D 3.2 User guide of the modeling tools

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FIREBOX
Innovative Tools for Wildfire Prevention

Executive summary

Deliverable D3.2 provides the user guide for the wildfire simulation platform developed by CNR IBE within the FIRE-BOX project. The platform, based on the Sardinian Wildfire Simulator (SWS), was specifically extended and adapted to support wildfire risk management across Italian National Parks, and is accessible via secure web interface at https://sws.ss.cnr.it.

The system integrates three core modules: a data management component, a wind field downscaling model operating at high resolution based on the mass-continuity principle, and a fire front propagation engine combining the Rothermel semi-empirical model with the Level Set method. The simulator operates through a client-server architecture, allowing users to run simulations from any web-connected device without dedicated software installation.

The platform supports two main operational modes. In simulation mode, users can run deterministic or probabilistic wildfire spread simulations by specifying ignition point coordinates, wind conditions, fuel moisture values, simulation duration and spatial resolution. Outputs include maps of rate of spread, fireline intensity, flame length, time of arrival, burn probability and crown fire behavior, all visualizable through the web-GIS interface. In fire hazard maps mode, users can retrieve pre-computed propagability and rate of spread maps by selecting a meteorological scenario defined by wind speed, wind direction and fuel moisture conditions. These maps are pre-calculated for 144 scenarios and provide an immediate assessment of territorial fire susceptibility under observed or forecast weather conditions, supporting both tactical and strategic planning by park operators and fire management authorities.

Keywords

Wildfire simulation; fire spread modelling; fire hazard mapping; web-GIS interface; National Parks

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1. Introduction

The Sardinian Wildfire Simulator (SWS), developed by CNR IBE, was further implemented within the FIRE-BOX project to support wildfire risk management across Italian National Park territories, through the release of two distinct modelling tools. The first tool is a web-GIS application capable of running deterministic simulations of wildfire spread and providing a set of output data essential for characterizing fire propagation and behavior within the simulation domain of each National Park. The second tool is a web-GIS application capable of running probabilistic simulations of wildfire spread and providing the parameters that determine fire hazard across a comprehensive set of meteorological scenarios defined for each National Park simulation domain. The input themes required by the simulator were developed within WP1 FUEL BOX, and specifically within the scope of Deliverable D1.2 (Fuel Type Map at the national scale), which provided the fuel type maps and associated fuel properties subsequently used to assign fuel models according to the methodology described in Deliverable D1.3 (Fuel model map parameterized for Rothermel-based modeling applications).

The wildfire spread simulator is a software tool developed to support public institutions engaged in the implementation of tactical and strategic interventions for wildfire risk prevention and management. Its objective is to provide, in real time or off-line, accurate predictions of fire front evolution using actual meteorological data or climate scenarios representative of a given territory. The system comprises three integrated modules: (1) a data management module, which coordinates simulation inputs; (2) a wind downscaling model, which adapts wind fields to the simulation resolution, accounting for orographic complexity through a mass-consistent model based on the principle of mass conservation; and (3) a fire front propagation module, which simulates fire advance by combining the Rothermel semi-empirical model — describing fire behavior as a function of wind, fuel moisture and slope — with the Level Set method for spatial front propagation.

The simulator produces maps of rate of spread, fireline intensity and time of arrival, which are key parameters for assessing the severity of both real and simulated fire events, defining and evaluating the effectiveness of suppression strategies, and assessing the safety of firefighting operations. The system is also capable of computing fire propagability, defined as the probability that a given point in the territory will be reached by fire within a specified time window. Propagability maps are pre-computed for 144 meteorological scenarios (3 wind intensity levels × 16 wind directions × 3 fuel moisture conditions) and can be selected by the operator based on observed or forecast weather conditions, providing a risk estimate useful for tactical and strategic planning.

The simulator is built on a client-server architecture, in which the computational and user interface components are separated and communicate over the network. The server side hosts the system's computational modules — wind downscaling, fire front propagation and

input/output data management — running on a dedicated machine optimized for parallel computing. The client side, accessible via web browser, provides the interface through which the operator interacts with the system: setting simulation parameters, launching computations and visualizing results as maps and charts. Communication between client and server is handled via the HTTPS protocol, ensuring security and compatibility with existing network infrastructures. This architecture allows the simulator to be used from any network-connected workstation without the need to install dedicated software on the user's device.

2. System access

The simulator is accessible in secure web mode at the following address: https://sws.ss.cnr.it. The use of Chrome or Firefox browsers is recommended; users should ensure that their browser is updated to the latest version before connecting. Once the page has loaded (Figure 1), enter the credentials and click the Login button (on the right-hand side). A new screen will appear, displaying the updated version of the simulator developed within the FIRE-BOX project to support Italian National Parks. On the left-hand side of the screen, a drop-down menu allows the user to select the simulation domain and the base map of the relevant National Park.

Figure 1: Web-GIS interface of the Sardinian Wildfire Simulator (SWS). The left panel displays the main navigation menu and the drop-down field for selecting the National Park simulation domain. The top bar provides fields for enter user credentials and completing the login.

3. User Menu

The simulator can operate in two distinct modes: (1) Simulation, which allows the user to run a wildfire spread simulation by entering the required input parameters on screen; (2) Fire Hazard Maps, which allows the user to retrieve pre-computed propagability maps for a wind and fuel moisture scenario defined by the user.

3.1. Simulation Menu

In Simulation mode, the simulator allows the user to set up and run new wildfire spread simulations. Clicking the **Simulation** button opens a drop-down panel on the left-hand side of the screen (Figure 2-3), where the following input parameters must be entered.

- **Latitude and Longitude** of the ignition point of the fire to be simulated. Coordinates can be typed directly into the relevant fields, or alternatively the user can right-click on the area of interest on the map to set it as the ignition point.
- **Date and Time** of fire ignition. It is recommended to enter these values, although in the current version of the simulator — initialized with user-defined inputs — they do not affect the simulation output.
- **Duration** of the fire to be simulated, expressed in hours.
- **Name**: a text label to be assigned to the simulation; A default value is set by the system.
- **Custom wind**: wind speed and direction to be used during the simulation. The user must specify the height at which wind data are measured (typically 2 or 10 metres), followed by the speed and direction values. If only one wind record is entered, it will be assigned to step 0 and applied throughout the entire simulation. If additional records are added using the Add button, each will be valid from the time step shown on the left until the next record or the end of the simulation.
- **Custom moisture**: fuel moisture content values for dead and live fuel fractions, expressed as a percentage of dry weight. For dead fuel, three size classes are considered:

1-hour (< 0.6 cm), 10-hour (0.6–2.5 cm) and 100-hour (2.5–7.5 cm). For live fuel, only the 1-hour fraction (< 0.6 cm) is considered. The user must enter fuel moisture values for the entire simulation or for each time step by adding records with the Add button.

- **Domain dimension** in km: defines the side length of the simulation area. A value of at least 10–15 km is recommended, as larger domains improve simulation accuracy.

- **Domain resolution** in metres: defines the spatial resolution at which simulations are run and outputs are generated. A resolution of approximately 100 m can be used to reduce computation time, while resolutions down to approximately 20 m can be set for greater accuracy, at the cost of longer computation times.

- **Model — Deterministic/Probabilistic**: the Probabilistic option introduces small perturbations to the coordinates of ignition point in order to identify the areas with the highest probability of being reached by fire.

- **Crown fire**: activates crown fire simulation, using default parameters automatically differentiated for broadleaf and conifer species: crown base height (CBH, in metres), i.e. the height of the first potentially combustible branch in the event of crown fire initiation; fuel moisture content (FMC, expressed as a percentage) of the canopy materials; and crown bulk density (CBD), i.e. the amount of fuel per unit volume of the canopy (kg/m^3).

- **Barrier lines**: a function that, when activated via the Driving Tools panel, allows the user to draw lines directly on the map that the simulator will treat as non-burnable barriers. Lines can also be imported in KML format.

Once all input parameters have been entered, click **Set Simulation** to generate the simulation domain and the corresponding input data. Finally, click **Run Simulation** to launch the simulation. A progress panel will appear on screen and remain visible until the simulation is complete. Once the panel closes automatically, the simulated fire perimeters will be displayed on the map.

Figure 2: Detail of the input panel for general simulation parameters: ignition point coordinates, date and time of ignition, simulation duration and simulation name.

Figure 3: Input panel for wind speed and direction and fuel moisture content of the different fuel fractions, across multiple simulation time steps; definition of the simulation domain size and spatial resolution; selection of the simulation mode (deterministic or probabilistic) and activation of the crown fire option.

3.2 Visualize Menu: fire event maps

All outputs characterizing fire behavior can be accessed by clicking on **Visualize** and selecting the **Fire Event Maps** option (Figure 4). The selected maps will be displayed together with their legend (top right corner). Once a map has been loaded (Figure 6-8), the value of each individual pixel can be retrieved by left-clicking on the area of interest. To deselect a map, click on the checkbox below the corresponding output button. The available output layers are listed below.

- **Fire perimeters (partial/final)**: displays fire advance polygons at 30-minute intervals.
- **Burn probability**: displays the probability that each point in the area will be burned, accounting for small perturbations of the ignition point.
- **Rate of Spread**: displays the fire spread rate map in metres per minute.
- **Time of arrival**: displays the estimated time, in minutes, at which fire is expected to reach each point within the simulation domain.
- **Fireline intensity**: displays fireline intensity values in kW/m, providing essential information for assessing the effectiveness and safety of suppression operations and for identifying areas requiring preventive treatment.
- **Flame length**: displays flame length in metres.
- **Crown fire**: indicates whether active or passive crown fire is expected to develop in a given area, and shows its contribution to total fireline intensity. Clicking on the map displays the fireline intensity values for surface fire and total fire separately.
- **Fuel**: displays the fuel types present in the area, indicating for each type the roughness height and a summary label of the fuel category.
- **Wind**: displays wind vectors across the domain; wind direction and speed values can be retrieved by clicking directly on individual arrows.

If a burned area perimeter is available in *.kml format, it can be loaded and displayed on the map using the **Load Custom Perimeter** option, allowing a visual assessment of simulation accuracy.

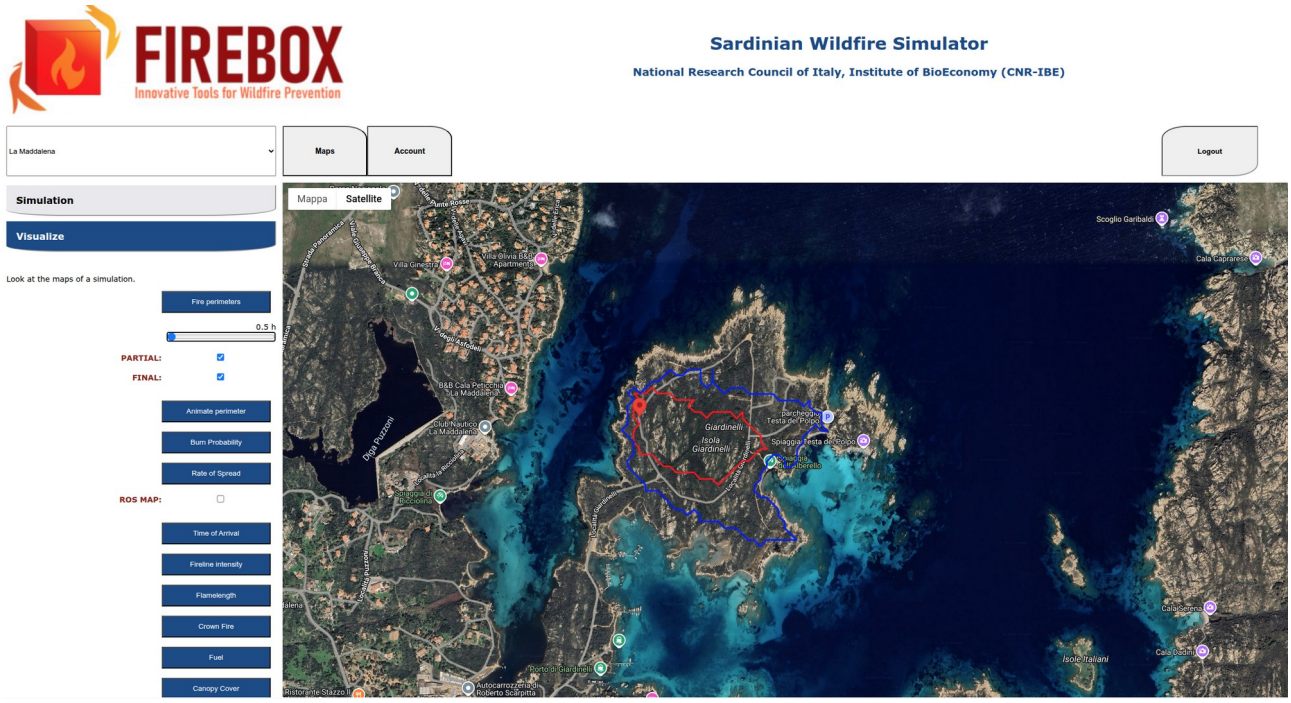

Figure 4: Visualization of simulation outputs in Fire Event Maps mode; list of output parameters available in raster and vector format (partial and final fire perimeter; wind field map).

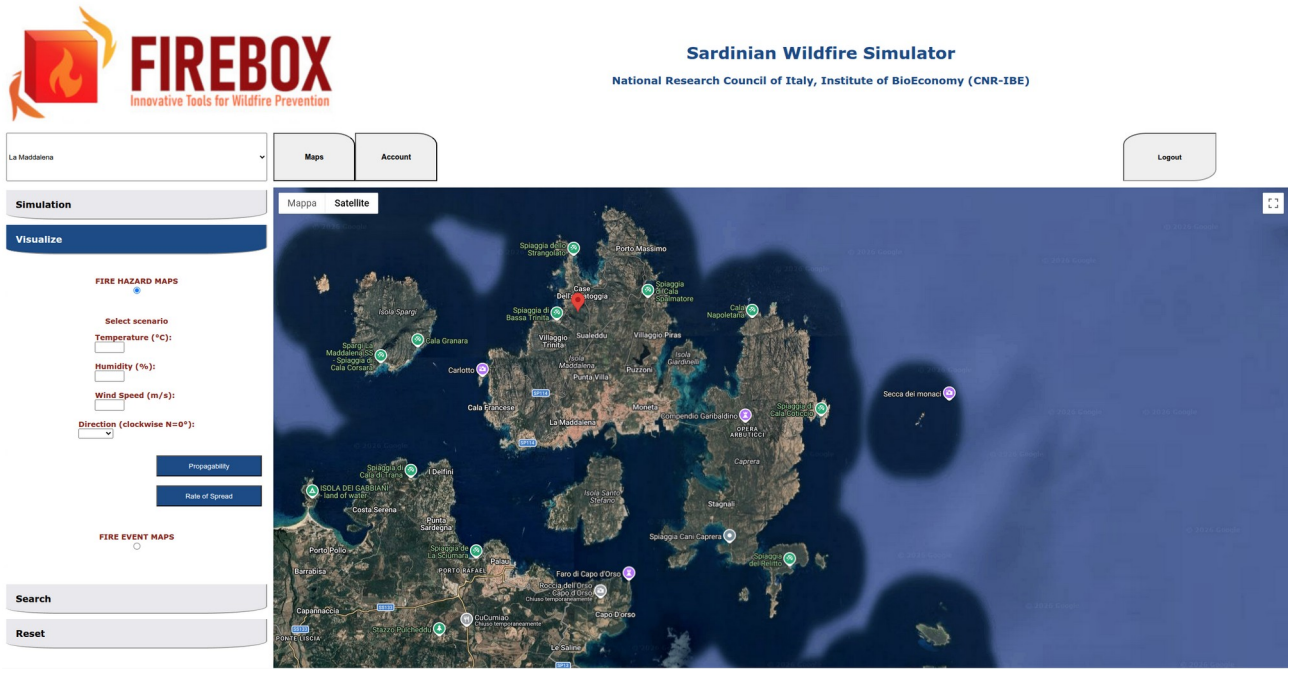

Figure 5: Visualization of simulation outputs in Fire Hazard Maps mode; scenario selection through the input of air temperature, relative humidity, wind speed and wind direction values.

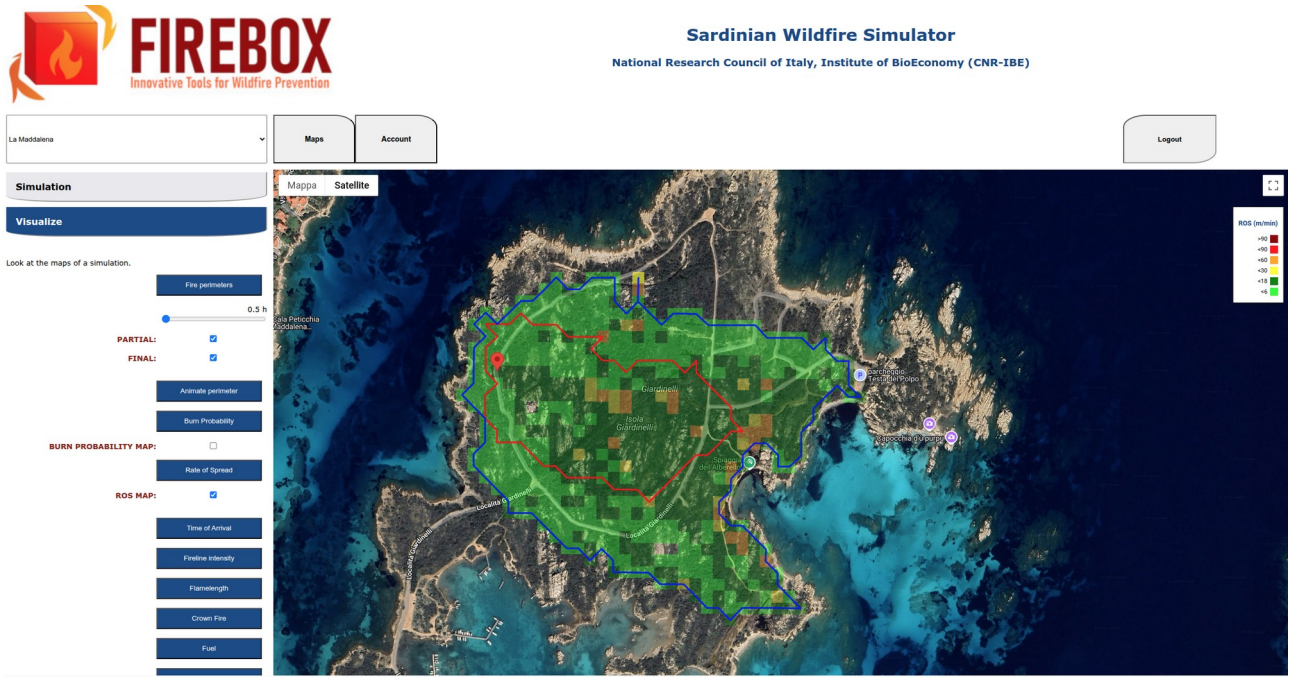

Figure 6: Map of rate of spread values in metres per minute, with corresponding legend.

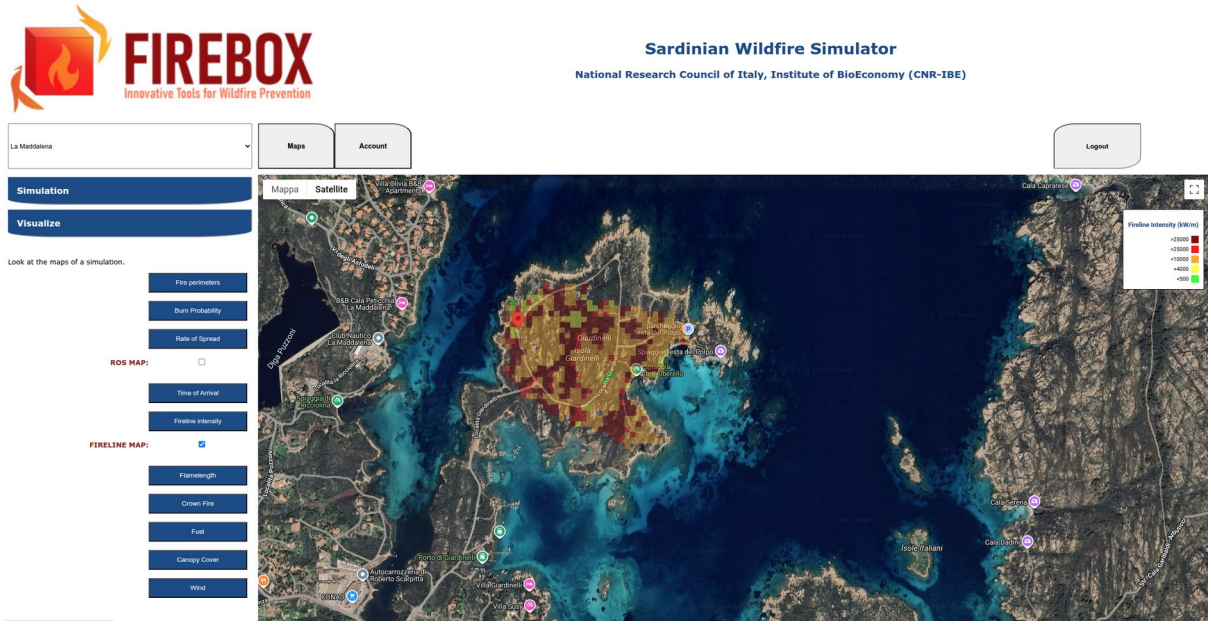

Figura 6: Map of fireline intensity values in kW/m, with corresponding legend.

Figura 7: Map of wind speed values; wind intensity and direction at each point can be retrieved by clicking on the individual arrows.

3.3 Visualize Menu: fire hazard maps

The simulator also allows users to visualize Fire Hazard Maps (Figure 5) for the entire National Park area, representing the susceptibility of the territory to wildfire spread. These maps (Figure 8-9) are retrieved by entering the meteorological conditions forecast for the day: air temperature, relative air humidity, wind speed and wind direction. Once these parameters have been set, the user can select and display either the **Propagability** layer — which, for a given meteorological scenario, represents the percentage of fires affecting a portion of the territory relative to all fires ignited within the neighbourhood of the point of interest — or the **Rate of Spread** layer, which indicates the expected fire spread rate under the selected meteorological scenario for each point in the domain. This component of the simulator can provide valuable information for identifying areas within the park with higher or lower fire probability, which is essential both for forecasting purposes and for planning prevention and suppression interventions.

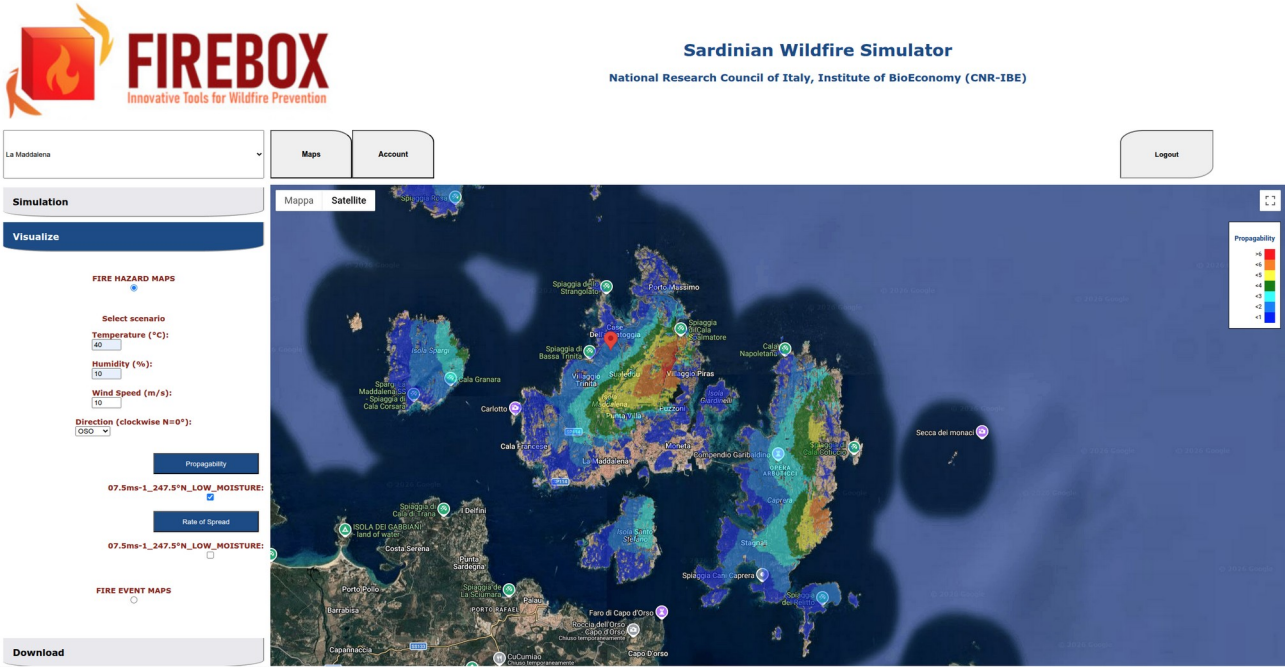

Figure 8: Visualization of outputs in Fire Hazard mode; the scenario can be selected through the parameters on the left-hand panel. The map is displayed in classes as indicated in the legend.

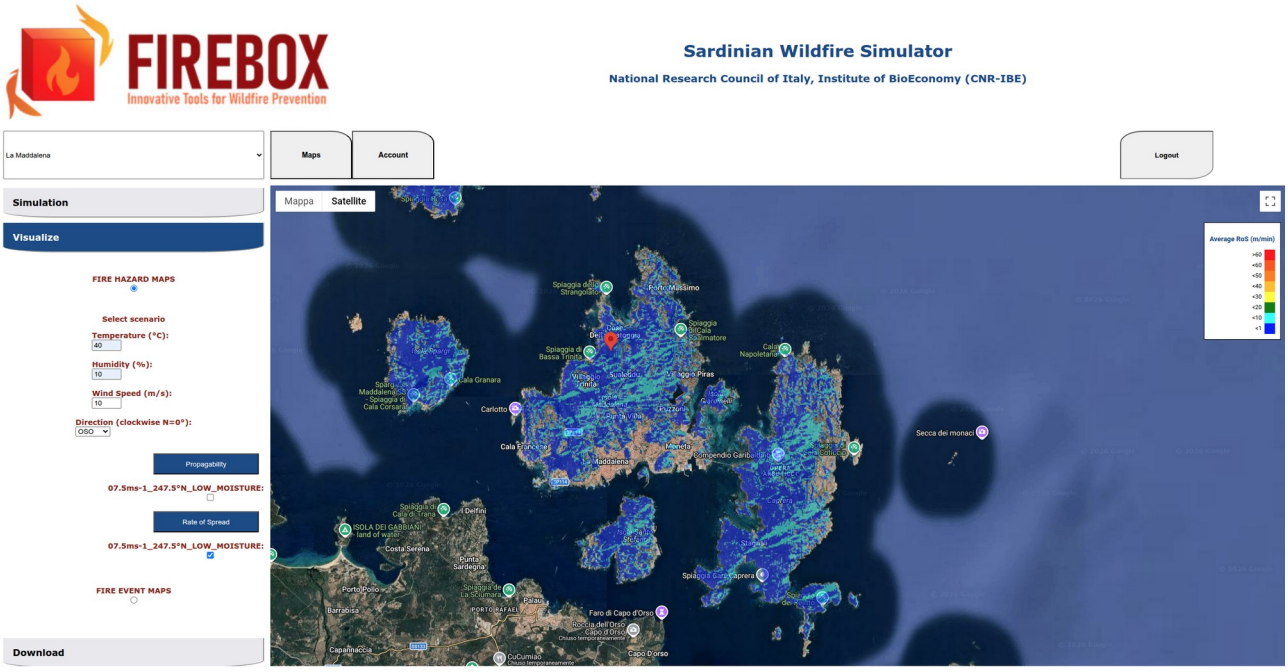

Figure 9: Visualization of outputs in Fire Hazard mode; rate of spread map.

3.4 Search Menu

Previously run simulations can be retrieved from the archive using the **Search / Search Simulation** function. The simulations already available in the archive will be listed at the bottom of the page, each identified by a name and its main parameters. Any of these simulations can be reloaded by clicking the **Load** button.

3.5 Reset Menu

The **Reset** button provides options to clear the system state: **Reset Interface** clears the graphical interface; **Clear Morphology and Meteo** deletes the files associated with meteorological and vegetation conditions; **Erase Simulation Directory** permanently removes the simulation values and all associated files.