water bodies are represented, mainly, by the river Olt located in the north-west part of the studied area. The most important localities are the villages Halchiu, Dumbravita, Persani, Sinca Veche, Venetia de Sus, and Venetia de Jos.

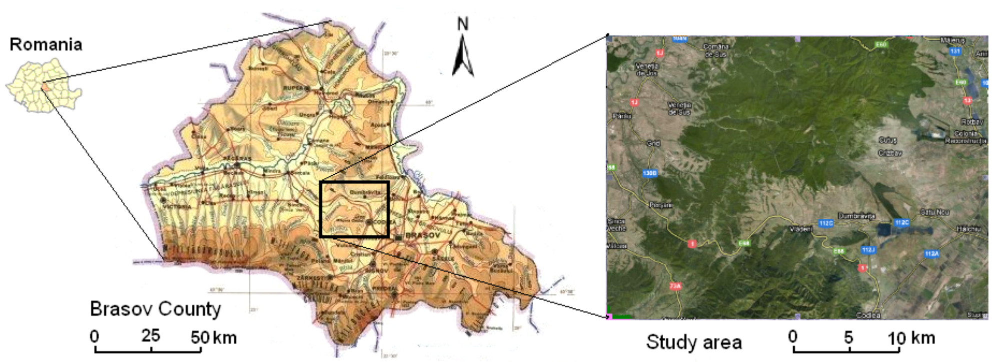

Fig. 1. *Study area*

The specific altitude is that of Persani Mountains and ranges between 550 m and 1100 m, from flat land represented by cropland to Magura Codlei Peak (1292 m). Persani Mountains are a less common lithological mosaic, reflecting a mixed trend. The high lithological complexity is reflected by the diversity of landforms, of soils and vegetation. The average annual temperature is 8.5°C and the average temperature for July is 19.5°C, with annual thermal amplitudes between 22.5°C and 23°C. The average annual quantity of precipitations is about 650 mm.

3. Materials and methods

This paper used two frames clipped from Landsat 5 TM images acquired on 14.09.1987 and 14.07.2011. The images are part of path 183 and row 28 and have a spatial resolution of 30 m. The projection system is Universal Transverse Mercator (UTM), zone 35 N, datum WGS 84.

The flowchart of the researches is presented in Figure 2. The images without atmospheric corrections were classified through the supervised method using the maximum likelihood algorithm. The classification included six land cover classes: (1) cropland (agricultural land cultivated with different cultures); (2) pasture and hay; (3) uncultivated (agricultural uncultivated land); (4) forest and shrubs (deciduous, evergreen, bushes); (5) urban and assembled (residential, industrial, transportation, communication and utilities, industrial and commercial complexes, mixed urban or assembled land, roads); 6) water (streams, lakes, canals). The accuracy assessment was performed by comparing the classified images with the reference data (orthophotos, cadastral maps, stand maps) verified by field trip. On the basis of the error matrix, the accuracy indicators were calculated for each applied algorithm: the overall accuracies, the user's accuracy, the producer's accuracy and the kappa statistics (KS) [16]. The classified images were used to perform binary masks in order to delimit each land cover class.

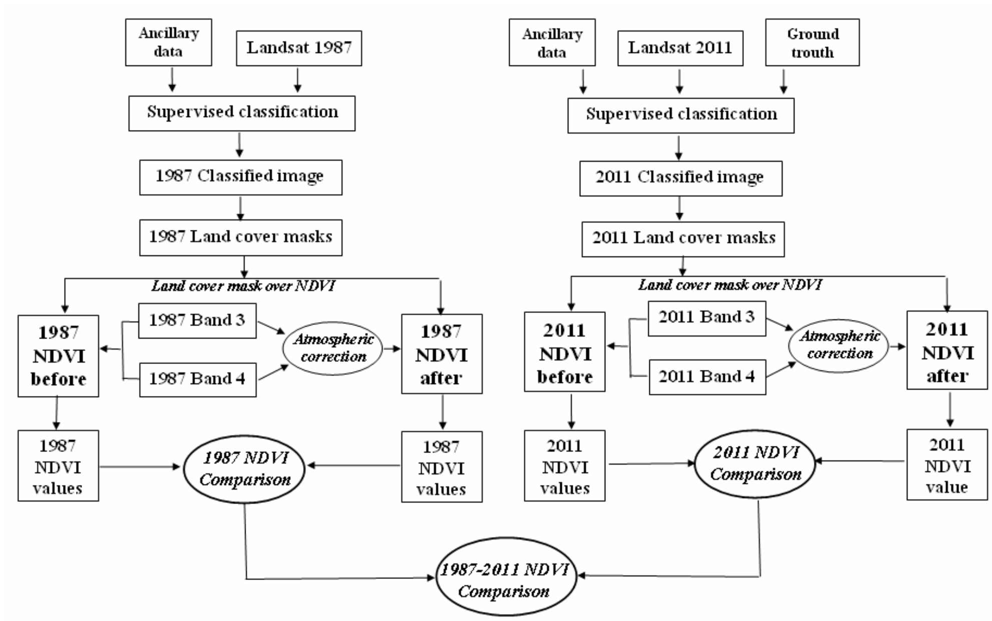

Fig. 2. *Flowchart of the researches*

The NDVI index, developed by Rouse et al. [12], was computed with the formula:

$$NDVI = \frac{NIR - R}{NIR + R} \quad (1)$$

where *NIR* represents the reflectance in the near-infrared band while *R* is the red band reflectance. The values of this index vary between –1 and +1. Generally, the negative values characterize the areas with water, clouds, snow; small values, but higher than zero, are specific to soil with sparse vegetation, whereas the surfaces covered by dense and healthy vegetation have the values 0.7–1.0. To obtain the NDVI, both images, before and after atmospheric corrections, were used.

Atmospheric corrections were applied using the Cos(t) model. The input data were: acquisition date for each satellite image, wavelength of band center (microns), DN haze, input image, radiance at DN 0 (Lmin), radiance at DN max (Lmax), sun elevation. Some data were found in the metadata file of satellite images.

The images obtained after applying the binary masks, in order to define each land cover class, were also used to separate the NDVI for each land cover class. The classes taken into consideration were cropland, pasture and hay, uncultivated, forest and shrubs, urban and assembled. Water was not taken into account. In each NDVI image, obtained for each land cover class, 15 random points were generated in the same locations on both images acquired in 1987 and 2011. The points were used to determine the NDVI values on the basis of which the flowcharts representing the NDVI values were drafted, before and after atmospheric correction, for each land cover class.

4. Results and discussions

Overall accuracy for the 1987 image was 88.52%, with kappa statistics of 0.86, and for the 2011 image was 86.67%, with kappa statistics of 0.84. The NDVI images, before and after atmospheric corrections, are presented in Figure 3. The graphs produced are presented in Figure 4. Means and standard deviations of NDVI were calculated for each land cover class and for each image (Table 1).

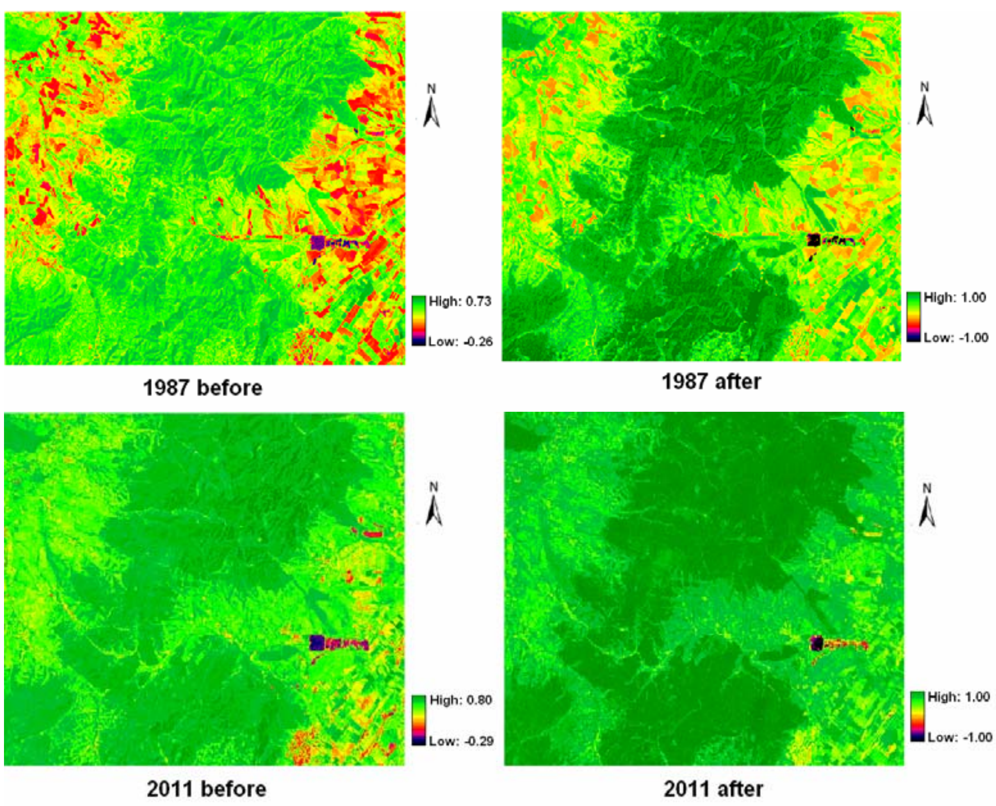

Fig. 3. *NDVI images before and after atmospheric corrections*

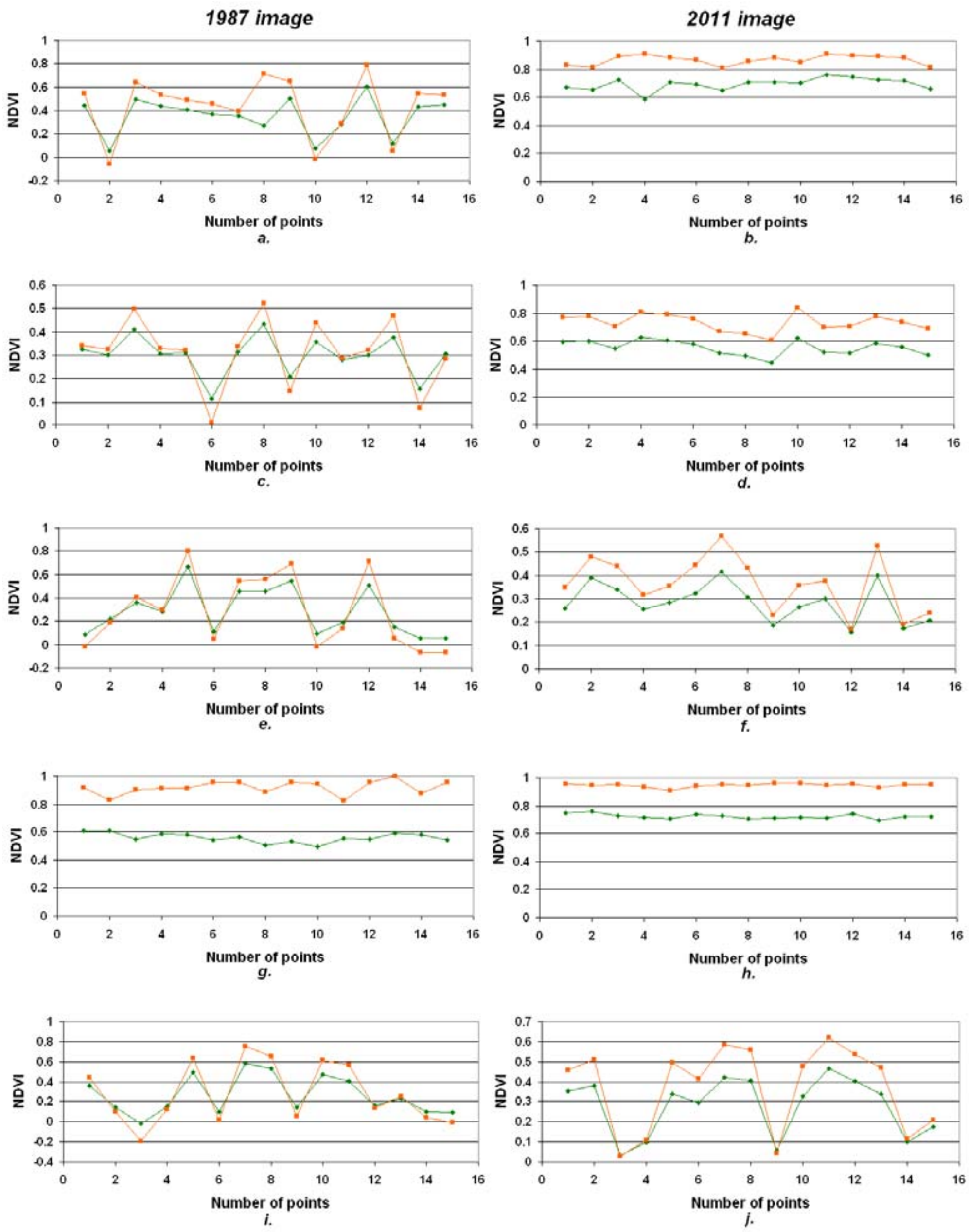

Fig. 4. *NDVI before (green line) and after (orange line) atmospheric correction:*
a. cropland 1987; b. cropland 2011; c. pasture and hay 1987; d. pasture and hay 2011;
e. uncultivated 1987; f. uncultivated 2011; g. forest and shrubs 1987;
h. forest and shrubs 2011; i. urban andassembled 1987;
j. urban andassembled 2011

Table 1

Means and standard deviations for NDVI values before and after atmospheric correction in 1987 and 2011 images

Land cover class	Mean		Standard deviation		Mean		Standard deviation	
	NDVI 1987 before	NDVI 1987 after	NDVI 1987 Before	NDVI 1987 after	NDVI 2011 before	NDVI 2011 after	NDVI 2011 before	NDVI 2011 after
Cropland	0.354	0.438	0.162	0.261	0.693	0.867	0.044	0.036
Pasture and hay	0.300	0.314	0.086	0.146	0.555	0.733	0.054	0.064
Uncultivated	0.283	0.286	0.203	0.310	0.283	0.364	0.082	0.120
Forest and shrubs	0.559	0.916	0.033	0.049	0.724	0.947	0.019	0.014
Urban andassembled	0.262	0.280	0.191	0.301	0.279	0.375	0.146	0.210

A mean difference between 1% and 64% for the NDVI was recorded before and after the atmospheric corrections in both images. The minimal difference was recorded for uncultivated land, and the maximum for forest and shrubs, in both images. In this range, the NDVI mean differences, in ascending order, were: 5% for pasture and hay (1987), 7% for urban and assembled area (1987), 24% for cropland (1987), 25% for cropland (2011), 29% for uncultivated (2011), 32% for pasture and hay (2011), 34% for urban and assembled (2011) and for forest and shrub (2011). Thus, the mean NDVI values for all the land cover classes were higher after the atmospheric corrections were applied. High differences among the NDVI means calculated before and after the atmospheric corrections were also noticed in the case of forest and shrubs and urban and assembled. Smaller mean differences were recorded in the 1987 image as compared to the 2011 one. This does not mean that the NDVI calculated from scenes acquired at different dates and in different atmospheric conditions, after the atmospheric corrections are applied, leads to different results.

The standard deviations calculated after the atmospheric corrections were applied, with the exception of the values for cropland, forest and shrubs, were higher than those recorded before the atmospheric corrections (Table 1), which shows a wide variability. In the case of cropland and forest and shrubs the standard deviation NDVI values after corrections were lower by 18%, respectively 26%, both values recorded in the 2011 image. For the other land cover classes, the standard deviation differences, expressed as percentages, ranged from 18% to 70%. Both values were recorded for pasture and hay in the 2011 image, and the 1987 one respectively. High values of the standard deviation differences were also recorded for cropland, 61% in 1987, urban and assembled, 58% in 1987, for uncultivated, 53% in 1987, respectively 46% in 2011, for forest and shrubs, 48% in 1987. The standard deviation differences recorded in the 1987 image were higher than in the 2011 image because of, most likely, a wide variability within the image. High standard deviation differences for the same land cover class, within the same satellite image, indicate that applying atmospheric corrections had a considerable effect. The NDVI values in the corrected image are, mostly, higher than the uncorrected NDVI values. However, in the case of the 1987 image, after the atmospheric corrections were applied, the minimal NDVI values obtained at certain points were lower for all classes, with the exception of forest and shrubs (Figure 4).

For the same land cover class, in the same locations, but on the two images acquired at different dates, the NDVI values recorded were different because of the changes which occurred over time. A part of the pixels chosen in order to determine the NDVI values, before and after the atmospheric corrections, passed from one class to another because of the period of 24 years between the two images. The NDVI differences also occurred because the studied area includes a complex landscape from the point of view of its spectral variability. The land cover classes with high spectral variability, like pasture and hay, cropland, urban and assembled and uncultivated, also present high standard deviation difference, causing problems in the classification of the images. Consequently, a part of the classification errors were found in the binary masks used to delimit land cover classes which, in their turn, were used to delimit the NDVI for each land cover class.

The wide variation found in satellite reflectance values suggests that the atmospheric effects were variable and significant in both images. Their removal led to the change of NDVI values in different degrees for each land cover class. They did not have a uniform effect for the entire image given the difference between the NDVI values before and after atmospheric corrections in the analysed points.

5. Conclusions

This study used two frames of Landsat 5 TM images, acquired at different dates, in order to test the effects of applying the atmospheric corrections for retrieving an accurate NDVI index for different land cover classes. The study revealed that the atmospheric effects are considerable in calculating the NDVI index. The wide variations of NDVI values, highlighted by statistical indicators, the mean and the standard deviation, suggest that the atmospheric effects are variable and significant for each land cover class. The results show that a clear hierarchy, according to land cover classes, of the NDVI values before and after the corrections is not possible. Nevertheless, in this study, a high mean difference was identified for forest and shrubs, urban and assembled and pasture and hay. On the basis of the NDVI, widely used in many applications, concerning especially the health of vegetation, the estimation of evapotranspiration, crop management and production, leaf area index calculation, land surface temperature retrieving, the mean difference of 1% to 64% between the atmospheric corrected and non-corrected values is highly significant.

References

1. Ahern F.J., Goodenough D.G. et al., 1977. Use of Clear Lakes as Standard Reflectors for Atmospheric Measurements. Proceedings of the 11th International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, p. 731.
2. Chavez P.S.Jr., 1975. Atmospheric, Solar, and M.T.F. Corrections for ERTS Digital Imagery. Proceedings American Society of Photogrammetry Fall Conference, Phoenix, Arizona, p. 69.
3. Chavez P.S.Jr., 1988. An Improved Dark-Object Subtraction Technique for Atmospheric Scattering Correction of Multispectral Data. In: Remote Sensing of Environment **24**, 3: 459-479.
4. Chavez P.S.Jr., 1989. Radiometric Calibration of Landsat Thematic Mapper Multispectral Images. Photogrammetric Engineering and Remote Sensing **55**, 9 : 1285-1294.

5. Chavez P.S.Jr., 1996. Image-Based Atmospheric Corrections - Revisited and Improved. Photogrammetric Engineering and Remote Sensing **62,** 9 : 1025-1036.
6. Curcio J.A., 1961. Evaluation of Atmospheric Aerosol Particle Size Distribution from Scattering Measurement in the Visible and Infrared. Journal of the Optical Society of America **51**, 5 : 548-551.
7. Hall D.K., Chang A.T.C. et al., 1988. Reflectances of Glaciers as Calculated Using Landsat 5 Thematic Mapper Data. Remote Sensing of Environment **25**, 3 : 311-321.
8. Leprieur C.E., Durand J.M. et al., 1988. Influence of Topography on Forest Reflectance Using Landsat Thematic Mapper and Digital Terrain Data. Photogrammetric Engineering and Remote sensing **54,** 4 : 491-496.
9. Markham B.L., Barker J.L., 1986. Landsat MSS and TM Post-Calibration Dynamic Ranges, Exatmospheric Reflectances and At-Satellite Temperatures. EOSAT Landsat Technical Notes **1**, 1 : 3-8.
10. Moran M.S., Jackson R.D. et al. 1992. Evaluation of Simplified Procedures for Retrieval of Land Surface Reflectance Factors from Satellite Sensor Output. Remote Sensing of Environment **41**, 2-3 : 169-184.
11. Price J.C., 1987. Calibration of Satellite Radiometers and the Comparison of Vegetation Indices. Remote Sensing of Environment **21,** 15 :15-27.
12. Rouse J. W., Haas R. H., et al. 1974. Monitoring the Vernal Advancement and Retrogradation (Green Wave Effect) of Natural Vegetation. Final Rep. RSC 1978-4. Remote Sensing Center, Texas A&M Univ., College Station.
13. Sabins F.F.Jr., 1978. Remote Sensing Principles and Interpretation. San Francisco. W.H. Freeman and Company.
14. Turner R.E., Malila W.A. et al., 1971. Importance of Atmospheric Scattering in Remote Sensing. Proceedings of the 7th International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, p. 1651.
15. Vincent R.K., 1972. An ERTS Multispectral Scanner Experiment for Mapping Iron Compounds. Proceedings of the 8th International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, p. 1239.
16. Vorovencii I., Muntean D.M., 2012. Evaluation of Supervised Classification Algorithms for Landsat 5 TM Images. RevCAD Journal of Geodesy and Cadastre **11,** 1 : 229-238.
17. *** Idrisi Kilimanjaro Tutorial. Available at: http://gisgeek.pdx.edu/G424-GIS/KilimanjaroTutorial. Accessed: 10-01-2014.