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Analysis of climate and topographic effect on wildfire regime in Liguria, Italy

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Introduction

Wildfire risk is particularly significant in Italy, both in summer and winter season due to the high topographic and vegetation heterogeneity of the territory. Liguria is one of the few regions in Italy affected by wildfires both in summer and winter. Most of the fires in Italy occur in summer season and the burned area is largely greater than in winter season. In Liguria, the number of wildfires and the burned area is higher in winter than in summer. Winter fire regime is mainly due to frequent extremely dry winds from the north in condition of curing for most of the herbaceous species. Southern and central regions and the large islands are characterized by a severe summer fire regime, because of the higher temperatures and prolonged lack of precipitation. The threat of wildfires in Italy is not confined to wooded areas as they extend to agricultural areas and urban-forest interface areas. In view of the limited availability of fire risk management resources, most of which are used in the management of national and regional air services, it is necessary to precisely identify the areas most vulnerable to fire risk. The few resources available can thus be used on a yearly basis to mitigate problems in the areas at highest risk by defining a program of forest management interventions. The availability of a mapping of fire perimeters spans almost 20 years (1996-2013), and this, combined with a detailed knowledge of topography, climate and land cover allowed to understand which are the main features involved in forest fire occurrences and their behavior. The seasonality of the fire regime was also considered, partitioning the analysis in two macro season (November-April and May- October). Total precipitation and average air temperature obtained from the interpolation of 30 years-long time series from 164 raingauges and 127 thermometers series were considered. The analysis was based on a recursive-quantiles subdivision of the territory in classes based on the different available information layers: elevation, slope, aspect, total precipitation, temperature (the latter subdivided in winter and summer periods). The algorithm is designed in order to assure the equal representation of each class, in which the number of fires occurred in the period of analysis is considered, in order to have an estimation of the fire hazard with a constant statistical confidence.
The analysis was carried out at a spatial resolution of 20 m on the Liguria region territory (5400 km2) by using a dataset of fires occurrences that spans from 1996 to 2013.

Methodology

The analysis was based on the historical wildfire dataset occurred in the territory of the Liguria Region (Northern Italy, Figure 1) and on the dependence on the geomorphological and climate characteristics of the territory, namely height above the sea level, slope, aspect, total precipitation (summer and winter) and air temperature (summer and winter).
The hazard was assessed as the fraction of cells interested by fire on the total number of cells for each class of geomorphology/climate in which the territory was subdivided in. In order to assure a constant statistical significance in the estimation of the fraction of burned cells and, at the same time, maintain a classification based on the five variable above-cited, the following statistical algorithm was implemented:

1) *The samples of the 5 variables (height, slope, aspect, total precipitationand air temperature) are subdivided in equally numbered intervals (with sample percentiles)*
2) *For each interval of each variable the percentage of burned cells is computed*
3) *The Spearman Correlation coefficient (that accounts also for nonlinear dependences) is computed and the variables are ordered in decreasing correlation order*
4) *Chosen a number n of classes for each variable, and starting from the first variable, the territory of the analysis domain is subdivided in n subsets (intervals of the given variable), each one having the same number of cells. This is obtained by using the appropriate sample percentiles of the distribution of the given variable.*
5) *For each one of these intervals, or territory portions, the same intervals subdivison is performed for the second variables, again using the sample percentiles.*
6) *Step 5) is repeated until the last variables. In the end, the territory is sibdivided in n^5 intervals, all equally-numbered that assure the same statistical significance.*

The variables were used in order of decreasing correlation. From the probabilistic point of view, the iterative subdivision is equivalent to consider the conditional estimation of the fire hazard given the fact that the previous considered variables lay in the given intervals. In symbols:

$$P(F \mid (Px1i < X1 < Px1i+1) \cup (Px2i < X2 < Px2i+1) \cup \ldots)$$

In Figure 2 it is represented the Conditional Distribution Density of the Fire Hazard given that the single cell is contained in a given territory class, where the classes are defined as described above.

Figure 1. Liguria region in Italy.

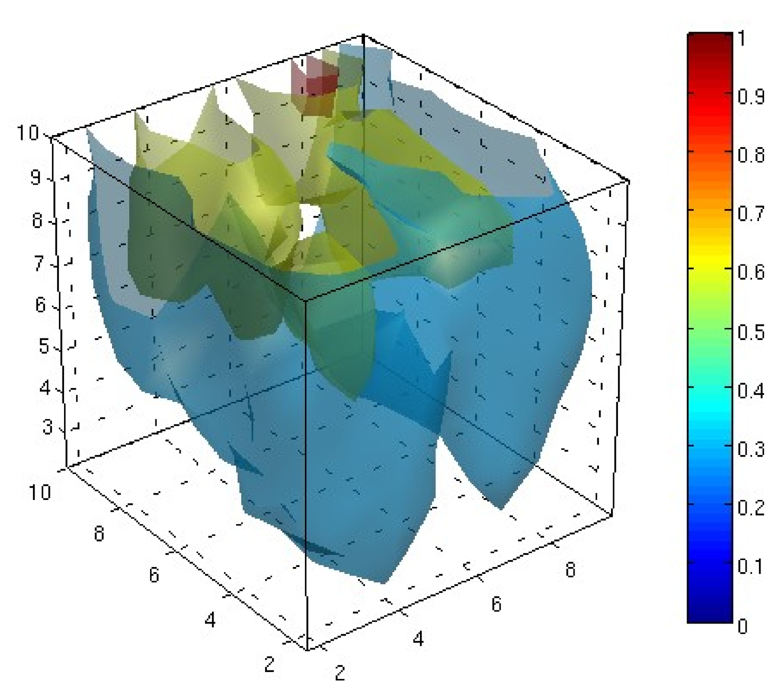

Figure 2. Conditional Probability Distribution Density for the fire hazard.

Fire Hazard Maps

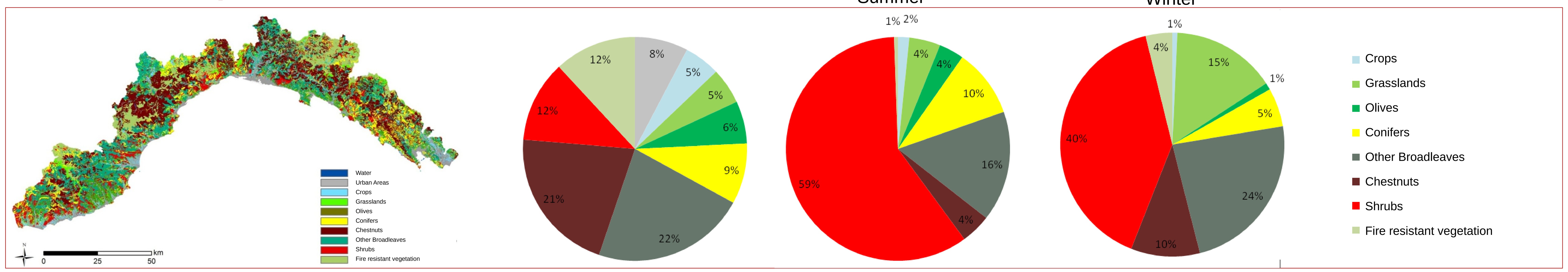

Figure 4. Vegetation cover and burned areas

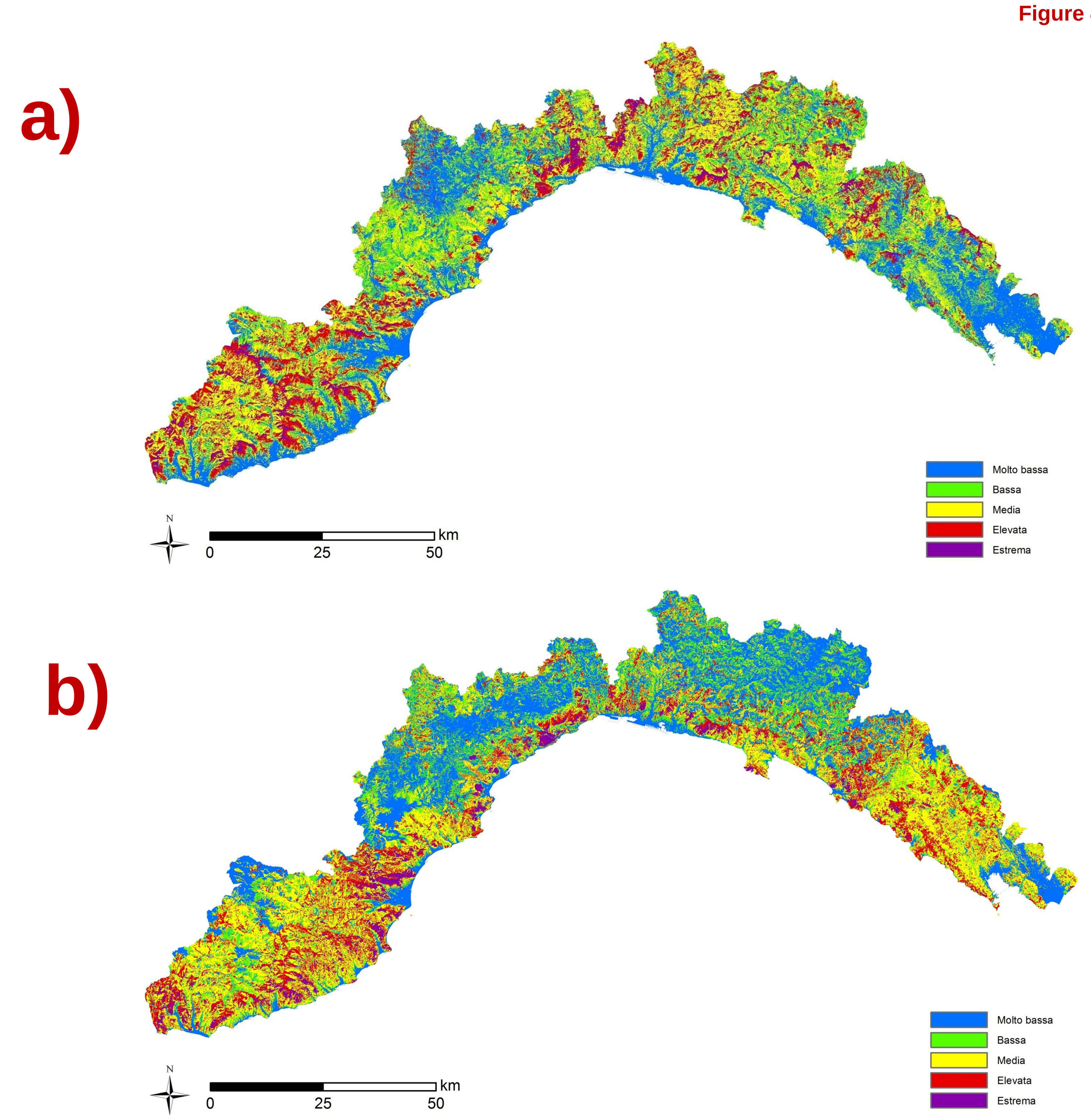

Figure 6. Fire hazard, new methodology: a) winter, b) summer.

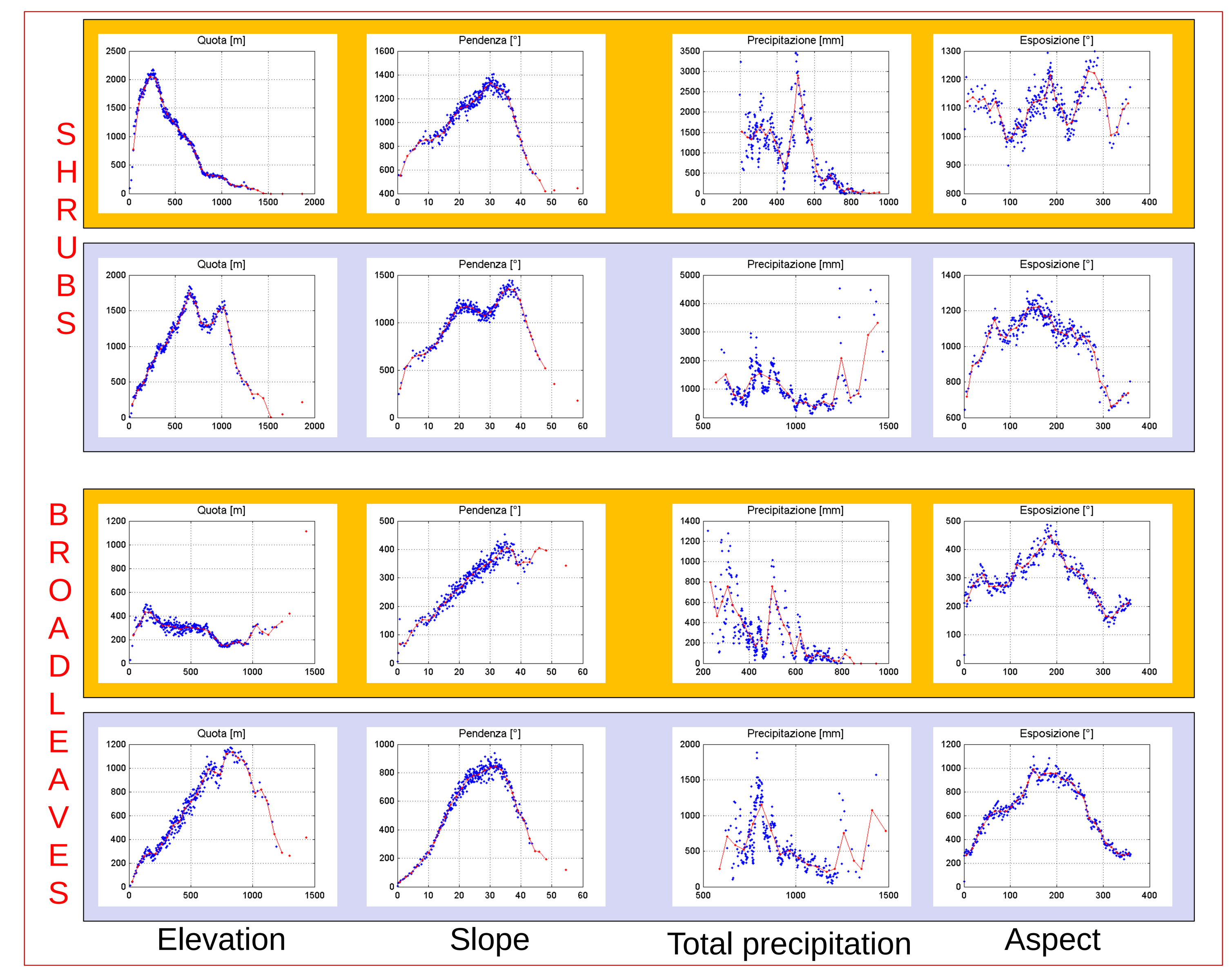

Figure 5. Examples of distribution of burned areas for different topographic and climatic variables in summer (orange) and winter (light blue) for shrubs and broadleaves, respectively.

The analysis was carried out separately for each vegetation class. The final maps were obtained with a mosaic of the single classes. The results show a very high correlation with topography both in winter and summer. Total precipitation is almost uncorrelated in both season. Air temperature is high correlated with the burned area but it is strictly related with elevation. Independently by the season and the vegetation cover, elevation and slope show a very high correlation with the burned area determining almost completely the wildfire regime in Liguria.