Spatial and auto correlation of ecological change: disturbance and perturbation analysis in Circeo National Park (south Latium, Italy).

Gina Galante[1]
1 Sapienza University of Rome – Environmental Biology Department,
gina.galante@uniroma1.it .
Rossana Cotroneo[2]
[2] Statistical National Institute
Stefania Mandrone[3]
[3] Institute for Environmental Protection and Research, ISPRA
Ilaria Strafella[1]
[1] Sapienza University of Rome – Environmental Biology Department

Abstract: "Ecological change" has different meanings: disturbance and perturbation. In this study, disturbance and perturbation were both spatially characterized using Normalize Vegetation Index (NDVI) delta maps (25 years: 1984- 2009) derived by Landsat 5TM imagery. In Circeo National Park, the ecological change spatial pattern was characterized using geostatitsc techniques. Instead, the spatial correlation of data was performed elaborating Euclidean Distance (ED) maps of urban and industrial areas and combining ED maps with disturbance cartography. At 45° a strong anisotropy was revealed by the empirical semivariogram of NDVI losses density, whereas NDVI's gains showed isotropy. The perturbation corresponds to processes of forests re-colonization, whereas the disturbance was human-induced.

Keywords: NDVI, Ecological change, Autocorrelation, Disturbance, Landscape metrics, Spatial correlation

1. Introduction

The ecological systems are heterogeneous, showing a considerable complexity and variability in space and time (Li and Reynolds 1994).Variability and heterogeneity are as well described by all those events that allow modifications or changes (e.g. disturbance) in ecosystem nominal state. Three landscape characteristics may be considered in ecology studies: structure, function and change (Forman and Godron 1986; Gillanders et al. 2008). "Structure" refers to the distribution of energy, materials and species in relation to the sizes, shapes, numbers and types of landscape components. "Function" refers to the interactions between the spatial elements and "change" is usually identified like the "alteration in the structure and function of the ecological mosaic through time". Ecological systems, in fact, are characterized by dynamics, disturbance and change (Reice 1994). The term ecological change can have different ecological meaning: disturbance and perturbation are two aspects of the change. In according with Grime (1979), the removal of biomass from a system constitutes disturbance, or, alternatively, disturbance is a rare and unpredictable event that occurs at different spatial and temporal scale (White 1979, Allen and Star 1982, Rykel 1985; Pickett and White 1985). Remote sensing offers the possibility to identify the reference state of vegetation using an appropriate temporal interval, and the NDVI (Normalized

Difference Vegetation Index). For its character of completeness, it is an excellent carrier of information for both disturbance and perturbation patterns studies (Griffith et al 2002; Zurlini et al 2007). In this study the ecological change phenomenon was detected using the NDVI delta map and change events were disaggregated in its components: NDVI gains (perturbation) and losses (disturbance). The spatial distribution of ecological change and its physical relationships with landscape structure were studied using both geostatistic and spatial analysis technique. The Circeo National Park is a protected area since 1984 and has a superficies of 8.440,00 hectares. This natural reserve is constituted by a variety of different biomass: transitional waters, sandy dunes very rich in alophilic vegetation, Mediterranean and xero-thermophilic forests. Anthropic pressure is relevant in park area due to tourism, intensive agricultural and farming. Disturbance events resulted autocorrelated with a strong anisotropy at 45°, corresponding to the main urban settlements. Perturbation events instead resulted auto-correlated with isotropic pattern, as for a natural driving force. The disturbance data were also spatial correlated with the main urban settlements: disturbance intensity decrease exponentially at the increasing of distance from the main urban areas.

2. Materials and Methods

Two Landsat 5TM remote sensed images with a temporal interval of 25 years (Landsat TM5; July 1984-July 2009, ENVI 3.4) were used to highlight main land use changes in the investigated area. The imagines were acquired respectively in July the 20th 1984 and in July 25th 2009. Imagines were pre-processed to correct atmosphere scattering phenomenon with dark object subtraction method (Chavez 1988, 1996), georeferenced UTM WGS 84 zone 33North, and co-registered to enhance their comparison and superposition (software ENVI 4.7). Band composite (enhancement) and masking with NDVI threshold value techniques were performed to emphasize differences between vegetated and urbanized areas in order to enhance visual interpretation. Principal Component Analysis was applied to the resulting masked vegetated and unvegetated areas to empathise the spectral variance and to better discriminate the different land arrangement within the classes. After the pre-elaboration a supervised classification of land use was performed (Maximum Likelihood categorization algorithm) starting from 30 in field relieved ground true training regions (ROI). In a next step the image difference technique was applied to NDVI maps derived by images using a pixel by pixel's values subtraction (Coppin et al. 2004, Singh 1989): Difference map data were selected for statistical significance by percentiles method. The change thresholds were calculated using the tenth and the ninetieth percentiles of pixels distribution (Fung & LeDrew, 1998) and allows to assign each pixel to one of the following classes: NDVI's increase (perturbation), no change (e.g. stable areas), and NDVI's decrease (disturbance). The output of this procedure is the map of ecological change. Data were exported in GIS environment and study area change map was cut in homogeneous square overlaying a regular grid of 1 km^2. Change density was calculated for any square and geographic coordinate were assigned using the centroid values. Matrix of density values were elaborated for spatial autocorrelation using GS+ software. To asses spatial relationships between disturbance events and anthropic pressure the categorized recent image (2009) was elaborated with spatial analysis ArcGis tool to extract the urban and commercial areas generating two source layers. The Euclidean distance was computed for both this source layers and the resulting features were combined with disturbance map values. The output matrix explicit how many disturbed pixels were located in the focal classes (source layers) proximity. The data were plotted to highlight spatial relationships between disturbance events and human pressure.

3. Results

The main results can be resumed in two topics: the disturbance autocorrelation data showed a geographical gradient coherent with urban settlements and athropized areas were related with disturbance events. The geostatistical analysis highlighted different patterns of distribution and propagation of ecological change. The disturbance, intended as NDVI losses (biomass losses) semivariogram showed a strong anisotropy in the main urban settlement geographic location. The semivariogram range of about 2 km is coherent with a local scale. Although this is not a cause-effect relation, we can assert that the antrophic areas distribution “justify” the disturbance spatial pattern. This consideration is enforced by the ED results: disturbed pixels decreased exponentially with the urban areas distance increase. On the contrary, perturbation events showed an isotropic spatial autocorrelation: biomass increase proceeded with a natural pattern of distribution and is not influenced by urban and commercial areas location. Moreover, NDVI gains resulted cross-correlated with stable areas, as for an enhancing effect of stability on biomass increase. The perturbation events were also related with urban and commercial ED maps: NDVI gain pixels increase with an opposite trend on respect the NDVI losses.

4. Concluding remarks

The natural pattern of NDVI gains distribution is drive by natural forcing, in fact, the Tobler axiom states that “The closest things are more similar than those distance”, and this is the true variables nature of ecological data. In particular, a fundamental ecological process as biomass primary production tends to be constant at high hierarchical level (landscape level). Instead, NDVI losses are not always spontaneous (as for fire, storms or spontaneous vegetation regression dynamics), but often caused by human activity. In this case, we appreciate a non-natural forcing that modifies the distribution pattern of change: gradients are evident and coherent with anthropized area distribution. It is important to establish directional pattern of ecological change to modify the environmental policies of natural and protected areas management and to enhance the natural resources recovery.

References

Allen TFH, Star TB, (1982) Hierarchy, Perspectives for Ecological Complexity. Chicago Press, Chicago, p. 310.

Chavez PS Jr, 1996 Image-Based Atmospheric Corrections-Revisited and Improved. Photogramm. Eng. Rem. S. 62(9), 1025-1036.

Coppin P., Jonckheere I., Nackaerts K., Muys B. and Lambin E. (2004) Digital change detection methods in natural ecosystem monitoring: a review. International Journal of Remote Sensing, 25:9, 1565-1596

Forman, R.T.T., Godron, M. 1986. Landscape ecology. Wiley, New York.

Fung T, LeDrew E (1988) The determination of optimal threshold levels for change detection using various accuracy indices. Photogramm. Eng. Rem. S. 54(10), 1449-1454.

Gillanders SN, Coops NC,Wulder MA, Gergel SE, Nelson T (2008) Multitemporal remote sensing of landscape dynamics and pattern change: describing natural and anthropogenic trends. Prog. Phys. Geog. 32(5), 503-528.

Griffith J. A., Martinko E. A., Whistler J. L., Price K. P. (2002) Preliminary Comparison of Landscape Pattern-Normalized Difference Vegetation Index (NDVI), Relationships to Central Plains Stream Conditions. Journal of Environmental Quality, 31:846-859.

Li H., Reynolds JF. (1994) A simulation experiment to quantify spatial heterogeneity in categorical maps. Ecology, 75:2446–55.

Pickett STA, White PS (1985) The ecology of natural disturbance and patch dynamics. Academic Press, Orlando

Reice SR (1994) Nonequilibrium determinants of biological community structure. American Scientist, 82, 424-35.

White PS (1979) Pattern, process and natural disturbance in vegetation. Bot. Rev. 42, 229-299.

Singh A. (1989) Digital change detection techniques using Remotely sensed Data. Remote Sensing and Tropical Land Management, Eden M.J. and Parry J.T. (eds), John Wiley & Sons, London, pp. 237-254.

Zurlini G, Riitters KH, Zaccarelli N, Petrosillo I (2007) Patterns of disturbance at multiple scales in real and simulated landscapes. Landscape Ecol. 22, 705-721.