Collaborative Project

CLIM-RUN

Climate Local Information in the Mediterranean region Responding to User Needs

WP 6 – Wild Fires Case Study

Task 6.4 - Vulnerability report: Assessing the vulnerability of the Mediterranean and specific target location to fire risk occurrence within the context of climate change.

Deliverable 6.4: Vulnerability report

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1. Introduction

Forest fires constitute a major environmental and socioeconomic issue in the Mediterranean. An average of 50,000 fires per year burn a range of 470,000 hectares annually causing, apart from ecological catastrophe, severe damages in infrastructures and, quite often, human casualties (Schmuck et al., 2011). Although forest fires have always been present in the Mediterranean and the Mediterranean climate-type forest areas are extremely fire prone, their destructive capacity is on the rise for the last few decades (Pausas and Vallejo, 1999), while an extension of the fire season has been reported (e.g. Flannigan et al., 2009; Dimitrakopoulos et al., 2011).

A series of factors are thought to be influencing fire activity, such as weather conditions (Balling et al.,1992b), human activities (Vélez, 1993), fuel characteristics (e.g. Mouillot et al., 2002), fire management activities (Badia et al., 2002; Fried et al., 2008), topography and land use changes (Rego, 1992; Moreira et al., 2011), fire suppression policies and priorities, fire control organisational size and efficiency (Flannigan et al. 2005), as well as climate change (Davis and Michaelsen, 1995; Flannigan et al., 2000; Fried et al., 2004).

Forest fires are highly sensitive to climate change because fire behaviour responds immediately to fuel moisture (Weber and Flannigan 1997, Stocks et al. 2001). Thus, the projected increase in temperature increases fuel dryness and reduces relative humidity and this effect worsens in those regions where rainfall decreases. Accordingly, increases in climate extreme events are expected to have a great impact on forest fire vulnerability (Beniston 2003). The contribution of meteorological factors to fire risk is simulated by various non-dimensional indices of fire risk. Viegas et al. (1999) validated several such indices in the Mediterranean against observed fire occurrence, with the Canadian Fire Weather Index (FWI, van Wagner 1987) being amongst the best performers.

The FWI model is non-dimensional, based on physical processes and has been used at several locations, including the Mediterranean basin (e.g. Moriondo et al., 2006, Carvalho et al., 2008; Giannakopoulos et al., 2012); thus it seems a sensible choice for exploring the mechanisms of fire risk change. Furthermore, since 2007 the FWI has been adopted at the EU level by the European Forest Fire Information System (EFFIS) of the Joint Research Centre of the European Commission (http://forest.jrc.ec.europa.eu/effis). This was done following a test phase of 5 years, during which different fire danger methods were implemented in parallel by EFFIS, until the FWI was selected as the method to assess the fire danger level in a harmonized way throughout Europe.

The FWI System provides numerical ratings of relative fire potential based solely on weather observations. The meteorological inputs to the FWI System are daily noon values of temperature, relative humidity, 10m wind speed and precipitation during the previous 24 hours and are described in detail in van Wagner (1987).

The FWI system consists of six standard components each measuring a different aspect of fire danger. The first three primary sub-indices are fuel moisture codes and are numerical ratings of the moisture content of litter and other fine fuels (FFMC), the average moisture content of loosely compacted organic layers of moderate depth (DMC) and the average moisture content of deep, compact organic layers (DC). The two intermediate sub-indices (ISI, BUI) are fire behaviour indices. The Initial Spread Index (ISI) is a numerical rating of the expected fire rate of spread. It combines the effect of wind and FFMC on rate of spread without the influence of variable quantities of fuel. The Buildup Index (BUI) is a numerical rating of the total amount of fuel available for combustion that combines the DMC and the DC. The resulting index is the Fire Weather Index (FWI) which combines ISI and BUI. FWI represents the frontal fire intensity and is used to estimate the difficulty of fire control.

The aim of this report is to study the vulnerability of the selected target country of Greece to fire risk occurrence within the context of climate change. In the first part of our study, maps illustrating changes in the near and distant future in indices relevant to fire risk for the Mediterranean as well as for Greece are presented. Next, the feedback of the stakeholders concerning the project's products is presented. Finally, the future vulnerability of Greece to forest fires is assessed in terms of their sensitivity, exposure and adaptive capacity based on available quantitative and qualitative data.

2. Future climate and fire risk projections for the Mediterranean

For the Mediterranean-type ecosystems, fire occurrence strongly depends on the drought conditions that drastically increases flammability during summer period, on the temperature reached during this period as well as on the amount of fuel load (Mouillot et al., 2002). In this section, maps for the control period as well as the projected changes in the near and distant future for climate indices of maximum temperature and precipitation of relevance to fire risk will be discussed.

For that reason, daily output data from three regional climate models (RCMs) developed at KNMI (Netherlands), ETHZ (Switzerland) and MPI (Germany) within the framework of the EU ENSEMBLES project have been used (www.ensembles-eu.org). All models have a horizontal resolution of 25 km × 25 km and use the A1B greenhouse gases emissions scenario (Nakicenovic et al., 2000). Present day simulations cover the period 1961-1990 and used here as reference for comparison with future projections for the periods 2021-2050 (near future) and 2071-2100 (distant future).

2.1. Changes in climatic indices relevant to fire risk for the Mediterranean

2.1.1. Changes in precipitation indices

Among the climatic parameters with implications on fire risk, the maximum length of dry spell (amount of rainfall less than 1 mm) as well as the number of dry days have been examined as they can contribute to increases in fire risk and can influence forest species due to their sensitivity to soil moisture content.
As far as the maximum length of dry spell is concerned, the RCM ensemble mean results (Figure 1 right side) show an increase of more than one additional month with dry conditions for the most part of Spain in the distant future (2071-2100). For Italy and the coastal parts of France, an increase of about 20-25 days, is expected. Finally, for Greece and Cyprus an increase of 20-30 days is depicted. In the near future (2021-2050), increases are milder and reach 10-15 days in all European Mediterranean countries.
The number of dry days, namely the days with daily total precipitation less than 1mm, ranges between 200 to 330 days for the control period (figure 1 left side). Higher values are depicted for southern Spain, Morocco, Sicily, Eastern Greece and Cyprus. For the distant future (2071-2100), increases of up to 40 additional days per year are expected in northern Spain and Portugal. In north-western African countries, Italy and Greece an increase of 20 days per year is anticipated. In the near future (2021-2050), increases are milder and reach 15-20 in Northern Spain, southern France and 10-15 days in Italy, Greece and the rest of Spain.

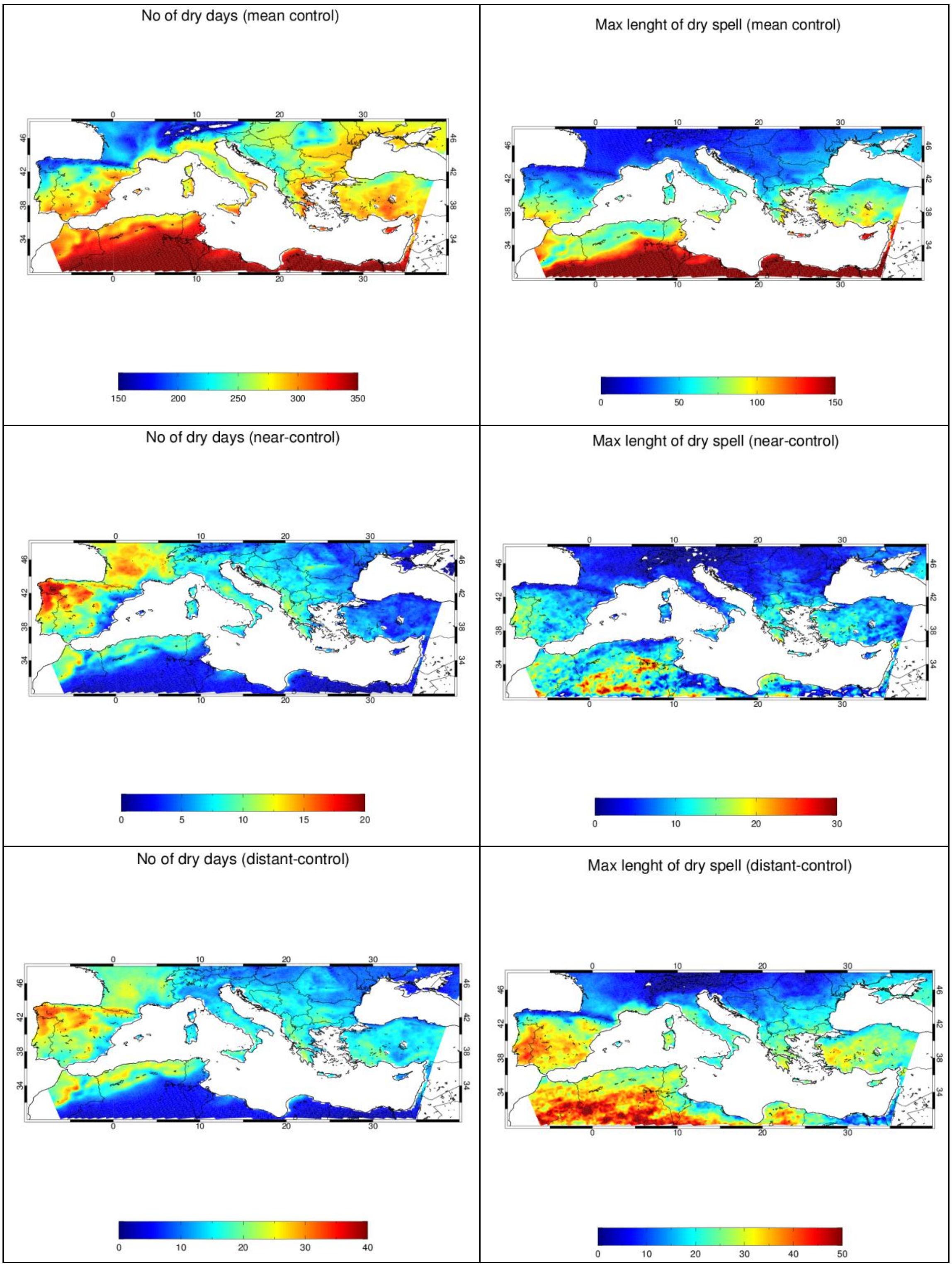


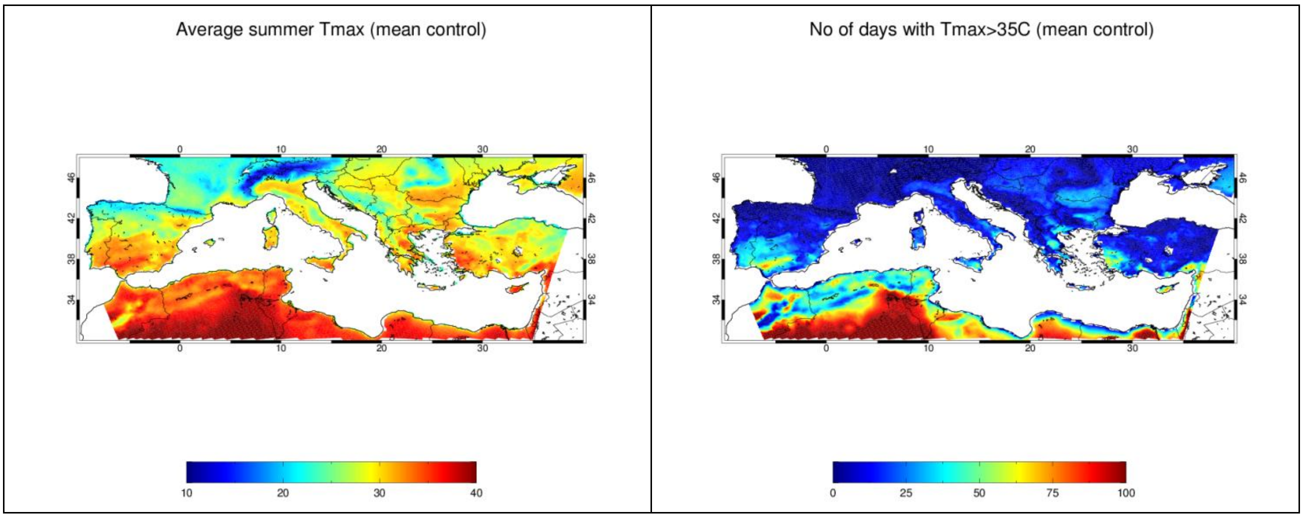
Figure 1: Mean number of dry days (P<1mm) and maximum length of dry spell for the control period and projected changes during near and distant future for the Mediterranean region.

2.1.2. Changes in maximum temperature indices

As previously mentioned, the projected increase in temperature will increase fuel dryness and reduce relative humidity. This, in combination with reduced winter precipitation, is likely to increase the potential for larger and more destructive fires in the future. For the above reasons, the maximum summer temperature and the number of hot days (Tmax>35°C) have been examined and presented below.

From Figure 2 (left side) it becomes evident that in the control period, the average summer maximum temperature ranges between 20 in the northern and higher elevation parts to 35°C in the southern parts of the study domain. For the near future, an increase of about 2-3°C is expected, with higher values depicted at the higher elevation areas and the northwestern coasts of Africa. For the distant future the increases will be even higher, with values reaching even 7°C in the largest part of the Iberian Peninsula.

The hot days (i.e. days with maximum temperature above 35^{o}C) reach up to 70 days per year in southern Spain and northwestern Africa during the control period (Figure 2 right side). An increase of up to 30 and 60 additional days per year is expected for the near and distant future, respectively. The hot spots of this increase are southern Spain and Portugal, Italy, Eastern Greece as well as Cyprus and Turkey.



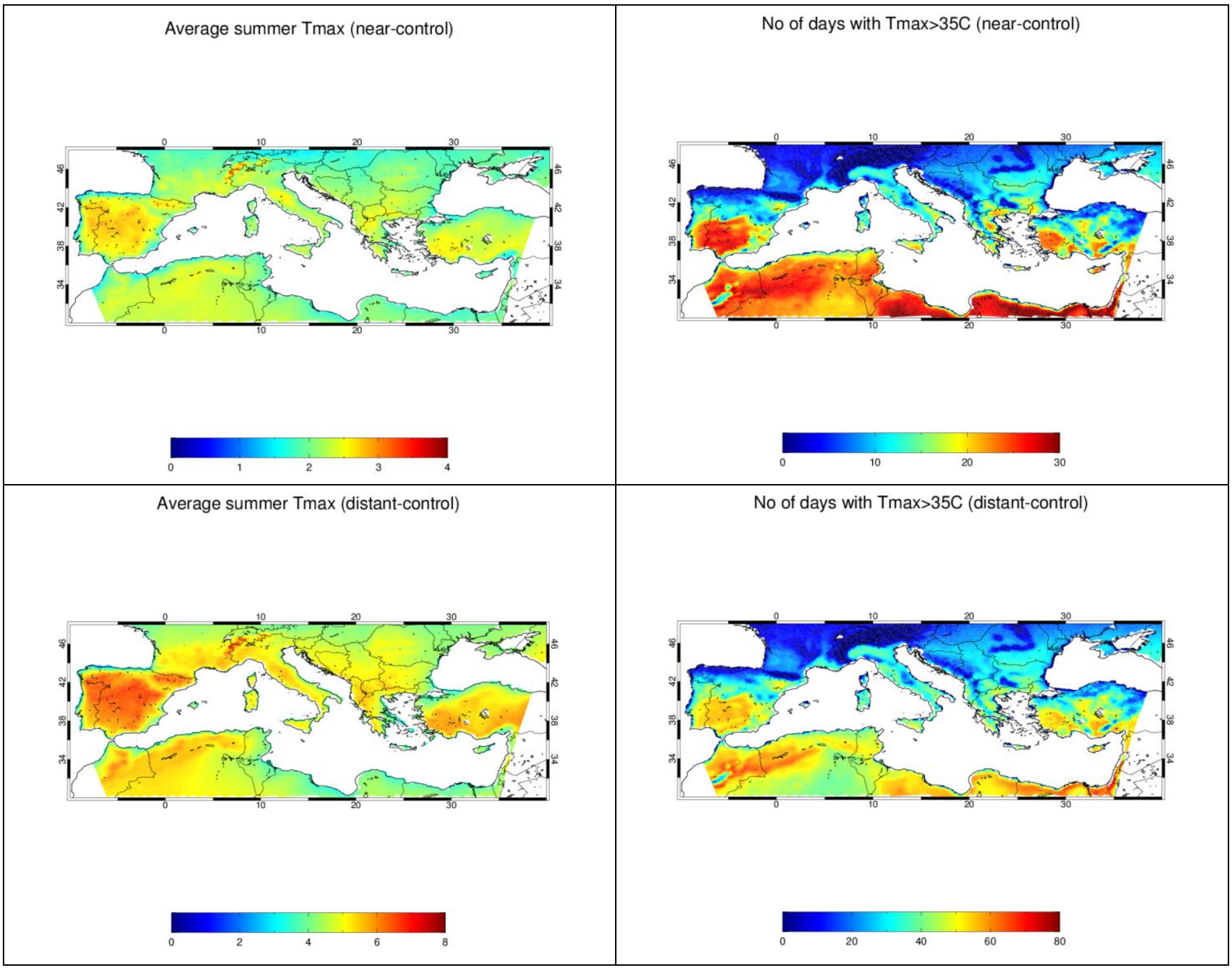


Figure 2: Average summer maximum temperature and mean number of hot days (Tmax>35°C) for the control period and projected changes for the near and distant future for the Mediterranean region.

2.2. Future fire risk projections for the Mediterranean

Previous research studies (Hanson and Palutikof, 2005, Good et al., 2008) have shown that fire risk is low for FWI<15 and increases more rapidly with FWI>15. In this study a threshold of FWI>15 was selected as a measure of fire risk in the area of interest and FWI>30 was selected as a measure of elevated fire risk.

For the Mediterranean region, the ensemble mean of the models was calculated and the maps produced illustrate the number of days with fire risk (FWI>15) and increased (FWI>30) fire risk for the control period (1961-1990) as well as the changes in the number of days with fire risk and increased fire risk between the reference and the two future periods (Fig. 3). Furthermore, the

average summer FWI for the control period as well as the changes for the two future periods were calculated.

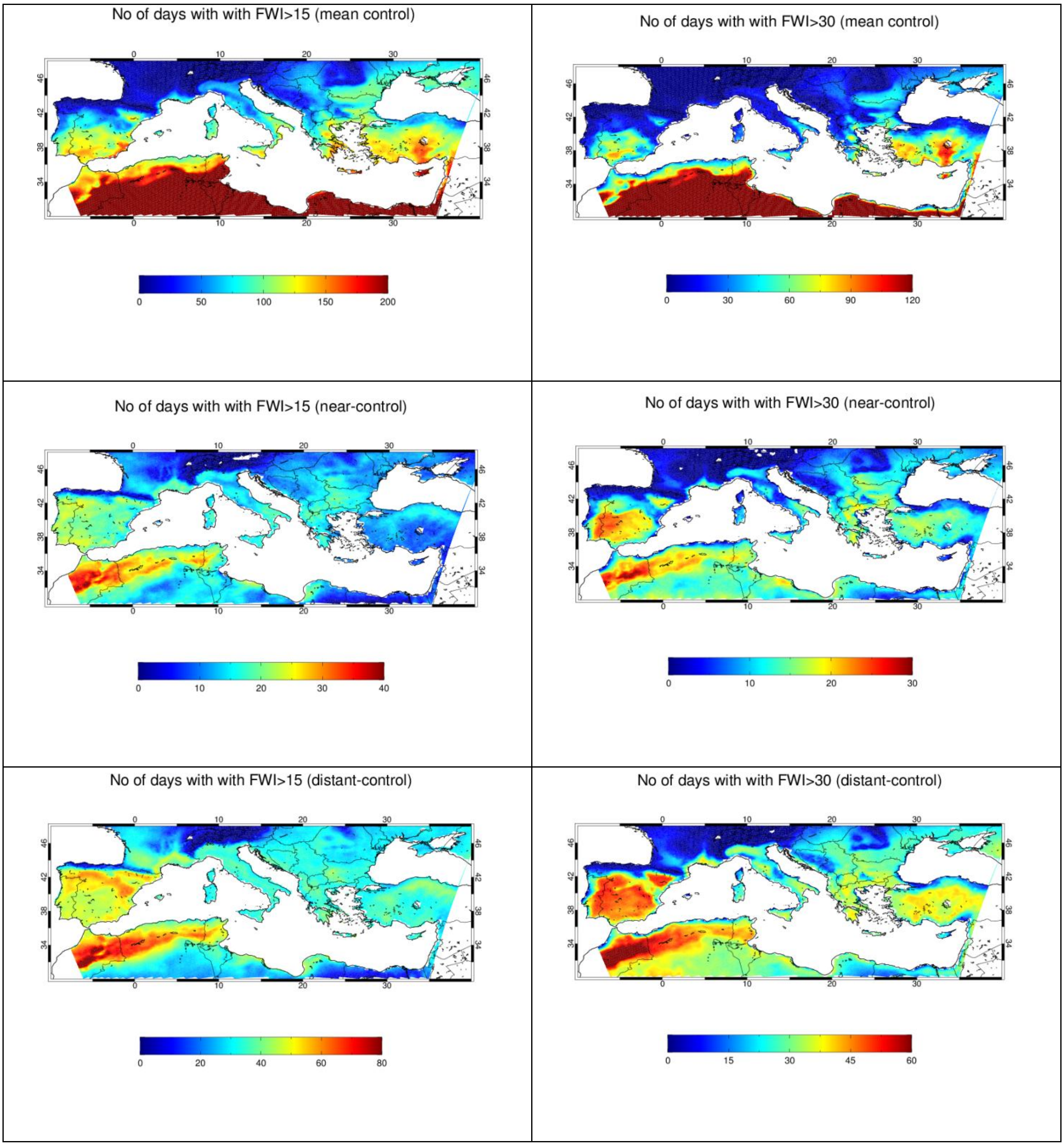


Figure 3: Mean number of days with FWI>15 and FWI>30 for the control period and projected changes in the number of days with FWI>15 and FWI>30 during near and distant future for the Mediterranean region.

As shown in Fig. 1, the days with fire risk are expected to increase in the entire domain, for the near future. In the southern part of the Iberian Peninsula, Morocco and Tunisia an increase of up

to one more month of increased fire risk per year is expected. In Eastern continental Greece, Italy and Sicilia, an increase of up to 20 more days with increased fire risk is estimated.
The increase in the days of fire risk is even greater for the distant future. For the Iberian Peninsula, Morocco and Tunisia the period of increased fire risk lengthens substantially, reaching values of up to 60 more days per year. Furthermore, substantial increases of approximately 30 days or more will be evident in Greece, Italy and Sicily. Finally, by the end of the century, an increase of up to 40 more days per year with increased fire risk is expected at the coastal areas of France.

3. Forest fire vulnerability assessment for Greece

In the previous sections, the changes in indicators of relevance to climate change and fire risk for the Mediterranean basin were presented. Since in this CLIMRUN workpackage (WP6), Greece is the main target region for studying future fire risk with regards to climate change, this section focuses on the forest vulnerability assessment as well as the possible adaptation options only for the Greek territory.

The word ‘vulnerability’ is usually associated with natural hazards like floods, droughts, forest fires and social hazards like poverty etc. Recently, it is extensively used in climate change literature to denote the extent of damage a region is expected to be affected by various factors influenced by climate change. In the context of climate change there are many studies on vulnerability and its definitions vary according to the perception of the researchers.

For the purpose of this report, we follow the IPCC Third Assessment Report according to which vulnerability is defined as “*The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity*” (McCarthy et al. 2001). Thus as per this definition, vulnerability has three components: exposure, sensitivity and adaptive capacity. These three components are described as follows (IPCC 2001):

- **Exposure** can be interpreted as the direct danger (i.e., the stressor), and the nature and extent of changes to a region’s climate variables (e.g., temperature, precipitation, extreme weather events).
- **Sensitivity** describes the human–environmental conditions that can worsen the hazard, ameliorate the hazard, or trigger an impact.
- **Adaptive capacity** represents the potential to implement adaptation measures that help avert potential impacts.

The first two components together represent the potential impact and adaptive capacity is the extent to which these impacts can be averted. Thus vulnerability is potential impact minus adaptive capacity. This leads to the following mathematical equation for vulnerability:

Vulnerability=Impact-Adaptive capacity

where

Impact= sensitivity * Exposure

Under this framework, a highly vulnerable system would be a system that is very sensitive to modest changes in climate, where the sensitivity includes the potential for substantial harmful effects, and for which the ability to adapt is severely constrained.

According to the ATEAM (Advanced Terrestrial Ecosystem Analysis and Modelling) Project, high potential impact and low adaptive capacity constitutes a high degree of vulnerability for the system (ATEAM 2004). Adaptive capacity according to Brooks (2003) has no direct implications to current vulnerability and can only diminish future vulnerability. IPCC (2007) defines adaptive capacity as the ability of a human-environment system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

In this section, the vulnerability of Greek forests to the future climate changes is assessed in terms of their sensitivity, exposure and adaptive capacity based on the available quantitative and qualitative data for Greece according to the aforementioned definitions. In particular, exposure is defined as the degree to which forests will be affected by climate change, sensitivity is the degree to which forests are exposed to land hazard that will be discussed later in detail, while the adaptive capacity is defined by the ability of forests to adapt to changing environmental conditions which is also enhanced by the measures implemented in the country, in order to mitigate the adverse impacts of climate change on this sector. The same methodology was used in EU LIFE+ project CYPADAPT which provided the national adaptation plan for the island of Cyprus. In particular the reader is referred to CYPADAPT deliverable 3.4downloadable from http://uest.ntua.gr/cypadapt/?page_id=105

3.1. Assessment of Impact

3.1.1. Exposure

As mentioned above, exposure reflects both the direct danger (stressor) and the extent of changes to a region's climate variables. In order to study the exposure of Greek forests to forest fires, climate indices and the meteorologically based Fire Weather Index (FWI) will be examined.

Tables 1-2 present mean control values as well as the changes in the near and distant future of the aforementioned indices for Greece. Most of the indices presenting below derived from the product application for '*Future fire risk in Greece and its sub-regions*' hosted in the IERSD/NOA

site under the 'Web-platform for Climate change impacts' tab (http://www.meteo.noa.gr/oikoskopio/index.php?lng=en-US) and in the WWF Greece website of 'Oikoskopio' (http://www.oikoskopio.gr/map).
Greece was divided into four sub-regions following geographical and climatologic criteria, in order for our results to be presented in a more comprehensive and illustrative way.

Table 1: Values of indices with particular relevance to forest fire risk for Greece for the control period (1961-1990)

	Eastern lowlands	Eastern high elevation areas	Western lowlands	Western high elevation areas
No of dry days (P<1mm)	290-310	270-310	250-270	210-250
Max length of dry spell (days)	80-120	70-90	70-90	30-70
No of days with Tmax>35 °C	20-40	5-20	5-15	10
Average summer Tmax (°C)	31-35°C	27-30°C	29-32°C	25-27°C

Table 2: Potential future changes in indices with particular relevance to forest fire risk for Greece.

		Eastern lowlands	Eastern high elevation areas	Western lowlands	Western high elevation areas
No of dry days (P<1mm)	Near Future	+5-15	+5-15	+5-10	+5-10
	Distant Future	+15-20	+15-30	+12-15	+12-15
Max length of dry spell (days)	Near Future	+10-30	+5-30	+10-20	+10-20
	Distant Future	+20-50	+15-30	+20-30	+15-25
No of days with Tmax>35°C	Near Future	+15-25	+5-15	+10-15	+5-10
	Distant Future	+35-60	+25-40	+40-60	+25-35
Average summer Tmax (°C)	Near Future	+1.5-2.5°C	+1.5-2.5°C	+1.5-2.5°C	+1.5-2.5°C
	Distant Future	+3.5-5.5°C	+4.5-5.5°C	+4.5-5.5°C	+4.5-5.5°C

As it can be seen above, the number of dry days is expected to increase in the entire domain up to 15 and 30 days in the near and distant future, respectively. Maximum increases are expected for the eastern parts of Greece.
In the near future, the increases in the maximum length of dry spell may vary between 5-30 and 10-20 additional days per year in the eastern and western part of Greece, respectively. In the distant future, this increase will be up to 50 additional days for the eastern and up to 30 additional days per year for the western parts.
Moreover, the average summer maximum temperature is expected to increase up to 2.5°C in the near future for the entire domain. At the end of the century this increase will reach 5.5°C in western and northern parts of Greece.

In order to study the present and future exposure of Greek forests to forest fires, fire weather index (FWI) indicators both for the control and the first future period, namely the period 2021-2050, will be examined. As FWI is based solely on meteorological variables the aforementioned changes in temperature and precipitation patterns will be reflected in the FWI patterns throughout the domain of study.
As shown in Figures 4 and 5, derived from the product application for '*Future fire risk in Greece and its sub-regions*' the number of days with elevated fire risk (i.e. FWI>30), in both periods, are higher for the lowlands in the eastern part of Greece. In particular, the Greek domain can be divided into 4 sub-regions of different fire risk behaviour and exposure. These sub-regions are the eastern lowlands and high elevation areas as well as the western lowlands and high elevation areas. As depicted in the figures, the eastern lowlands are more exposed to fire risk followed by eastern high elevation areas. This means that they present a high number of days with elevated fire risk, both for the control and the future period. The western lowlands and high elevation areas are the least exposed regions, as they depict few days with elevated fire risk both for the control and the future period.

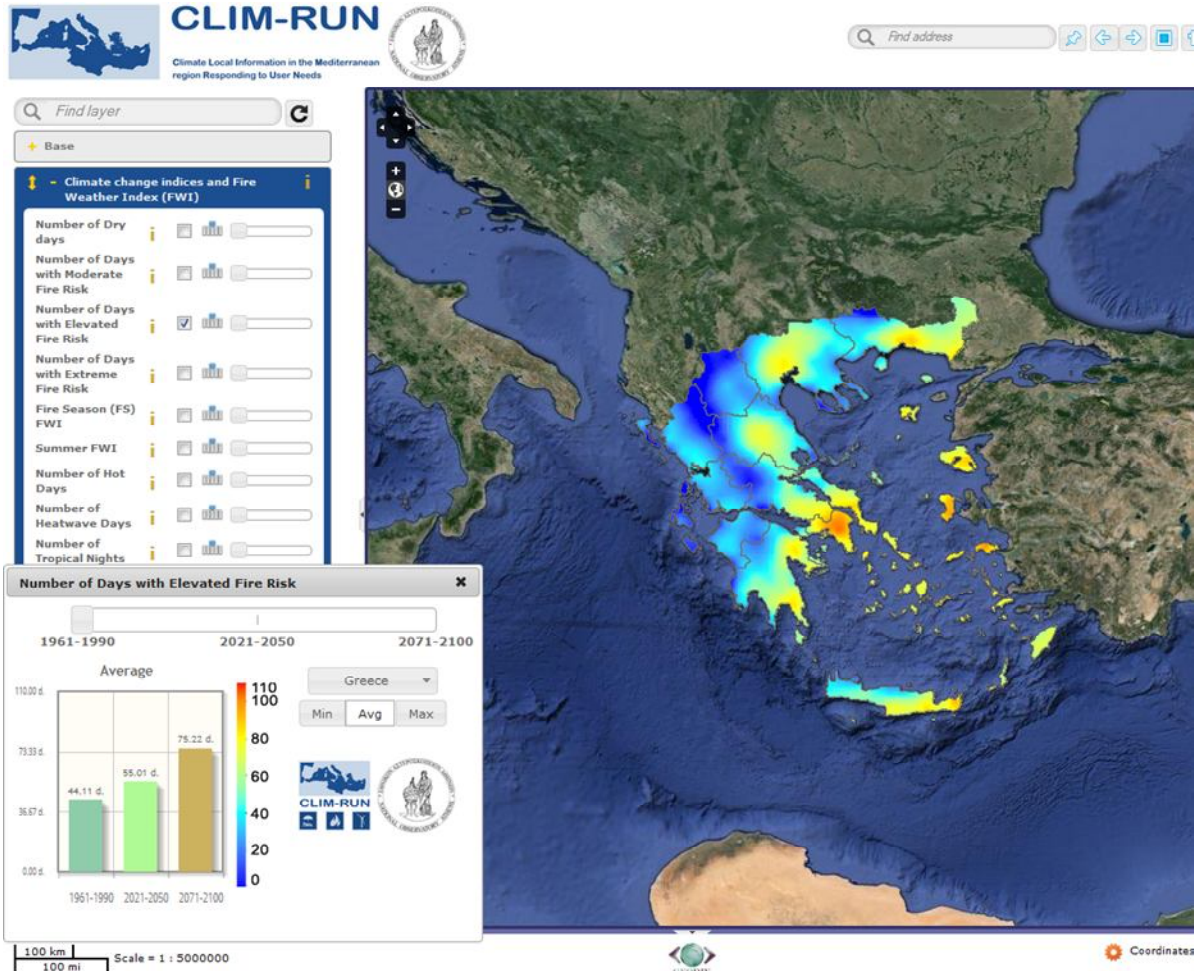


Figure 4: Mean number of days with increased fire risk (FWI>30) for the reference period (1961-1990) for Greece.

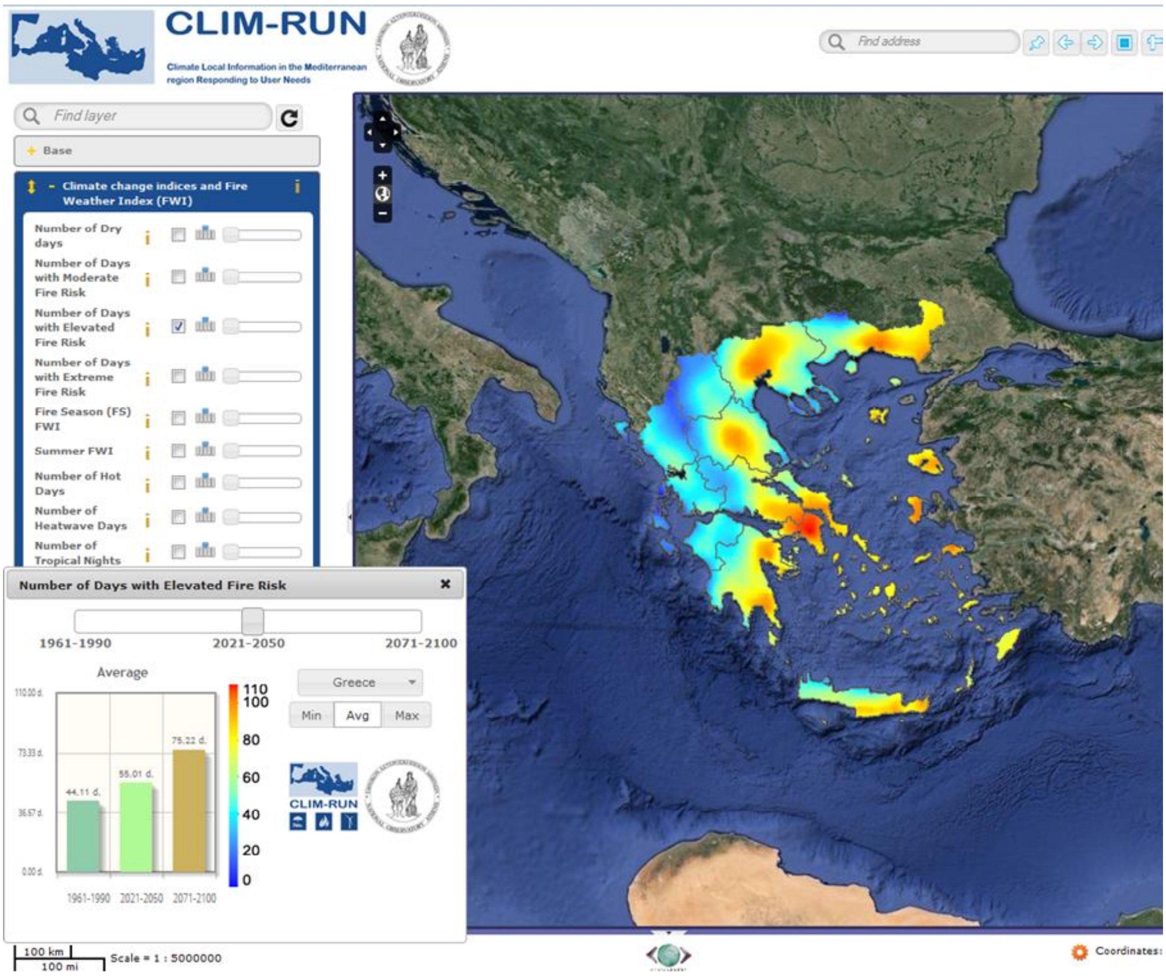


Figure 5: Mean number of days with increased fire risk (FWI>30) for the future period (2021-2050) for Greece.

3.1.2. **Sensitivity**

As already mentioned, sensitivity describes the human–environmental conditions that can worsen or ameliorate the hazard. In our study, static information concerning fire affecting factors, namely topography and vegetation, was used to create a fire hazard map in order to assess the sensitivity factor.

Starting with static information, Hardy (2005) notes that fire hazard expresses the potential fire behaviour for a fuel type, regardless of the fuel type's weather-influenced fuel moisture content. This means that based solely on vegetation information a sensitivity map of an area can be produced. In order to create such a map, vegetation should be categorized in fuel type categories, denoting how much combustible material the vegetation would be able to provide in a possible fire event.

The first step is to use available information on the land cover categories for the entire Greek territory. Land cover categories do not comprise of a single fuel type, and it is possible that a number of different fuel type description models will arise if a detailed survey will occur. However, we believe that it is important to start with a coarse mapping of this static component in order to assess a preliminary form of a Fire Hazard map for the area of Greece.

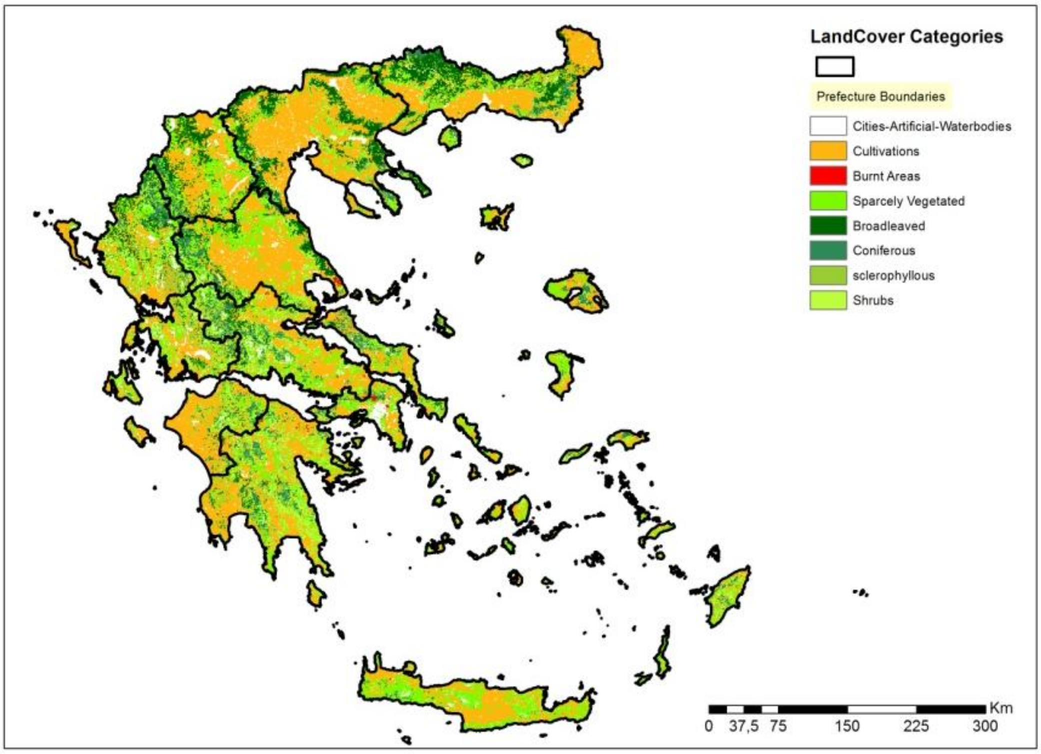


Figure 6: Land cover categories map for Greece

For this information layer, raw data pertaining to land cover types in Greece for the year 2007, which have resulted from the processing of Landsat satellite imagery, through the implementation of automated grading model were used. Original data were obtained from WWF Greece (www.wwf.gr) and were developed by the Laboratory of Forest Management and Remote-Sensing of the Faculty of Forestry and Natural Environment at the Aristotle University of Thessaloniki in Greece. Categorized data are shown in Figure 6.

On the categories shown in Figure 6, certain weights were given to each, according to their evaluated fuel load and combustibility. For example, shrubs and sclerophyllous vegetation were assigned the higher weights contrary to the burnt areas and agricultural cultivations that were given much lower weights. Cities, artificial constructions and water bodies were assigned zero weights.

It is also known that topography affects forest fires, in terms of aspect and slope. Aspect generally refers to the horizontal direction to which a mountain slope faces. As south and west aspects are generally hotter and drier than the adjacent north ones in any given area of Greece,

this affects vegetation as well. This means that south facing slope vegetation is usually drier and more fire prone than north facing slopes. Slope affects mainly fire behaviour rather than ignition.

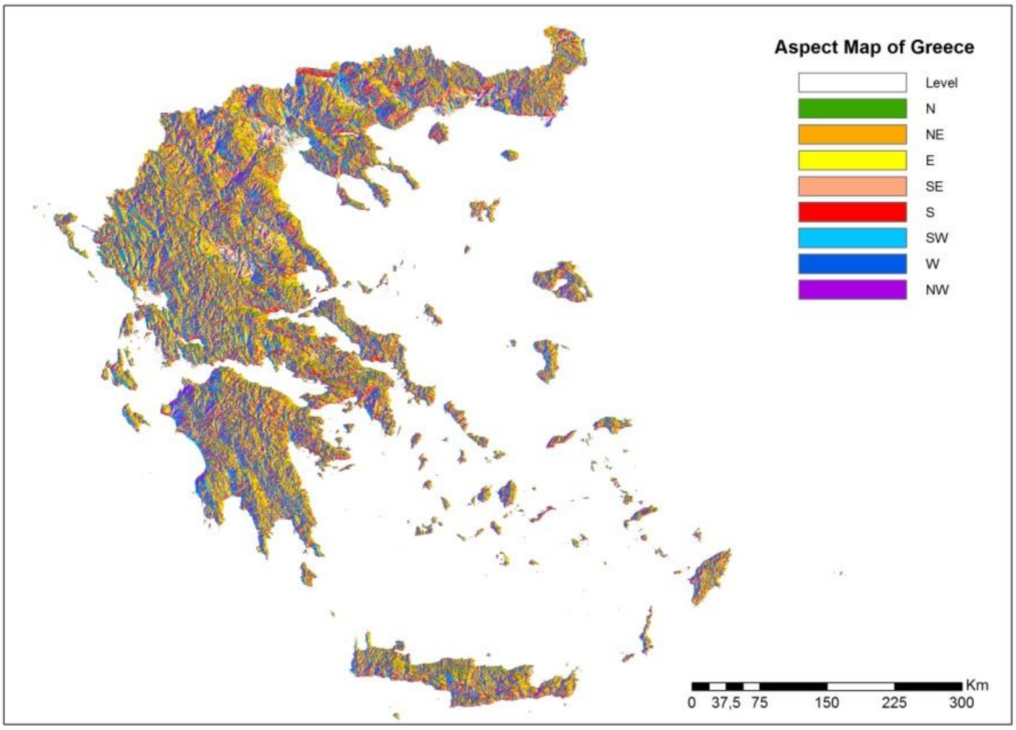


Figure 7: Aspect map of Greece

In the current study, topographic information deriving from a digital elevation model (DEM) developed at the National Oceanic and Atmospheric Administration's National Geophysical Data Center (http://www.ngdc.noaa.gov/mgg/topo/globe.html), available at a 30-arcseconds (approximately 1 km) resolution, was used. The final Fire Hazard map was constructed by combining the two information layers of fire affecting static information mentioned above (landcover and aspect) and giving certain weights to each of their categories. The weights used, are given in Figure 8.

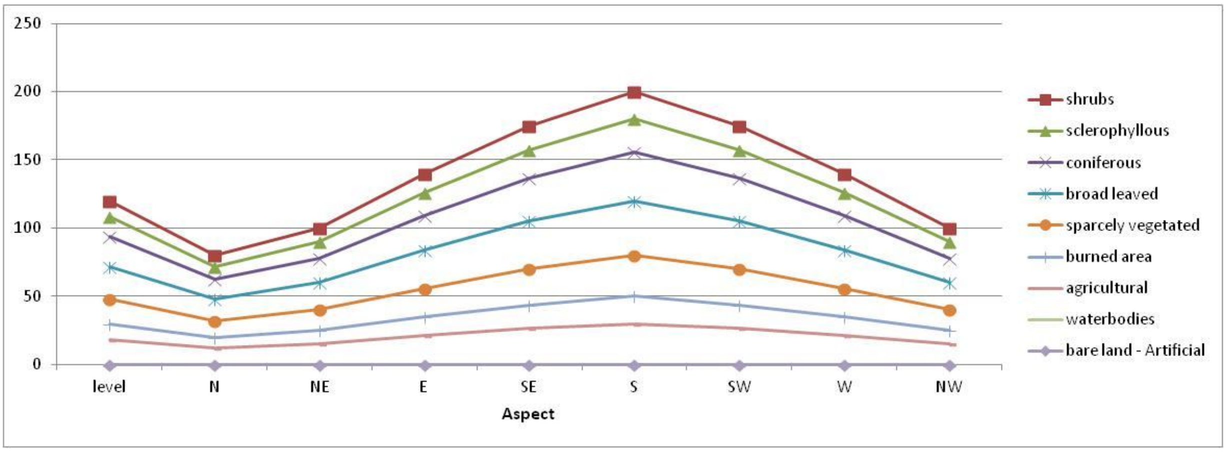


Figure 8: Weights for the different aspects and land cover types used in the current study.

The last step was to categorize the final Fire Hazard Map in six different classes, from the least possible one that is found inside cities, artificial constructions and water bodies to the very high level of the south oriented vegetated areas. Our final results for the whole Greek domain are depicted in Figure 9 (which combines information from Figures 6-8).

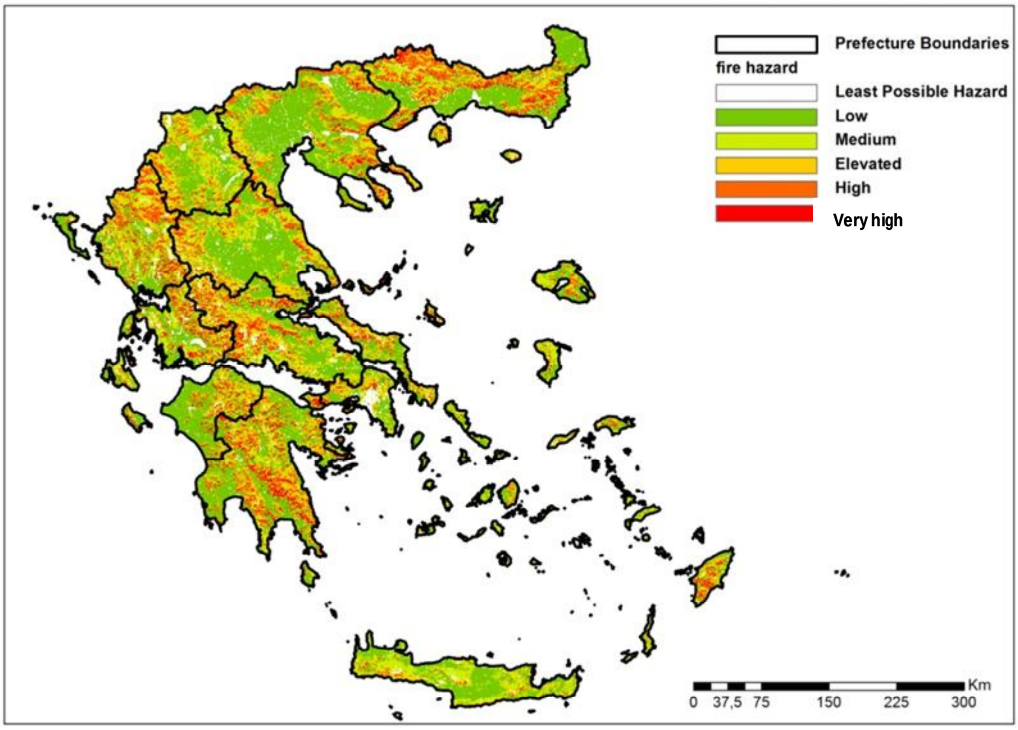


Figure 9: Final Hazard map for Greece

As shown in Figure 9 the high elevation continental areas can be characterized as “high” fire hazard areas while the lowlands can be characterized as “low” and “medium” fire hazard areas.

Part of a future work would be to incorporate human factor, in terms of number of citizens on the area and types of activities taking place in each season (i.e. recreational, agricultural, etc.) and infrastructure.

3.2. Assessment of adaptive capacity

Adaptive capacity is a significant factor in characterizing vulnerability. In climate change literature, adaptive capacity is similar or closely related to other commonly used concepts such as adaptability, coping ability, management capacity, stability, robustness, flexibility, and resilience (Smit and Wandel 2006). According to Brooks (2003), the adaptive capacity of a system or society reflects its ability to modify its characteristics or behavior in order to better cope with existing or anticipated external stresses and changes in external conditions. IPCC (2001) describes *adaptive capacity as the potential or ability of a system, region, or community to adjust to the effects or impacts of climate change (including climate variability and extremes)*. The capacity to adapt is context-specific and varies from country to country, from community to community, among social groups and individuals, and over time (IPCC 2001; Smit and Wandel 2006). Adaptive capacity is considered to be "a function of wealth, technology, education, information, skill, infrastructures, access to resources, and stability and management capabilities (McCarthy et al. 2001).

Our SET person in charge, Anargyros Roussos, concluded after discussions with the local stakeholders and with the help of the questionnaire (see annex in this deliverable) handed out to them that when vegetation information and changes in meteorological conditions due to climate change are combined, forests of northern and western Greece are expected to be more adaptive than their eastern counterparts. That is mainly due to the fact that the aforementioned areas receive greater amounts of precipitation, together with less human activities due to lower population density, compared to southern and eastern areas of Greece (Attica or Crete, for example). The already predominating vegetation species are not certain to survive the projected climate change, yet the forecasted conditions are most likely to be able to support a tall forest ecosystem, assuming that no major environmental catastrophe will occur in the meantime. As an overall assumption, all ecosystems in Greece are likely to degrade given less precipitation and more extreme climate events are going to take place in the future.

In order to assess the adaptive capacity of Greek forests and to select the most appropriate adaptation options for Greece, a Multi-Criteria Analysis (MCA) approach has been used like in CYPADAPT project (http://uest.ntua.gr/cypadapt/) . Multi-criteria analysis (MCA) is proposed as the most appropriate method to accomplish decision making in the field of adaptation to climate change. MCA can accomplish handling of all available technical information and incorporation of different stakeholder views.

MCA is used to evaluate options based on a set of criteria. Stakeholder analysis and expert judgment provides identification of all possible decisions/options. In the following, relevant criteria are selected in order to prioritize alternative adaptation options. Through weights and scores, the performance of each adaptation option is measured against criteria. This step in particular, reflects the preferences of the decision makers. Finally, the weighted sum of the different criteria is used to rank the different options (UNFCCC-United Nations Framework Convention on Climate Change, 2000).

In terms of adaptation to climate change, the Multi-criteria analysis (MCA) is able to allow the assessment of various different adaptation options against a significant number of criteria. Every criterion is given a relevant weighting. This weighting can result to an overall score for each adaptation option. The adaptation option with the highest score is most prominent to be selected. Furthermore, the Multi-criteria analysis (MCA) allows the assessment of various different adaptation options when only partial data is already available and when cultural and ecological considerations are difficult to be quantified.
Moreover, efficiency of the MCA result relies on the (un)certainty of the information relevant to the selected criteria, the relative priorities given to criteria (weights, scores) and whether the weights are commonly agreed by stakeholders. In order to check robustness of the result for changes in scores and/or weights, sensitivity analysis must be used (UNFCCC, 2000).

In terms of adaptation to climate change five steps are taken in MCA assessment of adaptation options in summary:
1. Agree on the objective of adaptation and identify various potential adaptation options.
2. Agree on criteria of decision making: Description of each criterion is essential, including the unit and span of all possible scores. This would ensure that participants involved in the assessment process have a common understanding.
3. Score each adaptation option performance against each of the selected criteria. When this is completed, standardization is essential in case scores of the various criteria differ in units (e.g. monetary or qualitative values) or spans (e.g. 1 – 5 or 0 –100). Transformation of the scores into similar units permits effective comparison of the criteria. A value function is used for standardization or a standardization procedure where scores lose their dimension and their measurement unit.
4. Weight assignment to criteria in order to reflect priorities. In particular, if there are criteria more important than others and there are known priorities then different weights could be assigned in different criteria. In this way their relative importance is indicated.
5. Ranking of the options. In each option a total score can be calculated by multiplication of the scores. Scores have been previously standardized with their appropriate weight. Finally weight adjusted scores must be aggregated and compared.
MCA results in a ranked order of adaptation options and an appreciation of strengths and weaknesses of all the attributes of each of the options.

The MCA type selected for the current study is the Analytical Hierarchy Process (AHP), developed by Saaty (1980). AHP is a widely used method for addressing decision making problems with multiple criteria and a mixture of qualitative and quantitative data inputs.
AHP method can be used efficiently by dividing the problem characteristics into sub-criteria in situations where criteria can be organized into a hierarchy this method. Operation researchers and decision scientists have used this method in the last decades particularly in the USA.
In general, AHP has number of significant advantages. For example, it is a relatively simple method for decision makers. Furthermore, AHP includes collection of pairwise comparison data, especially in the subjective cases, that is an attractive aspect which involves directly the decision makers.

The evaluation criteria which are chosen and used in the framework of the CLIM-RUN Project for the case study of Greece are the following:
I. Efficiency of the Measure
II. Environmental Friendliness
III. Supporting the Prevention of Climate Impacts
IV. Urgency for Implementing the Measure
V. Usefulness of Implementation Irrespective of Climate Change
VI. Technical Viability
VII. Economic Viability
VIII. Social Acceptance

As has already been mentioned, each adaptation measure performance was scored by the SET member against each of those criteria. Each measure was scored against each criterion on a scale from 0 to 100. In this scale 1 represents the least preferred option and 100 is associated with the most preferred option. More analytically, the scores are:
80<excellent ≤100,
60<very good ≤80,
40<good ≤ 60,
20<Low ≤40,
0≤Very Low ≤20

In case of the criterion *Economic Viability*, the following scale is followed:
80<extremely expensive ≤100,
60< extremely expensive ≤80,
40<expensive≤ 60,
20<not very expensive ≤40,
0≤inexpensive ≤20

After the implementation of the MCA method, the proposed adaptation measures for Greek forests in descending order of priority are the following:

1. Fire Prevention measures

2. Inclusion of the private forest covered areas in the fire fighting schemes of the Department of Forests
3. Classification of forests according to the risk of fire, designation of high-risk areas
4. Vital national resources and the implementation of a national fire protection plan
5. Reforestation of burnt areas
6. Immediate reforestation / restoration of areas destroyed by fire and implementation of appropriate silvicultural measures
7. Fire suppression measures
8. Infrastructure to improve forest resilience to fires
9. Set up of infrastructure in the private forest areas for protection from fires
10. Planning and development of forest ecosystems that would make the start and speed of expansion of fires more difficult

Furthermore, some comments concerning the aforementioned adaptation options made by the SET members are the following:

- Preventive measures are of wide social acceptance and have proven to mitigate both the risk of fire, and the effects of the severity of the fire.
- Suppression measures are usually expensive, environmentally harmful due to vast energy footprint. Furthermore, their effectiveness depends directly on the number of active fires under suppression and current weather conditions. Public opinion is often very positive for the Fire Brigade and Suppression forces.
- Fire is part of the ecosystem's dynamics. Protection from fires therefore should refer to the overall management of the ecosystem, focusing on high-risk areas, e.g. wildland urban interface (WUI).
- Burnt areas restoration is a complex process that requires a long period of time (usually more than 10 years), and practice has shown that human interference in restoration processes is not always with positive results. This measure must be used with caution.
- Forests do burn, regardless of their structure and vegetation species. The only scientifically acceptable solution is to split forest fuel (combustible material) with appropriate management techniques.
- Classification of forests according to the risk of fire is one of the very important parts of fire prevention and suppression. Fuel maps should be created immediately.
- Infrastructure installation can hardly protect from fire.
- Prevention and suppression of forest fires should be dealt through a single policy regardless of the ownership status. Of course owners should be informed and updated regarding prevention as well as suppression possibilities.
- Ecosystem includes not only plants and trees, but also animals, birds, insects and the environment they live in (abiotic factor). Therefore, it is not possible to change it into non combustible material on the one hand, and on the other hand, any significant changes in an ecosystem will trigger the loss of its ecological balance.

Finally, the SET expert pointed out the importance of residents of sensitive areas (e.g. Wildland Urban Interface, Wildland Rural Interface, etc) being more aware of prevention issues and protection of their property from fire.

3.3. Assessment of overall vulnerability

As has already been mentioned, vulnerability is defined by the following formula:

Vulnerability=Impact-Adaptive capacity
where **Impact=Sensitivity * Exposure**

Sensitivity, exposure and adaptive capacity are evaluated on the same 6-degree qualitative scale ranging from “least” to “very high” (Table 6).
“Impact” and “Adaptive capacity” should be evaluated on the same scale (1-6). For this to be achieved, the square root of “Sensitivity x Exposure” is used.

Taking into account the findings of sections 3.1 and 3.2, the overall vulnerability of Greek forests to forest fires, was estimated. The results are summarized in Table 7. For ecosystems in the eastern part of the country the vulnerability is medium while lower vulnerability exists for the ecosystems in the western part of the country. In particular, western Greece lowlands have the lowest vulnerability values followed by the higher elevation areas.

Table 6: Degree of sensitivity, exposure & adaptive capacity

Degree of sensitivity and exposure & adaptive capacity		Degree of vulnerability		Legend
Least	1	Least	V≤1	
Low	2	Low	1<V≤2	
Medium	3	Medium	2<V≤3	
Elevated	4	Elevated	3<V≤4	
High	5	High	4<V≤5	
Very high	6	Very high	5<V≤6	

Table 3: Overall vulnerability assessment of forests to climate change in Greece

	Eastern Greece		Western Greece	
	Lowlands	**High elevation areas**	**Lowlands**	**High elevation areas**
Sensitivity	Medium(3)	High(5)	Medium(3)	High(5)
Exposure	Very High(6)	High(5)	Elevated(4)	Elevated(4)
Adaptive Capacity	Low(2)	Low(2)	Medium(3)	Medium (3)
Vulnerability	Medium	Medium	Least	Low

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5. Annex

##	Measure Group	Measure	Efficiency of the Measure	Urgency for Implementing the measure	Usefulness of Implementation Irrespective of Climate Change	Technical Viability	Environmental Friendliness	Supporting the Prevention of Climate Impacts	Economic Viability	Social Acceptance
			100 - Most Efficient 0 - Least Efficient	100 - Most Urgent 0 - Least Urgent	100 - Most Useful 0 - Least Useful	100 - Most Viable 0 - Least Viable	100 - Most Env. friendly 0 - Least Env. Friendly	100 - Most Supporting 0 - Least Supporting	100 - Most Expensive 0 - Least Expensive	100 - Most Acceptable 0 - Least Acceptable
1/23	Measures to confront forest fires	Fire Prevention measures	100	100	100	75	100	90	15	85
		Comments In general, preventive measures are of wide social acceptance and have proven to mitigate both the risk of fire, and the effects of fire severity.								
2/23		Fire suppression measures	40	30	30	20	1	10	100	70
		Comments Suppression measures are usually expensive and environmentally harmful due to vast energy footprint. Furthermore, their effectiveness depends directly on the number of active fires under suppression and weather conditions at that time. Public opinion is often very positive for Fire Brigade and Suppression forces in general (volunteers etc).								
3/23		Vital national resources and the implementation of a national fire protection plan	70	50	50	50	50	50	50	25
		Comments Fire is part of the ecosystem's dynamics. Protection from fires therefore should refer to the overall ecosystem management, focusing on high-risk areas, eg wildland urban interface (WUI)								

##	Measure Group	Measure	Criteria							
			Efficiency of the Measure	Urgency for Implementing the measure	Usefulness of Implementation Irrespective of Climate Change	Technical Viability	Environmental Friendliness	Supporting the Prevention of Climate Impacts	Economic Viability	Social Acceptance
			100 - Most Efficient 0 - Least Efficient	100 - Most Urgent 0 - Least Urgent	100 - Most Useful 0 - Least Useful	100 - Most Viable 0 - Least Viable	100 - Most Env. friendly 0 - Least Env. Friendly	100 - Most Supporting 0 - Least Supporting	100 - Most Expensive 0 - Least Expensive	100 - Most Acceptable 0 - Least Acceptable
4/23	Measures to confront forest fires	Immediate reforestation / restoration of areas destroyed by fire and implementation of appropriate silvicultural measures	50	50	50	30	50	30	70	80
		Comments Restoration of burnt areas is a complex process that requires a long period of time (usually more than 10 years), and experience has shown that human interference in restoration processes is not always with positive results. This measure must be used after special study.								
5/23		Infrastructure to improve forest resilience to fires	10	1	10	30	10	10	95	30
		Comments Forests do burn, regardless of their structure and vegetation species. The only scientifically acceptable solution is to break forest fuel continuity (combustible material) with appropriate management techniques.								

##	Measure Group	Measure	Criteria							
			Efficiency of the Measure	Urgency for Implementing the measure	Usefulness of Implementation Irrespective of Climate Change	Technical Viability	Environmental Friendliness	Supporting the Prevention of Climate Impacts	Economic Viability	Social Acceptance
			100 - Most Efficient 0 - Least Efficient	100 - Most Urgent 0 - Least Urgent	100 - Most Useful 0 - Least Useful	100 - Most Viable 0 - Least Viable	100 - Most Env. friendly 0 - Least Env. Friendly	100 - Most Supporting 0 - Least Supporting	100 - Most Expensive 0 - Least Expensive	100 - Most Acceptable 0 - Least Acceptable
6/23	Measures to confront forest fires	Classification of forests according to the risk of fire, designation of high-risk areas	100	100	50	50	100	50	1	50
		<u>Comments</u> This is one of the very important parts of fire prevention and suppression. Fuel maps should be created immediately.								
7/23		Set up of infrastructure in the private forest areas for protection from fires	10	1	10	30	10	10	95	30
		<u>Comments</u> Infrastructure installation can hardly protect from fire.								

##	Measure Group	Measure	Criteria							
			Efficiency of the Measure	Urgency for Implementing the measure	Usefulness of Implementation Irrespective of Climate Change	Technical Viability	Environmental Friendliness	Supporting the Prevention of Climate Impacts	Economic Viability	Social Acceptance
			100 - Most Efficient 0 - Least Efficient	100 - Most Urgent 0 - Least Urgent	100 - Most Useful 0 - Least Useful	100 - Most Viable 0 - Least Viable	100 - Most Env. friendly 0 - Least Env. Friendly	100 - Most Supporting 0 - Least Supporting	100 - Most Expensive 0 - Least Expensive	100 - Most Acceptable 0 - Least Acceptable
8/23	Measures to confront forest fires	Inclusion of the private forest covered areas in the fire fighting schemes of the Department of Forests	100	100	100	50	100	50	50	50
		Comments Prevention and suppression of forest fires in general should be dealt through a single policy regardless of the ownership status. Of course owners should be informed and updated regarding prevention as well as suppression possibilities and obligations.								
9/23		Planning and development of forest ecosystems that would make the start and speed of expansion of fires more difficult	1	1	1	1	1	1	100	50

##	Measure Group	Measure	Criteria							
			Efficiency of the Measure	Urgency for Implementing the measure	Usefulness of Implementation Irrespective of Climate Change	Technical Viability	Environmental Friendliness	Supporting the Prevention of Climate Impacts	Economic Viability	Social Acceptance
			100 - Most Efficient 0 - Least Efficient	100 - Most Urgent 0 - Least Urgent	100 - Most Useful 0 - Least Useful	100 - Most Viable 0 - Least Viable	100 - Most Env. friendly 0 - Least Env. Friendly	100 - Most Supporting 0 - Least Supporting	100 - Most Expensive 0 - Least Expensive	100 - Most Acceptable 0 - Least Acceptable
		Comments Ecosystem does not only include plants and trees, but also animals, birds, insects and the environment they live in (abiotic factor). Therefore it is not possible to change it into non combustible material on the one hand, and on the other hand, any significant changes in an ecosystem will trigger the loss of its ecological balance.								
	Fill in your own proposed adaptation measures	Awareness raising on residents of sensitive areas (eg Wildland Urban Interface, Wildland Rural Interface, etc) on issues of prevention and protection of their property from fire.	80	80	80	60	100	50	10	80
		Comments The citizen needs to get into the first line of defence regarding forest fires, therefore it is necessary to raise his/her awareness and keep him/her informed, to make him/her actively involved on the issue.								