THE FOREST FIRE RISK INDEX (ICRIF) OPERATIONAL PROCESSING AND VALIDATION

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Abstract: Forest fires are one of the most important natural risks affecting Portugal, especially over the summer time, with enormous direct economical impact and indirect consequences, introducing fast changes on the land cover. Just a sustainable management of forest allows continuity on the forest exploitation.

The Forest Fire Risk Index, the ICRIF, produced by the Portuguese Meteorological Institute (IM), combining meteorological conditions (FWI), vegetation status (NDVI) and structural information will be presented. The ICRIF value, ranging from 0 to about 100, is calculated weighting the FWI value with a factor connected with a fuel burn index, and the vegetation index NDVI.

The results for the year 2006 are presented, evaluating the number of high-risk pixels in each Portuguese District area and the amount of fire events (area and number of fires). The correlation, for each district area, between the number of pixels with higher ICRIF (above 25 or 35) and the forest fire occurrence numbers/burnt areas was, during the forest fire season, calculated showing values above 60%.

Keywords: ICRIF, FWI, Forest fires

1. Introduction

Forest fires are one of the most important natural risks affecting Portugal, especially during the summer time. The Climate of Portugal is characterised by a warm and dry summer, resulting in a large deficit on the soil water budget. Due to these conditions, and taking into consideration the vegetation type characterising the land cover in Portugal, a large number of the forest fires and corresponding significant burned areas, occur every Summer. The forest fires have a direct economical impact and indirect consequences, introducing fast changes on the land cover and increasing desertification witch also contributes to the global warming.

On other hand, the problems of forest fires are also linked to land cover and land use. The highest values of the forest fire risk must be associated with dense forest areas. Areas like Alentejo, although having meteorological high-risk values, don't have vegetation like forest to spread the fire.

There are different forest fire indices. Some are strictly meteorological, but others, are including also structural fire risk indices based on parameters that do not change in the same time scale as weather does. They include variables like topography or vegetation cover.

The Portuguese Meteorological Institute computes a combined Forest Fire Risk Index, the ICRIF ("Índice Combinado de Risco de Incêndio Florestal"). It is a dynamic index, combining meteorological, vegetation status and structural information. With the

ICRIF we intend to compute not just the probability of forest fire ignition, but also the capability of fire spread.

2. Model and Data

The ICRIF agglomerates several factors, taking into account both, structural and meteorological indices, combining the FWI (Fire Weather Index, Canadian Index) with a fuel map, based on the CORINE 2000, and the NDVI (Normalised Difference Vegetation Index).

The ICRIF is calculated weighting the FWI value with a factor connected with a fuel burn index and a vegetation index, the NDVI. The weights are values scaled from 0 to 100 and the final value of ICRIF can range from 0 to about 100 (the scale of the FWI is open but ranges from to about 100).

2.1. *Fire Weather Index (FWI)*

One of the inputs of the ICRIF is the FWI ("Fire Weather Index"), processed from the Portuguese meteorological stations network and spatiallised to a resolution of 1.1 km x 1.1 km. The FWI is calculated for 85 meteorological stations in Portugal. The meteorological parameters required to process as input are: temperature of air, relative humidity of the air, the direction and velocity of wind, measured at 10m of height, and the rainfall in the last 24 hours.

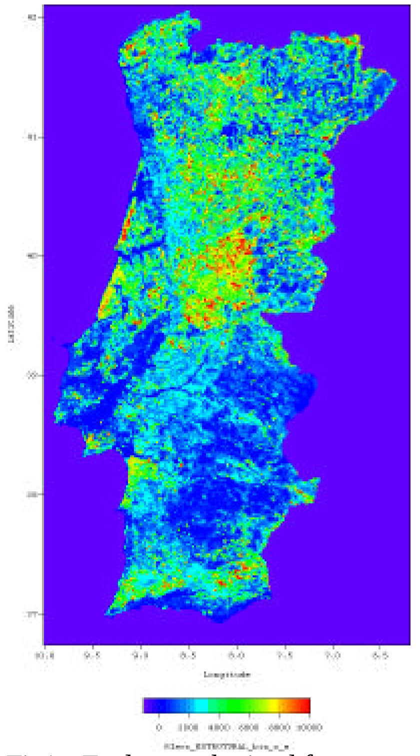

Fig1 - Fuel map obtained from Corine2000

2.2. *Structural Index: Fuel Map*

The structural index, with the same resolution (1.1km x 1.1km), is obtained from the land cover database, CORINE 2000 (*CO-oRdination of Information on the Environment*), built with a initial spatial resolution of 100m

The land occupation of each pixel was given by a vector with 44 values, representing the fraction of the total area occupied by each class (A_k). The fuel map was built associating a risk weight to each classes (R_k),.

The final value of structural index (*fuel*), for each pixel, is calculate by:

$$FUEL = \sum (A_k * R_k)$$

Fig.1 represents the fuel map for the year 2006.

Forests are periodically burned, resulting in an immediate change of the land cover in the burned surface. This can result in changes in the structural fire risk map starting the recover of natural vegetation or forest species that were present before the fire. The new characterisation of the land cover is done, updating the value of the fuel risk pixel value. This exercise shall be done, at least, once a year, on the beginning of the fire season (April), using imagery and observing changes in the NDVI index.

2.3. *Vegetation Index*

Normalised Difference Vegetation Index (NDVI), Justice et al, 1985, is one of the most used vegetation index and is a measure of the amount and vigour of vegetation at the surface. The magnitude of NDVI is related to the level of photosynthetic activity in the observed vegetation.

NDVI are calculated using measurements from the Advanced Very High Resolution Radiometer (AVHRR) on board the USA's NOAA polar orbiting meteorological satellites system. The reflectance measured from Channel 1 (visible: 0.58 - 0.68 microns) and Channel 2 (near infrared: 0.725 - 1.0 microns) are used to calculate the index**:**

$$\mathbf{NDVI = (Ch2-Ch1)/(Ch2+Ch1)}$$

The differential reflectance in these bands provides a means of monitoring density and vigour of green vegetation, using the spectral reflectivity of solar radiation. Green leaves commonly have larger reflectance in the near infrared than in the visible range. Leaves under water stress, become diseased or die back, becoming more yellow and reflecting significantly less in the near infrared range. Clouds, water, and snow have larger reflectance in the visible channels than in the near infrared, leading to a negative value of NDVI, while the difference is almost zero for rock and bare soil. NDVI typically ranges from 0.1 up to 0.6, with higher values associated with greater density and greenness of the plant canopy. Surrounding soil and rock values are close to zero while the differential for water bodies such as rivers and dams have the opposite trend to vegetation and the index is negative. The value of NDVI over evergreen conifer forests doesn't change very much during a year, ranging typically from 0.25 to 0.35.

The NDVI is affected by a number of different phenomena, including cloud contamination, atmospheric perturbations, variable illumination and viewing geometry, scattering by dust and aerosols, Rayleigh scattering, subpixel-sized clouds, all, in general, with an impact of reducing the NDVI value. To address these effects, NDVI data are often used as a composite, taking the maximum value over a specified time period, usually a week or ten days.

To minimise the error due to illumination and viewing geometry, the selected NOAA image has the best observational zenith angle, below 45º, and the best solar zenith angle, below 35º of solar elevation angle. The receiving station is able to perform an automatic geometric correction with several reference ground control points, about 200 landmark points. The final error is estimated in one

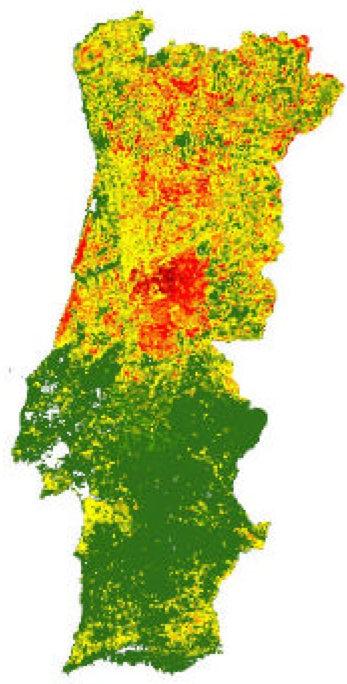

Fig 2 - ICRIF on 1 June 2006

pixel.

3. Results of ICRIF

ICRIF results were compared with several others indices showing a very good performance. It was calibrated to give results near of the FWI, in order to be classified in the same fire danger classes, based on the statistical data of number of fires and burned area for each district of Portugal (D. X. Viegas et al, 2004).

The ICRIF, at the spatial resolution of 1.1 km x 1.1 km, is being calculated since May 2006. The version 2006 of ICRIF is well synchronising either in the increase or in the decrease of meteorological forest fires conditions.

For instance, by the end of May and beginning of June it was observed synoptic conditions for forest fires in northern part of Portugal. On the contrary, in the southern part of Portugal lowest temperature and cloudy conditions with precipitation were observed. This can also be clearly identified in the ICRIF map for 1 June (Fig 2), showing Portugal divided in two different areas: northern and southern parts.

From 7 to 16 June the weather in Portugal was conditioned by a quasi-stationary High, localised over British Islands, together with a Low centred at Southwest of Azores Islands, moving slowly in continent direction. The weather in Portugal was influenced by this depression causing some precipitation by the end of the period. The forest fire risk index, ICRIF, was following this evolution, showing relatively high values for all regions of Portugal, especially in Centre until 6 June (Fig. 3), decreasing after, and presenting the minimum of ICRIF values on 13 June (Fig 4).

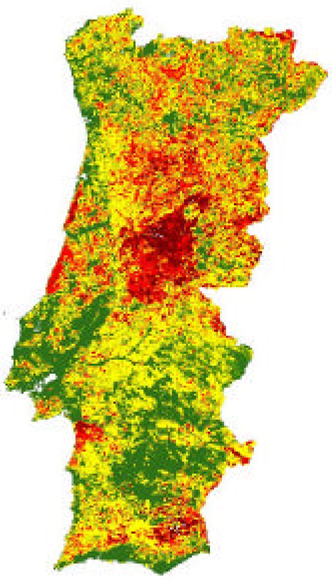

Fig 3 - ICRIF on 6 June 2006

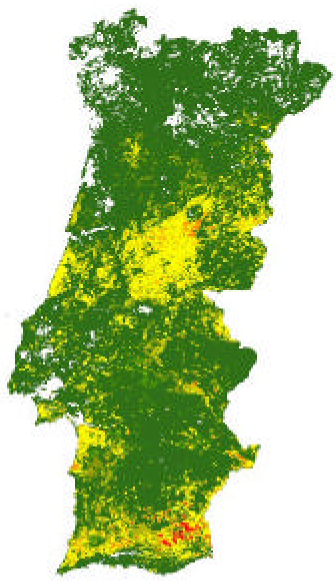

Fig 4. ICRIF on 13 June 2006

4. Validation and Discussion of the Results

The results of the ICRIF for the forest fire season 2006 (May-August) was validated with occurrence number of fires and the burnt area, provided by DGRF (Direcção Geral de Recursos Florestais, Portugal).

For each district a daily six-class histogram of ICRIF was computed:

1)]0,5]

2)]5,15]
3)]15,25]
4)]25,35]
5)]35,45]
6)]45,100[

As expected the highest values of ICRIF (with more pixels in the class 5 or/and 6) were related with meteorological conditions favourable to forest fires, like high temperature and low values of relative humidity, and with forest areas, which amplify the meteorological index and increase the ICRIF value.

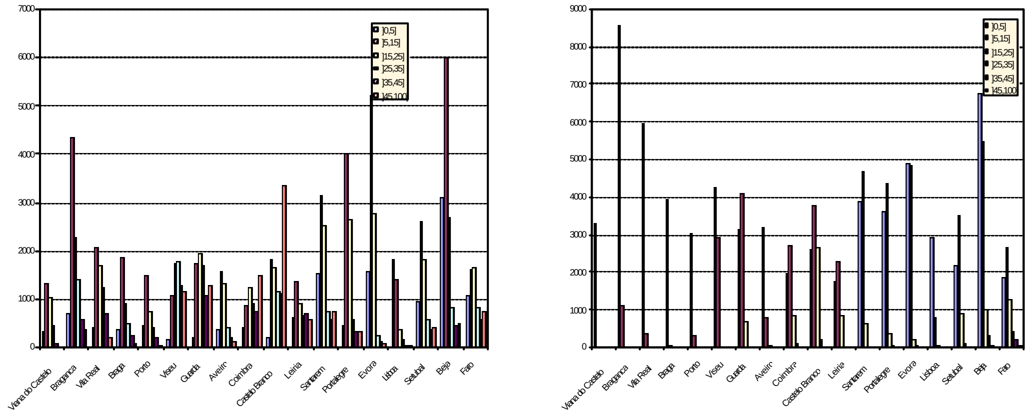

Fig. 5 Histogram of the ICRIF for all district at 6 June (left) and 13 June (right) 2006

The correlation between the number of pixels, for each district, with highest values of ICRIF (above 25 or above 35) and the number of occurrence of fires was calculated between May and August 2006. In general, the correlation is above 50% for all districts, reaching 94% in same of them, as it is possible to see in Table I. When the fire occurrence number is low, below 6 occurrences in a month, the correlation was not possible to be computed.

Table I

Correlation between the number of pixels with ICRIF >25 and the number of occurrence of fires

	May	June	July	August
Aveiro	94%	84%	60%	91%
Braga	52%	87%	50%	95%
Bragança	-	72%	-	72%
Coimbra	68%	68%	63%	85%
Porto	93%	76%	77%	86%
Santarém	50%	45%	56%	62%
V.Castelo	74%	68%	-	82%
V.Real	80%	88%	51%	74%
Viseu	67%	84%	61%	78%

From Table I it is possible to conclude that the correlation is very good when the fire occurrence number is big enough.

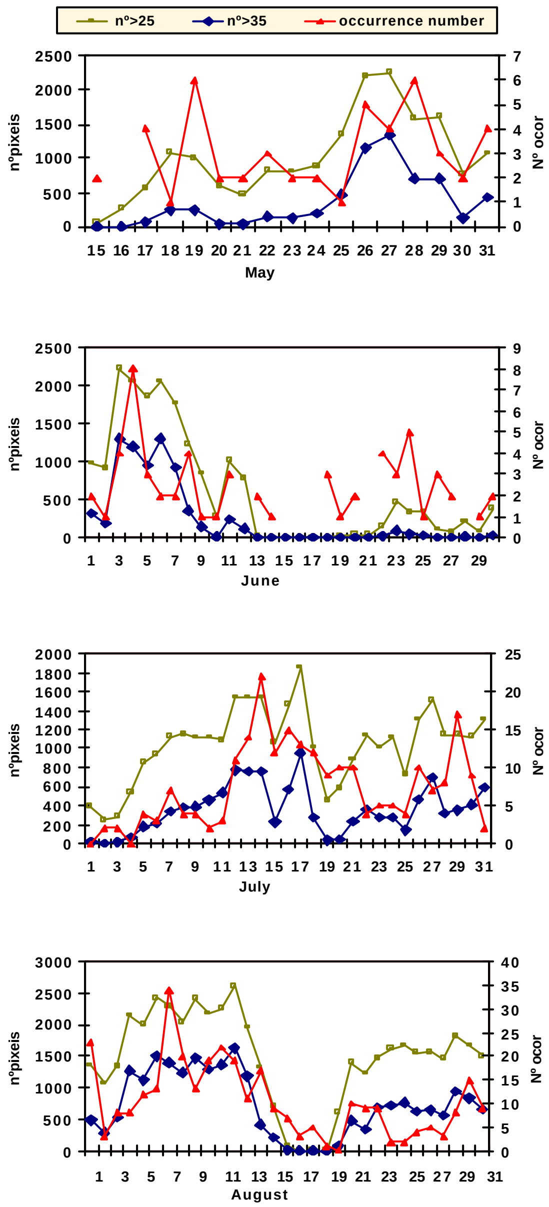

Fig 6. Number of pixels with ICRIF value above 25 and 35 and the fire occurrence number for Santarém

The Fig. 6 shows the results for the district of Santarém for May, June, July August 2006, with correlation values below 50%. Even with this low correlation factor the figure show a good agreement, and it possible to consider the number of pixels with ICRIF value above 25, as a good indicator of the risk of occurrence of fires. The choice of Santarém was done to be one with low correlation value. Of course in another cases, where the correlation factor was higher the agreement is even better.

The correlation obtained between the number of pixels, for each district, with highest values of ICRIF (above 25 or above 35) and the dimension of burnt area was, in general, between May and August 2006, lower than the correlation number using the number of occurrence of fires.

The lowest correlation values were associated with the months and districts where the burnt area was small, even if sometimes the number of fire occurrences was significant, Table II.

Tabela II
Correlation between the number of pixels with ICRIF >25 and burnt area

	Maio	Junho	Julho	Agosto
Aveiro	87%	53%	75%	54%
Braga	56%	65%	52%	73%
Bragança	-	-	53%	61%
Coimbra	77%	-	47%	-
Porto	73%	89%	65%	56%
Santarém	-	-	56%	-
V.Castelo	99%	-	-	-
V.Real	-	-	68%	-
Viseu	63%	54%	-	50%

5. Conclusions

The ICRIF show good results, and a strong agreement with related risk of forest fire. In general, there are very good correlation between high values of the ICRIF and high number of fire occurrences or burnt area.

In fact, it is possible observe high values of ICRIF without forest fire occurrences. Other factors, as human activities or fire combat infra-structures, shall also be consider, and could minimise the correlation factor. Nevertheless, it is clear that, high ICRIF values correspond in general, to areas with strong risk of having fires.

6. Future Work

The ICRIF still need some validation for different regions and vegetation types. The results can led to a change on the weight given for each kind of vegetation that could be adapted for each region of Portugal. This task in an on-going activity and shall be ready before the next forest fire season.

Another aim will be to include other vegetation indices as LAI, FVC or fAPAR, available in the next future for EPS and processed and distributed by IM under the responsibility of LSA SAF. The use of other type of products distributed by the LSA SAF, namely LST, ET, SM, DSSF should be also addressed in the future, as potential inputs to improve the ICRIF.

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