A critical check is performed on the Coordinate Reference System (CRS) of each layer and the overall project, verifying spatial alignment and consistency. The datasets are confirmed to use EPSG:3857 (WGS 84 / Pseudo-Mercator), ensuring compatibility and preventing spatial distortions. Further inspection of layer properties is carried out to validate essential metadata including file paths, file sizes, data types (e.g., 32-bit floating point), compression formats, and data extent. All the layers must be local and written to disk. The user also could load a vector file, as shapefile or similar, containing a polygon to be considered as a study area. This step guarantees the use of up-to-date and properly formatted data, reducing the risk of processing errors.

Together, these preparation steps establish a controlled and precise project framework, readying the environment for the plugin's processing tasks. This meticulous approach exemplifies best practices in geospatial data management and supports robust decision-making processes within Pan-European initiatives.

4.3.3 Interacting with background tasks

The plugin is designed to balance computational intensity with user-friendliness. To achieve this, it implements non-blocking, asynchronous background tasks that perform calculations while the user continues to interact with the interface. When such processes are triggered, the user is notified by a disappearing message toolbar, which directs their attention to the QGIS Background Task Manager, where they can monitor the task progress or even cancel it if necessary.

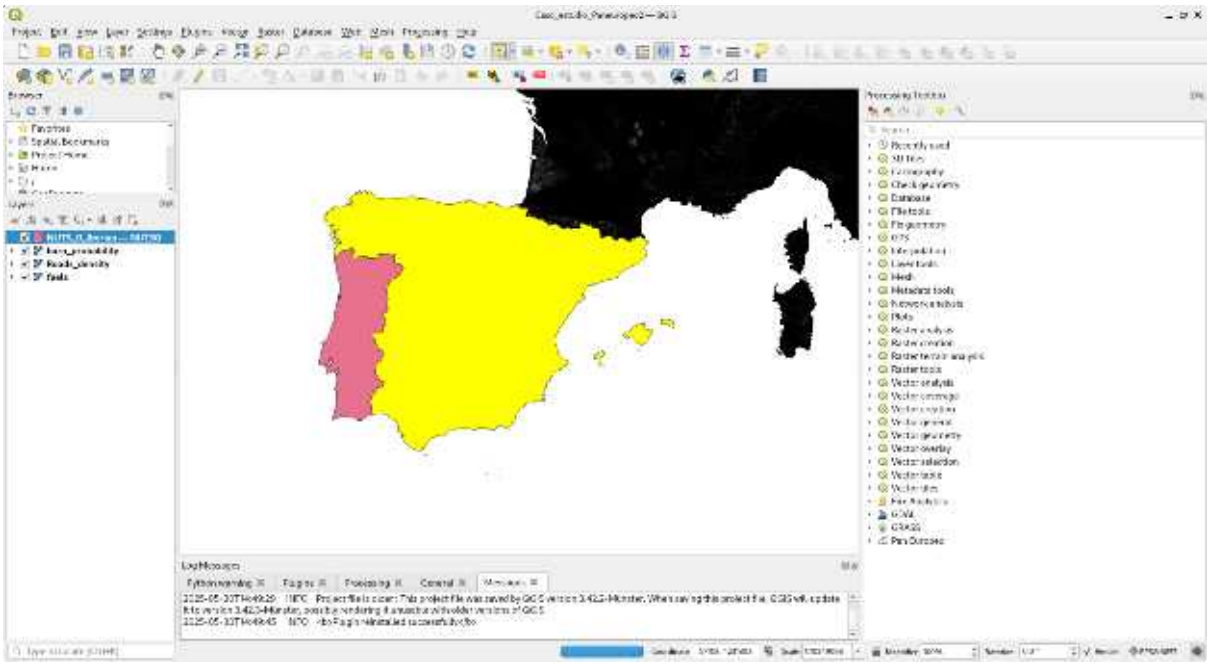

Figure 12: Task Progress Bar of the system within QGIS

These tasks are executed in the following instances:

- **Study area or zone selection**: When the user clicks on a polygon (namely a NUT or LAU zone) or sets the study area using the extent tool, it is important that the user can review and interact with the maximum and minimum values of that geometry. These values are represented in the ranges of the sliders of the corresponding multi-attribute functions of each input raster. To enable this functionality, separate zonal-statistics jobs (one per input raster) are dispatched to QGIS Background Task Manager.
- **Normalization and summation**: When the user initiates the final calculation, a background task is launched to handle the process. This task includes the normalization of each input raster, followed by the final weighted summation, which depends on the normalized layers.

This program is designed to achieve a *Non-Blocking Workflow*: while background tasks are running, the user can continue to navigate the map and adjust layer visibility. It also provides *Real-Time Results & Logging:* as tasks completed, their status is updated in the panel, and detailed messages appear in the dedicated "Pan Europeo" and "Processing" log tabs. These messages report successes, warnings, or errors, along with the computed minimum and maximum values.

4.3.4 Proper usage

Once the project has been prepared and the user understands the background tasks interactions, the project should be saved, and the "Pan European" plugin icon clicked. A polygon feature can then be selected to define the study area if a vector file has been loaded, the currently visible map extent is used.

To continue, within the "Pan Europeo" plugin interface, the following steps should be performed (Figure 13):

- **Enable layers**: tick the checkbox for each raster layer to include it in the prioritization process.
- **Assign weights**: use the spin box or drag the slider to assign weight percentages that reflect each layer's relative influence in the multi-criteria evaluation.
- **Select a utility function**: open the dropdown menu next to each weight and choose one of the following eight options:
    - Min-Max
    - Max-Min
    - Bi-piecewise-linear (values or percentages)
    - Step-Up (value or percentage)
    - Step-Down (value or percentage)

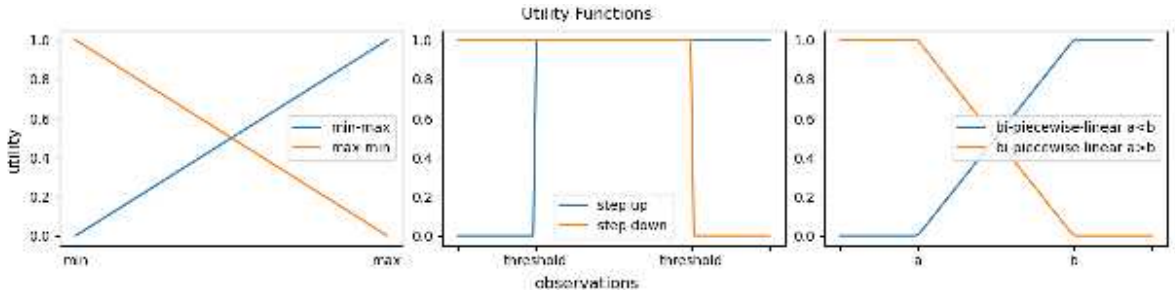

Figure 13: Example of Fuzzy models for data standardization

- **Adjust parameters**: set breakpoints or thresholds using the numeric fields and sliders. Notice that for the Bi-Piecewise-Linear functions, crossing the breakpoints will invert the function's slope.
- Optionally, users can configure the target raster creation in the **output section**. However, it is recommended to skip this section because the default values are generally suitable for most cases.
    - Filename: specifies the name and location for saving the resulting prioritization layer . If left empty, a temporary file will be generated.
    - NoDataValue: defines the value to be used for pixels with no data.
    - DataType: specifies the data type to be used for the resulting prioritization layer .
- **Click the "Apply" button** to recalculate the parameter range values of raster layers in the new study area.

5. Pan European server

In addition to the main Pan-European server developed using Google Earth Engine and R, a complementary Web-GIS platform was developed, aimed at visualizing and sharing spatial data related to fire risk and management priorities across Europe. The solution is based on Lizmap Web Client, an open-source tool for publishing QGIS projects online, and all QGIS projects are prepared and configured using the official Lizmap plugin for QGIS Desktop.

The platform is fully containerized and deployed using Podman, ensuring portability, reproducibility, and compatibility with secure institutional environments.

5.1. Deployment and Architecture

The general architecture of the Lizmap-based platform follows the standard client-server model for publishing QGIS projects on the web. Figure 14 provides a simplified overview of the interaction among the QGIS Desktop administrator, the server components, and end users accessing the data via the Lizmap Web Client or other applications compatible with Open Geospatial Consortium (OGC) standards.

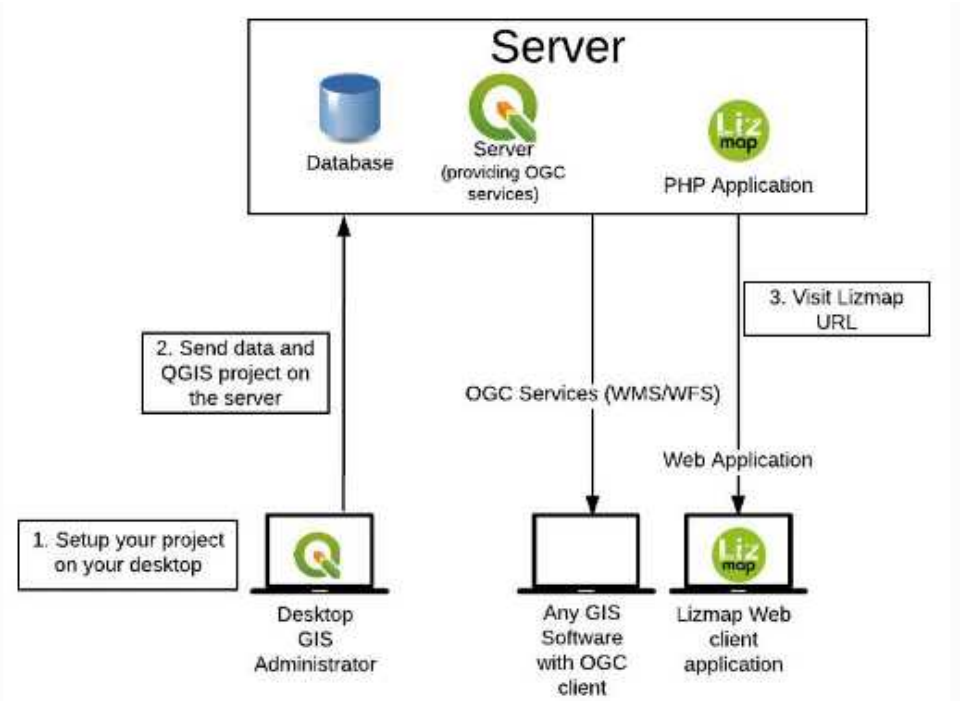

Figure 14: Lizmap architecture obtained from Lizmap documentation

The system architecture takes advantage of a containerized setup that includes five essential services:

- **QGIS Server**: renders maps and exposes geospatial layers through OGC services such as WMS and WFS. It reads .qgs projects files and delivers spatial data dynamically.

- **Lizmap Web Client**: provides a web interface for navigating QGIS projects, enabling users to interact with maps, switch layers, query data, and access metadata.
- **PostgreSQL/PostGIS**: manages spatial datasets, particularly vector layers and their attributes, offering robust data handling and query capabilities.
- **Redis**: servers as a caching backend, optimizing performance by storing repeated responses and reducing server load.
- **Nginx**: routes web traffic, serves static content, and functions as a reverse proxy between the frontend and backend services.

These components are orchestrated using Podman Compose, allowing a rootless deployment strategy that does not rely on a privileged background service (https://docs.lizmap.com/3.8/en/introduction.html). The entire setup is automated via a custom configure.sh script, which generates environment variables and initializes shared volumes, such as lizmap/instances/, where the QGIS projects are stored.

Functional Scope

This platform's main purpose is to display administrative units at both NUTS 0 and NUTS 2 levels for all of Europe, all integrated into a single and cohesive QGIS project. The user interface offers the following interactive features (Figure 5):

- **Layer tree**: users can toggle visibility of individual layers or groups.
- **Map themes**: predefined map views, configured in QGIS, that control which layers are visible on startup (https://docs.lizmap.com/3.8/en/publish/customization/themes.html).
- **Popups on click**: clicking on a raster or vector layer opens a window with information such as pixel value, attributes, and metadata, configured using the Lizmap plugin from QGIS Desktop (https://docs.lizmap.com/3.8/en/publish/configuration/popup.html).
- **HTML metadata per layer**: each layer includes a custom description, download link, and relevant context added through the plugin interface (https://docs.lizmap.com/3.8/en/publish/configuration/project.html).

An example of this interaction is shown in Figure 15, where clicking on a raster cell reveals its ID, classification, and download link.

Figure 15: Example of an interactive web platform

To display the QGIS project with the administrative units of Europe on the platform the following steps were needed to enable the visualization of it:

- **Add directory with files**: The first thing to do is to add the directory of the project inside "lizmap/instances". And inside that repository add the raster files needed inside another repository.
- **Project Properties**: All data sources were set with relative paths to ensure that the platform could locate files regardless of environment. This was configured via "Project → Properties → General → Save paths → Relative" in QGIS Desktop. On the same page a title for the project was needed to be defined.
- **Overview pyramids for raster layers**: To enable raster files visualization on the platform, pyramids must be created for each raster layer. From QGIS Desktop, open the raster properties by double-clicking the layer. In the "Pyramids" menu, select all the resolutions on the right side of the panel. Set "Overview format" as "External" and "Resampling Method" as "Average". Click "Build Pyramids", and once the process is complete, click Accept. Repeat this procedure for every raster file.
- **The Lizmap .cfg configuration file**: This an important step, as this file allows to visualize the project on the platform. When opening the lizmap on QGIS desktop, and press accept, the file should be created automatically.
- **Standardized map scales and initial extent**: To define the initial project extent, first position the map view in QGIS Desktop as desired. Then, in the Lizmap plugin, navigate to "Lizmap Plugin→Map Options→Initial Map Extent" and click "Set to current map canvas extent"., In the same "Map Options" menu, map scales can be defined by adding them in "Scales→Map Scales".

- **HTML metadata for each layer**: In the "Lizmap plugin→Layers", metadata can be specified for each layer. Using "HTML" editor, it is possible to include a link for downloading the layer and to provide a description of what the layer represents.

Data Access and Distribution

Currently, the platform supports external download links for associated raster files (e.g., .tif) that are hosted on Google Drive. While this setup provides temporary functionality, it is intended as an interim solution. Future updates will implement a direct hosting approach using a private server infrastructure or a dedicated file storage system hosted at CTFC. This upgrade will help ensure better long-term availability, traceability, and smoother integration with other services.

Similarly, Ngrok is being used as a stopgap to make the platform accessible from local environments for demos and testing. Once we reach the final deployment phase, the plan is to host the platform on a dedicated external server, providing a secure and permanent access route through a registered domain or institutional gateway.

6. An exercise for Iberia

As part of this deliverable, we conducted a case study to test the applicability of a multi-criteria decision analysis (MCDA) framework at the scale of the Iberian Peninsula. This work serves as a prototype exercise to demonstrate the value and scalability of harmonized, Pan-European datasets and tools in supporting large-scale strategic decision-making in the context of wildfire prevention and forest management. While the focus is on the Iberian Peninsula, the methods and tools employed are scalable and transferable across the EU thanks to the harmonization of underlying spatial data.

The goal of this case study was to identify and prioritize areas within the Iberian Peninsula where forest management actions could most effectively reduce wildfire risk and its associated impacts. The analysis was conducted at a high spatial resolution of 100x100 m. The MCDA framework was structured around three major thematic criteria: Fuels, Fire Behaviour, and Values at Risk. These criteria encompass both the biophysical environment and societal considerations.

6.1. Data and Tools

6.1.1. Data sources

The data used in this study are derived from harmonized, Pan-European sources to ensure consistency, interoperability, and replicability across regions. For the Fuels criterion group, we employed datasets from the Pan-European Fuel Map Server developed within FIRE-RES. These datasets include harmonized vegetation structure layers such as canopy cover, above-ground biomass, crown base height, and crown bulk density, all of which are relevant for assessing forest fuel characteristics in a wildfire context. Fire Behaviour data layers- including flame length, fireline intensity, and rate of spread- were derived from simulations using standardized models implemented by Technosylva. Values at Risk were captured through harmonized datasets on population density, proximity to primary roads, and the location of protected areas. The consistent spatial resolution and EU-wide coverage of these datasets are essential for enabling a robust and scalable prioritization model.

6.1.2. Tool

A dedicated QGIS plugin, developed by ISCI Chile, was used to operationalize the MCDA workflow. This plugin enables the integration of stakeholder-derived weights and supports the definition of scale parameters for each sub-criterion. It offers multiple options for converting sub-criterion values into utility scores, including direct thresholds, percentile-based transformations, and step-up or step-down functions, etc. These capabilities allow for high flexibility in adapting the model to local or regional contexts while maintaining consistency in the underlying logic. The plugin also performs the normalization of input layers and automates the final weighted overlay operation, generating the composite priority map. Through this tool, the entire MCDA process (from

stakeholder input to spatial prioritization) can be conducted within a unified and reproducible environment.

6.1.3. Stakeholder engagement

Stakeholder participation was embedded in the study design to ensure the model reflects diverse expert perspectives. The engagement process consisted of two sequential phases:

- First, an online survey was distributed to 14 FIRE-RES Innovation Action leaders and representatives from each Living Lab to gather input on which sub-criteria should be included under each main criterion (Figure 16). Respondents evaluated the relevance and applicability of various potential indicators. Based on this feedback, the sub-criteria that received the highest levels of agreement were selected for inclusion in the model (Figure 17). This participatory approach ensured that the problem structure itself was co-designed with stakeholders, reflecting their operational priorities and local knowledge.

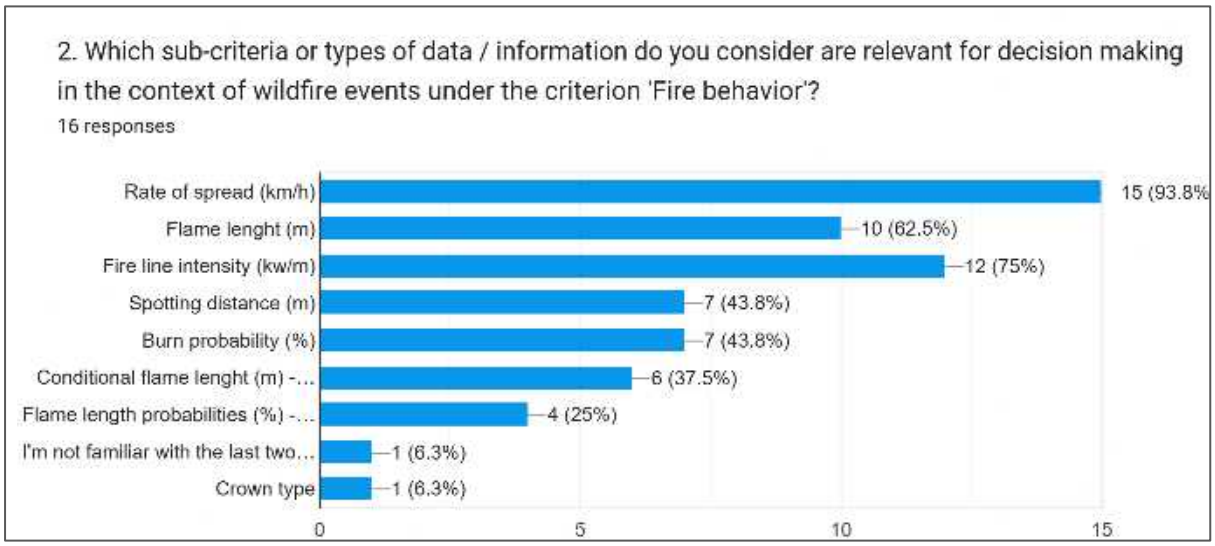

Figure 16: Example of the results obtained for one of the questions in the survey to elicit the sub-criteria

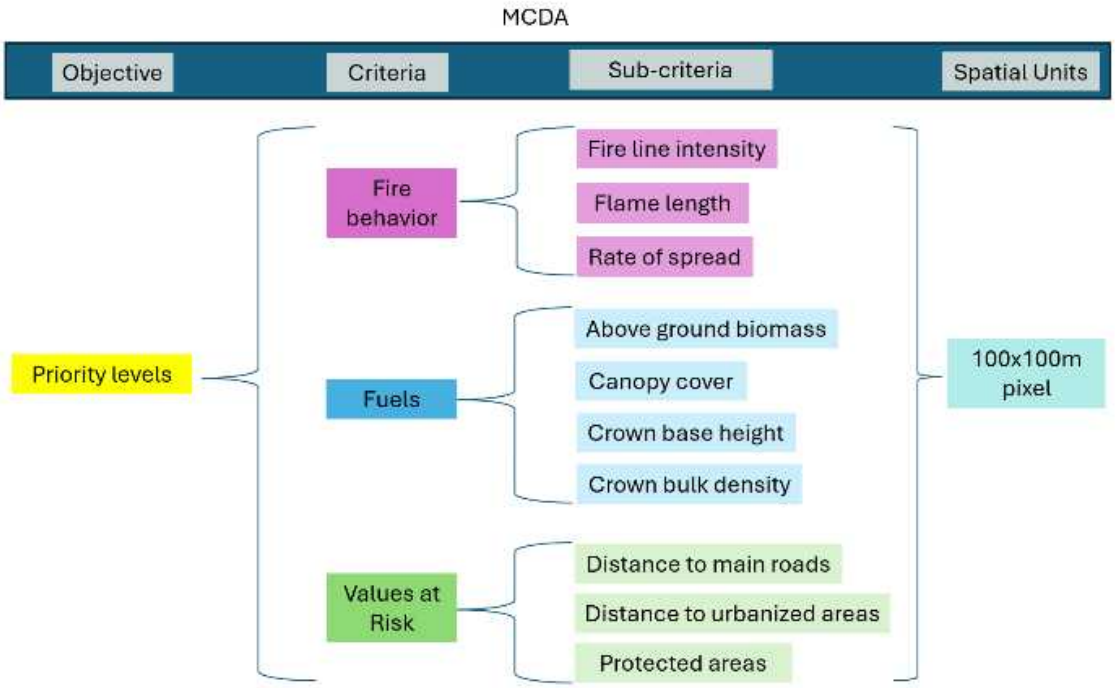

Figure 17: MCDA hierarchical model after eliciting sub-criteria with experts

- In the second phase, a focused Analytic Hierarchy Process (AHP) exercise was conducted to derive relative weights through pairwise comparisons (Figure 18). This was implemented via an online survey designed using Google Forms, in which participants were asked to compare each pair of main criteria and sub-criteria in terms of their relative importance. The responses were collected from 14 experts. Final weights were then calculated by aggregating the individual judgments using the geometric mean, following standard AHP methodology.

Figure 18: Example on how the weights are retrieved from the individual pairwise comparisons conducted within Google Forms. The graph represents the level of importance that each participant gave to Fuels vs. Values at risk (e.g., four participants gave 7 times m

Table 2: Aggregated weights by all 14 experts

Criterion	Sub-criterion	Weight
Fire Behaviour	Flame Length	0.397
	Fireline Intensity	0.307
	Rate of Spread	0.296
Fuels	Above Ground Biomass	0.560
	Crown Bulk Density	0.209
	Crown Base Height	0.062
	Canopy Cover	0.168
Values at Risk	Distance to urbanized areas	0.913
	Distance to Primary Roads	0.057
	Presence of Protected Areas	0.030
Main Criteria Weights	Fire Behaviour	0.226
	Fuels	0.299
	Values at Risk	0.475

6.1.4. Utility Function Definition and Scaling Parameters

To support utility function construction, scale parameters and threshold values for each sub-criterion were defined (Table 3) through a review of relevant scientific literature and operational guidelines. This approach ensured that utility functions were grounded in empirically supported benchmarks while maintaining consistency across the study area. By applying the same functions across the entire Iberian Peninsula, we ensured spatial comparability while reflecting regionally meaningful benchmarks.

Table 3: Scale parameters to define the utility functions

Main Criterion	Sub-criterion	Priority Scale (Utility 0 - 1)	Interpretation
Fire Behaviour	Flame Length	1.2 m - 3.4 m	Higher flame length increases fire severity
	Rate of Spread	0.06 km/h - 1.2 km/h	Faster spread increases risk
	Fireline Intensity	346 kW/m - 3459 kW/m	More intense fireline = higher priority
Values at Risk	Distance to Primary Roads	1000 m - 150 m	Closer proximity increases strategic importance
	Distance to Urbanized Areas	600 m - 30 m	Higher priority near settlements

Main Criterion	Sub-criterion	Priority Scale (Utility 0 - 1)	Interpretation
	Protected Areas (Binary)	Outside (0) - Inside (1)	Protected areas are prioritized
Fuels	Above Ground Biomass	Lowest observed - Highest observed	Greater biomass implies higher fuel accumulation
	Crown Bulk Density	< 0.15 kg/m^3 - ≥ 0.15 kg/m^3	Step function: above threshold increases crown fire risk
	Canopy Cover	20% - 60%	Denser canopy > risk of canopy fire propagation
	Crown Base Height	5.0 m - 2.5 m	Lower height favours crown fire initiation

6.2. Resulting Priorities

Once all layers were transformed into utility scores, a weighted linear combination was applied using the experts' aggregated weights. The QGIS plugin handled all overlay calculations and output generation, including the intermediate normalized layers for each sub-criterion, for each criterion group (Figures 19,20,21), and the final integrated priority index (Figure 22). This composite map highlights areas where management interventions would have the highest potential impact.

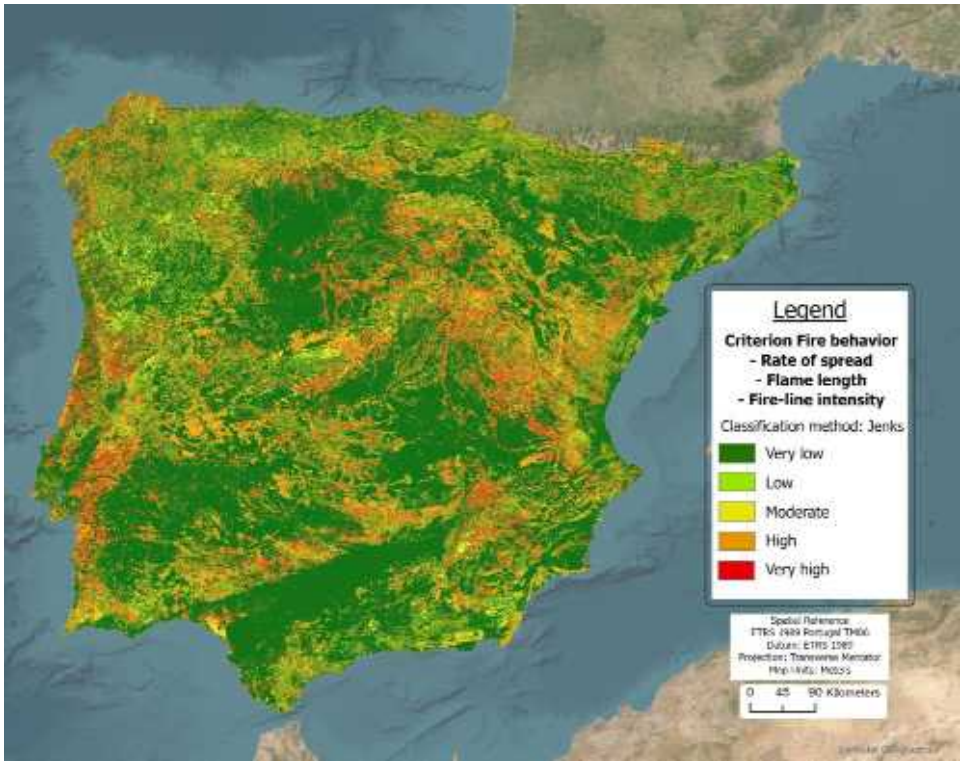

Figure 19: Priorities for forest management interventions regarding criterion Fire behaviour

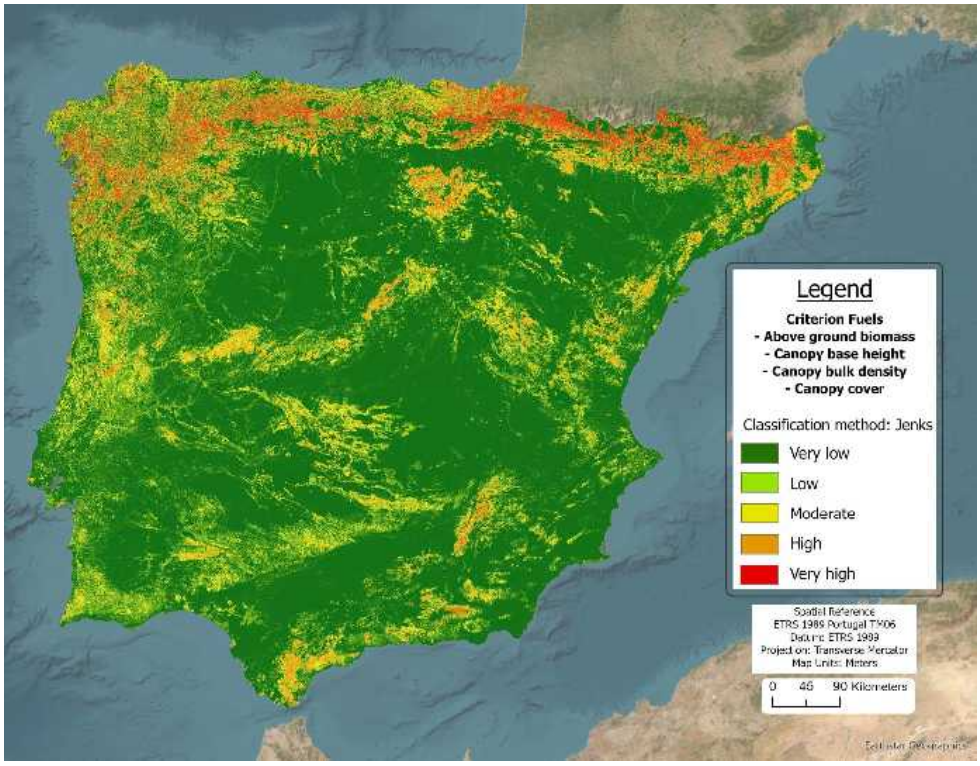

Figure 20: Priorities for forest management interventions regarding criterion Fuels

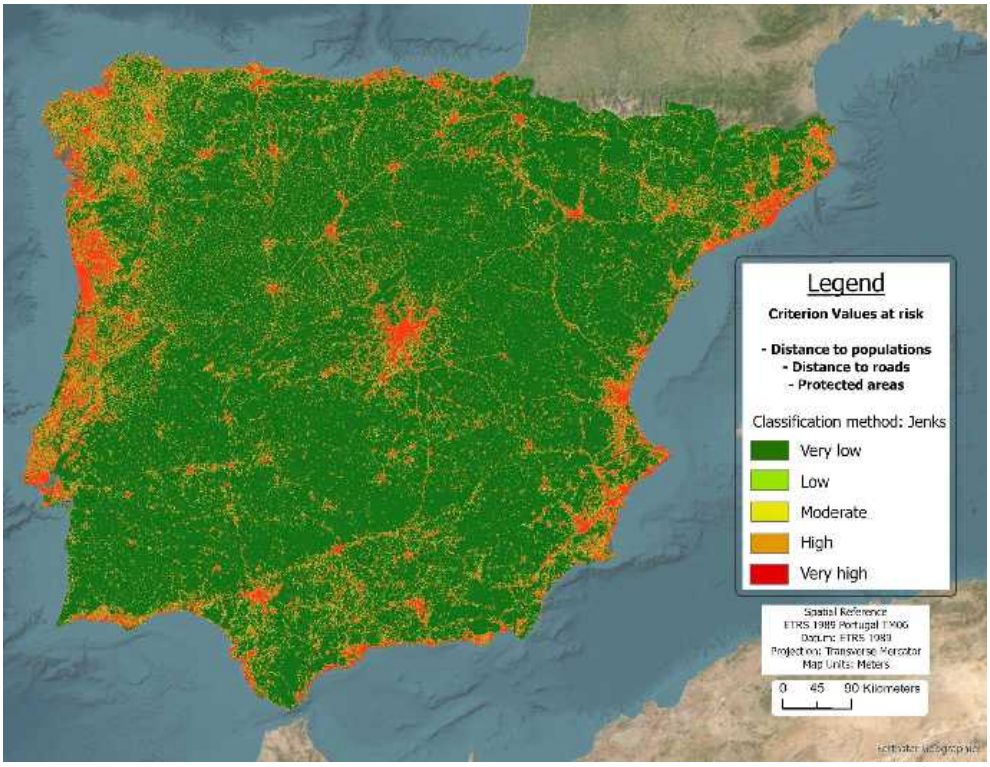

Figure 21: Priorities for forest management interventions regarding criterion Values at risk

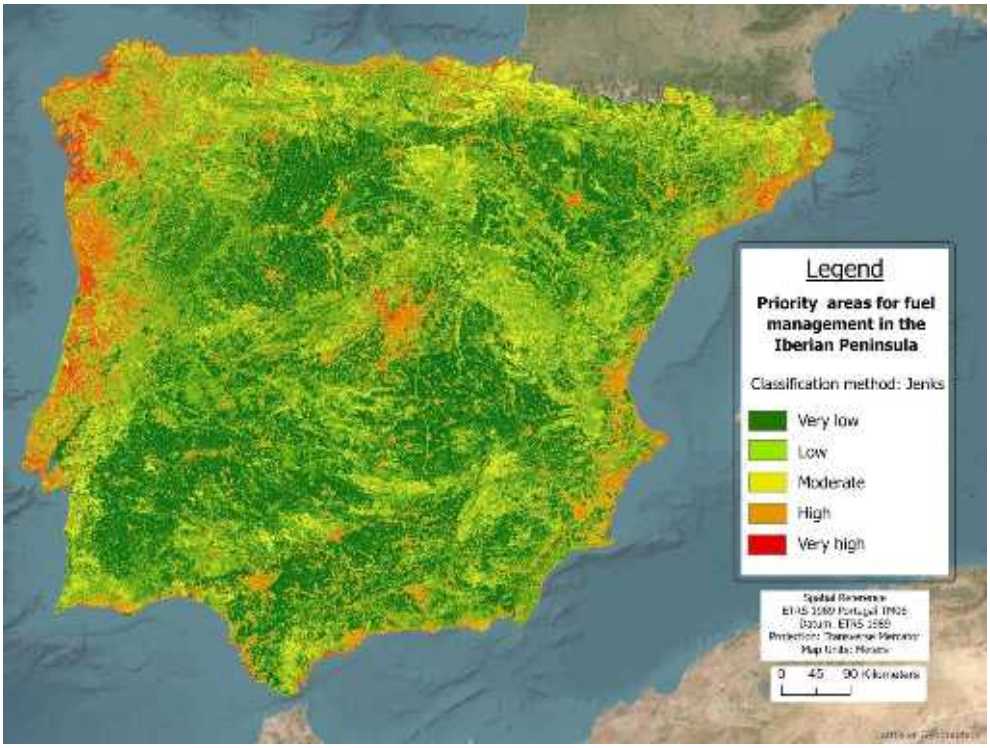

Figure 22: Final map of priorities for forest management interventions after aggregating the four criteria groups

The spatial outputs generated through the MCDA model further highlight key regional patterns relevant for fire prevention strategies. The Fire Behaviour criterion reveals that the most severe conditions are concentrated in the central mountainous regions of the Iberian Peninsula, where topography and fuel continuity favour intense fire dynamics. The Fuels criterion shows the highest priority values along the northern fringe of the peninsula, particularly in areas with a well-developed forestry sector. These regions, characterized by extensive pine and eucalyptus plantations and more humid climatic conditions, tend to accumulate substantial tree and shrub biomass, which contributes to increased fire risk.

For the Values at Risk criterion, the sub-criterion Distance to Urbanized Areas was overwhelmingly prioritized by experts, receiving approximately 91% of the total weight within that criterion. This is reflected in the spatial distribution of high-priority areas, which cluster around densely populated zones and major cities, indicating a strong concern for human safety and infrastructure exposure.

The final priority map represents a balanced integration of the three main criteria, weighted according to expert input. It identifies Portugal, especially the coastal area stretching from north of Lisbon to Galicia, as a key region of concern. Similarly, the Cantabrian Mountain range emerges as another hotspot, primarily driven by dense fuel loads and associated fire behaviour risks. These results underscore the utility of the model in highlighting priority areas for targeted wildfire prevention measures, supporting more effective and geographically nuanced decision-making across national and regional levels.

This case study demonstrates the feasibility and strategic value of using harmonized Pan-European datasets within an expert-informed MCDA framework for wildfire prevention. The combination of consistent geospatial layers, participatory model definitions and weighting, and open-source tools provides a robust foundation for cross-border planning and governance.

7. Conclusions

The system integrated 3 different functions for its completion. For each one we found different levels of difficulty, specific challenges and potential uses. Still, a common challenges, related to the use of the system and its components was the use of a pan-European scale that required both harmonization rules, and the capacity to deal with very large datasets.

A first step called for the development of an operational fuel map, with a 100 by 100-meter resolution. It was the first Fuel map server at European level with all the vegetation features to run forest fire simulations. It presented an harmonized methodology for the EU-27 countries, including same coordinate reference systems and spatial resolution. The server presented an Interactive tool to visualise and download data at different NUTS levels. All the layers produced in the Pan-European Fuel Map Server were published and are well documented following the FAIR principles, as presented in chapter2. The scale and harmonization rules are quite adequate for European or national level assessments, but still if more accurate assessments are required for regional level, probably not only the scale is to be considered coarse, but also some of the rules used for defining surface fuels, is to be adjusted to specific regional data.

When simulating fire behaviour, following the philosophy of the FIRE-RES project, which aims to respond to the increasingly changing and extreme forest fire events in the European context, more extreme climatic conditions in the time series analysed were used. For this reason, the 2nd percentile for relative humidity and the 98th percentile for the other variables were used, simulating the conditions that generate this type of events. The use of average values would have greatly limited the analysis of the DSS's response to the new and growing context of extreme events in Europe. This methodology allows to identify the areas of greatest risk for better planning of both preventive actions in the territory and rapid response by the emergency services. Still, use of more historically based scenarios, although may have limited identifying potentiality of intense fires occurrence, may help to identify priorities for many other purposes, as for example it could have been used for potential damage estimations, not based on extreme but on averages.

When developing the MCDA tool, we identify different aspects to be consider. For example, it allows the plugin to run in the background, so the user can continue doing other tasks without collapsing. It is designed for easy understanding by any type of user due to its simplicity and help schemes in the plugin itself. In general, we and say that the tool is an adequate way to deal with such large amount of data an implement spatial prioritization assessment. It works quite well for the generated data and may also be used for similar analysis based on other but similar data. We would also like to make the processing happen online so that the speed does not depend on the user's computer and test the plugin with layers saved in other data type formats. That is formats other than float32, such as int8 or float64. Now the system works with administrative boundaries, and in the future, it can be positive if we are able to apply user defined polygons, to download the data and implement the analysis.

In general, we can say that the development of this tool represented a challenge for its scale, and harmonization requirement, Initially it was assumed that the tool would move from a TRL 6 to a TR9, during the process we observed that the lack of data at EU, and the need of specific analysis requirement, situated us more into an TRL3 when talking on a EU scale basis, even if approaches like the applied in IA 2.5 we similar in a sense and already tested, but required a new approach for the present tools and associated data. The final system and method can be consider reaching between a 7 and 9 TRL. In the case of fuel mapping and the subsequent fire simulation, it can be said that around a TRL9 can be assumed, as the final product is available for use in the case of fuels, and the simulation tools are well proven. The multicriteria toll as shown it has been tested for the Iberian peninsula, but still further stress trials are required, and there is a lack of sufficient criteria and indicators, related to values at risk, that should be achieved in the future if higher TR Levels are to be considered.

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