DESIGN AND IMPLEMENTATION OF AN OPERATIONAL METEO FIRE RISK FORECAST BASED ON OPEN SOURCE GEOSPATIAL TECHNOLOGY

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ABSTRACT

We designed an integrated platform for early prediction of meteorological fire risk. The system is operative since the end of 2014 and estimates the fire danger index automatically, based on the 72 hours forecast of the Weather Research and Forecast (WRF) model. Though the system is in experimental phase, the first results showed a quite acceptable performance. Moreover, this index is capable of continuously improving the algorithms to produce enhanced risk estimation. Thus, in the short term, the system would also include geospatial information and satellite based products to help firefighting activities during all phases: early warning, pre-disaster planning, preparing and forecasting, response and assistance, recovering and reconstruction throughout a web map service.

Index Terms—Fire risk, warning system, weather variables, Argentina, GRASS GIS 7.

1. INTRODUCTION

Fire is the major disturbance agent in many environments because it represents a threat that can spread across large areas over short periods of time. In Latin America, Argentina has the second largest area affected by fires with an average 1.5 million of hectares burned per year [1] affecting population economy and natural systems. The undesirable effects of fires encompass the decline of biodiversity [2], forest complexity and area [3], livestock infrastructure, forage resources for cattle and timberlands. Fires can also affect the biogeochemical cycles, emit greenhouse gases, magnify erosive processes and alter the hydrological cycle [4] and water reservoir quality [5]. Additionally, fires pose a risk to human lives and goods, especially in areas of wildland-urban interface due to the proximity between houses and fuels [6]. It is essential, therefore, to develop an early warning system of fire risk for the management and conservation of natural resources and human life. This challenge for the fire managers and authorities at this time coincided with strong development and increased accessibility to geospatial technology in an inter-institutional and interdisciplinary framework offering the opportunity to link remote sensing data and the need for information for fire prevention and extinction.

Although at present there is a global agreement that fire regimes are strongly affected by humans, climate is also crucial since it exerts a strong control on fire activity by regulating fuel production and desiccation [4] which, ultimately, are the factors determining the ignition and spread of fire. It seemed adequate then, to implement these ideas into operative projects and to develop an early index of fire risk useful to fire authorities, managers and researchers alike. This work describes the design and preliminary implementation of the meteorological fire danger index based on the Australian system at the national level [7].

The Argentinean Space Plan is focused on the Space Information Cycle concept which involves all the needed activities to produce actual benefits for the citizens. One of these cycles is the Natural Disasters Information Cycle. The Argentinean Space Agency have a specific unit is working on the use of spatial information, high performance computation, and advanced methodologies in order to contribute to environmental hazard prevention, evaluation, and monitoring [8]. This challenge has promoted the development of the new tools for earlier fire prevention and extinction based on remote sensing information and geospatial technology in an inter-institutional and interdisciplinary framework. In this way a group of researchers from several governmental and non-governmental agencies has founded the IGNIS group, with the objective to provide decision-making tools for personnel devoted to wildfire management in emergencies related to forest fires. In this context one of the first operational and free access systems developed is presented in this paper.

2. MATERIALS AND METHODS

In order to obtain an operational free product (features derived from our user requirements) we based our development in the state of the art of meteo fire indexes. In this case the Australian index is adopted. This Australian index was introduced by McArthur in 1958 [7]. At present, the fourth version of the algorithm is being used [9]. This version divides fire risk in 5 classes regarding difficulty of fire suppression (low, moderate, high, very high and extreme). As most fire risk indexes, the McArthur index is based on an empirical model of fire behavior in open forests, but it is currently applied to a wide variety of covers. The adaptation to different covers is done by re-defining risk classes in each of them. The structure of the Meteorological Fire Danger Index (MFDI) is shown in figure 1.

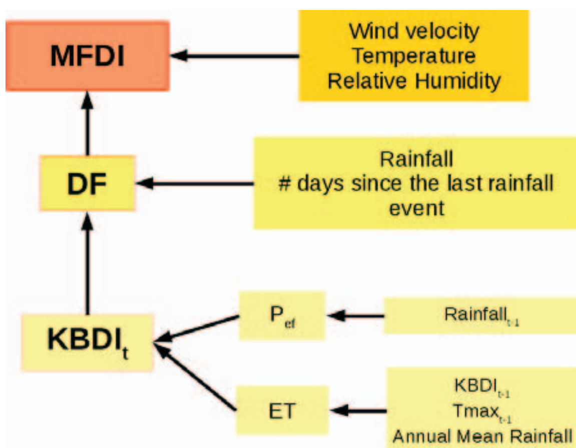

Figure 1. Flow chart to obtain the Meteo Fire Danger Index (MDFI). P_{ef}: Effective Rainfall, ET: evapo-transpiration, KBDI: Keetch-Byram drought index, Tmax: Maximum Temperature.

The weather variables needed as inputs to run the algorithm are: temperature (°C), relative humidity (%), wind velocity (km/h) and a drought factor (DF) that is estimated on the basis of accumulated rainfall (mm) in the previous 24 hours, the period of time since the last rainfall event [10] and the Keetch-Byram drought index (KBDI) [11]. The KBDI is estimated from the daily maximum temperature, the daily rainfall, the mean annual rainfall (mm) and the KBDI from the previous day.

All the weather input data are obtained from the output of WRF (Weather Research and Forecast) model already implemented and operative for the area covering Argentina, Chile, Uruguay and Paraguay. These climatic layers are obtained once a day starting at 00:00 UTC (Coordinated Universal Time) and provide a 72 hours forecast for the area described, with a spatial resolution of 15 km [12]. All forecast products derived from WRF are published daily in a website (meteo.caearte.conae.gov.ar/wrf) that provides display of several variables and their evolution in time, and allows the download of this information in csv, png and GeoTIFF formats, which can be then visualized or included in other GIS, models or algorithms, as in this case.

The mean annual rainfall value was drawn from WorldClim data set (http://www.worldclim.org/). The KBDI is estimated only once per day, using accumulated rainfall at 9 am (local time), while the MFDI is obtained automatically with every new output of WRF. Besides, the resultant fire danger index is weighted according to land cover type [13]. Following the requirement to produce an operational free product, the implementation of fire danger index was done in GRASS GIS, a multi-purpose Free and Open Source GIS which can be used for geospatial data production, analysis, and mapping [14]. The software was chosen because it can be run fully automated and embedded into service chains as the GIS backend for Web Services [14], which is one of the main objectives of this work. Besides, it integrates well with other software packages and it runs on various computer operating systems. The final product, the MFDI, is accessible (and available to download as GeoTIFF) via a map server built also under free and open source technology (geoserver and geoexplorer).

In order to validate the MFDI, we conducted some exploratory analyzes on index effectiveness and temporal evolution of MFDI values in certain places. To test index effectiveness we used MODIS active fire data (MCD14DL) product from 02/01/ 2015 to 03/17/2015) and recorded fires occurring in each MFDI risk category. Also, to observe the variation range of MDFI values we conducted an exploratory analysis at random points for the period 11/22/2014-03 /16/2015.

In turn, the MDFI was validated based on occurrence of recent fire events versus the mapping generated for the day of fire occurrence. Here, two cases are showed, one of them in the province of Chubut (Argentina; 02/19/2015, source http://www.cba24n.com.ar/content/chubut-los-incendios-consumen-mas- de-four-thousand-acre); and the other around La Auracanía (Chile; 03/16/2015, source http://www.emol.com/noticias/nacional/700-hectareas-de-araucarias-en-reserva-nacional-en-la-araucania.html).

3. RESULTS AND CONCLUSION

The system is operative and estimates the meteo fire danger index automatically based on the 72 hours forecast of WRF. The MFDI is available to download as png and GeoTIFF formats.

MFDI validation is showed on Table 1. The index seems to work better in areas classified as high and very high fire risk, not recording focuses on extreme risk of fire.

MFDI	Detected focus (%)	Area (km^2)
Low	16.02	$4.09\ e^{+06}$
Moderate	22.58	$1.66\ e^{+06}$
High	25.47	$1.06\ e^{+06}$
Very high	32.07	$5.50\ e^{+04}$
Extreme	0	-

Table 1: Fire focus detected on each fire category estimated.

Figure 2 shows the results obtained for evolution of the system analysis. The point at -58.76 W,-37.12 S shows average risk values of MDFI (moderate and high). The point at -69.30 W, -35.90 S takes values in the range of moderate, high and very high risk.

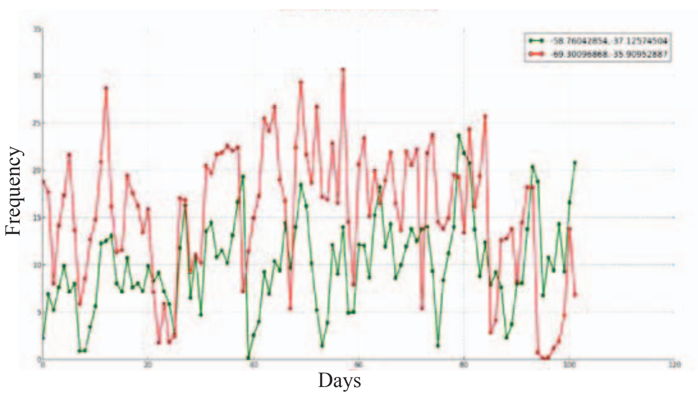

Figure 2: Evolution of the MFDI (estimated to 24 hs) during a period of 100 days.

In Figure 3, maps derived from the fire risk estimation for Chubut (Argentina) and La Auracanía (Chile) are shown. Figure shows the province of Chubut included in the category of high risk of fire (yellow) and in the case of The Auracanía the risk is high and very high (yellow, orange).

This first result of exploratory analyzes show a quite acceptable performance of MFDI as a predictor of fire risk index, considering that it is also estimated from predicted meteorological variables. This operative system, which started working by the end of 2014, is yet in an experimental phase. In the short term, the system would also include a wide range of geospatial information and satellite based products to help firefighting activities during all phases: early warning, pre-disaster planning, preparing and fore casting, response and assistance, recovering and reconstruction throughout a web map service. The server will contain and update products such as: a) improvements of this fire risk index including vegetation fuel characteristics, b) active fire data, c) localization of hydrological resources, access routes and fire management personnel for fire attack, d) burned area, e) site hysteresis cycle. On the user side, the system would incorporate mobile technology with several capabilities.

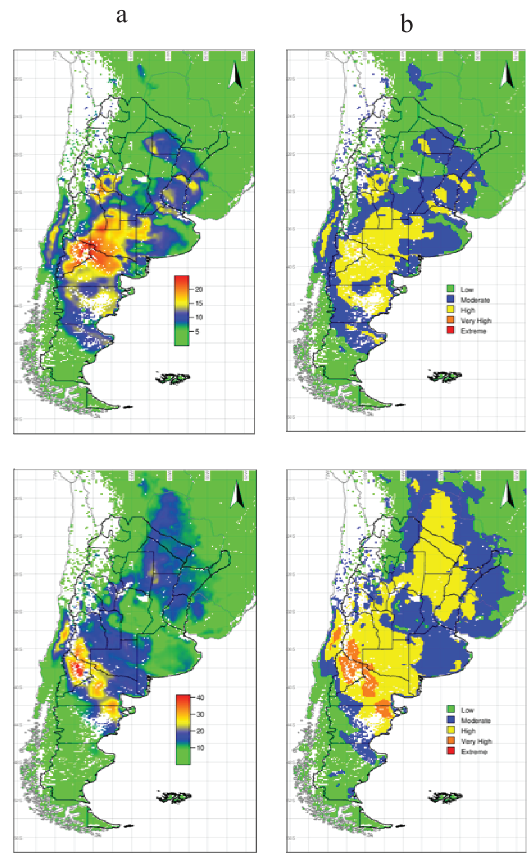

Figure 3. Continuous (a) and reclassified (b) MFDI for fires occurred in Chubut province (Argentina, 02/19/2015) and la Araucanía (Chile, 03/16/2015).

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