The Influence of Meteorological Factors on the Wooded Fires in Messina Province: a Statistical Modeling

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Dedicated to Professor Marius Stoka on the occasion of his 80th birthday

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Abstract

The problem of forest fires takes on dramatic dimensions, so as to arouse uproar at all levels. This paper aims to provide a detailed overview of the fires in Messina province, occurred in the period June 2002 -August 2010 and, particularly, we want to analyze, through adequate statistical modeling, the influence of meteorological variables into favouring the extension of fires. For this aim we analyzed the cause (fraudulent, negligent and unknown causes), the wooded and not wooded compromised surface and the meteorological variables recorded in whether station located in the country in which the fire happened. By obtained results, both the temperature and the relative humidity play an important role in the spread of the fire, when the cause is fraudulent or unknown; in particular the increase of the temperature

assumes a significant importance. The influence of weather factors on the expansion of fires does not change if the involved surface is wooded or not wooded. Moreover in the different weather stations there is a great variability related to the influence of meteorological factors, due to the diversity of geographical location and heights from sea level.

Keywords: Fires, Meteorological Factors, Statistical Modeling.

1 Introduction

Every year, with fixed deadlines, the problem of forest fires takes on dramatic dimensions, so as to arouse uproar at all levels. [2].

It is undeniable that the climate factor has a significant influence on predisposing favourable conditions to the development and spread of forest fires. However, fires do not occur uniformly over the territory, in fact the phenomenon is more pronounced in some areas than in others.

The origin of almost all of the fires is to be charged to several fraudulent cases. From the information obtained through the leaves of the Forest Fire News, it's possible to notice that the causes of criminal behaviour may be related to the search for a profit, protests or resentment towards the public administration and private employment issues (relating to workers hired to work on fire or forest), the desire to obtain products due to the passage of fire such actions due to poaching, to organized crime and to behavioural disorders. In order to oppose such a broad phenomenon, the need of fulfilling field research increases to validate official statistics, trying to seize the "invisibility".

Therefore, the expressed and developed evaluations in the present paper are the result of a detailed study of the fires that occurred in the Messina province from 2002 to 2010. The aim is to provide a detailed overview of the fires in the province, linking it to the concomitant meteorological factors in which each fire occur. In this way, it's possible individuate the relevant meteorological variables, as well as factors favouring the extension of fire. In particular, through the use of appropriate statistical methodologies [4], factors that contribute to the risk of fires were identified, in order to obtain information that will allow a monitoring of the studied phenomenon and, as a result, a quick and effective organization of interventions for the prevention and suppression of wildfires [3].

The present paper aims to study, through adequate statistical modeling, the phenomenon of the fires in the Province of Messina; in particular, we want to evaluate the influence of meteorological variables, taking in account the causes of the fires, in order to prevent them.

2 The Data

The dataset used to evaluate the influence of meteorological factors on fires has been created on the base of:

- data related to the fires;
- data related to the meteorological variables.

In correspondence of every fire the meteorological situation is reconstructed. For this, for every day when the fire is occurred we used the information recorded by the meteorological stations more neighbor to burnt territory.

The data related to the fires have been furnished by the Forest Management of Messina; the data related to the meteorological variables have been furnished by the SIAS (Sicilian Agro-meteorological Information Service) of Palermo.

The dataset is constituted by 8167 fires occurred in the period June 2002 -August 2010. For every fire we analyzed:

- the cause (fraudulent, negligent and natural, accidental and unknown causes);
- the wooded and not wooded compromised surface;
- the meteorological station related to the country in which the fire happened (Buzza, Fiumedinisi, Leni, Messina, Militello Rosmarino, Mistretta, Monte Soro, Naso, Novara di Sicilia, Patti, Pettineo, Pomiere, San Fratello, San Pier Niceto, Taormina, Torregrotta, Vignazza) (Figure 1);
- the daily average temperature;
- the daily total precipitations;
- the maximum daily relative humidity;
- the daily average speed of the wind;
- the daily prevailing direction of the wind;
- the daily total solar radiation.

Figure 1 – Localization of meteorological stations in Messina province

3 Results

Since the response variable (extension of burned surface) has a continuous nature, we considered appropriate to use the Linear Regression Model to assess the influence of the considered covariates. Ordinary Least Squares (OLS) was used to estimate the unknown parameters in the linear regression models [5, 6].

Initially we estimated all univariate models in order to individuate the factors that significantly influence the extension of wooded and not wooded surface (Table 1). For each univariate model we provided parameter estimations (standardized coefficients β and relative p-value). Successively, on the bases of the significant predictors obtained by univariate approach, we estimated multivariate regression models. With the symbol § we indicated the significant variables at multiple regression models.

Table 1: Regression models for influence of each meteorological variable on wooded and not wooded surface

	Wooded Surface		Not Wooded Surface	
Factors	β	p	β	p
Temperature	0.104	0.000 §	0.068	0.000 §
Precipitations	-0.012	0.267	-0.006	0.595
Relative humidity	-0.053	0.000	-0.036	0.001
Speed of wind	0.016	0.157	-0.407	0.684
Direction of wind	0.005	0.661	0.011	0.325
Solar radiation	-0.013	0.441	-0.008	0.658

§ significant variable in multiple regression model, $p < 0.001$

Since considerable differences between wooded and not wooded surface were not found, for the subsequent analyses we decided to use the total surface.

Successively, we took in account the origins of fire, so we estimated regression models, stratifying for causes (Table 2).

Table 2: Regression models for influence of each meteorological variable on total surface, stratifying for causes of fire

	Fraudulent		Negligent		Unknown	
Factors	β	p	β	p	β	p
Temperature	0.091	0.000 §	0.163	0.059	0.081	0.013
Precipitations	-0.009	0.462	-0.058	0.506	-0.002	0.957
Relative humidity	-0.047	0.000	-0.178	0.039	-0.132	0.000 §
Speed of wind	-0.002	0.869	0.099	0.253	0.019	0.568
Direction of wind	-0.014	0.254	-0.033	0.704	-0.046	0.164
Solar radiation	-0.010	0.594	0.033	0.807	-0.011	0.821

§ significant variable in multiple regression model, $p < 0.001$

For fraudulent and unknown causes only temperature and relative humidity resulted statistically significant at univariate approach and, at multivariate model, temperature remains the only significant predictor of fires. For negligent causes the multivariate regression model was not estimated because at univariate approach only a variables (relative humidity) resulted statistically significant.

Afterwards we estimated regression models for data related to each meteorological station, located in the territory of Messina province, in order to individuate differences among the considered areas due to characteristics of the territory. In Table 3 we reported the results.

Table 3: Regression models for influence of each meteorological variable on total surface, stratifying for meteorological station

	Buzza		Fiumedinisi		Leni	
Factors	β	p	β	p	β	p
Temperature	0.393	0.000[§]	0.139	0.000[§]	0.272	0.000[§]
Precipitations	-0.027	0.686	-0.016	0.672	-0.031	0.674
Relative humidity	0.018	0.856	-0.095	0.010	-0.226	0.002
Speed of wind	0.065	0.516	0.026	0.476	0.149	0.042
Direction of wind	0.085	0.393	0.006	0.877	-0.046	0.535
Solar radiation	0.027	0.584	0.025	0.407	0.011	0.883
	Messina		Militello Rosm.		Mistretta	
Factors	β	p	β	p	β	p
Temperature	0.128	0.000	0.101	0.008[§]	0.151	0.019
Precipitations	-0.011	0.630	-0.006	0.874	-0.010	0.879
Relative humidity	-0.014	0.539	-0.076	0.046	-0.131	0.042
Speed of wind	-0.001	0.959	-0.002	0.963	0.034	0.596
Direction of wind	0.019	0.418	0.008	0.840	-0.054	0.398
Solar radiation	0.002	0.919	0.032	0.705	0.012	0.741
	Montesoro		Novara di S.		Patti	
Factors	β	p	β	p	β	p
Temperature	0.030	0.820	0.159	0.000[§]	0.148	0.000[§]
Precipitations	-0.057	0.662	-0.025	0.347	-0.009	0.777
Relative humidity	0.091	0.251	-0.094	0.000	-0.109	0.001
Speed of wind	0.232	0.039	0.031	0.248	-0.010	0.765
Direction of wind	0.271	0.033	0.078	0.003	0.042	0.197
Solar radiation	-0.059	0.651	0.057	0.563	-0.064	0.069
	Pettineo		San Pier Niceto		Taormina	
Factors	β	p	β	p	β	p
Temperature	0.325	0.000	0.182	0.000[§]	0.063	0.125
Precipitations	-0.012	0.870	-0.022	0.633	-0.030	0.463
Relative humidity	-0.391	0.000[§]	-0.068	0.138	-0.099	0.016[§]
Speed of wind	0.314	0.000[§]	-0.002	0.965	0.078	0.057
Direction of wind	0.081	0.281	-0.072	0.131	-0.005	0.903
Solar radiation	-0.086	0.249	0.036	0.727	0.018	0.832

[§] significant variable in multiple regression model, $p < 0.001$

Regression analysis for weather station allowed to highlight a split into several groups, on the basis of a differentiated influence exercised by meteorological variables: temperature and relative humidity play an important role in the spread of the fire, for most places located next the weather stations.

Increasing temperature is a risk factor in stations of Buzza, Fiumedinisi, Messina, Militello Rosmarino, Novara, Patti and San Pier Niceto (all placed in first phyto-climatic area, *Lauretum*). In the station of Pettineo, the decrease in relative humidity and the increasing wind speed are factors whose influence is statistically significant. In Taormina area only increasing humidity would seem to be a factor influencing the propensity to fire extension.

For the station of Montesoro, although the speed and direction of wind were significant in univariate models, no meteorological variable resulted statistically significant in multivariate model.

Regression models were estimated for the stations of Naso, Pomiere, San Fratello, Torregrotta and Vignazza, but no variable was statistically significant in univariate approach; for this reason, the results were not reported in the Table 3. This situation is probably due to occur, in these areas, of few fires and almost all of fraudulent causes, so that a significant influence of some meteorological factors cannot be detected.

The variability of the influence of meteorological factors in different weather stations, considered in this study, is probably due to the diversity of their geographical location and, above all, to their different heights from sea level (it's to be considered, for example, that Patti station is situated in flat area, at 70 meters above sea level; Pettineo station is located in a hilly environment, at 210 meters above sea level, while Vignazza station is located practically in mountain environment, at 820 meters above sea level). For these reasons this paper is a preliminary study, that constitutes the basis of a further and more detailed research that will focus attention on the phyto-climatic areas.

For all regression models we performed residue analysis, which allowed to establish that they are adequate for the analysis of the considered data. After evaluating the adequacy of the regression models, the R-squared coefficient of determination was calculated in order to test the goodness of fit of the statistical model [1]. In all estimated multiple regression models, the R-squared value was always greater or equal to 0.75; therefore, we can affirm that the models are adequate to explain the variability of the studied phenomenon.

4 Final remarks

The present paper aims to analyze the influence of weather variables on fires, in order to contribute to their prevention. The majority of fires in Messina province has fraudulent causes, but natural, accidental and unknown causes

assume a remarkable relevance, too.

The statistical analysis on the weather factors shows that both temperature and relative humidity play an important role in the spread of the fire, when the cause is fraudulent or unknown; in particular the increase of the temperature assumes a significant importance. This result can probably be explained by the desire, of those who causes the fire, to operate in conditions that favour the spread of the bushfire, so that it can cause major damage. In the case of negligent origin low relative humidity seem to take on an important role. This may be due to the habit of farmers who, in order to clean their land, burn the dry grass above all during the periods of absence of sirocco wind (that, as it is known, is a warm and humid wind occurring over the northern Mediterranean Sea and southern Europe, where it blows from the south or southeast and brings uncomfortably humidity in the territory). The influence of weather factors on the expansion of fires does not change either if the involved surface is wooded or not wooded: on the basis of the obtained results and in the same weather conditions, the probability of the spread of fires is equal in both cases. However, it is important to emphasize that in this study we have focused our attention neither on the damage done to the forest nor the difference between fire and grazing of foliage. The variability of the influence of weather factors in the different meteorological stations, considered in this paper, is probably attributable to the diversity of their geographical location and, above all, to their different height from the sea level.

Today, the availability of more information in comparison with the past and the more detailed analysis of risk situations allow the realization of more and more advanced fire control plans, with the aim of prevention. It has been shown that most fires, developed in the areas of urban-forest interface, are not a natural disaster but a result of anthropogenic behaviors such as the abandonment of agriculture, conflicts over land management, the carelessness, the non-compliance with laws and regulations. In fact, in areas where economic activities are closely related to the rural environment, the number of fires tends to decrease significantly. This paper could be used by fire prevention services (provincial, forestry, municipal, civil protection, etc...) to increase controls during the unfavourable climatic periods, in order to avoid the spread of fires.

References

- [1] David M. Glover, William J. Jenkins, and Scott C. Doney: *Least Squares and regression techniques, goodness of fit and tests, non-linear least squares techniques*. Woods Hole Oceanographic Institute, 2008.

- [2] Marzano R., Bovio G., *Analisi dell'interfaccia urbano-foresta mediante dati telerilevati per la caratterizzazione del rischio di incendio boschivo*. Atti della 8a Conferenza Nazionale Asita, Geomatica:Standardizzazione, interoperabilità e nuove tecnologie. Fiera di Roma, 14 -17 dicembre 2004, p.1413-1418.
- [3] Marzano R., Ceccato R., Wolynski A., Bovio G., *La pianificazione antincendi boschivi nella Provincia Autonoma di Trento: nuovi approcci e sinergie*. Atti del Terzo Congresso Nazionale di Selvicoltura. Taormina (ME), 16-19 ottobre 2008. Accademia Italiana di Scienze Forestali, Firenze, 2009, p. 1301-1307.
- [4] Piccolo D., *Statistica*, Il Mulino, Collana strumenti, 2010
- [5] Tofallis C., Least Squares Percentage Regression, *Journal of Modern Applied Statistical Methods*, **7** (2009), .526-534, doi.10.2139/ssrn.1406472
- [6] Seber G. A. F., Lee A. J. *Linear Regression Analysis*, 2nd ed. Wiley, Hoboken, 2003.

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