Dipartimento
di Ingegneria Astronautica
Elettrica ed Energetica

Sapienza
Università di Roma

FINAL REPORT

Project: "Observation and Detection Systems for Forest Fires Management" (ODS3F)

Coordinating Beneficiary : Sapienza Università di Roma, Dipartimento di Ingegneria Astronautica, Elettrica e Energetica

Associated Beneficiaries :

(1) Centro de Servicios y Promocion Forestal y de su Industria de Castilla y Leon – Spain

(2) University of West Macedonia, Greece

(3) Office Nationel de Forets – France

(4) Provincia di Roma - Italy

Grant Agreement ECHO/SUB/2012/638450 – Project co-funded by the Financial Instrument for civil protection

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1. The ODS3F Project

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 by the Province of Rome, a system based on thermal cameras operated by Castilla y Leon province with the involvement of the Cesefor Centre, a system based on a network of detectors also managed by the Cesefor Centre, a camera based monitoring system operating in Greece and similar system operating in France. Some of these systems have been already investigated by some of the project partners in the framework of the INTERREG IVC project EFFMIS (European Forest Fire Monitoring using Information Systems). Taking advantage from the past experience this project aims at improving this knowledge by sharing the practice, assessing performances and comparing data, and results provided by the different systems. In recent years an effort is made for the use of an advanced approach to human forest fire surveillance, which is mainly based on the use of advanced Information Systems. It is clear that the activity of prevention can play a significant role in decreasing the number of fires. But, due to the relevance of the human factor in determining the onset of a fire and therefore its unpredictability, more that a prevention activity oriented at decreasing the probability of the ignition, a monitoring system capable of reducing the reaction time and increasing the information available in real time to be used in the extinction phase would be needed.

1.1 Project Objectives

The present project 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 among remote visual systems and detectors network 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, evaluate the possibility of exploit such information for simulating the fire propagation behaviour. Furthermore the project has the objective to promote the cooperation in spreading and sharing practices, objectively recognized, of success 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.

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 countries of the partners of the project;
- comparing the results taking into account the different characteristics of the monitored area and the observation system;
- assessing the possibility of complement 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).

1.2 Coordinating Beneficiary and associated beneficiaries

- Name of coordinating beneficiary (CO): Dipartimento di Ingegneria Astronautica, Elettrica e Energetica -Sapienza Università di Roma, Italy
- Name of associated beneficiary (AB1) CESEFOR, Centro de Servicios y Promoción Forestal y de su Industria de Castilla y León, Spain
- Name of associated beneficiary (AB2): University of West Macedonia, Greece
- Name of associated beneficiary (AB3): Office National des Forets, France
- Name of associated beneficiary (AB4): Provincia di Roma - Servizio di Polizia Provinciale e Protezione Civile, Italy

1.3 Project Budget

Total project eligible cost: 634,291 €
EC financial contribution requested: 475,719 € (= 75% of total eligible costs)

1.4 Project Policy Area / Theme

Actions aimed at limiting the consequences of emergencies through sharing experience and best practices on developing and making use of situational reports.

1.5 Expected Results

As result of the technical and operational analysis that will be carried out on the information provided by the investigated technological systems, as well as the comparison of the performances and the final utilization of the available information will contribute in the adoption of these technologies as common and shared good practices at EU level. The comparison of the systems can bring to define 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. In particular, a deliverable consisting in a guideline describing the elements to be taken into account for selecting the most suitable surveillance system for monitoring and preventing forest fires.

2. The Project Implementation Process

2.1 Overview of the process

ODS3F project started on the 1st of January 2013 and was intended to last 24 months. Actually, an extension of 3 months was requested to complete some of the activities. Therefore the project ended on the 31st of March 2015. The process of the project activities can be synthesized in three main steps:

- the first step was devoted to describing and share the characteristics of the different observation systems available in the different countries;
- the second step was devoted to assess the performances of such systems by carrying out a series of measurement/calibration/validation campaigns coordinated among the partners. In fact, the measurements were carried out during an assigned time interval (2014 fire season) and an agreed list of parameters was collected;
- the third step was devoted to compare the different systems taking into account the measurement collected during the previous campaigns and all the data allowing to assess the context in which each one of the systems works (topography, weather, vegetation, etc.).

2.2 Initial and actual time schedule

The following table (Tab. 1) compare the planned project time schedule with the actual one.

Table 1 *- Initial and Actual time schedule*

Task Title	Initial time schedule	Actual time schedule
Scientific and technical Coordination & Project Management (Task 1)	M0 - M24	M0 - M27
Analysis and technical assessment of the observation/detection systems (Task 2)	M0 - M15	M0 - M24
Definition of situational data set, utilization	M12 - M24	M12 - M27

strategy & simulation of fire behaviour (Task 3)		
Good practices and experiences exchange (Task 4)	M12 - M24	M12 - M27
Communication & Dissemination (Task 5)	M02 - M24	M02 - M27

2.3 Expected and actual results

The expected results of the ODS3F project are recalled in Table 2, where they are compared with the actual reached results.

***Table 2** - Expected project results compared with the actual results reached*

Expected Results	Actual Results
The correct management of the project and the achievement of the objectives. The correct financial and administrative management of the project. Correct coordination of the scientific and technical activities of the project and involvement of external experts. Ensure the achievement of overall technical and scientific objectives of the project (Task 1)	The overall (administrative, financial, scientific and technical) management of the project has been satisfactorily carried out. The technical and scientific objectives of the project have been achieved.
Cost-benefit analysis, comparison with other IT solutions for forest fires detection, such thermal and smoke sensors. The creation of a database with the fire events occurred in the area of interest and detected from the different methods. The definition of a common methodology for testing detection system. The assessment of the advantage and disadvantage associated with each available system; Sharing experiences. (Task 2)	The cost-benefit analysis has involved the Spanish partner which was interested in evaluating the feasibility of forest fires detection based on a network of detectors, such thermal and smoke sensors. Actually, CESEFOR did not go far in the development of forest fires detection system because it was judged useless. However, CESEFOR has worked and has already implemented a system for smart object detections, which can be linked to forest fires and civil protection: detection of people in the forest. A database with the fire events occurred in the area of interest and detected from the different methods has been created considering the events occurred on years 2013 and 2014. A common methodology for testing detection system has been defined. The assessment of the advantage and disadvantage associated with each available system has been carried out; Experiences on systems and use of the provided information has been shared among project partners
The definition of a common strategy for the	A common strategy for the exploitation of the

exploitation of the reports provided in real- time from the different systems available and operating. Developing of a fire behaviour simulation module suitable for exploiting the situational reports provided by the 'in situ' or 'remote' sensors network. Optimization of system performance and maximization of utilization of the provided information, by the identification of margins for improvement thanks to the identification of best practices from the partner's territory. Design, development and integration of the web application. Assessment of the possibility to add a module for the fire spread prevision (Task 3)	reports provided in real- time from the different systems has been defined by identifying the minimum number of needed parameters (fire coordinates, time, wind, etc.). A fire behaviour simulation module has been developed for exploiting the fire detection capabilities of the Italian system. All partners have identified, thanks to the exchange of best practices possible margins of improvement for the systems present in each partner's region. Design, development and integration of the web application.
Comparison of systems and good practices and experiences exchange. Development of guide lines for the optimized utilization of the situational reports (Task 4)	The systems have been compared and good practices and experiences have been exchanged. The guide lines for the optimized utilization of the situational reports are contained in this document.
Design and creation of a website. Dissemination plan and elaboration of brochures and presentations. of a database and mailing list for the dissemination of information and events and establishment of a communication tool for the consortium (Task 5)	The project website has been created and continuously updated. Brochures and newsletter have been produced and disseminated by using an extended mail list The project results have been disseminated by attending international conferences and publishing papers on scientific journals or books.

3. Technical Results and Deliverables

This section describes the deliverables of the project and a short description of the deliverables. (Deliverables/reports can be provided in the Appendices)

3.1 Description of individual deliverables

In accordance with the rules of the projects on Preparedness and Prevention two progress reports at regular intervals have been submitted in electronic and paper version (August 2013, April 2014) and the present final report.
The two intermediate reports are provided in the Annexes.
Two one page financial summaries have been also submitted together with the reports.

Report 1 (January 2013 - August 2013)

This document aims at providing a synthetic description of the results obtained in the framework of the ODS3F activity regarding the first 7 months of the project (January - July 2013). The activity concerns the analysis of the performances of the monitoring systems available in the different countries. Reports describing in detail the activity carried out by the partners have been made available on a dedicated area of the ODS3F website (www.ods3f.eu).

Report 2 (September 2013 - April 2014)

This document aims at providing a synthetic description of the results obtained in the framework of the ODS3F project activity carried out in the 9 months comprised between August 2013 and April 2014. The activity concerns:
- the completion of the analysis of the performances of the monitoring systems available in the different countries;
- the development and application of observation system calibration techniques;
- the development of the procedure for the comparison of the different systems.

Reports describing in detail the activity carried out by the partners have been made available on a dedicated area of the ODS3F website (www.ods3f.eu).

3.2 Values added at local and EU level

The main contribution given by the ODS3F project concerns:
- at local level this project has provided the opportunity to national/regional/provincial institutions to evaluate the own systems against other similar systems available in Europe. Therefore it was possible to identify areas of possible improvement of the own system by sharing best practices and information.
- at European level this project, by defining an agreed evaluation scheme, allowed to compare in an objective way the performances of available monitoring systems based on visible or thermal camera by taking into account the different characteristics of the monitored area and the observation system. This is the most significant contribution given by this project. It aims at identifying the characteristics of a optimized camera based surveillance systems providing advices (guide lines) which should be taken into account for planning the installation of this kind of systems.

4. Project Evaluation and Recommendations

4.1 Positive aspects and opportunities

ODS3F gave the opportunity to operational and research institutions to cooperate in analyzing and compare the surveillance system performances by defining a objective to assess the possible limits which each one of the considered systems could exhibit.
Further, the ODS3F project has been a great opportunity for:

- exchanging experiences and identify areas of possible improvement of the each one of the systems;
- learning procedures and testing tools for the system calibration;
- introducing a scientific approach in the assessment of the performances of the surveillance systems;
- identify a minimum number of 'environmental' parameters to be taken into account for evaluating the performances of each system 'in absoluta' and with respect to other Europe-wide available systems.

4.2 Internal and External difficulties encountered

DIAEE, No difficulties have been encountered during the project apart of some resistance of the people managing the surveillance systems in collecting, during the summer 2014 test period, the requested information filling the excel file provided to them. The main reason was that, in some cases, they felt this activity as an extra effort.

CESEFOR has not faced any important constraint due to be the direct users of the early detection systems and forest fires managers in the region. The main pilot project developed within this initiative was to develop an hardware/software system for smart object detection in the forest. This system has helped not only to complement thermal cameras but also to extend its use to other important public use and civil protection of the forest, like forestry roads vehicles detection.

ONF has faced two difficulties:
- a delay of more than a year of installation of the camera system due to two constraints: first administrative, with a long approval process to settle on an existing pylon, then the second technical with complicated settings for put the camera system consistent with the communications system and the computer system of firefighters. In feedback, it appears that these two aspects are important to consider in the prior consideration to the establishment of such a system.
- Summer 2014 (the only one to have been tested in real conditions of use due to the aforementioned delay) had a very low operating activities (small number of fires) due to wet weather. This resulted on the one hand that the data collected were not sufficient to statistically analyze the real fires detection performance, and also in the analysis of false alarms there is a significant proportion due to fog and clouds that could end up less during a very dry season.
No internal difficulties inside the partnership.

UOWM, No difficulties have been encountered during the project duration apart from some resistance of the people managing the surveillance systems in collecting, during the summer

2014 test period the requested information recording the data concerning any fire incidents. The activity was considered as extra work.

4.3 Cooperation of the partnership and the Commission

The cooperation within the consortium was excellent. However, we have to stress the fact that 4 of the 5 project partners have already cooperated in a previous project (EFFMIS, INTERREG IV) then they know each other very well. This fact has certainly had positive impact on the project implementation. In fact, we encountered no obstacles in the exchange of data, information and experiences.

The relationship with Commission was good in the sense that the responsible of the project in the Commission answer to any question raised by us quickly and clearly.

Unfortunately, the representative of the Commission never had the opportunity to participate to our meetings in a case because of the late communication of the project meeting from the project coordinator but in the other cases because the date were n conflict with other commitments. This was a pity because I had never the opportunity to meet the project team and see how we organize the Meeting to present to all the partners the activity carried out by each partner and disseminate the project results to the potential user community.

UOWM: Cooperation with partners was constructive with frequent exchange of information, methods of work and support from the LP to carry out the project activities in line with the project proposal. The LP supported all partners while the project progressed and provided useful guidance and information on the methods of delivering the activities in order to come up with comparable results and conclusions.

4.4 Value added at a European level

All reports on the state of Europe's forests indicate that the broad Mediterranean area is systematically affected by uncontrolled forest fires with large impact on ecosystems, soil erosion, slope instability, desertification trends, and local economies as a whole, whit a negative mid-to-long term prospect because of Climate Change. In France, Greece, Italy, Portugal and Spain every year, hundreds of thousands of hectares of forest are burned (see Fig. 1, courtesy of FP7 PREFER project) as a consequence of fires. We shall note that the above figure did not change in the last 30 years despite the deployment of newer fire-fighting techniques, larger water-bombing means and the diversification of containment strategies, accompanied by more and more sophisticated detection, mapping and ICT technologies to address tactical (support to fire-fighting and crisis management) and strategic issues (assessment, intelligence and prevention).

In this scenario, the need to improve the information and the intelligence support to forest fire prevention is widely recognized to be relevant. The ways to respond to such need of Southern Europe's forests could be different. In particular, it could involve the:
- enhancement of the use of timely information products based on the exploitation of all available spacecraft sensors;
- improvement of the prevention activities;
- enhancement the early fire detection systems based on ground or space observation systems.

The ODS3F project focuses on the ground based surveillance systems. Even if observation systems based on satellite are capable to provide a synoptic view of a large area at an affordable cost the present spatial and temporal resolution characteristics of these systems is still poorly suited to the needs of a forest fires early warning system. Therefore, a ground system based on cameras could be a valid alternative, especially for protecting natural area of considerable economic, touristic, environmental value.
As confirmation of this, many surveillance systems based on visible or thermal cameras have

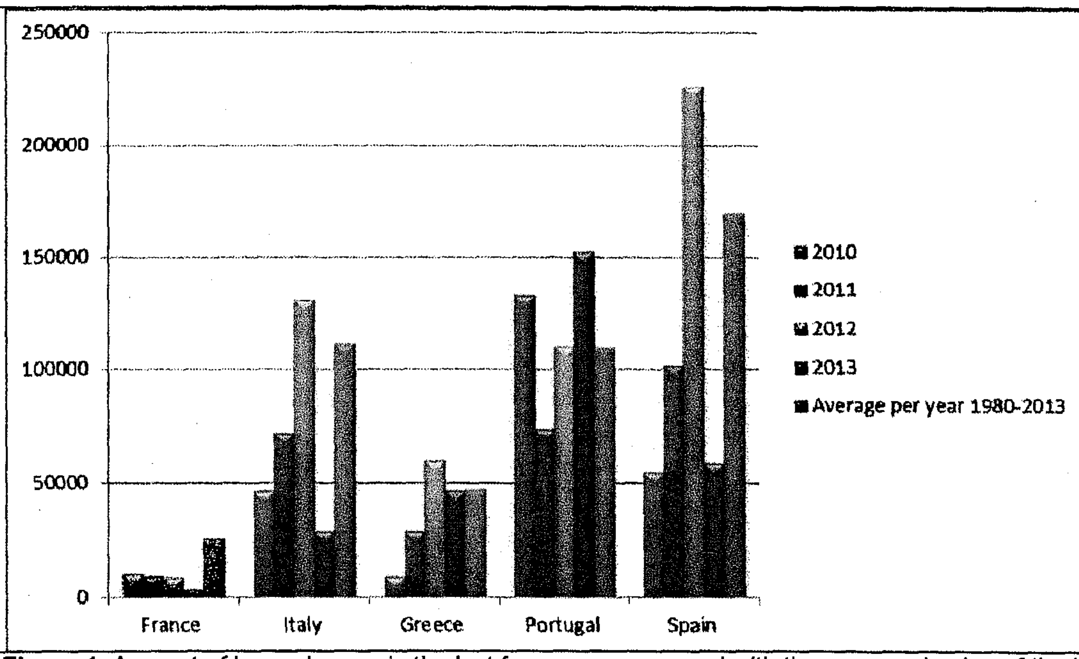


Figure 1. Amount of burned areas in the last few years compared with the averaged value of the last 30 years in the European countries most affected by fires.

been installed across Europe. Fig. 2 reports only those taken into account by the ODS3F project.

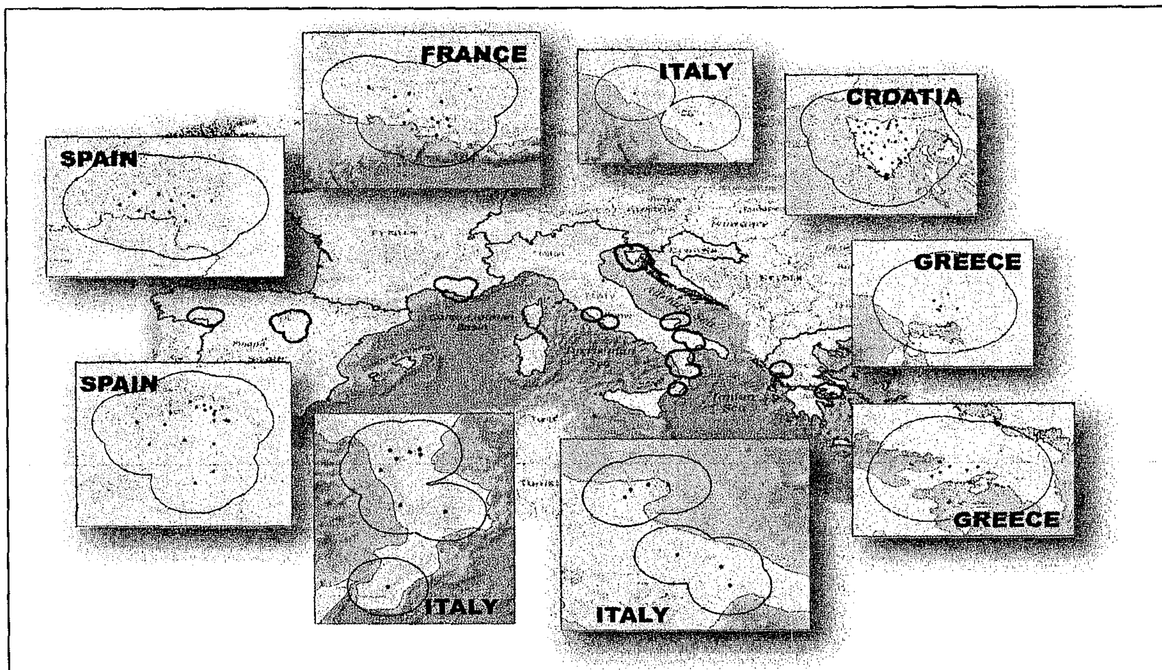


Figure 2. Geographic distribution of the surveillance systems taken into account by the ODS3F project.

The performances of these systems are far from being optimal. This happens for many reasons;
- to reduce the cost the cameras are usually distributed according with the availability of towers devoted to other purposes (often telecommunication, TV broadcasts, etc.);
- the reduced number of visible cameras does not allow the utilization of the triangulation technique for correctly locating the fire event;
- the detection algorithms needs a long training phase to minimize the number of false alarms;
- the topography of the area of interest could be unsuitable for surveillance systems based on thermal cameras;
- environmental conditions (clouds, haze, etc) could exacerbate the problem of false alarms.

The list of surveillance systems considered in the project and their main characteristics are given in Table IV.

Table 3 *- List of surveillance systems considered during the ODS3F project.*

Region	Spectral region	Num. of cameras	Owner
Castilla y Leon (Spain)	Thermal	19+2 visibles (Soria)	Prov. of Castilla y Leon
Castilla y Leon (Spain)	Thermal	11 (Zamora)	Prov. of Castilla y Leon
Provence (France)	Visible	2	ONF
Lazio (Italy)	Visible	2	Prov. of Rome
Calabria (Italy)	Thermal	7	Italian Fire Brigades
Puglia (Italy)	Thermal	9	Italian Fire Brigades

Istria (Croatia)	Visible	19	iForestFire Net
Arta (Greece)	Visible	5	Provence of Epiros
Artiki (Greece)	Visible	6	Provence of Attika

Then, the ODS3F aimed at developing a common understanding of the capabilities of vision (optical or thermal) systems on which a fire remote detection network can be based. The main objective of such project is the technical assessment and operational comparison among remote visual systems devoted to monitor wooded areas or areas of particular environmental, touristic and/or cultural interest. Furthermore the project has the objective to promote the cooperation in spreading and sharing practices, objectively recognized, of success 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. But, in our opinion, the most important topic covered by this project concerns the definition of an as impartial as possible evaluation scheme, to be applied for the evaluation of the performances of the already available monitoring systems based on visible or thermal camera. From the comparison of the results obtained during a test campaign carried out during the summer 2014, taking into account the different characteristics of the monitored area and the observation system it has been possible to identify the parameters, environmental, topographic and meteorological to be taken into account for an optimal selection of the system to choose in terms of wavelength, position and number of cameras, detection algorithm and so on.

Therefore, the main valuable results of the project which could have a significant impact at European level are:

- the definition of a series of parameters to e taken into account when planning the acquisition of surveillance systems for monitoring forested or protected or natural areas.
- the development and the exchange of a series of techniques and instruments for calibrating and assessing the sensitivity of the surveillance systems.

Fig. 3 shows some of the surveillance cameras (visible and thermal) calibration systems tested during the project activity.

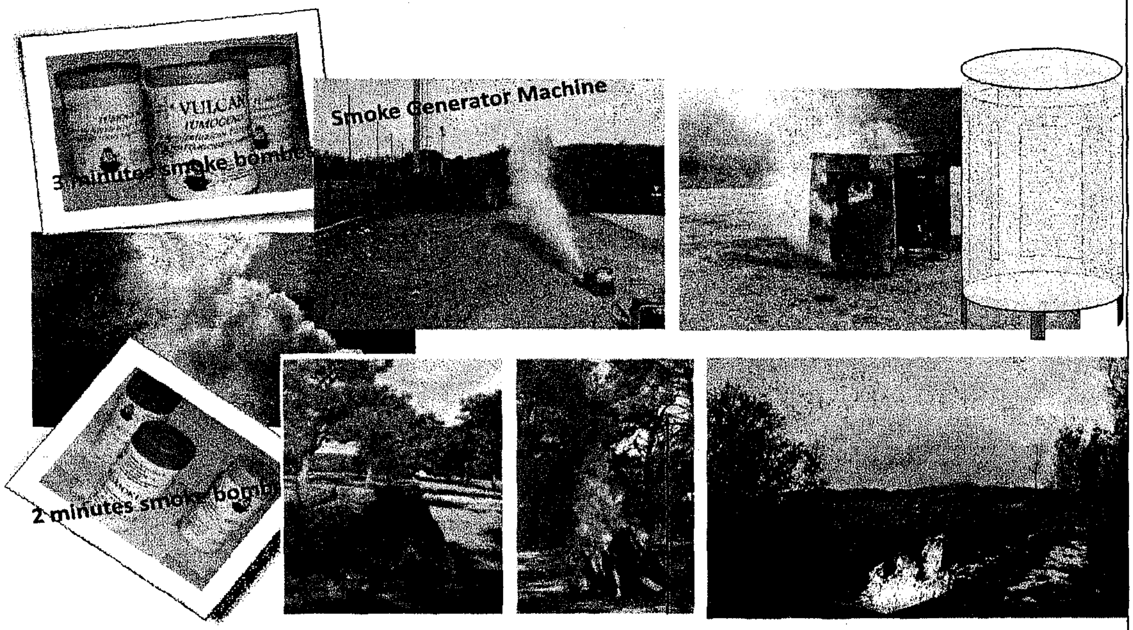


Figure 3. Examples of the tools used within the project to calibrated the visible and thermal observation systems.

The test campaign of the surveillance systems managed by project partners carried out during the summer 2014 has highlighted some aspects to be considered:

- the high number of false alarms of the systems working on the detection of smoke.
- the difficulty of the visible camera to correctly locate the fire when the monitored area is covered by a single camera. That is, the triangulation technique to geo-locate the position of the occurrence cannot be applied.
- the high number, in mountainous areas, of undetected fire events.
- the long time requested to train the software devoted to detect fire occurrences for limiting the number of false alarms. The training of the detection algorithm could cover two or more years and requests a strong support from the system operator that should rectify the wrong detections for improving the reliability of the system.
- an ideal system should include a module devoted to simulate the fire behaviour after its ignition. A module like this, if the requested input (meteorological data, vegetation fuel map, DEM) are provided, could be very useful for planning evacuation strategy or intervention actions.

CESEFOR, have tested and validated another thermal cameras-based system, due to incorporate within the current system better and newer technology. This evolution is helping to increase 3 times the detection range (15-20km), to increase the analysis performance speed (2 minutes) and to achieve a much important system reliability.

CESEFOR has developed a prototype of a hardware-software system (Fig. 4), consisting of a camera hidden in a nest box that allows continuous recording range of up to seven days of real-time video is output to a data server if there is mobile coverage in the place of installation of the device (or stores the information in a memory card for later reading in the office).
The objective is to have a flexible, portable system for civil protection control in the forest, to detect people, vehicles and animals for different purposes, such forest fires negligence (potential forest fires starters), public use, natural resources theft (wood and infrastructures).
This camera has an infrared sensor for recording nocturnal, microphone, and, if applicable, a volumetric sensor. Besides a (replaceable by a solar panel) battery, and the communication unit: GPRS router and modem.

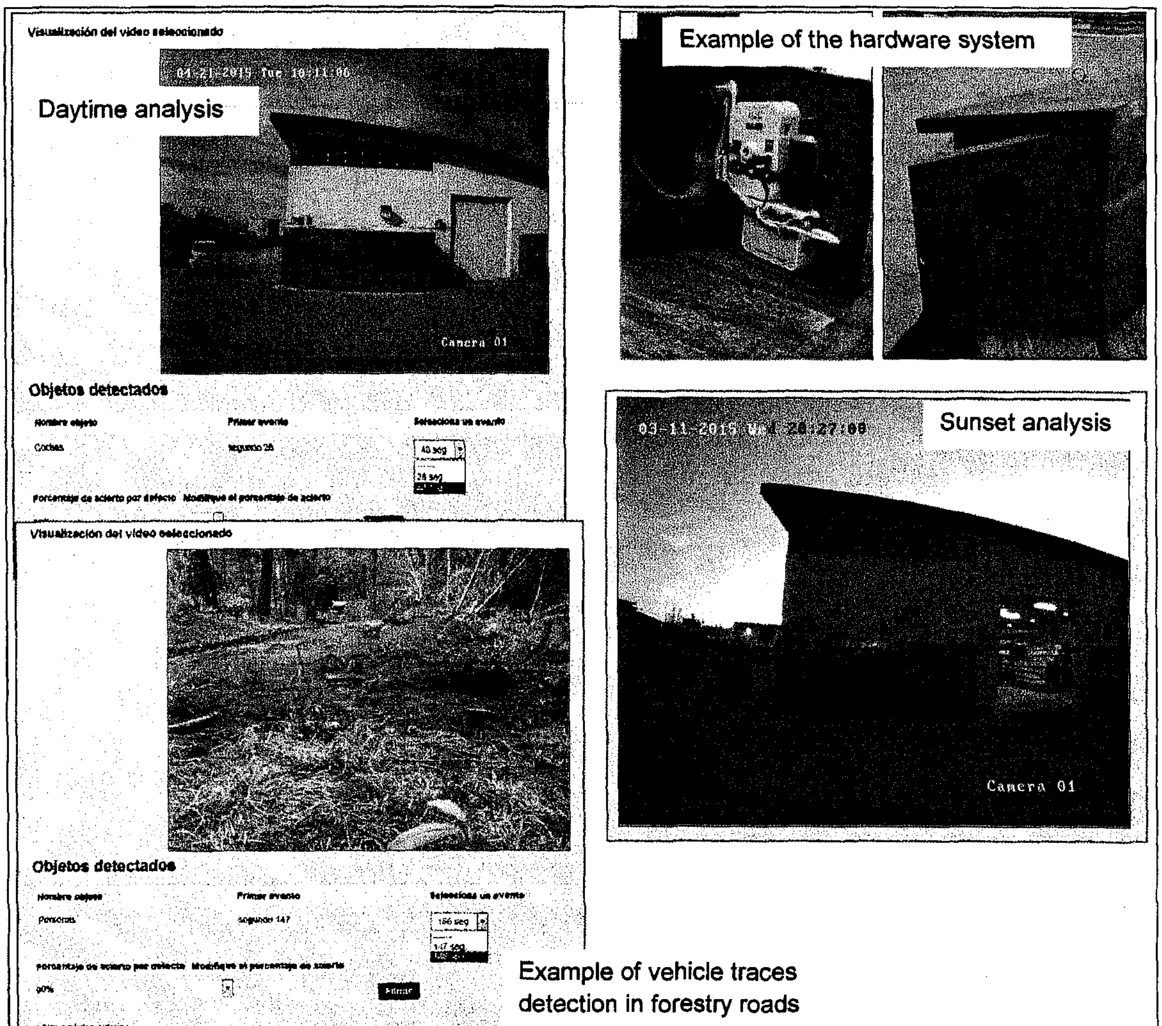


Figure 4. Example of the prototype developed by CESEFOR for forest monitoring and detection of

people, vehicles, etc..

The software prototype seeks to step beyond the observation of objects and identification, but the application is pre-trained to understand what is expected to be observed. That is, it does not require a technical review and understand the recording made, very common in mature analysis uses information in the forest.
For several months the application has been tested, training it with common events, such as detection of vehicles and persons on the premises of CESEFOR, and this 2015 will face the real phase moment locating cameras in the forest and analyzing trends, generating real time alerts and helping the forestry managers.

UOWM, the mountainous nature of the Mediterranean area results in having areas where visibility with cameras cannot be achieved at all i.e. hidden views. These hidden views that cannot be seen by cameras can be addressed with complementary equipment that can be incorporated to existing systems such as wireless sensors, CO2 emissions and temperature, marked on the GIS.

4.5 Lessons learnt

ODS3F gave the opportunity to institutions involved in the field of forest fire management and research centre to cooperate:
- in identifying possible improvement or limits of the surveillance systems,
- in defining calibration procedures and techniques.
- in identifying the elements to be taken into account for an optimal selection of the most suitable system for a given area to be monitored.

The space application of earth Observation are not yet enough mature to allow a prompt and accurate detection of forest fires. Therefore camera based surveillance systems could represent presently the only solution to reduce the effect of forest fires by improving the promptness of the detection. However, to optimize the performances of these systems a part the quality of the cameras many other things should be taken into account. In particular, for reducing the number of false alarms which is main problem of the visible cameras. In fact, a high number of false alarms could make operationally useless the system.
The studies and tests carried out during the project allowed to highlight the main parameters to consider for the development of an optimized fire detection system:
- **terrain characteristics**. The topography of the area monitored by cameras could be characterized by introducing the:
    - TPI (topographic Position Index) that gives an estimate of the landform type (Fig. 4);
    - Aspect, that identifies the down-slope direction of the maximum rate of change in value from each cell to its neighbors (Fig. 5 left);

- Illumination, which put into evidence different 8 different hill-shades on different hours of the day, providing relative measures of solar illumination, which potentially define contrast values with previous Aspect direction. From this set of Hillshades images, a new illumination layer is constructed containing relative measures of solar illumination. The original values (that run from 0 to 255) were divided in 4 classes (low – medium – high – very high) (Fig. 5, bottom-right);
- Binary Viewshed analysis, which gives the possibility to quantify the amount of covered area seen at surface level, especially useful for thermal cameras (Fig. 6 left) and Minimum Smoke Height maps (Fig. 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 (Fig. 7);
- The impact on visibility can be approximated from FSI values by a comprehensive statistical analysis.

- **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.

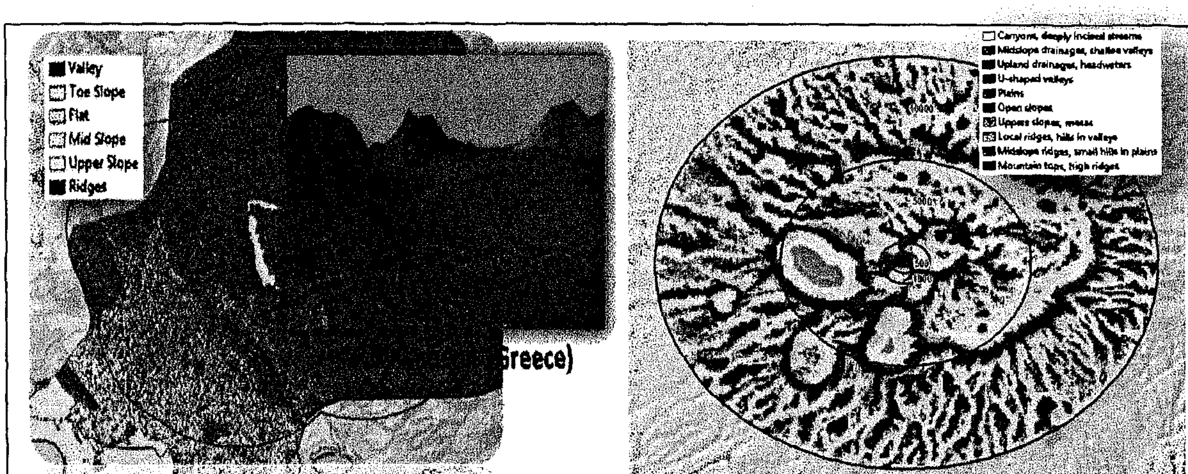


Figure 4. Topographic analysis of the Greek's system in Arta region (left), Provence Region (right).

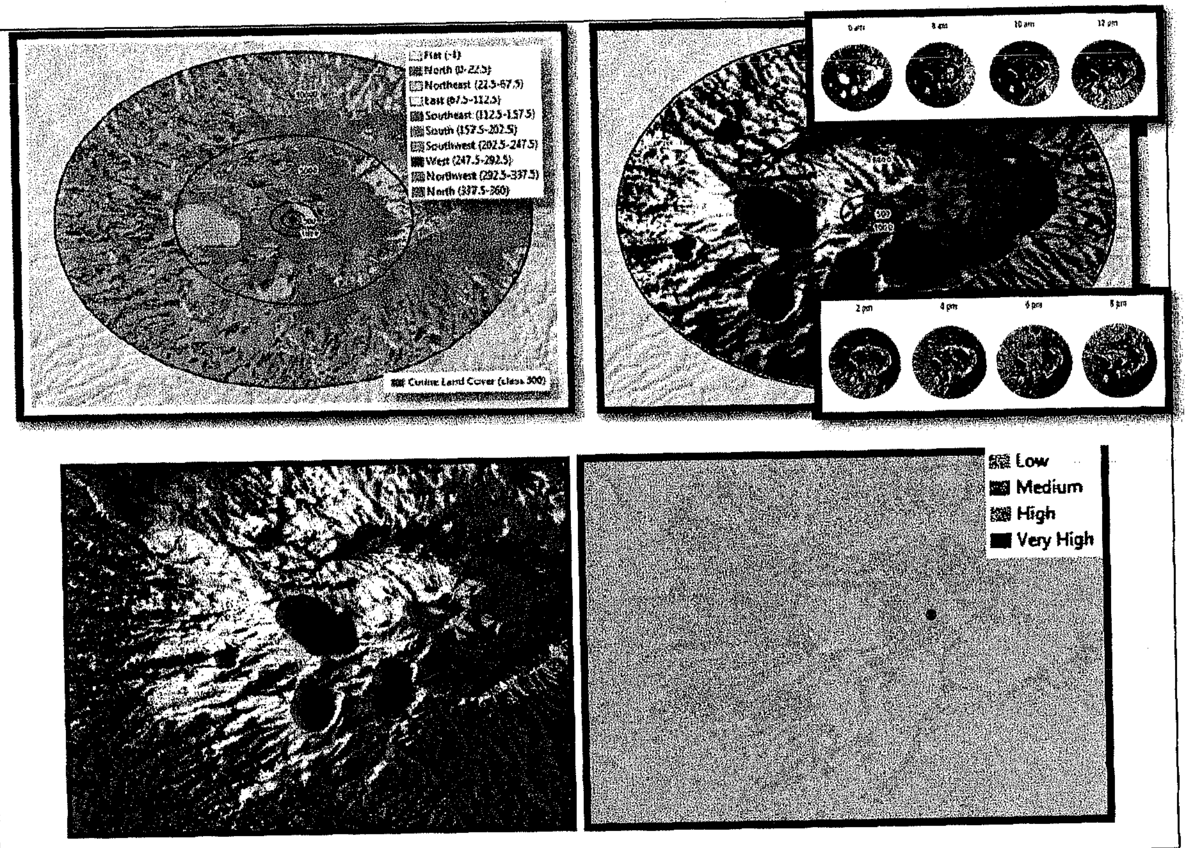


Figure 5. Aspect (left) & Illuminations products (top-right).
Cavo Illumination layer and Illumination reclassification (down)

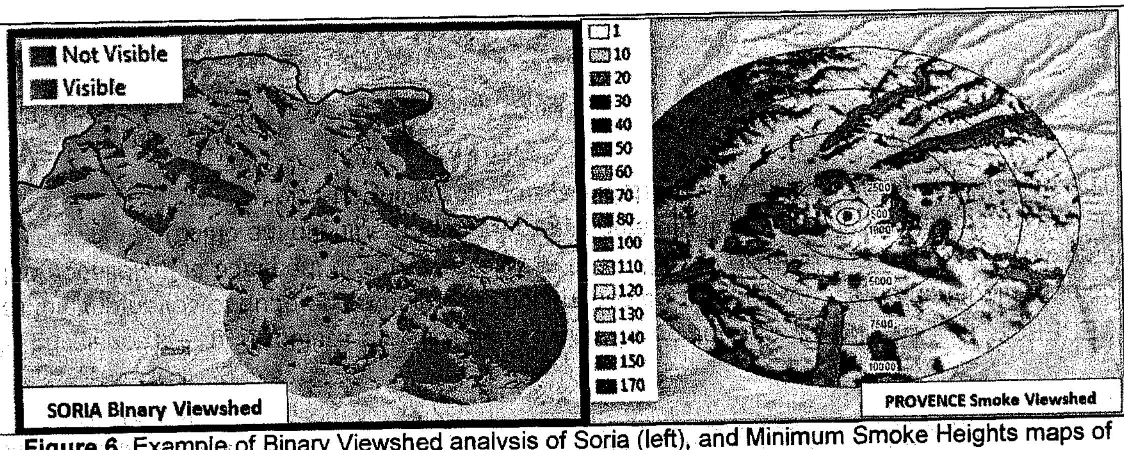


Figure 6. Example of Binary Viewshed analysis of Soria (left), and Minimum Smoke Heights maps of Provence (right).

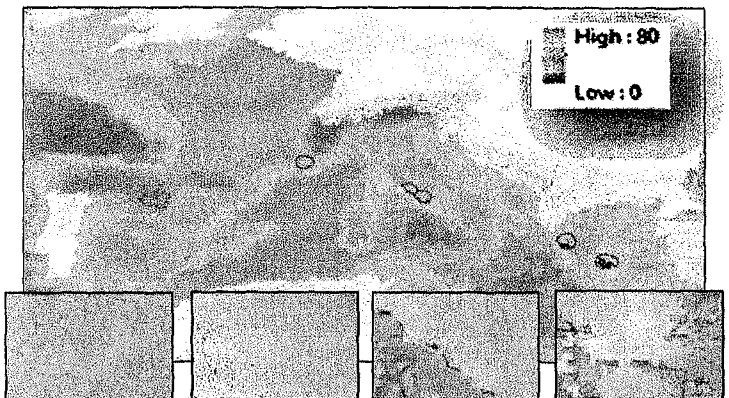


Figure 7. Example of a FSI map (06 AM). In detail a FSI stretching showing the significant differences, between the countries covered by the project, in terms of this index (higher FSI values means lower Risk)..

- **No predictable aspects that could affect a contrast analysis and further feature extraction process**: Overcast days when illumination was due to diffused light and not strongly directional, the contrast between the plumes and their background did not show the extreme variation with viewing direction that was apparent on clear days; rather, the contrast fluctuates randomly as overcast areas of varying density passes in front of the sun. The plume-to-background contrast of a white plume on an overcast day can be extremely complex and can vary in no predictable manner as overcast conditions vary from day to day and minute to minute (Conner and Hodkinson, 1972). (Fig.8)

Figure 8. *Left:* Terrain contrast decrease (in yellow) and visibility decrease (in red) due to illumination and atmospheric changes, *Right*: Contrast changes due to overcast changes.

- **Feature Extraction algorithm analysis**: Nevertheless smoke detection and feature extraction processing is a topic developed in many studies, focusing on different approaches[1], the analysis of the algorithms implemented by each monitoring system was not accomplished by the consortium.

[1] (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)

The Fog Stability Index (FSI), that provides the frequency of potential fog conditions can be evaluated when the meteorological conditions are known. The FSI (Holstslag 2010, Wantuch 2001) is an empirical method, developed by the US Air Force, which is calculated according to the following formula:

$$FSI^2 = \underbrace{2 * (TS - T850)}_{\text{stability}} + \underbrace{2 * (TS - DP)}_{\text{humidity}} + \underbrace{W850}_{\text{wind speed}}$$

Fog formation is favored for high humidity (TS-DP small), the atmosphere is stable (weak mixing, TS-T850 is small) and low wind speed (no mixing, W850 is small) (Holtslag 2010, Freeman 1998).

A historical analysis of FSI index was carried out (from January 2009 to February 2014), at 06:00 am, 12:00 pm and 06:00 pm[3].

The results show low fog stability in Greece test areas, while the worst situation was evidenced in Soria (Spain). Nevertheless, an analysis aimed at characterizing the FSI for each ROI could be more or less successful depending on the availability of higher spatial resolution weather data (Fig.9 - Up).

During winter rather similar values between ROIs. at 06:00 AM. & at 06:00 PM, while during winter, at 06:00 AM, Spain ROI evidence greater FSI risk than the other ones (Fig. 9 - Down).

This historical analysis, put into evidence how representative each region is, respect to each country. In this case, FSI values extracted for France and Spain regions of interest, are less representative respect to the values analyzed for the entire country.

[2] where: TS = Temperature near Surface, T850 = Temperature at 850 hpa, DP = Dew Point near Surface, that is calculated from Relative Humidity and Temperature near Surface (TS), and W850 = Wind at 850 hpa.
This index indicates that values lower than 31 have high probability of fog formation, between 31 and 55 implies moderate risk of fog, and values greater than 55 suggests low fog risk.

[3] Source Meteorological data: European Centre for Medium-Range Weather Forecasts (ECMWF)

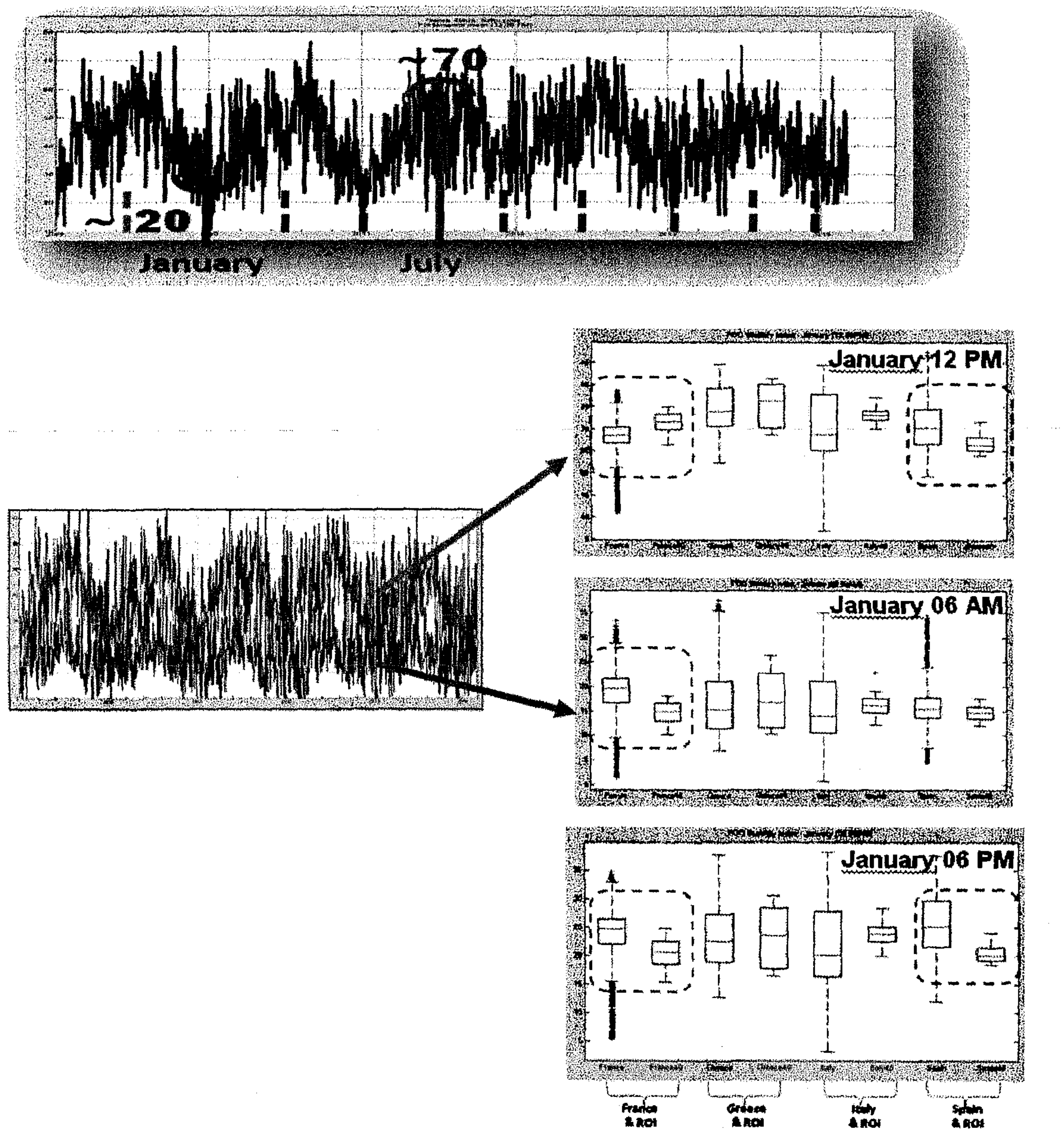


Figure 9. Seasonality of FSI index during the 5 years of analysis (red: July, black: January)
Down: Maximum Constant Difference in FSI index from 06:00 to 12:00 products

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, as shown hereinafter, the potential influences of the territory on each fire monitoring system (Fig. 10).

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	V	V		V
false alarm	X	X	V		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 10. Classes extracted from parameters

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.

The consortium agreed on defining a minimum number of variables that could vary according to the detection type systems (heat or smoke) and should be considered for comparing different systems:

- 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 to be considered to assess the efficiency and effectiveness of forest fires surveillance systems 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 variables:

- 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.

From the analysis of the operational 'environment' of the cameras located in France, Greece, Italy, and Spain and the 2014 test campaign we were able to conclude, for instance, that:
- from the point of view of the minimum smoke height, that is, the minimum high that the column of smoke should reach to be detectable by the camera (visible camera case) we can see that

the (Fig. 11) Soria ROI shows better conditions (for an optical system) in terms of minimum altitude of the smoke for detection. While worst situations can be seen in Arta and Cavo ROIs, where for about 65%-70% of the observed area an event can be detected when produces a smoke column comprised between 250 and 500 mts. This, in a certain sense confirms the correctness of the decision made in Castilla y Leon to adopt a monitoring system based on thermal camera since in this case, cameras opportunely located could observe the surface (as requested by thermal systems) of a large part of the area of interest.

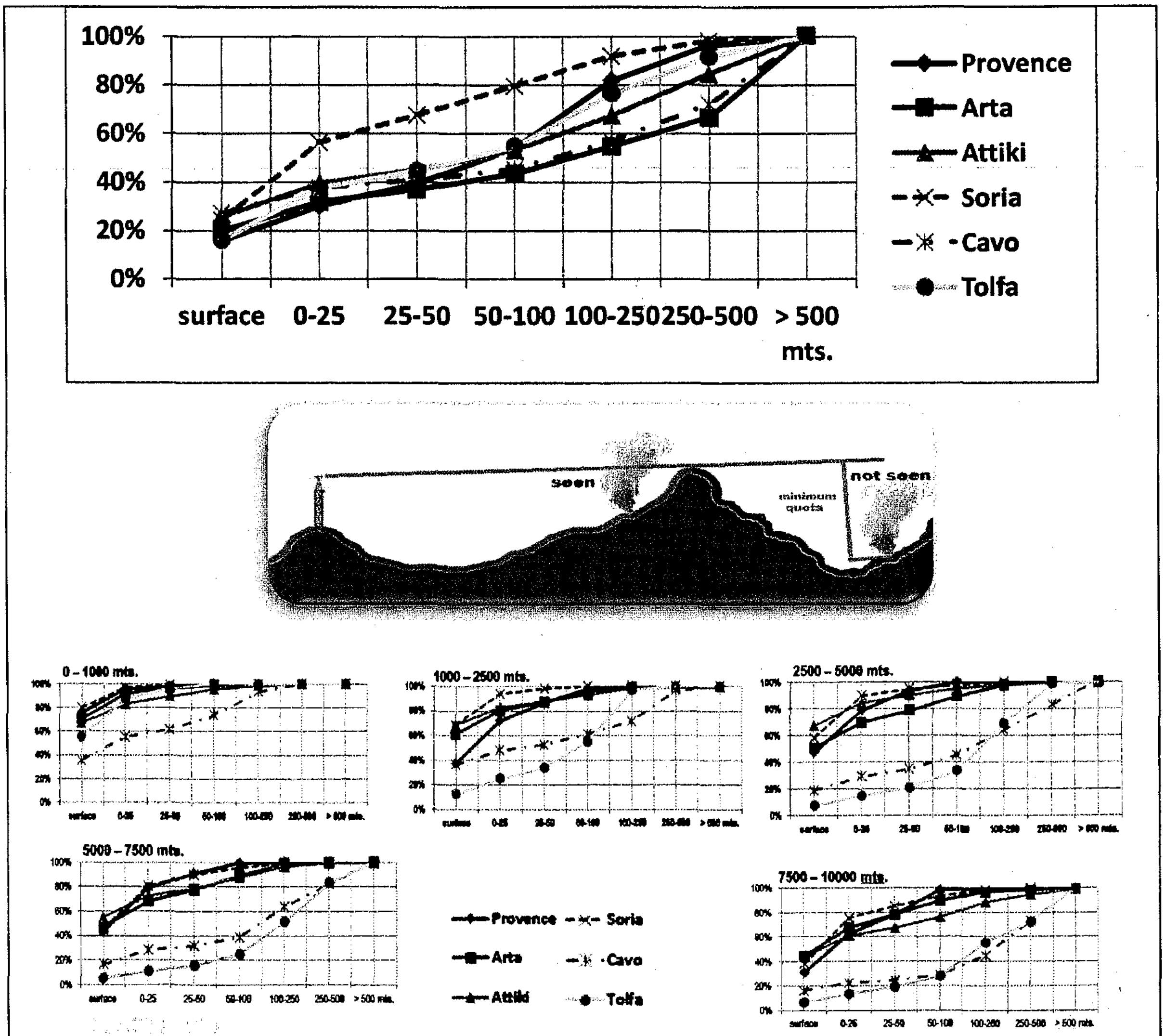


Figure 11. Examples of assessment of the FSI (left) and the visibility (right) for ODS3F countries for a range of 40kms. Y axis = percentage of covered area, X axis = minimum height of potential event (up).

Analysis of regions of interest for a total area of 10 kms. divided in 5 buffer rings, which shows disadvantages for Cavo and Tolfa regions (down).

- the monitoring systems located in Greece and Italy don't exploit properly the advantage of seeing areas (above MSH limits) that are not visible by thermal ones (hot spot on surface), in fact, most of the detected events were localized in surface visibility areas. The events not located inside this area could reveal system geo-location problems (an example is shown): Areas with not surface visibility are definitely hidden for the monitoring system that operates with only one camera.
- **Event geo-location:** France system, seems to take advantage of triangulation for precise distance measurements. But at the same time, the imprecise azimuth definition creates a wide zone of ambiguity, in accordance with the range (see Fig. 12). However, as ONF has demonstrated the location can be improved by transferring data in the GIS (see Fig. 12bis) and this solution is interesting because it can work even in the directions where there is not another camera for triangulation.
- **Minimum Smoke Heights:** this product evidences a clear "key" for weighting the potentiality of each visible system, in terms of coverage area,
- **Coverage:** Most of the events are located inside the forest class, according to the available Corine Land Cover.
- **Omission Errors:** In order to improve the performance of the tests, it should be necessary to include "omission errors" (true events not detected).
- **False alarms reason:** The main reasons of false alarms are fog and reflections.

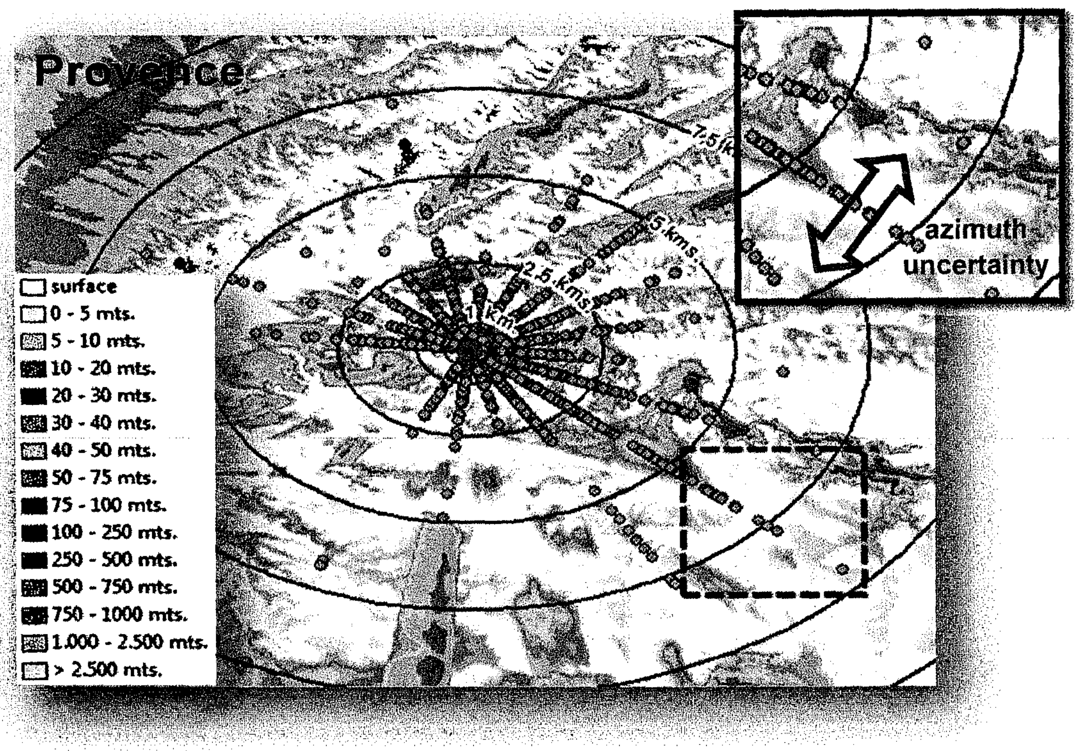


Figure 12. Distribution of the alarms detected during the test campaign (July - September 2014). The azimuth uncertainty of the detection system is clear. All the detected events are aligned along the line of view of the camera.

Let us analyze more in detail the results of the 2014 summer test.
As said above, the performances of the detection systems have been evaluated during the 2014 summer season (15 June - 30 September) by: reporting for each event a common set of information, recording the false alarm according to defined categories, reporting system failures, providing statistical figures at the end of the season.

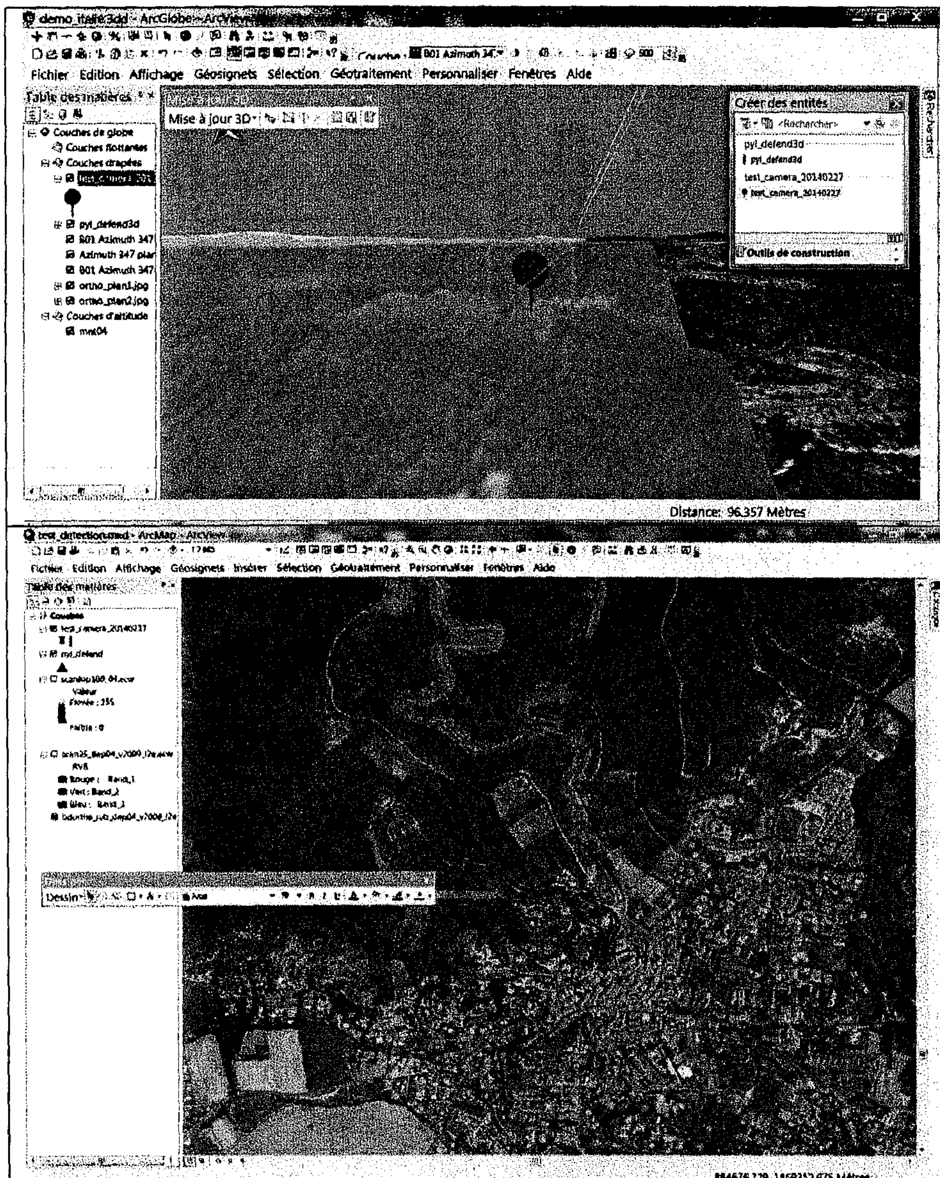


Figure 12bis. The image from the camera is draped over a DTM using ESRI ArcGlobe and the fire is pointed manually as precisely as possible (upper). The coordinates obtained in ArcGlobe are transferred in ESRI Arcmap to have a better visualization (lower)..

The results of the test campaign are summarized hereinafter. Table 4 shows the number of events recorded during the three months of test (July - September 2014).

Table 4 *- Results of the test campaign carried out in 2014 in the framework of the ODS3F project.*

System	N. of registered events	True alarms	False alarms
PdROM	1097	94	1003
ONF	5735	0	5735
UOWM	69	17	52
CESEFOR	628	8	620

The problem of the high rate of false alarms that characterize the fire detection systems based on cameras can be noted looking at the results of the test campaign.
However, having a knowledge of the characteristics of area observed by the cameras with can try to understand the main causes of the false alarms, apart from them due to system failure, and reducing the incidence of false alarms acting appropriately on the image processing software.
For instance, from the 2014 test campaign we learn that the main causes of false alarms of the systems managed by the Province of Rome are:
Fog = 31%
Clouds = 22%
illumination (reflection) = 16%
Coverage = 26%
Sunrise/sunset = 5%.

To underline the importance of the operational environment of the cameras these percentages differ from a system to another (Table 5) but for the same system (hardware and software) can be different (Table 5) according with the characteristics of the monitored area.

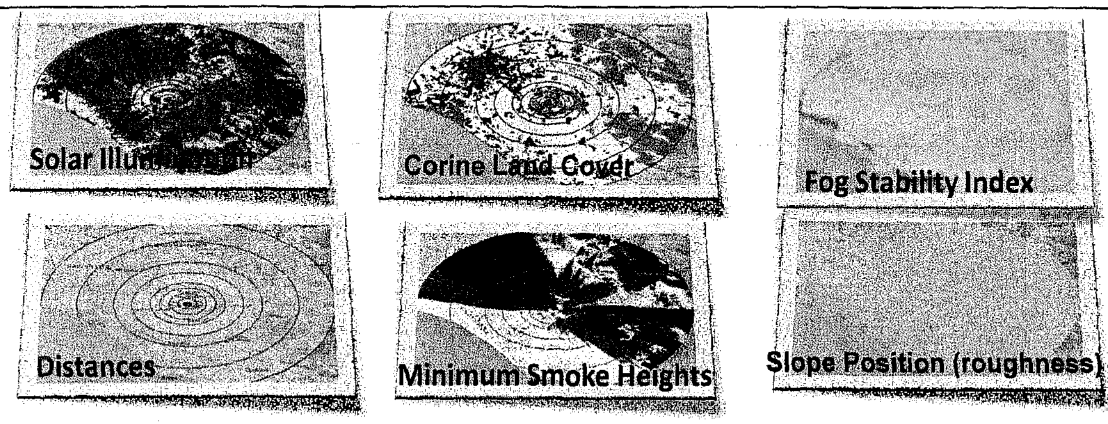
Table 5 *- Results of the 2014 test campaign. False alarms divided according to its cause.*

System	N. False alarms	Fog	Clouds	Illumination (reflection)	Coverage	Other
PdROM	*616 (M. Tolfa)*	25%	12%	19%	38%	6%
	389 (M. Cavo)	40%	37%	11%	6%	6%
ONF	*5735*	46%	2%	48%	2%	2%
UOWM	*(Arta) 24*	21%	8%	17%	37%	17%
	(Attiki) 28	4%	16%	16%	45%	19% (dust)
CESEFOR (thermal)		**Technical**[4]		**Natural**[4]	**Other heat sources**	
	620	34%		56%	10%	

[4] *Technical causes*: generated by the system as consequence of a system technical failure.
Natural causes: originated by natural events like sunrise and sunset, reflections, clouds, etc.
Other heat sources: any other cause of hot spot not related to wildfire such as barbecue, factories, car/truck fire, etc.

When the area monitored by the system is characterized by taking into account the parameters considered above we can define particular territorial classes for which the probability of a false alarm is higher and modify, the processing system accordingly. This procedure is explained below.

Fig. 13 shows the 6 parameters taken into account (Fig. 13 upper) for characterizing the area covered by a observation camera. By using this 6 characteristics we can divide the territory in classes of homogenous territory (HTC, homogenous territory classes), that is areas having the same values of the considered 6 parameters (Fig. 13 lower).



Distance ClassBUF	< 1000 100000	1000 - 2500 200000	2500 - 5000 300000	5000-7500 400000	7500-10000 500000	10000-15000 600000	15000-20000 700000	20000-30000 800000	30000-40000 900000
Minimum Smoke Height ClassMSH	Surface 10000	0 – 25 20000	25 - 50 30000	50 – 100 40000	100-250 50000	250-500 60000	>500 70000		
Fog Stability Index ClassFSI	Very Low 1000	Low 2000	Medium 3000	High 4000	Very High 5000				
Illumination ClassILU	Low 100	Medium 200	High 300	Very High 400					
Corine Land Cover ClassCLC	Forest 10	Agricultural 20	Other 30						
Slope Position Classification ClassSPI	Valley 1	no valley 2							

120 840 7560

Figure 13. Distribution of the territory among the different classes. If we consider the parameters: slope, land cover, illumination, Fog Stability Index, separated in 2, 3, 4 and 5 classes, respectively, we can distinguish the territory, in 120 homogeneous classes. If we consider all the parameters we can divide, in general, the territory in 7560 classes.

Each one of the identified classes is defined through a code, for instance, the classes 231121 represents an area:

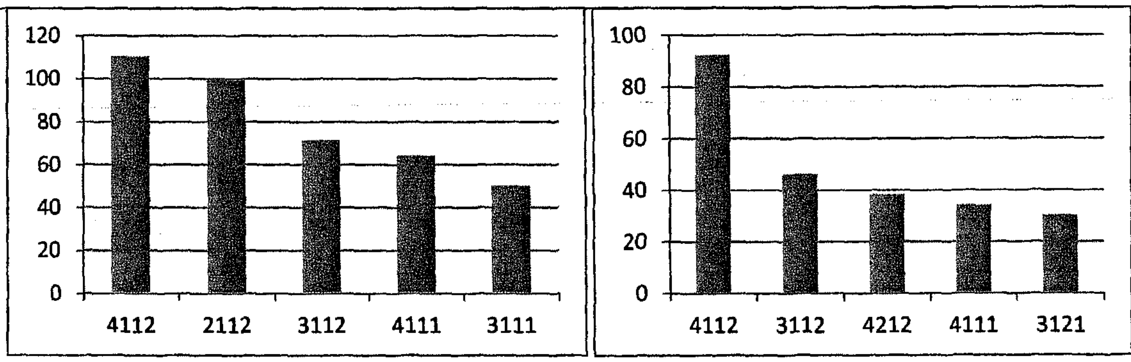
distance, 2: located at a distance comprised between 1000 - 2500 m from the camera.

smoke height, 3: a fire in such area to be observable should reach an altitude comprised between 25 - 50 m.

FSI =1: Very Low Fog Stability (indicates a high probability of fog formation)

Illumination, 1: low illumination conditions.
land cover, 2: agricultural area.
Slope position, 1: valley.

Now, having divided the territory in homogeneous classes we can analyze if there is a relationship from some of these classes and the false alarms, that is, if false alarms originate with higher probability from some territorial classes. This analysis is shown in Fig. 14. In fact, this figure shows the distribution of the false alarms in the case of the camera located on Mount Tolfa and Mount Cavo (Province of Rome).



HTCs obtained by considering only 4 of the 6 parameters (distance and smoke height have been excluded).

Figure 14. Distribution of the false alarms among the different HTC (classes of homogeneous territory) in the case of Mount Tolfa (left) and Mount Cavo (right).

As it can be observed most of the false alarms originate in only 5 of the territorial classes of the 120 possible.
In particular, such classes are characterized by presenting:
high fog stability (lower risk) (first code number = 3 or 4),
low illumination condition (2nd code number = 1),
forested area (3rd code number = 1).
No-valley (4th code number = 2).
This observation can be better visualized by looking at Fig. 15. In fact, in such figure it is shown the distribution of the false alarms in the area covered by the camera located on Mount Cavo. It can be seen from the figure on bottom-left as most of the false alarms originate in the areas of low illumination and/or high probability of fog. On the right of figure 15 is shown the change of the illumination condition of a certain area during the day that represents one of the main problem with visible cameras. In the identification of the HTC, in the case of the Mount Tolfa and Mount Cavo systems the *smoke height* and *distance* conditions have not been used due to the inability of the system to correctly locate the fire event since the two camera are monitoring different areas (no triangulation is possible).

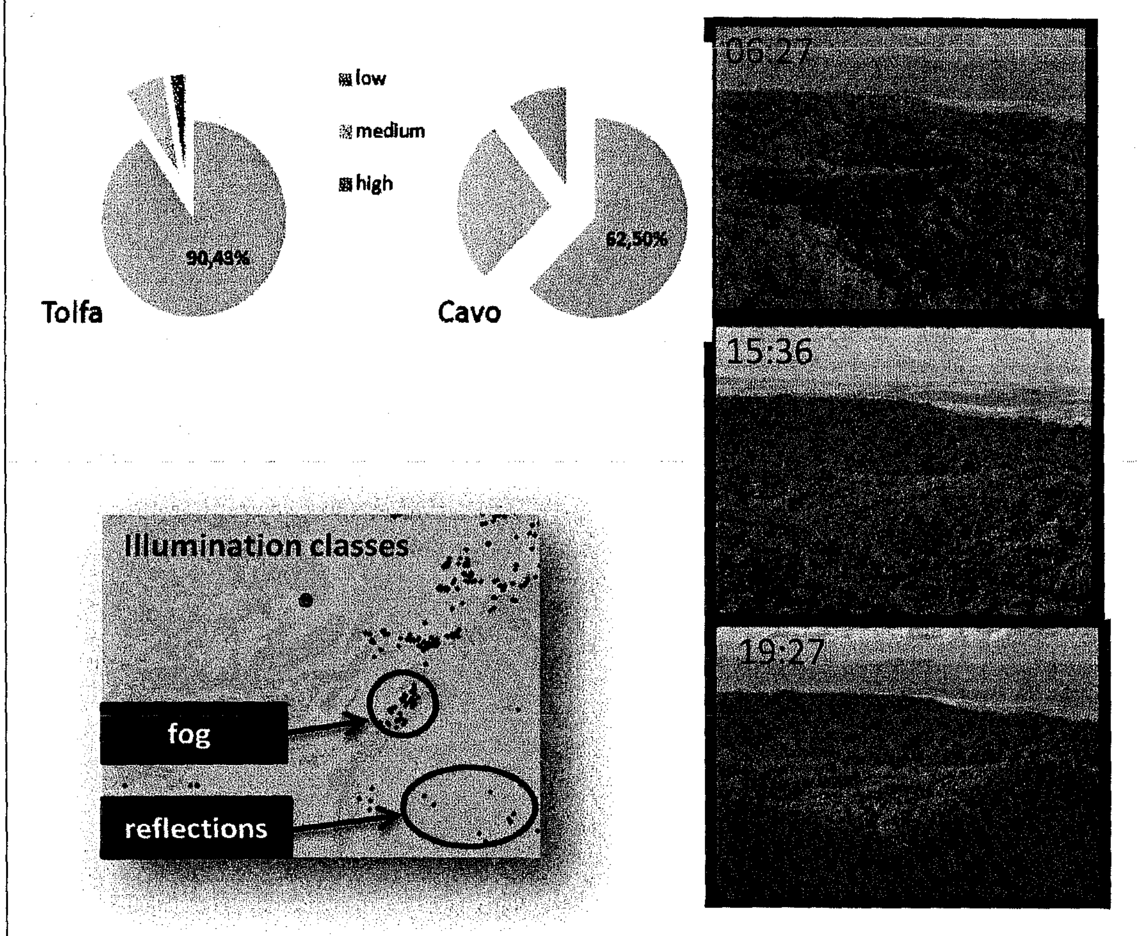
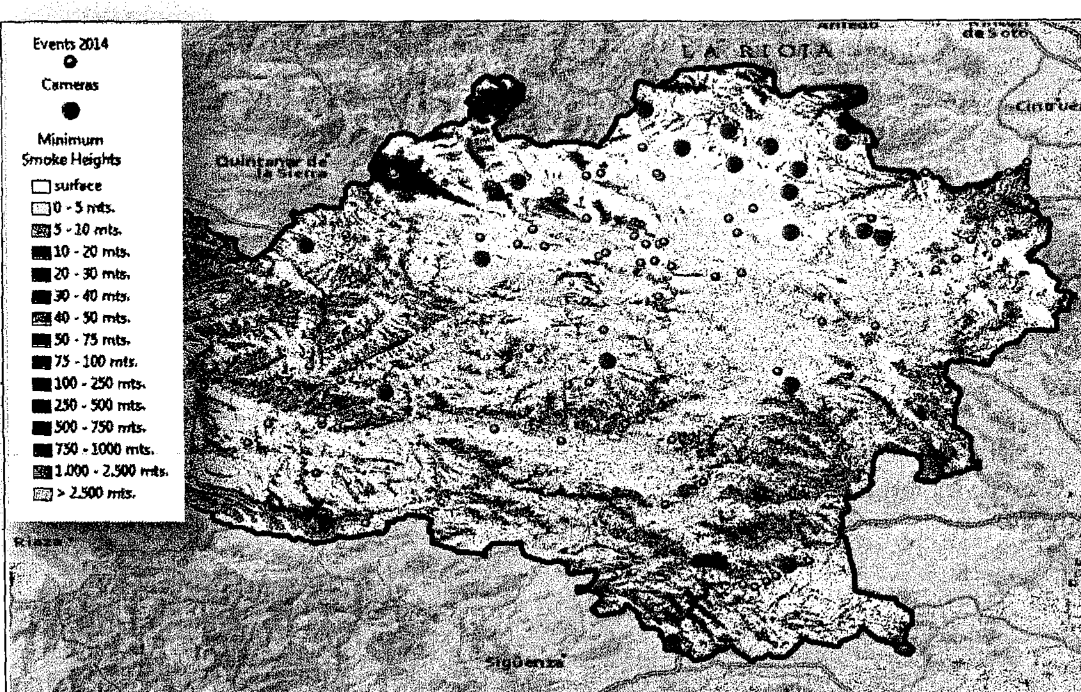


Figure 15. The illumination layer is a map of relative measures of solar illumination, taken from hill-shades for 8 different hours throughout the day. Original values that run from 0 to 255 were divided in 3 classes (low – medium – high). From the bottom-left figure (for Mount Cavo) it can be seen as many of the false alarms occur in areas of low illumination or characterized by high fog probability.

Implementing these territorial information in the processing software would result in a significant reduction of the false alarms rate.

In the case of the thermal monitoring system installed in the Soria area we have also an estimate of the omission error (the number of undetected fires). This is interesting to show because allows to emphasize a limit of the thermal cameras. In fact, during the 2014 campaign 34 fires occurred in the Soria province but only 8 of them occurred in areas observable by cameras, that means less than the 25% (Fig. 16). This represents the main limit of thermal systems: they can detect events occurring on a surface directly observable by cameras.



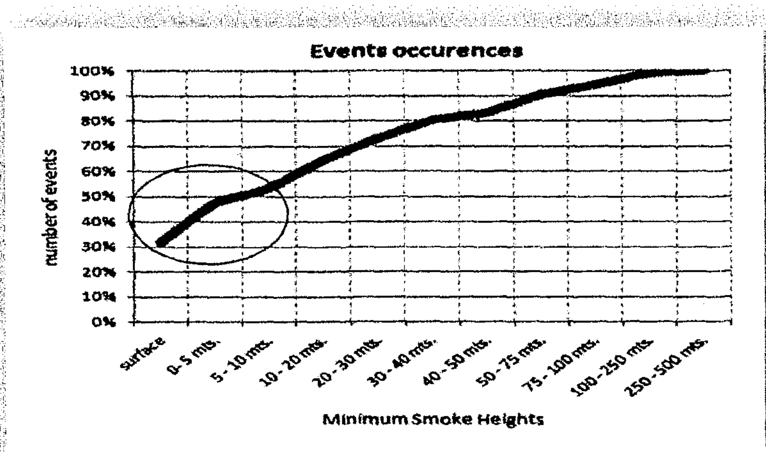


Figure 16. The minimum smoke heights map, shows the minimum height that an event need to reach in order to be seen by a monitoring system. In the case of the thermal monitoring system installed in Soria, the detection is limited to those events occurring in visible surfaces (where the flame is present). In 2014, around 50% of the events occurred in areas where the minimum smoke heights is less than 10 m. While only 30% occurred in surface areas, potentially seen by the system.

Further elements we want to bring out as lessons learned, suggested by ONF partner, include:

<u>* Evaluation of detection systems:</u>
We must be careful to follow two different settings:
-the false alarm rate relative to the total number of detections;
-the rate of omission (undetected fires) relative to the total number of real fires.
These two parameters must be jointly minimized to optimize the system. in fact, they are linked and the improvement of one can be to the detriment of the other (for example by excluding an area in which we observe many false alarms you can miss real fires occurring near the area) so the balance of these two parameters is important.

<u>* Concept of false alarm:</u>
We must not confuse the false alarm "operational" (agricultural prescribed burning is not a forest fire so do not require intervention, but it still produces a smoke plume) and false alarms "technical" (a cloud or a lighting change).
The latter are false alarms which we must to minimize by improving the system. The 'operational' false alarms do not impact the system performances and we can try to minimize it by an organization adapted but not by modifying the system.

<u>* good use of camera systems:</u>
The analyzes conducted within the framework of the project have shown that there is no "magic" detection system that would not have false alarms and detect 100% of fires in its monitoring area. Beside the technical improvement it is clear that:
- a proper management of spatial or temporal exclusions may avoid "flooding" of the operator and allow focus on places, dates and hours of maximum risk;
- even without detection a camera system remains a very useful tool (real-time visualization, localization) for centralized command which otherwise remains blind for remote crisis management

<u>* elements for the choice of a system:</u>
At the beginning of the project we hoped to produce a guide that works as an automatic tool giving precise rules like: "I have a territory with the conditions X, Y and Z, I have to use the system A with the settings b and c". In the course of implementation it became clear that the subject is too complex to make such rules. However, the studies conducted have helped identify important parameters to follow to measure the effectiveness of a system, and the conditions (topography, weather, vegetation, infrastructure and human activities, schedules) which will have a significant effect on this efficiency.
Further, the results allow to give major trends such as the fact that the thermal camera system give poor results in a very rugged terrain or covered with large trees, or that visual detection systems work better in a homogeneous landscape with stable weather conditions

<u>* Constraints of implementation:</u>
When thinking about setting up a camera system, in addition to the choice of system, we must be take into account two things:
- implementation possibilities: land ownership, technical or financial constraints of building a tower or administrative constraints of using an existing tower, facilities for electric alimentation and communication, can lead to different choices from implementation technical optimum for monitoring.
- transmission network: camera systems data are very heavy and must be transmitted reliably and in real time to the central command post. The performance of the network is therefore essential and can be very costly.

<u>Cost analysis:</u>
If creating a system of cameras is expensive, we must also pay attention to operating and maintenance costs to maintain optimum use of the system, which can also be very high. This is even more true that it is often possible to find funding for investment (grants, sponsorship, etc.) but then it is the system's management body which must ensure the operating costs on its equity. there are several systems that no longer work because of this problem.

4. Monitoring and dissemination of activities

4.1 Monitoring

The progress of the project has been monitored through periodic meetings (about every 6 months) which took place according the following table (Table 6):

Table 6 *- List of meetings organized during the project activity.*

Events	Where & when	Reasons for travel
1st Meeting with partners	Rome, 6th February 2013	Kick-off meeting among partners
2° Progress Meeting	Soria, 19th - 20th June 2013	Progress meeting
3° Progress Meeting	Thessaloniki, 30th - 31st January 2014	Progress meeting
4° Progress Meeting	Rome, 15th - 16th May 2014	Progress meeting/Planning comparison procedure
Final Progress	Aix en Provence, 15-16	Experiences comparison, common data

Meeting/ Workshop	October 2014	utilization strategy definition, best practices identification

The progress meetings were devoted to illustrate he effective implementation of the foreseen actions for the period. Usually the progress meetings were also devoted to discuss within the consortium the plans of the following period of activities.
Further, these meetings were composed of 2 parts:
- a part aiming at illustrating the project activity and results to stakeholders and interested users or representatives of institution possibly interested in the topics covered by the project.
- a part aiming at sharing among the consortium the activity carried out by each one of the partners; at describing the status of the project at defining the work plan for the following period.

Further, several bilateral meetings between partners have been organized during the project for discussing specific topics. For instance, DIAEE met four times PdRom for discussing aspects concerning:
- the use of the CICLOPE system in order to satisfy the needs of the ODS3F project,
- the organization of the progress meeting hold in Rome,
- planning the summer 2014 test of the system.

DIAEE met also UOWM for planning the project activities taking into account the actual status of surveillance systems in Greece.
However, periodic (8-months) reports have been produced by partners and provided to project coordinator which has used these documents to prepare the 2 progress reports foreseen, in accordance with the grant agreement, given the 24 months duration of the project.
The two progress reports, with one page financial summary, have been submitted as described in the following table (Table 7):

***Table 7** - List of the periodic reports submitted during the project activity.*

Report	Date	Main content
I Progress Report	15th of September 2013	Analysis of the monitoring systems available in France, Greece, Italy and Spain.
II Progress Report	30th of May 2014	Development of an evaluation scheme for the monitoring systems performances comparison.

The complete periodic reports submitted by partners are available as appendices to this document.
The utilization of the financial resources, synthetically reported in the periodic 1-page financial summary has been proved through invoices and time sheets.

4.2 Dissemination

The dissemination of the project activities and achievement has been carried during the entire project duration and has not yet completed because final results will be disseminated by participating to thematic workshops and distributing a synthetic report, a document containing a sort of guide line concerning the territorial and environmental elements to be taken into account to make a decision on the implementation of a forest fire monitoring system.
In particular, the dissemination as been carried out through:
- a website;
- the preparation of a project brochure;
- the compilation of newsletter distributed via internet to a list containing hundreds of potential users;
- poster and oral presentation during international workshop;
- organizing workshop, joined with the project progress meeting, to which potential users have been invited.

The project website has been created at the following address: www.ods3f.eu. Fig. 17 gives a snapshot of the ODS3F Website homepage whereas the Table 8 describes the website map.

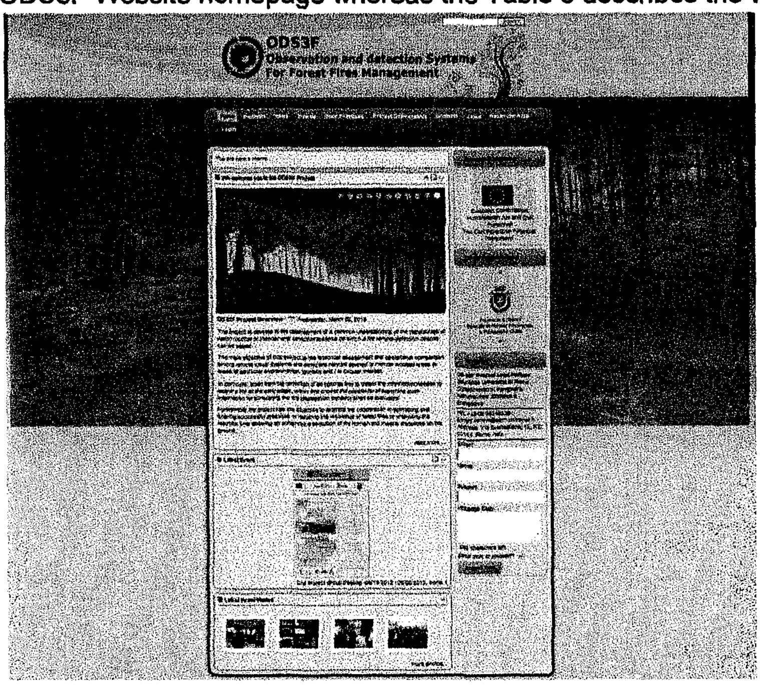


Figure 17. Snapshot of the ODS3F website Homepage.

Table 8. *ODS3F web pages description*

ODS3F WEB SITE MAIN PAGES	CONTENT
HOME PAGE	General project description
News	News about the ODS3F project
Events	Description of the ODS3F past and coming events
Good Practices	Description of the observation systems analyzed and the identified good practices
Project Deliverables	Area for upload/download of project deliverable documents
Contacts	ODS3F partners contact information
Reserved area	The area is accessible to project partners only

The dissemination activity carried out during the project includes:
- the participation, with a speech, to the *Euro Mediterranean conference on Wildfire* held in Barcelona between the 18th and 20th November 2013.
- the participation to the IV Mediterranean Forest week, held in Barcelona in March 2015. Plenary session, hundreds of public representatives of Mediterranean (European and African) governments. (http://med.forestweek.org/)
- the participation to the National Forestry Congress. Vitoria (Spain), 10 - June 2013, reported by 5 national media: Public Spanish television report and Regional televisions and press media
- the preparation of a flyer (Annex II);
- the preparation and distribution of two newsletters (Annex II);
- the submission of an paper to the *VII International Conference on Forest Fire Research* to be held in Coimbra in November 2014. The paper title *The ODS3F project: evaluating and comparing the performances of the ground optical and thermal fire monitoring systems.* has been published on the book Advances in Forest Fire Research published by the University of Coimbra (http://dx.doi.org/10.14195/978-989-26-0884-6, pp. 1553 1560, 2014).

Dissemination of project activities and results have been also achieved with closed meetings with the Civil Protection Authorities of the Region of West Macedonia in order to explain the project objectives and capitalize the results of the project. ODS3F project results are now informing the strategic planning of the Civil Protection in the Region of West Macedonia and the investment programs in equipment that are launching for the period 2014 -2020 regarding fire protection.

Articles about the project have been made available on ONF website and local technical publication (INFO-DFCI) and presentation of results to all partners in French Mediterranean area in the occasion of pre-season meetings.

5. Final conclusions and recommendations

This section describes the main conclusions of the project and recommendations for future research.

5.1 Main conclusions

Camera based surveillance systems could still be an effective and efficient way to reduce the potential damages of a wild fire by speeding up the response actions. In fact, satellite based observation systems still lack the needed revisit frequency or the spatial resolution for precisely geo-locate the fire. Of course, satellite systems have the advantage of providing a synoptic view of the fires distribution useful in planning and prioritizing the intervention. Especially in summer when, in the Mediterranean countries many fires could occur simultaneously.
However, present available camera based systems to be really useful should be improved in two main aspects:
- in the case of system operating in the visible region of the spectrum the number of false alarms, that could be higher than 100 per day per camera, should be reduced otherwise the operator loses confidence in the system and tends to ignore the alarms;
- in the case of system operating in the visible region of the spectrum for a precise localization of the fire it is requested that at least two cameras see the same event, otherwise the fire detected through its smoke will be located at the intersection between the view direction and the topographic model;
- in the case of thermal camera the number of omissions could be high, depending on the topographic characteristics of the area of interest. Therefore, this kind of systems requires a detailed analysis of the local orography and the accurate selection of the installation point in order to maximize the surface observed.
- thermal systems are not significantly affected by false alarms.
- an accurate analysis of the environmental operational conditions of the camera, that is developing a software capable to take into account: land cover type, DEM, illumination conditions, fog probability, etc. can significantly help in reducing the false alarms of the systems operating in the visible part of the spectrum.

Finally, we can conclude that while the surveillance systems can be considered mature from the technological point of view with the possibility of having sensitive systems at affordable cost the software devoted at processing images and detecting fires presents some limits in terms of robustness and accuracy. These limits result in a generalized high false alarms rate which could overshadow the usefulness of this kind of systems.

5.2 Recommendations

Since there are many initiatives in Europe concerning the installation of fire devoted surveillance systems based on cameras (we know about a project in Serbia to be completed in the next few weeks) we think that the results of this project should be made available to stakeholders as much as possible. In fact, the results of the project, including the evaluation of the environmental conditions (territorial, meteorological, etc.) to be taken opportunely into account, could help in selecting the most appropriate system for the area of interest even if, as said in a previous paragraph, some time the needs for optimization collides with practical consideration (availability of tower, communication network, etc.).

5.3 Follow up activities and measures

DIAEE: The Department has started a collaboration with Italian Fire Brigades aiming at supporting the calibration and evaluation of the surveillance system recently built up by them in the Calabria and Apulia regions. Further, the Department has been very recently involved in supporting the European Union Delegation to the Republic of Serbia in the preparation of the technical specification for a Forest Fire monitoring and suppression system in Western Serbia. The final results of the projects have been presented at the *SafeChania 2015: The Knowledge Triangle in the Civil Protection Service (Education, Research, Innovation)* Conference in Crete, to be held on the 10 - 12 June 2015.

UOWM, There is continuous communication and several meetings held between the University of West Macedonia and the Civil Protection of the Region of West Macedonia between January 2015 and May 2015. The meetings concern the design and the installation of more appropriate systems detecting fires funded by the new ERDF programming period. Project results and expert technical support is provided to the Region and a new program is expected to launch in 2015.

CESEFOR, as described in a previous paragraph is going to explore the possibility of using camouflaged thermal cameras for tracking cars, trucks, people in the forest to enforce the law.

ONF, from the project results two main activities will follow:
Modifications of the system:
- improvement of the stability of the confirmation camera to get better images
- modification of the algorithm: for now the image was compared with the one from the previous round, for a time between 2 images of about 2 min 30 (lap time). the new method will compare two images taken at 10 second intervals at each position, which will lengthen the duration of the tour but should improve the efficiency of detection and reduce the number of false alarms.

New tests:

the same tests that in 2014 (using smoke units and recording of operational data during the summer) will be conducted in 2015, firstly to assess the relevance of the change of algorithm, secondly to try to have more statistical data to assess the parameter "detection rate" and finally to ensure that the decrease in attempts false alarms (technical improvements, exclusion of areas and / or periods) do not cause a risk of decrease in efficiency by missing detections of real fires

PDROM, has decided to further develop the system paying more attention at continuing to train the system through a more efficient intervention of the operators of the control room and trying to integrate it with the one developed by the Lazio region.

6. References

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