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# Deliverable No: 6.3

## *Online monitoring data services for ecosystem indicators*

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| **EC Project Officer** | Gaëlle Le Bouler |
| **Abstract** | Deliverable D6.3 conveys the activities carried out within Task 6.4 of the EU Horizon 2020 ECOPOTENTIAL Project, which aims to provide pre-operational online data services by assimilating EO data for ecosystem monitoring. Service development considered the storylines' concept described through ECOPOTENTIAL and outlined in Deliverable 2.2. Each data service is implemented for a specific (or more) PA(s) and is (are) linked to a specific (or more) storyline(s). Online data services are to be found mounted on the Virtual Laboratory Platform (D10.1 & D10.2) as free access services for the users. |
| **Keywords** | Earth observation, data assimilation, online services, models, ecosystem services |

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# Abbreviations and Acronyms

| | |
|---|---|
| AUC | Area under Curve |
| AWMPFD | Area-Weighted Mean Patch Fractal Dimension |
| BFAST | Breaks For Additive Season and Trend |
| BIC | Bayesian Information Criterion |
| BIO_SOS | BIOdiversity multi-Source monitoring System |
| CA | Class Area |
| CC-BY-NC | Creative Commons Attribution Non-Commercial |
| CoBiOS | Coastal Biomass Observatory Services |
| CLC | Corine Land Cover |
| DEM | Digital Elevation Model |
| EFA | Ecosystem Functional Attributes |
| EO | Earth Observation |
| ES | Ecosystem services |
| GDEM | Global Digital Elevation Model |
| GEO | Group on Earth Observations |
| GEOSS | Global Earth Observations System of Systems |
| IPR | Intellectual Property Rights |
| LAI | Leaf Area Index |
| LC | Land Cover |
| LiDAR | LIght Detection And Ranging |
| LST | Land Surface Temperature |
| MODIS | MOderate Resolution Imaging Spectroradiometer |
| MIT | Massachusetts Institute of Technology |
| MPS | Mean Patch Size |
| MNDVI | Modified-Normalized Difference Vegetation Index |
| NDVI | Normalized Difference Vegetation Index |
| OCN | Optimal Channel Network |
| OLI | Operational Land Imager |
| PA | Protected Area |
| PD | Patch Density |
| PIA | Pseudo Invariant Areas |
| PIL | Python Imaging Library |
| PLAND | Percentage of LANDscape |

| | |
|---|---|
| RGB | Red Green Blue |
| ROC | Receiver Operating Characteristic |
| QA | Quality Assurance |
| QC | Quality Control |
| SAR | Synthetic Aperture Radar |
| SDM | Species Distribution Modelling |
| SPOM | Spatial Patch Occupancy Model |
| SWIR | Short-Wave Infrared |
| TM | Thematic Mapper |
| WP | Workpackage |
| VL | Virtual Laboratory Platform |

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# 1. Executive Summary

A key aim of the EU Horizon 2020 ECOPOTENTIAL project is to realize online monitoring data services for ecosystem indicators for the users' community. WP6 activities and especially Task 6.4 provided resources and expertise for their development and deployment onto the Virtual Laboratory Platform (VL). Models, able to assimilate EO data, and applied within Task 6.2 and Task 6.3 were transformed into online data services. Experimentation, product generation and model integration into services took advantage of the pre-processed data delivered via the EO Data toolbox (Cloud Sandbox environment), maintained by WP3.2 (EO data processing tools). Processed data from WP4 and WP5 were used either as input data to models or as calibration/ validation data. These are stored in the project's repository and accessible according to the Data Management Plan. Further modules (initially in the form of manual workflows developed in WP4) for the derivation of map and land cover feature products from EO data were also transformed to easy-to-initiate-and-use operational online data services; (i) either as stand-alone services or (ii) as workflow components to generate input for models. This way, the automated execution of models or modules by the users is integrated and mounted onto the open access Virtual Laboratory Platform (as described in Deliverables 10.1 and 10.2) and may make use of existing or new input EO data.

# 2. Introduction

Selected process-based (Task 6.3), conceptual/correlative models (Task 6.2) and other model supportive workflows (WP4 modules) were transformed into online data services (the explicit list of services is presented in chapters 3 and 4), and then integrated into the VL platform. The VL is conceived as a virtual environment enabling information access and knowledge generation for the ecosystem science community of practice. VL is deployed and operated in a cloud-based infrastructure as a service-based platform for a virtual (i.e. online distributed) and open (i.e. accessible) laboratory to study ecosystems and contribute to GEO/GEOSS (D10.1). Following the completion of the services' upload to VL, users have the ability to run the provided services in an automated way given inputs and parameters needed.

Data service development within the ECOPOTENTIAL project followed the FP7 CoBiOS (2011- 2013) paradigm. CoBiOS aimed to integrate satellite products and ecological models into a user-relevant information service on high biomass blooms in Europe's coastal waters. Within CoBiOS, service lines were generated and provided data to ecological model services. Modelling results were placed on the CoBiOS web portal to give users an overview of past and current events and predictions. ECOPOTENTIAL project capitalized on CoBiOS results and further developed a platform (VL) to provide users the capacity to utilize various services themselves and generate products in relation with different ecosystem types.

**Linkages with others WPs and Tasks**

Multiple communication channels were pursued to establish the necessary coupling and synergy among contributing partners, project generated data, models and modules developed. Guidelines and scheduling material were distributed to interested parties, while information and data were collected, interpreted and redistributed to the respective working groups within the project.

Figure 1: Established links between T6.4 and other WP6 Tasks and ECOPOTENTIAL WPs. illustrates the linkages between Task 6.4 and other WPs and WP6 Tasks within ECOPOTENTIAL project.

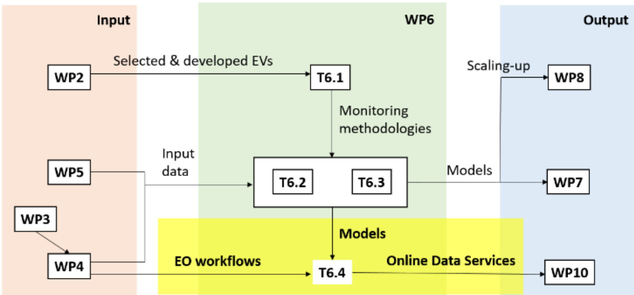


*Figure 1: Established links between T6.4 and other WP6 Tasks and ECOPOTENTIAL WPs.*

**Process followed for models' selection**

All ECOPOTENTIAL partners that were involved in models' application tasks were reached. An initial explicit list of those partners included: Universitaet Potsdam (UP), Instituto Superior Tecnico (IST), Karlsruher Institut fuer Technologie (KIT), Umweltbundesamt Gesellschaft mit Beschrankter Haftung (EAA), Centre National de la Recherche Scientifique (CNRS), Helmholtzzentrum Fuer Umweltforschung Gmbh (UFZ), Foundation for Research and Technology Hellas (FORTH), Ecole Polytechnique Federale De Lausanne (EPFL), Instituto de Ciencias, Technologias e Agroambiente da Universidade do Porto (ICETA), Universidad de Granada (UGR), University of Cordoba (UCO), Ben-Gurion University of the Negev (BGU), Stichting DELTARES (DELTARES), Université de Bretagne Occidentale (UBO), Agencia Estatal Consejo Superior De Investigaciones Cientificas (CSIC), Fondation Tour Du Valat (TdV), University of Leeds (UNIVLEEDS), Politecnico di Milano (POLIMI), Consiglio Nazionale delle Ricerche (CNR), and Centre for Research and Technology Hellas (CERTH).

Aforementioned partners were asked for the status of their models and e-discussions took place in relation with the possibility to integrate their models into online data services and coupled with the VL. The focus of the request was placed on the degree of assimilation of earth observation data into a model's processing chain. Additionally, of importance was the capacity of the models to integrate data and/or information existing into the ECOPOTENTIAL knowledge base, as these data were generated following the consultation of users and according to the user requests. Other main issues of the discussions included, the functionality of the model, the PA and storyline of implementation, main inputs and outputs, as well as copyright requirements.

In Section 3 are listed and briefly described Models that have been finally selected through the aforementioned process and are implemented as online data services on to the VL. In Section 4 are listed and briefly described selected Workflows that are implemented as online data services on to the VL. In Section 5 are listed additional Models and Workflows that are still in the process of integration in the VL by the respective partners, and are expected to be available by the end of the project. Latter cases and partners still need to make necessary upgrades or adjustments as a result of additional testing or copyright issues.

# 3. Models as online data services

## 3.1 INSTAR

**Storyline (related or applied to):** Temporal evolution of ecosystem services in Sierra Nevada (M9)
**Protected Area:** Sierra Nevada (Spain)
**Service brief description:** INSTAR implements an agent-based model aiming to aid environmental decision making in pine plantations affected by *Thaumetopoea pityocampa* forest pest. Specifically, it aims at generating a deeper understanding of the population dynamics of this pest and at forecasting the probability of occurrence and intensity of the pest outbreaks at a landscape scale, under different climate as well as land use scenarios.
ECOPOTENTIAL virtual lab allows a demo execution for INSTAR model, where input datasets are already defined. By running this demo, a potential user becomes familiar with the type of inputs that the model requires, as well as the outputs it generates. Moreover, by following the link to INSTAR GitHub repository, a potential user could download INSTAR code and run it locally with a different dataset.
**Relevant reference/ material/ publications:** A manuscript is under preparation and will be submitted for review in the coming month.
**Input Data and Format:**
**- *EO-data:*** (i) DEM, as raster (.asc file), (ii) a vectorial file containing pines location (.shp), (iii) Land cover map, as raster (.asc file).
- ***Other:*** WiMMed-produced (http://www.uco.es/investiga/grupos/dinamicafluvialhidrologia/) maps of daily minimum and maximum temperature, as raster (.asc files)
**ECOPOTENTIAL products used:** Through WP4, LiDAR images of Sierra Nevada and Sierra de Baza have been processed to generate the map of pines used as input dataset for INSTAR. In this work, some point data (tree height and coordinates) were used to calibrate the algorithm recognizing individual trees from LiDAR images.
**Output Data and Format:** INSTAR generates a table (.csv file), where state variables are described for the whole simulated area. These cover the number of pine processionary moths, at each stage for each day of the simulation, as well as the percentage of infected pines and average biomass of the pines. INSTAR can also generate maps of those state variables, therefore disaggregating the table into spatial units. By default, these maps are generated on a monthly basis, and the monthly data can also be provided as a table. These options, however, are turned off in the demo provided by the virtual lab.
**Source code location:** http://sl.ugr.es/github_instar
**Input data location:** http://sl.ugr.es/github_instar
**Transferability:** The service may be applied to the same site in a different period and/ or to other sites, where pine plantations exist (given input, parameterization and calibration). Executing INSTAR for a different period would only require generating the temperatures maps for that period. This could be done by running WiMMed during such period, or by generating the maps based on climate projections or other assumptions, therefore allowing testing different climate scenarios. Generating a new map of trees could also be considered, depending on the time scale of the period or in the case of important forest management measures taking place and therefore altering the structure of the forest (by clearings, thinning, etc). Parameterization and adjustment may be required.
In order to run INSTAR in a different area, a new input dataset for that area should be provided, containing:

- Raster elevation map
- Vectorial map of trees
- Raster daily maps of minimum and maximum temperatures for the period to be executed

Moreover, and especially if the simulated area differs a lot from our study area (Sierra Nevada, semi-arid Mediterranean climate), parameterization and adjustment may be required.
**Validation:** Model validation is in progress, but not conclusive yet. *Error in model parameters:* Most of the values are provided without error measures. *Error in in-situ data:* The model itself does not use in-situ data other than the parameter values already reported above, although in-situ data are used for input data generation. On one hand,

LiDAR image processing was calibrated using a set of tree height measures collected in Sierra Nevada. On the other hand, climate data are generated by WiMMed model, which uses all available data from the meteorological stations around the study area. *Error in model process description (structural uncertainty):* INSTAR design, as any other modelling process, implies inherent structural uncertainty as it constitutes a simplified representation of our perception of the natural system functioning. *Error in EO products (at product level e.g. confusion matrix):* EO products in INSTAR correspond to the map of trees of the simulated area, which is generated through LiDAR image processing. Therefore, the error in EO product is involved in INSTAR only regarding this layer of input data, as stated above (see section "Error in in-situ data"). *Input data uncertainty:* Input data in INSTAR come from the processing of EO data (LiDAR image is used to generate the map of trees) and the execution of a hydrometeorological model (WiMMED). At this stage, input data uncertainty cannot be visualized through INSTAR execution, since no measure of uncertainty has been included in the input data. *Model-based uncertainty:* This source of uncertainty results from stochasticity being included in some model functions in order to simulate the system. Several stochastic processes are included in INSTAR during its initialization: assigning values of biomass quantity to hosts, assigning number of individuals and days remaining to bags and selecting which are the initial infected hosts. Moreover, in order to simulate the intrinsic variability of natural processes, pseudorandom numbers are also used during the model running to assign sex to moths, decide whether a female moth becomes mated or not and choose the hosts where moths lay their eggs. This uncertainty can be estimated by running multiple executions of the model with the same input dataset and comparing the outputs of the executions.

**Programming Language:** NetLogo (v. 5.2.1) running on Java virtual machine

**Technical details, if any:** The implementation of INSTAR into the virtual lab required some extra effort since a NetLogo Docker image had to be created.

**IPR:** Creative Commons Attribution (CC BY)

**Other:** -

**Partner:** Universidad de Granada (UGR)

## 3.2 WiMMed

**Storyline (related or applied to):** Temporal evolution of ecosystem services in Sierra Nevada (M9)

**Protected Area:** Sierra Nevada (Spain)

**Service brief description:** The service is used to calculate two ecosystem services (ES) related to hydrology (aquifer recharge and surface runoff) with the hydrological model WiMMed in Sierra Nevada (Spain) for a specific period. Surface runoff is an ES of water regulation, as it represents the excess of water that will directly flow into the rivers, making it susceptible to generate floods. Accumulated aquifer recharge is an ES of water provisioning. It is highly related with the available water for drinking and cropping in low-elevation places during the summer periods. WiMMed is a hydrological model, fully distributed and physically based, that simulates the whole water cycle. It starts with the interpolation of the meteorological variables in space (meters) and time (hourly). Then it simulates interception, snow accumulation/snowmelt, infiltration, surface runoff, soil water movement, evapotranspiration, aquifer recharge/discharge, river flow, sediment production/transport. The included example simulates the whole Sierra Nevada at 90x90 m for 2007-2008.

**Relevant reference/ material/ publications:**

Webpages:

www.uco.es/dfh

http://www.uco.es/dfh/snowmed/

Publications:

Polo, M. J., Herrero, J., Pimentel, R., and Pérez-Palazón, M. J. (in review, 2018). The Guadalfeo Monitoring Network (Sierra Nevada, Spain): 14 years of measurements to understand the complexity of snow dynamics in semiarid regions. Earth System Science Data Discussion.

Pérez-Palazón, M.J.; Pimentel, R.; Polo, M.J. (2018). Climate Trends Impact on the Snowfall Regime in Mediterranean Mountain Areas: Future Scenario Assessment in Sierra Nevada (Spain). Water, 10, 720.

Pimentel, R.; Herrero, J.; Polo, M.J. (2017). Quantifying Snow Cover Distribution in Semiarid Regions Combining Satellite and Terrestrial Imagery. Remote Sensing, 9, 995.

Pimentel, R., Herrero, J., & Polo, M. J. (2017). Subgrid parameterization of snow distribution at a Mediterranean site using terrestrial photography. Hydrology and Earth System Sciences, 21(2), 805-820.

Herrero, J., Polo, M. J., & Eugster, W. (2016). Evaposublimation from the snow in the Mediterranean mountains of Sierra Nevada (Spain). Cryosphere, 10(6).

Pérez-Palazón, M. J., Pimentel, R., Herrero, J., Aguilar, C., Perales, J. M., & Polo, M. J. (2015). Extreme values of snow-related variables in Mediterranean regions: Trends and long-term forecasting in Sierra Nevada (Spain). Proceedings of the International Association of Hydrological Sciences, 369, 157-162.

Pimentel, R., Herrero, J., Zeng, Y., Su, Z., & Polo, M. J. (2015). Study of snow dynamics at subgrid scale in semiarid environments combining terrestrial photography and data assimilation techniques. Journal of hydrometeorology, 16(2), 563-578.

Gómez-Giráldez, P. J., Aguilar, C., & Polo, M. J. (2014). Natural vegetation covers as indicators of the soil water content in a semiarid mountainous watershed. Ecological indicators, 46, 524-535.

Millares, A., Polo, M. J., Moñino, A., Herrero, J., & Losada, M. A. (2014). Bedload dynamics and associated snowmelt influence in mountainous and semiarid alluvial rivers. Geomorphology, 206, 330-342.

Gómez-Giráldez, P. J., Aguilar, C., & Polo, M. J. (2012, October). NDVI sensitivity to the hydrological regime in semiarid mountainous environments. In Remote Sensing for Agriculture, Ecosystems, and Hydrology XIV (Vol. 8531, p. 85311A). International Society for Optics and Photonics.

Herrero, J., & Polo, M. J. (2012). Parameterization of atmospheric longwave emissivity in a mountainous site for all sky conditions. Hydrology and earth system sciences, 16(9), 3139-3147.

Millares, A., Gulliver, Z., & Polo, M. J. (2012). Scale effects on the estimation of erosion thresholds through a distributed and physically-based hydrological model. Geomorphology, 153, 115-126.

Aguilar, C., & Polo, M. J. (2011). Generating reference evapotranspiration surfaces from the Hargreaves equation at watershed scale. Hydrology and Earth System Sciences, 15(8), 2495-2508.

Herrero, J., Aguilar, C., Millares, A., Egüén, M., Carpintero, M., Polo, M.J., Losada, M. (2010): WiMMed. User Manual v1.1. Grupo de Dinámica Fluvial e Hidrología. Universidad de Córdoba. Grupo de Dinámica de Flujos Ambientales. Universidad de Granada. (download).

Aguilar, C., Herrero, J., & Polo, M. J. (2010). Topographic effects on solar radiation distribution in mountainous watersheds and their influence on reference evapotranspiration estimates at watershed scale. Hydrology and Earth System Sciences, 14(12), 2479-2494.

Herrero, J., Polo, M. J., Moñino, A., & Losada, M. A. (2009). An energy balance snowmelt model in a Mediterranean site. Journal of hydrology, 371(1-4), 98-107

Millares, A., Polo, M. J., & Losada, M. A. (2009). The hydrological response of baseflow in fractured mountain areas. Hydrology & Earth System Sciences Discussions, 6(2).

**Input Data and Format:** Meteorological data are ascii format (see WiMMed user manual for details). Raster maps are ESRI ASCII Grid format and use ED50 UTM zone 30-North projection (EPSG: 23030) for this example.

***- EO data:***

- Topography: DEM, from which the rest of topographical properties are automatically calculated.
- Vegetation canopy fraction calculated using NDVI and LAI derived from remote sensing information

***- Other:***

- Meteorological data, point measurements of: 1) daily precipitation, 2) hourly precipitation, 3) daily minimum, maximum and mean temperature, 4) daily wind speed, 5) daily mean solar radiation and 6) daily mean relative humidity.
- Soil properties maps: physical and hydrological properties as saturated hydraulic conductivity, depth, soil moisture saturation, etc., for two different layers
- Vegetation canopy: maximum storage capacity and transpiration potential

**ECOPOTENTIAL products used:**

- Land Cover / Land use, Bare ground circa 2010
- LAI
- Surface albedo

**Output Data and Format:** All the following raster are written in format ESRI ASCII Grid at the end of the simulation:

- accumulated precipitation as rainfall+snowfall (file *_Pre.asc in mm),
- accumulated snowfall (file *_P_n.asc in mm),
- mean temperature (file *_T_m.asc in ºC),
- accumulated potential evapotranspiration (file *_ET0.asc in mm),
- accumulated solar radiation (file *_Rad.asc in MJ),
- accumulated vegetation interception (file *_Int.asc in mm),
- accumulated soil surface infiltration (file *_Inf.asc in mm),
- accumulated evaporation/sublimation from the snowcover (file *_EvN.asc in mm)
- accumulated evapotranspiration from the soil (file *_EvS.asc in mm)
- accumulated surface runoff generated in each cell (file *_Exp.asc in mm)
- accumulated aquifer recharge (file *_Per.asc in mm)

**Source code location:** Not available

**Input data location:** https://github.com/fherlan/WiMMed_ES_SierraNevada

**Transferability:** WiMMed can be transferred to any other location provided that a Digital Elevation Model is available (recommended spatial resolution between 10-50m), and the input data (see above) include at least daily weather variables.

**Validation:** WiMMed has been validated in different watersheds in Spain for different time spans ranging from 5 to 60 years of historical data sets. In this example of Sierra Nevada, it has been validated using remote sensing information (snow cover) and point measurements (river discharge at 6 gauge stations).

**Technical details, if any:** The example is included in a Docker image running on fedora 22.

**IPR:** WiMMed is a model developed from the following previous projects (see list below) and it is also freely distributed from www.uco.es/dfh

- CGL2014-58508-R. “Global Monitoring System of snow in Mediterranean regions: trend analysis and impact on water resources management”. Economy and Competitivity National Ministry. Call 2014 R+D+i Governmental Project Challenges for the society. 2015-2017
- CGL2011-25632 “Snow dynamics in Mediterranean regions and its modeling at several scales”. Science and Innovation National Ministry. Call 2011 R+D+i Governmental Project. 2012-2014
- NET862490/1 “Service of implementation of the Guadalfeo model and transfer tools”. University of Granada. 2009-2011
- “Pilot study for the integrated Management of the Guadalfeo River Watershed”. University of Granada and Córdoba. Funded by Ministry of Public Works and Transport of the Andalusian Regional Government. 2002-2009.

**Other:** -

**Partner:** Universidad de Córdoba (UCO)

## 3.3 COINS

**Storyline (related or applied to):** Interaction between agro-ecosystems and natural grasslands: stone graining and loss of natural ecosystems (A3)
**Protected Area:** Murgia Alta
**Service brief description:** COINS implements a modelling approach for the optimal spatiotemporal control of invasive species in natural protected areas of high conservation value. The model is based on diffusion equations, is spatially explicit, and includes a functional response (Holling type II), which models the control rate as a function of the state variable, i.e. the invasive species density. The control variable is represented by the effort needed to eradicate the invasive species. Furthermore, a budget constraint is imposed to the amount of effort made available. The growth of the species is modulated by a habitat suitability function internally computed by using the land cover map of the study area and the map of the initial density of the invasive species. The routine solves a constrained optimal control problem, by searching for the optimal allocation of effort, which minimizes the density of the invasive species in both time and space. In the current version integrated into the VL, the model is applied to the *Ailanthus altissima* plant species populating the ECOPOTENTIAL study site of Murgia Alta, where there is an on-going eradication program ran within an EU LIFE project. The initial density of the invasive species and the land cover map for the demo have been produced by CNR-IIA within ECOPOTENTIAL. The in-field data has been provided by the EU LIFE Alta Murgia Project (LIFE12 BIO/IT/000213).
**Relevant reference/ material/ publications:** Baker, C.M., Diele, F., Marangi, C., Martiradonna, A., Ragni, S. (2018). Optimal control governed by a diffusion PDE with Holling type II reaction term and budget constraint, Natural Resource Modelling.
**Input Data and Format:**
(i) Text file containing all the parameters of the model (species parameters e.g. growth and diffusion, budget constraint etc) (csv); (ii) Map of initial density of the species (tif); (iii) Boundary of the area (shp); (iv) Land cover map (shp).
- ***EO data:*** Land cover map.
**ECOPOTENTIAL products used:** (i) Initial species distribution extracted by VHR images; (ii) Land Cover Map
**Output Data and Format:** (i) Habitat suitability map (tif); (ii) Raster time series of the effort allocation strategy for the control of the species along the simulation period (rts); (iii) Raster time series of the population density under control along the simulation period (rts).
**Source code location:** https://github.com/CnrIacBaGit/COINSvlabrepo
**Input data location:** ECOPOTENTIAL EO Data Archive[1]
**Transferability:** The model implements a simplified dynamic, where the species behavior is determined by a set of parameters that can be changed in the input parameters file, to allow the application to other invasive species. Moreover, the service can be easily adapted to accept an input suitability map of the species, instead of generating a rough estimation based on the land cover map, as in the current version of the demo. There are no limitations in the transferability to different sites and/or different dates.
**Validation:** Still ongoing due to the lack of in-field data. Initial steps towards a full QA/QC are taken as the model is just developed. As such, different kind of uncertainty ranging from structural to numerical is inherent in the model. Each input layer has its own errors that propagate further within the model. Lack of in-situ data and VHR images are delaying the uncertainty assessment process. Efforts are placed to finalize a paper and make a statistical test to check if the rough estimate of the habitat suitability is sound. Furthermore, activities include visual comparison of the diffusion of the species as predicted by the model with image series taken from Google Earth.
**Programming Language:** R version 3.5.0

[1] The base URL for the ECOPOTENTIAL EO Data Archive is *frontend.recas.ba.infn.it* and the credentials are attributed by CNR PoC. The specific folders, where the reference datasets are stored, are accompanied by the respective metadata, while paths are subject to changes to be concluded with the completion of the ECOPOTENTIAL project.

**Technical details, if any:** None.
**IPR:** The routine has been implemented and developed by Angela Martiradonna, Fasma Diele and Carmela Marangi, who are the owners of the IPR. It can be used under the conditions of CC-BY-NC 2.0.
**Other:** -
**Partner:** Consiglio Nazionale delle Ricerche (CNR)

## 3.4 MountainMetapop

**Storyline (related or applied to):** Mountain biodiversity as a sentinel of environmental change (M4)
**Protected Area:** Gran Paradiso National Park
**Service brief description:** MountainMetapop studies the impact of landscape topography on species distribution. In detail, it simulates the average presence of a species with certain traits in a landscape, based on spatial patch occupancy model (SPOM). The model consists of local colonization and extinction events that randomly occur in space and time. The probability of occurrence of these events on a particular grid cell depends on the global species occupancy and on the fitness of the species to the local landscape features. Demo case for the Gran Paradiso National Park is implemented.
**Relevant reference/ material/ publications:**
i) Hanski, I. (1998). Metapopulation dynamics. Nature, 396(6706), 41. and ii) Bertuzzo, E., Carrara, F., Mari, L., Altermatt, F., Rodriguez-Iturbe, I., & Rinaldo, A. (2016). Geomorphic controls on elevational gradients of species richness. Proceedings of the National Academy of Sciences, 113(7), 1737-1742.
**Input Data and Format:**
- ***EO data:*** Digital elevation model (DEM)
- ***Other:*** Specific parameter values of a focus species (i.e. optimal elevation, dispersal rate, niche width, colonization- and extinction rate).

**ECOPOTENTIAL products used:** Digital Elevation Model (DEM) of the GPNP Region.
**Output Data and Format:** Average Presence of the species over multiple runs as a .tif file.
**Source code location:** https://github.com/GieziJo/mountain_metapopulation
**Input data location:** https://github.com/GieziJo/mountain_metapopulation/tree/master/exampleData
Example input data:
- OCN.tif: Optimal Channel Network (OCN, Realistic Landscape).
- parameters.csv: File containing the names and values of the parameters.

**Transferability:** The model consists of a case study on how elevation influences metapopulation dynamics in time and space. It is therefore only useful as a null-model against which to compare other more complex models in order to understand the topographic part of these models. The model is therefore applicable with any DEM, but only relevant for scientists interested in this particular problematic.
**Validation:** The model is running virtual species in a virtual/realistic and/or real landscape. This version of the model is the one used in a paper, where species data are not taken into consideration, but the parameter space is explored in order to understand the influence of topography.
**Programming Language:** Python 3
**Technical details, if any:** Requires Numpy, Pandas, PIL, Rasterio, Numba.
**IPR:** MIT license
**Other:** -
**Partner:** Ecole Polytechnique Federale de Lausanne (EPFL)

### 3.5 IRIS-SDM

**Storyline (related or applied to):** Vegetation Dynamics as a Proxy of Socio-ecological Transitions and Future Societal Benefits in Mountain PAs (M7)

**Protected Area:** Peneda-Gerês National Park

**Service brief description:** IRIS-SDM stands for "*Infrastructure for Running, Inspecting and Summarizing Species Distribution Models*". This modelling service aims to predict the spatial distribution of suitable habitat conditions for narrowly distributed species (tested here with *Iris boissieri*) based on satellite-derived Ecosystem Functional Attributes. It implements a 'generic' version of the R-*biomod2* correlative ensemble Species Distribution Modelling (SDM) framework (Thuiller et al. 2009, Thuiller et al. 2014). The service currently runs a demo based on the approach described in Arenas-Castro et al. (2018) for modelling the distribution of *Iris boissieri* ('Gerês lily') for the northwest corner of the Iberian Peninsula (which includes the species' full range). It is based on pre-existing in-field records for the species presence as well as on a set of predictors from satellite-derived Ecosystem Functioning Attributes (EFA), namely the annual dynamics (average for the period 2001-2016) of three components related to carbon gains (EVI), sensible heat (LST) and radiative balance (albedo). The service aims at generality so that any species can be modeled against EFA predictors and their trends, using the IRIS-SDM service based on its R code structures and the *biomod2 package* designed for performing a multi-algorithm ensemble forecasting approach.

**Relevant reference/ material/ publications:**

**i)** Arenas-Castro, S., Gonçalves, J., Alves, P., Alcaraz-Segura, D., & Honrado, J. P. (2018). Assessing the multi-scale predictive ability of ecosystem functional attributes for species distribution modelling. PloS one, 13(6), e0199292., **ii)** Carvalho-Santos, C., Monteiro, A., Arenas-Castro, S., Greifeneder, F., Marcos, B., Portela, A., & Honrado, J. (2018). Ecosystem Services in a Protected Mountain Range of Portugal: Satellite-Based Products for State and Trend Analysis. Remote Sensing, 10(10), 1573., **iii)** Thuiller, W., Lafourcade, B., Engler, R., & Araújo, M. B. (2009). BIOMOD–a platform for ensemble forecasting of species distributions. Ecography, 32(3), 369-373., **iv)** Thuiller, W., Georges, D., Engler, R., (2014). biomod2: Ensemble platform for species distribution modelling, R package version 3.1-48, URL: http://CRAN.R-project.org/package=biomod2.

**Input Data and Format:**

- ***EO data***: MODIS derived Ecosystem Functional Attributes (EFA) calculated from time series of spectral vegetation indices (MOD13Q1, MOD09A1), land surface temperature (MOD11A1) and albedo (MCD43A1, MCD43B3).
- ***Other:*** Species occurrence data collected from pre-existing datasets and/or from dedicated in-field surveys; the algorithm runs with confirmed presence records complemented with the generation of pseudo-absences. However, confirmed absence records may also be used for model calibration. Climatic/bioclimatic data extracted from WorldClim and land cover data from Corine Land Cover (CLC) were also tested/used for a comparative purpose in Arenas-Castro *et al.* (2018); however, these are optional inputs as the model can be exclusively fitted based on EO variables.

**ECOPOTENTIAL products used:** Currently, the service uses several ECOPOTENTIAL products related to satellite-derived Ecosystem Functioning Attributes, namely the annual dynamics (average for the period 2001-2016) of three components linked to carbon gains (EVI), sensible heat (LST) and radiative balance (albedo) computed in the Google Earth Engine platform by project partners.

**Output Data and Format:** Outputs generated by the service are model-based, spatially-explicit predictions for the current distribution of the target species in raster format and GeoTIFF format (Arenas-Castro *et al.* 2018). Outputs also include tables (in .csv format) containing a summary of model performances for partial and ensemble models as well as an importance ranking for each predictor variable. The approach has recently been extended to support yearly projections of habitat suitability (Carvalho-Santos *et al.* 2018).

**Source code location:** https://github.com/joaofgoncalves/ECOP-VL-SDM

**Input data location:** https://github.com/joaofgoncalves/ECOP-VL-SDM/input

**Transferability:** The service currently provides spatial predictions of habitat suitability of an endemic and narrow-ranged species, exclusive to NW Iberian Peninsula, for which spatial transferability is not required to other

ECOPOTENTIAL sites. The demo service also provides spatial predictions for the entire species range (NW Iberia). Although issues related to the model temporal transferability for the demo species were not specifically addressed, it is reasonable to use the same model to make predictions to other (past or future) dates using the same set of predictors computed with the same methodology. However, it is reasonable to assume that uncertainty will increase as time goes further from the calibration interval (2001-2016). Despite the specificities of modelling the demo species (*I. boissieri*), with its particular distribution range and ecological requirements, the service should be capable of providing relevant outputs for other target species, different settings and environmental conditions.
**Validation:** Model performance is evaluated by holdout cross-validation and through the calculation of several threshold-dependent metrics (e.g., Cohen Kappa, True skill-statistic) and threshold-independent metrics (Area Under the Receiver Operating Curve) calculated from the confusion matrix for the test dataset. Formal validation with independent data depends on in-field collection of occurrence data in relevant future dates, for which spatial projections of habitat suitability, can be produced.
**Programming language:** R (including the *raster* and *biomod2* packages along with their dependencies) and Linux bash
**Technical details, if any**: None.
**IPR:** CC-BY-NC 2.0
**Other:** -
**Partner:** ICETA / InBIO - Instituto de Ciências, Tecnologias e Agroambiente, University of Porto, Portugal

## 3.6 EO-SDM

**Storyline (related or applied to):** Mountain biodiversity as a sentinel of environmental change (M4)
**Protected Area:** Gran Paradiso National Park
**Service brief description:** EO-SDM stands for 'Ensemble modelling of species distributions using Earth observation data'. The modelling framework is not based on a new algorithm, but makes used of established species distributions modelling algorithms (Maxent, Random Forest and Generalized Linear Models, as implemented in the *biomod2 package* version 3.1) and tests their applicability in combination with remote sensing data (Landsat).
**Relevant reference/ material/ publications:** A manuscript entitled "Modelling distributions of rove beetles in mountainous areas using remote sensing data" has been submitted to the journal *Remote Sensing*. We received a review, which requires major revisions and are still working on a revised version. This revision might lead to slight changes in the model.
**Input Data and Format:** The model uses point data (coordinates of species occurrences) and raster data (environmental layers) derived from EO data.
- ***EO data:*** Landsat 5-TM (2006), Landsat-8 OLI (2013), ASTER GDEM
- ***Other:*** Point data (coordinates of species occurrences, collected in the context of the long-term monitoring project "Monitoring of Animal Biodiversity in Mountain Ecosystems" which is an initiative of the GPNP.
**ECOPOTENTIAL products used:** NDVI & Tasseled Cap Transformation derived from Landsat (generated by EURAC); NDVI-based Land Surface Temperature (LST) (generated by Parastatidis et al. within ECOPOTENTIAL, see doi:10.3390/rs9121208)
**Output Data and Format:** Maps of species-specific habitat suitability and model uncertainty (raster data, GeoTIFF).
**Source code location:** https://github.com/ec-ecopotential/EO-SDM.git
**Input data location:** ECOPOTENTIAL EO Data Archive
**Transferability:** The model was run for two different time periods (2006 and 2007). It can be in principle applied for other taxa in GPNP, given that they have similar habitat requirements and that data about species occurrences are available. The source code is flexible and can also be used to establish species distribution models in other study areas.

**Validation:** Area under Curve (AUC) of the Receiver Operating Characteristic (ROC) was used to assess how well the model discriminates between species presence and (pseudo)absence data. *Error in model parameters:* Standard settings for the statistical algorithms used in the modelling framework were applied. In addition, to avoid over-fitting, a stepwise backward selection was applied to select final models based on the Bayesian Information Criterion (BIC). *Error in in-situ data:* Species occurrence data were carefully examined by specialists working in GPNP. *Error in model process description (structural uncertainty):* This is a statistical modelling framework, so no process description is included. *Error in EO products (at product level e.g. confusion matrix):* Please see WP4 and product metadata for error quantification. *Error in EO products (at pixel level):* as delivered by WP4. *Visualization of uncertainty:* The difference between the 97.5-percentile and the 2.5-percentile of cell values derived from the prediction maps for each species (based on 50 model repetitions) was calculated.
**Programming language:** R
**Technical details, if any:** Model algorithms were used as implemented in the biomod2 package version 3.1 using R version 3.0.2
**IPR:** CC-BY-NC 2.0
**Other: -**
**Partner:** Helmholtz Centre for Environmental Research (UFZ)

# 4. Workflows as online data services

## 4.1 HydroMap

**Storyline (related or applied to):** Conserving dynamic wetlands under combined global, regional and local stressors (O3)
**Protected Area:** Doñana, Camargue
**Service brief description:** HydroMap generates a hydroperiod map from a series of water masks, falling within the time period between the starting and the ending date of hydroperiod, by applying the following interpolation approach. For two dates separated by n days, the occurrence of water is compared. If a pixel is inundated on both dates, then it is assumed inundated for n-days. If a pixel is not inundated on both dates, then it is assumed inundated for n/2 days. The total number of days of inundation per pixel in the hydroperiod map is determined by accumulating the water masks throughout the desired time period.
**Relevant reference/ material/ publications:** Díaz-Delgado, R., Aragonés, D., Afán, I., & Bustamante, J. (2016). Long-term monitoring of the flooding regime and hydroperiod of Doñana marshes with Landsat time series (1974–2014). Remote Sensing, 8(9), 775.
**Input Data and Format:** i) A 'zip' file containing the water masks (GeoTIFF files) of the area to be processed. At minimum 2 rasters must be included inside the 'zip'. Input water masks must comply with some specifications, otherwise execution will fail: - Same dimensions for all the water masks. - Same pixel size (e.g. 10m x 10m). - Be valid GeoTIFF files (only .tif and .tiff files are supported). - Each file should be named by the actual date that it depicts, i.e. YYYY_MM_DD (e.g. 2018_03_29.tif). ii) Upload a text file named 'settings.txt' containing the core configuration settings: -Set hydroperiod start date (e.g. 2015_12_20) and hydroperiod end date (e.g. 2016_02_25). -Define the values for inundated and non-inundated pixels. Example values: for flooded "1", for dry "0". Other values are accepted as well, provided that they are integer numbers in the range of 0 to 254. All rasters in 'zip' must have common distinct values for flooded and dry pixels that the user defines at this point. Finally, 'settings.txt' file will always consist of 4 lines with the exact order that was previously described. For example: 1st line = 2015_12_20, 2nd line = 2016_02_25, 3rd line = 1, 4th line = 0.
**ECOPOTENTIAL products used:** Water masks generated by CERTH's 'WaterMasks' (see Section 4.2).
**Output Data:** A 'zip' file that contains: - the HydroMap - GeoTIFF file, - the 'input_report.txt' with critical errors about the input and general information on configuration used, - the 'rasters_info.xlsx' with information for the water masks provided.
**Source code location:** https://github.com/ec-ecopotential/OnlineServices-CERTH-Hydroperiod
**Input data location:** ECOPOTENTIAL EO Data Archive
**Transferability:** Yes, provided that water masks covering a year period are available for a specific area.
**Validation:** Not performed due to the lack of ground truth data; however, accuracy is based on the one of the validated water masks. The quality of the Hydroperiod map depends on the frequency of the available inundation maps falling in each hydroperiod cycle. The quality metrics of hydroperiod are: (i) the mean of inundation maps frequency, (ii) the standard deviation of inundation maps frequency, (iii) Gini index that gives an assessment on the evenness of the frequency of available inundation maps along the flooding cycle (values from 0 to 1). The aformentioned quality metrics were estimated for: (a) Donana hydroperiod map for 1-Sept-2015 to 31-Aug-2016, (b) Donana hydroperiod map for 1-Sept-2016 to 31-Aug-2017, (c) Camargue hydroperiod map for 1-Sept-2016 to 31-Aug-2017. More information may be found in D4.6.
**Programming language:** Python
**Technical details:** -
**IPR:** The routine has been implemented and developed by CERTH working team members, who are the owners of the IPR. It can be used under the conditions of CC-BY-NC 2.0.
**Other:** -
**Partner:** Centre for Research and Techology Hellas (CERTH)

## 4.2 WaterMasks

**Storyline (related or applied to):** Conserving dynamic wetlands under combined global, regional and local stressors (O3)
**Protected Area:** Doñana, Camargue
**Service brief description:** WaterMasks integrates an unsupervised local thresholding approach to estimate water extent of an area relying on a single Sentinel-2 radiometrically corrected image. This module detects automatically thresholds on the Short-Wave Infrared (SWIR) band and on a Modified-Normalized Difference Vegetation Index (MNDVI), derived from radiometrically-corrected Sentinel-2 data. Then, it combines them in a meaningful way based on a knowledge base coming out of an iterative trial and error process. Classes of interest concern water and non-water areas. The inundation map generated by the WaterMask module can be used as input in the HydroMap one.
**Relevant reference/ material/ publications:** Kordelas, G., Manakos, I., Aragonés, D., Díaz-Delgado, R., & Bustamante, J. (2018). Fast and Automatic Data-Driven Thresholding for Inundation Mapping with Sentinel-2 Data. Remote Sensing, 10(6), 910.
**Input Data and Format:** i) A compressed 'zip' file, that contains the folders (indicating dates) with the rasters (GeoTIFF files of the required bands) of the area to be processed. Six Bands are required: Band 2 - Blue, Band 3 - Green, Band 4 - Red, Band 5 - Red Edge Vegetation, Band 7 - Infrared Edge Vegetation, Band 11 - SWIR. Include at minimum 1 folder (for 1 date) within the 'zip'. In each folder, band rasters shall comply with following specifications, otherwise execution will fail: - All required rasters that represent bands must exist once in a folder (date). Required bands: ["B02", "B03", "B04", "B05", "B07", "B11"]. Each filename must contain only one Band-ID and appear only once in a folder(date). Example filenames, for the B02 band, that are acceptable: "B02.tiff" or "some_area_B02_clipped.tiff". But cannot be both of them in the same folder (date) - each band must be stored uniquely inside a single folder! {Rejected: B2.tiff (it should be B02 not B2!), B12.tiff (B12 is not required!)} - Same area extent (bounding box) among rasters of the same folder (max deviation: 1/10000). - Be valid GeoTIFF files (only .tif and .tiff files are supported). - Data type of rasters that depict Bands: Unsigned integer 16 or/and Unsigned Integer 32 . - Data type of rasters that depict the active area mask: Unsigned Integer 8. | ii) Optionally one raster image with filename that contains "active_area_mask" may be included in the folder (date) to mask out non desired areas. The required Data Type is Unsigned Integer 8, whereas pixel value "0" shall be assigned for the areas to be masked out. Each raster "active_area_mask.tiff" will apply only for the folders(dates) wherein it is found.
**ECOPOTENTIAL products used:** Sentinel-2 preprocessed images (planned to use despeckled Sentinel-1 images in the future as well, preprocessed by CERTH's 'SpeckleRemoval – see Section 4.3).
**Output Data:** A 'zip' file that contains: - the WaterMask(s) - GeoTIFF file(s); - the 'input_report.txt' populated with possible critical errors about the input and general information on the configuration used; - a subfolder named 'rasters_info' with '.xlsx' files with information for each folder(date)'s rasters attributes.
**Source code location:** https://github.com/ec-ecopotential/OnlineServices-CERTH-WaterMasks
**Input data location:** ECOPOTENTIAL EO Data Archive
**Transferability:** Yes, the transferability of WaterMasks module is currently examined for Camargue.
**Validation:** Accuracy assessment was performed for Doñana PA using as ground truth 7 Landsat based inundation maps coinciding with Sentinel-2 inundation maps. The accuracy results are summarized in D4.6. Sentinel-2 data are selected based on their minimum cloud coverage. Images are examined for possible geo-registration errors. Images are radiometrically corrected. The algorithm has been reiterated to check the stability of the outcome.
**Programming language:** Python
**Technical details, if any: -**
**IPR:** The routine has been implemented and developed by CERTH working team members, who are the owners of the IPR. It can be used under the conditions of CC-BY-NC 2.0.
**Other: -**
**Partner:** Centre for Research and Technology Hellas (CERTH)

## 4.3 SpeckleRemoval (as a pre-operational data service supporting 4.3-WaterMasks)

**Storyline (related or applied to):** Conserving dynamic wetlands under combined global, regional and local stressors (O3)
**Protected Area:** Doñana
**Service brief description:** Suppress speckle in the SAR Sentinel-1 product (developed for GRD data) by using guided image filtering. The guided filter computes the filtered SAR output by considering the content of a guidance image (Sentinel-2 RGB image). Guided filter has a good edge-preserving property, while it suppresses speckle noise.
**Relevant reference/ material/ publications:** Verdoliva, L., Amitrano, D., Gaetano, R., Ruello, G., & Poggi, G. (2014, July). SAR despeckling guided by an optical image. In Geoscience and Remote Sensing Symposium (IGARSS), 2014 IEEE International (pp. 3698-3701). IEEE.
**Input Data and Format:** A 'zip' file containing: ___i) A geotiff image file that represents the guided image. ___ii) A geotiff image file that represents the guidance image ___iii) a text file named 'despeckling.settings.txt' that includes the definitions of the images' filenames to be used and the core configuration settings. Latter refer to (a) the radius '-r' of the filtering/support window w_k (see the description of the guided filter methodology for the definition of w_k), and (b) the smoothness parameter '-e', which is the criterion of separating a "flat patch" from a "high variance patch", e.g. the patches with variance smaller than value of '-e' are smoothed whereas those with variance larger than this value are preserved. More information on the despeckle parameters can be found in the paragraph "4.4.4.2 Spatial speckle filtering" of Deliverable 4.1. The required format for the 'despeckling.settings.txt' is in the form of [identifier] [separated by one space] [filename or value], where: Identifier '-i' shall be followed by the full name (including file extension) of the geotiff input SAR image to be despeckled; identifier '-g' shall be followed by the full name (including file extension) of the geotiff Sentinel-2 RGB image to be used as guidance image; identifier '-r' shall be followed by a number that represents the radius of the support window used in the guided filtering process (Optional. If not provided, default value is 3, radius should be an even positive integer number); identifier '-e' shall be followed by a number that represents the smoothness parameter used in the guided filtering process (Optional. If not provided, default value is 0.001, smoothness parameter should be a positive decimal value below "1"); Identifier '-m' shall be followed by the full name (including file extension) of the file for the cloud mask that is a binary image denoting with “1” areas in the image covered by clouds. For image areas covered by clouds, despeckling is performed via median filtering, instead of the guided filtering process (Optional); Identifier '-o' shall be followed by the full name (including file extension) of the output geotiff file. __Example 1, defining all six parameters, the content of 'despeckling_settings.txt' will look like: '-i SAR_image.tif -g RGB_image.tif -m Cloud_mask.tif -o Despeckled_SAR_image.tif -r 5 -e 0.002' (without the quotes). Example 2, defining only the guided, guidance and output image, omitting the cloud mask raster, radius and smoothness parameter (the default values will be used), the content of 'despeckling_settings.txt' will look like: '-i SAR_image.tif -g RGB_image.tif -o Despeckled_SAR_image.tif' (without the quotes). | _Important note: The raster files inside the input 'zip' must comply with following specifications, otherwise execution will fail: - Be valid geotiff files (only .tif and .tiff files are supported). -Be at the same resolution and area extent (bounding box).
**ECOPOTENTIAL products used:** WP3 downloaded S-1 images.
**Output Data:** A 'zip' file that contains: - A raster file with the output despeckled SAR image.
**Source code location:** https://github.com/ec-ecopotential/ECOP-WP4-CERTH
**Input data location:** ECOPOTENTIAL EO Data Archive
**Transferability**: Yes, Sentinel-1 data and Sentinel-2 data should be geometrically and timely (as possible) aligned, while Sentinel-2 data should have been corrected for atmospheric effects and exhibit low cloud coverage.
**Validation:** The SpeckleRemoval module was compared qualitatively and visually against other filters. Relevant information may be found in D4.1. Sentinel-2 data are selected based on their minimum cloud coverage. Co-registration errors between Sentinel-2 and Sentinel-1 images have been assessed. Sentinel-2 images are radiometrically corrected. The algorithm has been reiterated to check the stability of the outcome.
**Programming language:** Python

**Technical details, if any: -**
**IPR:** The routine has been implemented and developed by CERTH working team members, who are the owners of the IPR. It can be used under the conditions of CC-BY-NC 2.0.
**Other: -**
**Partner:** Centre for Research and Technology Hellas (CERTH)

## 4.4 PhenologyMetrics

**Storyline (related or applied to):** Conserving dynamic wetlands under combined global, regional and local stressors (O3)
**Protected Area:** Doñana
**Service brief description:** PhenologyMetrics generates phenology related layers relying on NDVI time series covering a vegetation growth period. The phenology metrics, which are calculated using the phenex R package, include (a) the day of the growth period, at which the greenup takes place, (b) the day of the growth period with the highest NDVI value and (c) the day of the growth period, at which senescence takes place. PhenologyMetrics is able to estimate the aforementioned metrics for multiple vegetation cycles occurring within a set period.
**Relevant reference/ material/ publications:** Lange, M., Dechant, B., Rebmann, C., Vohland, M., Cuntz, M., & Doktor, D. (2017). Validating MODIS and Sentinel-2 NDVI products at a temperate deciduous forest site using two independent ground-based sensors. Sensors, 17(8), 1855.
**Input Data and Format:** A) A text file named 'phenology_start_end_date.txt' with a single line where start date and end date are defined, separated by a white space, at format 'Day-Month-Year', e.g. '06-05-2016 05-05-2017' (dates' range shouldn't necessarily cover a whole year). B) A 'zip' file containing: i) The normalized difference vegetation index (NDVI) GeoTiff files. They will be used to create an interpolation for all calendar days within the dates that previously the user specified in 'phenology_start_end_date.txt'. ii) A text file named 'phenology_files.txt' that defines the previous dates to be used, followed by their corresponding image file name, separated by a single white space character. Each line in the text file will be used for a single date declaration. The date should be in the format 'Day-Month-Year' separated by hyphens. The file name of the NDVI rasters has no naming limitation. E.g. in the case of a NDVI raster image of the 1st August of 2017 in a file named 'marshes_august_2017.tif' (can be a random name) the line inside the 'phenology_files.txt' file should be: '01-08-2017 marshes_august_2017.tif' (without the quotes). The lines do not need to be ordered chronologically. iii) (Optional) A GeoTiff image named specifically 'active_area_mask.tif' in order to exclude some areas from the calculations (this file has NOT to be declared in the 'phenology_files.txt'; just to exist inside the 'zip' file, if needed). | The rasters inside the input 'zip' must comply with some specifications, otherwise execution will fail: - Be valid GeoTIFF files (only .tif and .tiff files are supported). - They must be at the same resolution and extent. Should be of data type FLT4S (float32) or/and FLT8S (float64). File 'active_area_mask.tif' can be of any data type, where positive values denote the areas to be calculated
**ECOPOTENTIAL products used:** Sentinel-2 NDVI products
**Output Data:** A 'zip' file that contains: - The raster file 'PhenologyMetric.tif', consisting of multiple layers. For each one of the detected NDVI peaks, 3 consecutive layers are recorded sequentially in the 'PhenologyMetric.tif', i.e. for the first NDVI peak the first 3 layers, for the next NDVI peak the next 3 layers, and so on. Pixel values denote the distance in days from the given by user starting date, that represent: a) Day at which greenup takes place; b) Day at which senescence takes place; c) Day with highest NDVI value. Finally, there is one last layer that denotes per pixel (i.e. pixel value) the total number of the phenological cycles that have been detected within the set date range. - File 'phenology_report.txt', only in case that wrong input files have caused critical erors, stalling the execution. - The file 'phenology_rasters_info.xlsx' with information about the input rasters and their compliance to the aforementioned specifications.
**Source code location:** https://github.com/ec-ecopotential/OnlineServices-CERTH-PhenologyMetrics.
**Input data location:** ECOPOTENTIAL EO Data Archive
**Transferability:** Yes, provided that NDVI maps covering an annual period are available for a specific area.

**Validation:** Not performed due to the lack of ground truth data. Sentinel-2 data are selected based on their minimum cloud coverage. Images are examined for possible geo-registration errors. Images are radiometrically corrected. Thorough search has been conducted to search for possible missed/ gap filling images.
**Programming language:** R programing language
**Technical details, if any:** Phenex R package (https://CRAN.R-project.org/package=phenex) is used for the estimation of the phenology metrics.
**IPR:** The routine has been implemented and developed by CERTH working team members, who are the owners of the IPR. It can be used under the conditions of CC-BY-NC 2.0.
**Partner:** Centre for Research and Technology Hellas (CERTH)

## 4.5 PhenologyChanges

**Storyline (related or applied to):** Conserving dynamic wetlands under combined global, regional and local stressors (O3)
**Protected Area:** Doñana
**Service brief description:** PhenologyChanges registers the abrupt trend changes/ breaks in the vegetation phenology cycles throughout numerous annual NDVI series, based on the iterative decomposition of the time series into trend, seasonal and remainder components, which is performed using the BFAST R package. The module calculates per pixel the total number and occurrence dates of abrupt changes that have occurred, and the date of the maximum abrupt change.
**Relevant reference/ material/ publications:** Verbesselt, J., Zeileis A., Hyndman, R.: Breaks For Additive Season and Trend (BFAST), R Package Version 1.5.7. Available online: https://cran.r-project.org/web/packages/bfast (accessed on 15 June 2018).
**Input Data and Format:** A 'zip' file containing: i) The normalized difference vegetation index (NDVI) GeoTiff files. Several raster files should be provided covering a wide range of years. They will be used to create an interpolation for all calendar days within the years range, which is based on the earliest and latest chronological dates of the provided raster files. ii) A text file named 'bfast_files.txt' that defines the previous dates to be used, followed by their corresponding image file name, separated by a single white space character. Each line in the text file will be used for a single date declaration. The date should be in the format 'Day-Month-Year' separated by hyphens. The file name of the NDVI rasters have no naming convention. E.g. in the case of a NDVI raster image of the 1st August of 2017 in a file named 'marshes_august_2017.tif' (can be a random name) the line inside the 'bfast_files.txt' file should be: '01-08-2017 marshes_august_2017.tif' (without the quotes). The lines do not need to be ordered chronologically. iii) (Optional) A GeoTiff image named specifically 'active_area_mask.tif' in order to exclude some areas from the calculations (this file has NOT to be declared in the 'bfast_files.txt'; just to exist inside the 'zip' file if needed). | The rasters inside the input 'zip' must comply with some specifications, otherwise execution will fail: - Be valid GeoTIFF files (only .tif and .tiff files are supported). - They must be at the same resolution and extent. Should be of data type FLT4S (float32) or/and FLT8S (float64). File 'active_area_mask.tif' can be of any data type, where positive values denote the areas to be calculated by PhenologyChanges.
**ECOPOTENTIAL products used:** Sentinel-2 NDVI products
**Output Data:** A 'zip' file that contains: - The raster file 'All_break_times_startYear_to_endYear.tif', where its pixels have multiple values (layers) that denote the dates that abrupt changes occured. - The raster file 'Maximum_break_time_startYear_to_endYear.tif' containing for each area the single date of the most pronounced abrupt change. - The raster file 'Maximum_number_of breaks_startYear_to_endYear.tif' containing for each area the number of changes that occurred during the given years' range. - File 'bfast_report.txt', only in case that wrong input files have caused critical errors, stalling the execution. - The file 'bfast_rasters_info.xlsx' with information about the input rasters and their compliance to specifications.
**Source code location:** https://github.com/ec-ecopotential/OnlineServices-CERTH-PhenologyChanges
**Input data location:** ECOPOTENTIAL EO Data Archive
**Transferability:** Yes, provided that NDVI maps covering multiple years are available for a specific area.

**Validation:** Not performed due to the lack of ground truth data. Landsat data are selected based on their minimum cloud coverage. Images are examined for possible geo-registration errors. Images are radiometrically corrected. Thorough search has been conducted to search for possible missed/ gap filling images.
**Programming language:** R programing language
**Technical details, if any:** BFAST R package (https://cran.r-project.org/web/packages/bfast) is used for the estimation of the phenology changes.
**IPR:** The routine has been implemented and developed by CERTH working team members, who are the owners of the IPR. It can be used under the conditions of CC-BY-NC 2.0.
**Other**: -
**Partner:** Centre for Research and Technology Hellas (CERTH)

## 4.6 LandMetrics

**Storyline (related or applied to):** Invasive species impacting the functioning and services of island protected areas through losses of endemic species (O7)
**Protected Area:** Sierra Nevada (Spain), Samaria, Montado, Lake Prespa, La Palma, Curonian Lagoon
**Service brief description:** LandMetrics calculates a number of landscape measures used as indicators of fragmentation and/or connectivity of land cover or habitat classes in the selected study area. In particular, the following FRAGSTATS measures are calculated: - percentage of landscape (PLAND); - patch density (PD); - shape index distribution (SHAPE); - total class area (CA); - and Mean patch size (MPS); - effective mesh size (MESH); - area-weighted mean patch fractal dimension (AWMPFD). The input to the landscape indicators estimation approach is comprised of land cover (LC) or habitat maps and the output is a raster file for each calculated landscape measure and a file containing the values of the measures for each LC or habitat object.
**Relevant reference/ material/ publications:** Petrou, Z.I., Manakos, I., Kosmidou, V., Lucas, R., Adamo, P., Tarantino, C., Blonda, P. Indicator extraction software. FP7 project BIO_SOS, Deliverable 6.12, 2013.
**Input Data and Format:** A 'zip' file containing: i) a GeoTiff image file that represents a land cover or habitat class, ii) (Optional) a GeoTiff image file that represents the above image's segmentation class.
**ECOPOTENTIAL products used:** Land cover and habitat maps.
**Output Data:** A 'zip' file that contains: - A raster file for each calculated landscape measure is generated. The name of the measure is contained in each filename. - A file 'indValues.csv' containing the values of the indicators for each object is produced. The file contains also the object ID of the respective object and the class ID where this object belongs to. - The automatically generated segmentation class as a GeoTiff raster, in the case that was not provided by user as input.
**Source code location:** https://github.com/ec-ecopotential/OnlineServices-CERTH-LandMetrics
**Input data location:** ECOPOTENTIAL EO Data Archive
**Transferability:** Yes, provided that land cover or habitat class map(s) of an area is(are) available.
**Validation:** Not performed due to the lack of ground truth data. Module is originally developed in a previous version in BIO_SOS FP7 project, D6.12. Input data are reported with the delivered error/ accuracy assessments. More information may be found in D4.6.
**Programming language:** Python
**Technical details, if any:** -
**IPR:** The routine has been implemented and developed by CERTH working team members, who are the owners of the IPR. It can be used under the conditions of CC-BY-NC 2.0.
**Other**: -
**Partner:** Centre for Research and Technology Hellas (CERTH)

# 5. Models and Workflows being integrated as online data services (ongoing status)

## 5.1 Mohid-Land

**Storyline (related or applied to):** Mediterranean wood-pasture for people and nature (A4)
**Protected Area:** Alentejo Natura 2000 sites
**Service brief description:** The MOHID-Land model is used to simulate soil water dynamics and pasture growth in a *montado* area. The Remote sensing LAI data are used to update model estimates of water fluxes and aboveground biomass showing the potential of combining in situ data derived from remote sensing with a process-based model for improving pasture management in the *montado* ecosystem. Demo case for Alentejo region, southern Portugal, is implemented.
**Relevant reference/ material/ publications:** i) Source code of MOHID-land is at the MOHID code repository (https://github.com/Mohid-Water-Modelling-System/Mohid), ii) Trancoso, A. R., Braunschweig, F., Leitão, P. C., Obermann, M., & Neves, R. (2009). An advanced modelling tool for simulating complex river systems. Science of the total environment, 407(8), 3004-3016. iii) Simionesei, L., Ramos, T. B., Oliveira, A. R., Jongen, M., Darouich, H., Weber, K., ... & Neves, R. (2018). Modelling soil water dynamics and pasture growth in the montado ecosystem using MOHID land. Water, 10(4), 489.
**Input Data and Format:**
- ***EO data:*** Leaf area index (LAI)
- ***Other:*** Weather data (i.e. daily temperature, precipitation, solar radiation, relative humidity, and wind speed), soil hydraulic properties.
MOHID ASCII files is the type format of the input data.
**ECOPOTENTIAL products used:** Leaf Area Index derived from NDVI Sentinel-2 (as input data), NDVI from Sentinel-2 (for calibration/validation purposes).
**Output Data and Format:** Surface water content and biomass in timeseries or hdf5 format
**Source code location:** https://github.com/Mohid-Water-Modelling-System/Mohid
**Input data location: -**
**Transferability:** The model can be used for different periods, but for the same location, as long as meteorological data is available.
**Validation:** The model is validated for the case of Machoqueira de Grou, Alentejo, southern Portugal. *Error in model parameters:* Impact assessment of assimilated LAI on the final estimates of soil water balance and biomass using a Monte Carlo method. *Error in in-situ data:* Comparison of model simulations with field data. *Error in model process description (structural uncertainty):* Comparison of periodic LAI simulations given by the model with data from satellite imagery. *Error in EO products (at product level e.g. confusion matrix):* Please see WP4 and product metadata for error quantification.
**Programming Language:** FORTRAN
**Technical details, if any:** Our code can be compiled for now, only with Intel Compiler.
**IPR:** Open source
**Other:** -
**Partner:** Instituto Superior Tecnico (IST)

## 5.2 Delft 3D Flow & Gem

**Storyline (related or applied to):** Improving coastal lagoon benefits under multiple pressures (O1)
**Protected Area:** The Dutch Wadden Sea
**Service brief description:** The Delft3D GEM (described as a water quality module) will be uploaded into the VL for a smaller case study area. Due to the computational need for resources and size of the model, a smaller site example will be provided within the VL. This will provide users with the opportunity to explore the model and to see the processes and potential output; however, it will not be based on the entire North and Wadden Sea, which

is utilized in the scientific investigation. It is able to compute the nutrient fluxes and uptake by primary producers within the modeled space as well as providing key abiotic indicators such as salinity, temperature, water level. The GEM is driven by a complementary hydrodynamic model known as Delft3D flow. The outputs of this latter model will be provided via an ftp in order to drive the ecological model.

**Relevant reference/ material/ publications:**

**i)** Mészáros, L. and El Serafy, G. (2018). Setting up a water quality ensemble forecast for coastal ecosystems: a case study of the southern North Sea. Journal of Hydroinformatics, 20(4), pp.846-863., **ii)** Van de Vries, C.A.M. (2017). Master of Science Thesis: Approach to the use of uncertainty for management purposes- Quantification of the uncertainty in the turbidity for the ecosystem of the Wadden Sea. https://repository.tudelft.nl/islandora/object/uuid:f5e8d907-8123-4110-8713-04b5e4fff858/datastream/OBJ/download, **iii)** Blauw, A. N. (2015). Monitoring and prediction of phytoplankton dynamics in the North Sea. PhD thesis., **iv)** Janssen, A. B., Arhonditsis, G. B., Beusen, A., Bolding, K., Bruce, L., Bruggeman, J., ... & Gal, G. (2015). Exploring, exploiting and evolving diversity of aquatic ecosystem models: a community perspective. Aquatic ecology, 49(4), 513-548., **v)** Li, H., Arias, M., Blauw, A., Los, H., Mynett, A. and Peters, S. (2010). Enhancing generic ecological model for short-term prediction of Southern North Sea algal dynamics with remote sensing images. Ecological Modelling, 221(20), pp.2435-2446., **vi)** Blauw, A. N., Los, H. F., Bokhorst, M., & Erftemeijer, P. L. (2009). GEM: a generic ecological model for estuaries and coastal waters. Hydrobiologia, 618(1), 175. **vii)** Los, F. (2009). Eco-hydrodynamic modelling of primary production in coastal waters and lakes using BLOOM. Amsterdam: IOS Press., **viii)** Los, F., Villars, M. and Van der Tol, M. (2008). A 3-dimensional primary production model (BLOOM/GEM) and its applications to the (southern) North Sea (coupled physical–chemical–ecological model). Journal of Marine Systems, 74(1-2), pp.259-294.

**Input Data and Format:** (to be populated when finally uploaded on to the VL)

- ***EO data:*** (to be populated when finally uploaded on to the VL)
- ***Other:*** (to be populated when finally uploaded on to the VL)

**ECOPOTENTIAL products used:** (to be populated when finally uploaded on to the VL)

**Output Data and Format:** The model outputs are in combinations of .his, .map, and .mon files, which are unique to Delft-3D but can be visualized and inspected using any of the following: Python, MatLAB, and QuickPlot (a free tool provided with Delft-3D which makes visualization, inspection, and basic calculations of the output files). Additional information on the file formats and interpretability are found in all of the freely available manuals: https://content.oss.deltares.nl/delft3d/manuals/D-Water_Quality_User_Manual.pdf

**Source code location:** https://oss.deltares.nl/web/delft3d and https://www.deltares.nl/en/software/module/d-water-quality/ . The source code is also freely available via the Deltares website with a multitude of help and installation manuals; should users be interested in accessing and utilizing this model.

**Input data location:** ECOPOTENTIAL EO Data Archive

**Transferability:** The model itself as it exists in the “docker” software container can be utilized for any site application. This does, however, require the generation of a dynamic grid, input and forcing variables, calibration and validation of the model. Due to the open source nature of the software, this is possible for any number of sites and by any person seeking to install and initialize the software. Within the context of the VL, we have not allowed for the changing of all parameters and forcing data, as this was seen as untenable, given the amount of work it would require.

**Validation:** The model provided is an exemplar model offering an insight into the potential of the model and giving users the capacity to change some of the inputs, However, as the model has over 300 tunable parameters, it was not determined as feasible to offer all of these options to the user to adjust and a small sub-selection of elements have been provided. For the given truncated time period provided within the model, the hydrodynamics have been validated and the Water Quality elements are considered acceptable. *Error in model parameters:* A multitude of publications can be provided as context for the parameter uncertainty and probable parameter uncertainty. If a list of publications is requested these can be provided. *Error in model process description (structural uncertainty):* As shown in point i) above (Relevant reference/ material/ publications), publications can be provided that have explored the structural uncertainty of the Delft-3D model. However, within this exemplar case there have not been

studies but rather on larger and more complex situations. *Error in EO products (at product level e.g. confusion matrix):* Please see WP4 and product metadata for error quantification. *Error in EO products (at pixel level):* Please see point iv) above. *Visualization of uncertainty:* An MSc thesis has been conducted under the ECOPOTENTIAL project in relation to this with specific regard to the Delft-3D model. The thesis, excerpts, and images can be provided to be included in the deliverable once a template has been circulated.
**Programming language:** FORTRAN
**Technical details, if any:** A full technical report and specifications of the model can be found and downloaded from the Open Source Community forum provided by Deltares at the link: https://oss.deltares.nl/web/delft3d. This provides all model specifications, capacities, etc. and is available to all users and maintained by Deltares.
**IPR:** The models and their codes are freely available online and can be utilized by any user. The models are available for download from the open software portal of Deltares than can be found at the link: https://oss.deltares.nl/web/delft3d. The model used for the North Sea and Wadden Sea is a pre-existing IP element of Deltares, which was initialized before ECOPOTENTIAL and outside of the context of the project and is not available for download.
**Other: -**
**Partner:** Stichting Deltares (DELTARES)

## 5.3 CSIC's Workflow

**Storyline (related or applied to):** Conserving dynamic wetlands under combined global, regional and local stressors (O3)
**Protected Area:** Doñana
**Service brief description:** Our service consists in the generation of a series of thematic rasters from a Landsat scene: NDVI, water turbidity, and flood mask. The process first generates a normalized image based on pseudo-invariant areas and, based on it, the indicated products. In a last step, flood masks are used to compute the annual hydroperiod.
**Relevant reference/ material/ publications:**
Díaz-Delgado, R., Aragonés, D., Afán, I., & Bustamante, J. (2016). Long-term monitoring of the flooding regime and hydroperiod of Doñana marshes with Landsat time series (1974–2014). Remote Sensing, 8(9), 775.
**Input Data and Format:**
- ***EO data:*** Original Landsat scenes (L1T)
- ***Other:*** Shapefile or raster of Pseudo Invariant Areas (PIAs) for normalization
**ECOPOTENTIAL products used:** (to be populated when finally uploaded on to the VL).
**Output Data and Format:** NDVI, water turbidity, flood mask, hydroperiod, format: GeoTIFF rasters
**Source code location:** https://github.com/LAST-EBD/Protocolo
**Input data location:** Earth Explorer USGS
**Transferability:** The model is dependent on the PIAs that have to be defined, so currently it is only applicable to the scene Landsat 202/34 where the Doñana Natural Area is located. For new areas PIAs have to be defined and tested. A reference scene for normalization needs to be selected also.
**Validation:** Accuracy for (1) Flood masks (or water body delineation) is given as an estimate of thematic accuracy based on cross-validation of the different classification. Overall Agreement = 0.93 Cross-validation Kappa Index = 0.60. (2) Water turbidity estimate for inland waters is provided with R-squared with ground control points for a set of dates for the GAM model for the marsh and for the linear regression model for the river. GAM explained deviance = 40% (Shallow Marshland) and 70% (River Estuary). (3) Hydroperiod (seasonal water bodies). Cross-temporal validation using R-squared between estimated values and hydroperiod based on with water column readings of limnimetric scales in different locations for 3 flooding cycles: Average $R^2$ = 0.8.
Normalization procedure was doubly assessed by:

a) Levene-test to assess variance homogeneity was applied using band 5 (SWIR) normalized reflectance values using sand dunes, deep ocean and urban as pseudo-invariant areas all showing significant values ($L=2.97$, $p<0.05$; $L=5.85$, $p<0.05$; $L=1.55$, $p<0.05$).
b) The effect of normalization was also assessed using the flooding masks (8 scenes from 2004 to 2007 with ground-truth data). Average overall agreement = 93.5% and average Kappa 0.65.
We also have an estimate of geometric accuracy of the co-registration (RMS<0.78 pixel) and a mean error estimate for each cover with 120 control points per image: RMS=13.77 m.
**Programming language:** Python (GDAL and FMASK are also used during the process)
**Technical details, if any:** Info about the process is stored in a MongoDB Database
**IPR:** CC BY-NC-ND
**Other: -**
**Partner:** Agencia Estatal Consejo Superior de Investigaciones Cientifica (CSIC)

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