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Original Article

Forest Fires – Causes, Detection and Impact on Forest Ecosystems

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Abstract

In recent years, globally, more and more attention is given to maintaining strong, balanced, healthy forest ecosystems, able to perform with maximum of efficiency the purpose for which they have been created. Forest fires have a special role within the complex risk factors, with direct influence on them. The causes of the forest fires are mainly due to human interventions and less to natural phenomena. The fire setting and extending are conditioned by the simultaneous presence of three factors: fuel material, oxygen and fire source. In forest ecosystems, fuel material and oxygen can be found in excess, so that we approached rather the fire setting factor. Fire detection, especially in the initial phase, and its signalizing can reduce the damages and localizing costs very much. In this respect, we present in this article a variant of fire detection and of warning the competent authorities by modern informatics methods (using sensors, computers, etc.). In order to establish the locations of the sensors we analyzed all the fires in Cluj County. All data regarding their evolution during 2000 – 2012 were centralized. The data refer to forest areas from Cluj County, but the causes of the fire ignition were observed in the neighboring counties, too.

Keywords: risk factors, forest fires, fuel material, oxygen, wireless sensor network, forest fire detection ad monitoring, virtual instrumentation

1. Introduction

From their beginning to their logging or physiological decline, the forests are subjected to external damaging factors, such as biotic (disease and insects, animals, parasitical plants etc.) abiotic (wind, floods, avalanches, hail, frost etc.) and anthropic factors (illegal chopping, grazing etc.) that sometimes – due to their severe attack – can produce unimaginable damages.

In Romania, most damages are produced by the wood waste caused by wind, due to the presence of the spruce fir in the mountain forests. Another risk factor, often noticed during these last years is the fire that can cause significant material and human losses. The high danger of fire is represented by the fact that most forests are in areas hard to reach, so that its localizing and extinguishing becomes extremely difficult. Statistically, the annual average number of fires in forests between 1965 and 1998 was of circa 150-200, and the affected area was of 2-4 ha/fire [1]. Although the affected average areas were not higher than 1.000 ha annually, a special attention should be paid to forest fires, mainly due to the possible losses in case of their getting out of control. By definition, we can speak about a fire if it

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extends on a surface of minimum 1 ha of forest vegetation and several vegetation sublevels are affected (litter, herbaceous layer, trees). According to the components of the affected forest ecosystems, the fires can be classified in: subterranean fires, litter fires and crowning fires. If analyzed separately, all three types produce serious losses to the forest ecosystems. Thus, the subterranean fires (like the litter ones) destroy most of the soil micro-organisms, with direct negative effects on its fertility. Sub-stand burning leads to the destruction mainly of bird habitat with direct negative effects on the stand phyto-sanitary condition. Crowning fires have the most serious negative effects mostly on the wood quantity and quality [2]. Generally, the lighting and extending of fires is conditioned by the simultaneous presence of three factors: fuel, oxygen and fire source.

The forest ecosystems' components represent mainly inflammable materials. Taking into account the oxygen is not the problem in such a situation, the fire starting factor is the source. Each country has its own – more or less effective - surveillance, identification, isolation and smothering system. The information exchange regarding the above presented aspects can lead to the improvement of actions and control of damages. Thus, the countries members of European conventions have estimated that, besides the population's informing and awareness making, it is also necessary to be familiar with the fire causes, their socio-economic contexts and the psychological profile of the authors [3]. The setting up of a European data bank regarding the forest fires has been proposed, which would centralize the data received from the national banks network and draw up join projects to fight against this serious danger for the ecosystems' stability. Thus, the European Forest Fire Information System (EFFIS) represents an essential instrument for collecting data regarding fire causes, damages and ways of intervention, specific to the different regions of Europe. According to EFFIS, in Europe, 50% of fires are caused by people's negligence and only 10% by natural phenomena (self-lighting, storms).

2.Material and Method

The purpose of this paper has been to analyze the fire causes, the size of damages and their evolution in order to make recommendations and to find solutions regarding the fire detection, localizing and smothering. Therefore, the phenomenon was observed and the data regarding its evolution between 200 and 2012 were centralized. The data refer to the forest surfaces in Cluj County, but the causes of fires were observed in the neighboring counties, too. At the same time, we studied the way this phenomenon was recorded in the world literature.

Besides the preventive measures, the localization of fire in the shortest possible period of time has a special role so that the intervention should be easier and cheaper. The most used smoke and fire detection is usually based on collecting particles from the fire area, on measuring temperature and on testing the air transparency. Among the fire monitoring methods we can mention

A. Using certain monitoring towers

In these towers people have to observe the area around them. If a fire starts, the person has the obligation to report it. However, the human exact observation can be limited by the tiredness of the operator, by the season and geographical location.

There is also the option of developing certain automatic video surveillance systems [4]. Most systems use Charge Coupled Device (CCD) cameras and Infrared (IR) detectors installed on top of towers. Automatic video surveillance systems cannot be applied to large forest fields easily and cost effectively.

B Using certain forest fire detection systems based on satellite imagery [5].

These can monitor a large area, but the satellite resolution is low. A fire is detected when it has already spread on a relatively large surface; consequently, we cannot speak of real time detection. Moreover, these systems are extremely expensive. The weather conditions –e.g. clouds – considerably reduce the accuracy of forest fire satellite detection.

C. Using certain solutions based on an IP camera and wireless sensor networks (WSN) [6, 7, 8]. A WSN (fig. 1) consists of many small devices called sensors which are spatially distributed and which measure physical parameters from the environment. The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors.

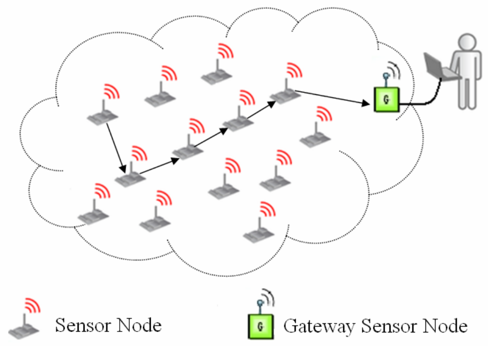

Figure 1. The structure of a wireless sensor network (WSN)

The sensors are equipped with wireless interfaces and report the environmental changes (temperature, humidity, pressure, illumination) to other nodes over flexible network architecture. The acquired data is transmitted to the gateway, which provides a connection to the wired world where you can collect, process, analyze, and present the measurement data using specific software. Size and cost constraint on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network.

A network camera, often called an IP camera, can be described as a camera and computer combined in one unit. The main components of a network camera include a lens, an image sensor, one or several processors, and memory. With its own IP address, network cameras connect directly to wireless networks and can be accessed remotely over the internet.

In the specialized literature, several technological solutions for fire detection and monitoring are analyzed, such as: Firesensorsock [9], Firebug [10], FireNet [11], Forest-fires Surveillance System (FFSS) [12], FireWeather Index (FWI) [13], FireWxNet [14], or the „Wireless Sensor Network for rural and forest environments fire detection and verification" [6] etc. Starting from the previous applications, our research combines some ideas in a new proposal which can be well adapted to our local conditions.

3.Results and Discussions

In Cluj County there is a surveillance system for the surfaces with forest vegetation, especially during the periods of time with maximum risk of fire (in spring until vegetation begins and in autumn after the leaves fall). Besides the local authorities, the field forest personnel within both State and private forestry have an important, even vital role. These alert the responsible authorities once they detect a fire and act together with mixed teams (foresters, fire fighters, soldiers) and volunteers from the local population to the fire localizing and smothering. The Cluj Department of Forestry has clear fire records which include causes, surfaces and damages, according to the products' type (table 1).

We can observe that during the analyzed period, the main fire causes are represented by the burning of the grass for field cleaning and losing control of fire (106 cases), followed by the unattended fire (especially by tourists, but mostly by agricultural or forest workers) (32 cases). It seems the 7 fires with unknown authors have the same causes, but they haven't been discovered. From the point of view of the geographical areas (field, hill, mountain), only 5 fires (3,44 %) were registered in the mountain area, good thing if we think about the huge damages that could result from a fire in the coniferous stands.

From the point of view of stand composition, the fires started in the pine or mixed (in combination with other species of deciduous trees like hornbeam, sessile oak, acacia, ash tree etc.) stands have a significant percentage (51,85%). The age of the affected stands differs quite a lot (from regenerations of 4-7 years old to the adult stands of 70-80 years old). The majority of these (over 65%) took place in the young stands and especially in those installed in the improvement areas (fig. 2).

Over 90% of the fires emphasized in table 1 take place in spring (after snow melting and before vegetation) or in autumn (after leaves' falling and before the snow), when the inflammable materials (dried grass, leaves fallen on the ground) can be found in abundance. Due to their fostering and accelerating the fires, the weather conditions have a direct influence on them. Thus, the fire spreads quicker in situations of drought, lack of precipitations, winds, and last but not least, it depends on the state and quality of the affected vegetation. High speed winds from different directions make the fire localization and smothering almost impossible. At the same time, their intensity is proportional with the vegetation's dryness degree (herbaceous, shrub-like and even tree-like) [2].

The high humidity of the soil can obstruct or reduce the propagation speed of forest fires. Likewise, the terrain toponymy can favor fire spread by influencing the wind speed [15]. Fires, especially the subterranean ones or those of litter destroy – besides the non-decomposed organic matter – the whole soil fauna (especially the microorganisms and the mycotrophic fungi). The technical solutions regarding these areas' regeneration have to take into account these realities. One positive aspect is that all fires - due to the quick reaction of the personnel directly involved in these actions: firefighters, foresters, local population – were localized and smothered without serious damages. To avoid certain material responsibilities, it is possible that the damages were not registered at their real value.

In order to have a clear image and to establish other details of the fire causes, fig. 3 presents the locations of the fires registered during 2000 - 2012. The graphical representation helps establish the risk areas (maximum, medium and minimum), with direct effects on the common action plans of the involved decisional personnel.

Table 1. Situation of forest fires recorded in Cluj County during 2000-2012

Crt No.	Year	Number of fires				Causes of fires			Affected surface (ha)	Value of damages (lei)
		Total	sub terraneous	litter	litter + crowning	Grass firing	Unsupervised open fire	Un known		
1	2000	24	1	18	5	14	6	4	33,4	21.110
2	2001	4	-	4	-	3	-	1	10,0	-
3	2002	12	-	9	3	6	5	1	37,2	25.091
4	2003	27	-	22	5	19	8	-	37,7	13.206
5	2004	1	-	-	1	-	1	-	2,0	5.700
6	2005	8	-	8	-	5	3	-	22,6	-
7	2006	-	-	-	-	-	-	-	-	-
8	2007	30	-	2	28	30	-	-	76,7	-
9	2008	1	-	-	1	-	1	-	10,0	-
10	2009	-	-	-	-	-	-	-	-	-
11	2010	-	-	-	-	-	-	-	-	-
12	2011	24	-	21	3	17	6	1	103,1	
13	2012	14	-	14	-	12	2	-	72,1	
14	Total	145	1	98	46	106	32	7	404,8	65.107

Figure 2. Forest fires in Chinteni area (Cluj Country, 2012)

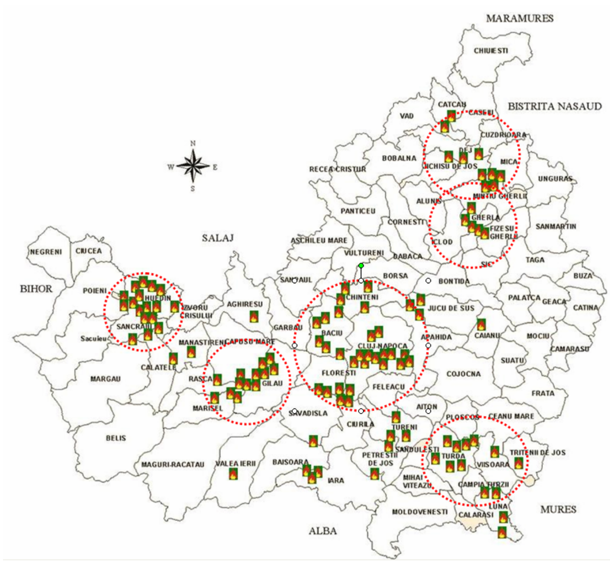

Figure 3. Locations of the fires registered in Cluj Country during 2000-2012

We can observe that the fires, in an overwhelming percentage are localized in the neighborhood of urban areas (Cluj-Napoca, Turda, Huedin, Gherla, Dej) and in touristic ones.

Taking into account the analyzed data and the necessity of real time monitoring of the areas with fire risk in Cluj County, our proposition relies in the implementation of certain networks of wireless sensors and IP cameras in these areas. The architecture of the suggested network type (Figure 4) has to fulfill the following requirements:

- Optimum installation (from the point of view of the covered area and of the transmitted signal) of the sensor nodes and IP video cameras in the respective areas and their GPS position registration in the data base of the software application
- Protection of the field equipment and avoidance of an ecosystem disequilibrium
- Installation of the same type of sensors and a GPS positioning system on the patrolling team's car
- The use of low power consumption equipment and maybe of certain rechargeable photovoltaic systems

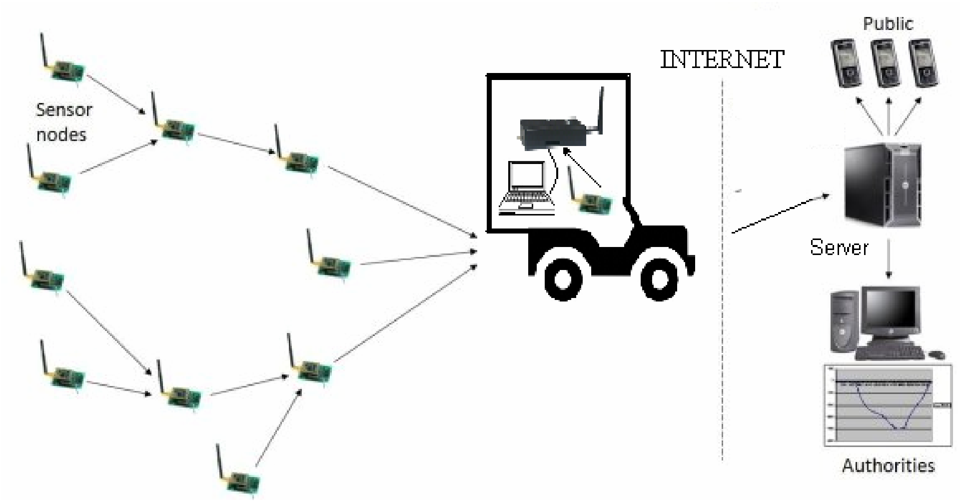

Figure 4. The architecture of the proposed network

In order to monitor the forest areas with fire risk, we propose the following way of operation within the proposed network type. The patrolling team has in the car an independent computing system (laptop) to which the sensor gateway node is attached. The laptop's software calculates permanently the differences between the parameters' values of the network nodes and the ones read from the car's sensors; when a difference is significant, as a consequence of an alarm, the personnel can connect remotely to the cameras and view live images from the laptop, smart phone, or tablet device. The received data, alarms and imagines are, at the same time, sent to a central server that manages the entire county's networks. Thus, a commanding team has the possibility to monitor the areas and take the best decisions to solve the respective situations.

An application with the following components was implemented to test the proposed architecture in a laboratory:

- Starter kit for wireless sensor network from Crossbow (fig. 5)

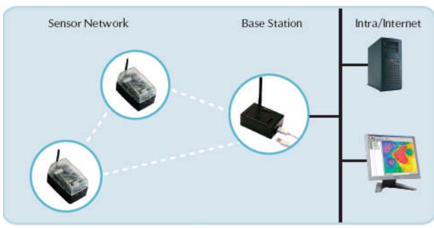

Figure 5. Starter kit for WSN (Crossbow)

- Sensor nodes:
  - Processor/Radio Board: IRIS/MICA modules to enable the low-power wireless sensor networks measurement system (2.4 GHz).
  - Sensor Board: MTS400 multi sensor board including temperature, humidity, barometric pressure and ambient light sensing capabilities.
- Base station:
  - Processor/Radio Board: IRIS/MICA module functioning as a base station when connected to the USB PC interface.
  - USB PC Interface Board: MIB520 Gateway provides a USB Interface for data communications.
- Conrad wireless video camera (2,4 GHz cu 4 channels) and the image acquisition board NI PCI 1411 (National Instruments)
- LabVIEW software (National Instruments)

The experimental fire detection and control system (Figure 6), is implemented using virtual instrumentation techniques [16] proved itself efficient from the point of view of the proposed system's requirements.

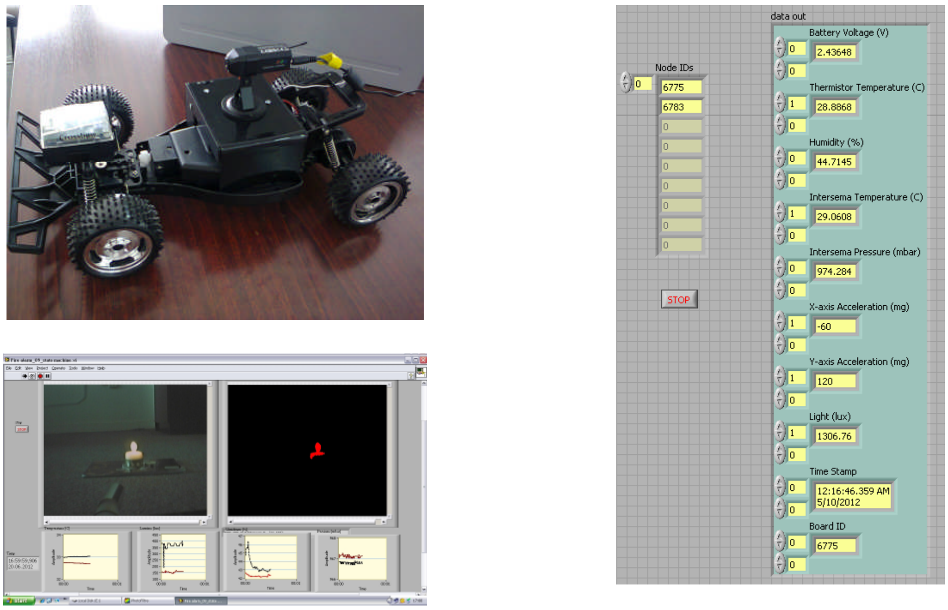

Figure 6. Experimental prototype (hardware and software components)

4. Conclusions

Analyzing the above presented data, we can reach the following conclusions:

• The familiarization with the potential forest fire risk areas is benefic for the establishing of the adequate measures of fire prevention

• The corroborated actions of the competent authorities with responsibilities in this domain increase the success chances in the fire localization and prevention

• Supplementary equipment, i.e. materials, logistic and in general, the means of quick intervention will be installed mainly in these areas exposed to fires

• The lab experiments regarding the monitoring of forest areas exposed to fire risk are promising, from the point of view of the implementation of such real networks based on wireless sensors and IP video cameras

• A concrete project will rely on the cooperation with the institutions involved in such actions: Prefect's Institution, The Inspectorate for Emergency Situations (ISU), Forestry Departments (OS) etc.

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