An innovative approach to Floods and Fire Risk Assessment and Management: the FLIRE Project

Chrysoula PAPATHANASIOU[1], Christos MAKROPOULOS[2] and Maria MIMIKOU[3]

(1) *Civil Engineer, PhD candidate, Research assistant, Department of Civil Engineering, National Technical University of Athens University of Athens, Greece, e-mail: papathanasiou@chi.civil.ntua.gr*

(2) Assistant Professor, Department of Civil Engineering, National Technical University of Athens University of Athens, Greece, e-mail: *cmakro@chi.civil.ntua.gr*

(3)Professor, Department of Civil Engineering, National Technical University of Athens University of Athens, Greece, e-mail: *mimikou@chi.civil.ntua.gr*

Abstract: Floods are classified among the most dangerous natural disasters that significantly affect human lives and the environment. Particularly for periurban areas, special attention needs to be paid to flash floods which have tremendous impacts on local societies. Forest fires are another frequent threat with devastating consequences, especially for the forested with flammable vegetation species Mediterranean areas. The risk management of both hazards is recognized as an issue of high importance, however their interaction is often ignored and an integrated approach of both menaces is missing. The FLIRE Project aims to assist robust "FLoods and fIre Risk assessment and managEment", by supporting an innovative, holistic approach towards risk management of both hazards in near real-time. The main objective of the Project is the development of a DSS platform that will host a short-term weather forecasting component, flood and fire modelling components and Flood and Fire Early Warning Systems. These components will communicate at near real-time, producing warnings for stakeholders for a possible upcoming flood or fire event. The platform will also incorporate a planning tool that will support long-term flood risk management. The application area of this innovative approach is the Rafina stream river basin (appr. 130 km2) in Eastern Attica (Greece), a typical periurban Mediterranean area that is prone to both hazards. The proposed approach is expected to increase accuracy and efficiency in risk management decreasing in parallel its computational and financial cost, and promote the applicability of its results to other areas with similar hydrometeorological and topographic characteristics.

Key words: The FLIRE Project, flash floods, forest fires, risk assessment, DSS platform, early warning system, Eastern Attica

1. INTRODUCTION

Floods are considered among the most devastating natural disasters at a global scale and their occurrence has tremendous impacts on society, economy and the environment. More specifically, floods can cause loss of human lives, health and quality of life degradation, damage to private and public properties, disruption of economic activities and destruction of ecosystems. At European level, floods seem to be the most frequently reported natural disaster and they affect approximately 26% of people who have been affected by any natural disaster (Prevention Web, 2013). Forest fires are another equally devastating natural disaster, with similar socioeconomic and environmental impacts. Particularly in Europe, forest fires concern mainly the Mediterranean areas, which are forested with flammable vegetation species. Every year approximately 65000 fire events occur in Europe, burning about half a million hectares of forested areas and wildland and 85% of these events occur in the European Mediterranean region (San-Miguel-Ayanz et al., 2012). It should be noted that both floods and forest fires have also significant aesthetic impacts and often pose considerable threats to the cultural heritage of the affected areas.

Apart from the impact that each disaster individually has on both the society and the environment, it should not be ignored that their combined action has even more severe consequences, and such a combined action occurs often. Specifically, the occurrence of a flood event, and more particularly of a flash flood event, is more probable and the disaster caused by flooding is more catastrophic when it occurs in a formerly forested area that has been burnt during a wildfire. And of course the shorter the time period between the occurrence of a fire and the occurrence of a flood, the more tremendous and magnified is their combined impact.

The existing weather conditions in an area affect its vulnerability to both floods and fires. Yet, a major factor that needs to be accounted for and upon which the occurrence and the extent of both natural disasters depend, is human intervention. Such intervention is pronounced in periurban areas, which are areas around core urban zones, they usually extend over different and often conflicting land uses and they undergo constant urbanization. Land uses in periurban areas may vary between forests, industrial areas, arable soils, rural areas, urbanized parts etc and thus on the one hand these areas are vulnerable to wildfires and on the other hand a potential flooding will have significant socioeconomic and environmental impact.

Both natural hazards are particularly highlighted in the national priorities agenda of all Mediterranean Member States as well as in the priorities agenda of the European Commission and their risk management is considered as an issue of high importance. To this end, relevant research is favored and applicable outputs for efficient management of both risks are sought for. So far research and outputs mainly focus on either aspects of this twofold problem. An innovative Project that focuses on both problems and also on their interaction, particularly in a periurban environment, is the FLIRE Project; a demonstration project implemented within the framework of LIFE+ Environmental Policy and Governance. The project, which is presented in more detail in the following, is co-financed by European Commission General Directorate for the Environment, LIFE financial instrument with 50% and is implemented in a periurban area in Eastern Attica region, Greece.

2. AN OVERVIEW OF THE FLIRE PROJECT

2.1 AIM AND OBJECTIVES OF THE PROJECT

FLIRE (FLoods and fIre Risk assessment and managEment) is a demonstration Project that aims to develop an integrated Decision Support System (DSS) that will support effective flash floods and forest fires risk assessment and near real-time risk management in a periurban area in Eastern Attica (Greece). This DSS will host inter alia an Early Flood Warning System (EFWS) and an Early Fire Warning System (EFiWS), which will provide warnings on imminent risk; either flash flood risk or forest fire risk. State of the art tools, technologies and methods will be adopted for the design of the DSS, while prevention, adaptation and interaction issues will be carefully taken into consideration. The final tool will provide online filtered information to the general public through the website of the Project, while key stakeholders and relevant authorities (both local and national) will receive more detailed information that will allow them to proceed in time with the necessary procedures in case of emergency.

The main objectives of the FLIRE Project that will be reached with the application of its final products, i.e. warnings on floods and fires, are listed below:

- minimization of the impact of floods and forest fires on human lives, ecosystems and properties
- assistance in flood prevention
- amelioration of flash flood mitigation
- improvement of forest fire prevention
- contribution to forest fire protection
- awareness raising of the general public and the relevant authorities on both hazards and their combined impact on the society and the environment for Eastern Attica

Therefore, FLIRE has the target to correctly identify flood and fire events before their expansion and has the ambition to engage stakeholders and public authorities in the effective use of its outputs and the application of its tools, improving thus the current practice adopted for floods and fires prevention, mitigation and management.

2.2 THE STUDY AREA OF THE PROJECT

The implementation area of the FLIRE Project is a periurban area in the Eastern Attica region in Greece. More specifically, the results of the project will be applied to the Rafina river basin, a typical Mediterranean area that covers approximately 130 km^2 and geographically extends east of Ymittos Mountain to the coastline of Evoikos Gulf. The main watercourse of the area is the stream of Rafina, which discharges to Evoikos Gulf, and its main tributaries are the streams of Lykorema, Ag. Paraskevi and New Voutza that originate from the south hillsides of Penteliko Mountain.

In the last 30 years the area has been under rapid urbanization and the urban expansion remains in many cases unorganized. The population of the area at its main settlements has been significantly increased in these years. Typical examples are the population increase in Pikermi community from 1971 to 2007, which was estimated to reach 420%, while for Drafi and Rafina communities the population was increased by approximately 80 and 40% respectively in the period between 1971 and 2001 (Papathanasiou et al., 2009). Parallel to that and especially during the last decade, great scale public works have been constructed in the area. The new national airport of Athens in Spata, the developing Rafina port, which is the second largest port in Attica, and major roads such as the Attiki Odos motorway that connects the airport and the greater study area with the rest of the prefecture and the business center of Athens are some of the major works constructed in the area.

Further to the urbanization that has contributed to a considerable land use change in the area, significant forest fire events have destroyed part of its forested land. Especially during the last 15 years most of the northern part of the area, which was mainly covered by forests, has been affected by large scale wildfires. As a result, not only have ecosystem services in the area been significantly degraded, but also the upper soil layers of the affected land have dramatically changed to practically impervious land cover, due to the development of a hydrophobic coating (DeBano, 2000) and the affected area has become particularly vulnerable to erosion (Marinos et al., 1995).

Even though the water flow in the tributaries of Rafina stream usually remains low during the summer, the unprecedented urban development of the study area, the impact of forest fires (i.e. the existence of hydrophobic coating, the increased soil erodibility and sediment load transfer), the land use change and the inadequacy of the existing hydraulic works to release floods (Giakoumakis, 2000), result in the increased vulnerability of the area to flood events. In addition to that, the dominant vegetation in the forests of the area is very flammable and thus the area becomes particularly prone to forest fires, as well. As a result, risk assessment and management of floods and fires prevails as an issue of high priority for the study area, which is an area of increasing interest also because of its proximity to Athens, the capital of Greece, and thus the study area becomes an ideal pilot catchment for the testing and validation of the results of the FLIRE Project.

3. METHODOLOGY

FLIRE is a 3year LIFE Project, with starting date the 01/10/2012 and ending date the 30/09/2015. Nonetheless, partners that are involved in its implementation are committed to keep the system updated and operational for at least 5 more years after its completion. During this 3year time period a list of actions that will gradually allow the development of a DSS platform and in the end its successful application is foreseen. These actions are classified into Preparatory Actions, Implementation Actions, Monitoring Actions, Communication and Dissemination Actions and Management and Progress Monitoring Actions. Preparatory, Implementation and Monitoring actions are presented in brief in the following.

Two Preparatory Actions, i.e. the “Technical Planning” and the “Identification of the current status of the study area” will support data collection and processing and will provide technical assistance and guidance to the partners involved in the project.

The core, technical actions are the Implementation Actions. These actions are related to floods, fires, weather forecasting or DSS development. “Flood actions” include catchment and urban flood modelling, flood risk assessment and strategic planning of flood management. A fire model will be applied for the simulation of the forest fire risk assessment and effort will be invested in the coupling of parameters of flood and fire models. Products of short-term weather forecasting will be used in flood and fire modelling and a DSS platform that that will host databases with simulation outputs from both the flood and fire modelling components as well as the EFWS and EFiWS will be designed.

More specifically, after the setting up, running and calibration of a hydrological model that will be properly selected for the case study, its results (i.e. discharge time series at appropriate locations) of the area will be imported in a properly selected hydraulic model that will simulate urban flooding. The coupling of these models will support the production of flood hazard and flood risk maps that will mainly concern the urbanized part of the area. As far as fire modelling is concerned, fire risk analysis and fire propagation analysis will be performed and support the production of forest fire hazard and risk maps. Floods and fire models will be initially set up and run using historic datasets. To this end, relevant datasets from the Hydrological Observatory of Athens (HOA) (Papathanasiou et al., 2013), a dense hydrometeorological network that covers the greater Athens area and is operated by the Laboratory of Hydrology and Water Resources Management of NTUA, as well as datasets from the meteorological network of the National Observatory of Athens (NOA, 2012), an Associated Beneficiary, will be exploited. The interaction between floods and fires will be considered during the calibration of the models in an attempt to quantify it as much as possible. Climate change and urban development scenarios will be run in the flood model and a Planning Tool will suggest measures for flood prevention and mitigation at a planning basis.

For the real-time operation of the system short-term weather forecasting is necessary and it will be produced and provided to the models with a time lag of a few hours ahead and spatial resolution 1 x 1 km. Instead of running at real-time the models (the flood model chain in case imminent flood is forecasted or the fire model in case weather conditions that increase fire risk are forecasted), which requires time and increased computational effort, a methodology based on off-line model runs will be applied. According to this methodology, the forecasted weather condition will be matched, using e.g. a Case Based Reasoning approach, with one of the historic weather conditions that were initially used as inputs to the models. The output that corresponds to the historic weather conditions which match best with the current, forecasted conditions will be selected and used for further analysis. In case high flood risk is foreseen, appropriately selected triggers will be activated and warnings will be sent to key stakeholders and local authorities by means of the EFWS. Similarly for foreseen increased fire risk, appropriate triggers will be activated and warnings will be sent by means of the EFiWS. These warnings will be properly filtered and then become available to the general public through the website of the project. The interaction between models, inputs, outputs, databases and tools of the Early Warning System is illustrated in Figure 1.

The impact of the project on the local society and the environment will be monitored during the implementation of two dedicated actions (“Monitoring of the Project impact on local society” and “Monitoring of the Project impact on the environmental problem targeted”). Both actions will be implemented throughout the 3-year period of the running of FLIRE and aim to identify appropriate parameters that will quantify this impact and estimate their value.

In order to successfully implement the FLIRE Project, experts in flood modelling (National Technical University of Athens, Imperial College London and Research Institute for Geo-Hydrological Protection – Italian National Research Council), fire modelling (ALGOSYSTEMS S.A.), weather forecasting (National Observatory of Athens) and DSS development (Foundation for Research and Technology Hellas – Institute of Applied and Computational Mathematics) will collaborate and make full use of their expertise and previous experience.

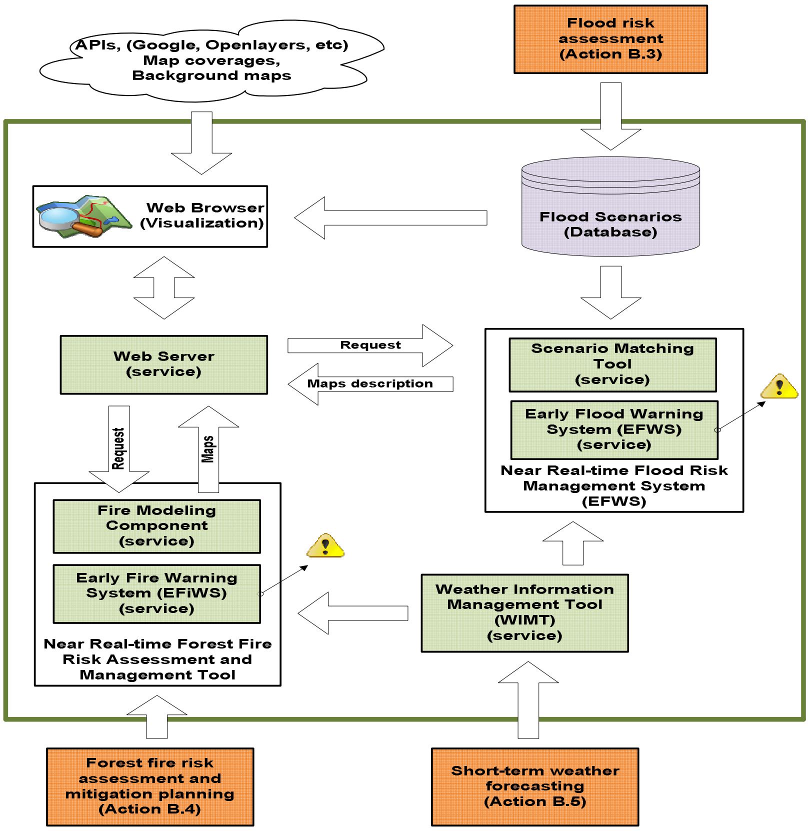

Figure 1. The flow chart with the components of the DSS platform and the tasks related to their development (provided by FORTH).

4. INNOVATIVE ASPECTS OF FLIRE

FLIRE is a demonstration project that has several innovative aspects. These aspects include conceptual innovation, modelling progress beyond the state of the art, as well as technological innovation.

Regarding its conceptual innovation, FLIRE addresses two of the most significant natural disasters, floods and forest fires, at the same time, through the same platform and making use of relevant datasets (e.g. historic hydrometeorological information, weather forecasts, land cover information, topographic data etc). So far, the approach adopted in the study area towards flood and fire protection, mitigation and management has been uncoordinated and thus insufficient. This can be attributed not only to the complexity of the topography of the area and its constantly increasing urbanization rate, but also to the limited reliable datasets and supporting modelling techniques and warning tools. This combined approach results in increased efficiency and economy, and also in increased accuracy in the representation and simulation of both hazards, since their interaction, which is often ignored, is thereby taken into account.

Regarding the modelling components of the platform, i.e. flood modelling, fire modelling, modelling of the flood-fire interaction and atmospheric modelling, current, though validated trends will be examined, adjusted and adopted, if appropriate. Particularly for flood modelling, the coupling of catchment and urban modelling in a periurban environment with mixed land uses is one of the main challenges for flood modelers involved. Separate approaches that have been adopted so far will have to be efficiently combined. Specifically for urban flood modelling, surface and sewer models that simulate flow in major and minor urban flow systems respectively, need to be realistically (yet computationally efficiently) coupled, as well. Simplified 1D/1D approaches for hydraulic simulation will be examined and compared with more complex, though often more realistic, 1D/2D approaches, referred as dual drainage concept (Leandro et al., 2009, Maksimovic et al., 2009).

As far as fire modelling is concerned, several fire models have been developed and applied in the last decades. These models vary between simplified empirical models and computational demanding physical models. Their main drawback is their strict requirement for significant amounts of input data, which are not always effortlessly, if at all, available. An intermediate solution represented by semi-empirical models, seems to meet the requirements of FLIRE. Most of the fire models that are widely applied are built based on a 1D, steady fire line spread hypothesis, which relies on a combustion interface and a flat, rectangular, inclined isothermal fire front that advances across a fuel bed. The characteristics of the fuel bed (e.g. moisture content, packing ratio, surface area to volume ratio of its constituent particles etc) are usually assumed to be uniformly distributed in all directions. Approaches already applied in the U.S., Australia and Canada (FCFDG, 1992), as well as in Europe (Eufirelab, 2002) and other regions of the world will be examined, properly adapted and used, if appropriate.

Innovations in modelling will also concern approaches that will be adopted for the modelling of interaction between flash floods and forest fires. In the last decades progress has been made in assessing and managing risk separately for both hazards. Recent work has been made towards the linking between these disasters, mainly focusing on the impact assessment of the fires on following floods (e.g. Rulli et al., 2007, Papathanasiou et al., 2012, MEDIGRID and SCIER projects). These works make an attempt to quantify the impacts of forest fires on the hydrological response of a river basin, both direct (destruction of vegetation cover, reduction in infiltration and evapotranspiration, alteration of the physical, chemical and hydraulic soil properties etc.) and indirect (increased runoff, peak discharges, erosion, sediment load transfer etc and thus increased flood risk in the affected area). However, there is still work to be done in order to investigate further these links, draw systematic and generalized conclusions and develop operational tools that will make use of the tangible research outputs. This work, which is an issue of high priority especially for peri-urban areas, in which the risk of combined flood-fire events is high and the impacts may be particularly devastating, will progress in the framework of the implementation of the FLIRE Project.

In terms of innovation in atmospheric modelling, the main issue that needs to be addressed is the short time lag that usually exists between the prevailing weather conditions (either rainy or extremely dry and windy weather) and the resulting event (flash flood or forest fire, respectively), which poses restrictions to the in-time preparedness for protection against potential damages. To this end, short time step in weather forecasting is necessary. Operational Numerical Weather Prediction (NWP) systems that are currently applied are using global atmospheric models with 20-50 km horizontal resolution and mesoscale limited area models with 5-10 km grid meshes. Their replacement or complementation with a new generation of non-hydrostatic atmospheric models with 1-3 km horizontal resolution is foreseen for the near future. One such NWP model, the MM5 model, will be used for the production of short weather forecasts for the FLIRE Project and achieve increased computational time and accuracy of high resolution forecasts for the study area.

Apart from its conceptual innovation and the state of the art modelling techniques, FLIRE also incorporates innovative technological elements that will be used to achieve its goals. Datasets from the HOA monitoring network, a state-of-the-art, fully automatic, telemetric network of hydrometeorological stations, which records information in 10min temporal resolution and stores it in an online database (Papathanasiou et al., 2013), will be customized to the requirements of the modelling components of FLIRE and appropriately delivered to the system. A similar process will be followed for datasets from the NOA database (NOA, 2012). Products of technological advance, such as processed satellite images for the production of regularly updated land cover datasets, will also be fusing to the system. Furthermore, modern technology will be used for the development and communication of all tools that will be hosted in the DSS platform. These tools include the Weather Information Management Tool (WIMT) that will process and store weather information (both weather observations and forecasts), a near real-time flood risk management tool that will incorporate the EFWS, a near real-time forest fire risk assessment and management tool that will incorporate the EFiWS and the Planning Tool for flood management. All tools will be based on recent technological advances, which will incorporate optimization, statistical and spatial interaction functions (Nyerged, 2010).

5. EXPECTED RESULTS FROM FLIRE

During the first stage of the project, research has been focusing on the setting up, calibration and validation of the flood model chain and the fire model, so flood and fire risk maps are expected to be produced. In parallel, specifications and particular requirements of the platform in terms of I/O formats, timescales and spatial resolution, appropriate coordination system that will be later used for visualization of projected outputs etc have started being finalized, supporting the design of the tools of the platform. Following that, weather forecasts will be produced and properly processed, the interaction between floods and fires will be further analyzed and quantified as much as possible and the components of the platform will start being finalized. As mentioned above, consultation with local authorities and key stakeholders is foreseen to take place throughout the whole implementation phase of FLIRE, increasing thus the reliability of the simulations (since they will provide valuable feedback for model calibrations), determining the format of the outputs and indicating their applicability and adoption from the local society.

After the successful testing of all the platform components and as described above, the tools will be applied, producing the most significant outputs of FLIRE, the ones that magnify its impact and importance as an EU demonstration Project. These outputs include the in-time warnings for imminent flash floods and forest fires and the suggested measures and/or practices for strategic flood prevention and management. In particular, it is expected that these outputs will assist the <u>accurate quantification of the flood and fire risk assessment</u>, by means of adopting a combined approach for flash floods and forest fires. The use of state-of-the-art scientific knowledge and technology will support the development of efficient early earning systems for <u>effective flood and fire risk management and prevention</u>.

Furthermore, floods and fires are traditionally investigated through separate systems that collect the necessary information and assess the corresponding risk in an approach that overlooks the fact that the required datasets are to a great extent common and also these two hazards are tightly interrelated. The methodology that will be adopted for the FLIRE Project encloses numerous innovative aspects, one of the most important being the holistic approach towards flood and fires, taking into consideration their interrelation, particularly in a complex periurban environment. As a result of this holistic and complicated, though comprehensive approach, it is foreseen that the application of the platform will result in considerable <u>improvement in plans and measures for protection against and management of both hazards</u> that have been adopted so far in the area by the pertinent authorities.

In addition, the outputs of the FLIRE Project, which will be produced and validated before its completion, are of significant importance not only for flood and fire risk assessment and management in the study area, but also for the environmental problem targeted in general. The study area is a typical Mediterranean area that is particularly vulnerable to both hazards. One of the secondary, though not of less importance, targets of the Project is its contribution to change the paradigm for combined and robust floods and fires risk assessment and management in other areas and/or countries with similar hydromorphologic and meteorological conditions. To this end, partners from three EU countries (Greece and Italy, two Mediterranean countries that share common hydrometeorological and geomorphologic conditions and United Kingdom, a country particularly vulnerable to flash floods) will collaborate and exchange knowledge and experience in order to effectively achieve the goals of the Project. This <u>transferability of FLIRE outputs and their application to other, similar areas</u> is one of the most important issues to be expected from the Project, since it will validate its outcomes and will assure its continuation.

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