Experiment #7

Environmental Assessment of Fire-affected Ecosystems [SQUAREDEV]

Overview and Objectives

Squaredev is a sophisticated PPDR solution focusing on reforestation policies and strategies implied by PPDR agencies. The platform solution has been developed within the context of the EU-funded project TREEADS.

The solution is a holistic and user-friendly Post-fire Decision Support System (DSS), to support the effort of related public and private agencies for the successful post-fire management and restoration process.

The TREEADS Decision Support System is a tool for integrating the phases of the environmental assessment and management process of burned areas (Figure 1). It assists managers in making necessary decisions for the restoration and adaptation of fire-affected ecosystems. This task aims to incorporate technological solutions into the current system, and introduce new techniques for assessing, monitoring, managing, and restoring burned wildland areas. The DSS is part of the TREEADS platform, facilitating agile environmental assessment of burned areas through remote sensing and mapping capabilities (Figure 2). It provides fire severity maps, management priority zoning maps, and management zoning maps with objectives and recommended actions.

Figure 1: TREEADS DSS UI component

This project has received funding from the European Union's Horizon 2020 Innovation Action programme under Grant Agreement No 101016521.

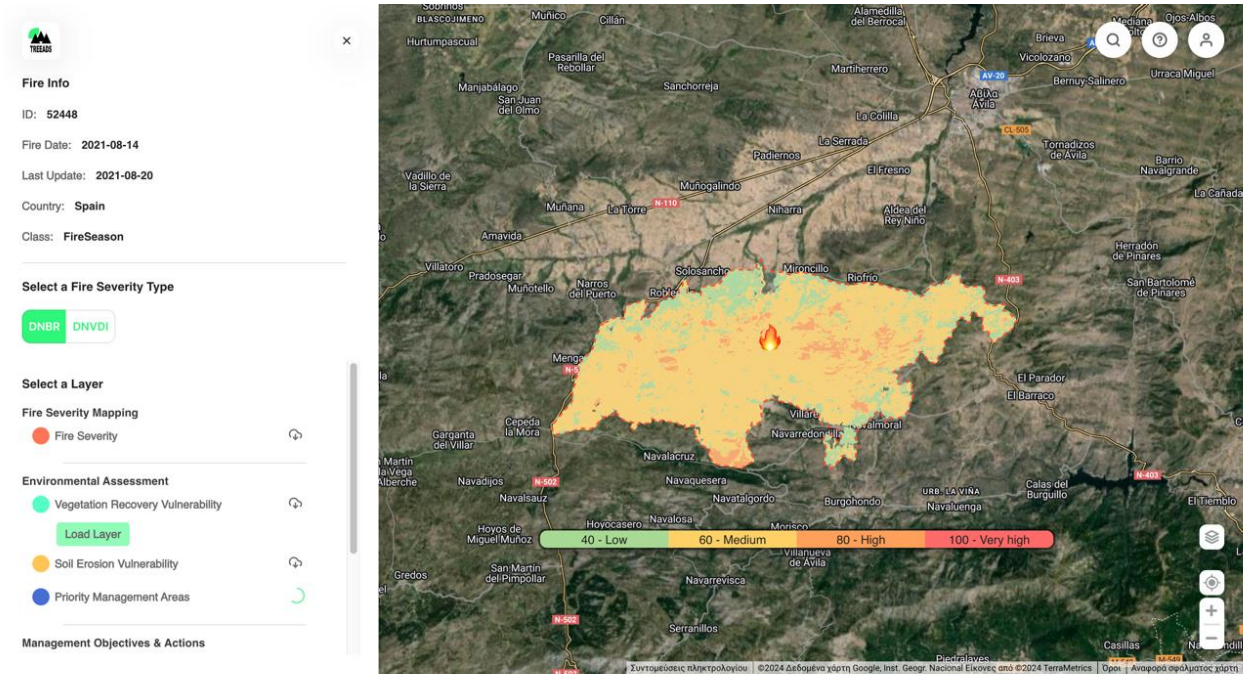

Figure 2: TREEADS DSS Environmental Assessment

The DSS is composed of several interconnected components, each playing a crucial role in the system's functionality (see Figure 3):

- **DSS UI** provides a user-friendly interface for accessing and interacting with the DSS. It allows users to view burned areas and the various modules of the DSS. Through interactive maps and visualization tools, users can analyse fire severity maps, assess vulnerability, and explore management recommendations.
- **DSS API** handles data processing for the various modules of the DSS. It consists of *Module 1: Assessment of Fire Severity in the Ecosystem*, which outputs fire severity maps; *Module 2: Environmental Assessment of Vulnerability*, which assesses vegetation recovery and soil erosion; and *Module 3: Management Objectives and Actions*, which identifies management objective areas, wood extraction suitable areas, and proposes management actions. The API utilizes Google Earth Engine (GEE), Geospatial Data Abstraction Library (GDAL), and Celery for asynchronous task processing, with Redis used for Celery's task queue management.
- **DSS COG** is a dynamic tile server built on Rasterio/GDAL, designed for serving Cloud Optimized GeoTIFFs (COGs). It provides efficient access to geospatial data through dynamic tiling, enabling quick and scalable data visualization.
- **Object Storage** acts as the object storage service for the DSS, storing geospatial data, including COGs, processed datasets, and other relevant files. This component ensures that large volumes of data are securely stored and readily accessible for processing and analysis.
- **Redis** is an in-memory data structure store used for Celery's task queue management. This allows for efficient handling of asynchronous tasks, improving the overall performance and responsiveness of the DSS API.
- **MongoDB** is a NoSQL database used for storing DSS-related data, metadata, assessment results, and other non-spatial data. This database provides a flexible and scalable storage solution, accommodating the diverse data requirements of the DSS.

KPIs were defined in alignment with the common experimental definitions outlined in D1.6, including types of performance – **upgradeable (U)**, **acceptable (A)**, and **optimal (O)**. They are presented in Table 1.

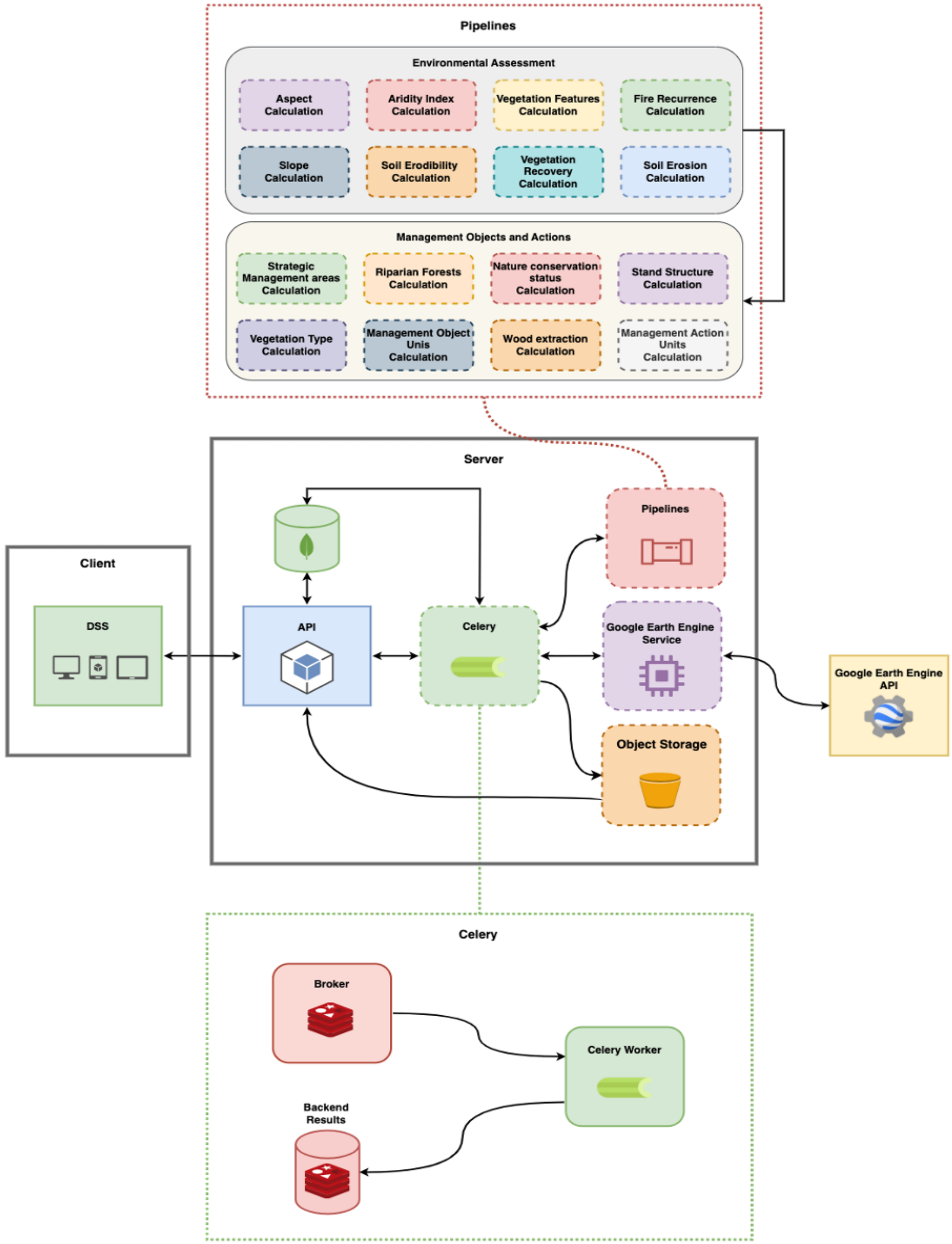

Figure 3: TREEADS DSS components

Table 1: Test Case definitions for Squaredev experiment

KPI Type	Parameter	Target values	Test description
Time-related	Latency (L), measured in *ms*	**Upgradeable (U):** L > 500 **Acceptable (A):** 100 ≤ L ≤ 500 **Optimal (O):** L < 100	For API testing, we sent requests to the API and measured the time taken for each request to reach the server and receive a response. Using tools like K6[1], we calculated the average latency and compared it against defined ranges. For UI testing, we loaded various UI components and measured the time taken for rendering using browser developer tools, then compared rendering latency against specified ranges.
Time-related	Response Time (RT), measured in *ms*	**Upgradeable (U):** RT > 1000 **Acceptable (A):** 200 ≤ RT ≤ 1000 **Optimal (O):** RT < 200	We sent various types of requests to the API and measured the time taken for the server to process each request and send a response back to the client. Using performance monitoring tools like K6, we compared response times against specified ranges. For UI testing, we interacted with UI components and measured the time taken for user actions to receive a response, then compared response time against specified ranges.
Throughput-related	Throughput (T), measured in *requests per second*	**Upgradeable (U):** T < 100 **Acceptable (A):** 100 ≤ T ≤ 500 **Optimal (O):** T > 500	We used load testing tools (K6) to simulate concurrent requests to the API and measured the rate at which the server processed incoming requests, then compared them against specified ranges. For UI testing, we performed actions in the UI that triggered API requests and measured the throughput of UI components in terms of data retrieval and rendering, comparing against specified ranges.

Testbed Readiness and Experiment Deployment

The deployment of the TREEADS DSS on the 5G-EPICENTRE platform was relatively straightforward, especially facilitated by the use of the Helm chart packaging format/yaml manifest files. The provision of essential documents, such as sample manifests and propagation policy was maintained throughout a preparation phase. In addition, a dedicated namespace in the CTTC cluster of the 5G-EPICENTRE Barcelona testbed was set up and a Role-Based Access Control (RBAC)-based access control scheme was established. Openebs for dynamic PVC/PV management were successfully installed, enabling Squaredev to commence their service deployment.

Experiment Execution and Results

The experiment was executed using a controlled testing environment, with the DSS deployed on the CTTC infrastructure. The experiment involved both API and UI testing scenarios, each executed independently to assess the system's functionality and performance.

API testing was performed using K6, an open-source load testing tool, to simulate real-world scenarios and measure various performance metrics. The test involved sending requests to the API endpoints under varying load conditions to measure latency, response time, and throughput. The experiment aimed to identify any bottlenecks or performance issues within the API infrastructure. The quantitative results obtained from the experiment (Table 2) provided valuable insights into the performance of the DSS components.

[1] https://k6.io/

Table 2: Squaredev API testing results

KPI	Average	Minimum	Median	Maximum	90th Percentile	95th Percentile
Status	100% requests returned status 200 (success)					
Latency	134.28 ms	96.08 ms	127.48 ms	377.97 ms	158.70 ms	180.71 ms
Response Time	137.00 ms	96.71 ms	130.11 ms	378.10 ms	163.29 ms	183.64 ms
Throughput	70889 requests completed over 5 minutes (236 requests/second)					

UI testing focused on assessing the responsiveness and rendering efficiency of the DSS interface. Various user interactions were simulated to measure the responsiveness of UI components, while data-intensive tasks were performed to evaluate data retrieval and rendering speed. The experiment aimed to ensure a seamless user experience and efficient utilization of resources. Results from UI testing showed that the interface efficiently rendered components and responded quickly to user interactions. Specific metrics captured using browser developer tools indicated that:

- **Latency for UI Rendering:** Consistently below 100ms for most components.
- **Response Time for User Actions:** Typically between 400ms and 500ms, meeting the acceptable range.
- **Throughput:** Performed actions in the UI that triggered API requests and measured the throughput of UI components in terms of data retrieval and rendering, which was consistent with the API throughput

Performance interpretation by types of performance indicatd the following:

- The average latency was 134.28 ms, which falls within the acceptable range (100 ms ≤ Latency ≤ 500 ms). The maximum latency observed was 377.97ms, indicating that all requests were within the acceptable range, without any exceeding the upgradeable threshold.
- With a 90th percentile response time of 163.29ms and a 95th percentile of 183.64ms, the majority of requests fall within the optimal range (RT < 200ms). These results indicate that the system is performing very well in terms of response time, providing a swift user experience.
- With an average of 236.01 requests per second, the throughput is within an acceptable range but indicates potential for optimization to handle higher request rates.

These results will inform future development and optimization strategies, to ensure the DSS operates efficiently under various load conditions. Further efforts will focus on maintaining or improving the current performance to enhance overall system reliability and user satisfaction.

Overall evaluation

The experiment demonstrated that the DSS for managing burned areas performs well under various load conditions. KPIs, such as latency and response time, were mostly within acceptable ranges, with response times frequently falling into the optimal range. These results highlight the robustness and efficiency of the DSS whilst operating in a 5G environment, ensuring reliable performance during critical post-fire environmental assessments.

The integration of the 5G-EPICENTRE platform has the potential to significantly enhance Public Protection and Disaster Relief (PPDR) operations. For applications like the DSS, the 5G-EPICENTRE platform provides:

- **Low Latency:** The low latency capabilities of the 5G-EPICENTRE platform ensure rapid data transmission, enabling real-time decision-making and faster response times during emergencies.
- **High Throughput:** the 5G-EPICENTRE platform's high throughput facilitates the handling of large datasets, such as high-resolution satellite images and extensive environmental data, improving the accuracy and efficiency of environmental assessments.

Within the testbed context, the solution did not aim to leverage the full benefits of the 5G core, since the requirements, mainly the size of information inputs, were limited to high-resolution images and maps used within the solution. Using the 5G-EPICENTRE platform, the DSS can provide faster and more accurate fire severity maps, management priority zoning maps, and actionable insights for ecosystem restoration, significantly improving the efficiency of disaster response and recovery efforts. In addition, the augmented features of the 5G-EPICENTRE Platform and the network applications used for testing and validation, provided useful insights to the Squaredev technical team, for the upgrade and upscaling of the solution to an experimental 5G environment.

Finally, the KPIs provided to the team provided useful information for future developments, such as receiving inputs from images/videos from drones/UAVs, and the need to elaborate bigger real-time data and information for the reforestation decision-making, as well as managing to achieve real-time flow of information. Despite the deployment, testing, and validation of the solution in a 5G environment, 5G-EPICENTRE features provided a set of complete information for the needs of the solution and the possibilities for a successful uptake and commercialization.

The following is testimonial received from Squaredev, regarding the evaluation of the experiment results:

"Our experience with the 5G-EPICENTRE platform has been transformative for the development and optimization of our Decision Support System. The advanced capabilities of the 5G-EPICENTRE platform, particularly in terms of low latency and high data throughput, have enabled us to enhance the performance and reliability of our system significantly. The experimentation process on the 5G-EPICENTRE platform has provided us with invaluable insights, allowing us to fine-tune our applications to meet the stringent demands of Public Protection and Disaster Relief operations".