RELATION BETWEEN NDVI AND-RAINFALL IN A APENNINES BEECH FOREST

RELAZIONE NDVI - PIOVOSITÀ IN UNA FAGGETA DELL'APPENNINO BOLOGNESE

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Abstract
We analyzed the time series NDVI derived from MODIS sensors in a pure beech forest of the Bolognese Apennines and sought relations with rainfall (interpolated from data ERG5 for the Emilia Romagna Region) in order to characterize the behavior of the beech with changing climatic conditions.

Keywords: NDVI MODIS Beech Drought
Parole chiave: NDVI MODIS Faggio Siccità

Introduction

Remote sensing provides tools for spatially explicit monitoring of drought across large areas. A range of MODIS based spectral indices have been proposed for monitoring of drought in agricultural and semi arid areas (Gu *et al*., 2007; Rhee *et al*., 2010), but only few studies have explored spectral indices to monitor drought in forested areas (Anderson *et al*., 2010). Since spring 2007 ARPA has produced bulletins based on NDVI (Normalized Difference Vegetation Index) anomalies in order to detect drought areas. From 2011, the monitoring focuses on forest areas located in the Apennines mountains which are characterized by a rather stable vegetation cover. This analysis integrates other weather indices adopted ad regional level to monitor drought and desertification (http://tinyurl.com/cy67azy). The aim of the present work is to statistically evaluate vegetation stress in forests caused by drought using NDVI.

Methods

The 16 days NDVI composites from 2000 to 2011 acquired by MODIS sensors mounted on AQUA and TERRA have been analyzed to characterize a pure beech forest located in the Apennines of Bologna (Brasimone). The NASA code product are MOD13Q1 and MYD13Q1 at 250 m spatial resolution (Spisni *et al*, 2012). The NDVI time series cover the period from May to October every year with 9 images per year. A 9x9 grid of 250 m was created and 38 pixels were identified that fall within a mere wreck of old coppice selection method beech which has been abandoned since more than 50 years and partially converted to high forest. NDVI values were studied by descriptive and inferential statistical analysis in order to characterize their behavior in relation to seasonal rainfall patterns.

Tab. 1 - ANOVA Table of MODIS TERRA NDVI
Tab. 1- Analisi della varianza dell'NDVI di MODIS TERRA

Source	*SS*	*DF*	*MS*	*F*	*p(F)*	*Signific.*
Year	0.776	11	0.071	1.624	0.105	
Data	4.199	8	0.525	12.131	0.000	***
Point	0.252	37	0.007	5.477	0.000	***
Year*Data	3.807	88	0.043	39.758	0.000	***
Data*Point	0.351	296	0.001	1.091	0.148	
Year*Point	0.506	407	0.001	1.143	0.032	*
Error	3.543	3256	0.001			

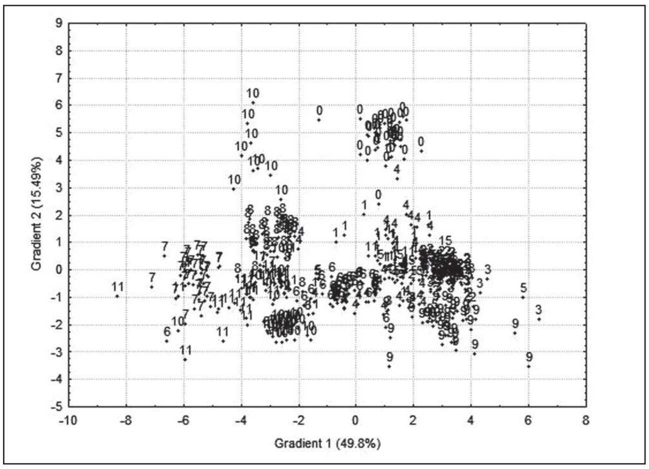

Fig. 1 - CDA: first two Roots of NDVI analysis.
Fig. 1 - An.Discriminante.Canonica dell'NDVI rilevata.

Results and Discussion

Univariate analysis showed statistically different responses between the data from the two sensors: there is a significant interaction between years, dates and satellites (Tab. 1).
We focused on data from MODIS-TERRA, because of the greatest number of years available (2000-2011). MODIS-TERRA also provides for greater data differentiation. We observed a strong interaction between years per date and years per points, thus we moved to a Canonical Discriminant Analysis (CDA), depending on the year, to analyze the multidimensional array data NDVI. This analysis extracted two gradients which interpret the 70% of information (Fig.1), showing a clear differentiation between low NDVI values of the years 2011, 2007 and 2010 contrasted with large values of the years 2005, 2003 and 2009.
The NDVI value of the first decade of June showed a strong correlation with the first gradient. By overlaying these results with the monthly rainfall data of the same period emerged that year's behavior is closely related to April's rainfall.
The rainfall at the beginning of the growing season appears to affect the NDVI response throughout the year. A more detailed analysis of the rainfall data at different time intervals (quarterly,

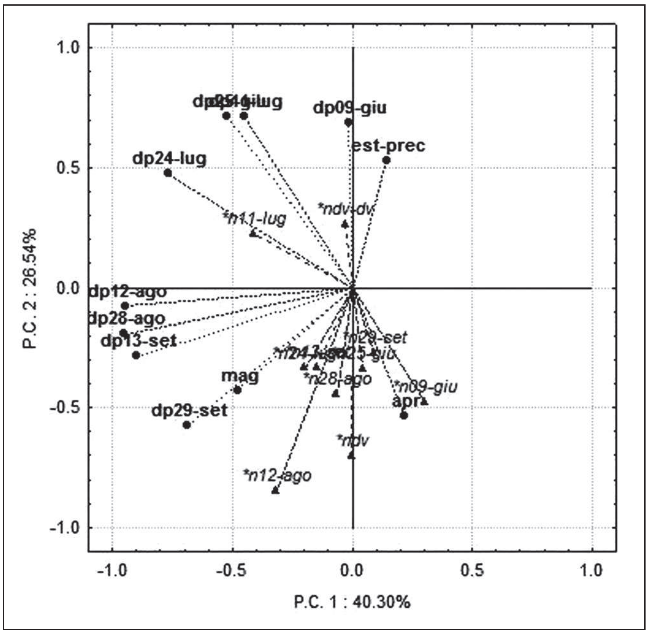

Fig. 2 - PCA. of fortnightly data (NDVI and cumulative rain).
Fig. 2 - ACP dell'NDVI e della pioggia cumulata relativa.

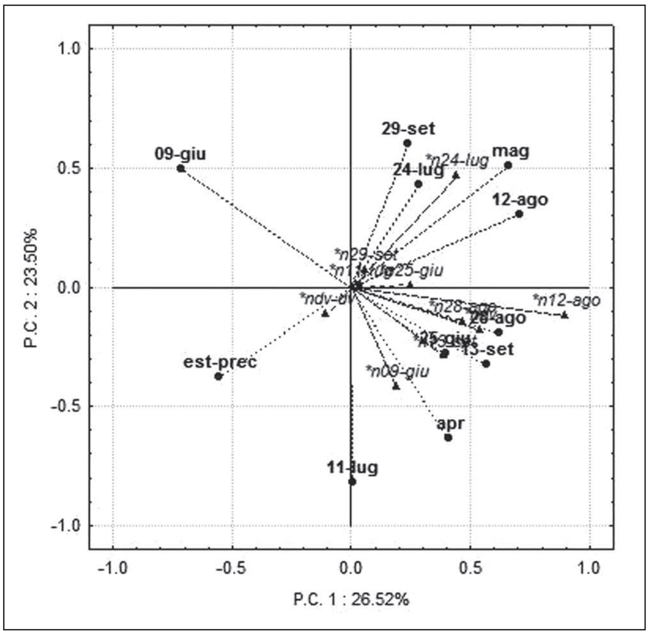

Fig. 3 - PCA of fortnightly data (NDVI and rain data).
Fig. 3 - ACP dell' NDVI e della pioggia quindicinale.

bi-monthly, annual, cumulative and fortnightly) and NDVI data (annual, monthly and fortnightly) with some multivariate statistical methods (PCA,CCA) showed a clear correlation between the response of NDVI and:

1) the rainfall of the initial phase of the vegetative stage (April/May) (Fig. 2);

2) the rainfall in the NDVI detection period (Fig. 3).

Anyway these correlations didn't explain completely the information collected.

To study the tree's behavior in response to water availability the change in color of beech's leaves has been also analyzed. Comparing NDVI value of the first decade of September to the values of the 12 years derived from MODIS-TERRA, it's possible to detect a different and independent behavior between dry years and wet years. Among the dry years there was a clear differentiation between the 38 points, those located at lower altitudes having lower NDVI values. Based on that response, we analyzed the relationship between NDVI and morphological parameters obtained from digital surface model from CIAT-CSI SRTM (Reuter *et al*., 2007 and Jarvis *et al.* 2008). The comparison between multivariate morphological parameters and average annual values of NDVI showed a positive and statistically significant relationship between NDVI and altitude.

This relationship has been interpreted by the different forest's structure in different relief's units. Looking at the forest management plans, in the past decades cuts have been done at low altitudes to convert the trees from aged coppice selection method to more valuable high forest, reducing the number of suckers, so the reflective green mass and associated LAI (Leaf Area Index).

Finally, looking for a relationship between NDVI and diametric growth, we collected wood cores from some trunks to measure dendrochronological data and estimate the annual growth of trees in 3 areas located where NDVI manifests different response. For each areas we collected 6 cores: 3 of dominant and 3 of codominant trees aggregated in 3 points (2 cores each point).

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