International Journal of Agriculture and Agricultural Sciences ISSN 1712-3496 Vol. 3 (1), pp. 025-029, September, 2016. Available online at www.advancedscholarsjournals.org © Advanced Scholars Journals

Full length Research paper

Long-go determined connections in decade-long SPOT-VGT NDVI records of flame affected and fire un-influenced destinations

Gianni Bruni* and Rose Caesr

Department of Agricultural science, university in Pisa, Italy.

Accepted 21 July, 2016

We investigated the fire-induced variability in the 1999-2005 time series of Normalized Difference Vegetation Index (NDVI) from SPOT-VEGETATION sensor for two different types of vegetation sites: fire un-affected and fire-affected. The statistical analysis, performed by using the detrended variation analysis (DFA), it appears that fires contribute in increasing the persistence of time dynamics of vegetation, driving unstable patterns in vegetation dynamics of burned areas.

Key words: Fires, NDVI, detrended variation analysis, spot-vegetation sensor.

INTRODUCTION

Long-range correlations characterize the time dynamics of many complex systems. The presence of long-range correlations indicates that the system is featured by the existence of memory phenomena, identified and quantified by using several methods (Feder, 1988; Theyler, 1991). The detrended fluctuation analysis (DFA), proposed by (Peng et al., 1994), is a well-known methodology, which allows to detect long-range power-law correlations in observational and experimental signals possibly affected by non stationarity. This non stationarity has to be well evidenced, since it can mask the true correlations in the signal fluctuations (Kanthelhardt et al., 2001).

The characterization of land surface conditions and land surface variations can be efficiently approached by using satellite remotely sensed data mainly because they provide a wide spatial coverage and internal consistency of data sets. In particular, NDVI (Normalized Difference Vegetation Index) obtained from the visible (Red) and near infrared (NIR) by using the following formula NDVI= (NIR - Red)/(NIR + Red), is regarded as a reliable indicator for land cover variations (Myneni et al., 1996; Huemmrich et al., 1999), since its temporal evolu tion is strongly correlated to changes in the state of surface. In this context, it is worth to describe vegetation dynamics by means of methods and techniques, which are able to detect temporal structures in observational time series in order to obtain information on features and causes of variations at different time scales.

Vegetation can be viewed as a very complex system, since variations in its composition and distribution can arise in response to natural hazards and anthropic stresses.

Vegetation stress can be defined as any disturbance that adversely influences plants and it can be due to many factors, one of which could be fires. In particular, fires could be a human-induced stress on vegetation for human- driven frequent fire regimes in ecosystems that have evolved under fire-free conditions.

However most of the Mediterranean vegetation has evolved under conditions of periodic fires and in some instances, suppression of natural occurring fire cycles inflicts considerable stress on the ecosystem (Piñol et al., 2005).

Forested ecosystems crown wild fires can have devastating effects while understory rapid cool fires can actually be beneficial to reduce fire risk. Indeed, the total amount and proportion of large fires tends to decrease by the use of prescribed fires, which greatly reduces the importance of large fires.

In the Mediterranean regions, fires are considered the most important cause of land degradation (UNCCD,

*Corresponding author. E-mail: giannibruni@yahoo.com

1994) . Every year, on average 45,000 forest-fires break out in the Mediterranean basin causing the destruction of about 2.6 million hectares (FAO, 2001). Several studies dealing with the effects of fires on the vegetation within the Mediterranean basin found that fires induce significant alterations in short as well as long-term vegetation dynamics (Perez and Moreno, 1998). Fires lead to permanent changes in the composition of vegetation community, cause decrease in forests, loss of biodiversity, soil degradation, alteration of landscape patterns and ecosystem functioning thus speeding desertification processes up (see, for example, UNCCD, 1994). Recently, it has been found that fires facilitate alien plant invasion, patch homogenization, and create positive feedbacks in future fire susceptibility, fuel loading, fire spreading and intensity (Cochrane et al., 1999). Moreover, fires can trigger disasters, such as soil erosion and flooding (Trabaud and Lepart, 1981).

In this study, we analyze the temporal series from 1998 to 2003 of NDVI satellite SPOT VEGETATION data acquired for several fire-affected and fire-unaffected vegetation sites. Our objective is to reveal the effect of fires in the fluctuation dynamics of vegetation.

Data and study areas

We investigated two types of natural vegetation covers, forest and shrub-land, for some test sites located in Italy. The different land cover types were recognized by using the Corine land cover map (by the European Topic Centre on Land Cover at Environmental satellite data Center in Kiruna, Sweden) recoded and re-sampled at the same spatial resolution as satellite data. Some of the investigated test sites are fire-affected (Bocchigliero, Bolotana, Borgetto, Cagnano, Loceri, Palizzi and San Giovanni); whereas others are fire-unaffected (Capizzi, Gaeta, Orsomarso, Monte Sant'Angelo, Monterotondo and Salina). Both fire-unaffected and fire-affected sites were selected on the basis of detailed information extracted from the Forest Fire Archive provided by the Italian National Forestry Service (http://www.corpoforestale.it). In particular, the fire-unaffected test sites were selected because they were never involved in fire events for the whole considered time window. Whereas, the fire-affected test sites were selected because involved in large fires. The following statistical analyses were not performed on the total burnt areas, but only on those naturally vegetated (forest and shrub-land), so excluding agricultural lands because they are not representative of the intrinsic time dynamics of vegetation. For each site, we analyzed the 1998- 2003 time series of 5 or 10 pixels of NDVI data derived from the sensor VEGETATION on board the SPOT satellite platforms. Each pixel has a spatial resolution of 1 km^2. Such data are available free of charge at the Vlaamse Instelling voor Technologisch Onderzock (VITO) Image Processing centre (Mol, Belgium) http://www.vgt.vito.be. In particular, we analysed the ten-day (decadal) maximum value composition (MVC) of daily NDVI maps. The temporal evolution of decadal NDVI composition is regarded as an effective time window able to show the natural seasonal variations, the consequences of extreme climatic events and the man-induced damage suffered by ecosystems. The data were subjected to atmospheric corrections performed by CNES on the basis of the Simplified Method for Atmospheric Corrections (SMAC) . The considered NDVI composition also allows for redu-cing the contamination effects due to residual clouds and atmospheric perturbations that are generally present in daily NDVI maps. Moreover, for each considered pixel we carefully checked the absence of residual errors due to cloud edges and shadows, image navigation inaccuracy and changing of viewing-illumination conditions by using a visual inspection and additional information obtained from the four single SPOT-VGT channels and viewing geometry available on-line from VITO web-site.

The detrended fluctuation analysis method

Persistent signal fluctuations correspond to a $1/f^{\alpha}$-power spectrum, where f is the frequency and the scaling exponent α >0. By estimating the scaling exponent we are able to obtain quantitative information on the strength of persistent correlations of the signal and to gain insight into the kind of mechanisms that may be responsible of its generation. The strength of these correlations provides useful information about the inherent memory of the system (Miramontes and Rohani, 2002). The detrended fluctuation analysis (DFA) (Peng et al., 1995) avoids spurious detection of correlations that are artefacts of trends and non stationarity, that often affects experimental data. Such trends have to be well distinguished from the intrinsic fluctuations of the system in order to find the correct scaling behavior of the fluctuations. Very often we do not know the causes and the scales of these underlying trends (Kantelhardt et al., 2001). The DFA method is based on the analysis of the scaling of a fluctuation function

$$F(n) = \sqrt{\frac{1}{N}\sum_{k=1}^{N}\left[y(k) - y_n(k)\right]^2} \qquad (1)$$

Where y(k) is the integrated function of the NDVI time series and yn(k) the trend of the data in the box of duration n. Calculating F(n) for all the available scales n, one obtains a relationship between F(n) and the box size n, which for long-range power-law correlated signals is a power-law

$$F(n) \propto n^{\alpha}. \qquad (2)$$

The scaling exponent α quantifies the strength of the long-range power-law correlations of the signal: if α = 0.5,

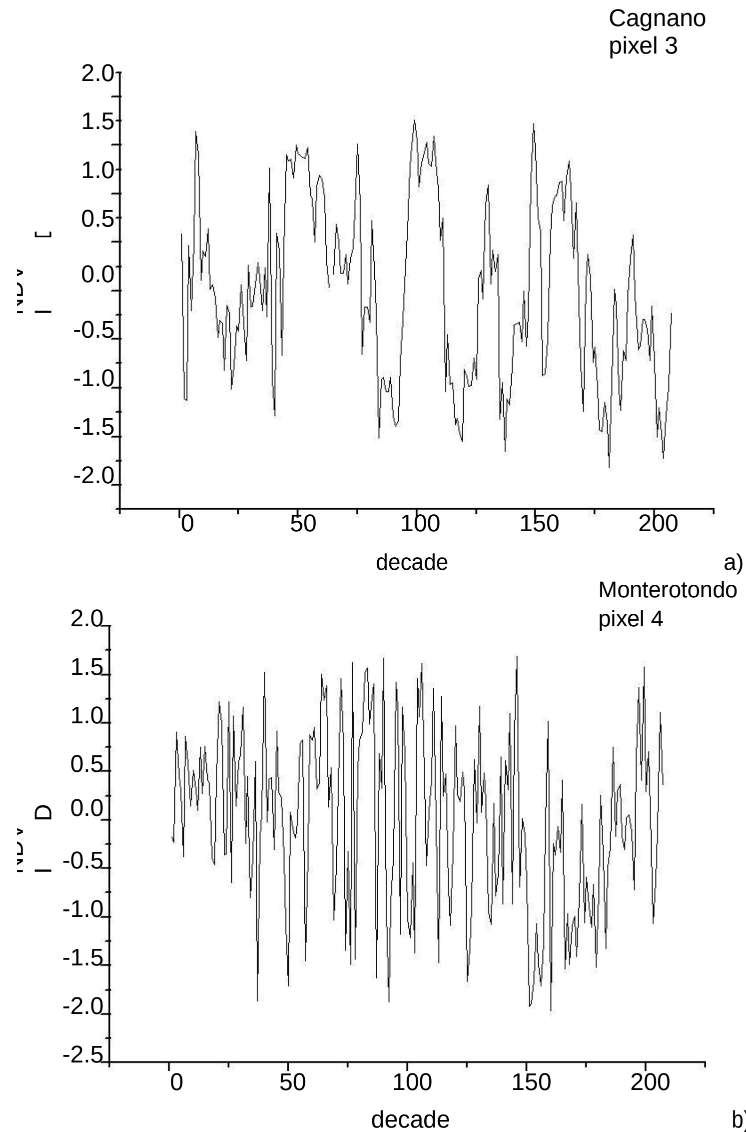

Figure 1. 1998-2003 $NDVI_d$ data for two pixel time series: a) Cagnano (fire- affected) and b) Monterotondo (fire-unaffected).

the signal is uncorrelated; if α >0.5 the correlations of the signal are persistent, where persistence means that a large (small) value (compared to the average) is more likely to be followed by a large (small) value; if α <0.5 the correlations of the signal are antipersistent, which indicates that a large (small) value (compared to the average) is more likely to be followed by a small (large) value.

RESULTS

We analyzed the temporal series from 1998 to 2003 of decadal NDVI satellite SPOT VEGETATION data acquired for fire-affected and fire-unaffected test sites. In order to eliminate the phenological fluctuations, for each decadal composition of each pixel, we focused on the departure $NDVI_d = (NDVI - \mu_{NDVI})/\sigma_{NDVI}$ from the decadal mean μ_{NDVI}, normalized by the decadal standard deviation σ_{NDVI}. The quantities μ_{NDVI} and σ_{NDVI} were calculated for each decade, e.g. 1st decade of January, by averaging over all years in the record. Figure 1 shows the time variation of $NDVI_d$, corresponding to two pixels of a fire-affected and fire-unaffected site respectively.

Figure 2 shows the results of the DFA performed on the time variation of $NDVI_d$ of two pixels of Figure 1. We observe that both pixels show a value of the scaling exponents, estimated by the slope of the line that fits in a least square sense the curves plotted in log-log scales, larger

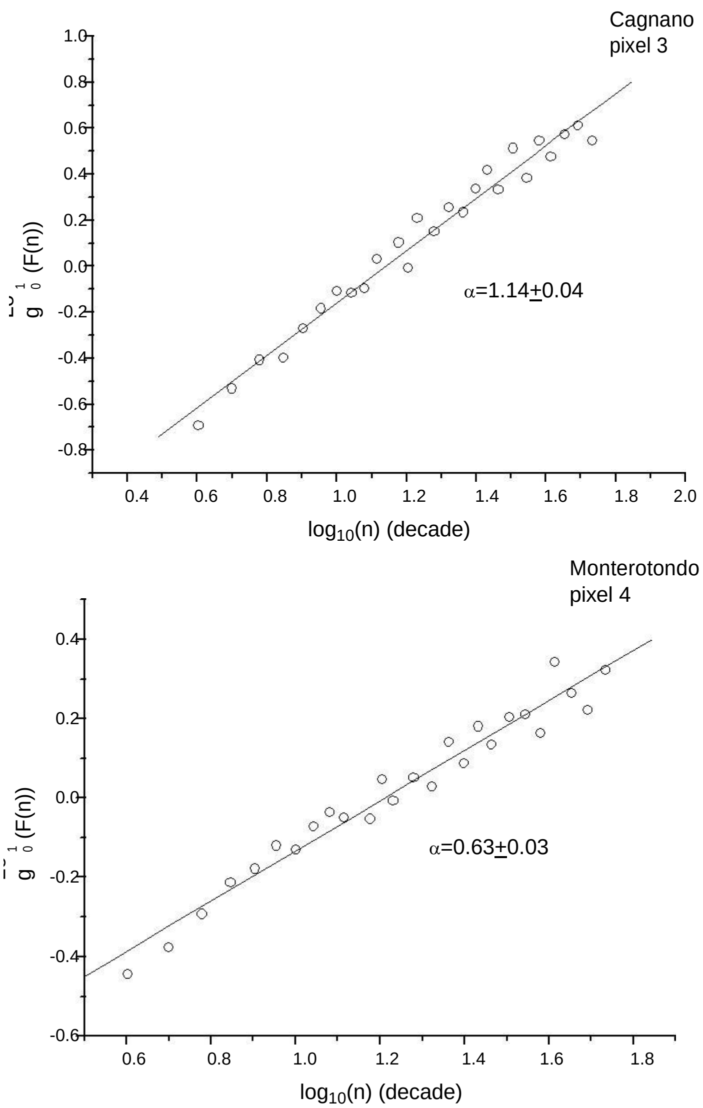

Figure 2. DFA results for the time series of the NDVId time series plotted in Figure 1

than 0.5. This indicates that the temporal fluctuations of both time series are positively correlated or persistent. Persistence means that the investigated ecosystems are governed by positive feedback mechanisms, which tend to destabilize the system under external forces.

The feed-back mechanisms express a positive circular causality that acts as a growth-generating phenomenon and therefore drives unstable patterns. Therefore the vegeta-tional processes take memory of external shocks, which drive the time dynamics of the vegetational covers.

We performed the same analysis on all the pixels for each site, and Figures 3 and 4 shows the results.

The scaling exponents for fire-affected pixels range around the mean value of □ 1.12, while those for fire-unaffected pixels vary around the mean value of □ 0.85.

Therefore, the two classes of vegetation (fire-affected and fire-unaffected) are significantly discriminated from each other (with t- Student test, $p<0.001$).

This indicates that fires play an important role in the temporal evolution of vegetation, increasing the persistence of its dynamics.

This seems to express the inherent character of the fire-related vegetation recovery processes, which indicate the existence of positive relation between the amounts of burned and regenerated biomass.

This result highlights the existence of positive relation between the amounts of burned and regenerated biomass.

This result highlights that fire drives more unstable patterns in vegetational covers, and this indicates an efficient fire-induced vegetation recovery processes.

The α exponent larger than 0.5 in unburned sites probably is linked to the successional status of ecosystem.

In the situation of dynamical equilibrium the annual variation responds to the meteorological oscillations, whereas the intra- annual change responds to the seasonal dynamics of biomass (phenologycal changes). Due to the

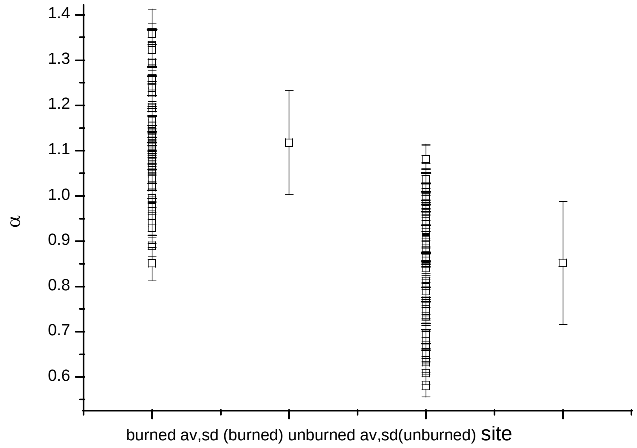

Figure 3. α-exponents of the time series of pixels extracted from all the burned and unburned sites

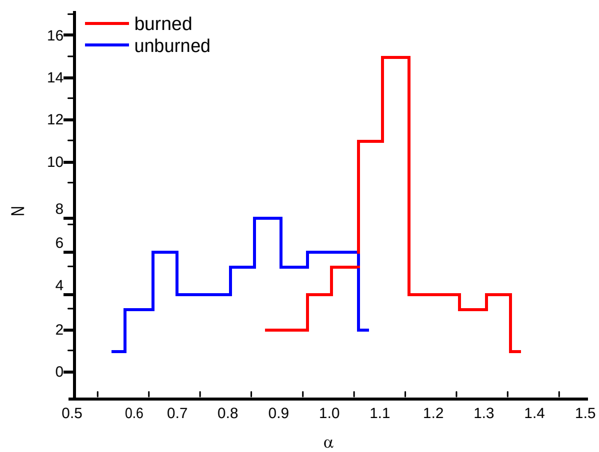

Figure 4. Histograms of the α-exponents of the time series of pixels extracted from all the burned and unburned sites.

perturbation caused by fire occurrence, the persistence of NDVI signal indicated by a larger □ in the burned sites denotes the strong trend of ecosystem in accumulate biomass rapidly.

The value of □ , after the fire occurrence, can be used as a quantitative indicator of the resilience, which indica-tes the existence of positive relation between the amou-nts of burned and regenerated biomass (Díaz-Delgado et al., 2002).

CONCLUSION

A quantitative analysis of the scaling behaviour of two classes of vegetation (fire-affected and fire- unaffected) has been performed by using the detrended fluctuation analysis. The estimated scaling exponents of both clas-ses suggest a persistent character of the vegetational dynamics. But, the fire-affected sites show much larger exponents than those calculated for the fire- unaffected sites. This result points out to the role played by fires in driving a more unstable vegetational pattern for fire-affec-ted areas, which indicates an efficient fire-induced vege-tation recovery processes. The capability of vegetat-ation communities to return to pre-disturbance conditions may be expressed in terms of resilience. The concept of vege-tation resilience (Diaz-Delgado et al., 2002) has been applied in the context of fire ecology for evaluating the effects of disturbance on ecosystem properties (Mala-son and Trabaud, 1987; Westman et al., 1986). Stronger per-sistent dynamics in burned sites indicate that the investi-gated ecosystems are governed by feedback mecha-nisms, which carry on the vegetation regrowth. Within this feedback framework, the concept of persis-tence is very useful in order to characterize the stabi-lity/instability properties of vegetation dynamics. The methodology approached in the present study could be fruitfully applied to investigate other types of vegetational stresses.

REFERENCES

Cochrane MA, Alencar A, Schulze MD, Souza JrMC, Nepstad DC, Lefebvre P, Davidson EA (1999). Positive Feedbacks in the Fire Dynamic of Closed Canopy Tropical Forests. Science 284:1832-1835.

Díaz-Delgado R, Lloret F, Pons X, Terradas J (2002). Satellite evid-ence of decreasing resilience in Mediterranean plant communities after recurrent wildfires. Ecology 83:2293-2303.

FAO (2001). Global forest fire assessment 1990-2000. Forest Resou-rces Assessment Programme, working paper n. 55, http://www.fao.org:80/forestry/fo/fra/docs/Wp55_eng.pdf

Feder J (1988). Fractals (Plenum Press, New York) p. 181.

Huemmrich KE, Black TA, Jarvis PG, McCaughey JH, Hall EG (1999). Remote sensing of carbon/water/energy parameters: High temporal resolution NDVI phenology from micrometeorological radiation sensors J. Geophys. Res. 104:27935-27944.

Kantelhardt JW, Konscienly-Bunde E, Rego HHA, Havlin S, Bunde A (2001). Detecting long-range correlations with detrended fluctuation analysis. Physica A 295:441-454.

Malason GP, Trabaud L (1987). Ordination analysis of components of resilience of *Quercus coccifera* garrigue. Ecology 68:463-472.

Miramontes O, Rohani P (2002). Estimatine $1/f^{\square}$ scaling exponents from short time-series. Physica D 166:147-154.

Myneni RB, Los SO, Tucker CJ (1996). Satellite-based identification of linked vegetation index and sea surface temperature anomaly areas from 1982 to 1990 for Africa, Australia and South America. Geophys. Res. Lett. 23:729-732.

Peng C-K, Buldyrev SV, Havlin S, Simons M, Stanley HE, Goldberger AL (1994). Mosaic organization of DNA nucleotides. Phys. Rev. E 49:1685-1689.

Peng C-K, Havlin S, Stanley HE, Goldberger AL (1995). Quantification of scaling exponents and crossover phenomena in nonstationary heartbeat time series. CHAOS 5:82-87.

Perez B, Moreno JM (1998). Methods for quantifying fire severity in shrubland fires. Plant Ecology 139:91-101.

Piñol J, Beven K, Viegas DX (2005). Modelling the effect of fire-exclusion and prescribed fire on wildfire size in Mediterranean ecosystems. Ecol. Model. 183:397-409.

Theyler J (1991). Some comments on the correlation dimension of $1/f^{\square}$ noise. Phys. Lett. A 159:480-493.

Trabaud L, Lepart J (1981). Changes in the floristics composition of a Quercus coccifera L. Garrigue in relation to different fire regimes. Vegetation 46:105-116.

UNCCD (1994). United Nations Convention to Combat Desertification, report, Paris.

Westman WE, O'Leary JF (1986). Measures of resilience: the response of coastal sage scrub of fire. Vegetation 65:179-189