Monitoring Burnt Areas in Portugal Using NOAA/AVHRR Imagery

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Abstract – The summer season of 2003 in Continental Portugal was by far the worst in what respects both to the number of forest fires and the amount of burnt area. In the present work, burnt area monitoring was performed using NOAA/AVHRR imagery by means of a neuro-fuzzy (ANFIS) algorithm that was applied on an operational basis to the surface of the country. Validation of obtained results was performed both in space and time against information from an end of fire season burnt area map based on TERRA/MODIS data and from the General Directorate of Forests (DGF) database, respectively. A good agreement between the automatic classification and in situ observations was found for the cases of wildfires of larger extent.

Keywords: NOAA/AVHRR, forest fires, neuro-fuzzy, TERRA/MODIS, burnt area.

1. INTRODUCTION

Forest fires in southern Europe are a major source of concern for environmental security. Every year several hundred thousand hectares of forest are burned. These fires put at risk, not only human life and property but also the sustainability of forests. Hence, it is important to have an accurate and timely knowledge of the total area burned during the fire season, as well as of the type of forest that has burned.

According to the Portuguese General Directorate of Forests (*Direcção Geral das Florestas, DGF*), the total burnt area in Continental Portugal during the period 1980-2003 (Fig. 1) has reached 2.606 million hectare (equivalent to 29% of the surface of the country). As shown in Fig. 1 the year of 2003 was by far the worst in what respects to the extension of burnt areas (Pereira *et al.*, 2005). According to DGF the burnt area reached 453,097 ha (equivalent to 17% of the total), a value that is worth comparing to the amount of 182,486 that was reached in 1991, the second worst year in the series.

For instance, in August alone wildfires burned a total of 280,550 ha and were responsible for the death of 21 human beings and an estimated loss of 15.5 million euros.

This catastrophic situation caught the media attention and originated public discussions about the human, the environmental and the economical consequences of wildfires in Portugal.

The aim of the present work was to assess the spatial distribution and the temporal evolution of the large wildfires that affected Continental Portugal during August and the first half of September 2003.

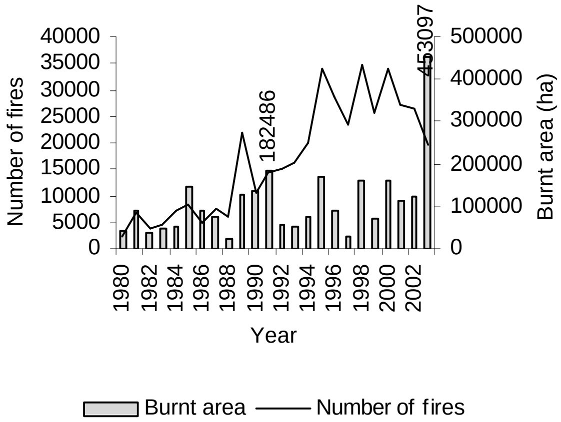


Figure 1. Burnt area by wildfires (1980-2003).

2. DATA

The dataset consists of 36 images of the "early afternoon" orbit (between 13:25 and 17:25, local summer time) containing count values of the five AVHRR channels based on information from NOAA-12 or –16. The images were previously geometrically corrected and geocoded to the size of 1100 m^2. Data were defined on a 548×292 pixel matrix covering Continental Portugal, the coastal waters and a small part of Spain (Fig. 2).

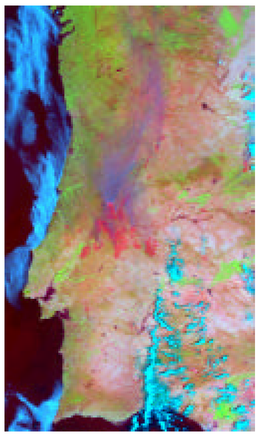


Figure 2. The NOAA image (RGB: channels 4,2,1) for August 3.

Validation of obtained results was performed based on a vector image of fire scars based on radiative information retrieved by MODIS/TERRA on September 14. The vector image was *rasterized* and pixels were degraded to the NOAA size (Fig. 3).

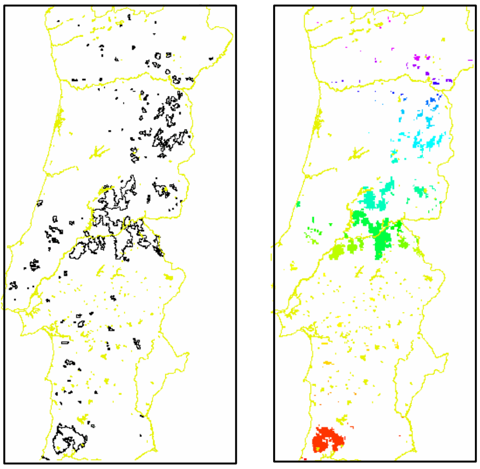


Figure 3. Burnt area map for 2003. (a) MODIS vector image (250 m resolution); (b) raster image after resampling to NOAA 1100 m resolution. The yellow lines delimit the country and the water bodies.

In order to obtain a validation of results along time, the official database provided by DGF was also used. The database includes information of fire location organised by district, county and parish, date and time of ignition and extinction, area of forests, shrublands and agricultural crops burned by each fire and land ownership status (public or private) of the burned area.

3. IDENTIFICATION OF BURNT AREAS

In order to identify burnt pixels a neuro fuzzy (Nauck *et al.*, 1997) algorithm (ANFIS) (Jang, 1993) was applied to the spatially normalized clear sky pixels of the near infrared and thermal infrared (Calado and DaCamara, 2002; Chiu, 1996) NOAA/AVHRR channels (channels 2 and 5, respectively). FIS surface (Jang *et al.*, 1997) as obtained from the ANFIS model (Fig. 4) confirms what is to be expected from burnt area signatures, *i.e.*, low values of channel 2 (lower reflectance of burnt areas when compared to other types of surfaces) and high values of channel 5 (relative increase in temperature after a fire event).

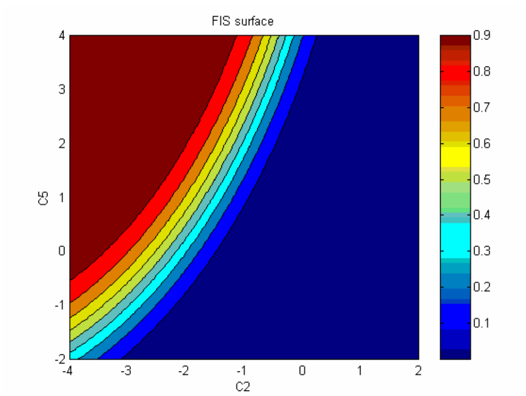


Figure 4. FIS surface of the ANFIS model. Colours from blue to brown identify low to high membership values.

Fig. 5 presents an example of obtained results for August 3: the reddier the pixels the higher the possibility of being burnt surfaces.

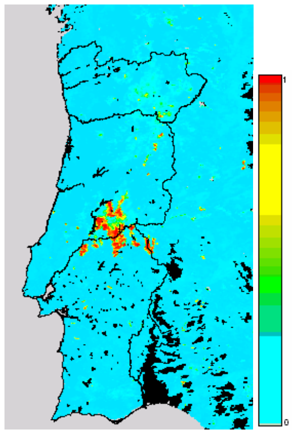
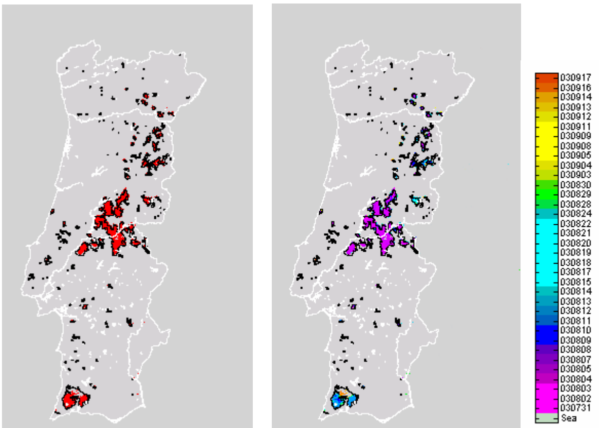


Figure 5. Pseudo-colour image for August 3, with membership values obtained from ANFIS model. Pixels in grey and black represent the sea and cloud masks, respectively. Black lines delimit the county and the water bodies.

A maximum value composite of the burning scores that were obtained using the ANFIS model was then built and results were deffuzified using a threshold of 0.8 (Calado and DaCamara, 2002; Calado, 2004). The respective first day of occurrence was estimated by identifying the first image where the respective pixel was considered as a burnt area.

A visual comparison of burnt areas with the vector lines from MODIS revealed the presence of commission errors that might be due to several causes, *e.g.* spurious contamination by water bodies and errors in georeferencing, other than a bad performance of the method. Accordingly, we have considered that such occurrences should have a random nature and might therefore be eliminated by considering a pixel to have burnt if the signature had persisted at least for two consecutive images. Fig. 6 presents the results obtained after applying the correction based on persistence of burnt area.

It may be observed that the largest fires in the Northern and the Central regions of Continental Portugal occurred in the beginning of August (pixels in purple), while those in the South took place in mid-August (pixels in blue) and in mid-September (pixels in red). These results are in accordance to the ones obtained by DGF.



(a) (b)

Figure 6. Composite of (a) burnt areas after applying the threshold of 0.8; (b) initial day of occurrence of fires. Black curves represent vector scars from MODIS and white lines delimit the country and the water bodies.

4. TEMPORAL AND SPATIAL ANALYSIS

Fig. 7 shows the evolution of total burnt area along summer and it is worth noting the two jumps that took place from August 2 to 3 and from August 12 to 13. It is also worth pointing out that fires responsible for 50% of the total amount of burnt area occurred mainly between August 1 and 5. This was to be expected if one takes into account that, for instance, August 2 was the hottest day of the year, with maximum temperature values exceeding 30°C in all territory and presented extremely low values of humidity.

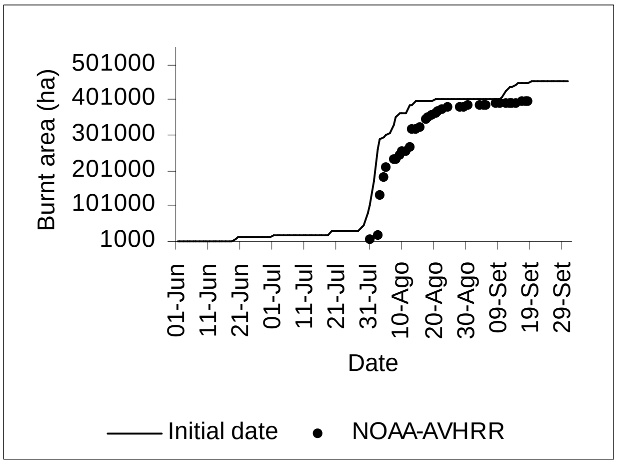


Figure 7. Evolution of burnt areas in Continental Portugal along time.

The severity of 2003 is well illustrated by noting that 5% of Continental Portugal has burnt in that year, 2% of the total between August 2 and 5. Comparing the value of burnt area estimated by us until September 17 (457,912 ha) with the one measured *in situ* by DGF (453,097), we are led to the conclusion that there was an overestimation of only 1%, a difference that may be considered as negligible taking into account the spatial resolution of NOAA/AVHRR.

Fig. 8 shows three days characterized by presenting the largest amounts of burnt areas in the summer of 2003, namely those due to the fires that took place in the Central Region of Portugal on August 3 (Fig. 8 a) and in the South on August 13 and between September 14 and 16 (Figs. 8 b and c, respectively).

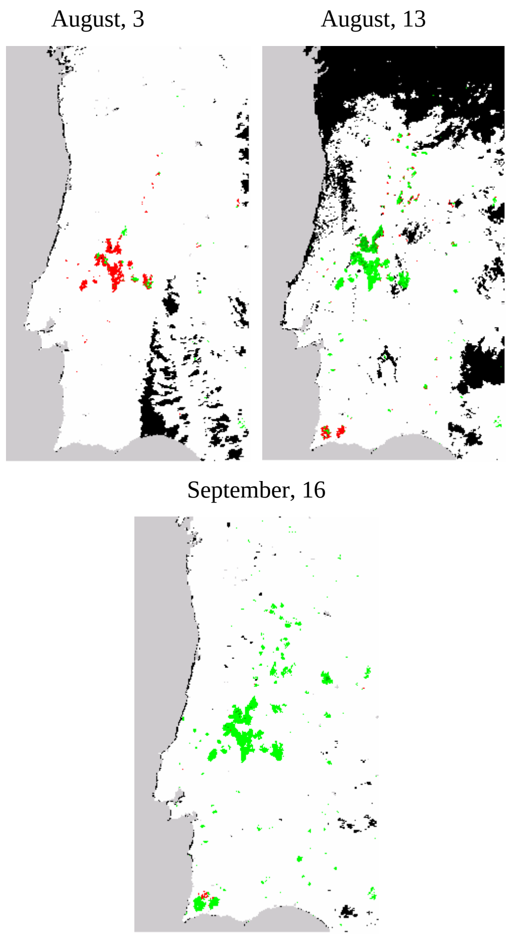


Figure 8. Images of the largest fires that occurred in Continental Portugal during the fire season of 2003. Pixels in red and green represent new and old scars, respectively.

5. VALIDATION AND CONCLUDING REMARKS

According to the reference MODIS estimate, the total burnt area in continental Portugal reached the amount of 430,725 ha that, compared to the value obtained using the AVHRR, indicates that our method overestimated this figure by *circa* 6%. This discrepancy may be explained by differences between the two instruments, namely the much higher spatial resolution of MODIS.

In order to validate the results, a confusion matrix, respecting to the classification based on AVHRR and on MODIS, was computed (Table A), as well as measures of accuracy namely the Producer's Accuracy (PA=72%), the User's Accuracy (UA=72%)

and k-hat ($\hat{k}$ =70%). Fig. 9 shows a comparison of results obtained with AVHRR and MODIS and a visual inspection of the two classifications suggests that there is a general agreement (pixels in red) between the two classifications, especially in what respects to the larger fires. Obtained results are therefore quite promising if one takes into account that MODIS presents a much better spatial resolution than AVHRR.

Table A. Confusion Matrix of the Classification Composite Obtained from Application of ANFIS Model.

		MODIS end-of-season map	
		Burnt	**Non-burnt**
ANFIS model	**Burnt**	1391	533
	Non-burnt	554	33920

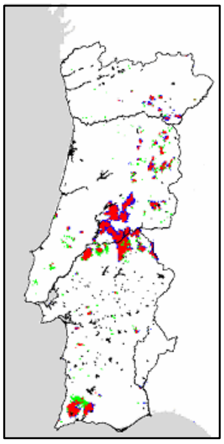


Figure 9. Pseudo-colour image of burnt areas obtained with ANFIS model and MODIS data: pixels in red, green and blue represent burnt pixels identified by both methods, only by MODIS and only by ANFIS model, respectively. Pixels in grey correspond to sea and water bodies mask.

6. REFERENCES

Calado, T.J. and DaCamara, C.C., 2002: “Burnt area mapping in Portugal with a neuro-fuzzy approach”. *The 2002 EUMETSAT Meteorological Satellite Data Users’ Conference.* Dublin, September 2002.

Calado, T.J., 2004: “Identification of clouds and burnt surfaces in satellite imagery based on neuro-fuzzy systems”. *Ph.D Thesis*, Lisbon, 2004.

Chiu, S., 1996: “Selecting input variables for fuzzy models”. *J. of Intelligent and Fuzzy Systems*, **4**, 243-256.

Jang, J.-S.R., 1993: “ANFIS: Adaptive Network-based Inference System”. *IEEE* Transactions on systems, Man and Cybernetics, **23**, nº 3,665-685.

Jang, J.-S.R., Sun, C.-T. and Mizutani, E., 1997: *Neuro-Fuzzy and Soft Computing: A computational approach to learning and machine intelligence*. Prentice Hall, Inc. 614 pp.

Nauck, D., Klawonn, F. and Kruse, R., 1997: *Foundations of neuro-fuzzy systems*. England: John Wiley & Sons Ltd. Press, 305 pp.

Pereira, M.G., Trigo, R.M., DaCamara, C.C., Pereira, J.M.C., Leite, S.M., 2005: Synoptic patterns associated with large summer forest fires in Portugal. *Agricultural and Forest Meteorology*, **129**, 11-25. DOI:10.1016/jagrformet.2004.12.007.