Highlander

High performance computing
to support smart land services

D5.1 ROADMAP OF ACTIONS AND MATERIAL TO BE USED IN INTERACTIONS WITH USERS (QUESTIONNAIRES, MAILING LIST, SOCIAL PLATFORM, ETC.)

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Creator	DIBAF
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Contributors	Federica Gabbianelli, Giovanni Chillemi, Giulia Villani, Fausto Tomei, Monia Santini, Nicola Loglisci, Lucia Mazzoni
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1 Introduction

Activity 5 is based on user-tailored Downstream Application and (pre-)Operational Services (DApOS). 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. Activity 5 is divided into two main tasks and here we are presenting the fourth report of the first one. It consists of an update about exchanges among project partners and interested users to maximize the usefulness, exploitability, and sustainability of implemented applications and generated services that will be developed in task 5.2.

Highlander is promoting a user participatory approach for different purposes, such as review and understanding of each user's needs and priorities, co-design and improve of the DApOS directly with users, support the implementation and test of user-tailored DApOS, in order to make it tailored for multiple users at the same time.

All the data, from surveys, working groups, meetings, etc., will be collected in a user platform. It will be a science-society interface, able to facilitate co-design and user-tailored production of applications and services. The dialogue with users will be essential to achieve the purpose and improve the services. Different categories of users will be identified and potentially involved by project partners, such as associations, farmers' organizations, researchers, practitioners, entrepreneurs, etc.

The pandemic situation has slowed down these activities, making it necessary to develop new ways of carrying out the actions envisaged in the presence.

Two blocks of services have been identified: i) continuous short-term forecasts to medium-term projections of climate variability and ii) Integration of climate data, satellite observations, and IoT data.

A roadmap of actions has been set up on how to use previous experiences and projects knowledge and tools and how to implement them for the users. Some partners are collaborating on the same DApOS in different Italian regions. This screening on how expected applications and services are currently going on was made through web-call with partners concerning updates related to different DApOS. The roadmap of actions will be implemented and updated every six months.

2 DApOS description and development

2.1 Soil erosion

The DApOS "Soil erosion" is being developed by CMCC.

Actions already taken

The literature has been reviewed about the approaches available to compute the different factors of the Revised Universal Soil Loss Equation (RUSLE), already applied in the C3S Demo Case Soil Erosion in Italy (https://climate.copernicus.eu/soil-erosion). However, in HIGHLANDER, these approaches can benefit from finer resolution climate data and also from tuning of other parameters, thanks to better consideration of territorial, land use, and land cover features.

In terms of data, the huge recent efforts to collect sub-hourly rainfall measurements from regional agencies (e.g. environmental, agro-meteorological, hydrological) will be exploited and the harmonization of these time series was completed. Sub-hourly measurements will be used to validate, at point station level, the approach to calculate rainfall erosivity applied to downscaled ERA5. This work is in progress right now.

Stakeholders' preferences have been largely investigated thanks to the C3S Demo Case Soil Erosion project, allowing to select, as period of interest, the recent 1991-2020 and the medium term 2021-2050 or, if runs will allow, 2036-2065.

Data from climate simulations (ERA5 downscaling VHR-REA) to use were examined, including needs of pre-processing (units conversion, derivation of secondary variables from primary ones, etc..). Twelve algorithms have been selected, all based on precipitation, to provide a sort of uncertainty due to the use of different empirical models. The workflows to be implemented to calculate the rainfall erosivity factors (R factors) have been defined step by step in the "DApOS specifications" Deliverable 5.2.

In order to apply the above algorithms, it was first necessary to pre-process the precipitation variable output from VHR-REA. First, the units of precipitation were converted to *mm*, then the monthly and annual sums were computed, and finally their climatological means were calculated for the 30-year period 1991-2020. Successively the Modified Fournier Index (MFI) at the basis of some of the empirical models, was derived. At this point, the twelve R factor models were executed. In order to improve the sharing of data the metadata were also adjusted: attributes, units, variables names, references, etc. as well as the whole dataset was remapped to a regular grid (maintaining the high resolution of about 2 km) to enable interoperability with the HIGHLANDER platform. Successively, the R and the other factors composing the soil erosion

calculation through the selected RUSLE model (LS=topography, K=soil erodibility, C=land cover and management, P=soil protection) were resampled to 250 m from their native resolution (see Panagos et al., 2015) and clipped over Italy to calculate the indicator of the potential Soil Loss (SL).

Next actions

As soon as the SL indicator is calculated at 250 m resolution under the twelve R factor empirical models, these intermediate results (as just based on VHR-REA product) will be provided to the CINECA team to design Datasets and Apps on the HIGHLANDER platform. It is expected to conclude this step by 2021-Q4.

In 2022, after the completion of Task 4.2 on downscaling of climate projections from 1989 to 2050, (VHR-PRO) the steps above will be repeated for the new dataset and the anomaly future vs. historical for R and SL will be calculated so that final results will be ready to populate the HIGHLANDER platform and to finalize Datasets and Apps to enable access and visualization by users. Indicatively, the mode of return to the user will be via web-GIS maps starting from ready-made layers in which the user can choose the parameters and/or the area of interest and can visualize spatial statistics, in terms of current status and changes across time periods and similar.

Actions not foreseen and taken

The main new, and unexpected, step undertaken was the remapping of the R and SL indicators datasets to a regular lat/lon grid to allow ingestion in the platform's GeoServer.

Pilot area: Italy

2.2 Human wellbeing

The DApOS "Human wellbeing" is being developed by CMCC.

Actions already taken

The literature has been reviewed about the indicators, and their threshold/classification, available to quantify the (dis)comfort for humans due to climate conditions, in particular temperature "real" vs. "perceived" due to relative humidity (e.g. Humidex, Apparent Temperature, Temperature Humidity Index), or also indicators considering wind speed (Wind Chill index). The advantage of using very high resolution simulations with a special configuration of urban areas will be also evaluated, analyzing the same indices, as available from existing datasets/projects, obtained under the same model but with other spatial resolutions and without similar configurations.

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.

Stakeholders' preferences have been largely investigated thanks to previous projects (ICARUS, BLUE-Health), allowing to select, as a period of interest, the medium term 2021-2050 or, if runs will allow, 2036-2065.

Data from climate simulations (ERA5 downscaling VHR-REA) to use were examined, including needs of pre-processing (units conversion, derivation of secondary variables from primary ones, etc.). The workflows used for this DApOS were simpler than others because there are only four indicators (WC=Wind Chill (°C), H=Humidex (°C), DI=Discomfort Index or Modified Thom DI or Temperature-Humidity-Index (°C), AT=Apparent Temperature (°C)), although intermediate/secondary variables had to be calculated. Instead, the processing was heavier than others since the indicators were maintained hourly and then daily statistics were derived.

In order to apply the selected algorithms to calculate WC, H, DI, AT, it was first necessary to pre-process the variables temperature (air and dew point at 2 m) and wind speed components outputs from VHR-REA. First, the units of temperature were converted from °K to °C and the wind direction was calculated from its components both in m/s and km/h. Secondary variables derived were relative humidity (%) and vapour pressure (kPa). At this point, the four indicators were calculated and then their daily statistics (maximum, minimum, average) were computed. In order to improve the dissemination of data on the HIGHLANDER platform the metadata were also adjusted: attributes, units, variables names, references, etc.

Next actions

The daily datasets (three for each indicator) were remapped to a regular grid (maintaining the high resolution of about 2 km) to enable interoperability with the HIGHLANDER platform. Indeed, these intermediate results (as just based on VHR-REA product) will be provided to the CINECA team to design Datasets and Apps on the HIGHLANDER platform. It is expected to conclude this step by 2021-Q4.

After the completion of Task 4.2 on downscaling of climate projections from 1989 to 2050, (VHR-PRO) the steps above will be repeated for the new dataset, and the anomaly future vs. historical for monthly, seasonal and annual climatologies of the four indicators will be calculated so that final results will be ready to populate the HIGHLANDER platform and to finalize Datasets and Apps to enable access and visualization by users. Indicatively, the mode of return to the user will be via web-GIS maps starting from ready-made layers in which the user can choose the parameters and/or the area of interest and can visualize spatial statistics, in terms of current status and changes across time periods and similar.

Actions not foreseen and taken

The main new, and unexpected, step undertaken was the remapping of the WC, H, DI, AT indicators datasets to a regular lat/lon grid to allow ingestion in the platform GeoServer.

Pilot area: Italy

2.3 Land suitability for vegetation

2.3.1 Land suitability for vegetation (forests)

The DApOS "Land suitability for vegetation" related to forests is being developed by CMCC.

Actions already taken

The literature has been reviewed to select the approach to be used in the project, evaluating *pros* and *cons* of ensemble of simple to complex algorithms (e.g. BIOMOD) vs. simplified (clustering/grouping or maximum entropy procedures already working with GIS compatible formats and languages). Considering the purposes of HIGHLANDER and the need to exploit HPC for embedding workflows of operations and related services to access results, the latter approach was finally selected.

In terms of data, base maps on forest species at national to regional level have been analyzed and elaborated, to evaluate their representativeness of valuable species for multiple sectors and purposes (e.g. ecosystem services) and to overcome/reduce their heterogeneity and thus required effort for harmonization in terms of classes and map units.

Stakeholders' preferences have been investigated, thanks to some previous projects (Interreg Central Europe TEACHER-CE, Climate KIC MADAMES, and MADAMES-AX). The information obtained allowed us to select, as a period of interest, the medium term 2021-2050 or, if runs will allow, 2036-2065.

The algorithms to be implemented to derive bioclimatic indicators, predictors of forest suitability, have been defined step by step, from raw data to output variables; moreover, forest presence probability will be extracted through the species distribution modelling tool as final information for end users about the changes from historical to future period.

The DApOS will be run offline because ready routines from old jobs will be used. "Offline" means that the tool implemented to assess forest suitability will not run on HPC due to difficulties in integrating codes that are already running on other machines (and do not need HPC). HPC will be instead used to post-process climate data feeding these tools. This DApOS will be complementary with another component related to land suitability for crops and developed by CIA-PIEMONTE and ARPAP (see below).

Data from climate simulations (ERA5 downscaling VHR-REA) to use were examined, including needs of pre-processing (units conversion, derivation of secondary variables from primary ones, etc.). Then, in order to apply the selected workflows to calculate the bioclimatic indicators, it was first necessary to pre-process the variables from hourly to daily for temperature (minimum, maximum, and mean of the day) and accumulated precipitation, then deriving monthly

climatological means along 30 years 1991-2020. The datasets (four for each monthly climatology) were remapped to a regular grid (maintaining the high resolution of about 2 km) to enable GIS-based calculation of bioclimatic indicators.

Next actions

Starting from monthly climatologies, bioclimatic indicators will be calculated via GIS tools and then provided as products on the HIGHLANDER platform. Such intermediate results (as just based on VHR-REA product) will be provided to the CINECA team to design Datasets and Apps on the HIGHLANDER platform. It is expected to conclude this step by 2021-Q4. Moreover, bioclimatic indicators will be clipped and remapped over Italy (choosing proper mask/resolution according to forest maps), to feed the training/calibration of a SDM (Species Distribution Modelling) algorithm (MaxEnt) to predict forest suitability.

After the completion of Task 4.2 on downscaling of climate projections from 1989 to 2050, (VHR-PRO), steps described above will be repeated and bioclimatic indicators (BioClimInd) for the future will be bias-corrected, to apply the SDM algorithm under bias-corrected BioClimInd to extract future forest suitability. Final results (bioclimatic indicators and forest suitability map for the historical and future periods) will be ready to populate the HIGHLANDER platform and to finalize Datasets and Apps to enable access and visualization by users.

Indicatively, the mode of return to the user will be via web-GIS maps starting from ready-made layers in which the user can choose the bioclimatic indicator and the species of interest and the area to be selected in order to explore e.g. spatial statistics about environmental conditions or forest presence (proxy of habitat suitability).

Actions not foreseen and taken

The main new, and unexpected, step undertaken was the remapping of the monthly climatology to a regular lat/lon grid to allow ingestion in the selected GIS tool.

Pilot area: Italy

2.3.2 Changes in the land suitability for vegetation (forests, crops)

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 the analysis 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, such as vineyards, autumn-winter, and spring-summer cereals, particularly relevant for the regional economy.

Actions already taken

Previously, web meetings have been organized between CIA and ARPAP to better define the DApOS; development and test of procedures to manage climate data, which will be carried out by ECMWF and CMCC, have been made.

2.3.2.1 Mycotoxins on cereal

Actions already taken

Currently, a study on mycotoxins (DON on wheat – AFLATOXINS in corn) in 2 territories (Carmagnolese, Canavese) is ongoing. The first data on the impact of mycotoxins on the agri-food chain date back to 2006. CIA has obtained organized data about corn from 2006 onwards (without interruption) from the Canavese area and data about corn and wheat from Carmagnolese area from 2012 onwards, with interruptions of a few years.

This is a complex path and CIA is experiencing difficulties in the willingness of those who own the analytics to provide the data (even if it is anonymous and aggregated), however CIA is putting additional resources into this.

Next actions

Data from ARPAP and VHR_REA_IT from CMCC will be used by specialists for the first evaluation aimed at characterizing the level of criticality.

2.3.2.2 Evaluation of the grapevine vocationality at regional level

Actions already taken

Maps based on ARPAP grid have been produced, CC effects on RCP4.5 and RCP8.5 scenarios were assessed using EUROCORDEX data, and maps of the grapevine vocationality of Piedmont have been produced using VHR_REA_IT data from CMCC.

Next actions

Regarding viticulture, ARPAP is waiting for high-resolution data for the models but ready for testing.

2.3.2.3 Changes in forest habitat suitability

Actions already taken

Prof. Garbarino (UNITO), from the Department of Agricultural, Forestry and Food Sciences, has been identified as one of the most qualified experts to be assigned to work on forest habitats and their potential change with future climate and on regional forest fires.

Starting from own climatic data with those of ensemble, a comparable downscaling to that made by CMCC was prepared. UNITO validated COSMO-CLM data to calculate current forest habitat suitability for vegetation using ARPAP analyses and is producing maps for habitat.

Next actions

ARPAP is waiting for high-resolution data for the models but is ready for testing.

Pilot area: province of Torino

2.4 Water cycle and sustainability of competing uses

The DApOS "Water cycle and sustainability of competing uses" is being developed by CMCC.

Actions already taken

The literature has been reviewed to calibrate the approach to be used in the project, evaluating *pros* and *cons* of sophisticated and spatial distributed hydrological models (e.g. ArcSWAT, TOPKAPI) - better representing hydraulic connectivity over hill slopes but with a lot of parameterization required - vs. simplified lumped models - less accurate spatially but with the advantage of reducing the number of initializing information/parameters often impossible to find.

Considering the purposes of HIGHLANDER and the need to exploit HPC for embedding/running workflows of operations and related services to access results, the latter approach was finally selected.

In terms of data, previously collected information from *Hydrological Yearbooks* (Bari Compartment) on rainfall and discharge, has been checked for possible errors in data registering (spikes, gaps) and in the digitizing operations. Besides the outlet station San Samuele di Cafiero, other hydrological stations were added to investigate upstream and downstream hydrological behavior in the watershed.

Stakeholders' preferences have been investigated, thanks to some previous projects (South East Europe Transnational Cooperation Programme ORIENTGATE, Interreg Central Europe TEACHER-CE). The information obtained allowed to select, as a period of interest, the medium term 2021-2050 or, if runs will allow, 2036-2065.

A study on which combination of climatic variables affects the dynamics of the Ofanto river discharge is ongoing. Some indicators - especially related to droughts - have been tested but they did not return interesting correlations at this time.

River flow data are analyzed for the first time and simulations are complete, indicator analysis is underway.

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 (see 2.5.3).

Pilot area: Ofanto river basin, Puglia.

2.5 Crop water requirements forecasts

The DApOS “Crop water requirements forecasts” is being developed by ARPAE.

It is a climate service addressed to irrigation water management in agriculture. The accomplishment of the Tasks is ongoing, in synergy with Highlander partners and stakeholders. The stakeholders’ involvement will allow collecting input data and validating the results.

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.

A networking activity was carried out in order to set up and organize the work devoted to the development of the DApOS and apply it to the Highlander pilot regions (Emilia-Romagna, Trento province, Piedmont, Apulia). Therefore, several virtual meetings were held between ARPAE and the project partners in order to define the needs, aims, and specific features of applications of the DApOS in the pilot areas.

2.5.1 ARPAE preparatory activities

Technical documentation on data requirement specifications and output format has been provided to the HIGHLANDER partners involved in the DApOS pilot development. The 2 reports on soil water balance (SWB) output are made available at the following links:

Highlander SWB output description

Highlander SWB data requirements

The definition of input data format for sub-seasonal forecasts was provided to ECMWF.

In previous months a document has been compiled to clarify the specifications of the DApOS: data flow, input and output data, etc. This information is needed by the CINECA and CMCC partners who are designing the Highlander platform architecture. The specifications of the DApOS "Crop irrigation" have been collected in a document that is proposed as a template to all DApOS managers to provide the specifications of their DApOS.

Subsequently, a test match has been made and a requirement has been added: the data rotated pole grid format has been re-interpolated on a regular lat-lon grid only in the areas of interest of the DApOS.

Then, identification of meteorological variables and format needed for the DApOS has been made, and also a pipeline modification to move from deterministic prediction data to probabilistic prediction data (ECMWF format).

2.5.2 DApOS Crop water requirements forecasts in Emilia-Romagna pilot

Actions already taken

Activity plan of ARPAE: The crop water requirement forecasts outputs will be delivered to the users through a webGIS platform, starting from the prototype developed within CLARA project (https://servizigis.arpae.it/moses/home/index.html). CLARA project conceived so far to produce 7-day deterministic forecasts and seasonal probabilistic forecasts. The webGIS has been activated on Burana Irrigation Consortium (representative of Emilia sub-region) and Romagna Irrigation Consortia (representative of Romagna sub-region).

Using ECMWF sub-seasonal forecasts the platform has been extended to produce probabilistic monthly forecasts of crop irrigation needs for three ER Consortia: Burana, Renana, and Romagna. Thanks to the suggestion of the consortia, ARPAE added to the outputs the probabilistic forecast of monthly precipitation. ECMWF produced the bias-corrected (based on ecpoint post-processing) variables between April (minimum and maximum temperature) and June 2021 (daily total precipitation). In the meantime, ARPAE tested applications with the non-calibrated ones. The conversion of monthly irrigation output on netcdf format to transfer on HIGHLANDER data portal was made and CINECA is testing it.

Next actions

Next actions regarding sub-seasonal forecasts of irrigation needs for crops will be the work on data visualization on HIGHLANDER data portal for users.

Pilot area: 4 Land reclamation and Irrigation Boards (consorzi di bonifica) from Emilia-Romagna

2.5.3 DApOS Crop water requirements projections in Apulia pilot

Actions already taken

Activity of ARPAE and CMCC: The coordination activities via web call allowed to frame the opportunity to set up the DApOS of climate projections of irrigation in the Apulia region, with a focus on land reclamation and irrigation consortium of Capitanata. In this area, an interest in impact study of climate projections of irrigation has been identified, due to the strategic value

of information on water resource planning in agriculture, conceived in the broader context of water resource management, by means of synergy with the DApOS 'Water cycle and sustainability of competing uses'.

The case studies have been decided, the arrival of the first data was prepared.

Next actions

CMCC will finish providing scenarios at the end of 2021, meanwhile, test data will be downloaded and tested.

It will obtain land climatic data through Corine Land Cover (CLC) inventory.

Pilot area: sub-area of irrigation consortium of Capitanata, to be defined

2.5.4 DApOS Crop water requirements projections in Trento pilot

Actions already taken

Activity of ARPAE and Fondazione Mach (and Dedagroup): web meetings have been organized in order to define the DApOS with Fondazione Mach and Dedagroup. An impact study on climate change projection of irrigation can provide data and information that could be useful in order to add further contents and details within the Climate change Adaptation Plan of Trento Province.

The case studies have been decided: an impact study on apple trees' irrigation in Pianura Rotaliana.

Next actions

The next action is to investigate through Corine Land Cover (CLC) inventory the different land covers of Pianura Rotaliana.

Pilot area: Pianura Rotaliana, where orchards and vineyards are widespread. The area was selected due to the strategic importance of these crops, in terms of economic value.

2.5.5 DApOS Crop water requirements projections in Piedmont pilot

Actions already taken

Activity of ARPAE and ARPAP: web meetings have been organized in order to define the DApOS, involving also the Agriculture department of the Piedmont Region. ARPAE and ARPAP, in

collaboration with Piedmont Region, will set up the pilot by collecting input data. Furthermore, an exchange of knowledge between ARPAE and ARPAP, in terms of tools aimed at assessing water balance in agro-ecosystems, will be done. An impact study on climate change projection of irrigation in Piedmont can be useful to assess the water needs of arable lands and orchards.

ARPAP has downloaded and installed the software Criteria and has conducted some tests on weather data. Three territories with different crops have been identified. The model ran on

Global models produced by ARPAP itself until data processing from CMCC will be completed.

Climatic projections were assessed using EUROCORDEX data, then COSMO CLM were applied to agriculture to assess irrigation in the past period and models from Criteria were applied.

Next actions

Tests will be made with high-resolution data from CMCC.

Actions not foreseen and taken

The dissemination of this task was made during:

- the R2B on air – Research to business digital edition, June 16th, 2021
- AIAM Conference - XXIII National Agro-meteorology Conference, Online from 30th June to 2nd July 2021
- the free Masterclass "Glocal Eyes: giovani guardiani del clima intorno a noi", Torino, September 10th, 2021

Pilot area: possibility to select the plain areas of Cuneese, Alessandrino, and Torino/Carmagnola, where arable land and orchards are widespread.

2.6 Animal welfare and land suitability for farming

The DApOS “Animal welfare and land suitability for farming” are 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.

Actions already taken

To carry on the activity several web meetings have been organized to better define the needs. A study on how pastures can be compromised by climatic variations was made.

Actions not foreseen and taken

A process of sharing with the DISAFA of the University of Turin was initiated for the definition of a protocol (using the method of "pastoral types of the Piedmontese Alps" of Cavallero et al. 2002) that allowed the technicians identified to proceed during the summer to field sampling of forage in the pastures of the selected reference areas, Usseglio (TO): 9 georeferenced botanical reliefs, at an altitude between 1200 and 2600 meters, were made and compared with those of 2002.

The other pastures identified were in the area of Vallone Lago Vannino (VB): 29 georeferenced botanical reliefs, at an altitude between 1900 and 2300 meters, identification of floristic equipment and attribution value % of vegetation cover were made and compared with those of 2010 (BIORICO). The methodologies used were different because of the comparison with their similar previous models.

Landolt indexes (Temperature and Humidity) and pasture quality index (qualitative characteristics and usability of the turf) were calculated. The pre-conclusions were that pastures were warmer and wetter and also of lesser qualitative value.

Next actions

Comparison and validation of ARPAP and CMCC data to estimate whether climate projects this scenario.

ARPAP will install a portable weather station in Usseglio in order to complete the reliefs made by CIA.

Actions foreseen and not implemented

From the end of October 2020 CIA has started to provide the historical data of ascent and descent from the pastures in order to investigate the possible link with climate. The attempt was left because it was not effective.

Pilot area: province of Torino

2.7 IoT for animal wellbeing

The DApOS “IoT for animal wellbeing” is being developed by DIBAF.

Actions already taken

At the beginning of the project, DIBAF has started a dialogue with different breeders associations, in particular Associazione Italiana Allevatori (National breeder association) - AIA; Associazione Nazionale della Pastorizia (Sheep and goat association) - ASSONAPA; Associazione Nazionale Allevatori Suini (Pig breeder association) - ANAS.

Collaborations have been established with ANAS, University of Bologna and “Università Cattolica del Sacro Cuore” of Piacenza. Visits have been organized to the ANAS Genetic Centre in Vittoria Di Gualtieri (Reggio Emilia), Bologna and Piacenza; this region is considered an important centre of swine husbandry.

Other dialogues were organized by phone, emails, and web-calls. From this collaboration with the stakeholders, in the first roadmap in March, it has been assessed that:

1) one of the major concerns regards the economic impact of climate changes on livestock production efficiency reduction due to heat stress. Therefore, DIBAF was actively involved in the evaluation of sensors for temperature detection in two different conditions: stable (cattle and swine) or pasture (cattle and sheep) breeding;

2) IoT capable of detecting livestock position and movements for pasture livestock would be very useful to identify the state of health and other conditions.

Therefore, DIBAF has been involved in the evaluation of sensors for temperature detection. Animal talkers are sensors that detect changes in animal’s physical features and relate them to their conditions like, for example, disease or stress. The sensors measure the animal skin temperature, in bovine and ovine. The data detected will be correlated, through appropriate relations, to the environment temperature and humidity, determining animal conditions. Different models of animal talkers were being evaluated (i.e. collar, subcutaneous, heartbeat detector). The expectation was to conduct the first field trial in early 2021. The dialogue with AIA has been continuing. Technical documentation has been provided to the HIGHLANDER partners and has been published in the wiki at the following link:

Animal talker HIGHLANDER data

DIBAF had also developed techniques for -omics analysis, in particular metabolomics. This is relevant, in particular in this DapOS, because -omics data could be used to evaluate the animal welfare state and the animal productions (quality/quantity). As an example, results from metabolomics have been disseminated through this article Anti-Inflammatory Potential of Cow,

Donkey and Goat Milk Extracellular Vesicles as Revealed by Metabolomic Profile, in which CEF HIGHLANDER Project is cited in the acknowledgments.

On June 15, 2021 was held the seminar "the development of sensor technology in animal husbandry" as part of the initiative “Porta Futuro Lazio -crescere e competere nel mondo del lavoro”.

The following contributions, in which CEF HIGHLANDER Project is cited in the acknowledgments, were presented at the 24th ASPA congress held in Padova from September, 21-24, 2021:

- Marco Milanesi, Cinzia Marchitelli, Michela Contò, Simona Rinaldi, Danilo Pignotti,Giovanni Chillemi, Alessandra Crisà

  Preliminary results of Genome Wide Association Study with milk functional moleculesin different cow breeds (O034)

- Daniele Pietrucci, Daniele Alberoni, Loredana Baffoni, Diana Di Gioia, Giovanni Chillemi **Genomic and functional diversity of honey bee gut microbiota, after exposure to veterinary drugs or natural feed additives** (O146)

- Marco Milanesi, Danilo Pignotti, Daniele Pietrucci, Sandy Sgorlon, Mariasilvia D’Andrea, Bruno Stefanon,Paolo Ajmone Marsan, Alessio Valentini, Stelios Arhondakis, Giovanni Chillemi

  Assessment of transcriptional activity within isochores in healthy and subclinical cattle (P141)

This DApOS consists of three connected elements:

2.7.1 AnimalTalker

Actions already taken

A suitable BLE chip was found (Nrf52840) and tested using evaluation boards. Both hardware and software tests were made. An accelerometer and a temperature sensor were connected to the BLE chip. A new possible technology (NB-IOT) to allow internet connection and a suitable GPS module was found. Two possible providers of RFID subcutaneous temperature sensors were contacted and an RFID reader was bought to perform some compatibility tests. Some subcutaneous temperature chips have been bought and a reader from FAREAD. A suitable low power module to implement NB-IOT technology has been chosen (SIM7000E) and tested, it has GNSS capability thus it can be used both as GPRS module and GPS module. It has been tested sending data to a server and reading data from it. Moreover, MQTT protocol has been

successfully tested to understand the limits and possibilities that this solution offers for real-time applications. First PCB (Printed Circuit board) prototypes were designed and produced for both the collar and the accelerometer.

Actions not foreseen and taken

A new accelerometer was found that allows up to 800 Hz sampling rate (MMA8452). Furthermore, PCBs programming tests have shown some problems that require a deeper analysis to be solved. In order to start the field tests as soon as possible, evaluation boards of selected sensors were ordered and are currently being assembled and programmed. For testing purposes, an sd card module will be added to save locally huge amounts of data.

Actions foreseen and not implemented

Field tests have been postponed due to issues with the programming interface of PCB boards.

Next actions

Field tests should start in October 2021. The data will be collected and analyzed in order to relate them to animal conditions and behaviors. During this phase, the reliability of the system will be assessed. The first two sensors that will be tested are the accelerometer and an oxypulsimeter. Also, an attempt to read the RFID subcutaneous temperature sensors using a different reader (smaller) than the one provided by FAREAD will be performed. In case of success, the subcutaneous temperature sensor will be implemented using Bluetooth technology. Finally, PCBs programming issues will be studied more in-depth in order to have an affordable and easy-to-produce solution for the following phases.

2.7.2 AIA production data

Actions already taken

AIA collects livestock production, reproduction, sanitary and managerial data from the entire Italy. Through the LEO project – Livestock Environment Opendata (https://www.leo-italy.eu/) and DIBAF collaboration, this data will be used in the Highlander project. An ad hoc database to store the data inside the Data Lake has been created. All the collected data will be analyzed together with climatic data using Machine learning approaches.
The objectives are to create indicators of animal wellbeing, due to climate conditions (in this case historical data -climate and productions- will be used) and to evaluate animal wellbeing, due to physiological (in this case, IoT data will be used) and environmental conditions.
AIA has shared dairy data production from Italian Simmental (Pezzata Rossa Italiana dairy cow). The data shared are milk yield, fat, protein, lactose, SSC, urea, casein, fatty acid profile

(partial and on few animals), coagulation parameters (R, A30, LDG), cryoscopy, BHB, pH, etc. Moreover, animal information such as coordinates, number of lactations, days in milk, etc. have been shared. These data were from Friuli-Venezia Giulia and Sicilia regions (to evaluate different environments), from 2015 and 2020. The dataset comprises more than 580000 entries, from more than 814 farms and more than 37000 cows. The objective was to start the test to identify the best model to predict the environmental effect in milk production.

Next actions

After testing the dataset related to Pezzata Rossa Italiana, the entire historical AIA dataset for Holstein and Simmental (almost 1.2M of animals and 10k of farms per year evaluated) will be used for the real algorithm training.

2.7.3 Climatic data

Actions already taken

The DApOS needs, from CMCC, downscaled ERA5 reanalysis data (1989-2018), at this moment computed until 2013, and downscaled projections data (2021-2050), starting when GALILEO 100 will be available. From ECMWF, ERA5 historical data and sub-seasonal forecast data (15-30 days), available from March/April 2021, will be used.
We identified the most suitable meteorological set of variables to use in the ML algorithm to evaluate animal wellbeing with the help of ECMWF and CMCC teams.
ECMWF extracts data from ERA5 hourly dataset, from 2015 to 2020 for entire Italy. The data has been used in a test, together with AIA data.
A pipeline for the extraction and preparation of climatic data for subsequent ML analyzes has been created: the climatic values for each farm are the average of the values of a 3x3 grid around the coordinate.

Actions not foreseen and taken

Italian durum-wheat pasta network

A collaboration with DEIM (ECONOMICS, ENGINEERING, SOCIETY AND BUSINESS ORGANIZATION) - UNITUS was undertaken about the wheat-durum pasta network of Italian quality.

Data from the 2018-2019 seasons were collected through FRUCLASS, an innovative system of data transmission and analysis. Some of the information gleaned from the data relates to the quantity of product delivered, the specific weight and the protein content, humidity, impurity,

etc. Production data from 2019-2020 regards about 220.000 tons of wheat and 16.000 tons of durum-wheat mainly collected in central and northern Italy. From 2021 the data is being collected from 70 centers in 26 Italian provinces.

The objectives are to identify the relations between climatic variability, production capacity, and quality attributes and which actions could mitigate the climatic effects.

Pilot area: Italia

2.8 Natural park 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 ecophysiological variables measured at individual level. The data continuously collected by the *in situ* monitoring network will be exploited for a fast assessment of forest health and trends (i.e. vulnerability, threats, response to disturbance). The average state of the forest will be made at different time scales through basic statistics. Advanced data analytics tools, including machine learning (ML), will be used. Moreover, ML algorithms will be tested as early warning systems. In the same area, Sentinel 2 data was used to test their suitability to predict meadow cuts and to improve pasture management. Satellite data was calibrated with field spectral data collected with a drone in three different pastures. The algorithms developed in the test area will be implemented and applied, thanks to HPC, throughout the Park area.

Actions already taken

At the beginning of the project, the importance of planning on the integration of short- and long-term climate data, satellite observations, and in-situ IoT data was highlighted. Using this integrated system we will apply animal welfare models to cow farms in the Trentino mountains. FEM has a database of satellite images, collected from the end of 2013, and ground data in high resolution, from Trento Province. The sites for the installation of the sensors were identified and installation permits were obtained. Fifty sensors will be used in two areas: beech and spruce forests. Moreover, FEM, in cooperation with Udine and Padova University, was developing collars equipped with GPS for monitoring animal wellbeing.

As a dissemination task, involving also ART-ER, FEM was in contact with "Nature Park Paneveggio - Pale di San Martino" to organize an event to present Highlander project, and with "Institution Trentino Sviluppo" to plan a seminar to display the potentiality of this DApOS.

Data collection related to tree talker has begun in July.

Tree talker is a device that allows measuring:

- tree radial growth, as an indicator of photosynthetic carbon allocation in biomass. It is measured using an infra-red pulsed distance sensor positioned at few centimeters away from the tree trunk's surface and kept in place by a carbon fiber stick anchored in the xylem;
- air temperature and relative humidity, to compare the data measured with the external conditions;
- tree stability parameters, to allow real-time forecast of potential tree fallings by mean of an accelerometer;
- stem humidity, to evaluate the xylem moisture content as an indicator of hydraulic functionality;
- light penetration in the canopy, in terms of fractional absorbed radiation and light spectral components related to foliage dieback and physiology. These measurements are performed using two spectrometers which are sensitive to bandwidth ranging from 450 nm to 860 nm;
- sap flow, as an indicator of tree transpiration and functionality of xylem transport. It is calculated according to the thermal dissipation method of Granier: a probe pair is inserted in the main trunk with a vertical separation of 10 cm, the upper probe is heated while the other is used to measure the reference temperature and includes a capacitive sensor of wood humidity (stem humidity). The sap flow can be obtained starting from the difference between the two temperatures.

Technical documentation on data have been provided to the HIGHLANDER partners and have been published in the wiki at the following link: Tree talker data

This DApOS consists of three parts: IoT data from tree talkers, satellite data for meadows and pastures, hyperspectral, and Lidar data for forests.

2.8.1 IoT data from tree talker

Actions already taken

Regarding sensors, two sites in Parco di Paneveggio have been chosen and there 25 sensors in each site were installed in July. Four other sites in Trentino (two in Parco Adamello- Brenta and

two in forests located in the East part of the Province) were added to extend the area of interest. In total 170 working devices are in place collecting data continuously.

FEM and DIBAF are processing the data independently and simultaneously. The part concerning calibration and quality check has been completed. Grafana has been used to visualize data.

Next actions

Regarding the database, the more effective procedure to implement in the server will be defined. Regarding data visualization, tests will be made, after the definition of the database.

2.8.2 Satellite data for meadows and pastures

Actions already taken

Regarding meadows and pastures, Sentinel 2 satellite images have been downloaded from ESA, the algorithm has been tested and the output consists of maps to estimate forage availability in pastures during the summer. The maps will be updated every fifteen days. In this use case, no climatic data are needed.

The action pertinent to meadows has been completed. There is a code working on google engine that suggests numbers and dates of cuts. It was on-demand for “Provincia di Trento” but along the lines of the HIGHLANDER project.

The action pertinent to pastures is ongoing: Sentinel 2 satellite images have been downloaded for the summer period of 2019/2020/2021, 8 vegetal indexes have been calculated and a scene classification map has been produced.

Next actions

Regarding meadows, FEM will define with DEDAGROUP the correct way to apply it in the portal. Regarding pastures, anomalies calculus will be established and graphs with temporal series and values will be produced.

2.8.3 Hyperspectral and Lidar data for forests

Actions already taken

Hyperspectral and Lidar data have been used to classify species and predict forest biomass. The algorithm has been partially tested in CINECA and implemented. The output consists of static

maps (2015) of these two variables. Map's update is not annual (because the data would not be useful for forests) but every five years.

Next actions

Maps will be updated over time using Sentinel 1 satellite images and regarding 2020.

Actions not foreseen and taken

Evaluation of damages after the Vaia storm

FEM has been using satellite data for the evaluation of areas destroyed in 2018 by the Vaia storm.

Assessment of bark beetle (Ips typographus) damages

After the damages caused by the Vaia storm, the outbreak of bark beetle is striking again Trentino forests, especially spruces. FEM has been using Sentinel 2 to evaluate these damages and foresee the next areas that will be affected.

Pilot area: Trentino

2.9 Forest fire prediction and controls

2.9.1 Forest fire prediction and controls

A DApOS similar to that defined by FEM in the Trentino area is being developed by DIBAF and CMCC in the Puglia region. Data coming from sensors will be used for monitoring variables potentially linked to fires. This DApOS is linked to the "OFIDIA – Operational FIre Danger preventIon plAtform" project, funded by: European Territorial Cooperation Operational Programme "Greece-Italy" (2007 – 2013). For these reasons, a Letter of Agreement for the exchange of data between Highlander and Ofidia has been produced.

Conservation of forest resources and prevention of forest fires are fundamental activities to mitigate and reduce climate change impacts. There are already services and projects to monitor, through remote and proximal sensing data, the progression of forest fires and the conditions that can trigger and foster them. The goal in "Forest fires prediction" is to set up and apply a model based on remote data, such as satellite images, proximal data, such as ground sensors (IoT), and medium term meteorological predictions, to provide a forest fire risk analysis service. This service will support the green areas and natural parks' management to preserve the forest resources of the area, and, at the same time, to guarantee the safety of human settlements nearby.

Actions already taken

Technical documentation on data have been provided to the HIGHLANDER partners and have been published in the wiki at the following link: Tree talker fire data

Fire risk in the Mediterranean regions can be modeled exploiting different data layers available in Highlander. All the following data will be included in Highlander DataLake for Machine Learning analysis:

- Climate data (CMCC, ECMWF) offering a perspective on drought which is the main driver of fire occurrence;
- tree talker fire;
- remote sensing data (from satellite or airborne) can produce information on
    - Vegetation senescence: by specific indices, linked to the amount of dry matter that favors fire occurrence and spread. E.g. satellite Sentinel 2 data (10-20 m spatial resolution)
    - E.g. airborne hyperspectral senescence indices
    - E.g. airborne lidar data to estimate vegetation (fuel) biomass

- E.g. satellite radar data linked to vegetation biomass and water content;

- ancillary information:
  - E.g. Historical fire maps: very important inputs in models to establish fire risk classes;
  - E.g. Local vegetation maps (including silviculture data) can help in the fine-scale classification of vegetation

The joint use of these layers as input in machine learning classification models allows predicting classes of fire risk in different environments. The accuracy of the fire risk prediction model is dependent on the amount and quality of input information.

The ground data collection campaign (and relative analysis) is continuing in some selected study areas: tree talkers with forest fire sensors have been installed in four sites with 30 devices each (Masseria Galeone, Alberobello area / Masseria Cuturi, south of Manduria / Cesine Natural Park, east of Lecce / Ugento, located on the coast).

The first step is linking dynamic ground collected variables to fine-scale forest and vegetation classification, in order to upscale the local information to vegetation unit level. For this step, the ground information is under elaboration and a vegetation suitable map has been identified. A second step is to link the ground dynamic variables to dynamic information provided by remote sensing. For this second step, the suitable satellite images are being identified (Sentinel 2) and a study is underway on which variables on the ground can best be correlated with those deriving from remote images (e.g. vegetation indexes) to spatialize the information on the territory, at the spatial and temporal resolution allowed by the satellite data.

Next actions

It is necessary to establish how to aggregate the data (collected at the very high temporal frequency) and prepare them to create a link with remote data.

Pilot area: Puglia

2.9.2 Forest fire potential

The DApOS “Forest fire potential” is being developed by ARPAP in collaboration with UNITO.

Prof. Garbarino (UNITO), from the Department of Agricultural, Forestry and Food Sciences, has been identified as one of the most qualified experts to be assigned to work on forest habitats and their potential change with future climate and on regional forest fires.

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 analyzed at the level of specific composition and alteration of the regimes of natural disturbances.

Actions already taken

Several web meetings have been carried out to better define the needs of such a DApOS. A preliminary activity to test the procedure for the evaluation of the forest fire potential using available climate data was carried out in order to build a tool to be used with CMCC climate scenarios.

Forest fire maps have been calculated using EUROCORDEX data and produced using VHR_REA_IT data from CMCC.

Personnel involved: in order to be able to carry out the activities described above, three internal employees from ARPAP have been assigned to the project, one temporary employer has been hired and an agreement has been signed with UNITO (University of Turin) to support a PhD fellow.

Next actions

ARPAP is waiting for high-resolution data from CMCC to continue.

Pilot area: Piemonte

MATERIALS TO BE USED

Questionnaires

ART-ER as leader of the communication and dissemination activities has developed and tested a very short questionnaire to capture the interests in the Highlander activities among the participants in the first webinar of the project.

The questionnaire was tested at the end of the first webinar held online within the context of R2B – Research To Business in June 2021.

The event was held in Italian language because the target addressed were Italian research center and firms involved in design or development of applications related to a better use of water in agriculture.

The participation was good so ART-ER decided to use the same questionnaire in all the future webinars. We include hereby the questions and answers in English language.

1. How did you hear about this event?
    a. E-mail
    b. The Internet (web site)
    c. Social Networks
    d. Word of mouth
2. Which organisation do you belong to?
    a. Public Administration
    b. Research Organization (public or private)
    c. High Technology Network member
    d. Firm
    e. Consultancy office
    f. Startup
    g. Not for profit organization (NGO,…)
3. Do you think the Highlander project can contribute to your activities?
    a. Yes
    b. No
    c. I'd like to go further
4. What interested you most about the Highlander project? (Answers were collected and showed as a TAG cloud)
5. If you would like to keep up to date with the latest news from the Highlander project, please leave us your email and we will send you communications at future meetings (the email will not be displayed to participants). (To collect the email of interested people)

The first question has the objective to verify the efficacy of the dissemination channels used by ART-ER. The second to identify which kind of organizations are interests in Highlander activities and results the most. The third to bring out any interest raised by the project and the fourth in which contents of the webinar.

The last one aims at building a list of interested people, the request is accompanied by the terms of use of the data that is provided under the European regulation by a General Data Protection Regulation (EU) 2016/679.