FOREST FIRE DANGER RATING USING METEOROLOGICAL SATELLITE DATA

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ABSTRACT

A study on forest fire danger rating using Meteosat thermal infrared data is being carried out and applied in the Piemonte region (Northwestern Italy).

The purpose of the study is to analyse the relationships existing between fire occurrence and Meteosat data.

A period has been chosen among those with average fire severity and with satellite image availability. The Piemonte region has then been divided into subareas of homogeneous environmental characters. The hypothesis of employment of a different fire danger level in each area is being tested.

Among the data provided by the satellite thermal infrared channel and used to relate with fire occurrence, the sum of emissions in the last days without rain, emission at midday and emission at dawn have been included.

The state-of-the-art of the research of a fire danger meter based on the probability level of fire occurrence using Meteosat data is presented.

Keywords: Fire danger, Remote sensing, Meteosat

1. PREFACE AND AIM OF THE WORK

In Italy to rate the forest fire danger a meteorological index is used which originates from the Australian McArthur index[1], calculated on a daily basis at the stations distributed throughout the whole national territory.

After a first experimental stage, it was noted that this index cannot be applied uniformly throughout the whole Italian territory[2] where noticeable climatic and vegetational differences can be observed.

For this reason, other indexes are currently being researched; among these the possibility of using remote sensing techniques to monitor the fire danger in real time is being studied.

The aim of this work is to highlight the possibility of using Meteosat satellite images, available at low costs and with a significant frequency.

With this in mind, methodological indications have been developed and procedures defined to study and elaborate a daily fire danger rating algorithm, with reference to Piemonte, the Northwestern region of Italy which covers approx. 25,399 km^2 of which 743,000 hectares covered by forests[3].

2.MATERIALS AND METHODS

(1) Materials and Study Environment

Thermometric and pluviometric factors have been considered using the following tools:

(a) Meteosat images (wave length in thermal infrared - 10,5-12.5 μm - spatial resolution: 5x5 km, image frequency: 30') for thermometric data.

(b) Network of 43 meteorological stations distributed throughout the whole territory to gather pluviometric data.

The study environment is Piemonte where there are an average of 400 wildfires a year concentrated, for the most part, from December to April. The average surface area affected is 21.1 ha per fire (historical data for 1980-1990). The forest environment is very diversified and heterogeneous; the fires are concentrated in the pre-alpine zone between 400-800 metres above sea level where chestnut (*Castanea sativa* Mill.) woods have been favoured in the past by man and are now abandoned with the consequent accumulation of fuel to the soil.

(2) General Considerations

First of all it has been established if and how the information and its flow which the tools considered provide, can be used to define a daily fire danger rating index.

A. Type of information surveyed.

(a) Meteosat images. They are recorded every 30' for a total of 48 maps per day. Only some of these will be used bearing in mind the following considerations.

The daily progress of the surface temperature for a given surface point reaches a maximum after midday and a minimum just before the sun rises[4]. With an equal solar load, and for the same point on a surface, the daily thermal excursion is a function of the water content because of the high thermal capacity of water. It has therefore been decided that 2 maps will be used per day: the first one at dawn (which will vary depending on the season) and the second one at midday (12.00). The choice of midday is based, on the one hand, on the necessity to have a time close to that of the max. surface temperature and, on the other, by the need to not delay the time of the rating useful to the fire fighting service. Indeed the distribution of frequency of the fires during the day in Piemonte is mainly concentrated during the first few hours after midday.

The parameters to be used in order to realize a rating algorithm are the following:

- Meteosat map data at 12.00 hours
- Meteosat map data before the sun rises
- The difference between these two maps
- The thermal sum obtained by adding together the map taken at 12.00 hours of the day in consideration and the maps taken at 12.00 hours of all previous days until one with significant rainfall is reached.

Significant rainfall may be defined as a quantity of daily rain which constitutes a real reduction in the danger. A threshold of 5 mm has been adopted, based on the supposition that this is the average amount absorbed by the vegetation and that evaporates[5].

(b) Pluviometric data. This has been taken by 43 meteorological stations distributed throughout the territory. The interpolation model described by Akima[6] for the attribution of the punctual data of the meteo stations to the surrounding territory, generating the rain maps framed in the same geographic reference grid as the Meteosat maps has been applied.

B. Spatial resolution.

As Piemonte is contained, for the most part, between the 44th and the 46th parallel, the Meteosat image whose pixels are of 25 km^2 (5x5), must be straightened resulting an increase of the size of the pixel itself. Such a spatial resolution is suitable for the rating to be calculated because the meteorological factors influence the fire danger on a scale also greater than 25 km^2.

C. Continuity of information flow

As regards the above, the largest problem is created by clouds which represent a barrier that impedes the signal from being received from the earth's surface.

Indeed when the sky is cloudy, the emission that the satellite records is not relative to the earth's surface but to the upper part of the cloud bands; in these cases the areas covered by clouds must be excluded and during cloudy days the index is not calculated.

D. Power of the computers

The calculation power and mass memory of the computers has proved to be an important aspect, at least during the experimental and study phase; indeed a large number of maps, kept in archives on magnetic tapes, need to be analyzed.

(3) Territorial and Time Subdivisions

An attempt has been made to modulate the danger index in accordance with the various areas and periods of the year. With this in mind, an attempt has been made to divide Piemonte into subareas with greater homogeneity with respect to the overall territory; in addition periods of the year have been identified to which reference should be made in order to determine different fire danger levels. The algorithm which puts the meteorological variables together in order to calculate a danger index, should, or so it would first appear, be the same for the whole region and for the whole year, but the danger levels that the index expresses will be different in accordance with the zones and vegetative period and should, therefore, be determined case by case.

First of all, the 12 forest zones of Piemonte are considered which have been described in previous studies[7] that are homogeneous geographical zones as regards orography, geological substratum, types of vegetation covers and, within certain limits, for the socio-economic reality.

Of these 12 forest zones, two, relative to hilly areas, have been united because they did not present significant differences from the forest fire point of view and both were areas that were not greatly affected by this phenomenon; from the fusion of these two zones, we have passed from having 12 zones to 11.

Therefore the data relative to the monthly distribution of fires in these areas has been elaborated using cluster analysis and the 11 forest areas have been grouped together into three zones with similar distribution and fire frequency characteristics.

We think of making reference to these three zones separately in order to identify the different danger thresholds.

As regards the subdivision for timing, the year has been divided into six two monthly periods, in order to take into account the seasonal modifications to vegetation.

The periods that have been identified are as follows:

First period: January-February
Second period: March-April
Third period: May-June
Fourth period: July-August
Fifth period: September-October
Sixth period: November-December

(4) Choice of Experimentation Period

The choice as to which period of time would be used for the first experimental analysis was based on different criteria. The best period has been defined as the one with the following characteristics:

(a) period in which the Meteosat images were available;

(b) period of time of around 2-4 months in order to easily manage the satellite images;

(c) period included in a year with timing and distribution of fires comparable to the historical average for the last ten years.

(d) frequency of fires which starts off increasing from a minimum value (no case) and then decreases.

(e) even distribution of cases, throughout the Piemonte territory, ie. comparable with the average distribution of fires throughout the territory noted in history.

3. PLAN OF OVERALL PROCEDURE

The work carried out has provided the opportunity of outlining, although in general terms, a provisional plan, which briefly describes the steps necessary to realize a first development procedure for the research of a forest fire danger rating algorithm. The activities which must be carried out to achieve this objective are illustrated below:

(1) Service and Preparatory Activities

In the first instance, certain activities should be carried out divided into service and preparatory activities.

A. Service activities: these involve obtaining and checking the information base.

This basically includes the set of activities necessary to put the data in the form of usable maps:

(a) decompression and loading of the Meteosat images recorded and filed on tapes;

(b) checking for eventual errors in the maps (disturbed or interrupted reception, filing errors etc.);

(c) correcting the time which may not be homogeneous as the local acquisition time is reported and not the real time at which they were taken from the satellite.

(d) translating the data from the forest fire data base in daily maps of the cases that have occurred.

B. Preparatory activities: transformation of the maps available in a form that can be adapted to future elaborations.

(a) preparation of Meteosat maps: straightening, extraction from the map of the area of interest (Piemonte), spatial recording with respect to the geographical reference grid.

(b) Preparation of fire maps: arranging the maps on the geographical reference grid.

(c) Preparation of rain maps: interpolation of the meteorological data from the network and framing in the geographical reference grid.

(2) Main Procedures

Once the basic information has been obtained and prepared, the procedures described below must be carried out:

A. Recording the IR map at dawn and the IR map at the 12.00 after elimination of pixel covered with clouds.

B. Calculating the difference between the IR map at 12.00 and that at dawn.

This procedure executes the difference between the 12.00 map and that at dawn of the current day. The areas with clouds are excluded from the calculation.

C. Calculating the days since the last significant rain.

For every pixel highlighted on the reference grid the number of days that have passed since the last day of significant rainfall are calculated, ie. greater than the rainfall threshold.

D. Calculating the thermal sum.

This procedure sums up the IR emissions recorded at 12.00, starting from the last day of significant rainfall.

4. CONCLUSIONS

This work describes the state-of-the-art of the research into a fire danger index in Piemonte using Meteosat satellite images.

Currently some general principles have been defined in order to obtain a procedural development draft for a differentiated index for forest areas and for periods in the year, to take into account the different influences of space timing variations.

It is believed that the procedure followed can provide indications for further studies which can be made concrete upon availability of a complete archive of Meteosat images for the past years, the data regarding the historical fires and a VAX computer.

The work carried out has allowed to set up a procedural address tracing a first methodology which although it can be improved upon, represents a first concrete result which has been realized only after resolution of several problems and which can be followed in order to validate a danger rating algorithm in the future on a stochastic basis.

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