Innovative and Sustainable Use of Stream Water to Suppress Fires in Protected Areas: Overview of the Streams-2-SUPPRESS-Fires Project

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***Abstract**:*

Establishing protected areas to maintain biodiversity is a priority worldwide. Protected areas can have minimal management practices that can lead to the intensive accumulation of fire fuel. Fires are major threats for all protected areas that cause irreversible damages to them or impacts that last for decades or even centuries. The impending climate change impacts will increase the potential of large fires even in regions with minimal fires in the past. The emphasis of this project is in the Black Sea region with six pilot areas in six different countries. The first action involves the establishment of a Neighborhood Network regarding fire suppression around the region. The network includes institutions that are responsible for mitigating forest fires and managing protected areas from the Black Sea region. Another important action taken is to understand the fire behavior and locating the areas with the greatest fire risk. When considering fire suppression it is essential to know the available water resources (stream water). Since fires occur during the summer, the runoff and stream flow during this period needs to be accurately predicted. Based on the fire behavior and water resources data, the number, dimensions of the reservoirs required to suppress forest fires will be estimated for the pilot areas. Finally, specialized software will provide the optimal locations of the reservoirs and the best routes for the fire vehicles to reach the reservoirs. Overall the use of innovative mechanisms will lead to the more cost-effective management that will allow the sustainable development and protection of natural protected areas.

Key Terms: Black Sea Region, protected areas, wildfires, water resources, innovative technologies, networks

Introduction:

The greatest land-use transformation at the end of the 20th century was the establishment of protected areas all around the world (Lockwood et al. 2006). Today, more than 100,000 sites that cover 12% of the earth terrestrial surface are in some type of protected status. Their development was deemed necessary since they provide a great range of ecological services and goods and simultaneously preserve the natural and cultural heritage (Convention on Biological Diversity 2003). Overall these areas can be considered one of the most significant land-use designations by humans. They help sustain life on earth by protecting different landscapes that have rich biodiversity (Lockwood et al. 2006). Additionally they provide opportunities for environmental educational, ecotourism, recreation and research especially in regards to climate change (Convention on Biological Diversity 2003). The above, clearly indicate their importance and justify the major efforts that have been done for their establishment and maintenance. Finally, it should be noted that these protected areas have different protection designation that range from sites managed and established by governments to those managed by indigenous people, local communities, non-governmental organization, and private companies and individuals.

In the European Union the ecological network of the Natura 2000 has been established (E.C. n.d.). The purpose of the network is to stop the decline in biodiversity; being a part of a global agreement to significantly reduce biodiversity loss. Currently, it protects around 18% of the land in the EU countries, and it can be considered almost completed for the EU terrestrial environment. The network comprises of more than 25,000 sites and covers approximately 80,000,000 ha.

Forest fires are a natural phenomenon inextricably linked to the environment and the structure of the landscape. In fire driven ecosystems types they play a decisive role in the structure of plant communities and their biodiversity on different levels. They are considered a complex phenomenon that is strongly influenced by environmental, climatic and socio-economic factors combined (Dimitrakopoulos and Mitsopoulos 2006). Since fires have occurred long before the arrival of human, many ecosystems have either adapted to them or are an integral part from them. In contrast fires, especially those because of anthropogenic reasons, cause many environmental and ecological impacts on forest ecosystems, in some case irreversible, but also direct economic and social impacts to societies including human fatalities (Fowler, 2003).

Today, even in regions where wildfire is a natural phenomenon, the frequency and severity of fires have increased due to the more favorable fire conditions, especially climatic (Lake, 2011). This increase has created the frequent recurrence of major fire problems. The increase of fires worldwide has substantial negative impacts on economies, livelihoods, human health and safety but also on ecosystems (DeBano et al., 2000). These impacts are comparable to other natural disasters such as earthquakes, floods, droughts and volcanic eruptions and indicate that measures need to be taken for their more effective management. While wildfires are considered as a major disturbance they have the capacity to improve or degrade sustainable environments. This is very true today since many places are suffering from too much fire, while other from too little or of the wrong kind (Pyne, 2001).

It is also important to understand that there is a strong interconnection between protected areas and fires (Lockwood et al. 2006). In the past there was a misconception that protection meant the elimination of fires in the protected areas. The elimination of fires coupled with the minimal management actions in these areas can and has led to the accumulation of forest fuels that can lead to major catastrophic fires. An example is from the Yellowstone National Park in the United States where such a fires occurred that proved very catastrophic because of the management practices that suppressed forest fires. It will be essential in future management plans of protected area to incorporate correctly the role of fires in order for these plans to be effective in the long term.

In general the natural forested areas of the Black Sea region are limited. This makes it a priority to protect them. The region has had anthropogenic activities for centuries that have heavily impacted the forested areas of the region. Extensive fires would substantially decrease the already limited forested areas of the regions. Due to different reasons, often wildfires are not a major concern in most of these countries so in many cases preparedness for this potential danger is not sufficient. Most countries have not developed extensive fire management plans and have limited technical capacity for firefighting, primarily land vehicles with no proper air support. In many cases large wildfires occurs in mountain conditions that seriously restrict the use of fire aviation.

While fires in many of the countries of the Black Sea Region are not a major threat this might not be true in the near future. Examples of large catastrophic fires, in areas that they do not frequent occur are the forest fires that occurred in 2010 in Russia, outside of Moscow. The main reason is climate change that is leading to substantially higher temperatures especially during the summer (the xerothermic period). This is the period when most fires occur and the increase in the temperatures of the region has significantly increased the potential of forest fires (especially large scale forest fires). In

addition, another major issue was that the fire preparedness and firefighting capacity was not enough for this new challenge.

Two of the main climatic characteristics that are expected to be impacted by climate change are temperature and precipitation. The latest IPCC report (Solomon et al., 2007), states that global temperatures have increased over the last 100 years and the rate of warming in the last 50 years (1956-2006) is almost double than what it was over the last 100 years. Increases in temperatures will lead to higher evapotranspiration rates but the atmosphere will also be able to hold higher percentages of water vapor. The above facts will also impact precipitation amounts, patterns and intensities. The IPCC concluded that it is most likely that heavy precipitation events will increase in most areas of the world. These increases in intensity are expected even in areas where the total precipitation is expected to decrease.

These changes will impacts the hydrological cycle that is expected to be completed quicker thus leading to more intense precipitation events and floods for short periods of time but also longer periods with little to no precipitation that will lead to greater drought periods. The longer drought periods can obviously lead to more fires. Drought weather conditions promote fires by drying the vegetation and producing high temperatures and winds (Lake, 2011). Flannigan et al. (2000) estimated that seasonal severity rating (SSR) will increase by 10–50% over most of North America due to climate change. The increased forest fire activity has also been quite evident in the last decade in Southern European countries like Greece, Italy, Spain and Portugal (Dimitrakopoulos et al., 2007; Xanthopoulos et al., 2006).

The main objective of the project is to promote research and innovation in the field of fire suppression to enhance the protection of natural areas by utilizing new technologies and developing a holistic and complete fire suppression system. These new technologies: a) include the operation of a neighbourhood network of experts form the Black Sea region to collaborate to suppress fires, b) allow to indentify the areas of greatest risk of having fires, c) utilize in a sustainable way stream water to suppress fires in protected areas, d) enhance the availability of water resources for land firefighting vehicles during nighttime when fire aviation can't be use, e) develop software for the optimal location of the water reservoirs and mobilization of fire vehicles and f) enhance the knowledge and awareness on forest fire suppression of the appropriate institutions and general public. The direct beneficiaries will be public administrations and their institutions responsible for fire management, and management of natural protected areas. Indirect beneficiaries are all stakeholders that have an interest in better protected areas management.

Partnership:

The objective of the project is to develop a system based on new technologies that will be utilized by the proper authorities to suppress forest fires for the entire Black Sea region. This is why the partners of the project are from six different countries for all around the Black Sea, the north, south, east, west regions. This is essential in order to incorporate the different forested ecosystems of the region. The specific organizations that are participating are: a) Anatoliki Makedonia and Thraki Institute of Technology, Department of Forestry and Natural Environment Management, from Greece (the lead partner); b) Artvin Coruh University, from Turkey c) Prefect's Institution of Braila County, from Romania; d) National University of Life and Environmental Sciences of Ukraine; e) Zikatar Environmental Centre, Ministry of Nature Protection, from the Republic of Armenia; and f) Eco-TIRAS International Association of River Keepers, from the Republic of Moldova.

The system developed is going to be science-based but also user-friendly in order to be easily adopted by the appropriate authorities of the Black Sea Region. This is the reasons why the partners are different types of organizations although all have a significant environmental aspect at some capacity. Specifically, three Universities are involved (partners a, b and d) that implement the scientific and innovative components of the project. Without the

Universities the new system would not be able to be developed. In addition, one Governmental Environmental Center (partner e), one Prefecture (partner c) and one non-governmental organization (partner f) are partners for the more practical aspects of the proposal. These organizations have the personnel to test the system and evaluate its applicability and user-friendliness. The Neighbourhood Network (discussed in a later section) will also contribute in this part of the project. In most projects one of the two components (science-based or applied) are missing that can lead to either not very innovative and scientific systems or systems that are not easily adopted and applicable.

Black Sea Region Fire Fighting:

Most countries of the Black Sea Region have limited resources for environmental issues that make it a necessity to utilize innovative ways in fire management and suppression. The existing fire fighting planning combined with the geomorphology in some of the forestred areas and with the lack of modern infrastructures and services, presents major problems in the effectiveness of preventing and suppressing of forest fires. The use of new tools and technologies as a decision support system to suppress fires with the help of experienced researchers specialized on natural disasters is essential because it helps better understand the environmental conditions and dangers that fires can pose to the region.

Pilot Areas:

The project is for the entire Black Sea region but the efforts will focus on six pilot areas in the participating countries (one in each country). All selected pilot areas have ecological importance because of their unique forest ecosystem that has led to their designation as protected areas. In addition, these areas have experienced fires issues particularly in the recent years.

The pilot area in Greece is the Menoikio Mountain. It is located in Northern Greece and belongs politically to Region of Eastern Macedonia and the Prefectures of Drama and Serres. It covers approximately an area of 50,500 ha. Parts of Menoikio have designated as a Birds Directive Site (SPA) (GR 1260009) and as a Habitat Directive Site (SCI) (GR 12600004) in the Natura 2000 Network. The main tree species are *Quercus pubescens, Quercus coccifera, Fraxinus ornus, Fagus Sylvatica, Carpinus betulus* and *Castanea sativa.* In the area, during the period 1984-2009, a total of 106 fires burnt 2208 ha.

The Bayam Forest District, in Kastomonu is the pilot area in Turkey. The study site has a total area of 16,006 ha with 80% of the area forested. The remaining 20% is used for agricultural, hay production, and residential purposes. The major tree species in the site include *Pinus nigra* subsp. *pallasiana*, *Pinus Silvestris*, *Fagus orientalis*, *Carpinus betulus*, *Ulmus minor* and *Quercus* spp. Fire is an important threat to these forests during the dry summer period. From 1963-2003, 101 fires occurred that burned 645 ha. The area falls in the second degree of fire sensitivity according to fire threat classes of Forest Service of Turkey.

In Romania the Natural Park Small Wetland of Braila was selected. It covers an area of 24,555 ha and it is a natural protected area having a triple protection status – national (natural park), EU (Natura 2000 site) and international (RAMSAR site). It is situated on the Danube Lower Meadow, between Brailei Meadow and the Small Island of Braila. In this pilot area 221 plant species of plants have been identified. Every spring the risk of fires increase because of the seeds from the poplars.

The Ukrainian pilot area is Yalta Mountain-Forest Natural Reserve. It is on the southern microslope of the main ridge of Crimean Mountains and occupies an area of 14,523 ha. The Crimean region is characterized by its great biodiversity. It was selected by WWF as one of most important among other eight regions selected in Europe. The main tree species include: *Quercus pubescens*, *Juniperus excels*, *Pistacia mutica*, *Pinus nigra* var *pallasiana*, *Quercus petraea*, *Carpinus betulus*, *Fraxinus excelsior*, *Pinus kochiana*, *Pinus sylvestris* and *Fagus silvatica*. In the Autonomous Republic of Crimea from 1993-2006 a total of 2120 forest fires occurred that burned more than 2170 ha

of forests lands, including 258 ha burned from crown fires.

The "Codrii" Reserve in the Republic of Moldova was founded with the aim to conserve the most representative areas of forests, specific to the Central Plateau of Moldova. It is located 47 km to the South-East from Chisinau. It is separated in three zones: a) *Strictly protected* (720 ha) with no human activity, except scientific research; b) *Buffer* (4,456 ha) that surrounds the previous zone to limit the human impacts; and c) *Transition* (12,300 ha) a 2-km area around the buffer zone that includes mainly private or public agriculture lands. The main species are *Quercus spp, Fagus silvatica* and *Salix* spp.

The Arevik National Park is in southern Armenia was also selected. Its boundaries start from Araks River Valley but also covers the mountainous region with its highest peak reaching 2550 m (asl). The park stands out because of its high biodiversity. The dominant tree species is *Quercus macranthera* occupying 70% of the total forested area. Other major species include; *Juniperus polycarpos, Carpinus betulus*, *Acer trautvetteri*, *Pyrus caucasica*, *Cerasus avium*, *Juglans regia*, *Amygdalus communis*, *Elaegnus angustifolia* and *Fraxinus excelsior*. In this pilot area in the last 5 yrs 200 ha have been burned.

Neighbourhood Network:

The Neighbourhood Network in regards to fire suppression for the entire Black Sea region has been established (Figure 1). The establishment of the network will strengthen and expand cooperation between existing institutions in regards to fire protection and management of protected areas of the Black Sea region. This will facilitate the communication among authorities managing natural protected areas and authorities responsible for fire protection in order to exchange expertise, best management practices and innovation in technical and scientific methodologies. The exchange of experience and best management practices will improve the protection of the forested areas and promote economic and social development.

The specific goals are: a) *Establish a sharing network among peers of the Black Sea region*. This will promote true collaboration among the institutions of the Black Sea region and develop more efficient and effective fire management plans. In addition, it will lead to faster, better, cheaper mitigation and postfires recovery in the region that will increase the region's resilience to fires and enhanced the protection of the forest areas. It will also facilitate formal and informal communications between the institutions and support peer learning and communication. Another objective is to create tools and resources for the region. Finally, the network will allow countries to assist each other before, during or after wildfire disasters occur. b) *Create mechanisms to inform the general public.* The network will enhance the general public knowledge on protected areas, on the dangers of forest fires and best management practices to mitigate fires. In addition written (brochures) and online material (website) will be developed and events (e.g. workshops, awareness events) will be hosted for the general public.

To facilitate the functionality of the Neighbourhood Network the Profile of the network has been written. The members of the Neighbourhood Network will review and provide feedback to improve it. The profile provides background information on protected areas fires and climate change, the goals, timetable and future activities of the network. The profile is approximately 80 pages and freely available through the project website at the url: www.suppressfires.eu.

The National Neighbourhood Network meetings in each participating country have occurred in July and August. Specifically, the Greek National meeting occurred on July 26th with 17 participants, the Turkish on July 29th with 10 participants, the Romanian on July 30th with 10 participants, the Armenian on July 31th with 18 participants, the Moldavian on August 7th with 13 participants and the Ukrainian on August 28th with 25 participants. All meeting were very successful with great participation. The major benefit was learning that the participating organizations are very excited about the development of the Network. Currently 40

organizations from the Black Sea are participating (Table 1). In the next meeting that will be online in October 2013, participants from all countries will be involved.

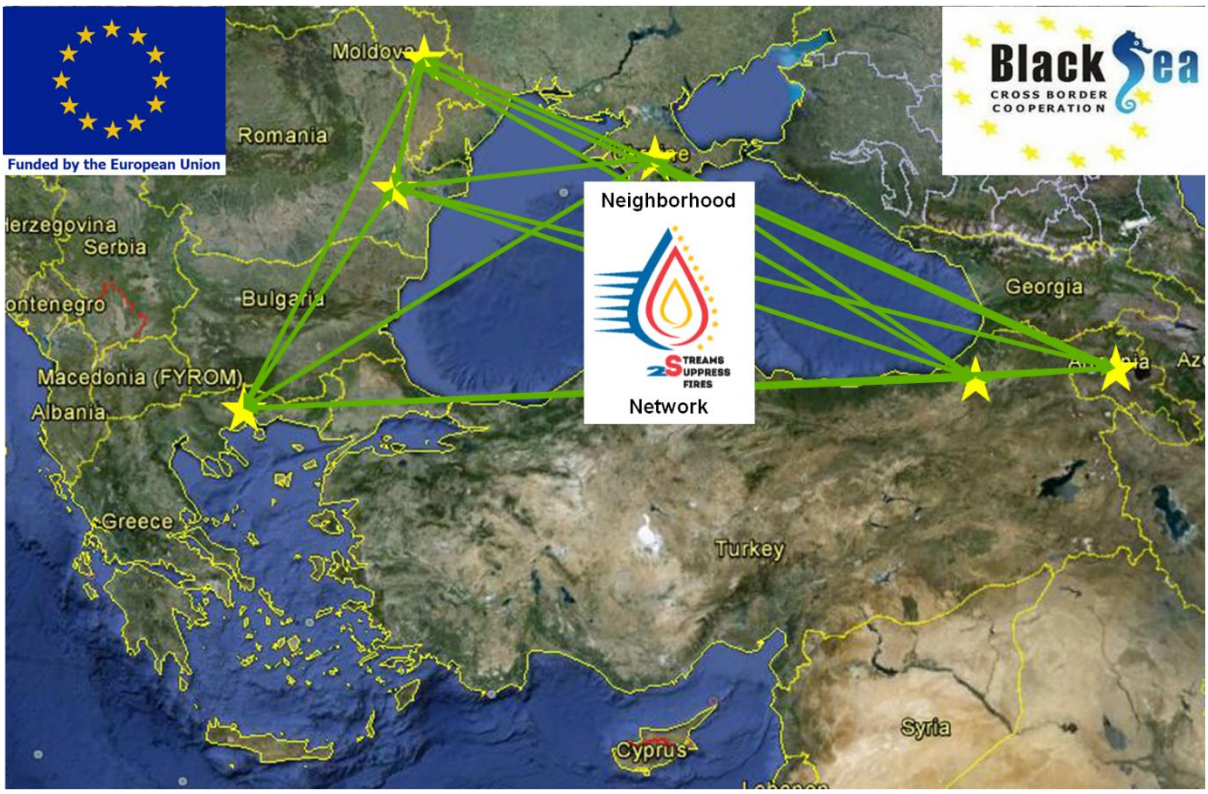

Figure 1. The logo for the Streams-2-SUPPRESS-Fires Neighbourhood Network. This Network will initially be specific for the Black Sea region. The logo indicates the six participating countries (Greece, Republic of Armenia, Republic of Moldova, Romania, Turkey and Ukraine) with the yellow stars indicating the location of the participating organizations. In the middle of the figure is the logo of the project Streams-2-SUPPRESS-Fires.

Table 1. The organizations in each country that have agreed to participate in the Streams-2-SUPPRESS-Fires Neighbourhood Network.

Organization	Country
Decentralized Authority of Macedonia and Thrace	Greece
Prefecture of Drama	"
Municipality of Xanthi	"
Forest Service of Drama	"
Forest Service of Kavala	"
Forest Service of Serres	"
Fire Department of Drama	"
Fire Department of Kavala	"
Ecological Movement of Drama (NGO)	"
Management Body of Rodopi Mountain Range	"
Rescue Service, Ministry of Emergency Situations	Republic of Armenia
Climate Change Information Center, UNDP/GEF	"
Hydrometeorology & Monitoring State Service, Ministry of Emergency Situations	"
"Hayantar" SNCO, Ministry of Agriculture	"
Water Management Agency, Ministry of Nature Protection	"
Bioresources Management Agency, Ministry of Nature Protection	"
"Arevik" National Park State, Ministry of Nature Protection	"
State Forestry Agency "Moldsilva" with branches	Republic of Moldova
Ministry of Environment	"
State Service for Emergencies	"
National Institute of Forestry	"
NGO Silva Mileniu III	"
Dept, of Forestry and Public Gardens, State University of Agriculture	"

BIOTICA Ecological Society – NGO	"
Prefect's Institution -Arges County	Romania
Prefect's Institution -Brasov County	"
Prefect's Institution - Braila County	"
Prefect's Institution -Calarasi County	"
Inspectorate for Emergency Situations Braila County	"
Inspectorate for Emergency Situations Brasov County	"
Inspectorate for Emergency Situations Prahova County	"
Inspectorate for Emergency Situations Mures County	"
Republican Committee of the Autonomous Republic of Crimea of forestry and game management	Ukraine
The Main Department of the State Emergency Service of Ukraine in Autonomous Republic Crimea	"
The Yalta Mountain Forest Natural Reserve	"
The Alushta Forestry Enterprise	"
The Crimean Natural reserve	"
NGO "CLUB 4x4"	"
Crimean Republican Association "Ekologiya i Mir	"
Kastamonu Forest Regional Directorate	Turkey
Provincial Directorate of Food, Agriculture and Animal Husbandry	"
City of Kastamonu Ministry of Forestry and Water Affairs Branch	"
Kastamonu Union of Village Development and Other Agricultural Cooperative	"
Taşköprü City Directorate of Forestry	"

Methodology:

Through this project an easy to use system for the suppression of forest fires that will utilize surface waters in a sustainable way will be developed. To accomplish this, firstly a unified Geographic Database is created with critical pre-existing information on the pilot areas. Based on the pre-existing data, maps that will be utilized in the next steps will be developed e.g. Digital Terrain Models (DTM), vegetation cover, soil, stream network etc.

The next step is the forest fuel sampling. All the study areas are stratified based on the vegetation maps according to the dominant vegetation type. The stratified areas are surveyed on site to estimate their fuel conditions and measure fuel load. This type of sampling has taken place in each pilot area. The NNFL standard approaches for inventorying surface fuels biomass are applied.

Once the fuel sampling is completed the fuel model mapping will be developed. Satellite images of the pilot areas will be delineated into individual meaningful objects, using a multi-resolution segmentation algorithm. Through this algorithm each individual object is perceived as the initial region. Each object is sequentially merged pair-wise into larger ones to minimize the heterogeneity of the resulting objects. The Classification and Regression Trees statistical technique classifies tree pixels based on certain characteristics and divides the data into homogeneous groups. Each group will be characterized with a specific fuel potential to help develop the fuel model for each pilot area.

The fire risk and behavior prediction for every fuel model map will afterwards be calculated. To accomplish this step, the FlamMap fire behavior and analysis simulator will be used. The data necessary for the model include the DTM, the spatial extent of the fuel models and the fuel parameters values of each model in the pilot area.

An extensive literature review of runoff models has been conducted. Based on this literature review the most appropriate model will be selected. The model selected will determine the variables collected in the field. These variables will primarily be hydrologic (e.g. stream flow) and vegetative. The field data will be used to validate and calibrate the selected runoff model. Once the model is validated it will be applied in the pilot areas in order to estimate the available stream flows during the summer months.

Based on forest fuel mapping, the forest fire risk and behavior and stream flow data, the numbers of reservoirs and their dimensions to

suppress the potential forest fires will be determined. Specialized software such as Intelligent Path Advisor and Interactive Map will provide maps with the optimal location of the reservoir, the best accessible routes to reach the reservoirs for the fire vehicles and a model on the optimal fire vehicles mobilization during a fire event. The locations of each reservoir will be validated by in situ visits.

Conclusions:

The proper use of this system for the suppression of forest fires will reduce substantially the hectares of forested land that are burned in the region. All institutions and organizations that deal with forest fires would have a great interest in this system. The use of new tools and technologies to suppress fires with the help of experienced researchers specialized on natural disasters is a necessity because it will provide a better understanding of the environmental conditions and dangers of the region. Climate change implications also require a new understanding of the new conditions that are developing that will enhance fire risk. For the particular region this system is needed because of the limited infrastructures that exist to face fires but also the limited experience in fire fighting. The implementation of the system will also enhance the feeling of safety and protection for its citizens and enterprises. Indirectly it will improve the standard of living and quality of life especially for rural areas while potentially increasing ecotourism opportunities. Finally this tool could be applicable to other regions such as the Mediterranean that also face serious problems with fires and water scarcity. This will of course require modifications and validations.

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