P1.10 USE OF FARSITE SIMULATOR TO PRODUCE FIRE PROBABILITY MAPS IN A MEDITERRANEAN AREA

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1. INTRODUCTION

Fire is an important, frequent and widespread disturbance in terrestrial ecosystems across the world. This is particularly true in natural vegetation of the Mediterranean basin where the areas burned each year are large and the fire frequency is high (Moreno *et al.*, 1998). In the last two decades of the 20th century, the annual cumulated burnt area in the Mediterranean European countries was estimated to be about 600,000 ha, almost twice as much as during the 1970s (European communities, 2002). Therefore, the development of fire management policies are required in order to reduce the wildland fire risk by applying methods and models for planning the operational phases of fire management. Although forest fires are predominantly ignited by arson, or by accident, the differences in fire occurrence and fire propagation are a combined effect of the involved environmental components: weather, vegetation, and terrain. The occurrence of fires depends on drought cycles, precipitation amount and timing, temperature reached during drought season and on the amount of fuel biomass (Mouillot *et al.* 2002). Changes in fire behavior in space and time occur in relation to changes in the environmental components but weather is the most variable component changing rapidly in both space and time (Pyne *et al.*1996). In this context, relatively few information are available on the interactions between wildfire regimes and frequency and projected climate change in Mediterranean Basin country.

Alcamo *et al.* (2007) in the last report of the IPCC reported that in central west Mediterranean Basin the projected impacts of climate change will create a greater variability and extreme weather events, wetter winters and drier summers and hotter summers and heat waves. The changes in the frequency of extreme events might be the first and most important change registered in the Mediterranean area.

At the long-term scale climate changes can affect the overall flammability of the plant material resulting from changes in total biomass, from redistribution of fuel load in the different layers of vegetation or from modification of dead live fuel ratio (Mouillot *et al.* 2002). At shorter time scale the increase of extreme weather events (heat waves, strong winds ecc.) can directly affect water status of fuel and fire behavior, and it can increase large fires occurrence probability.

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In this context, identifying areas that are characterized by high probability of large fires occurrence in relation to the projected climatic change could represent an important component of fire management planning.

In recent years several authors proposed using fire simulator as a convenient methodology to derive fire probability maps in function of particular weather conditions (Finney 2005, Farris *et al.* 2000). Given a large enough number of simulations across a landscape under relatively short-term extreme events, areas that have most probability to burn can be quantified and different scenario can be tested (Clarke *et al.* 1994).

FARSITE (Fire Area Simulator, Finney 1998) is one of the main fire simulation systems developed over recent years to describe the temporal and spatial variations of fire spread and behaviour (Rothermel, 1972). The use of the simulator as component of a decision support system for planning the fire management practices involves the assessment of the simulation accuracy under different environmental and vegetation conditions.

The aims of this study were to evaluate the capabilities of FARSITE simulator for estimating the probability of burning in a Mediterranean area predominantly covered by shrubland vegetation in relation to different weather conditions. The general goal is to provide basic information that is useful to produce maps of spatial burn probabilities in Mediterranean region in function of projected climate changes.

2. MATERIALS AND METHODS

The study area is located in North-East Sardinia, near the village of Budoni (lat. 40° 43’, long. 09° 42’, 50 m a.s.l.). The area (≈ 1976 ha) is affected historically by small and medium (≈ 100 ha) human-caused fires occurred during the summer season, mainly with severe environmental conditions. The area is characterized by the typical sub-arid Mediterranean climate, with a remarkable water deficit from May through September, and most of the annual rainfall amount (approximately 650 mm) occurring in fall and winter. The mean annual temperature is approximately 17 °C, with summer season highs often around 30 °C. The average wind speed is relatively high (≈ 4 m s^{-1}) in both winter and summer seasons, with about 50 – 70% of the days showing values between 1.6 and 8 m s^{-1}. The prevailing wind directions at the sites are typically west and northwest with a cumulative frequency greater than 50%. However, complex terrains typical of the studied areas

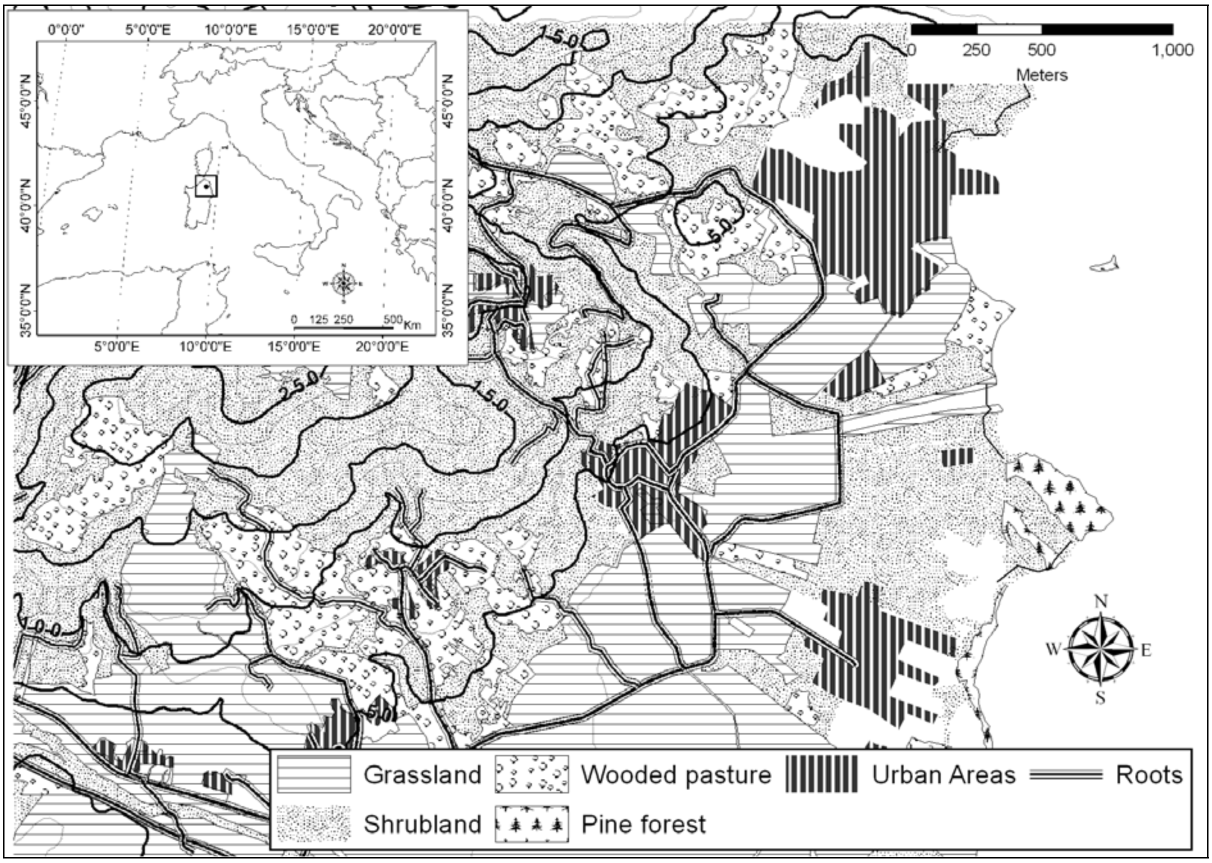

Figure 1 – Topographical map of the project area in North East Sardinia, Italy.

can modify the local wind direction.

The area (figure 1) is mainly covered by the typical shrubland Mediterranean vegetation, with plant height ranging from 1 to 4 m. Dominant species included *Olea europaea* L. var. oleaster, *Cistus monspeliensis* L., *Pistacia lentiscus* L., *Myrtus communis* L., *Calycotome spinosa* L., *Euphorbia dendroides* L. Link, and *Pyrus amygdaliformis* Vill. Small surfaces inside the area were covered by open wooded pastures and grasslands. The coastal area is characterized mainly by shrubland vegetation (maquis and gariga), with a small area covered by a pine forest (≈ 10 ha).

A sample of 30 point source ignitions was randomly distributed across a buffer area of 10 meters round the roads. Starting from each ignition point, several simulations were conducted in order to compare the performance of FARSITE simulator for a moderate and a severe weather and fuel moisture scenarios (table 1). Simulations were performed using a conditioning period of seven days in order to adjust fuel moisture prior to the start of simulations. Time step (20 minutes), perimeter and distance resolution (20 m) were set up to obtain the expected spatial and temporal resolution of simulations. We used a Geographic Information System (GIS, ArcGIS 9, ESRI Inc.) in order to manage the spatial information of the project area, and to obtain input layers needed to execute the model simulations. The grid resolution of all spatial information was 15 m. A digital elevation model (DEM) was used to produce the maps of slope and aspect. The study was conducted using hourly meteorological data (air temperature (T), relative humidity (RH), wind speed (U), wind direction (W), solar radiation (Rs), and rainfall (P) collected by a weather station of the Sardinian Agrometeorological Service (SAR) network, located 3 km away from the north boundary of the project area. Weather conditions were representative of the typical summer

Table 1 – Weather fuel moisture scenarios tested by FARSITE simulator.

	Moderate	Severe
1h (%)	15	8
10h (%)	15	10
100h (%)	15	13
LH (%)	-	-
LW (%)	80	60
Tmax (° C)	$37^a/28^b$	$37^a/28^b$
Tmin (° C)	$19^a/20^b$	$19^a/20^b$
RHmax (%)	$78^a/61^b$	$78^a/61^b$
RHmin (%)	$16^a/29^b$	$16^a/29^b$
Wind speed (m sec^{-1})[c]	6/10	6/10
Wind direction (°)[c]	250	250

[a] During the conditioning period
[b] During the burn period
[c] Prevailing wind speed and direction.

climatological conditions with relatively high wind speed. Wind speed and direction data were provided as raster maps with a grid resolution of 50 m, simulated by computational fluid dynamics models.

Fuel and canopy cover maps were produced by supervised classification of pre-fire aerial photographs (1:10,000), by field observation of the plant community and by the use of the 1:25,000 land cover map of Sardinia from the CORINE project (EEA ETC/TE 2002).

The initial values of fuel moisture content (FMC) for the 10-h time lag (TL) dead fuel were determined calculating the relationship between observed FMC values and fuel moisture sensor measurements (model CS505, Campbell Sci., Logan, UT, USA) obtained during days with meteorological conditions similar to those when the fire events occurred. The 1-h and 100-h TL dead fuel moisture content values were obtained from field observations and literature data (Fernandez 2001, Baeza *et al.* 2002, De Luis *et al.* 2004).

FARSITE simulations were run using a custom fuel model for shrubland vegetation (CM28), two standard fuel models for wooded pasture (FM2) and grassland (FM1), and a fuel model for surface fuels of pine overstory (FM7) (Anderson 1982). In addition, the urban areas and roads were assigned to fuel model n° 91 (NB1, Scott and Burgan 2005).

The following output parameters provided by FARSITE were used in order to describe the fire behavior: fire perimeter, rate of spread and fireline intensity.

The fire information provided by FARSITE in ASCII grid format was transformed into raster format and reclassified as burned and unburned areas, in relation to the whole extension of the project area. In addition, several maps were realized in order to provide information about (1) the number of times in which the simulated fires affected each pixel of the project area, and (2) the distribution of the values of both rate of spread and fireline intensity for the different simulations and scenarios.

3. RESULTS AND DISCUSSION

The fire probability and fire behavior maps obtained for the different fuel and weather conditions (moderate vs. severe) are shown in figure 2, 3 and 4. In most of the simulations, the highest values of spread probability were observed near the south-east boundary of the project area.

This flat area is very heterogeneous in terms of vegetation (shrubland vegetation, pine forests, and grasses) and human activities. The area and the surrounding plain are characterized by several roads, so that the probability of ignition, principally due to the arson, is high. In addition, in this area two villages and some resorts and beaches are present.

Figure 2a shows the probability of fire occurrence and propagation, with moderate weather conditions and with the relative fuel moistures (table 1). The probability was of around the 40% in the above mentioned area, while in the central area of the project boundary, the values of fire probability ranged from 20% to 30%.

The severe scenario (figure 2b) leads to an increase of about 100 ha in the area with fire probability between 20% and 40%; experimental results showed that these values of fire probability affected the coastal area and several sections (about 1700 m) of the wildland-urban interface.

The maps of rate of spread (ROS, $m\ min^{-1}$) provided by FARSITE simulator showed similar values for the moderate and severe scenarios (figure 3). The most representative values of ROS ranged from 10 to 40 %, whereas only limited flat areas on the south-east boundary were characterized by values of maximum ROS greater than 20 $m\ min^{-1}$; these values can be explained with the characteristics of the vegetation, mainly covered by grass and maquis.

Figure 4 provided the distribution of the maximum values of fireline intensity (FLI, $kW\ m^{-1}$). FLI ranged between 1200 and 1600 $kW\ m^{-1}$ in the central area, mainly covered by maquis. Higher values of FLI can be observed only in a few spots in the central area characterized by a steepness terrain and by high values of fuel load.

A combination of the values of ROS and FLI was realized in order to obtain information on fire severity. A threshold value of ROS and FLI was established using information on the sustainability of the direct attack to fire (Chandler *et al.* 1983). Values of fire severity were more affected by the level of wind speed (6 m^{-1} - 10 $m\ s^{-1}$) than by fuel moisture conditions.

4. CONCLUSIONS

The analysis of the information on fire behaviour provided by FARSITE simulator can be useful in order to identify the areas with high probability of fire, high level of danger, and therefore, with high potential risk due to the human activities (tourism, agriculture, etc.). Since FARSITE is a spatial and temporal explicit model, it can account for spatial variation of fuel and weather data that affect the accuracy of the scenarios, with particular regard for the high resolution wind field maps.

The future fire regimes determined by global change will result in severe fires with higher rate of spread and fireline intensity, due to the increased frequency of severe weather conditions. Both FARSITE outputs and the derived fire probability maps can be used as components of decision support systems for fire danger and fire risk assessment with actual and future fire regimes.

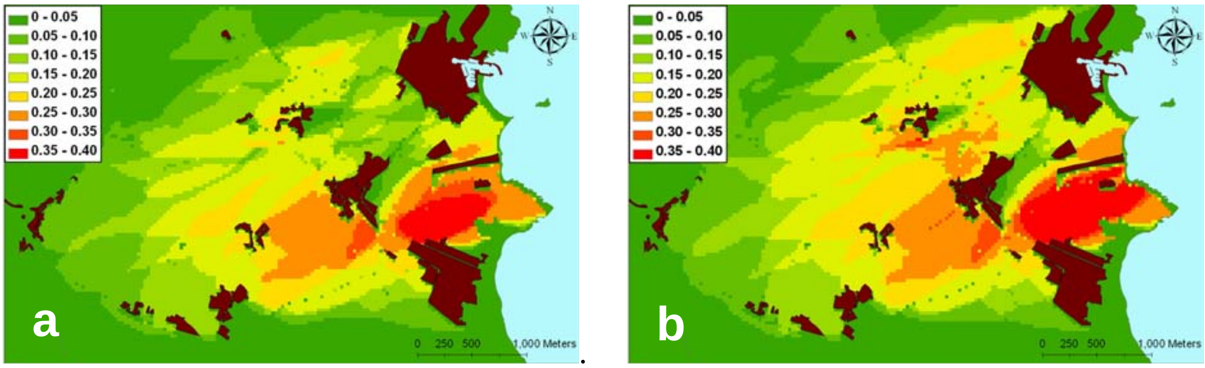

Figure 2 – Fire probability indexes for moderate (a) and severe (b) simulation scenarios (prevailing wind speed 6 m s^{-1}). Brown color indicates the urban areas.

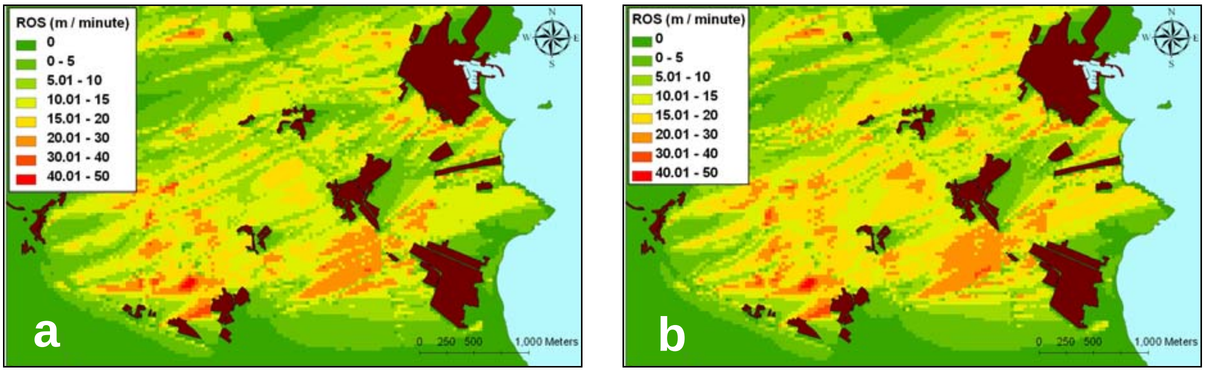

Figure 3 – Maximum values of rate of spread (ROS) for moderate (a) and severe (b) simulation scenarios (prevailing wind speed 6 m s^{-1}). Brown color indicates the urban areas.

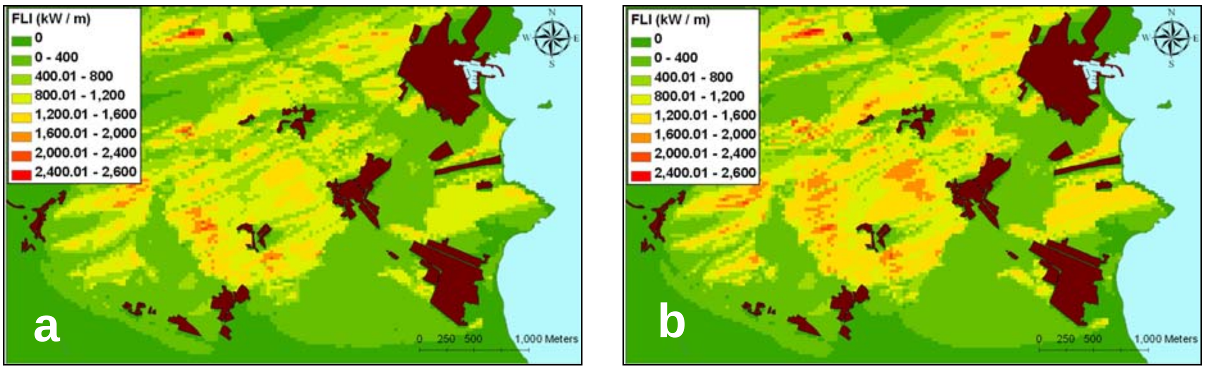

Figure 4 – Maximum values of fireline intensity (FLI) for moderate (a) and severe (b) simulation scenarios (prevailing wind speed 6 m s^{-1}). Brown color indicates the urban areas.

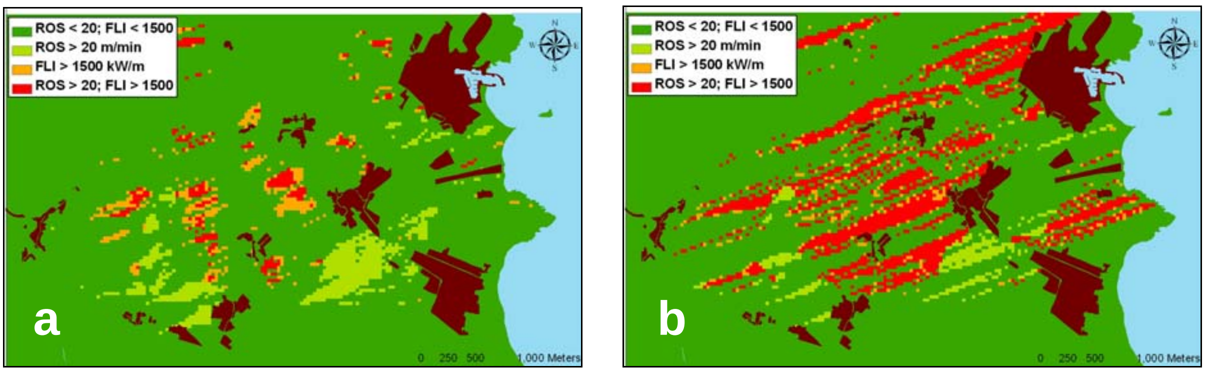

Figure 5 – Fire severity maps obtained using the severe scenario and two different wind conditions: wind speed 6 m s^{-1} (a) and 10 m s^{-1} (b). Brown color indicates the urban areas.

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