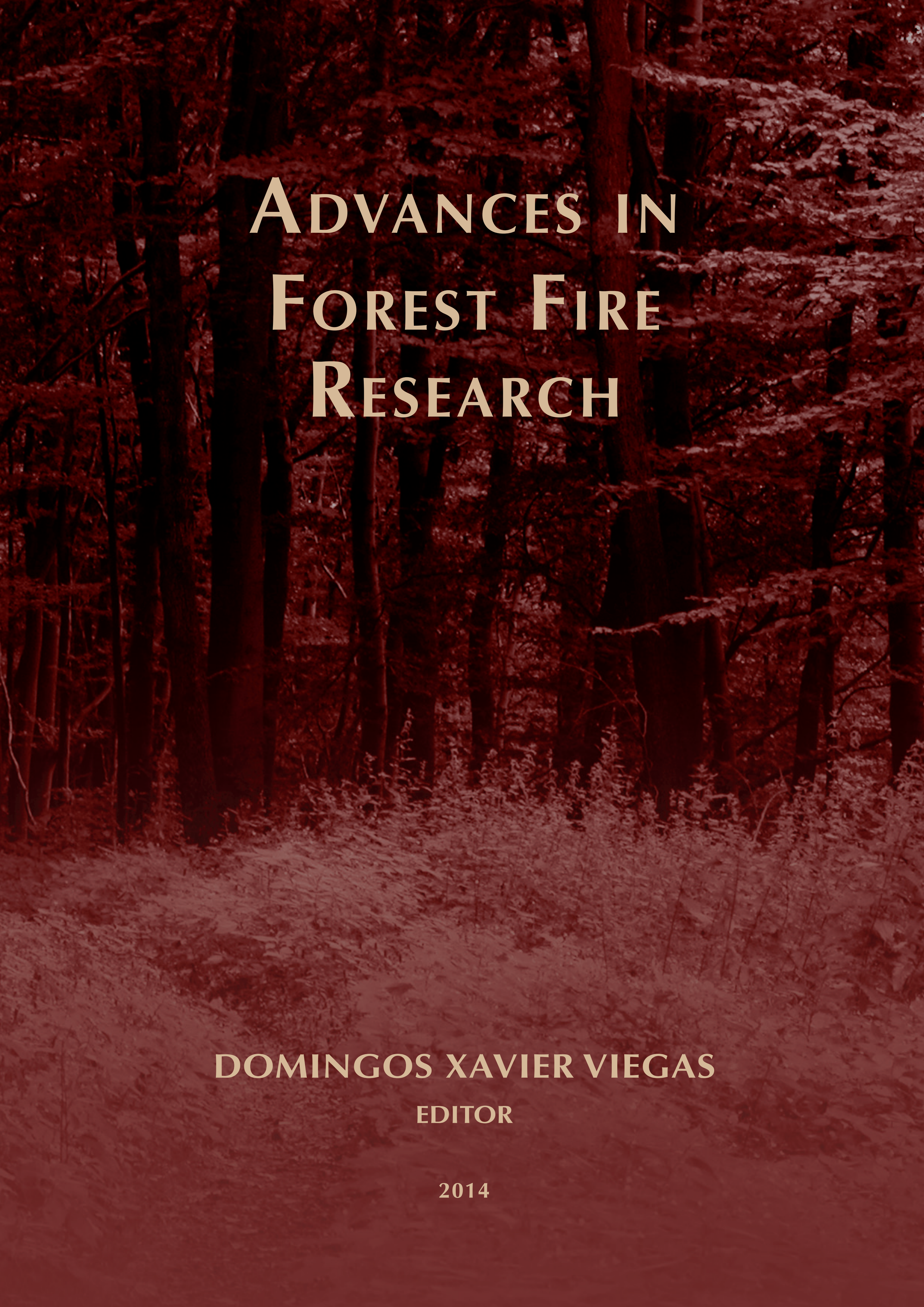

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The ODS3F project: evaluating and comparing the performances of the ground optical and thermal fire monitoring systems.

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Abstract
The ODS3F project (funded in the framework of the EC Civil Protection Financial Instrument) is devoted to the development of a common understanding of the capabilities of vision (optical or thermal) and detection systems on which a fire remote detection network can be based.
This paper illustrates the project results.

***Keywords**: camera, fire, performances, comparison*

1. Introduction

The ODS3F project (funded in the framework of the EC Civil Protection Financial Instrument) is devoted to the development of a common understanding of the capabilities of vision (optical or thermal) and detection systems on which a fire remote detection network can be based. The main objective of such project is the technical assessment and operational comparison between remote visual systems devoted to monitor wooded areas or areas of particular environmental, touristic and/or cultural interest. In particular, apart from the definition of an optimal way to obtain the information needed to detect a fire at the early stage, the project aims at evaluating the possibility of exploiting such information for simulating the fire propagation behavior. Furthermore, the project has the objective to promote the cooperation in spreading and sharing objectively recognized successful practices in reducing the incidence of forest fires or improving the reaction time allowing an enhanced distribution of the human and means resources on the ground
The project originates from the evidence that several surveillance systems devoted to monitor vegetated areas are available in Europe. In particular, the activity of the project relies on the availability of a system based on visible cameras operated in Italy, France and Greece and a system based on thermal cameras operated in Spain. Therefore, this project aims at: - evaluating, through an agreed evaluation scheme, the performances of the already available monitoring systems based on visible or thermal camera already available in the project partners countries; - comparing the results taking into account the different characteristics of the monitored area and the observation system; - assessing the possibility of complementing the monitoring network with a system capable to simulate the fire behaviour providing the most probable, time dependent, propagation conditions by taking into account the meteorological conditions, the orography and fuel (vegetation) type and status; - defining agreed criteria capable to guide the decision about the adoption of situation reports devices based upon remote observation system, in terms of convenience and/or basic characteristics (visible or thermal camera).
The paper is devoted to illustrate the project results.

2. **Methods**

The ODS3F project contemplates two levels of analysis:
- one devoted to evaluate the performances of the camera based surveillance systems in terms of omission and/or commission errors by comparing the events detected by such system with the events reported by other sources (watchtowers, satellite sensors, fire brigade or forest corps reports);
- the second one devoted to define the basic elements to be taken into account for a correct comparative evaluation of the different systems performances.

The first level of analysis (system performances) has been addressed by comparing the alarms (omission errors) provided by the system with the events detected by satellite systems (MODIS, SEVIRI) or reported by Forest Corps or Fire Brigades. Also the number of false alarms (commission errors) is taken into account.

The comparison among systems has been carried out taking into account:
- the land characteristics (as topography, vegetation type),
- main weather conditions in which each system operates,
- the landscape characteristics that could affect the contrast approach.

We assume that an analysis aimed at characterizing the ground/weather/contrast of each area of interest could be carried out, with more or less success depending mainly on the availability of accurate weather data.

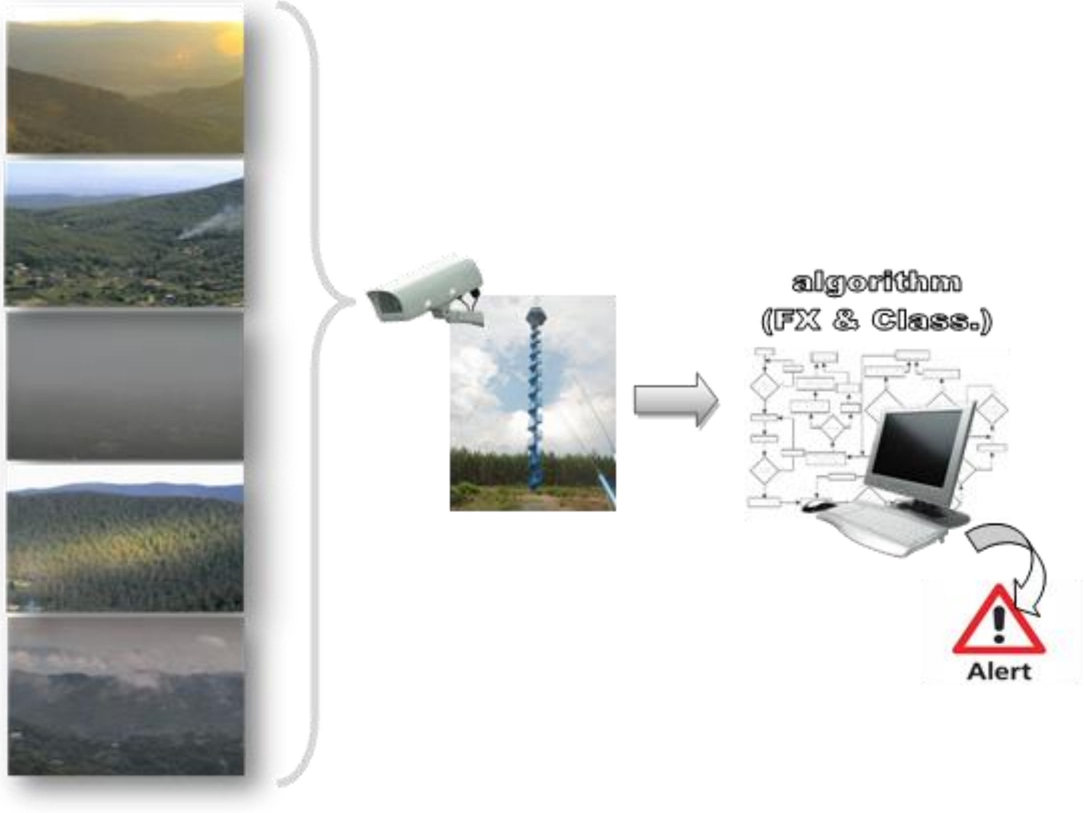

Figure 1. Fire monitoring/detection system.

Furthermore, we proceed by introducing an analysis of the algorithms on which the fire detection is based. Considering an outline of a monitoring/detection system architecture (Fig.1), beyond the above mentioned inherent complexity related to a landscape characterization due to its high dynamism, and leaving out a technical characterization of the cameras installed within the consortium, we intend to address the problem of how each system analyzes the information acquired by the cameras.

Smoke detection and feature extraction processing is a topic developed in many studies, focusing on different approaches (as wavelet decompositions, histogram-based smoke segmentations, colour space transformations, multi-temporal differences, area growth variable and smoke growth rate, spatial characteristics of smoke column, fractal self-similarity properties, RGB space thresholds, texture analysis with gray level co-occurrence matrix, irregular boundaries and background subtraction, neural network and support vector machine classifications).
Then we intend to give as an input in each system an imagery dataset including a number of different context situations (illumination, sunrises and sunsets, foggy and other extreme weather conditions, etc.) in order to evaluate the performance of each classification algorithm in several contrast circumstances.

3. Results

This paragraph is devoted to describe more in detail the results of the camera systems performances analysis (Figure 2 and Figure 3) and the strategy adopted for comparing the different systems in a way that will take into account the different conditions in which such systems are operating.

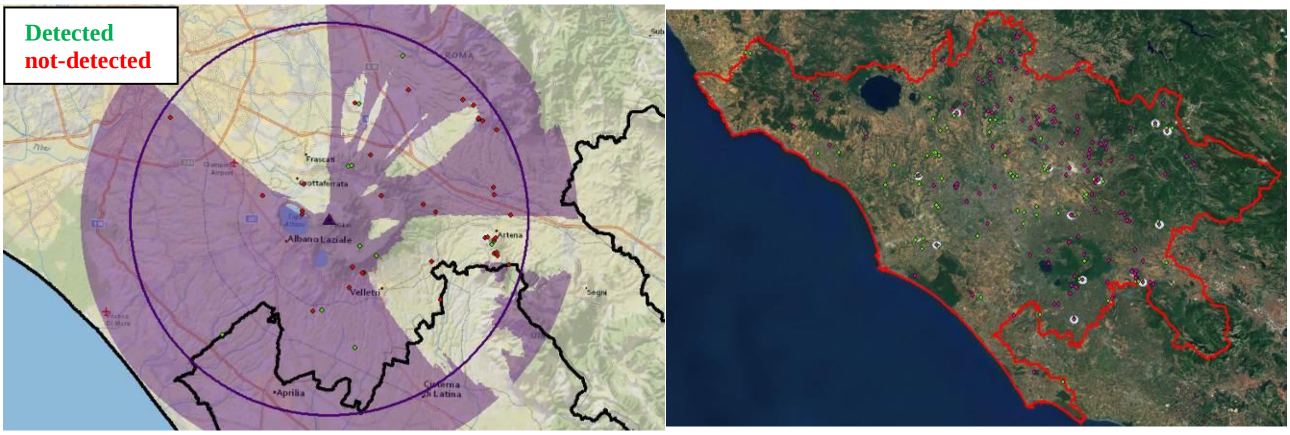

Figure 2. (left) CICLOPE system (Province of Rome) performances analysis. Comparison between camera system reported events (a single camera has been considered) and those provided by Italian Forest Corps, the camera visibility is shown in violet, the fires not detected by CICLOPE are given in red whereas those detected are shown in green. (right) Comparison between Forest Corps events (violet) and MODIS sensor based hot spot (green), the coincident events are highlighted with a cyan circle for the whole Province of Rome.

Figure 2 refers to the system available in the Lazio region (Italy) based on visible camera. Regarding the system based on thermal cameras operating in the Castilla y Leon region (Spain), some results of the analysis of the performances of the detection system are shown in Figure 3. The system is operational since 2006, even if, the number of cameras has increased with time. Figure 3 shows the increasing trend of the effectiveness of the system, reaching an average efficiency of 32%, from the date (2006) of commissioning to 2013.
Table 1 shows, more in details the results concerning the years 2012 and 2013. The year 2012 had a number of fires over the average of the decade. But, only 24 of them exceeded one hectare of burned area. However, to evaluate the full performance of the detection systems in 2012, all the occurred fires were considered, even in farmland.
2013 was one of the best years of the last decade in terms of the number of fires and burned surface in Soria province. 40% fewer fires than the average of the decade. This low incidence of fire in 2013 not facilitates to test the efficiency of the cameras and be able to provide data representative of actual performance. So we also considered all the occurred fires.

These data indicate an effectiveness in **viewed area** of **26,9%** and an effectiveness in all detection range (8km buffer) of 16,3% .

Table 1. Comparison of the surveillance system performances for years 2012 and 2013

	2012	2013
Nº Total fires in the year throughout the province	**207**	**76**
Forest fires	**156**	**47**
Fires between June and October	**110**	**67**
Fires in detection buffer (all the year)	**46**	**20**
Fires in detection buffer and in period of detection	**27**	**16**
Fires in viewed area	**28**	**10**
Fires in viewed area and in period of detection	**17**	**9**
Fires Detected	**4**	**3**
Monitored Fires	**35**	**10**

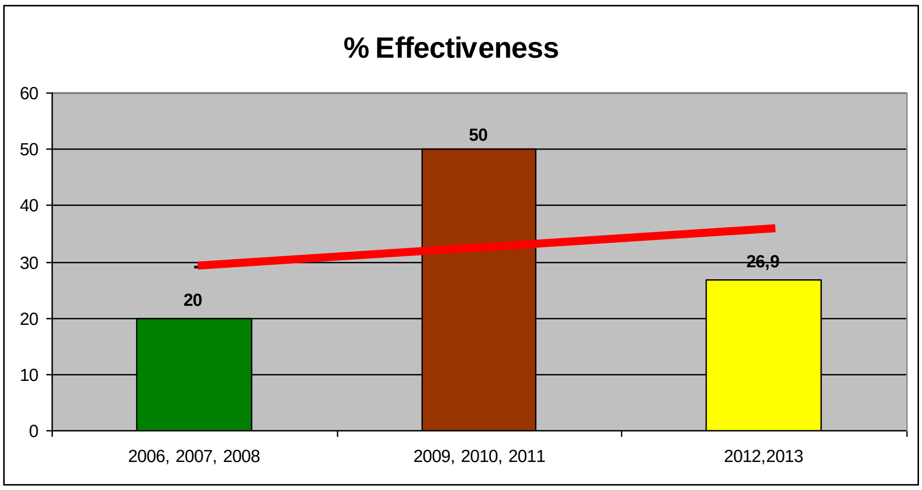

Figure 3. Trend of the effectiveness of the thermal system in Castilla y Leon.

The main causes of this, still low efficiency are:

- A high number of systems failures.
- Short operating time during the year.
- Low rotation speed of some systems.
- Bad calibration for fire detection under adult trees.
- High occurrence of small fire and fast extinction.
- Low visual coverage.
- Absence of qualified personnel throughout all the operation time.

From such analysis we come out with the idea that, besides trying to correct the technical failures and extend the system operating time during the year, it will be necessary to make changes in the operations protocol and mostly important to proceed with a new **calibration of the cameras.**

With reference to the definition of the parameters characterizing the operational 'environment' of the cameras we have identified:
- **terrain characteristics**. The topography of the area monitored by cameras can be characterized by introducing the:

- TPI (topographic Position Index) that gives an estimate of the landform type (Figure 4);

- Aspect, that identifies the downslope direction of the maximum rate of change in value from each cell to its neighbors (Figure 5 left);
- Illumination, which put into evidence different hillshades depending on different hours of the day, providing relative measures of solar illumination (Figure 5 right), which potentially define contrast values with previous Aspect direction;
- Binary Viewshed analysis, which gives the possibility to quantify the amount of covered area seen at surface level, especially useful for thermal cameras (Figure 6 left) and Minimum Smoke Height maps (Figure 6 right), which evidence the Minimum Smoke Height that a smoke column need to reach in order to be seen by the camera.

- **weather conditions** capable to produce fog that can impact the detection capabilities of the system.

- The frequency of fog conditions can be evaluated introducing the FSI (Fog. Stability Index) based on the knowledge of meteorological data (Figure 7 left);
- The impact on visibility can be approximated from FSI values by a comprehensive statistical analysis (Figure 7 right).

- **land cover/fuel type**. The vegetation type and status (dryness), potentially, define the amount and 'color' of the smoke, that should be taken into account for detection.

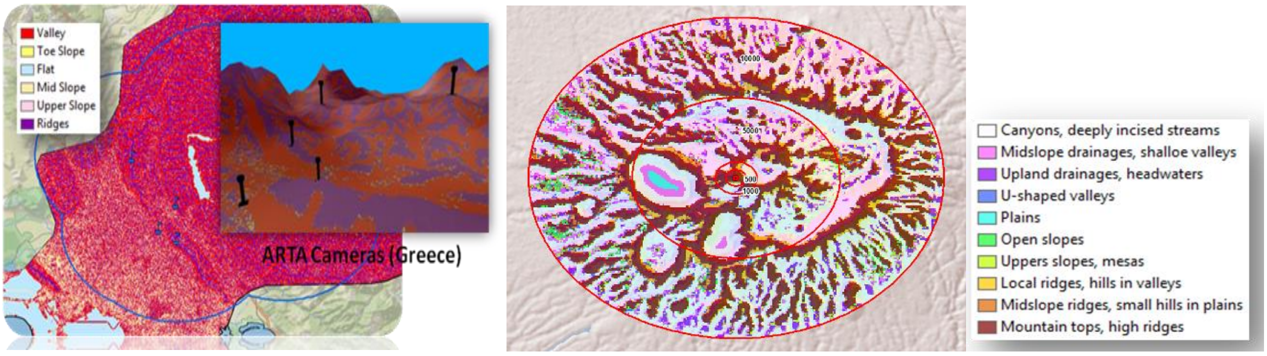

Figure 4. Topographic analysis of the Greek's system in Arta region (right), Provence Region (right)

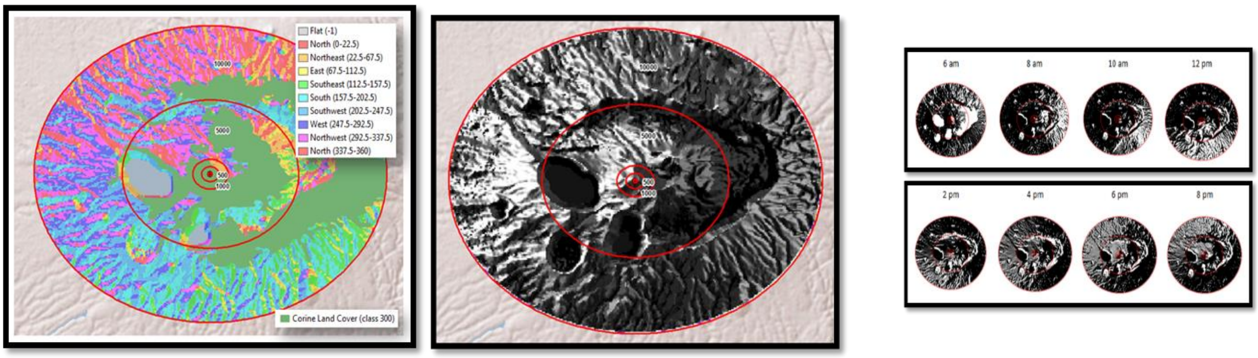

Figure 5. Aspect (left) & Illuminations products (right)

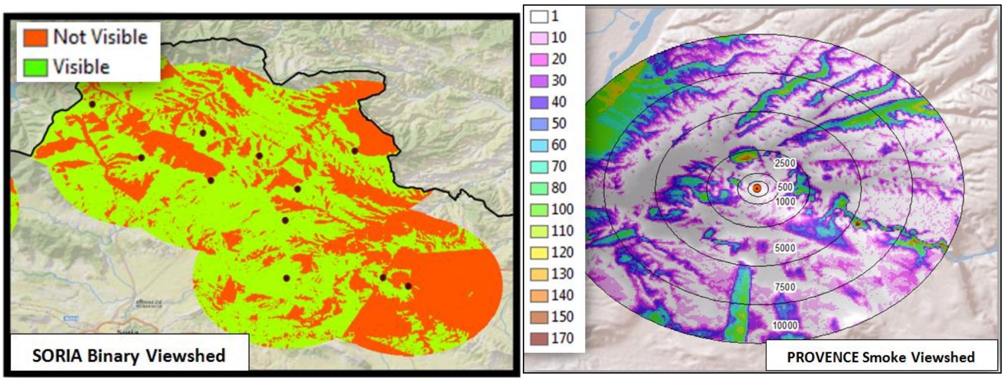

Figure 6. Example of Binary Viewshed analysis of Soria (left), and Minimum Smoke Heights maps of Provence (right).

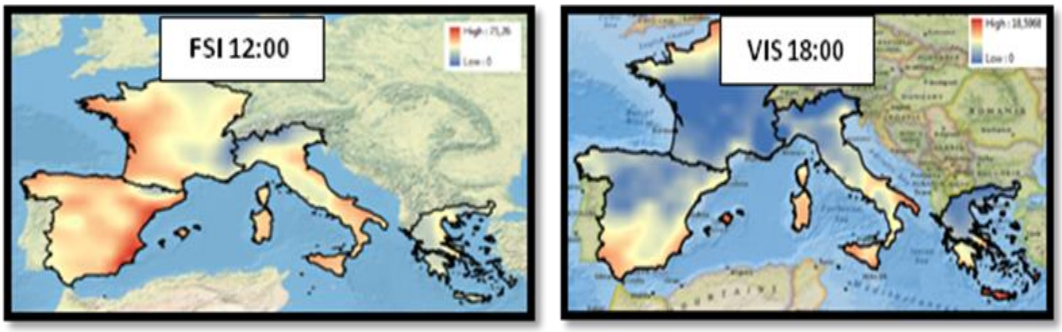

Figure 7. Examples of assessment of the FSI (left) and the visibility (right) for ODS3F countries.

From the different parameters and classes extracted and described above the potential weight that each parameter has can be measured to better understand principal omission and commission errors, and in a further work the potential influences of the territory on each fire monitoring system (Figure 8).

If from a side, as explained above, we are trying to define the 'environmental' parameters which can affect the effectiveness of the camera based surveillance system, on the other side, for comparing the different systems, it is also necessary to set certain common criteria related to the events analyzed.
In fact, during the summer 2014 a campaign covering the summer season will be carried. During such campaign, for each alarm provided by the fire detection systems under study, a template containing a minimum set of variables that could vary according to the detection type systems (heat or smoke) opportunely identified, will be filled:

- Type of detection: thermal or smoke, Kind of sensor and algorithm used.
- Detection range: maximum distance that can detect a fire. (radius).
- Nº Forest Fires in detection range: Official data of the fires that have occurred in the detection range of each system along the period of study.
- Fire forest in detection range and in operational time: Official data of the fires that have occurred in the detection range of each system and in its working time.
- Fire forest in detection range, operational time and in viewed area: Official data from fires that should have been detected by the system
- Fire Forest detected: Number of automatic real detections of fire
- Fire forest Monitoring: Number of fires not detected by the system but monitored
- % Effectiveness of detection: fires detected divided between those who should have detected

Other variables taken into account are:

Operability:

- Work time day / year: how many days the systems work during the year.
- Work time hour / day: how many hours the systems works during the day.

False Alarms:

- Type 1 (Technical): generated by the system when there is some kind of technical failure.
- Type 2 (Natural): are originated by natural causes, such as sunrise and sunset, reflections, clouds, etc.
- Type 3 (Realistic): any other cause giving rise to a hot spot or a column of smoke but no actual case of a wildfire. Such equipment, barbecue, fireplaces, agricultural practices.

Other:

- Installation cost: The cost of systems, excluding tower infrastructure.
- Maintenance cost: cost of commissioning, calibration and annual maintenance (€ / year / system).
- Lifetime of each system: estimated duration that each system can have with correct operation.

Product	Class 1	Class 2	Class 3	Class 4	Class 5	Class 6
Illumination	08:00 – 12:00	12:00 – 16:00	16:00 – 20:00			
Aspect	0	315º-45º	45º-135º	135º-225º	225º-315º	
Binary Viewshed	Visible	Not visible				
Minimum Smoke Height	0	< 10 mts.	< 20 mts.	< 50 mts.	< 100 mts.	> 100 mts.
Visibility	0	< 500	< 1000	< 2500	< 5000	> 5000
Fog Stability Index	low	medium	hight			
Slope Position Classification	Valley	Plain	Ridge			
Distance	500 mts.	1000 mts.	2500 mts.	5000 mts.	7500 mts.	10000 mts.
Corine Land Cover	Forest	Agricultural	other			

characteristic	event #1	event #2	event #3	...	event # n
Illumination	C1	C2	C2	...	C2
Aspect	C2	C5	C4	...	C1
Binary Viewshed	C1	C1	C2	...	C2
Minimum Smoke Height	C3	C5	C2	...	C2
Visibility	C4	C4	C1	...	C3
Fog Stability Index	C3	C2	C2	...	C2
Slope Position Classification	C3	C3	C2	...	C3
Distance	C2	C4	C6	...	C4
Corine Land Cover	C3	C2	C1	...	C1
event detected	X	√	√		√
false alarm	X	X	√		X

Omission errors (event Not Detected that is a not a False Alarm) >> **Need to be reduced**

Note: Event = feature detected by the system, not necessarily a fire/smoke event

Commission errors (event Detected that is a False Alarm) **>>Need to be reduced**

Figure 8. Classes extracted from parameters

4. Conclusions

The ODS3F project objectives originate from the circumstance that even if the systems based on (visible and thermal) cameras devoted to monitor/detect fires are spreading all over Europe a comprehensive study, of such systems and their limits compared with the environment where they operate is not available yet.

Through the comparisons of different systems ODS3F aims at defining an optimized system, a standardized set of information, a common method of using the situational reports for enhancing the correct, effective and efficient utilization of the available data in facing emergencies (as wildfires are) and in reducing their consequences. Finally, a guidelines document describing the elements to be taken into account for selecting the most suitable surveillance system for monitoring, protecting a given area of interest and for optimizing the exploitation of the produced information will be issued.