

D5.2 Report on DApOS design and basic specifications

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Index

[1 Executive Summary 5](#_Toc69304698)

[2 DApOS design and basic specification 6](#_Toc69304699)

[3 Crop water requirements forecasts 7](#_Toc69304700)

[3.1 DApOS “Crop irrigation” specification 7](#_Toc69304701)

[3.1.1 Workflow Sub-seasonal for ARPAE 7](#_Toc69304702)

[3.1.2 Workflow Climate projections for Apulia, Province of Trento, Piedmont 10](#_Toc69304703)

[4 Forest fire prediction and controls 13](#_Toc69304704)

[4.1 DApOS “Forest fire predictions and controls” specification 13](#_Toc69304705)

[5 Forest fire potential 16](#_Toc69304706)

[5.1 DApOS “Forest fire potential” specification 16](#_Toc69304707)

[6 Animal welfare and land suitability for farming 19](#_Toc69304708)

[6.1 DApOS “Animal welfare and land suitability for farming” specification 19](#_Toc69304709)

[7 Land suitability for vegetation (forests) 23](#_Toc69304710)

[7.1 DApOS “Land Suitability for Forests” specification 23](#_Toc69304711)

[8 Changes in the land suitability for vegetation 27](#_Toc69304712)

[8.1 DApOS “Changes in the land suitability for vegetation” specification 27](#_Toc69304713)

[8.1.1 Workflow Mycotoxins on cereals 27](#_Toc69304714)

[8.1.2 Workflow Evaluation of the grapevine vocationality at regional level 30](#_Toc69304715)

[8.1.3 Workflow Changes in forest habitat suitability 32](#_Toc69304716)

[9 Natural parks environmental management 35](#_Toc69304717)

[9.1 DApOS “Natural parks environmental management” specification 36](#_Toc69304718)

[9.1.1 Workflow “Tree species classification and AGB prediction with hyperspectral and lidar data” 36](#_Toc69304719)

[9.1.2 Workflow “Pasture monitoring tool for sustainable management” 38](#_Toc69304720)

[9.1.3 Workflow “Forest physiological tree monitoring” 40](#_Toc69304721)

[10 Soil erosion 43](#_Toc69304722)

[10.1 DApOS “Soil erosion” specification 43](#_Toc69304723)

[11 Human wellbeing 46](#_Toc69304724)

[11.1 DApOS “Human Wellbeing” specification 47](#_Toc69304725)

[12 IoT for animal wellbeing 50](#_Toc69304726)

[12.1 DApOS “IoT for animal wellbeing” specification 51](#_Toc69304727)

[12.1.1 Workflow: animal welfare using climate projection data 51](#_Toc69304728)

[12.1.2 Workflow: animal welfare in sub-seasonal framework 54](#_Toc69304729)

[13 Water cycle and sustainability of competing uses 57](#_Toc69304730)

# Executive Summary

This document contains the description of the workflows of applications and services belonging to task 5.1. The document is subdivided in DApOS; for everyone, there is a brief description and the specification template created by CINECA and completed by partners.

These templates include data flows, exchange protocols, input and output data, which output data will be accessible to the end-user on Highlander platform and with which policy, how the data is accessed/presented on Highlander platform.

This deliverable will be updated with missing information by the end of the project and it will be supported by D5.3 “Reports of results of the implemented DApOS”

# DApOS design and basic specification

Activity 5 is based on user-tailored Downstream Application and (pre-)Operational Services (DApOS).

It is divided into two main tasks and here we are presenting the first report of the second one (D5.2). It consists of the description of the workflows of applications and services belonging to task 5.1: data flows, exchange protocols, input and output data, which output data will be accessible to the end-user on Highlander platform and with which policy, how the data is accessed/presented on Highlander platform.

The purpose of this activity is to demonstrate the potential of intensive HPC exploitation, done in Activity 4, in generating and preliminarily post-processing huge datasets. Datasets will be combined to create several applications and services for multi-level and multi-sectoral users. Applications and services will be based on users’ active participation to define their needs and priorities and, then, to deliver customized products.

The aim of Task 4.4 is to integrate large arrays of continuous information coming from:

* spatial and temporal resolution of climate predictions and projections over both short- and long-term time-scales (Tasks 4.1, 4.2, and 4.3);
* IoT networks providing high throughput data at sub-hourly time resolution and site/ecosystem level (Task 4.4);
* space and airborne imagery (Task 4.4).

The classifier(s) produced on top of the data lake in T4.4 will be exploited in this Task to develop Downstream Applications and (pre-)Operational Services for smarter land management.

Services designed and developed in this Task will be available to the final users through the HIGHLANDER data portal and web platform (A6).

# Crop water requirements forecasts

The DApOS are being developed by ARPAE in Emilia-Romagna and subsequently applied to the Highlander pilot regions: Trento province (FEM), Piedmont (ARPAP), Apulia (CMCC). This DApOS is a climate service that will provide sub-seasonal forecasts of irrigation needs for crops and impact studies of crop irrigation under climate change projections. Therefore, this DApOS includes two different rationales according to the forecast/projections used as input. In general terms, this DApOS combines information on agricultural land use from satellite data, observed weather data, climate weather series, HIGHLANDER sub-seasonal forecast/future projections, and a soil water balance model.

## DApOS “Crop irrigation” specification

Author: Giulia Villani (ARPAE), Fausto Tomei (ARPAE)

DApOS manager: Giulia Villani (ARPAE), Fausto Tomei (ARPAE)

### Workflow Sub-seasonal for ARPAE

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| **Title** |
| Crop water requirement forecasts sub-seasonal |
| **Partners involved** |
| ARPAE |
| **Brief description** |
| This workflow will provide sub-seasonal forecasts of irrigation needs for crops.  In general terms, this workflow combines information on agricultural land use from satellite data, observed weather data, climate weather series, HIGHLANDER sub-seasonal forecast, and a soil water balance model.  It covers 4 Land reclamation and Irrigation Boards (consorzi di bonifica) from Emilia-Romagna region. |
| **Data flow** |
| * Highlander provides **Sub-SEA** data to ARPAE * Highlander receives the output data from ARPAE and saves them in its own repository * **Highlander does not integrate any processing of this DApOS, apart from** the necessary processing to **provide the input data according to the partners’ requirement**: for example, format conversion, aggregation, cropping, rotation, … * **The processing of this DApOS runs on ARPAE platform** |
| **Exchange protocols** |
| * **ARPAE usually sends data via** **FTP** * In this use case, **the processing is performed weekly**. At the moment we don’t yet decide how ARPAE will get the input data from Highlander, how ARPAE will send the output data to Highlander, and how to get the data. |
| **Input data** |
| **Input datasets**   1. **Sub-SEA**   D4.3 - **Downscaled sub-seasonal forecasts**  *Data description*: Temperature, Precipitation  *Format*: GRIB2  *Manager*: ECMWF  *Location*: CINECA repository   1. **DApOS specific data** (Emilia-Romagna)   *Data description*: Soil, crop, and observed weather data  *Format*: data will not be available in the Highlander platform  *Manager*: ARPAE  *Location*: ARPAE repository  **Arpae requirements**:   * + - Arpae would prefer to have also the Sub-seasonal data in the same NetCDF format as CMCC.     - Cropping on Northern Italy could be useful. |
| **Output data** |
| **Output datasets**   1. **Crop water requirements**   (NetCDF, high-res)  Forecast 1-month, weekly update = every week forecast for the next month, aggregated over the whole month.   1. **Early crop maps**   *Format*: NetCDF  *Manager*: ARPAE  *Location*: ARPAE repository  *Output*: 4 separate maps, 1 for each consortium  *Update frequency*: once a year  *Additional info*: based on the registry of the cultivation classes of Arpae   1. **Sub-seasonal irrigation forecasts**   *Format*: NetCDF  *Manager*: ARPAE  *Location*: ARPAE repository  *Output*: 4 boards -> 4 distinct maps -> 4 NetCDF files  *Update frequency*: **weekly** (depending on the frequency of the Sub-SEA datasets, from the information we have it should be weekly)  *Additional info*: forecast of the mm of irrigation; non-deterministic forecast, it could be 1 file for each percentile (5°, 25°, 50°, 75°, 95°) or 1 file with all the 5 percentiles.  **Arpae requirements:**   * + - The display of "Sub-seasonal irrigation forecasts" data on the map is useful, it facilitates the user.     - Raw data download: spatial crop could be useful as filter and also filter by time range (previous forecast) and on the 5 percentiles.     - The output data will be sent to Highlander via FTP? |
| **Which output data will be accessible to the end user on Highlander platform** |
| Both “Early crop maps” and “Sub-seasonal irrigation forecasts” data can be made accessible to the end user |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw data and maps) by this DApOS are open.  **License:**  **Attribution:** |
| **How the data is accessed/presented on Highlander platform** |
| In what form:   * numerical; graphics * filters can be applied |

### Workflow Climate projections for Apulia, Province of Trento, Piedmont

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| **Title** |
| Crop water requirement forecasts climate projections |
| **Partners involved** |
| ARPAE, CMCC, FEM, ARPAP |
| **Brief description** |
| This workflow will provide impact studies of crop irrigation under climate change projections.  In general terms, this workflow combines information on agricultural land use from satellite data, observed weather data, climate weather series, HIGHLANDER future projections, and a soil water balance model.  It covers 3 areas from the Italian Regions Apulia, Piemonte, Province of Trento:   * Apulia with CMCC: sub-area of Capitanata Irrigation Board. * Province of Trento with FEM: Pianura Rotaliana. * Piedmont with Arpap: possibility to select the plain areas of Cuneese, Alessandrino, and Torino/Carmagnola. |
| **Data flow** |
| * Highlander provides ARPAE with the **VHR-PRO\_IT** data (and possibly also VHR-REA\_IT) * Highlander receives the output data from ARPAE and saves them in its own repository * **Highlander does not integrate any processing of this DApOS, apart from** the necessary processing to **provide the input data according to the partners’ requirement**: for example, format conversion, aggregation, cropping, rotation, … * **The processing of this DApOS runs on ARPAE platform** |
| **Exchange protocols** |
| * **ARPAE usually sends data via** **FTP** * To get the data, Arpae could try with API but anyway **in this use case the processing is performed one-off**. |
| **Input data** |
| **Input datasets**   1. **VHR-PRO\_IT**   D4.2 - Downscaling at very fine resolution of COSMO-CLM over Italy  *Data description*: from 8km to 2.2km hor. res. for 1989-2050 (hopefully 1981-2065)  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **Arpae requirements:**   * + - Temperature and precipitation, over all the period, on the 3 areas.     - Aggregation for having the daily data.     - The data is in 'rotated pole grid' format, it would be very useful to have the data re-interpolated on a regular lat-lon grid.  1. **VHR-REA\_IT** (not sure yet if it will be used)   D4.1 - Dynamical Downscaling of ERA5 at hourly level with COSMO-CLM  *Data description*: 2.2 km hor.res. for 1989-2018 (hopefully 1981-2019)  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **Arpae requirements:**   * + - Temperature and precipitation, over all the period, on the 3 areas.     - Aggregation for having the daily data.     - The data is in 'rotated pole grid' format, it would be very useful to have the data re-interpolated on a regular lat-lon grid.  1. **DApOS specific data (Puglia, Trentino, Piemonte)**   *Data description*: soil, crop  *Format*: NA  *Location*: ARPAE repository  *Manager*: each partner must provide the data of the 3 areas to ARPAE |
| **Output data** |
| **Output datasets**   1. **Crop water requirements projections**   *Format*: NetCDF  *Manager*: ARPAE  *Location*: ARPAE repository  *Output*: 5 maps (one for each percentile) x 3 areas  Update frequency: only once  *Additional info*: based on the extent of the input climate data, the forecast will cover the next 20 or 30 years. It is a non-deterministic forecast -> 5 percentiles from 5 to 95 with the key one at 50. Range is seasonal: JJA quarter projection. The output is produced once and never updated again.  **Arpae requirements:**   * + - the visualisation of the output data is useful.     - Raw data download: no filters, or at least on the 5 percentiles.     - output data sent to Highlander via FTP? One-off output delivery: the output is produced once and never updated |
| **Which output data will be accessible to the end user on Highlander platform** |
| The “Crop water requirements projections” data can be made accessible to the end user |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw data and maps) by this DApOS are open.  **License:**  **Attribution:** |
| **How the data is accessed/presented on Highlander platform** |
| In what form:   * numerical; graphics * filters can be applied |

# Forest fire prediction and controls

The DApOS “Forest fire prediction and controls” is being developed by DIBAF in collaboration with CMCC. Conservation of forest resources and prevention of forest fires are fundamental activities to mitigate and reduce climate change impacts. The goal is to set up and apply a model based on remote data, proximal data from sensors (IoT), and medium-term meteorological predictions, to provide a forest fire risk analysis service.

## DApOS “Forest fire predictions and controls” specification

Author: Gaia Vaglio Laurin (DIBAF), Riccardo Valentini (DIBAF)

DApOS manager: Gaia Vaglio Laurin (DIBAF), Riccardo Valentini (DIBAF)

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| **Title** |
| Forest fire predictions and controls |
| **Partners involved** |
| DIBAF, CMCC |
| **Brief description** |
| This document illustrates the datasets and workflow to produce maps of fire risk and of variables relevant to fire prevention and control, in selected forested natural parks of the Puglia regions, based climate, remote sensing, and proximal sensing data properly integrated thanks to machine learning and Big Data analysis tools.  Specifically, a regional network of Tree Talker and Tree Talker Fire in-situ stations allows the characterization and continuous monitoring at tree level of selected parameters, that are recognized to be important in triggering and fostering forest fires.  The in-situ stations, linked through IoT technology, produce parameters that need to be spatially upscaled at stand and forest community level, to produce frequent (near real time) information on fire risk. The upscaling, requiring machine learning modelling, will be carried out in two ways:  -directly, linking spectral information from satellite data with parameters collected from in situ station  -indirectly, using satellite data to stratify at fine scale the forest- at community level or stand units-, where the in-situ data relevant for fire prediction can be treated homogeneous.  The combination of the upscaled parameters, local climate data, and ancillary information into an additional modelling steps will generate as output the time series of fire risk maps for the late spring-early fall period.  All information will be centralized and processed by Highlander computing facilities and made available to third parties (e.g., natural parks) through project platform and WebGIS tools. |
| **Data flow** |
| * UNITUS and CMCC define the study areas and the in-situ variables -relevant for fire control- that should be upscaled, based on reference literature and experimental design. * UNITUS defines the satellite data and the ancillary information available * UNITUS and CMCC define the machine learning and modelling tools * Data processing and modelling runs on CINECA platform * Outputs from CINECA platform are made available to third parties |
| **Exchange protocols** |
| * IoT data will be transferred on CINECA supercomputer by UNITUS * Satellite data will be ingested by CINECA using the Copernicus Sentinel API service * Ancillary data will be transferred to CINECA by UNITUS/CMCC * Algorithms for processing and modelling will be transferred to CINECA by UNITUS/CMCC |
| **Input data** |
| **Input datasets**   1. Sentinel 2 data   SENTINEL-2 products are available to users in SENTINEL-SAFE format, including image data in JPEG2000 format, quality indicators (e.g., defective pixels mask), auxiliary data and metadata.   1. IoT in-situ data   In total 240 sensors are distributed in 4 regional parks area (120 are TreeTalker devices and 120 TT- Fire devices). The TreeTalker devices variables are described in the Trentino (FEM) DApOS, while the TT – Fire devices variables are as follow:   * Air temperature * Relative Humidity * Foliage Temperature * CO2 concentration * O3 concentration * PM2.5 and PM10 concentration * Presence of flame  1. Ancillary data   Ancillary data - including climate information- will be provided as raster of vector layers in commonly used formats (.shp, .tif, etc.) |
| **Output data** |
| **Output datasets**   1. Upscaled fire-relevant forest parameters   Provided as raster of vector layers in commonly used formats (.shp, .tif, etc.), with a 15-days frequency if no limitation in satellite data (e.g., cloud coverage) is present, during the fire season (late spring-early fall)  Manager: UNITUS   1. Upscaled climate data   Local climate variables, relevant for fire risk modelling, will be interpolated to produce a vector or raster layer at proper spatial scale, comparable to satellite data scale, useful for modelling  Manager: CMCC   1. Fire risk maps   Vector or raster layers, resulting from the combination of upscaled in-situ vegetation parameters linked to water content and wetness of inflammable matter and vegetation status or dryness.  Manager: UNITUS |
| **Which output data will be accessible to the end user on Highlander platform** |
| Upscaled fire-relevant forest parameters and fire risk maps |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw data and maps) by this DApOS are open with license: (CC BY 4.0). |
| **How the data is accessed / presented on Highlander platform** |
| Data are available on DIBAF cluster and CINECA highlander repository |

# Forest fire potential

The DApOS “Forest fire potential” is being developed by ARPAP in collaboration with UNITO. The Mediterranean basin is considered a biodiversity hotspot and, more than other regions of the globe is subject to global change (climate and land use). With the help of historical data, high-resolution models using the past and future climatic data will predict the future dynamic trends of Mediterranean forests (mainly the alpine ones). The results will be analysed at the level of specific composition and alteration of the regimes of natural disturbances.

## DApOS “Forest fire potential” specification

Author: Nicola Loglisci (ARPAP)

DApOS manager: Simona Barbarino (ARPAP), Nicola Loglisci (ARPAP)

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| **Title** |
| Forest fire potential |
| **Partners involved** |
| ARPAP |
| **Brief description** |
| This workflow will provide a set of suitable bioclimatic indicators to assess the past to future impacts of changing mean climate conditions and accelerated variability on forest fire potential (hazards) in the alpine region. The indicators are based on meteorological parameters mainly, to be robust enough for the future assessment of forest fire potential. Validation of the indicator system will be carried on using forest fire data of the last 10 years.  The results will be used in the regional forest fire planning in collaboration with the Regione Piemonte. |
| **Data flow** |
| * ARPAP uses EUORCORDEX data to implement and test the software for the forest fire potential calculation * Highlander provides **VHR-REA\_IT** e **VHR-PRO\_IT** data to the processor of this DApOS * Highlander does not integrate any processing of this DApOS, apart from the necessary processing to provide the input data * The processing of this DApOS runs on ARPAP platform * Highlander receives the **output** data from the processor and saves them in its own repository, just once |
| **Exchange protocols** |
| * ARPAP retrieves the data via FTP * ARPAP provide the processed data via FTP * The format will be NetCDF |
| **Input data** |
| **Input datasets**   1. **VHR-REA\_IT**   D4.1 - Dynamical Downscaling of ERA5 at hourly level with COSMO-CLM  *Data description*: 2.2 km hor.res. for 1989-2018 (hopefully 1981-2019)  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **ARPAP requirements**:   * + - Temperature, Precipitation, Relative Humidity, Wind Speed (every 6 hours), maximum and minimum Temperature (daily), and Wind Gust (daily maximum)     - Cropping on the Alpine Region could be useful     - The NetCDF format will be used  1. **VHR-PRO\_IT**   D4.2 - Downscaling at very fine resolution of COSMO-CLM over Italy  *Data description*: from 8km to 2.2km hor. res. for 1989-2050 (hopefully 1981-2065)  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **ARPAP requirements**:   * + - Temperature, Precipitation, Relative Humidity, Wind Speed (every 6 hours), maximum and minimum Temperature (daily), and Wind Gust (daily maximum)     - Cropping on the Alpine Region could be useful     - The NetCDF format will be used |
| **Output data** |
| **Output datasets**   1. **Climate indicators for forest fire hazard**   Format: NetCDF  Manager: ARPAP  Location: CINECA repository  Update frequency: just once  Dataset size: about 400MB  **ARPAP requirements**:   * + - The display of aggregated data (exceedance of the highest percentiles over 30 year periods, differences of frequency of high danger days between two selected time period) on the map could be useful both for the users and for the project demonstration.     - The raw data could be download by area selection and indicators. |
| **Which output data will be accessible to the end-user on Highlander platform** |
| All the data are available for users. |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw data and maps) by this DApOS are open. |
| **How the data is accessed/presented on Highlander platform** |
| In what form:   * numerical; graphics * filters can be applied |

# Animal welfare and land suitability for farming

The DApOS “Animal welfare and land suitability for farming” is being developed by CIA in collaboration with ARPAP. Climatic variations can have an impact on the availability of forage in mountain pastures. Through the intersection of observed historical data, coming from high-resolution models and forecasts on scenarios, it is possible to suggest adaptation policies aimed at setting a more relevant pasture calendar for effective management rather than applying ordinary exceptions.

## DApOS “Animal welfare and land suitability for farming” specification

Author: Elena Massarenti (CIA)

DApOS manager: Elena Massarenti (CIA), Nicola Loglisci (ARPAP), Simona Barbarino (ARPAP)

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| **Title** |
| Animal welfare and land suitability for farming |
| **Partners involved** |
| CIA, ARPAP |
| **Brief description** |
| The aim of this activity is to analyse the optimal condition for herbaceous species growth, used by farmers to forage. The outcomes will be used to give an estimation of the forage availability in the future using high-resolution model data. |
| **Data flow** |
| * ARPAP uses EUROCORDEX data to implement and test the software for the statistical analysis * Highlander provides **VHR-REA\_IT** and **VHR-PRO\_IT** data to the processor of this DApOS * **Other input data**: climatic requirements of native and invasive forage species in pastures (CIA) * Highlander does not integrate any processing of this DApOS, apart from the necessary processing to provide the input data * The processing of this DApOS runs on CIA and ARPAP platforms * Highlander receives the **output** data from the processor and saves them in its own repository. |
| **Exchange protocols** |
| * ARPAP retrieves the climate data via FTP or SCP * ARPAP provide the processed data via FTP or SCP |
| **Input data** |
| **Input datasets**   1. VHR-REA\_IT   D4.1 - Dynamical Downscaling of ERA5 at hourly level with COSMO-CLM  *Data description*: 2.2 km hor.res. for 1989-2018 (hopefully 1981-2019)  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **CIA and ARPAP requirements**:   * Cropping on the North-western Italy Region could be useful * The NetCDF format will be used * Variables: Max, Min and Mean Temperature (daily), precipitation (daily), snow cover (daily), relative humidity (daily)  1. VHR-PRO\_IT   D4.2 - Downscaling at very fine resolution of COSMO-CLM over Italy  *Data description*: from 8km to 2.2km hor. res. for 1989-2050 (hopefully 1981-2065)  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **CIA requirements**:   * Cropping on the North-western Italy Region could be useful * The NetCDF format will be used * Variables: Max, Min and Mean Temperature (daily), precipitation (daily), snow cover (daily), relative humidity (daily)  1. Climatic requirements of native and invasive forage species in pastures   *Manager*: CIA  *Location*: CIA repository  *Format*: CSV |
| **Output data** |
| **Output datasets**   1. **Correlation between forage availability in pastures and climate in the past and in the future**   Format: NetCDF, tiff, png  Manager: CIA  Location: CIA repository  Update frequency: just once  **CIA requirements**:   * The display of aggregated data (exceedance of the highest percentiles over 30 year periods, differences of frequency of high danger days between two selected time period) on the map could be useful both for the users and for the project demonstration. * The raw data could be download by area selection and indicators.  1. **Probability maps of changes in invasive forage species development and setting**   Format: NetCDF, tiff, png  Manager: CIA  Location: CIA repository  Update frequency: just once  **CIA requirements**:   * The display of aggregated data (exceedance of the highest percentiles over 30 year periods) on the map could be useful both for the users and for the project demonstration. * The raw data could be download by area selection and indicators. |
| **Which output data will be accessible to the end user on Highlander platform** |
| The outputs produced by this activity are available for all users.  Dataset “Climatic requirements of native and invasive forage species in pastures” from CIA: free for research and for Highlander partners. |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw data and maps) by this DApOS are open. |
| **How the data is accessed/presented on Highlander platform** |
| In what form:   * numerical; graphics * filters can be applied |

# Land suitability for vegetation (forests)

The DApOS “Land suitability for vegetation” related to forests is being developed by CMCC and concern the characterizations of territories hosting several types of forest vegetation species through bioclimatic indicators and climate extreme indices to investigate the modification of areas suitable for the ecosystem.

This DApOS will be complementary with another component related to land suitability for crops and forests developed by CIA and ARPAP.

## DApOS “Land Suitability for Forests” specification

Author: Monia Santini (CMCC)

DApOS manager: Monia Santini (CMCC)

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| **Title** |
| Land Suitability for forests |
| **Partners involved** |
| CMCC |
| **Brief description** |
| The DApOS benefits of an analysis of the climate impacts on forest vegetation carried out by the CMCC Foundation for Southern Europe and Russia, thanks to research initiatives and international agreements. The study on Europe suggests a migration to the north and to the higher altitudes of the main Mediterranean species; the alpine chain could therefore become a refuge for species that do not find optimal conditions at lower altitudes. However, given the size of the geographical domains in the previous studies, the available data permitted a rather coarse spatial resolution compared to the detail useful for smaller domains such as the Italian territory. Therefore, HIGHLANDER aims at providing possible results achievable for Italy at a higher resolution, which will support the forestry sector. Starting from the current distribution of the forest species (focusing on the most valuable in terms of provided ecosystem services, such as wood production, recreational purposes etc.), projections will be produced on the possible modifications (displacement, reduction, expansion) of the typical areas (habitats) of forest species following climate evolution. |
| **Data flow** |
| **The processing to support this DApOS runs once** starting from four variables from **VHR-REA\_IT** e **VHR-PRO\_IT**: *TOT\_PREC (hourly), T\_2M (hourly), TMAX\_2M (hourly), TMIN\_2MC (hourly)*  The processing can run on CINECA HPC Cluster or Cloud, we suppose Cloud will be fine.  The steps to be followed in the processing are described and ordered here (from 1 to 8)  <https://docs.google.com/spreadsheets/d/1GSIvSqQ8IsRPGWpHrPzaMPwq0voG_tJm/edit#gid=1379091746>  **The steps with the same number are not depending on one another and can be run in parallel.**  Here below these steps are briefly illustrated:  Steps 1-2: Pre-processing of variables for VHR-REA\_IT (1989-2018 or 1991-2020, TBD) and VHR-PRO\_IT (1989-2018 or 1991-2020 and 2021-2050).  Steps 3-5: Calculation of bioclimatic variables for VHR-REA\_IT (1989-2018 or 1991-2020, TBD) and VHR-PRO\_IT (1989-2018 or 1991-2020 and 2021-2050).  Step 6: The outputs from steps 3-5 will be further operated in order to derive bias-corrected values for the period 2021-2050, applying the anomaly between the two periods VHR-PRO\_IT to the VHR-REA\_IT.  Step 7: The outputs from Steps 3-5 (for VHR-REA, 1989-2018 or 1991-2020, TBD) and from Step 6 (for 2021-2050) will be masked over Italy (to exclude not Italian territories) according to a mask provided by the DApOS team (CMCC) and then they will be available to be explored through the HIGHLANDER platform tools (e.g., for spatial clipping according to administrative, physical or user-defined boundaries, for extracting zonal statistics).  Step 8: working offline, outputs from step 7 will be further post-processed (resampled, converted into GIS-compatible formats) according to the best compromise with the extent/resolution of Ancillary data, in order to be included into a species distribution modelling (SDM) approach to project the land suitability for forest species (or species categories) over Italy for the future period 2021-2050. The results will be available to be explored through the HIGHLANDER platform tools (e.g., for spatial clipping according to administrative, physical or user-defined boundaries, for extracting zonal statistics). In addition, the Ancillary Forest Map will be harmonized (format, resolution) with these outputs to serve as basis for the Web Application. |
| **Exchange protocols** |
| * The processor will access the NetCDF files in Galileo (Deliverable 4.1 and 4.2) and will receive Ancillary dataset by DApOS team. * The processor will save the output in NetCDF * The processor will be developed by CMCC and will run on CINECA’s infrastructure. |
| **Input data** |
| **Input datasets**   1. **VHR-REA\_IT**   D4.1 - Dynamical Downscaling of ERA5 at hourly level with COSMO-CLM for 1989-2020.  *Data description*: see here: <https://wiki.u-gov.it/confluence/display/HIGHLANDER/Dataset+forms?preview=/359625290/393550377/ReanalysisDownscaling_(Template-Highlander-data_final-version)_CMCC_FINAL.docx>  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **CMCC requirements**:   * Application of steps 1-7 above, with mask for clipping (step 7)  1. **VHR-PRO\_IT**   D4.2 - Downscaling at very fine resolution of COSMO-CLM over Italy from 8km to 2.2km for 1989-2050  *Data description*: see here: <https://wiki.u-gov.it/confluence/display/HIGHLANDER/Dataset+forms?preview=/359625290/393550380/COSMO-CLM-Downscaling_(Template-Highlander-data_final-version)_FINAL.docx>  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **CMCC requirements**:   * Application of steps 1-7 above, with mask for clipping (step 7) |
| **Output data** |
| **Output datasets**   1. **Indicators of bioclimatic conditions and forest suitability**   *Format*: NetCDF  Manager: CMCC  *Location*: CINECA Repository  Update frequency: once  *Additional info*: to be accessed and explored through the HIGHLANDER platform the products of steps 7-8 above.  *Dataset size*: (indicative) Bioclimatic variables (at native resolution; ≈10 MB x 38 maps (2 periods x 19 bioclimatic variables = 380 MB) + Forest species suitability (resampled, 5 GB x max 30 maps (2 periods x 15 species/species categories max) = 150 GB  **CMCC requirements:**   * + - Raw data download: data will be accessed by end users as explained in the last point below |
| **Which output data will be accessible to the end user on Highlander platform** |
| See steps 7-8 above |
| **With which policy** (License and Attribution) |
| The data on the platform, i.e. results of steps 7-8, will be freely available for download. |
| **How the data is accessed/presented on Highlander platform** |
| The data will be accessed through a Web Application, indicatively composed of:  1) **Dropdown menus** to enable user’s choice about the type of **territorial units** (administrative, physical, user-selected) and the **indicator** (Bioclimatic variable or Forest species suitability) of interest.  **Administrative**: Italy, regions, provinces, municipalities  **Physical**: hydrographic basins and internal sub-basins.  **User-selected**: circle, rectangle, freehand created polygon.  2) **Live map**, at opening coloured by default according to species distribution in the harmonized Ancillary Forest Map, with radio-buttons to select: i) the period (historical or future); ii) the indicator: bioclimatic variable or the species/species category (based on the selection in 1).  After selections in 2) the live map shows the classified indicator under the period selected, then after choosing the territorial unit (by navigating and zooming), a child Application is launched with:  3) **a map** showing the values, for the selected territorial unit, of the chosen indicator under the selected period with the possibility to scroll through the other period.  4) **Box plots or similar** for the spatial statistics of the selected indicator for the two periods (for immediate comparison).  There will be also the possibility to download: i) NetCDF data clipped over the selected territorial unit: ii) a pdf report with map and box-plots obtained in the analysis. |

# Changes in the land suitability for vegetation

The DApOS “Changes in the land suitability for vegetation (forests, crops)” are being developed by CIA in collaboration with ARPAP. Climate change introduces new biological risks for the typical crops of the territory. By combining different analyses of data collected in the field, the historical data from high-resolution reanalysis, and the predictions of climate scenarios, it is possible to prevent these risks and define adaptation policies for particularly prone crops, relevant for the regional economy and also changes in forest habitat suitability. This DApOS is subdivided into three specific categories.

## DApOS “Changes in the land suitability for vegetation” specification

Author: Nicola Loglisci (ARPAP)

DApOS manager: Nicola Loglisci (ARPAP), Simona Barbarino (ARPAP), Elena Massarenti (CIA), Matteo Garbarino (UNITO)

### Workflow Mycotoxins on cereals

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| **Title** |
| Mycotoxins on cereals |
| **Partners involved** |
| ARPAP, CIA |
| **Brief description** |
| This workflow will try to link climate and the occurrence of mycotoxins on wheat and maize to assess the past to future impacts of changing mean climate conditions. By combining the analysis of data collected in the field, the historical data from high-resolution reanalysis, and the predictions of climate scenarios, the results of this workflow will be used to prevent risks and define adaptation policies. |
| **Data flow** |
| * ARPAP uses EUROCORDEX data to implement and test the software for the statistical analysis * Highlander provides **VHR-REA\_IT** e **VHR-PRO\_IT** data to the processor of this DApOS * CIA collects the data of DON and AFLATOXIN values on common wheat and maize * Highlander receives the **output** data from the processor and saves them in its own repository * The processing of this DApOS runs on ARPAP and CIA platforms |
| **Exchange protocols** |
| * ARPAP retrieves the climate data via FTP or SCP * ARPAP provide the processed data via FTP or SCP * The format will be NetCDF, tiff, png |
| **Input data** |
| **Input datasets**   1. **VHR-REA\_IT**   D4.1 - Dynamical Downscaling of ERA5 at daily level with COSMO-CLM  *Data description*:  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **ARPAP requirements**:   * Cropping on the North-western Italy Region could be useful * The NetCDF format will be used  1. **VHR-PRO\_IT**   D4.2 - Downscaling at very fine resolution of COSMO-CLM over Italy from 8km to 2.2km  *Data description*:  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **ARPAP requirements**:   * Cropping on the North-western Italy Region could be useful * The NetCDF format will be used  1. **DON and AFLATOXIN**   DON and AFLATOXIN values on common wheat and maize  *Data description*:  *Format*: csv  *Manager*: CIA  *Location*: CIA repository |
| **Output data** |
| **Output datasets**   1. **Risk class indicators of DON and AFLATOXIN** development values on common wheat and corn related to climate changes   Format: NetCDF, tiff, png  Manager: CIA  Location: CINECA repository  Update frequency: just once  Dataset size: about 500MB  **ARPAP requirements:**   * The display of aggregated data (i.e. exceedance of the highest percentiles over 20 year periods) on the map could be useful both for the users and for the project demonstration. * The raw data could be download by area selection and indicators. |
| **Which output data will be accessible to the end user on Highlander platform** |
| The outputs produced by this activity are available for all users.  DON and AFLATOXIN values are free only for Highlander partners (due to privacy issues). |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw data and maps) by this DApOS are open. |
| **How the data is accessed/presented on Highlander platform** |
| In what form:   * numerical; graphics * filters can be applied |

### Workflow Evaluation of the grapevine vocationality at regional level

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| **Title** |
| Evaluation of the grapevine vocationality at regional level |
| **Partners involved** |
| ARPAP |
| **Brief description** |
| This workflow will try to link climate and the vocationality of the regional territory to the cultivation of grapevine for wine production to assess the past to future impacts of changing mean climate conditions. Using the historical data from high-resolution reanalysis and the predictions of climate scenarios, the results of this workflow will be used to help different stakeholders to define adaptation policies. |
| **Data flow** |
| * ARPAP uses EUORCORDEX data to implement and test the software for the vocationality index calculation * Highlander provides VHR-REA\_IT e VHR-PRO\_IT data to the processor of this DApOS * Highlander does not integrate any processing of this DApOS, apart from the necessary processing to provide the input data * The processing of this DApOS runs on ARPAP platform * Highlander receives the output data from the processor and saves them in its own repository, just once |
| **Exchange protocols** |
| * ARPAP retrieves the data via FTP * ARPAP provide the processed data via FTP * The format will be NetCDF |
| **Input data** |
| **Input datasets**   1. **VHR-REA\_IT**   D4.1 - Dynamical Downscaling of ERA5 at daily level with COSMO-CLM  *Data description*:  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **ARPAP requirements**:   * Cropping on the Alpine Region could be useful, * The NetCDF format will be used  1. **VHR-PRO\_IT**   D4.2 - Downscaling at very fine resolution of COSMO-CLM over Italy from 8km to 2.2km  *Data description*:  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **ARPAP requirements**:   * Cropping on the Alpine Region could be useful * The NetCDF format will be used |
| **Output data** |
| Output datasets   1. **Climate indicators for grapevine vocationality**   Format: NetCDF, csv, tiff  Manager: ARPAP  Location: CINECA repository  Update frequency: just once  Dataset size: about 500MB  **ARPAP requirements:**   * The display of aggregated data on maps could be useful both for the users and for the project demonstration. * The raw data could be download by area selection and indicators. |
| **Which output data will be accessible to the end user on Highlander platform** |
| All the data are available for users. |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw data and maps) by this DApOS are open. |
| **How the data is accessed/presented on Highlander platform** |
| In what form:   * numerical; graphics * filters can be applied |

### Workflow Changes in forest habitat suitability

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| **Title** |
| Changes in forest habitat suitability |
| **Partners involved** |
| ARPAP, UNITO |
| **Brief description** |
| With the help of historical data from the past, high-resolution models on the past and future climate, the future dynamic trends of Mediterranean forests (mainly the alpine ones) will be analysed at the level of specific composition and alteration of the regimes of natural disturbances. |
| **Data flow** |
| * ARPAP uses EUORCORDEX data to implement and test the software * Highlander provides VHR-REA\_IT e VHR-PRO\_IT data to the processor of this DApOS * Other input data: IPLA Regional Inventory (2000); EU-Forest (2017) * Highlander receives the output data from the processor and saves them in its own repository * The processing of this DApOS runs on ARPAP platform * Highlander receives the **output** data from the processor and saves them in its own repository, just once * **UNITO implements** a forest Species Distribution Model for the Piemonte region and the Alpine region based on forest inventory and environmental data (**VHR-REA\_IT** e **VHR-PRO\_IT** climate data, DEM, LUCAS soil) for the current and future scenarios. |
| **Exchange protocols** |
| * ARPAP retrieves the data via FTP or SCP * ARPAP provide the processed data via FTP or SCP * The format will be NetCDF |
| **Input data** |
| **Input datasets**   1. **VHR-REA\_IT**   D4.1 - Dynamical Downscaling of ERA5 at hourly level with COSMO-CLM  *Data description*:  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **ARPAP requirements**:   * Cropping on the GAR (Greater Alpine Region) could be useful * The NetCDF format will be used  1. **VHR-PRO\_IT**   D4.2 - Downscaling at very fine resolution of COSMO-CLM over Italy from 8km to 2.2km  *Data description*:  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **ARPAP requirements**:   * Cropping on the GAR (Greater Alpine Region) could be useful * The NetCDF format will be used  1. **Regional Forest Inventory**   *Data description:*  *Format: dbf, shape, mdb*  *Manager: IPLA, REGIONE Piemonte, JRC*  *Location: SIFOR* |
| **Output data** |
| **Output datasets**   1. **Probability maps of changes in forest species suitability**   Format: Tiff, csv  Manager: DISAFA  Location: figshare open repository  Update frequency: just once  Dataset size: about 1GB  **ARPAP requirements:**   * Visualisation species distribution maps * Raw data download: forest species ecological niche, R codes |
| **Which output data will be accessible to the end user on Highlander platform** |
| All the data are available for users. |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw data and maps) by this DApOS are open. |
| **How the data is accessed/presented on Highlander platform** |
| In what form:   * numerical; graphics; maps * filters can be applied |

# Natural parks environmental management

The DApOS “Natural parks environmental management” is being developed by FEM, in collaboration with DIBAF. *In-situ* sensors’ network, combined with remote sensing images, will be used to monitor mountain forests’ health and climate variability in a natural Park, based on tree eco-physiological variables measured at an individual level, and also to predict meadow cuts and to improve pasture management. Advanced data analytics tools, including machine learning (ML), will be used. This DApOS is subdivided into three specific categories.

## DApOS “Natural parks environmental management” specification

### Workflow “Tree species classification and AGB prediction with hyperspectral and lidar data”

Author: Michele Dalponte (FEM), Damiano Gianelle (FEM), Loris Vescovo (FEM)

DApOS manager: Michele Dalponte (FEM), Damiano Gianelle (FEM), Loris Vescovo (FEM)

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| **Title** |
| Tree species classification and AGB prediction with hyperspectral and lidar data |
| **Partners involved** |
| FEM |
| **Brief description** |
| This workflow will provide the steps for tree species classification and aboveground biomass (AGB) using airborne hyperspectral and lidar data.  In general terms, this workflow combines information from airborne remote sensing data (hyperspectral and lidar) and field data in order to produce tree species and AGB maps at individual tree crowns level of an area. |
| **Data flow** |
| * FEM get the required data from their archives and from the Province of Trento (PAT). * Highlander receives the output data from FEM and saves them in its own repository. * **The processing of this DApOS runs on CINECA platform** |
| **Exchange protocols** |
| * **Data will be transferred on CINECA supercomputer by FEM** |
| **Input data** |
| **Input datasets**   1. **Hyperspectral data**   *Data description*: multiband images  *Manager*: FEM  *Format*: ENVI  *Location*: FEM repository   1. **Lidar data**   *Data description*: lidar point cloud data  *Manager*: FEM  *Format*: LAZ  *Location*: FEM repository   1. **Field data**   *Data description*: shapefile of trees locations with species, diameter at breast height, and height information  *Manager*: FEM  *Format*: SHP  *Location*: FEM repository |
| **Output data** |
| **Output datasets**   1. **Classification maps**    1. **Pixel level maps**   *Format*: TIF  *Manager*: FEM  *Location*: FEM repository  *Output*: one raster map  *Update frequency*: none  *Additional info*: each pixel in the map will be labelled with a species ID.   * 1. **ITC level map**   *Format*: SHP  *Manager*: FEM  *Location*: FEM repository  *Output*: one shapefile  *Update* *frequency*: none  *Additional info*: each polygon in the shapefile represent an individual tree crown (ITC) and to each ITC the species information will be provided.   * 1. **AGB map**   *Format*: SHP  *Manager*: FEM  *Location*: FEM repository  *Output*: one shapefile  *Update frequency*: none  *Additional info*: each polygon in the shapefile represent an individual tree crown (ITC) and to each ITC the AGB information will be provided. |
| **Which output data will be accessible to the end user on Highlander platform** |
| All the three maps |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (shapefile and raster maps) by this DApOS are open.  **License: CCBY 2.5/CCBY 3.0 IT**  **Attribution:** |
| **How the data is accessed/presented on Highlander platform** |
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### Workflow “Pasture monitoring tool for sustainable management”

Author: Michele Dalponte (FEM), Damiano Gianelle (FEM), Loris Vescovo (FEM)

DApOS manager: Damiano Gianelle (FEM), Loris Vescovo (FEM), Michele Dalponte (FEM)

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| **Title** |
| Pasture monitoring toolfor sustainable management |
| **Partners involved** |
| FEM |
| **Brief description** |
| This workflow will provide the steps for pasture monitoring using satellite data.  In general terms, this workflow aims at using the information from satellite remote sensing data to visualize Spectral Vegetation Indices changes across different years or during the year using a WebGIS system, providing information useful for a more sustainable pasture management |
| **Data flow** |
| * FEM defines what variables should be visualised by the WebGIS. * FEM defines the study areas of the Paneveggio park and Dedagroup gets the required dataset from the Sentinel 2 portal * Dedagroupdevelops the WebGIS platform for Spectral Vegetation Indices calculation, False-Color image creation, Spectral Vegetation Indices changes calculation, and data visualisation * WebGIS platform runs on CINECA platform |
| **Exchange protocols** |
| * Data will be transferred on CINECA supercomputer by FEM/Dedagroup |
| **Input data** |
| **Input datasets**   1. **Sentinel 2 data**   *Data description*: multiband images  *Manager*: DedaGroup  *Format*: TIF/JPEG2000  *Location*: Cineca |
| **Output data** |
| **Output datasets**   1. **False colour images**   *Format*: TIF  *Manager*: DedaGroup  *Location*: Cineca  *Output*: one raster map  Update frequency: 15 days  *Additional info*: each pixel in the map will be labelled with a RGB and visualized band value.   1. **Spectral Vegetation Index change images**   *Format*: TIF  *Manager*: DedaGroup  *Location*: Cineca  *Output*: one raster map  Update frequency: 15 days  *Additional info*: each pixel represents:   1. the change in percentage in a given Spectral Vegetation Index value compared to another date (e.g. 15 days before; or around the same date, but 1 year before), or 2. the change in percentage in a given Spectral Vegetation Index value compared an average of several dates (average value of a SVI around the same date of 5 precedent years |
| **Which output data will be accessible to the end user on Highlander platform** |
| Both “false colour images” and “Spectral Vegetation Index change” images |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project by this DApOS are open.  **License: CCBY compatible**  **Attribution:** |
| **How the data is accessed/presented on Highlander platform** |
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### Workflow “Forest physiological tree monitoring”

Author: Damiano Gianelle (FMach), Riccardo Valentini (DIBAF)

DApOS manager: Damiano Gianelle (DIBAF), Riccardo Valentini (DIBAF)

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| **Title** |
| Forest physiological tree monitoring |
| **Partners involved** |
| FMACH, DIBAF, CMCC |
| **Brief description** |
| This document illustrates the datasets and workflow to produce data of tree physiological parameters in the natural park of Paneveggio Pale di San Martino, based on the Tree Talker sensor.  Specifically, two sites with 25 Tree Talker sensors each, one in beech and one in spruce forest, have been installed in the natural park for continuous monitoring at tree level of selected parameters, that are recognized to be important to monitoring plant physiology.  The in-situ stations, linked through IoT technology, produce data on leaves spectra reflectance, tree growth, water use, soil and stem humidity, air temperature, plant stability that can be uses to understand the response of trees to climate.  The combination of measured parameters, local climate data, and ancillary information into an additional modelling steps will generate as output the time series of plant phenology and dynamics.  All information will be centralized and processed by Highlander computing facilities and made available to third parties through project platform and WebGIS tools. |
| **Data flow** |
| * FMACH and UNITUS define the study areas. * FMACH installs the sensors in the two sites and takes attention to the maintenance * FMACH and UNITUS define the quality check procedures and modelling tools * Data processing and modelling runs on CINECA platform * Outputs from CINECA platform are made available to third parties |
| **Exchange protocols** |
| * IoT data will be transferred on CINECA supercomputer by UNITUS * Ancillary data will be transferred to CINECA by UNITUS/FMACH * Algorithms for processing and modelling will be transferred to CINECA by UNITUS/FMACH |
| **Input data** |
| **Input datasets**   1. **IoT in-situ data**   In total 50 sensors are distributed in 2 regional park forests. The variables collected by the TreeTalker sensor are:   * Air temperature * Relative Humidity * Light transmission measured on 12 visible and infrared bands * Wood water content * Tree water fluxes * Stem growth * Plant stability  1. **Ancillary data**   Ancillary data - including climate information- will be provided from local meteorological stations |
| **Output data** |
| **Output datasets**   1. **Plant physiological data**   Time series of tree physiological data, integrated with local climate data and forest species distribution  Manager: UNITUS/FMACH |
| **Which output data will be accessible to the end user on Highlander platform** |
| Time series of tree physiological parameters |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw and processed data) by this DApOS are open with license: (CC BY 4.0). |
| **How the data is accessed / presented on Highlander platform** |
| Data are available on DIBAF cluster and CINECA highlander repository |

# Soil erosion

The DApOS “Soil erosion” is being developed by CMCC.

This DApOS aims to reduce soil erosion due to extreme climate conditions with the help of very high-resolution (spatial and temporal) data to understand the management options related to climatic variations over time. Historical data and high-resolution models, using the past and future climatic data, will predict the future dynamic trends of Mediterranean forests.

## DApOS “Soil erosion” specification

Author: Monia Santini (CMCC)

DApOS manager: Monia Santini (CMCC)

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| **Title** |
| Soil erosion |
| **Partners involved** |
| CMCC |
| **Brief description** |
| Extreme climate conditions affect the maintenance of soil functions, especially in areas particularly subject to rainfall-induced erosion. The DApOS Soil Erosion is based on a consolidated empirical model (RUSLE) to generate assessment and projections about the potential loss of soil due to intense rainy events and land management on both forests and agricultural areas. The application of the model at national scale will support in identifying areas particularly at risk under changes in climate variability and to formulate strategies to reduce soil erosion through appropriate management of forests and agricultural fields, also in terms of working practices and soil protection measures. The availability of very high-resolution (spatial and temporal) data will allow to more reliably reach the spatial detail useful for local to regional scales. |
| **Data flow** |
| **The processing to support this DApOS runs once** using three variables from **VHR-REA\_IT** e **VHR-PRO\_IT**: *TOT\_PREC (hourly), HSURF (fixed), lat (fixed).*  The processing can run on CINECA HPC Cluster or Cloud, we suppose Cloud will be fine.  The steps to be followed in the processing are described and ordered here (from 1 to 9)  <https://docs.google.com/spreadsheets/d/1GSIvSqQ8IsRPGWpHrPzaMPwq0voG_tJm/edit#gid=1217443738>  **The steps with the same number are not depending on one another and can be run in parallel.**  Steps 1-4: Calculation of R factor of the model RUSLE, for VHR-REA (1989-2018 or 1991-2020, TBD) and VHR-PRO (1989-2018 or 1991-2020 and 2021-2050).  Step 5: The outputs from Step 4 will be masked over Italy (to exclude not Italian territories) according to a mask provided by the DApOS team (CMCC) and then the VHR-REA based product of R factor will be available to be explored through the HIGHLANDER platform tools (e.g., for spatial clipping according to administrative or physical boundaries, for extracting zonal or ensemble members’ statistics).  Step 6: The VHR-PRO based outputs from Step 5 will be further operated into anomalies (future minus historical) of R factor to be then explored through the HIGHLANDER platform tools (e.g., for spatial clipping according to administrative or physical boundaries, for extracting zonal or ensemble members’ statistics).  Step 7: The outputs from Step 4 will be also resampled to a finer spatial resolution (100 to 500 m to be decided) over a grid provided by CMCC.  Step 8: The output from step 7 will be operated with (multiplied by) other 4 Ancillary datasets prepared by CMCC and already under the same masked grid provided by CMCC in step 7: and then the VHR-REA based product of Soil Loss (SL) will be available to be explored through the same platform tools than for R factor.  Step 9: The VHR-PRO based outputs from Step 8 will be further operated into anomalies (future minus historical) of SL to be to be explored through the same platform tools than for R factor. |
| **Exchange protocols** |
| * The processor will access the NetCDF files in Galileo (Deliverable 4.1 and 4.2) and will receive Ancillary dataset from DApOS team. * The processor will save the output in NetCDF * The processor will be developed by CMCC and will run on CINECA’s infrastructure. |
| **Input data** |
| **Input datasets**   1. **VHR-REA\_IT**   D4.1 - Dynamical Downscaling of ERA5 at hourly level with COSMO-CLM for 1989-2020.  *Data description*: see here: <https://wiki.u-gov.it/confluence/display/HIGHLANDER/Dataset+forms?preview=/359625290/393550377/ReanalysisDownscaling_(Template-Highlander-data_final-version)_CMCC_FINAL.docx>  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **CMCC requirements**:   * + - Application of steps 1-9 above, with mask for clipping (step 5) and for resampling (step 7) provided by CMCC.  1. **VHR-PRO\_IT**   D4.2 - Downscaling at very fine resolution of COSMO-CLM over Italy from 8km to 2.2km for 1989-2050  *Data description*: see here: <https://wiki.u-gov.it/confluence/display/HIGHLANDER/Dataset+forms?preview=/359625290/393550380/COSMO-CLM-Downscaling_(Template-Highlander-data_final-version)_FINAL.docx>  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **CMCC requirements**:   * + - Application of steps 1-9 above, with mask for clipping (step 5) and for resampling (step 7) provided by CMCC. |
| **Output data** |
| **Output datasets**   1. **Indicators of rainfall erosivity (R factor) and soil loss (SL) amount**   *Format*: NetCDF  Manager: CMCC  *Location*: CINECA Repository  Update frequency: once  *Additional info*: to be accessed and explored through the HIGHLANDER platform the products of steps 5-6 and 8-9 above.  *Dataset size*: R-factor (≈10 MB x 24 maps (2 products x 12 models) = 240 MB) + Soil Loss (5 GB x 24 maps (2 products x 12 models) = 120 GB  **CMCC requirements:**   * + - Raw data download: data will be accessed by end users as explained in the last point below |
| **Which output data will be accessible to the end user on Highlander platform** |
| See steps 5-6 and 8-9 above |
| **With which policy** (License and Attribution) |
| The data on the platform, i.e. results of steps 5-6 and 8-9, will be freely available for the download. |
| **How the data is accessed/presented on Highlander platform** |
| The data will be accessed through an application, indicatively composed of:  1) **Dropdown menus** to user’s choice about the type of **territorial units** (administrative, physical, user selected) and the **indicator** (R factor or Soil Loss) of interest.  **Administrative**: Italy, regions, provinces, municipalities.  **Physical**: hydrographic basins and internal sub-basins.  **User selected**: circle, rectangle, freehand created polygon.  2) **Live map**, at opening coloured by default according to classified value of the chosen indicator for the historical period, with radio-button to select the period (historical or future) and the R model (one or more) at the basis of R factor and Soil Loss.  After selections in 2) the live map shows the classified indicator under the selected period and R model(s) (ensemble mean if more than one), then after choosing the territorial unit (by navigating and zooming), a child Application is launched with:  3) **a map** showing the value, for the selected territorial unit, of the chosen indicator under the selected period and R model(s) (ensemble mean if more than one) with the possibility to scroll through the other period.  4) **Box plots or similar** for the spatial statistics of the selected indicator (under multiple R model(s) if more than one is selected) for the two periods (for immediate comparison).  There will be also the possibility to download: i) NetCDF data clipped over the selected territorial unit: ii) a pdf report with map and box-plots obtained in the analysis. |

# Human wellbeing

The DApOS “Human wellbeing” is being developed by CMCC. Suitable bioclimatic indicators and extreme indices will be used to evaluate the impacts of changing mean climate conditions and accelerated variability on comfortable conditions for humans. This DApOS will be in synergy with the one - conducted by DIBAF - evaluating (dis)comfort conditions for animals by using the same or additional climate variables combined into indicators tailored for the livestock sector.

## DApOS “Human Wellbeing” specification

Author: Monia Santini (CMCC)

DApOS manager: Monia Santini (CMCC)

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| **Title** |
| Human Wellbeing |
| **Partners involved** |
| CMCC |
| **Brief description** |
| Climate change tests the ability of individuals to perceive physical and mental well-being conditions in daily life, especially in the context of large urban settlements. The urban microclimate remains influenced by the physical processes related to the occupation of soils by artificial areas. The high resolution and last generation climate simulations produced in HIGHLANDER allow reproducing the interactions between atmosphere and surface taking into account the land cover with high spatial detail, especially thanks to the satellite-derived (CORINE) data.  Starting from the current distribution of land use and therefore the presence of densely populated or rural areas, the expected changes in those climate conditions - in particular heat and humidity - more or less comfortable for the population, will be studied through indicators based on combination of different variables. |
| **Data flow** |
| **The processing to support this DApOS runs once** starting from four variables from **VHR-REA\_IT** e **VHR-PRO\_IT**: *T\_2M (hourly), TD\_2M (hourly), U\_10M (hourly), V\_10M (hourly)*  The processing can run on CINECA HPC Cluster or Cloud, we suppose Cloud will be fine.  The steps to be followed in the processing are described and ordered here (from 1 to 6)  <https://docs.google.com/spreadsheets/d/1GSIvSqQ8IsRPGWpHrPzaMPwq0voG_tJm/edit#gid=1105583074>  **The steps with the same number are not depending on one another and can be run in parallel.**  Here below these steps are briefly illustrated:  Steps 1-2: Pre-processing of needed variables for VHR-REA\_IT (1989-2018 or 1991-2020, TBD) and VHR-PRO\_IT (1989-2018 or 1991-2020 and 2021-2050).  Step 3: Calculation of wellbeing indicators for VHR-REA\_IT (1989-2018 or 1991-2020, TBD) and VHR-PRO\_IT (1989-2018 or 1991-2020 and 2021-2050) at hourly time scale.  Step 4: Calculation of daily minimum, maximum, average of indicators from Step 3 for VHR-REA\_IT (1989-2018 or 1991-2020, TBD) and VHR-PRO\_IT (1989-2018 or 1991-2020 and 2021-2050).  Step 5: The outputs from Steps 4 will be masked over Italy (to exclude not Italian territories) according to a mask provided by the DApOS team (CMCC) and then the VHR-REA based indicators will be available to be explored through the HIGHLANDER platform tools (e.g., for spatial clipping according to administrative or land use boundaries, for extracting zonal statistics).  Step 6: The VHR-PRO based outputs from Step 5 will be further operated into anomalies (future minus historical) of the indicators to be then explored through the HIGHLANDER platform tools (e.g., for spatial clipping according to administrative or land use boundaries, for extracting zonal statistics). |
| **Exchange protocols** |
| * The processor will access the NetCDF files in Galileo (Deliverable 4.1 and 4.2) and will receive Ancillary dataset from DApOS team. * The processor will save the output in NetCDF * The processor will be developed by CMCC and will run on CINECA’s infrastructure. |
| **Input data** |
| **Input datasets**   1. **VHR-REA\_IT**   D4.1 - Dynamical Downscaling of ERA5 at hourly level with COSMO-CLM for 1989-2020.  *Data description*: see here: <https://wiki.u-gov.it/confluence/display/HIGHLANDER/Dataset+forms?preview=/359625290/393550377/ReanalysisDownscaling_(Template-Highlander-data_final-version)_CMCC_FINAL.docx>  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **CMCC requirements**:   * + - Application of steps 1-6 above, with mask for clipping (step 5)  1. **VHR-PRO\_IT**   D4.2 - Downscaling at very fine resolution of COSMO-CLM over Italy from 8km to 2.2km for 1989-2050  *Data description*: see here: <https://wiki.u-gov.it/confluence/display/HIGHLANDER/Dataset+forms?preview=/359625290/393550380/COSMO-CLM-Downscaling_(Template-Highlander-data_final-version)_FINAL.docx>  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **CMCC requirements**:   * + - Application of steps 1-6 above, with mask for clipping (step 5) |
| **Output data** |
| **Output datasets**   1. **Indicators of bioclimatic conditions and forest suitability**   *Format*: NetCDF  Manager: CMCC  *Location*: CINECA Repository  Update frequency: once  *Additional info*: to be accessed and explored through the HIGHLANDER platform the products of steps 5-6 above.  *Dataset size*: (indicative) Human Wellbeing indicators (at native resolution; ≈17 GB\* x 24 maps (2 periods x 4 indicators x 3 metrics (max, min, mean) = 410 GB)  **CMCC requirements:**   * + - Raw data download: data will be accessed by end users as explained in the last point below |
| **Which output data will be accessible to the end user on Highlander platform** |
| See steps 5-6 above |
| **With which policy** (License and Attribution) |
| The data on the platform, i.e. results of steps 5-6, will be freely available for the download. |
| **How the data is accessed/presented on Highlander platform** |
| The data will be accessed through a Web Application, indicatively composed of:  1) **Dropdown menus** to enable user’s choice about the type of **territorial units** (administrative, land use based, user selected) and the **indicator** (WC, HDEX, DI, AT) of interest.  **Administrative**: Italy, regions, provinces, municipalities  **Land use based**: e.g. forest lands, urban areas, rural/agricultural areas, artificial surfaces  **User selected**: circle, rectangle, freehand created polygon.  2) **Live map**, at opening coloured by default according to the selected indicator for the historical period, as classified long-term average of its daily mean value, with radio-buttons to select the period (historical or future), the aggregation\*\* (yearly; seasonal: DJF, MAM, JJA, SON; monthly: J, F, M, A; M, J, J, A, S, O, N, D), and the daily metric (mean, maximum, minimum).  After selections in 2) the live map shows the desired indicator as classified long-term average of its daily value under the period/aggregation/metric selected, then after choosing the territorial unit (by navigating and zooming), a child Application is launched with:  3) **a map** showing the values, for the selected territorial unit, of the indicator as classified long-term average of its daily value under the period/aggregation/metric selected, with possibility to scroll through the other period.  4) **Box plots or similar** for the spatial statistics of the values in 3) for the two periods (for immediate comparison).  There will be also possibility to download: i) NetCDF data clipped over the selected territorial unit: ii) a pdf report with map and box-plots obtained in the analysis.  \*assumed 13 GB the size of hourly data for 1 variable and 1 year, so (13/24)\*30≈17GB is the size daily data for 30 years  \*\* to be decided if aggregation made on the fly (only for the territorial units selected) or pre-calculated, the latter will require creating (through additional steps) 17 (aggregations) x 3 (metrics) x 4 (indicators) x 2 (periods)=204 layers. |

# IoT for animal wellbeing

The DApOS “IoT for animal wellbeing” is being developed by DIBAF. One of the major concerns regards the economic impact of climate changes on livestock production efficiency reduction due to heat stress: IoT capable of detecting livestock position and movements for pasture livestock would be very useful to identify the state of health. The data detected will be correlated, through appropriate relations, to the environment temperature and humidity, determining animal conditions and compared both to climate weather sub-seasonal forecast (from ECMWF) and to climate projection data (from CMCC) and AIA production data. This DApOS is subdivided into two specific categories.

## DApOS “IoT for animal wellbeing” specification

Author: Marco Milanesi (DIBAF), Francesco Renzi (DIBAF)

DApOS manager: Giovanni Chillemi (DIBAF)

### Workflow: animal welfare using climate projection data

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| **Title** |
| IoT for animal wellbeing - climate projections |
| **Partners involved** |
| DIBAF |
| **Brief description** |
| This workflow will provide indicators of animal wellbeing using projection data (2021-2050), based on historical climate conditions and production data.  In general terms, this workflow combines information on production data from dairy cows (from AIA, through DIBAF collaboration) and downscaled ERA5 reanalysis data (1989-2018) from CMCC. |
| **Data flow** |
| * Highlander provides downscaled ERA5 reanalysis data (**VHR-REA\_IT**) to DIBAF, through CMCC * DIBAF provides **AIA historical production data** * DIBAF identifies the best ML model to predict the impact of climate variables on production * Highlander provides downscaled projections data (2021-2050) (**VHR-PRO\_IT**) to DIBAF, through CMCC * DIBAF runs the ML algorithm to obtain predictions on DIBAF or CINECA servers * Highlander receives the output data from DIBAF and saves them in its own repository * **The processing of this DApOS runs on DIBAF. At the moment we are evaluating if the computing power of DIBAF infrastructure will be sufficient. If not, the algorithm will need to run also on CINECA infrastructure.** |
| **Exchange protocols** |
| * DIBAF retrieves the climate data and production data via FTP or SCP * DIBAF provide the processed data via FTP or SCP * This process is made only once |
| **Input data** |
| **Input datasets**   1. **VHR-REA\_IT**   D4.1 - Dynamical Downscaling of ERA5 at hourly level with COSMO-CLM  *Data description*: 2.2 km hor.res. for 1989-2018 (hopefully 1981-2019)  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **Requirements**:   * + - All the Italy     - The NetCDF format will be used     - Variables: 2m temperature, 2m dew point temperature, Total precipitation, U-component of 10m wind, V-component of 10m wind, 2m maximum temperature, 2m minimum temperature, mean sea level pressure, relative humidity, specific humidity, total cloud cover, Surface Evaporation, Averaged surface net downward shortwave radiation, Averaged surface net downward longwave radiation, RUNOFF\_G, RUNOFF\_S, W\_SNOW, W\_SO.  1. **VHR-PRO\_IT**   D4.2 - Downscaling at very fine resolution of COSMO-CLM over Italy  *Data description*: from 8km to 2.2km hor. res. for 1989-2050 (hopefully 1981-2065)  *Format*: NetCDF  *Manager*: CMCC  *Location*: CINECA repository  **Requirements**:   * + - All the Italy     - The NetCDF format will be used     - Variables: 2m temperature, 2m dew point temperature, Total precipitation, U-component of 10m wind, V-component of 10m wind, 2m maximum temperature, 2m minimum temperature, mean sea level pressure, relative humidity, specific humidity, total cloud cover, Surface Evaporation, Averaged surface net downward shortwave radiation, Averaged surface net downward longwave radiation, RUNOFF\_G, RUNOFF\_S, W\_SNOW, W\_SO.  1. **Production data from dairy cow**   *Manager*: AIA/DIBAF  *Location*: DIBAF server  *Format*: CSV & MySQL |
| **Output data** |
| **Output datasets**   1. **Indicators of animal wellbeing due to climate conditions**   *Format*: CVS, NetCDF, tiff, png  *Manager*: DIBAF  *Location*: CINECA repository  *Update frequency*: just once  *Additional info*: based on the extent of the input climate data, the forecast will cover the next 20 or 30 years. The output is produced once and never updated again.  **Requirements:**   * + - The display of warnings due to climate change in animal production on the map per year/period is useful and facilitates the user’s decision.     - The raw data could be download by area selection and/or year |
| **Which output data will be accessible to the end user on Highlander platform** |
| The outputs produced by this activity are available for all users. |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw data and maps) by this DApOS are open (CC BY 4.0). |
| **How the data is accessed/presented on Highlander platform** |
| In what form:   * numerical; graphics * filters can be applied |

### Workflow: animal welfare in sub-seasonal framework

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| **Title** |
| IoT for animal wellbeing - sub-seasonal |
| **Partners involved** |
| DIBAF |
| **Brief description** |
| This workflow will provide sub-seasonal monitoring and forecasting of animal wellbeing, using sub-seasonal climate data and IoT sensors on animals.  In general terms, this workflow combines information from AnimalTalker and climate weather sub-seasonal forecast from ECMWF. |
| **Data flow** |
| * Highlander provides **Sub-SEA** data to DIBAF, through ECMWF * DIBAF will provide by means of AnimalTalker IoT sensors data on animal movements using a 3-axis accelerometer, temperature with surface and under skin RFID sensors, and potential other physiological parameters * DIBAF identifies the best ML model to predict the impact of climate variables on animal physiological conditions * DIBAF runs the ML algorithm to obtain predictions on DIBAF or CINECA servers * Highlander receives the output data from DIBAF and saves them in its own repository * **The processing of this DApOS runs on DIBAF. At the moment we are evaluating if the computing power of DIBAF infrastructure will be sufficient. If not, the algorithm will need to run also on CINECA infrastructure.** |
| **Exchange protocols** |
| * DIBAF retrieves the climate data via FTP or SCP * DIBAF retrieves the AnimalTalker data using a dedicated IoT server for telemetry data * DIBAF provide the processed data via FTP or SCP * Processing twice a week, following sub-seasonal ECMWF release |
| **Input data** |
| **Input datasets**   1. **Sub-SEA**   D4.3 - Downscaled sub-seasonal forecasts  *Format*: NetCDF  *Manager*: ECMWF  *Location*: CINECA repository  *Data description*: ecPoint data from entire Italy  **Requirements**:   * + - All the Italy     - The NetCDF format will be used     - Variables: 2m temperature, 2m dew point temperature, Total precipitation, Wind speed at 10m, Wind speed at 100m, 2m maximum temperature, 2m minimum temperature, Mean sea level pressure, Surface pressure, Specific humidity, Relative humidity, Total cloud cover, Surface Evaporation, Averaged surface net downward shortwave radiation, Averaged surface net downward longwave radiation, Soil (multi-levels) water content, Soil type, orography, Land-sea mask  1. **AnimalTalker data**   *D4.4 – Animal physiological data*  *Format*: CSV, JSON  *Manager*: DIBAF  *Location*: DIBAF repository  **Requirements**:   * + - Data will be submitted daily     - Variables: environmental temperature and humidity of animal environment, GPS location, animal under skin temperature, animal skin temperature, animal movements, animal heart rate     - Server will show the updated data and will allow queries in space and time domain for multiple applications |
| **Output data** |
| **Output datasets**   1. **Evaluation of animal wellbeing due to physiological and environmental conditions**   *Format*: CSV, NetCDF, tiff, jpg  *Manager*: DIBAF  *Location*: CINECA repository  *Update frequency*: twice per week, based on ECMWF sub-seasonal forecast data  **Requirements:**   * + - The display of warnings due to climate change in animal production on the map per year/period is useful and facilitates the user’s decision.     - The raw data could be download by area selection and/or year |
| **Which output data will be accessible to the end user on Highlander platform** |
| The outputs produced by this activity are available for all users. |
| **With which policy** (License and Attribution) |
| The data produced in the framework of the Highlander project (raw data and maps) by this DApOS are open (CC BY 4.0). |
| **How the data is accessed/presented on Highlander platform** |
| In what form:   * numerical; graphics * filters can be applied |

# Water cycle and sustainability of competing uses

The DApOS “Water cycle and sustainability of competing uses” is being developed by CMCC. This DApOS will be strictly connected with the one on “Crop water requirements forecasts in Apulia pilot”, conducted by ARPAE in the area of Capitanata irrigation consortium. The aim is to analyse the dynamics of Ofanto river basin through climate variables, climate-based indicators, and indices. The analysis will be ready by the end of the summer, once the simulations are over, and hence also the specification of this DApOS.