LanDS Dashboard

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

REACT4MED

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2.1	7 April 2025	Elena Matta, Enrico Weber	Minor adjustments and final drafting of the report

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List of acronyms

CDD: Maximum Length of Dry Spell
CID: Climate Impact Drivers
CIHEAM Bari: Istituto Agronomico Mediterraneo di Bari
CLI: Command Line Interface
CY: Cyprus
CyI: The Cyprus Institute
CMS: Content Management System
D: Deliverable
DB: Database
DM: Decision Maker
DoA: Description of Action
EG: Egypt
ES: Spain
ERLL: Ecosystem Restoration Living Lab
GA: Grant Agreement
GPU: General Public Licence
GR: Greece
HMU: Hellenic Mediterranean University
IL: Israel
INRA: Institut National de la Recherche Agronomique
IT: Italy
JSON: JavaScript Object Notation
LanDS: Land degradation Decision-Support
M: Month
ML: Machine Learning
MO: Morocco
MS: Milestone
PA: Pilot Area
PAL: Pilot Area Leader
PDS: Participatory Development Solutions
PPs: Project Partners
PRIMA: Partnership for Research and Innovation in the Mediterranean Area
SH: Stakeholder
SOFTW: SoftWater s.r.l.
STAC: SpatioTemporal Asset Catalogs
TR: Turkey
TUC: Technical University of Crete
UH: University of Haifa
UOS: Osnabrück University
UTAEM: Turkish International Agricultural Research and Training Center
UV: Universidad de Valencia
WCS: Web Coverage Service
WFS: Web Feature Service
WMS: Web Map Service
WP: Work Package

Executive Summary

Deliverable D4.4 demonstrates the release of the LanDS Web Interactive Dashboard, available at the following URL: http://lands.soft-water.it and at the official project's website: https://react4med.eu. The Dashboard is the fifth tool of the science-based Land degradation and restoration Decision-Support Toolbox, which is composed of four other tools (see Deliverable D4.3 for details). It offers a user-friendly and interactive interface, supporting policy makers and other stakeholders in the assessment of land degradation and evaluation of the impacts of restoration measures. Combining existing knowledge from global and regional renowned repositories and expertise arisen from the living labs in the pilot areas, the LanDS is aimed at supporting better-informed land restoration actions and more sustainable resources management, enabling – towards the final stage of the project – the elaboration of policy recommendations and the identification of investment opportunities for public and private actors, based on the criteria of maximum cost-effectiveness and impact (in collaboration with WP5 and WP6).

1 Introduction

REACT4MED aims to extend the potential application of the land restoration actions promoted in the Ecosystem Restoration Living Labs (ERLLs) running in the different pilot areas (PAs) to the Mediterranean scale. Within the project, Work Package 4 (WP4, Science-based decision support toolbox) efforts are focused on developing a scientific Land degradation Decision-Support Toolbox (LanDS) and applying it at different spatial and temporal scales. The LanDS development followed a co-creation approach, involving stakeholders (SHs) and decision-makers (DMs) from ERLLs in the design and evaluation of the toolbox, to ensure portability and maximise its effectiveness. This brought tight collaboration with WP3 at the beginning of the project and PA leaders, who are our first SHs and experts of the study areas, but also with WP2, which reviews and provides robust literature sources and broad-level indicators, including satellite-based land productivity and climatic trajectories, on which the LanDS is based. An overview of the REACT4MED WPs interaction is shown in Figure 1 (from the Description of Action - DoA, i.e., Annex I of the GA).

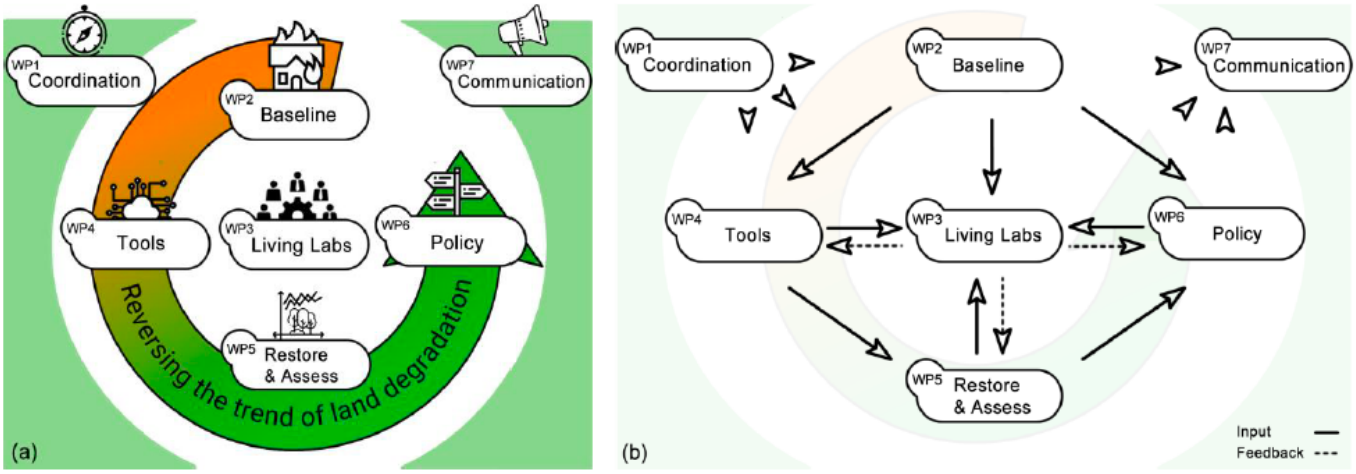


Figure 1 REACT4MED Work Package (WP) structure (a) and information flow within its conceptual framework (b).

In this framework, the multi-operational LanDS toolbox aims to support a harmonized land degradation assessment and impact evaluation of REACT4MED restoration measures, applicable to different geographical and social contexts. This deliverable consists in the accompanying document of the LanDS Web Interactive Dashboard's release. The Dashboard is deployed and accessible at LanDS website[1] and at REACT4MED website[2], while the software developed is released in an online public repository[3].

The scheme of the LanDS toolbox is shown in Figure 2. The five tools included in the LanDS are the following: (1) a geo-referenced data repository serving as a knowledge base by collecting site-specific data and resources from the ERLLs (WP3) as well as broader scale information from global or regional public repositories and satellite-based indices (WP2); (2) a data viewer, containing a set of visual analytics tools linked with this repository allowing effective data access and sharing among project partners and stakeholders, and interactive visualizations, supporting the monitoring of restoration actions (WP5) and dissemination of project outcomes (WP7); (3) an indicators library implemented as a modular and generalised code library applicable to different geographical contexts based on collected data and indicators identified in collaboration with WP2 and WP3; (4) a machine-learning based procedure (alias ML tool) to identify potentially suitable areas in the Mediterranean for up- and outscaling of restoration measures. The fifth tool (5) is the LanDS web interactive Dashboard, which offers a harmonised land degradation assessment and evaluation of impacts of restoration measures through a user-friendly interface.

[1] http://lands.soft-water.it
[2] https://react4med.eu/
[3] https://gitlab.com/lands-r4m

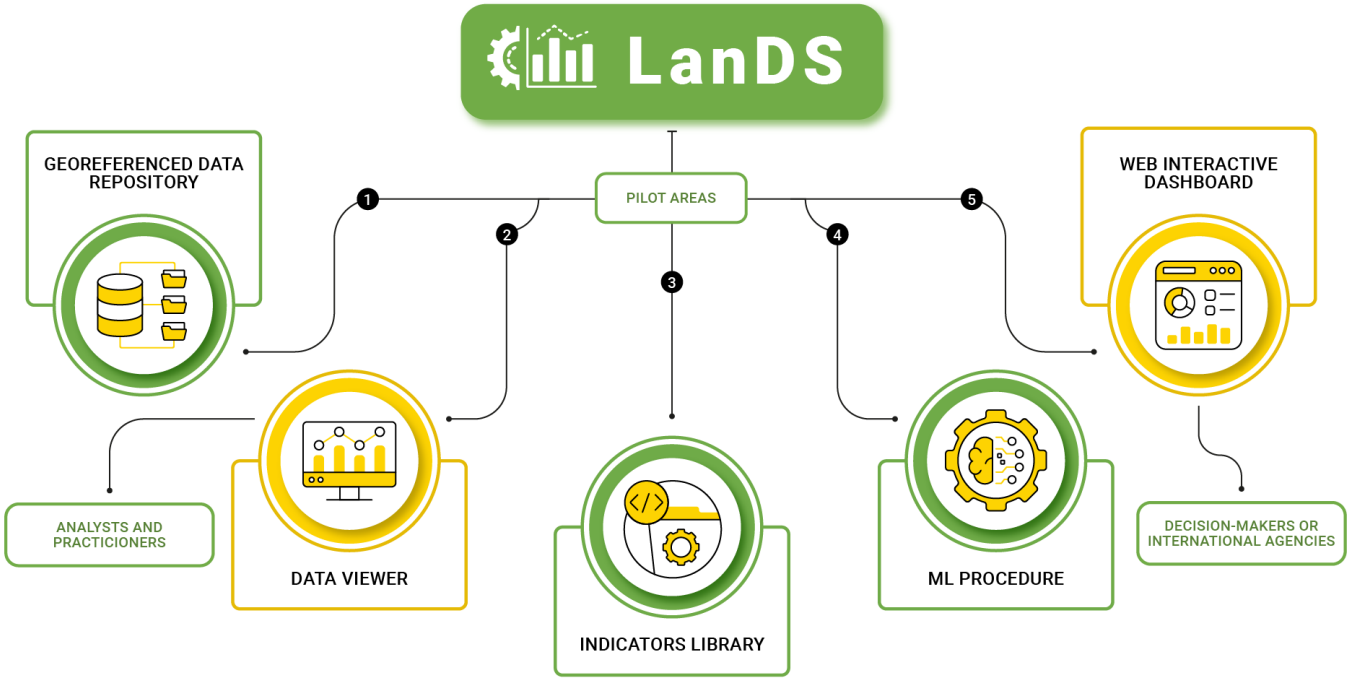


Figure 2 Scheme of the LanDS toolbox, composed of five main tools.

The document is structured as follows: after this introduction, Section 2 describes the LanDS Dashboard, including its structure and features (following the three different pages of the Dashboard, indicating threats, clustering analysis map and outscaling maps driven by the expert-based criteria of the restoration actions implemented in the eight pilot areas, respectively). Additional subsections are dedicated to the applied technologies and the online documentation page, while Section 3 draws some conclusions with an outlook on the next steps.

2 The LanDS Dashboard: structure and features

The LanDS is an innovative decision-support tool developed within the REACT4MED project to assess land degradation, evaluate restoration actions, and identify suitable areas for upscaling sustainable land and water management (SLWM) solutions. The Dashboard enhances LanDS functionalities with a powerful visualization tool, which allows combined visualization of climate indicators, machine learning clustering outcomes, and expert-based analysis to provide interactive visualizations for policymakers, scientists, and stakeholders. It is characterized by a modular structure that can be customised to include and compare interactive graphics, structured maps, text and content to foster project outcomes exploitation and dissemination. The current implementation includes the following visualizations:

- Climate change, socioeconomic, and land degradation indicators at the Mediterranean scale;
- Challenges and monitoring of restoration actions[4] in the REACT4MED pilot areas;
- Outcomes of the ML Tool and expert-based filter, to identify similar areas in the Mediterranean region and, at a higher resolution, potentially suitable areas for up- and outscaling of restoration actions, based on expert-driven criteria and different filtering levels.

The Dashboard is freely available at the LanDS URL[5], also accessible from the REACT4MED website[6], and the source code has been released with an open-source licence in a public code repository[7].

In this Section, we briefly present the structure, main features and snapshots of the current Dashboard, which can be reached from the top bar menu of the LanDS web interface. Further information and documentation on the LanDS Toolbox can be found in Deliverable D4.3 Final LanDS Toolbox.

The Dashboard will continue to evolve with user feedback and additional data integrations, supporting activities of Task 6.3: LanDS scenarios to inform policy making. Currently, it is structured into three main pages, described in the following subsections: Climate Extremes & Environmental Threats[8], Cluster Map[9], and Expert-Based Filtering[10]. Refinements and adjustments of those pages (e.g., legends, results of PAs' expert filters) are still ongoing.

2.1 Climate Extremes & Environmental Threats

This section provides an overview of land degradation challenges in the Mediterranean region and the REACT4MED pilot areas. It visualizes key climate extreme indicators (e.g., TXx, TR, R5days) and land degradation trends using interactive line charts and spatial maps (e.g., salinity, aridity). The line charts display temporal variations of LanDS climate indicators (see Section 2.3 of D4.3 for more details), with each line representing the eight pilot areas (i.e., correspondent hydrological subbasin from Hydrobasins 06[11]). At the same time, the background includes a grey-shaded area representing all other subbasins of the whole Mediterranean region to provide a broader context. This visualization supports users in identifying trends, assessing climate-driven land degradation, and understanding the severity of environmental threats across different regions.

[4] For more details on the implemented restoration actions, see D5.1 Restorations technologies tested and validated.
[5] http://lands.soft-water.it/
[6] https://react4med.eu/
[7] https://gitlab.com/lands-r4m
[8] https://lands.soft-water.it/node/6
[9] https://lands.soft-water.it/node/7
[10] https://lands.soft-water.it/node/8
[11] https://www.hydrosheds.org/products/hydrobasins

The main features of this Dashboard's page are:

- Interactive line charts showing historical trends of climate extreme indicators.
- Spatial maps highlighting land degradation hotspots.
- Comparative analysis of pilot areas against the wider Mediterranean context.

A snapshot of the first page of the LanDS Dashboard in its current status is reported in Figure 3:

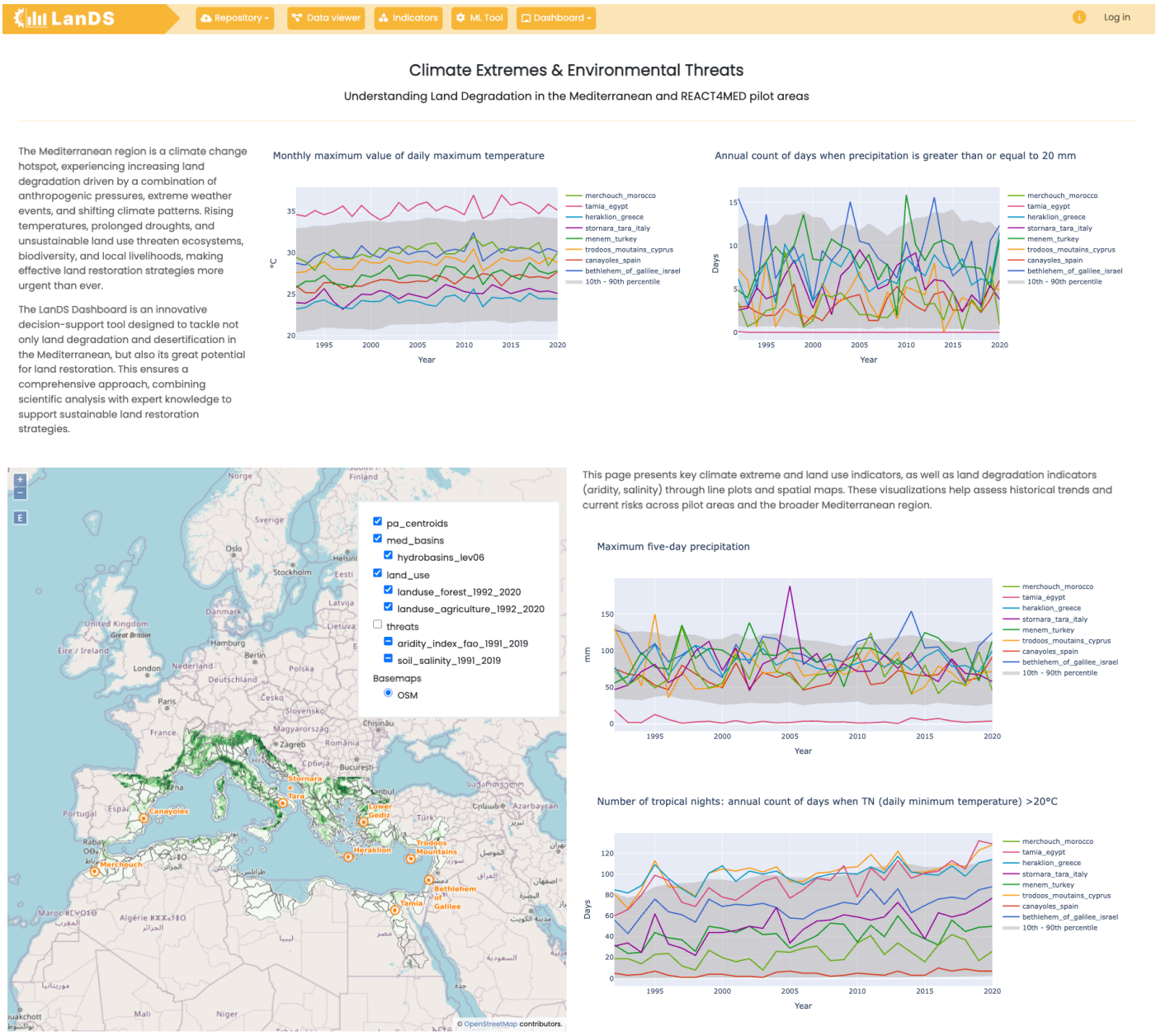


Figure 3 LanDS Dashboard landing page, showing climate extreme indicators, as well as salinity and aridity maps in the Mediterranean and REACT4MED pilot areas.

2.2 Cluster Map: Identifying Similar Areas in the Mediterranean

The Cluster Map page presents the results of the machine-learning-based classification of the Mediterranean region. Based on biophysical, climate, and socioeconomic indicators, this clustering analysis identifies regions with similar characteristics to guide the application of REACT4MED restoration measures.

The ML workflow followed these key steps (see D4.3 LanDS Toolbox for further details):

1. Selection of relevant input indicators through correlation and Principal Component Analysis (PCA).
2. Application of k-means clustering to group areas with similar environmental and socio-economic conditions.
3. Visualization of clusters on an interactive map, allowing users to explore regional similarities and restoration potential.

The main feature of this Dashboard's page is an interactive cluster map displaying one significant outcome of the machine-learning-based classification. By simply clicking on the location pins, you can be redirected to one of the eight collections corresponding to the pilot areas or to the third page of the Dashboard dedicated to the expert-based filtering results (see next subsection).

Figure 4 reports a snapshot of the second page of the LanDS Dashboard:

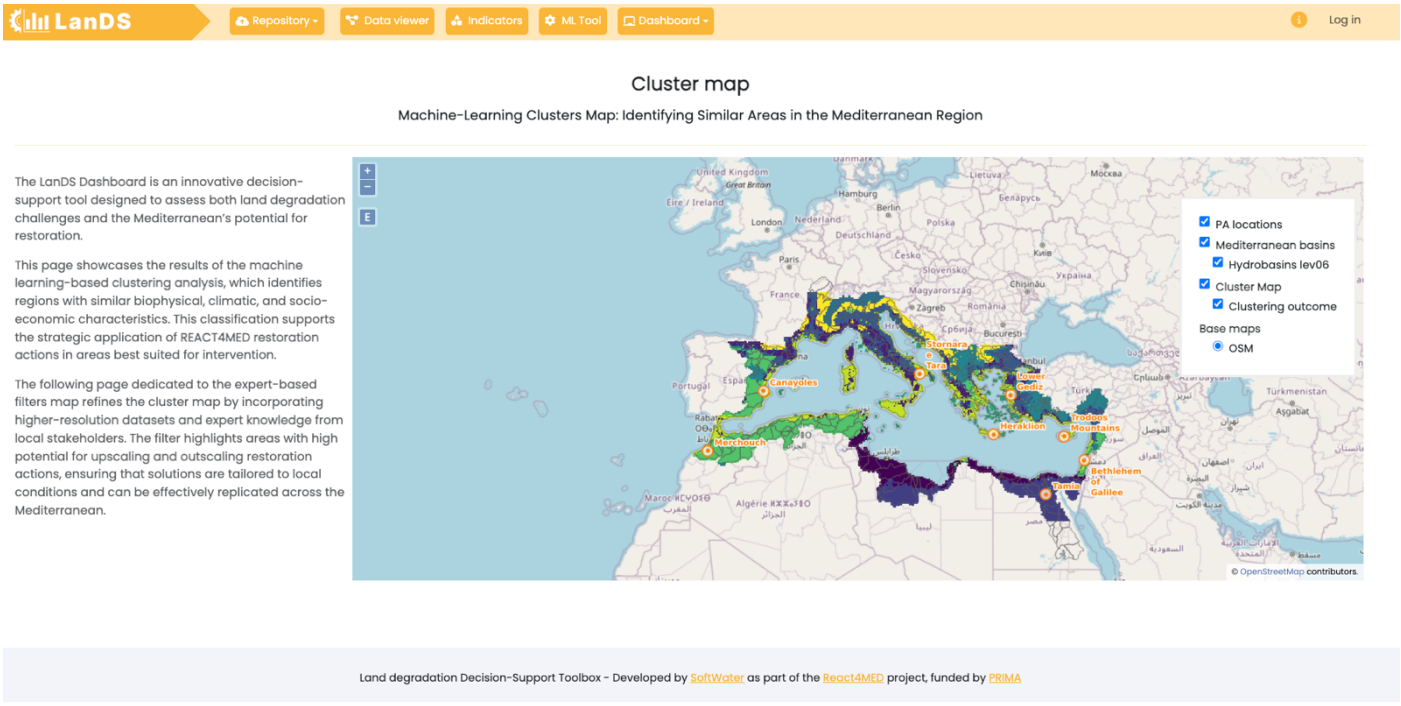


Figure 4 Snapshot of the second page of the Dashboard, showing one significant outcome of the clustering analysis output, identifying similar areas in the Mediterranean, based on a large set of biophysical, climate, and socioeconomic indicators computed by the LanDS.

2.3 Expert-Based Filtering: Refining Restoration Suitability

The Expert-Based Filtering page builds upon the clustering analysis map by incorporating higher-resolution datasets (from 1 km down to 250 m) and expert-driven criteria to refine the classification and assess the suitability of specific restoration actions in broader or other areas of the Mediterranean region (up- and outscaling potential). The criteria are given by the experts for each one of the restoration actions implemented in the eight REACT4MED pilot areas[12]. This participatory approach ensures that local knowledge and contextual conditions are considered in defining restoration priorities.

[12] For more details on the implemented restoration actions, see D5.1 Restorations technologies tested and validated.

The filtering process follows these steps:

1. Loading and preprocessing high-resolution datasets (e.g., elevation, soil properties, land use).
2. Defining expert-based criteria (e.g., thresholds from WOCAT factsheets and/or pilot area leaders) to refine classifications.
3. Applying filters and visualizing potential areas for restoration upscaling and outscaling.
4. Reviewing results with local experts and refining the methodology based on feedback.

The main features of this Dashboard's page are:

- High-resolution data integration for improved accuracy.
- Customizable filtering options to refine restoration suitability, depending on the restoration action in each pilot area.
- Interactive visualization of potential areas for SLWM and restoration upscaling.

Figure 5 reports a snapshot of the third page of the LanDS Dashboard in its current status:

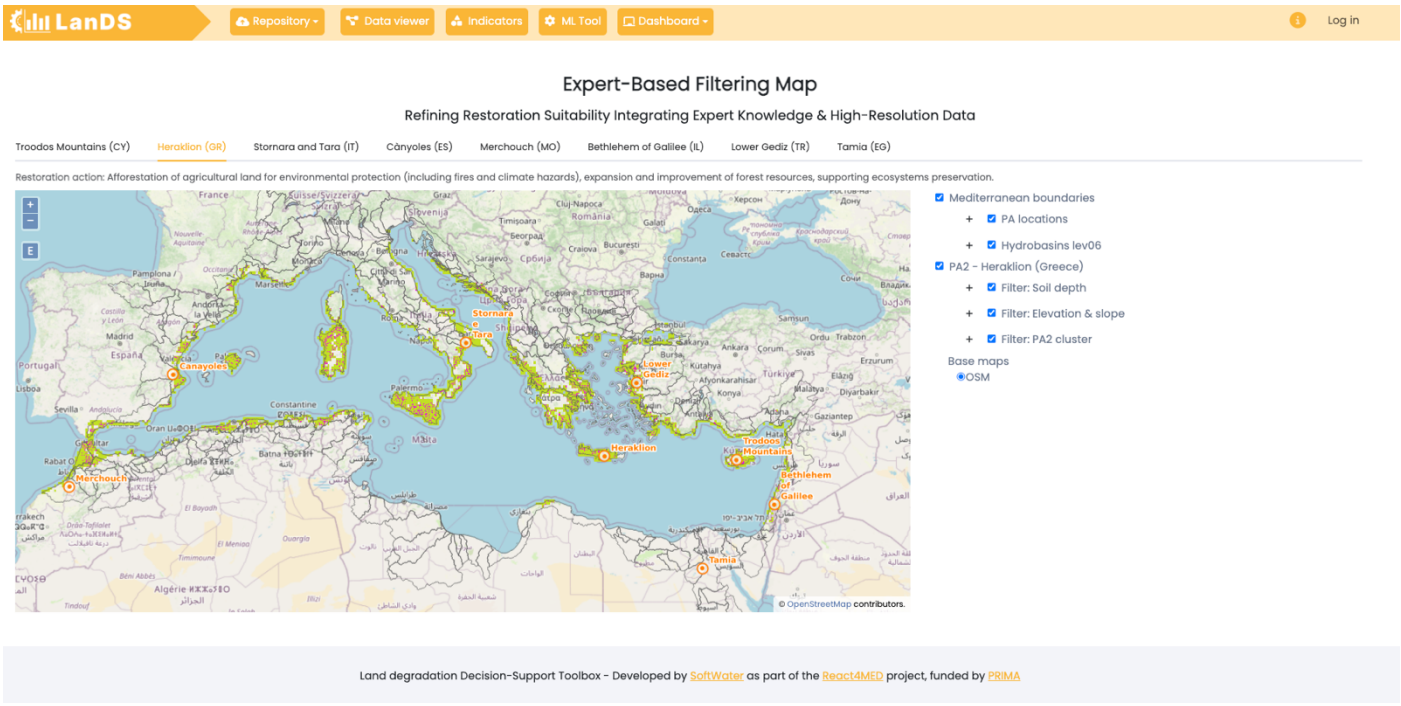


Figure 5 Third page of the LanDS dashboard in its current status, showing the outcome of the expert filtering driven by each restoration action implemented in the eight REACT4MED pilot areas.

2.4 Technologies

The LanDS Dashboard is built on an open-source technology stack, ensuring accessibility, transparency, and ease of use for stakeholders involved in land restoration. The platform provides an intuitive interface for exploring data, assessing degradation trends, and making informed decisions on land restoration strategies.

The technologies used to develop the Dashboard are integrated in the LanDS Toolbox, as schematised in Figure 6 and briefly described in the following:

- Postgresql[13] + PostGIS[14] for the creation of relational GeoDatabase: one of the most advanced and modern relational database managers. Its spatial extension PostGIS allows the managing and processing of geographical data, while its capability to manage also JSON structured data allows an extra-flexibility for application development and data storage.
- STAC SpatioTemporal Asset Catalogs[15], a common language to describe geospatial information, so it can more easily be worked with, indexed, and discovered.
- Leaflet[16] for creating interactive web maps, exposing directly geographical data or complex map providedby map servers.
- FastAPI[17] as a web framework for building APIs with Python programming language, with a modern, high-performance and scalable approach.
- Python code libraries for indicators computation, geographical data management, interactive charts generation, machine-learning: pandas[18], geopandas[19], rasterio[20], xarray[21], plotly[22], hvplot[23], sci-kit learn[24], keras[25], dask[26].
- Drupal[27] as Content Management System: a framework that can be tailored and customized to create simple websites or complex web applications. It has several standard features out-of-the-box, like easy content authoring, reliable performance, and excellent security, but it gains popularity because of its flexibility and modules library, to expand functionalities and customize the appearance.
- Vue[28]: a JavaScript framework for building user interfaces customising Drupal aspect.
- Jupyter[29]: interactive development environment for notebooks, code, and data. Its flexible interface allows users to configure and arrange workflows in data science, scientific computing and machine learning.
- Sci-kit Learn[36]: a ML library for Python, providing simple and efficient tools for predictive data analysis.

[13] https://www.postgresql.org/
[14] https://postgis.net/
[15] https://stacspec.org
[16] https://leafletjs.com/
[17] https://fastapi.tiangolo.com/
[18] https://pandas.pydata.org/pandas-docs/stable/index.html
[19] https://geopandas.org/en/stable/
[20] https://rasterio.readthedocs.io/en/stable/
[21] https://docs.xarray.dev/en/stable/
[22] https://plotly.com/
[23] https://hvplot.holoviz.org/
[24] https://scikit-learn.org/stable/
[25] https://keras.io/
[26] https://www.dask.org/
[27] https://www.drupal.org/
[28] https://vuejs.org
[29] https://jupyter.org/

- QGIS Server[30]: an open-source web mapping service that allows users to publish and share GIS data and maps online, providing OGC-compliant services (WMS, WFS, WCS) while maintaining full compatibility with QGIS Desktop for seamless cartographic rendering and spatial data management.

The full stack of these components has also been open sourced as docker containers on the LanDS code repository[31].

Figure 6 Overview of technologies used for the LanDS Toolbox (updated from D4.3 integrating the Dashboard-related technologies).

2.5 Online documentation

The LanDS documentation[32] is available as an online page on the LanDS web interface, accessible by clicking on the "i" button on the top bar menu next to "Login" (see Figure 7).

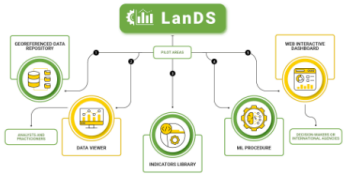
In its current version, it includes a general description of the LanDS toolbox, the list of WP4 submitted deliverables, a brief presentation of the five available tools (repository, data viewer, indicators library, ML tool, and Dashboard) with corresponding links and guidance on the main objectives and functionalities. It is enriched by examples and screencasts to guide the user in specific actions (e.g., login, upload/edit data, select visualization types for different file formats).

[30] https://docs.qgis.org/3.40/en/docs/server_manual/index.html#
[31] https://gitlab.com/lands-r4m/lands_web
[32] https://lands.soft-water.it/documentation

Documentation

The LanDS is a science-based Land degradation Decision-Support Toolbox targeted to support REACT4MED participants (partners, stakeholders, and policy makers), by providing a safe and effective georeferenced repository to store, share and reuse data collected by the pilot areas, and by implementing indicators to assess land restoration measures impacts across different geographic areas. Combining existing knowledge from public repositories and expertise coming from the pilot areas, the LanDS elaborates machine-learning (ML)-based procedures to identify critical areas in the Mediterranean, where to focus up or out-scaling of restoration measures, exploring future climate and socio-economic scenarios. Finally, the LanDS web dashboard, specifically addressed to decision makers, is in development to effectively share project's outcomes and support assessment and policy recommendation activities.

The LanDS is then composed of five different tools: 1) a geo-referenced data repository serving as a knowledge base by collecting site-specific data and resources from the pilot areas as well as from global or regional public repositories for the Mediterranean area; (2) a data viewer, containing a set of visual analytics tools linked with this repository allowing the effective sharing and access to data, and their interactive exploration; (3) an indicators library implemented as a modular and generalised code library applicable to different geographical contexts based on collected data and indicators identified; (4) a ML tool to identify potentially suitable areas in the Mediterranean for up- and outscaling of restoration measures; (5) a web interactive dashboard, providing a harmonised land degradation assessment and evaluation of impacts of restoration measures, as well as a user-friendly interface.



This online documentation servers as a user's guide to navigate the toolbox and getting started with its functionalities.

Before exploring the tools in more detail, please find the link to the submitted deliverables explaining the development process of the toolbox and correspondent functionalities:

- D4.1 LanDS requirements and specifications: Report summarising the outcomes of ERLL stakeholders' involvement process and defining features and requirements of the LanDS toolbox.
- D4.2 LanDS toolbox prototype: Prototype of LanDS toolbox, including first versions of the geo-referenced data repository, the visualization tools and the indicators library, ready to be shared with partners and stakeholders for testing and feedback gathering.
- D4.3 Final LanDS toolbox: Release of the final version of the LanDS toolbox, including the planned tools, populated with project data and documented by a user-guide with examples and tutorials. The software developed will be released in an online public repository.
- D4.4 LanDS Dashboard: Release of the LanDS dashboard, populated with outcomes of LanDS machine learning based tool, for land restoration area identification. The dashboard will be accessible through a web interface and published on the project website.

(1) The georeferenced data repository can be access from the LanDS landing page and/or from the top bar menu, selecting:

- Map (LanDS landing page), which shows the map of the Mediterranean Basin with nine location pins to highlight the nine available data collections (including the 8 pilot areas in Cyprus, Greece, Italy, Spain, Morocco, Israel, Turkey, and Egypt, plus a general one for the Mediterranean Area) and, on the right-hand side, a column with the collections represented by their reference image, their title/location, and associated tag (issues and/or restoration action), which can be easily scrolled down and selected as needed: the user has the option to select the collection / from the pins on the map or from the reference images;
- Collections, displaying the 9 collections as described in the previous point;
- Data Browser, a dynamic table where datasets (resources and indicators) are grouped by collection and linked to their descriptive page (by clicking on the dataset name) and to the related dataset (by clicking on file's link). Other available functionalities are listed below:
  - Show (on the top-left side of the page): it displays the selected number of available entries;
  - Search (on the top-right side of the page): it provides a quick filter on displayed rows based on text included in each field;
  - Advanced Search (next to Search): performs a more refined spatio-temporal query across all the collections.

Check out this quick overview to first navigate the LanDS from the landing page to the repository and datasets.

Full open access, data visualization and download is granted to anyone visiting the LanDS website, while the possibility to upload and edit data is given only to logged in users (here is how to quickly login, if your account is activated by the admin).

(2) The Data Viewer provides quick and effective visualizations of the different datasets uploaded in the repository and can be accessed from:

- from the dataset/item page, to contextually show the visualizations available for the specific dataset;
- from the top menu bar, to directly open the Data Viewer page.

The following file formats are supported by the LanDS and provide an automatic visualization:

Dataset type	File formats supported by LanDS	Available chart visualisations on LanDS	Map Visualisations
Tabular data	.xlsx .csv	Line Monitoring charts	Heatmap
Geographical data	.shp (in .zip) .gpkg .kml / .kmz WKT .csv/.txt .tiff / .asc	N/A	Simple/Geo Map Choroplet Map Tif map with slider to navigate different bands (e.g., different time step)
Distributed Time series	.nc	Time series line plot for spatially averaged data, with range of reference values Box plot and decade boxplot for decades period	Raster map with time slider to navigate different time step

A monitoring data template is available to store data from the pilot areas with the aim of assessing the effectiveness of the implemented restoration action, with the possibility of adding the measured parameters, the type of experiment/action, and the different sites.

A monitoring data example (provisional) is uploaded on the LanDS to further support the user. Check out how to upload your monitoring data file and visualize it in the *monitoring charts* visualization type. In this case, the dataset is uploaded to the Italian pilot area (Stornara and Tara) and the restoration action is organic farming (which is compared to traditional farming in different sampling sites).

The monitoring data file with real measurements is already uploaded and available for the Italian pilot area and can be visualized at this link. The correspondent sampling points are also uploaded as a GeoPackage file (.gpkg) and can be visualized as *geo map* as shown in this screencast, including information on latitude, longitude, type of restoration action, and soil depth.

Geospatial vector data can be also uploaded as Shape files (.shp) as shown in this example, with the attention to upload the zipped folder (.zip) containing the .shp, .shx, .dbf, .cpg files.

The user has the possibility to edit the dataset to change the description, the proper visualization type, the temporal frame, the spatial extent of the bounding box, if the item is an indicator or a resource, and the metadata, if needed. Check out at this link how to edit a dataset, e.g., for the monitoring data example, and how to visualize it in the data viewer.

Further, satellite-based indices have been computed by the team of UH (project's partners) and are available on the LanDS for different pilot areas. Satellite-based indicators can be uploaded as csv files (visualized as line charts), tif images, or NetCDF files. Check out how to upload, visualize, and edit a tif file, with slider to navigate the different bands.

(3) The code Library of Indicators can be accessed from the top bar menu, from which the user will land on a documentation page containing main information. The code library is structured as a Jupiter notebook, a web environment where is possible to integrate Python code with rich text description and interactive visualization. The code library is available in a software repository hosted on Gitlab and the code is released under the latest version of the GNU General Public License (GPL).

In total, 56 climate, biophysical and socioeconomic indicators have been computed by the LanDS based on data provided by TUC (project's partners) and are stored in the repository in the Mediterranean area collection. Check out at this link an example of a climate extreme index (sources: Climdex; IPCC 6th assessment report), which is stored as a NetCDF file (.nc) and can be visualized as a line chart, a boxplot, and a map with time slider.

In this other screencast, the biophysical and socioeconomic changes computed by TUC can be visualized in a *heatmap* for a baseline and extreme future scenarios (respectively, SSP245 and SSP585).

(4) The ML tool can be accessed from the top bar menu, from which the user will land on a documentation page, briefly introducing the procedure (methods, inputs and outputs). The software code has been released on the LanDS Gitlab repository.

(5) The LanDS web interactive dashboard is currently under development development and will be accessible from the top bar menu (expected around the beginning of April 2025). The dashboard is divided into three main pages, indicating respectively (1) the environmental threats in the Mediterranean and REACT4MED pilot areas, (2) one representative ML tool outcome of the clustering analysis, showcasing similar areas in the Mediterranean on the basis of a large set of biophysical, climate, and socioeconomic indicators (at around 12 km resolution), and (3) outscaling maps based on the expert-based filters driven by the different restoration actions implemented in the 8 project's sites at higher resolution (from 1 km down to 250 m).

Figure 7 Snapshots of the LanDS page documentation in its last update (March 31st, 2025).

This page will be periodically updated with refinements and additional information, if and when needed.

3 Conclusions

This deliverable briefly describes the release of the LanDS Dashboard, the fifth tool of the LanDS Toolbox, which provides a harmonised land degradation assessment and evaluation of impacts of restoration measures through a user-friendly interface. It is accessible at the LanDS URL[33] and characterized by a flexible structure and enriched by interactive graphics, structured maps, text and content. The LanDS and its Dashboard contribute to the REACT4MED scope of potential up- and outscaling land restoration actions promoted in the Ecosystem Restoration Living Labs to the Mediterranean area, driven by the ML tool clustering analysis and expert-based criteria. Besides, open access to the decision support tools developed facilitates the project's sustainability beyond its lifetime.

In this final stage of the project, we will still explore plausible combinations of future climate and land-use change, and socio-economic scenarios to facilitate the detection of potential degradation trends and to provide useful insights to orient policy recommendations and support decision-making processes (within WP5 and WP6). Such outcomes can be integrated into the Dashboard to support communication and dissemination activities, when they prove valuable.

Finally, a webinar will be organized jointly with WP7 (HMU) to disseminate the final LanDS Toolbox to stakeholders and policy-makers involved in the ERLLs and launch the LanDS Dashboard.

[33] https://lands.soft-water.it