Geophysical Research Abstracts
Vol. 15, EGU2013-4221, 2013
EGU General Assembly 2013

Evaluation of vegetation post-fire resilience in the Alpine region using descriptors derived from MODIS spectral index time series

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In this study a method based on the analysis of MODerate-resolution Imaging Spectroradiometer (MODIS) time series is proposed to estimate the post-fire resilience of mountain vegetation (broadleaf forest and prairies) in the Italian Alps. Resilience is defined herewith as the ability of a dynamical system to counteract disturbances. It can be quantified by the amount of time the disturbed system takes to resume, in statistical terms, an ecological functionality comparable with its undisturbed behavior.
Satellite images of the Normalized Difference Vegetation Index (NDVI) and of the Enhanced Vegetation Index (EVI) with spatial resolution of 250m and temporal resolution of 16 days in the 2000-2012 time period were used. Wildfire affected areas in the Lombardy region between the years 2000 and 2010 were analysed. Only large fires (affected area >40ha) were selected. For each burned area, an undisturbed adjacent control site was located. Data pre-processing consisted in the smoothing of MODIS time series for noise removal and then a double logistic function was fitted. Land surface phenology descriptors (proxies for growing season start/end/length and green biomass) were extracted in order to characterize the time evolution of the vegetation. Descriptors from a burned area were compared to those extracted from the respective control site by means of the one-way analysis of variance. According to the number of subsequent years which exhibit statistically meaningful difference between burned and control site, five classes of resilience were identified and a set of thematic maps was created for each descriptor. The same method was applied to all 84 aggregated events and to events aggregated by main land cover. EVI index results more sensitive to fire impact than NDVI index. Analysis shows that fire causes both a reduction of the biomass and a variation in the phenology of the Alpine vegetation. Results suggest an average ecosystem resilience of 6-7 years. Moreover, broadleaf forest and prairies show different post-fire behavior in terms of land surface phenology descriptors.
In addition to the above analysis, another method is proposed, which derives from the qualitative theory of dynamical systems. The (time dependent) spectral index of a burned area over the period of one year was plotted against its counterpart from the control site. Yearly plots (or scattergrams) before and after the fire were obtained. Each plot is a sequence of points on the plane, which are the vertices of a generally self-intersecting polygonal chain. Some geometrical descriptors were obtained from the yearly chains of each fire. Principal Components Analysis (PCA) of geometrical descriptors was applied to a set of case studies and the obtained results provide a system dynamics interpretation of the natural process.