"MANAGEMENT AND CONTROL OF FOREST FIRES THROUGH THE USE OF INTEGRATED REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEMS."

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ABSTRACT

Each year in Spain Forest Fires present a significant environmental hazard both with respect to our forests and the population at large. Last year (1994), more than 7.400 fires destroyed approximately 500.000 ha of woodland and resulted in the deaths of more than twenty persons. As a result, early detection and location of forest and wildland fires within Spain has become a critical problem which must be addressed immediately.

The use of satellite detectors permits the integration of real images and geographic information systems (GIS) with mathematical models of fire evolution and meteorological data.

A system has been developed which utilizes the four NOAA-TIROS meteorological satellites. These satellites provide images with a periodisity of 2 hours. The images utilize infrared portions of the electromagnetic spectrum, both in the near and thermal ranges, and in this way allow the differentiation of heat Centers as a function of temperature.

This system permits the visualization of the exact coordinates of the fire with respect to important physical structures, population centers, highways, electric power lines, rivers. Reservoirs, etc.

The precision of the system is sufficient to detect a fire of 100 m^2 within a region of interest of 500 x 500 meters.

1. INTRODUCTION

Early detection and location of forest and Wildland fires within Spain has become a critical problem which must be addressed in a comprehensive fashion.

The problems of early detection coupled with fire-fighters are of paramount importance to establish effective early containment of the fire.

In 1994 alone over 7.500 separate fires consumed nearly 500.000 hectares (1.235.500 acres) of forest and resulted in more the 20 deaths. Moreover to the loss of life, the 25 billion pesetas from the ICONA budget, and all the resources of independent communities utilized to fight these fires, material losses totalled over 90 billion pesetas. In addition, it is necessary to reforest the effected areas and to regenerate the ground cover in order to mitigate erosion problems. It has been estimated that over the next five years investments will reach nearly 220 billion pesetas.

The most serious aspect of forest fires, from the point of view of material losses, is the irreversible nature of the process, which leads to desertization of the soil. This occurs particularly when a fire is followed by heavy rains (the typical cold drop of the Levantine and Cataluña regions). The result is the definitive loss of the soil.

Another effect of the fires that is being seriously considered is their contribution to climatic changes due to the emission of carbon dioxide gases produced by the combustion. Estimates show that about 90 tons of carbon dioxide are produced per 2.4 acre of burned forest.

Statistics indicate that 95 percent of these fires are caused either by negligence or intentionally, and it is estimated that 40 percent of these are caused by arson (according to an analysis of fires with multiple focal points).

At any rate, regardless whether produced by man's action or by natural phenomena, there is a large number of fires in our country, some of which, under extreme climatic conditions (as those that prevailed this summer), have grown out of control. Therefore, it is clearly necessary to intensify the fight against these large fires, and to develop a new concept for the extinguishing efforts.

During the Cataluña fires there were reports of coordination problems affecting the fire fighting efforts. This shows, indeed, the need of a larger technological contribution, in cases of widely extended fires, to assist in proper fire containment management efforts.

In this connection, IBERSAIC (SAIC) has developed a forest fire detection, management and control system based on the use of meteorology satellites. The use of these satellites in detecting fires provides those charged with protecting against fires a tool heretofore unavailable, one that offers real information, with imaging of both the location and spreading of the fire. The system has already been acquired by the U.S. Federal Emergency Management Agency, as well as the Fire Department of California, where it has produced the first results in controlling the 1993 fires in the Los Angeles area.

2. SYSTEM DESCRIPTION

Until recently remote detection methods have been used as a means to evaluate the damage caused by forest fires and to obtain information as to how many acres were destroyed in a given territory.

A fundamental problem in developing the use of remote sensors was in the orbiting cycles of the satellites used in exploring natural resources (LANDSAT, SPOT, etc.) and the impossibility of getting images in quasi real time (in addition to the impossibility of a continuously free access to these images).

IBERSAIC (SAIC), however, has developed in the United States a Fire Detection, Management and Control System based on the use of NOAA-TIROS Meteorology Satellites. The fact that currently there are 4 of these satellite series orbiting the Earth (NOAA-09 through NOAA-12)[1] makes it possible to have images of the Earth in 2 to 2.5-hour cycles. In addition, these satellites are suitable for forest fire detection applications due to the fact that their sensors provide infrared (IR) imaging, both near as well as thermal. This allows us to obtain images of heat concentrations of different temperatures, and thus prevent [1] false alarms.

Because there are four satellites, the system provide frequent revisits. What this means is that a given site can be observed 8 to 12 times daily on average. The swath width of an image is approximately 2200 km (1500 mi). This means that the entire country of Spain fits easily inside a single image.

The resolution of the satellite is 1 kilometer. We have performed an analysis that indicates a fire as small as 100 square meters can be detected and located to within 1 kilometer. Fires that were started in the Los Angeles area during the civil disturbances there are discernable in the imagery yet the fires involved fewer than five houses.

The ability of the satellite to detect fires is based on the fact that fires emit a much stronger signal in the mid-range IR wavelengths (3 - 4 microns) than they do in the far IR wavelengths (10 - 12 microns). Consequently, a pixel containing a fire appears very hot in the mid-range IR channel relative to its surrounding pixels. Also, the mid-range IR channel value for a fire pixel is disproportionately hot relative to its far IR channel values. These phenomena are exploited to automatically identify those pixels which contain fires, and can even be used to estimate the amount of burning area and the average burn temperature.

Access to the data (images) released by these satellites is free, at no charge, and only requires the availability of adequate means (antennas, image processing systems). The space resolution provided by these satellites allows us to display Spain in one single image, although the proper territory management requires an autonomous community system.

This system effectively facilitates Management and control of the evolution of fires, since the imaging provides actual data of the direction in which the fire is spreading. These images are updated every 2 hour, providing adequate time to take strategic steps in difficult situation. Thanks to the 2-hour updating of the data, the system is also considered reliable for detecting fires as small as of 100 square meters (10 x 10 meters).

[1] NOAA-11 will be replaced by NOAA- 13 in December 1994

In simple terms, the operation of the system can be summarized as follows (Figure 1):

The receiving antenna, in conjunction with a control and positioning system, continuously receives data from 4 NOAA satellites, each orbiting the Earth every 12 hours. The data is transferred to an image processing and interpreting unit, which immediately carries out the process of fire identification. The system can be accompanied by a Geographic Information System (GIS), which allows the users to display on the screen the exact coordinates of the fire, and its proximity to main infrastructures -- expressways, highways, rivers, dams, etc.

The system's main characteristics can be summarized as follows:

- Coverage of the entire peninsula and islands with one satellite pass.
- Actual data of the evolution of fires every 2 hours.
- Exact location of the area with the help of the GIS (Geographic Information System).
- Detection of even small fires through the utilization of advanced image interpretation software, IBERSAIC's own system (fires covering an area of 100 square meters can be detected within a selected grid of an image of 500 x 500 meters). This figure is highly accurate for a meteorology satellite.
- Image integration with GIS and the mathematical model developed by IBERSACI (SAIC) of the fire's evolution, according to terrain orography and meteorological data of the area. This allows even to foresee the events and to prepare the resources more effectively.
- Automatic transmission to proper authorities, via fax, of a chart showing the location of the fire, its estimated dimension and nearly infrastructures.
- Detection of new fire eruptions within the same overall fire, undetected due to fire related causes, such as flames, smoke, damages, and signal excess by immediate ground detection systems (if any), etc.
- The system utilizes small size receiving antennas, that are connected to computer systems which can be installed directly in any decision making person's office, without having to really the information from one place to another through various media.
- There are no limitations to access the sensory systems, since they are available throughout the world. Moreover, space projects move forward in providing an increasing number of satellites to study the planet during the coming decades, thus providing an increasingly amount of better information. In this sense, the investment is well insured for the future.

3. SYSTEM IMPLEMENTATION

Acquisition and installation of the necessary hardware is the first step for receiving the NOAA satellite data. A principal component of the system is the antenna system which consists of a dish and tracking drive mechanisms. The antenna is mounted on a 3 inch diameter vertical steel pipe installed at ground level or rooftop to provide the best view of the horizon.

Installation and testing of the SAIC software on the workstation would also be required. The software package consists of several elements which process the raw satellite data and provides an image containing IR and visual signatures. Another software package distinguishes fire locations from the background. Another software module automatically alerts the operators of the location of detected fires. Finally, the image is overlaid with geopolitical and other feature (highway, river, etc.) databases to assist in locating the fire.

Integration of the computers and antenna is required for data transfer and antenna tracking. The antenna system tracks the NOAA satellites through signals sent from a PC on which satellite orbit information has been stored. These signals drive the antenna as the satellite passes overhead. The antenna can automatically switch frequencies as each satellite comes into view. The datastream received by the antenna is sent to the PC where the data is temporarily stored prior to its being sent to the workstation for processing.

4. EXPERIENCE IN THE UNITED STATES

IBERSAIC (SAIC) began to work for the Federal Emergency Management Agency of the United States two years ago, developing a fire detection system that would use NOAA satellites, since their visible and infrared multi-spectral sensors are adequate for fire detection.

The system was developed building upon the satellite-produced images of the Yellowstone National Park fires, in the northern United States.

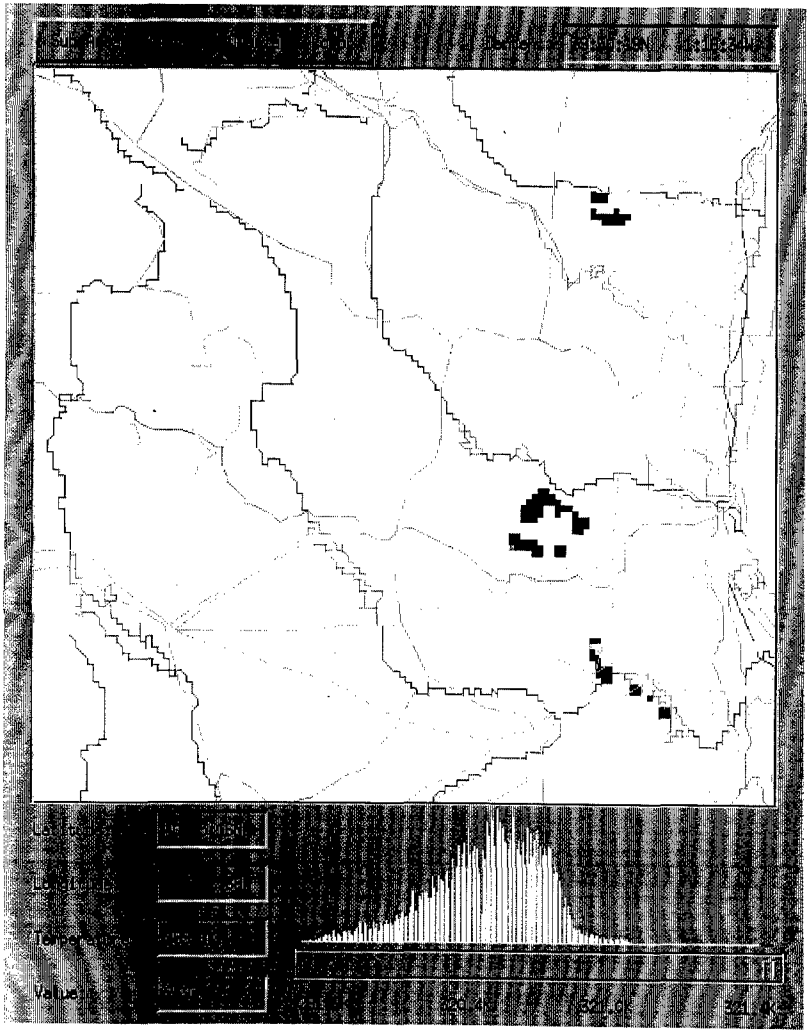
IBERSAIC (SAIC) has delivered the system, in perfect operating conditions, to the Federal Emergency Management Agency (FEMA) and the Fire Department of the State of California. As can be seen from the enclosed images, fires were detected in the Los Angeles, California, area. IBERSAIC (SAIC) engineers continue to cooperate with these agencies in optimizing the system and introducing new data.

5. EXAMPLES OF SYSTEM OPERATION

The following figures illustrate the different images and types of data which comprise the integrated satellite GIS system used in the management and control of forest fires. Images 1 through 4 are examples of how the satellite data and GIS permit the detection and localization of forest fires. The images show a region of the Autonomous Community of Valencia (near Millares) that was destroyed in a particularly dramatic fashion by last summer's forest fires. The images illustrate the progression of the blazes during the days of 5, 6, 7 and 8 of July 1994. Additional geographic information is shown such as highways, rivers, coast-line, etc., however the black and white reproduction does not allow for complete differentiation. The location and extent of each fire is clearly defined, however, as is the fires intensity (temperature) as indicated by the intensity of the grey scale.

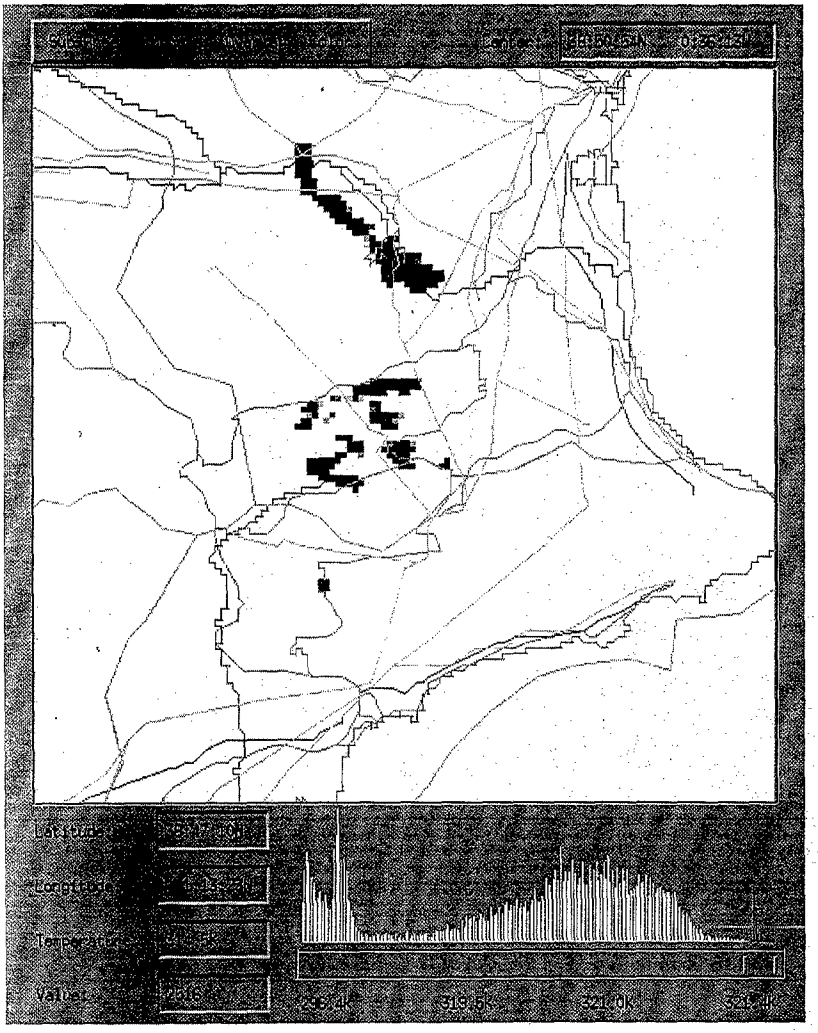
5 de julio de 1994 16:51

39:31:47 N	00:56:57 W	Requena
39:14:40 N	00:49:40 W	Millares
38:46:58 N	00:39:40 W	Baneres



6 de julio de 1994 8:30

40:01:51 N	00:28:36 W	Fuentes de Ayodar
39:36:51 N	00:55:41 W	Sot de Chera
39:34:06 N	01:02:42 W	Calvestra
39:17:27 N	00:53:07 W	El Oro
39:14:14 N	00:47:30 W	Millares



7 de julio de 1994 16:38

39:10:11 N	00:45:46 W	Millares
38:51:49 N	00:38:28 W	Baneres
38:33:37 N	00:39:09 W	Maigmo

8 de julio de 1994 7:07

40:01:32 N	00:36:57 W	Montan
39:38:56 N	01:03:32 W	Requena
39:16:47 N	00:57:21 W	Cortes de Pallas