

## **INTELLIGENT PREVENTION**

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**Abstract.** Forest fire prevention may be defined as a set of measures designed to reduce the number of forest fires, their extent and the damage they cause. This concept is closely linked to the risk of forest fires, to which are added factors such as climatic and physical-geographical conditions and the value of the forest. Knowledge of theories, policies and practices on forest fire prevention is very fragmented, dispersed and mostly unpublished.

Intelligent prevention of forest fires would require integrating Artificial Intelligence techniques, such as Intelligent Agents. Intelligent Agent-based prevention could evaluate overcoming obstacles related to prevention, establish links between agents involved in forest management and provide tools for the exchange of information between organizations.

The aim of this work is to sketch the achievement of a map of potential forest fires in Bacău County, Romania, after performing a statistical analysis on fire data (data provided by the Forestry Department of Bacău) and a study of the dangers that threaten the forest environment, managing all this data into a Geographic Information System (GIS).

### **1. STATISTICAL RISK OF FOREST FIRES**

This project designed in this paper seeks to identify and localize, referring to a regional scale, the areas where it is more likely that a forest fire will start.

The following describes the stages of this process of mapping potential risk areas in terms of forest fire risk.

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**Keywords and phrases:** Forest fire, GIS, Mobile GIS, Distributed GIS, Intelligent Agents.

**(2010) Mathematics Subject Classification:** 68T42.

### 1. Fire frequency calculation

In calculating the frequency of fires we have considered the fires that occurred over the years specified in the Appendix 1 (2007 - 2012). The formula used to calculate the rate of fires is

$$F_f = \frac{1}{y} \sum_{k=1}^y n_f(k)$$

where:

$F_f$  = Fires frequency

$y$  = Number of years in the series of data used (Appendix 1)

$n_f(k)$  = Number of fires in year  $k$

The following Fire frequency classification may be used:

#### Fire frequency Classification

Frequency	Fire frequency	Indicator
Low	0,16666	1
Moderate	0.16666-0.27777	2
High	0.27778-0.33333	3
Serious	0.33334-0.58333	4
Extreme	0.58334-0.83333	5

These figures for Fire frequency were obtained based on solid data, namely on the average frequency of fires for each forest district in part, from the database that can be found in Appendix 2.

### 2. Severity Rate calculation

The severity Rate represents the annual percentage of the burned area over the total forest area.

It is calculated with the following expression

$$R_s = \frac{1}{y} \sum_{k=1}^y \frac{A_{Bf}(k)}{A_{Tf}(k)} \cdot 100$$

where:

$R_s$  = severity Rate

$y$  = Number of years in the series of data used (Appendix 1)

$A_{Bf}(k)$  = Burnt forest Area in year  $k$

$A_{Tf}(k)$  = Total forest Area in year  $k$

The following severity Rate classification may be used:

### severity Rate Classification

Severity	severity Rate	Indicator
Low	<0.00023	1
Moderate	0.00023-0.00026	2
High	0.00027-0.00041	3
Serious	0.00042-0.00082	4
Extreme	0.00083-0.00144	5

These figures for severity Rate were obtained on the basis of solid data, namely on the average burnt forest area for each forest district in part, from the database that can be found in Appendix 3.

### 3. Causality calculation

Causality index is an indicator of the risk that a fire caused by a particular cause turns into a large forest fire.

The expression used for the calculation of the Causality is:

$$C_i = \frac{1}{y} \sum_{k=1}^y \frac{\sum_{i=1}^5 c(i,k) \cdot n_{fc}(i,k)}{n_f(k)}$$

where:

$C_i$  = Causality index

$y$  = Number of years in the series of data used (Appendix 1)

$c(i,k)$  = coefficients of risk for cause  $i$  in year  $k$

$n_{fc}(i,k)$  = number of fires for cause  $i$  in year  $k$

$n_f(k)$  = Number of fires in year  $k$

The following Fire Causes classification may be used:

Fire Causes	
Indicator	Cause
1	Beam
2	Deliberate Fire
3	Unattended Fire in the Forest
4	Unattended Adjacent Forest Fire
5	Unknown

Using the three indices altogether (Fire frequency - severity Rate - Causality index) one can obtain the statistical risk map, according to the following expression

$$S_R = F_f \cdot R_s \cdot C_i$$

where:

$S_R$  = Statistical Risk of forest fires (values between 1 and 125)

$F_f$  = Fire frequency (values between 1 and 5)

$R_s$  = severity Rate (values between 1 and 5)

$C_i$  = Causality index (values between 1 and 5)

## 2. INTELLIGENT AGENTS USED IN FIRE PREVENTION

The potential risk index tries to identify and to discriminate clearly which areas are the most dangerous and are more likely to have a fire.

Monitoring forest conditions to prevent and/or respond to events caused by fire could be achieved by placing teams of intelligent agents and sensors in the area that is being investigated, according to the following architecture:

TYPE OF AGENT	ENVIRONMENT	ACTIONS OF AGENTS
Reflexive	Trees	- Detecting risk situations
	People	- To act before the outbreak of fire
	Climate	
	Fire	

  

SENSORS	PERFORMANCE
<ul style="list-style-type: none"> <li>- Fire detectors</li> <li>- Risk detectors</li> </ul>	<ul style="list-style-type: none"> <li>- Not record forest fires</li> <li>- If a fire breaks out, it should be extinguished as soon as possible</li> </ul>

These agents must take quick decisions and act quickly, in order to avoid not realizing the performance measure for which they were created.

Intelligent agents should act according to a **PW** (Protect-Warning) **Protocol**:

**PROTECT**: Ensure the affected area.

**WARNING**: Announcement of the rescue teams, the authorities, indicating the place or location of events.

## 3. FUTURE DEVELOPMENT OF THE MONITORING SYSTEM

Our future work will be focused on the adaptation and optimization of the GIS application developed in [7] for smart phones. As the authors explained, “Mobile GIS extends the reach of ArcGIS to a broad range of mobile devices – including Windows Mobile handhelds, Windows Tablet PCs, in-vehicle mounted systems, iPads, iPhones and iPodTouch devices, Android phones and tablets and Windows Phones devices.” [6].

One can use a Mobile GIS solution on these platforms to view, collect and update important geographic information. Thus, once collected new information about the emergence in other areas of potential risk factor, GIS

maps on the server will be updated and users will be alerted through the intelligent agents.

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## Appendix 1

BACAU FORESTRY DEPARTMENT									
THE SITUATION OF FOREST FIRE									
Forest District	Town	Date		Type of fire		Total Area	Nature of Owners	Causes of fire	
		Started	Extinction	Litter	Canopy				Underground
YEAR 2012									
Oituz	Oituz	3/21/2012	3/21/2012	2			2	State	Unattended Adjacent Forest Fire
Comanesti	Asau	3/23/2012	3/23/2012	2.5			2.5	State	Unattended Adjacent Forest Fire
Comanesti	Asau	3/25/2012	3/25/2012	0.15			0.15	State	Unattended Adjacent Forest Fire
Zeletin	Vultureni	3/23/2012	3/25/2012	1.7			1.7	Private	Unattended Adjacent Forest Fire
Oituz	Oituz	3/26/2012	3/26/2012	3.5			3.5	Private	Unattended Adjacent Forest Fire
M.Casin	Casin	3/26/2012	3/26/2012	0.8			0.8	State	Unattended Adjacent Forest Fire
Comanesti	Brusturoasa	8/8/2012	8/8/2012	0.25			0.25	State	Unattended Adjacent Forest Fire
Tg.Ocna	Doftana	8/11/2012	8/11/2012	10			10	Private	Unattended Adjacent Forest Fire
Tg.Ocna	Doftana	8/13/2012	8/16/2012			0.5	0.5	Private	Unattended Adjacent Forest Fire
Bacau	Gioseni	3/21/2012	8/11/2012	5			5	Private	Unattended Adjacent Forest Fire
M.Casin	M.Casin	8/22/2012	8/28/2012	7	3		10	State	Unattended fire in the forest
Sasaut	Corbasca	9/6/2012	9/6/2012	1.5			1.5	State	Unattended Adjacent Forest Fire
Moinesti	Moinesti	10/6/2012	10/6/2012	0.5			0.5		Unattended Adjacent Forest Fire
TOTAL 2012				34.9	3	0.5	38.4		
YEAR 2011									
Tg. Ocna	Doftana	2/6/2011	2/6/2011	0.5			0.5	State	Unattended Adjacent Forest Fire
Livezi	Gura Vail	9/4/2011	9/4/2011	1.5			1.5	State	Unattended Adjacent Forest Fire
Tg. Ocna	Tg.Ocna	11/30/2011	11/30/2011	3			3	Private	Unattended Adjacent Forest Fire
Zeletin	Rachitoasa	11/28/2011	11/28/2011	1.8			1.8	State	Unattended Adjacent Forest Fire
M.Casin	M.Casin	12/1/2011	12/1/2011	1.5			1.5	Private	Unattended Adjacent Forest Fire
Oituz	Oituz	12/1/2011	12/1/2011	1.5			1.5	State	Unattended Adjacent Forest Fire
Tg. Ocna	Tg.Ocna	12/2/2011	12/2/2011	0.5			0.5	State	Unattended Adjacent Forest Fire
TOTAL 2011				10.3			10.3		
YEAR 2010									
Fantanele	Scorteni	3/21/2010	3/21/2010	0.5			0.5	State	Unattended Adjacent Forest Fire
Tg.Ocna	Doftana	5/6/2010	5/6/2010	2			2	State	Unattended Adjacent Forest Fire
Moinesti	Balceni	6/12/2010	6/12/2010	0.3			0.3	State	Unattended Adjacent Forest Fire
Rachitoasa	Rachitoasa	8/16/2010	8/16/2010	0.1			0.1	State	Unattended Adjacent Forest Fire
Tg.Ocna	Doftana	10/31/2010	10/31/2010	2			2	Private	Unattended Adjacent Forest Fire
Tg.Ocna	Doftana	11/1/2010	11/1/2010	1			1	State	Unattended Adjacent Forest Fire
Livezi	Helegiu	11/10/2010	11/10/2010	1			1	State	Unattended Adjacent Forest Fire
Comanesti	Brusturoasa	11/15/2010	11/15/2010	1			1	State	Unattended Adjacent Forest Fire
Fantanele	Garleni	11/16/2010	11/16/2010	3			3	State	Unattended Adjacent Forest Fire
TOTAL 2010				10.9			10.9		
YEAR 2009									
Tg.Ocna	Doftana	4/13/2009	4/13/2009	0.1			0.1	State	Unattended Adjacent Forest Fire
Rachitoasa	Rachitoasa	6/16/2009	6/16/2009	1.3			1.3	State	Unattended Adjacent Forest Fire
TOTAL 2009				1.4			1.4		
YEAR 2008									
Tg.Ocna	Doftana	3/26/2008	3/26/2008	0.5			0.5	State	Unattended Adjacent Forest Fire
Livezi	Helegiu	3/31/2008	3/31/2008	2			2	Private	Unattended Adjacent Forest Fire
Oituz	Oituz	4/15/2008	4/15/2008	0.5			0.5	State	Unattended Adjacent Forest Fire
TOTAL 2008				3			3		
YEAR 2007									
Traian	Plopana	1/16/2007	1/16/2007	3			3	State	Unattended Adjacent Forest Fire
Livezi	Helegiu	1/16/2007	1/16/2007	0.5			0.5	Private	Unattended Adjacent Forest Fire
Comanesti	Asau	1/16/2007	1/16/2007	1.5			1.5	State	Unattended Adjacent Forest Fire
Oituz	Oituz	1/19/2007	1/19/2007	2.4			2.4	State	Unattended Adjacent Forest Fire
Comanesti	Asau	1/29/2007	1/29/2007	1			1	Private	Unattended Adjacent Forest Fire
Tg.Ocna	Tg.Ocna	2/15/2007	2/15/2007	0.5			0.5	State	Unattended Adjacent Forest Fire
Rachitoasa	Colonesti	3/16/2007	3/16/2007	2.2			2.2	State	Unattended Adjacent Forest Fire
Traian	Ungureni	3/19/2007	3/19/2007	0.9			0.9	State	Unattended Adjacent Forest Fire
Fantanele	Margineni	3/19/2007	3/19/2007	11			11	State	Unattended Adjacent Forest Fire
Rachitoasa	Vultureni	3/19/2007	3/19/2007	10			10	State	Unattended Adjacent Forest Fire
Tg.Ocna	Doftana	3/19/2007	3/19/2007	0.5			0.5	State	Unattended Adjacent Forest Fire
Fantanele	Margineni	3/20/2007	3/20/2007	4			4	Private	Unattended Adjacent Forest Fire
Tg.Ocna	Slanic Mold	3/30/2007	3/30/2007	0.5			0.5	State	Unattended Adjacent Forest Fire
Sasaut	Corbasca	4/1/2007	4/1/2007	0.8			0.8	State	Unattended Adjacent Forest Fire
Rachitoasa	Isv.Berhec	4/13/2007	4/13/2007	0.4			0.4	State	Unattended Adjacent Forest Fire
Comanesti	Palanca	4/16/2007	4/16/2007	3			3	State	Unattended Adjacent Forest Fire
Comanesti	Asau	4/16/2007	4/16/2007	3			3	State	Unattended Adjacent Forest Fire
Comanesti	Agas	5/13/2007	5/13/2007	2			2	State	Unattended Adjacent Forest Fire
Rachitoasa	Rachitoasa	7/11/2007	7/11/2007	6			6	State	Unattended Adjacent Forest Fire
Sasaut	Corbasca	7/27/2007	7/27/2007	4			4	State	Unattended Adjacent Forest Fire
TOTAL 2007				57.2			57.2		
GRAND TOTAL				117.4	3	0.5	121.2		

## Appendix 2

Forest District	Town	Fire frequency	Fire frequency average rate per Forest District
Bacau	Gioseni	0.16666	0.16666
Comanesti	Asau	0.83333	0.58333
Comanesti	Brusturoasa	0.33333	
Fantanele	Scorteni	0.16666	0.22222
Fantanele	Garleni	0.16666	
Fantanele	Margineni	0.33333	
Livezi	Gura Vail	0.16666	0.33333
Livezi	Helegiu	0.50000	
M.Casin	M.Casin	0.50000	0.50000
Moinesti	Moinesti	0.16666	0.16666
Moinesti	Balceni	0.16666	
Oituz	Oituz	0.83333	0.83333
Rachitoasa	Rachitoasa	0.50000	0.27777
Rachitoasa	Colonesti	0.16666	
Rachitoasa	Izv.Berhec.	0.16666	
Sascut	Corbasca	0.50000	0.50000
Tg.Ocna	Doftana	1.16666	0.55555
Tg.Ocna	Tg.Ocna	0.33333	
Tg.Ocna	Slanic Moldova	0.16666	
Traian	Plopana	0.16666	0.16666
Traian	Ungureni	0.16666	
Zeletin	Vultureni	0.16666	0.16666
Zeletin	Rachitoasa	0.16666	

## Appendix 3

Forest District	Town	Burnt forest Area	Total Forest Area	severity Rate
Bacau	Gioseni	5.00000	242440	0.00033
Comanesti	Asau	14.40000		0.00083
Comanesti	Brusturoasa	18.50000		0.00116
Fantanele	Scorteni			
Fantanele	Garleni			
Fantanele	Margineni			
Livezi	Gura Vail	5.00000		0.00033
Livezi	Helegiu			
M.Casin	M.Casin	9.30000		0.00049
Moinesti	Moinesti	0.80000		0.00004
Moinesti	Balceni			
Oituz	Oituz	9.90000		0.00067
Rachitoasa	Rachitoasa	20.00000		0.00136
Rachitoasa	Colonesti			
Rachitoasa	Izv.Berhec.			
Sascut	Corbasca	6.30000		0.00042
Tg.Ocna	Doftana	21.10000		0.00144
Tg.Ocna	Tg.Ocna			
Tg.Ocna	Slanic Moldova			
Traian	Plopana	3.90000		0.00026
Traian	Ungureni			
Zeletin	Vultureni	3.50000		0.00023
Zeletin	Rachitoasa			

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