STSM Report

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July 2014

1 Introduction

An increase in fire hazard in the recent years has been reported in several areas with Mediterranean climate. In the countries of the Mediterranean Basin, as much as 10% of all the forests and shrublands are burned annually by wildland fires, which also constitute a serious threat to structures built in the rural-urban interface. The limited expansion of natural ecosystems in the Mediterranean regions, in combination with their high susceptibility to fire, necessitates the development of scientifically based programs of fire prevention, protection and control.

At the same time, an interest in a coppice silvicultural system has been renewed due to their advantages in terms of higher biodiversity, and the support which the EU states channel to energy production from renewable resources such as coppice firewood. An example of the renewed interest towards coppices in Europe is the COST Action FP 1301 started in 2013, which has the aim of bringing together European scientists, experts and young scholars to exchange knowledge on coppice forestry and to develop innovative management and harvesting concepts/techniques for modern multifunctional coppice management systems as well as of recent research studies on the discrimination of silvicultural systems (Bottalico et al., 2014).

Therefore, the interest on coppice forest systems must be further motivated by a thorough analysis of possible risks and advantages in the field of forest fires.

So far, some researchers suggest that coppice forests are particularly vulnerable to fire due to their biomass structure and therefore fuel management should focus on thinning and transformation to high forests (Ciancio and Nocentini, 2004, Raftoyannis et al. 2014). Additionally, national legislation in Mediterranean countries favors, where possible, coppice conversion to high forest as a fuel treatment measure (Xanthopoulos et al., 2006). However there is clearly a lack on the literature of a comparative study on the topics.

2 Focus of the study

The aim of the STSM was the analysis of the landscape effects on fire hazard arising from different silvicultural systems. The analysis was based on fuel and topography information at landscape scales utilizing spatial tools to estimate wildfire exposure profiles

3 Activities during the STSM stay

During the STSM stay the following activities were carried out:

- Attendance of a lecture/seminar given by Dr. Mark Finney (USDA Forest Service, Missoula Fire Sciences Laboratory, Montana, US) (Figure 1 and Figure 2)
- Field sampling for developing custom fuel models in the area of Monte Pisanu and Foresta Burgos (North Sardinia) along with Dr. Michele Salis, PhD, (DIPNET-CMCC), Dr. Olga Munoz Lozano (assistant researcher DIPNET), and Dr. Roghayeh Jahdi (Univ. Teheran)
- Training on Farsite and Flammap fire behavior software by Dr. Michele Salis

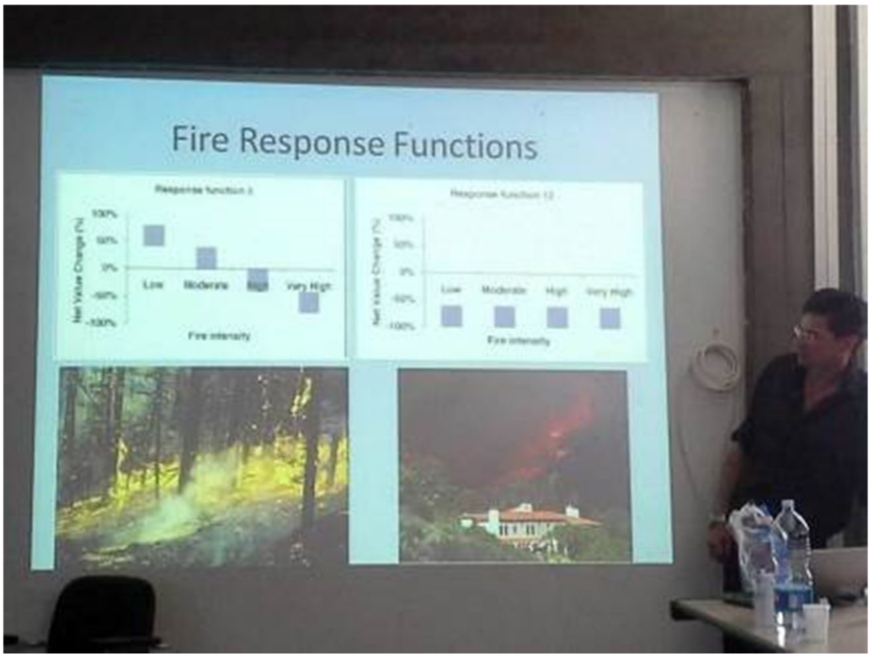

Figure 1 Lecture -Seminar attended on fire risk issues, given by Dr. Mark Finney

Figure 2 Lecture -Seminar attended on fire risk issues, given by Dr. Mark Finney

- Meeting with local forest service experts and scientific staff
  - Giovanni Piras (Ente Foreste Sardegna);
  - Tonino Cabizzosu (Ente Foreste Sardegna),
  - Roberto Pinna Nossai (Agenzia Regionale Protezione Ambiente Sardegna)
  - Dr. Valentina Bacciu (IAFENT- CMCC)

4 Methodology

The approach relied on the custom fuel model development, development of GIS study specific database and spatial explicit fire simulation in Italy and Greece.

A set of raster thematic layers related to the main environmental factors that affect the fire behavior were gathered for both areas: topography, vegetation and meteorological conditions. The topography factor includes three different layers (i.e. elevation, slope and aspect), which were derived from a digital elevation model.

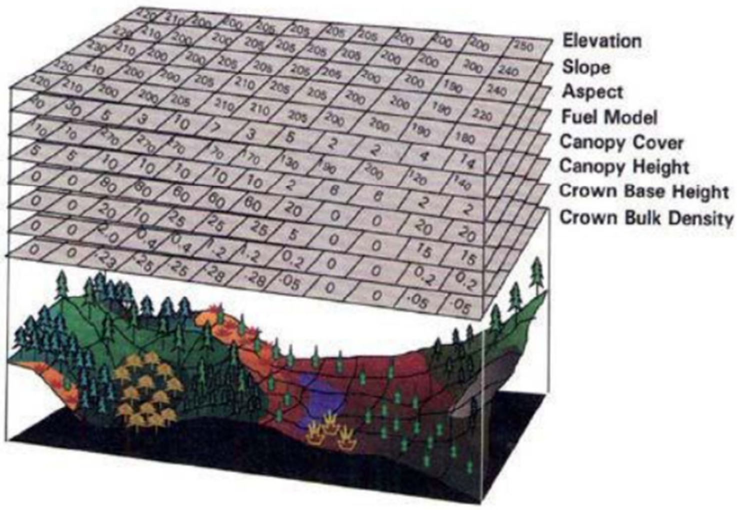

Figure 3 Raster landscape input layers required for the FARSITE simulation (Finney 1998).

The vegetation factor is composed by the fuel model and the canopy cover layers which are derived from remote sensing datasets. The fuel model map aims to provide a detailed structural description of the vegetation, by using standard or custom fuel models. The canopy cover layer describes the percentage of the horizontal surface plane covered by tree canopies across the landscape. Fuels were interpreted based on available remote sensing datasets and then assigned to standard or specific custom fuel models, developed as part of earlier research.

Predominant weather conditions and wind velocities were acquired from the Greek and Italian authorities in the vicinity of each area.

Field fuel sampling over coppice and high forests plots in Sardinia was carried out in order to develop custom fuel models for the respective classes. Representative locations with typical ('average') fuel conditions for each area were selected. Surface fuels biomass inventory was applied in every representative location and fuel parameters were measured.

4.1 Study areas

4.1.1 Italy

Monte Pisanu is located in North Sardinia, and is a State forest protected by royal decree since 1886. It stretches among the mountains of the municipalities of Bono and Bottidda, in the Goceano, and has an overall surface area of 1994 hectares (Figure 4).

The landscape vegetation is dominated by the *Quercus pubescens* oak, that pushes right up over 1000 m above sea level. At lower altitudes the vegetation is constituted more by cork oaks and holm oaks.

It is a public forest, identified as Site of Community Importance (SIC) by the European Union (ITB001102 Mountain range of Marghine-Goceano). The vegetation is characterized by woods of *Quercus ilex* and *Quercus pubescens*, individuals of *Taxus bacata*, *Ilex aquifolium*, *Quercus suber* and *Castanea sativa*.

In the area strong winds (35 km/h) prevail from W, SW and NW.

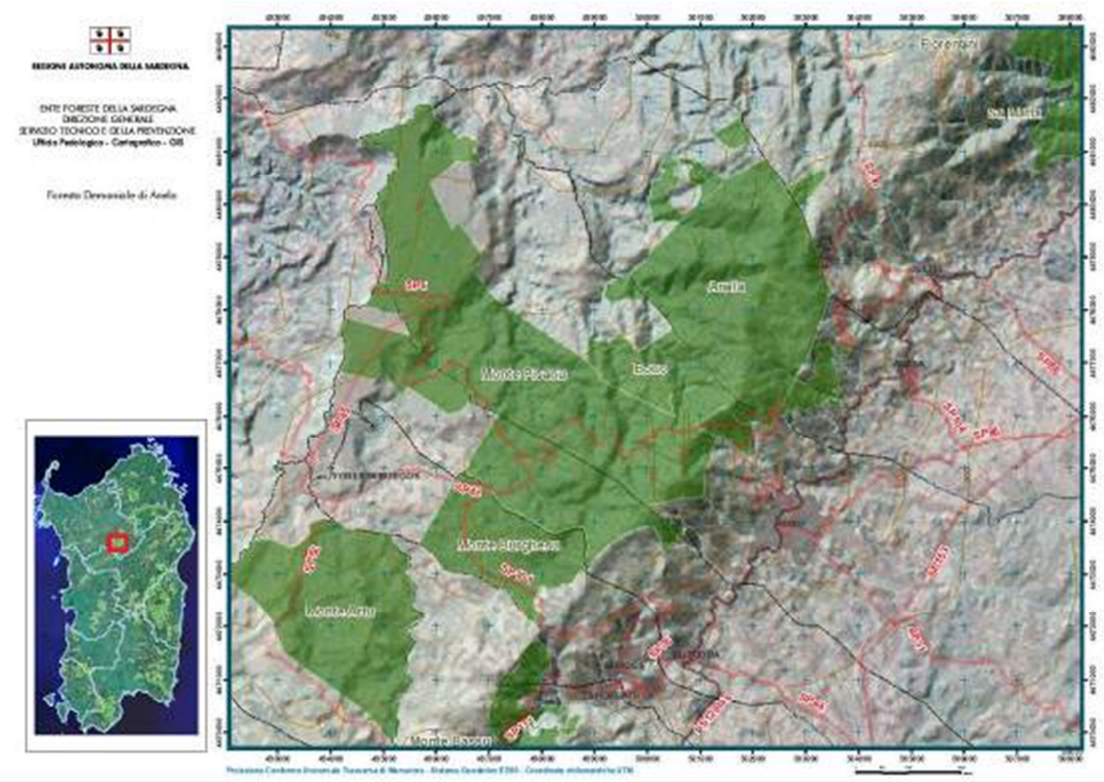

Figure 4 Location of the Monte Pisanu forest

4.1.2 Greece

Mount Voras is located in the north part of Greece, between 41°03' latitude (north) and 22°03' longitude (east). It is the third highest mountain in Greece and reaching 2,524 m in altitude. It is a large area of about 39,000 hectares with its landscape dominated by gentle slopes. Geologically, there is a great variability of substrates comprised of limestone, schist, gneiss and ophioliths. There are extensive, densely forested areas that hold a significant asset of timber (mainly *Fagus sylvatica* forests). The area is also significant because of the presence of relict stands of *Quercus trojana* woods, a vegetation types with a very limited distribution in Greece. Plots existed

4.2 Forest fuel sampling

All the areas in the study site of Sardinia were stratified on vegetation maps according to the dominant vegetation type and the management regime. All the stratified areas were surveyed on site and 26 (14 in Italy and 12 in Greece) representative locations (plots) with typical ("average") fuel conditions for each area were selected (Figure 5 to Figure 9). Field plots in Voras site have been measured in detail on 2010 in the framework of a fire risk project financed by the Greek Fire Brigade; during summer 2014, these locations were re-visited in order to verify the silvicultural system used in the area.

Figure 5 Plot sampling over Sardinia in high *Q. pubescence* forest

Figure 6 Plot sampling over Sardinia in coppice *Q. pubescence* forest

Surface fuel load was estimated with the Brown et al. (1982) method for inventorying surface fuel biomass. Fuel parameters were measured in each location as follows (Brown et al. 1982):

1) The 1-h, 10-h, 100-h, and total fuel loads were measured with the transect-line method (four 30 m-long transects)

2) Foliage load, litter load and depth, and herbaceous (live) vegetation loads were measured in six 10 m2 sampling plots with the clip and weight method.

The 1-h, 10-h, 100-h fuels correspond to plant parts (branches) with diameters of 0.0–0.5 cm, 0.6–2.5 cm, and 2.6–7.5 cm, respectively (Brown et al. 1982). The clip-and-weigh method was used to determine all fuel loads by size category. The percentage of the total area covered by each fuel type (shrub herbaceous, litter, etc.) was determined with the line intercept method in the fuel transects (30 m-long) that were used for fuel measurements (Bonham 1989). All fuel loads (fuel weight per unit surface area) were expressed on a dry-weight basis.

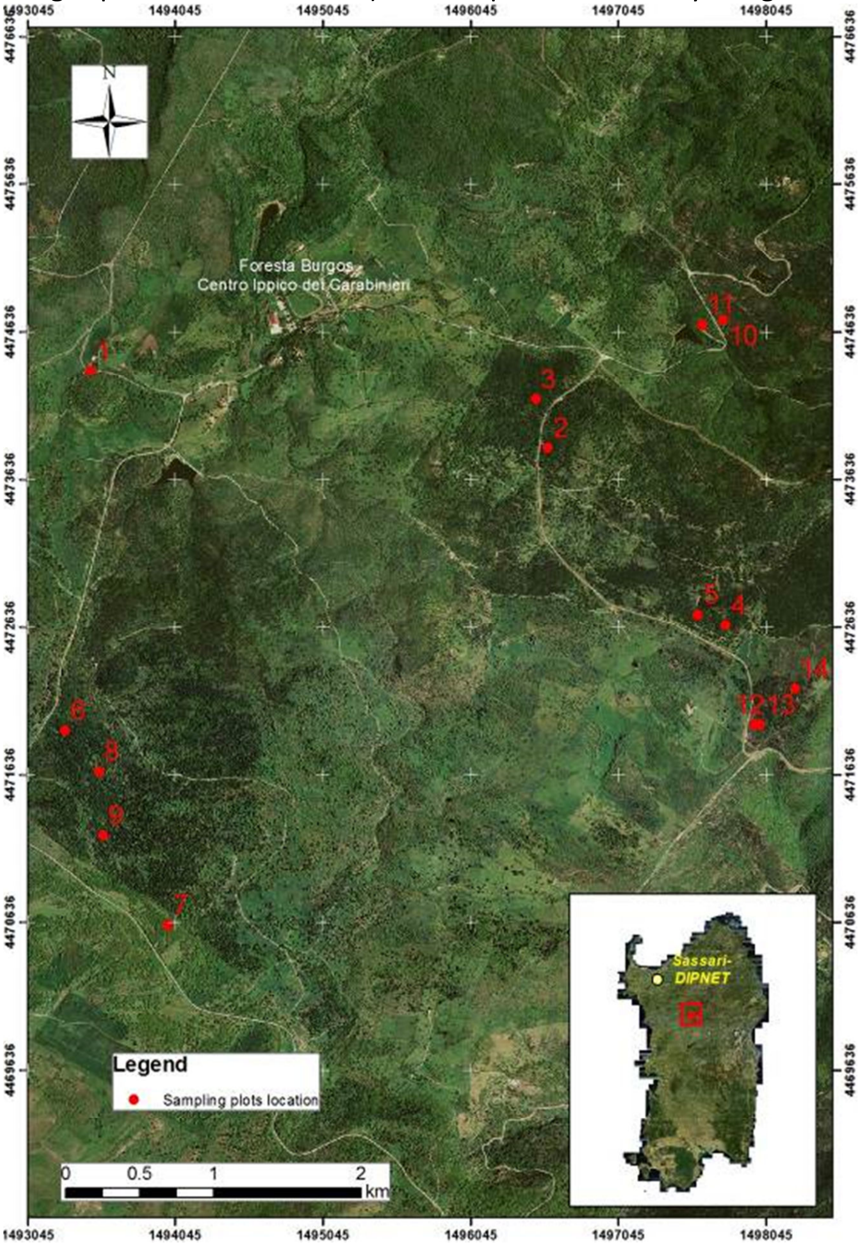

Figure 7 Location of Italian sampling plots

Figure 8 Biomass weighting over Sardinia sampling plot

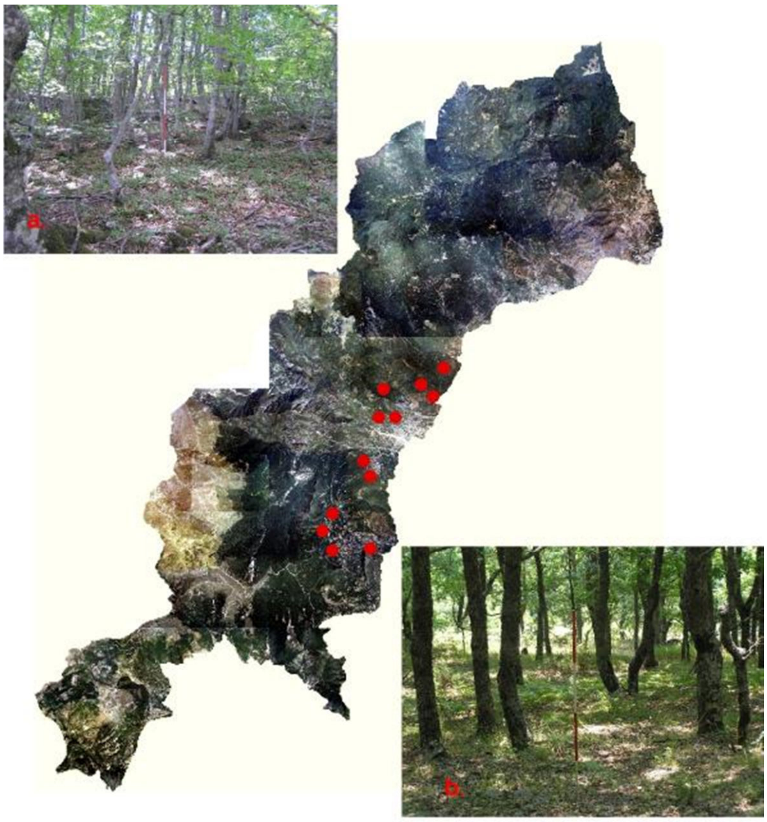

Figure 9 Location of sampling plots in Mt Voras (A: coppice, B: high forest plots).

4.3 Burn probability and CLF maps

In order to generate burn probability and CFL (weighted probability of flame length given a fire occurrence) maps, a landscape fire behavior modeling approach was used. Simulated wildfire spread and behavior was performed with the MTT algorithm (Finney 2002), as implemented in FlamMap software (Finney 2006). The MTT algorithm replicates fire growth by Huygens' principle where the growth and behavior of the fire edge is a vector or wave front (Richards 1990). MTT simulations (Figure 10) were conducted by using as input data the DTM of the areas (http://www.sardegnageoportale.it/index.php?xsl=1594&s=40&v=9&c=8756&n=10) the spatial extent of the fuel models and the fuel parameters values of each model in the study area were and used to build 30 m x 30 m raster input files for fire simulations (Figure 11 and Figure 12). Canopy cover information of the forest area was extracted from the satellite imagery (Greece) and orthophoto -Sardegna FotoAeree 2006 (Italy). Heat content and surface area-to-volume ratio values for the fuel models developed were obtained by Dimitrakopoulos and Panov (2001). Fire behavior was simulated by applying random ignitions across the study areas. The duration of all fires was set to 360 minutes.

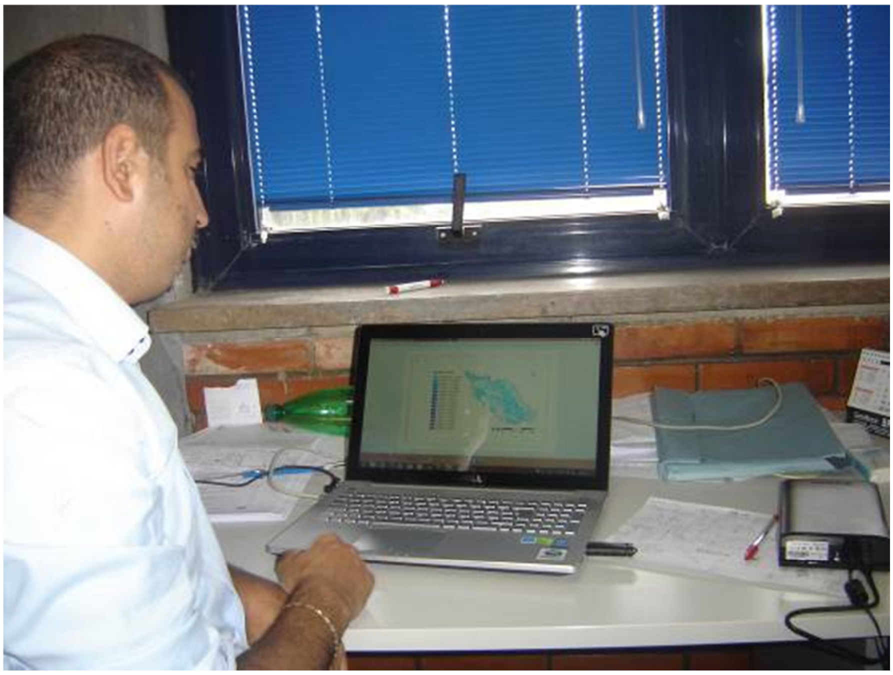

Figure 10 Hands-on training on the use of fire behavior simulation software by Dr. Michele Salis

Dominant wind speed, wind direction and fuel moisture values in each site were obtained from the historical fire occurrence data observed in the study areas. The outputs obtained for every simulation were burn probability (BP). The latter is the chance that a pixel will burn at a given flame length interval considering one ignition in the whole study area under the assumed fuel moisture and weather conditions (Ager et. al 2010). BP is defined as:

$$BP_{xy} = \left(\frac{F_{xy}}{n_{xy}}\right)$$

where F_{xy} is the number of times the pixel *xy* burns and n_{xy} is the number of simulated fires (5000). Conditional flame length (CFL) is a weighted probability of flame length given a fire occurrence, and is defined as:

$$CFL = \sum_{i=l}^{20} \left(\frac{BP_i}{BP}\right)(F_i) \quad (2)$$

where F_i is the flame length (m) midpoint and BP_i is the burn probability, on the *i*-th category. Conditional flame length is the average flame length given among the simulated fires that burned a given pixel and is a measure of wildfire hazard (Scott et al. 2013).

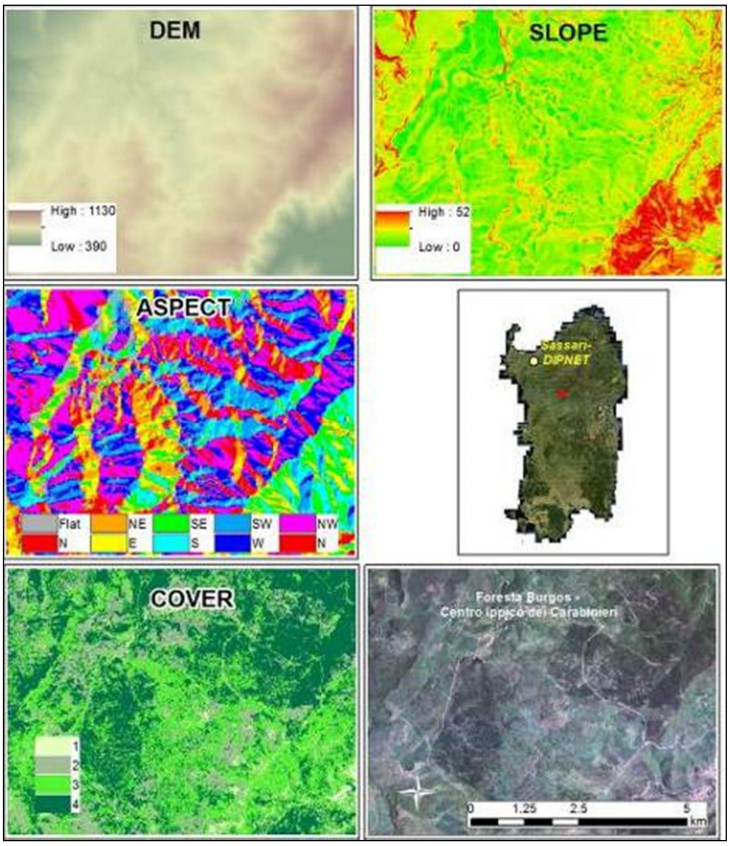

Figure 11 Datasets used for the implementation of the spatial behavior simulation over Sardinia

4.4 Statistical analysis

Statistical significant differences in terms of fuel parameters and burn probability values between coppice and high forests were assessed by the Student's *t*-test (Norusis 1997).

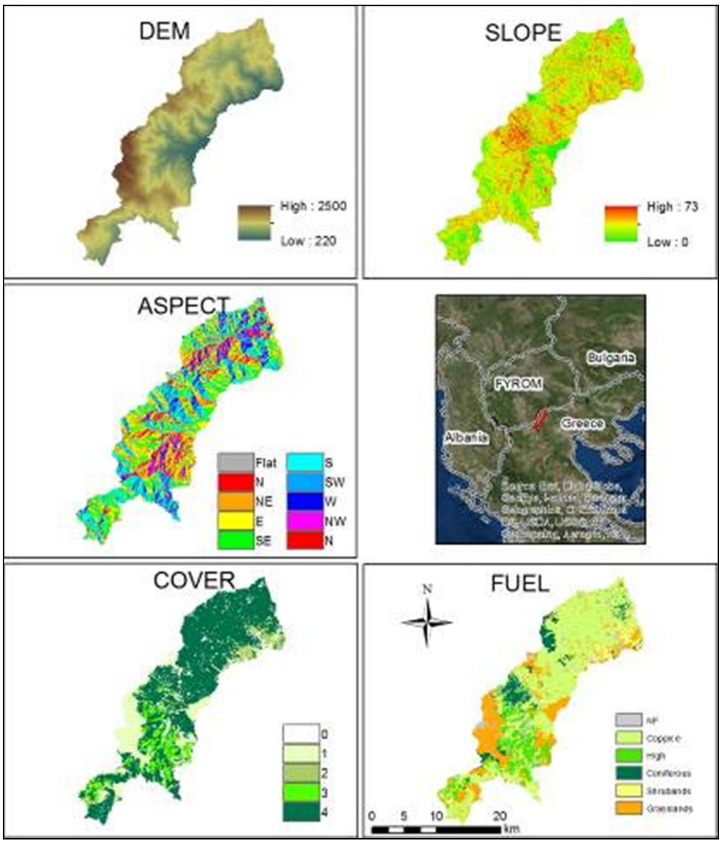

Figure 12 Datasets used for the implementation of the spatial behavior simulation over Greece

5 Results

Table 1 presents the average values of fuel parameters in coppice and high forests in the two study sites (Italy and Greece).

Table 1 Fuel parameter values in the two study sites. Test of significance was performed by Student's t-test, at p = 0.05. Values with the same letter are not significantly different

Monte Pisanu (Italy)		
Fuel parameters	Coppice	High forest
1-hr (t/ha)	5.52^{A}	4.61^{A}
10-hr (t/ha)	2.38^{A}	1.42^{A}
100-hr (t/ha)	1.95^{A}	1.12^{A}
Litter load (t/ha)	2.80^{A}	2.40^{A}
Live fuel load (t/ha)	1.52^{A}	1.37^{A}
Total fuel load (t/ha)	14.19^{A}	10.94^{B}
Litter depth (cm)	2.14^{A}	2.57^{A}
Fuel cover (%)	98.5^{A}	92.8^{B}
Mount Voras (Greece)		
Fuel parameters	Coppice	High forest
1-hr (t/ha)	2.44^{A}	1.31^{B}

10-hr (t/ha)	2.39 A	2.08 A
100-hr (t/ha)	3.05 A	2.23 A
Litter load (t/ha)	4.06 A	2.37 B
Live fuel load (t/ha)	1.08 A	1.05 A
Total fuel load (t/ha)	13.02 A	9.04 B
Litter depth (cm)	3.31 A	2.35 A
Fuel cover (%)	88.3 A	75.0 B

Figure 13 and Figure 14 present the spatial explicit maps depicting burn probability in the two sites.

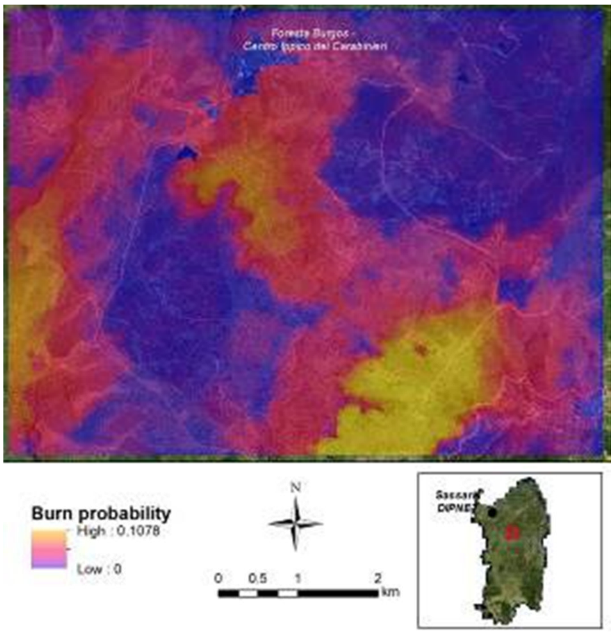

Figure 13 Burn probability in Sardinia test site

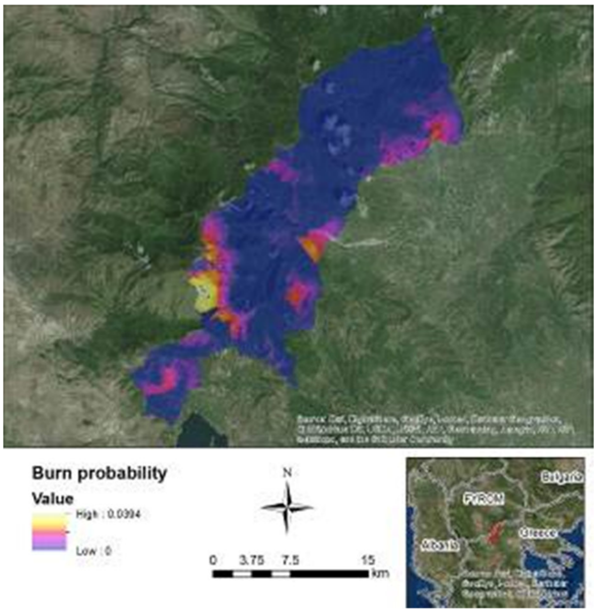

Figure 14 Burn probability in Voras test site

Table 2 Mean burn probability values in the two study sites. Test of significance was performed by Student's t-test, at p = 0.05. Values with the same letter are not significantly different

Monte Pisanu (Italy)		
	Coppice	High forest
Mean burn probability	0.0135 A	0.0108 A
CFL	0.3415 A	0.2950 A
Mount Voras (Greece)		
Mean burn probability	0.0131 A	0.0066 B

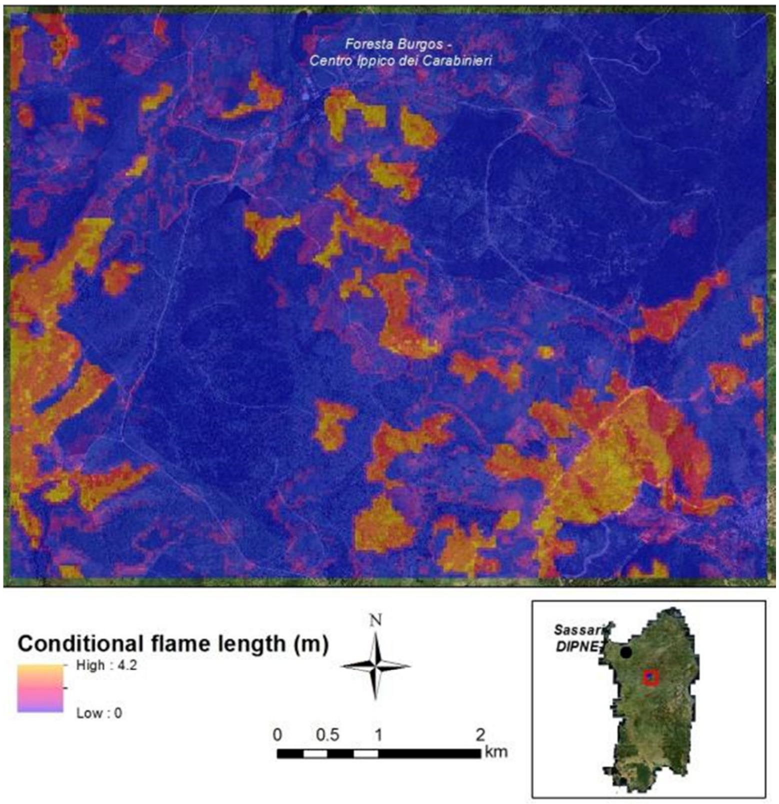

Figure 15 Conditional flame length for the Sardinia site

Surface fuel parameters in coppices demonstrated higher values compared to high forests in both study sites. However, statistical significant differences (t-test at 0.05) observed only in total surface fuel load and fuel cover in Italy and in 1-hr fuel, litter load, total fuel load and cover for the Greek site.

Mean burn probability and CFL values were not significant different for both coppices and high forests in Italy, but they presented statistical significant differences in Greek site. This could be expected since the 1-hr fuel and litter load were substantially higher in coppices compared to high forests in the Greek site.

6 Conclusions

From the current preliminary study, it seems that coppices pose a slightly higher fuel hazard and fire exposure profiles compared to high forests. This might had some implications both for selecting forest management systems within the area, or for developing system-specific fuel treatments. However, additional fuel sampling it is required in order to render these findings more regionally applicable.

Furthermore, the results of this work may enable forest and fire managers to assess fuel hazard and fire risk, to evaluate fuel treatments and to predict fire behaviour and effects at stand and landscape level in coppices.

7 Future collaboration and prospect with the host institution

The results of the studies will be used to produce a Conference paper and a joint article for submission to an international peer-review journal or a book chapter.

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I hereby certify that the STSM was carried out by Dr. Giorgos Mallinis according to the plan and with success

Sassari, 29 August 2014

Prof. Sandro Dettori