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Implementation of Apps

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Abstract	The present Deliverable, D10.3, introduces and illustrates two apps designed and developed in the context of ECOPotential Task 10.3. This document specifies the design and implementation of the web apps and mobile apps (i.e. computer programs specifically designed to run on smartphones, tablets, and other mobile devices). The web app is a map browser that allows the visualization, analysis and download of all datasets elaborated in WP4 as well as the position of the DEIMS sites in WP5. The full integration of the web app with the ECOPotential Virtual Laboratory platform has been discussed and alternatives have been presented. The map browser adopts the standards recommended by GEO in term or metadata and map creation. The map browser allows for user feedback (using the GUF OGC standard originated in the FP7 GeoViQua project).

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	The Virtual Lab integrates the EODESM application that is capable of providing unsupervised land use/land cover classifications. An app for gathering ground truth about land use/land cover classes has been developed to collect in-situ data that can validate and quality assess the result of the EODESM classifications. The description of this app has also been included in this deliverable.
Keywords	Earth observation, Map browser, On-line analysis, Ground truth, App

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1. Executive summary

ECOPotential WP10 is responsible of the implementation of a service-based platform for a virtual and open laboratory (VLAB) to study ecosystems of selected protected areas using Earth Observation (EO) data and algorithms prepared in WP4 and WP10, respectively. Users interact with the platform through a set of resources. This document describes two additional resources (the apps) designed to complement the virtual lab. On the one hand, the map browser allows discovery, visualization, access and downloads a harmonized set of open data, metadata and analytics provision completely on-line and without requiring any tool installation. This first data exploration carried out in the ECOPotential map browser will allow end user to select the best data and algorithm (according to its needs) to be finally run it in the Virtual Lab to get the result in full detail. On the other hand, EODESM app complements the EODESM system to support the Land use and land cover classification by providing experts and users a way to collect field data (ground truth) for validation of the EODESM results.

Abbreviation and acronyms

CHM	Canopy Height Model
CLC	Corine Land Cover
DEM	Digital Elevation Model
DoA	Document of Actions
EO	Earth Observation System
EODESM	Earth Observation Data for Ecosystem Monitoring
ESA	European Space Agency
FAO	Food and Agriculture Organization
GIS	Geographic Information Systems
GPS	Global Position System
LCCS	Land Cover Classification System
MODIS	Moderate Resolution Imaging Spectroradiometer
NDVI	Normalized Difference Vegetation Index
ODK	Open Data Kit
OGC	Open Geospatial Consortium
PA	Protected Area
PAfS	Protected Areas from Space
RGB	Red Green Blue
VLAB	Virtual Laboratory

2. Introduction

Deliverable D10.3 provides an overview of two apps developed during the last months, its functions and the capacities they offer to end users. It also provide some ideas on how to better integrated them into the virtual laboratory In the context of the WP4 of ECOPotential, a huge dataset of Earth Observation data and derived products (hundredths of GB) has been generated for each of the Protected Areas (PA) of the project. This data was centralized in a secured FTP were the data is stored and classified by protected area. The challenge of successfully deal with such dataset that is big in variety and volume (http://www.ibmbigdatahub.com/infographic/four-vs-big-data) appeared as soon as other WPs in the project tried to discover and use the data and was completely apparent when end users (i.e. the protected area managers) needed accessed the data. To provide and easy way to visualize the structure and the content of the data, a map browser app was created. The map browser is based on a previously existing MiraMon technology using international standards. Any other WMS compatible client is able to access the same data. However, new specific functionalities have been developed for ECOPotential that provide more user interaction. It provides a legend that serves as a catalogue of data in which end users can navigate to identify the most suitable products for them. This first version of the map browser was presented during the first meeting with Protected Area Managers in May 2017 in Pisa. The app had such a good reception by end users that PA managers started to ask for new functionalities, that were listed and that have been progressively included in the map browser. Today, the map browser it is not only a catalogue but a more complete tool that allows from exploring data giving a fast overview of each PA datasets available and its time series to doing spatial analysis. Technically the app is a combination of a client written in JavaScript and a server written in C. Both elements communicate using Open Geospatial Consortium Standards such as Web Map Server. Even if based on an existing standard, the approach used in ECOPotential is unique. The WMS server provides binary arrays of values, instead of static pictures, that are processed in the client to generate personalized visualizations and some analysis.

On the other hand, a mobile app that has been designed and developed in support of the EODESM system. Such app is useful for validating classifications of land use land cover and change by centralizing the capture of ground truth of selected locations, assisting in the determination of the uncertainty of the unsupervised classifications. The app uses a citizen science approach where everybody that is the protected area can provide data in a very easy way from its mobile phone.

Both apps have been applied to the different protected areas that are part of ECOPotential (Figure 1).

Figure 1. Location of protected areas considered by the ECOPotential Project

2.1 Current situation of the data and service elements in ECOPotential

In ECOPotential there are 4 components that need to be integrated

- The FTP repository of remote sensing products
- The map browser that produces services on top of the remote sensing products (Protected Areas from Space – PAfS)
- The DEIMS that is an observational sites database that in ECOPotential are assimilated to the PA descriptions as well as some access to in-situ data.
- The Virtual Laboratory (VLAB) that acts as a processing facility. The ECOPotential interface incorporates a map browser but does not provide a catalogue yet.

The FTP repository is a heterogeneous set of datasets in different formats, projections, levels of aggregation and with not many clues on how to symbolize the data. There has been an agreement in providing homogeneous metadata documents based on ISO19115 Inspire profile.

CREAF team is supporting ECOPotential by manually migrating the data to a homogeneous tiled repository that the MiraMon map service access to provide standard access to common picture formats (e.g. png and jpeg) as well as IMG formats. All remote sensing products that are migrated to the system have also a metadata record and available for download in tiff file in the UTM projection.

Currently, the virtual laboratory uses a fraction of what is available in the FTP, in special folder that has also been homogenized to a KEA format ready to be used in the EODEMS land use/land cover production system. In this sense, the KEA format is for the EODEMS what the IMG format is for the map browser. The VLAB browser and the PAfS browser are directed to different users (GEO Ecosystem community of practice, and PA managers respectively).

2.2 Integration of the DEIMS site description in the *Protected Areas from Space* Map Browser.

Recently the DEIMS database (https://data.lter-europe.net/deims/) has incorporated some OGC standards that make possible the integration into the map browser . One of the inclusions is a GeoServer instance that provides access as a WMS endpoint: https://data.lter-europe.net/geoserver/ows?

This WMS endpoint has been satisfactory integrated in the *Protected Areas from Space* Map Browser app and 3 datasets has been incorporated from it: *deims:deims_all_sites, deims:lter_all_formal* and *deims:ecopotential_all*.

3. The ECOPotential map browser app

The ECOPotential map browser is an app consisting of a graphical user web interface that allows viewing, querying, analyzing and downloading layers available in the ECOPotential map server. This app gives users access to remote sensing data without the need for specialized training in this field or setting up specifically designed software. The app runs on modern web browsers and has been tested in desktops, mobiles phones and LGC smart TVs.

The ECOPotential Map Browser app has been created using technologies that comply with international standards, namely Web Map Service (ISO 19128) and Web Coverage Service, approved by the Open Geospatial Consortium and the ISO. This makes it interoperable with other applications, especially with the ECOPotential Virtual Laboratory, and allows the browser to incorporate information from a variety of other servers provided by other partners in the project. The legend of the browser acts as a visual data catalogue: a relevant functionality for such a big project as ECOPotential, in which several partners produce data that if big in volume and variety.

The map browser is based on a previously existing MiraMon technology that has been enriched for this project. Initially able to provide a fast overview of the protected areas, their datasets available, styles and time series, other new aspects and functionalities have been added:

- Clipping data for the PA limits
- Selecting the information by criteria involving more than one dataset
- Comparing data from different moments and showing animations
- Extracting graphs (histogram and pie charts) and copying the numerical data to a spreadsheet for deeper analysis
- Creating RGB colour composites
- Creating band indices (band maths) (e.g. NDVI)
- Doing spatial analysis by doing flexible calculations involving more than one band.

The stable version of the map browser app can be found at: http://maps.ECOPotential-project.eu/. A development version, possibly with experimental functionalities, can be found here: http://www.ogc3.uab.cat/ECOPotential2

Please note that this browser is in continuous evolution, and that new datasets will be continuously included until the completion of WP4 in ECOPotential. Additionally, new analytical and visualization functionalities will be included in the browser until the end of WP10. Once ECOPotential project will be finished and since the map browser technology is a strategic product for CREAF-UAB group, other updates related to future projects could also be included, enriching the characteristics of the app.

The following subsections review the main functionalities of the map browser app with the main focus on the ones that has been developed specifically for the ECOPotential project.

3.1 Basic and specific concepts in the map browse. Status.

The browser interface consists in the following frames (Figure 2):

1. Location
2. Legend and layers (available and visible)
3. Current position value
4. Navigation buttons
5. Viewer
6. Area of interest (used here as Protected area selector)

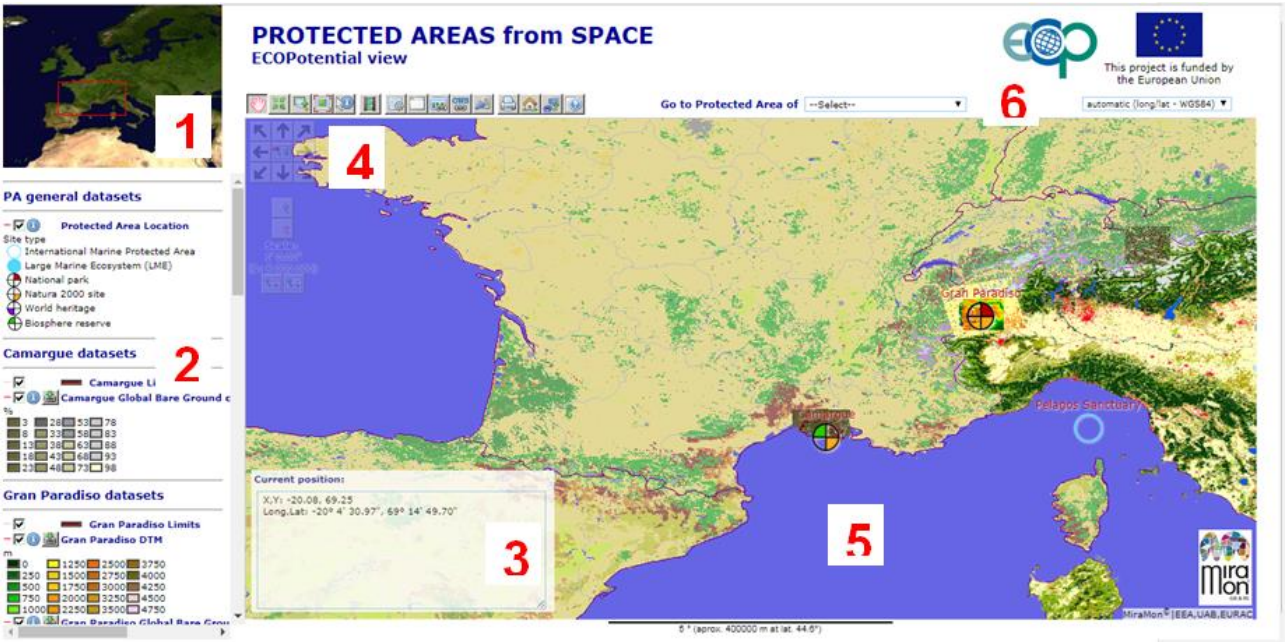
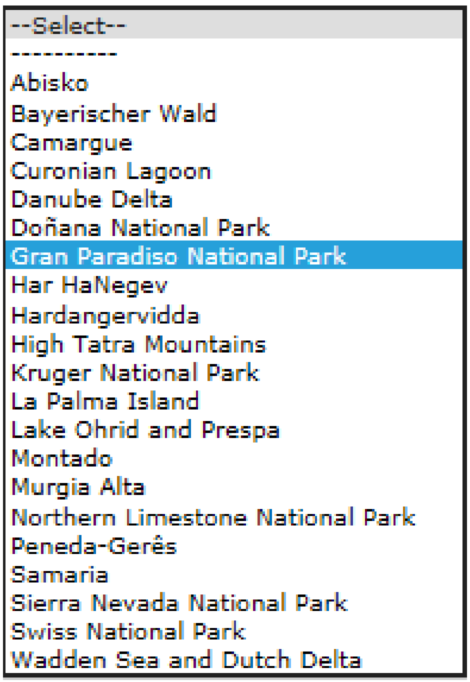


Figure 2. Element of the ECOPotential map browser app

3.2 General location

The location frame shows the whole area over which it is possible to navigate (location map). The area and position of the viewer on the location map is indicated by a coloured box. By clicking on the location map (outside the box), the viewer is relocated and centred on the point that was clicked on. By passing the cursor over the viewer, the projection coordinates and the geographic longitude and latitude are displayed in the coordinate's box.

3.3 Area of interest selection



This allows you to relocate the viewer over a given administrative area or a specific zone (e.g. a protected area in this case, municipality, region, hydrographic basin, etc). Normally, the first thing to do is to approach a specific protected area using a dropdown list that shows all available protected areas. Once this selection has been made, the viewer centers on the area where the object is located and the zoom is automatically adjusted to bring it into focus. After zooming into a protected area you will get the impression that you have a browser specialized in that protected area.

Once these two selections have been made, the viewer centers on the area where the object is located and the zoom is automatically adjusted to bring it into focus.

Additionally it is possible to position yourself over the desired area in any one on the following ways:

- By clicking on the location map and adjusting the zoom (with the buttons on the magnifying glass).
- By panning using the arrow buttons on the edges of the image and adjusting the zoom.

- By pressing the Center View button and clicking on the desired point of the view.
- By pressing the Window Zoom button and then positioning the window over the view.

As the browser window is of fixed proportions, it is not always possible to obtain the desired area exactly. In this case, it is possible to fall back on the same trick used by MiraMon Professional to obtain the right printable view. This consists in manually resizing the browser window.

3.3.1 Current position window

This frame shows the coordinates of the projection which are normally used in the study area and the geographic coordinates (longitude/latitude) of the position of the cursor over the viewer or over the location map. User can also copy this information to the clipboard being careful to not move the cursor, otherwise the coordinates will change.

In addition to the coordinates, the window is able to also show the values of the data active in the browser in real time only hovering over it (Figure 3):

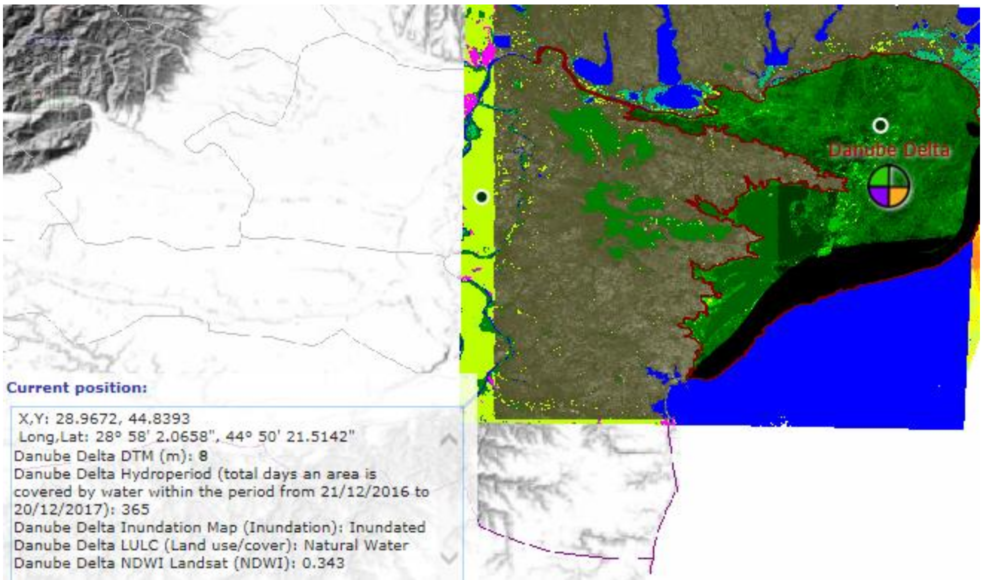
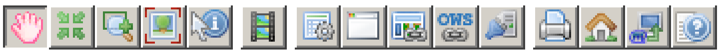


Figure 3. Current position window content depends on the content of the layers in the view.

3.4 Buttons



From left to right, the function of these 15 buttons is:

1. Pan view	2. Centre where click
3. Window zoom	4. New View
5. Query	6. Show animation
7. Options	8. Console
9. Link to map	10. Links to the servers
11. Add layers	12. Print
13. Home page	14. Install MiraMon Universal Map Reader
15. Interactive help	

More buttons area available in the map browser but has not been activated here to simplify the interface as much as possible.

The arrow buttons at the side of the viewer permit horizontal, vertical or diagonal movement over the layers. The magnitude of jump can be adjusted using the magnifier buttons to reduce or increase the zoom level.

Bottom buttons are used to go to a specific coordinate (left) or to jump to previous view (right).

User can also pass the cursor over the button and the description of each function will appear.

3.5 Viewing

The viewer displays the different layers activated from the legend.

By passing the cursor over the viewer, the projection and geographic coordinates appear in the coordinate box. It is also possible to execute the commands for centre view, window zoom and query by location by clicking on the viewer and depending on the status of the button bar.

3.6 Legend and layer control and its characteristics

The legend panel shows the list of layers available and a description of the categories of each layer. The legend allows you to control the status of the layer viewing, query and downloading options. There is no specific map browser for each protected area but a single and global browser for all protected areas. However, the browser has the capability to switch on and off layers that are not considered relevant because are not covering the current bounding box or the will be represented too coarse (limitation by scale) or are not available at the current projection. Layers switched off are shown neither in the view nor the legend. In summary, when you use the zooming tools to approach a protected area, only the layers available for this protected area are shown.

By default, too many layers are visible and you will have to switch them off leaving one on to familiarize with the data available.

The presence or absence of these layers depends on the degree of zoom selected. They are enabled or hidden with the check button ☑. Some polygon layers can be displayed semi-transparently by repeatedly clicking on the check button until it is displayed as: ☑. When the layer shows the plus (+) symbol on the left, this indicates that the layer categories are hidden and can be displayed in the legend by clicking on them. When the categories are displayed, the symbol – appears with which you can conceal the layer categories once again.

From the legend, this is the list of the main functionalities available (Figure 4):

- Switch a layer semi-transparent, on and off
- Select which datasets are queryable by location
- Change the visualization style of a layer
- Get information about the meaning of the colors
- Get metadata about the layer
    - By clicking in a layer name in the legend that is active in the view you will get a context menu with a metadata option if it is available. Sometimes the metadata is available at the style level and you will get by clicking in the style name.
- Download the data

- If a layer is downloadable, there is a small bottom next to the layer title that allows for downloading the data. In this map browser only full datasets can be downloaded.[1]

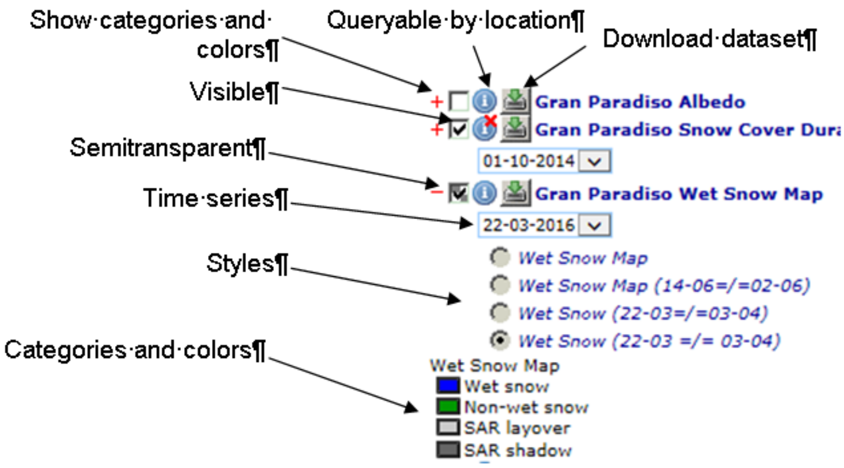


Figure 4. Structure of the legend of the ECOPotential map browser app

3.7 Managing the time variable in the map browser

In contrast with other map browsers you will not find a time slider in this browser[2]. Compounded by time series have a time drop-box with the list of available dates. Be aware that there is no time synchronization among layers and changing the date in one layer has no effect in the other time depended layers.

By pressing the “Show animation” button, the animation window is opened. It allows you to see the images which comprise the same temporal sequence in order, as if you were watching a video (Figure 5). The area loaded in the view is the one used in the animation. In the pop-up menus in the top part of the window you can choose the temporal series that you wish to see and its style.

Using the buttons in the bottom half of the window, you can control the animation (start, stop, pause, etc).

The images that make up the animation are shown in a horizontal strip in the bottom part of the panel. By selecting or clearing a check box you can enable or disable each image to include it in or exclude it from the animation (this is useful in series of satellite images in which some of the images may contain clouds).

[1] The capability of selecting a area of interest based on the current view bounding box is available in this technology but it has not been activated in this browser yet.
[2] This does not preclude that it could be incorporated in the future.

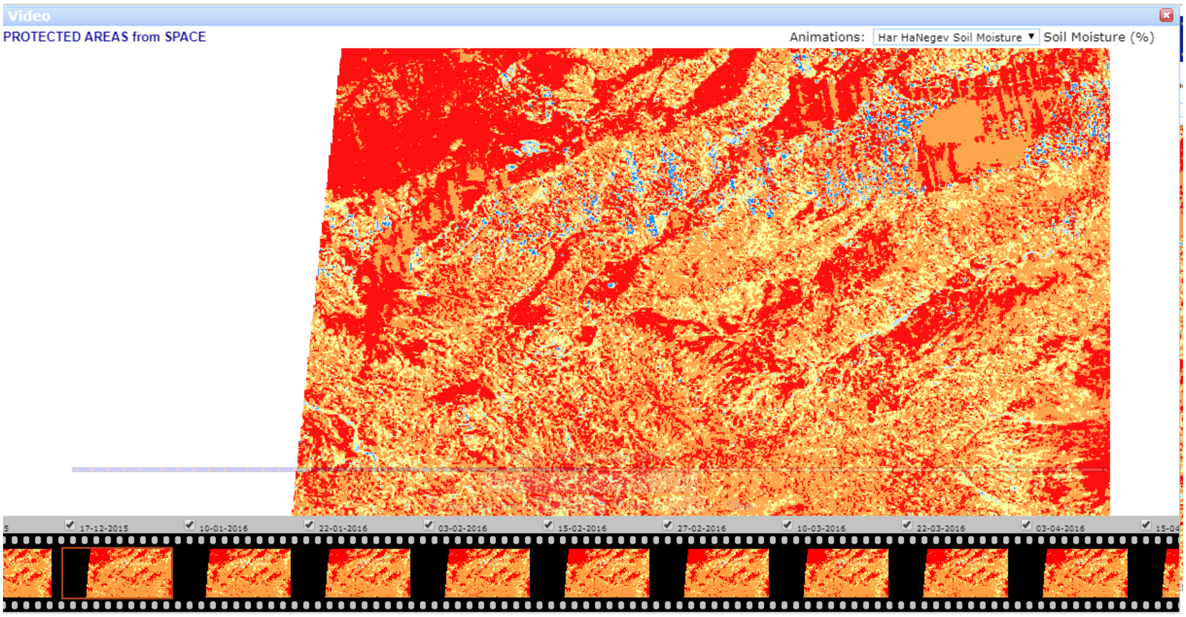


Figure 5. Animation window in the ECOPotential map browser app

3.8 RGB compositions

Usually users do 3 band composites to represent the response of such three bands in a single image. In the multiband layers it is possible to define a RGB combination by selecting 3 bands, one for each color (Figure 6).

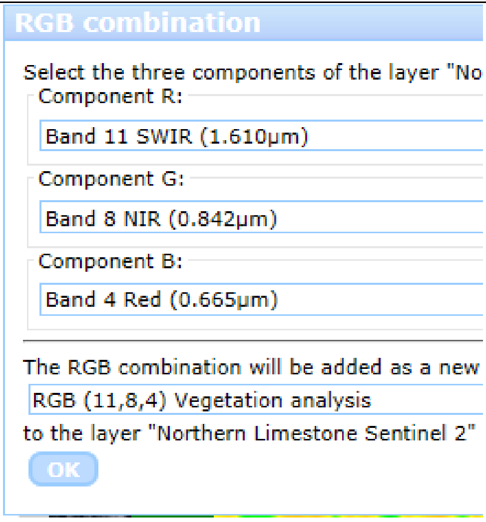
The most useful RGB combination of bands for Sentinel 2 are[3]:

Natural Colors/ True color: 4 3 2	Healthy vegetation: 8 11 2
False color Infrared: 8 4 3	Land/Water: 8 11 4
False color Urban: 12 11 4	Natural Colors with Atmospheric Removal: 12 8 3
Agriculture: 11 8 2	Shortwave Infrared: 12 8 4
Atmospheric penetration: 12 11 8a	Vegetation Analysis: 11 8 4

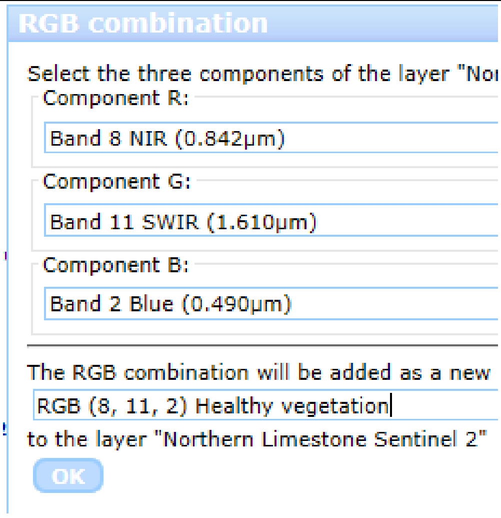
[3] (http://forum.step.esa.int/t/list-of-band-combinations-for-sentinel-2/1156) Note that RGB combinations are specific for each satellite. For Landsat 8 are:

Natural Color 4 3 2	Healthy Vegetation 5 6 2
False Color (urban) 7 6 4	Land/Water 5 6 4
Color Infrared (vegetation) 5 4 3	Natural With Atmospheric Removal 7 5 3
Agriculture 6 5 2	Shortwave Infrared 7 5 4
Atmospheric Penetration 7 6 5	Vegetation Analysis 6 5 4

Vegetation Analysis



Healthy vegetation



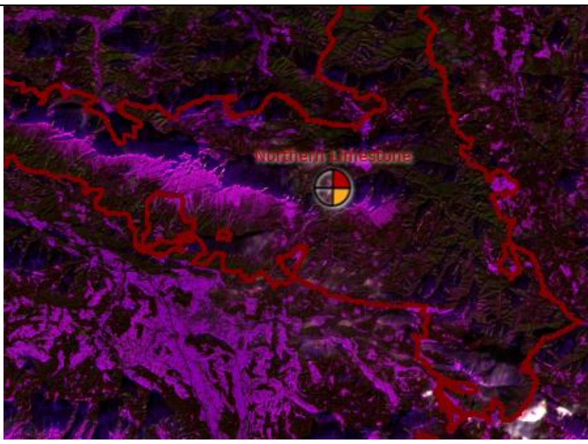


Figure 6. Examples of RGB combinations dynamically generated by ECOPotential map browser app

3.9 Retrieving information beyond visualization

3.9.1 Query by location

By clicking on the view a window emerges and detailed information about the position is shown only about the layers that are marked as queryable in the legend (Figure 7).

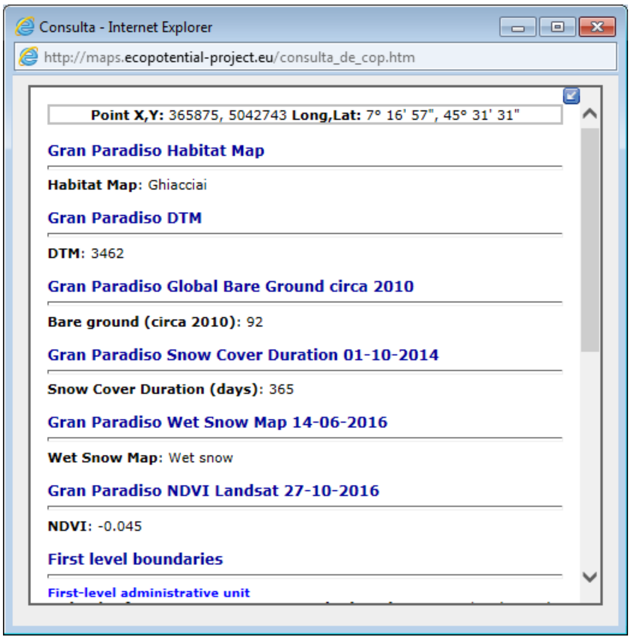
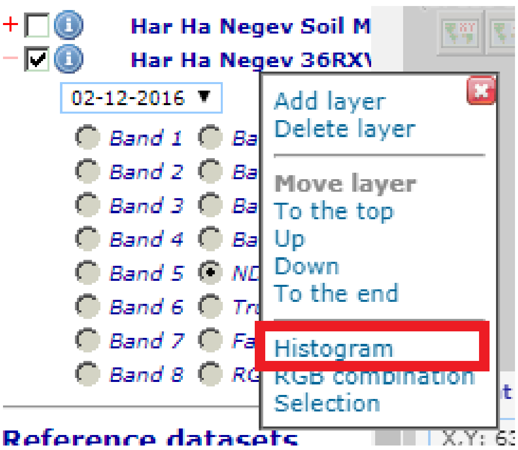


Figure 7. Query by location of a point in the screen

The information shown here is similar to the one shown in the current position window but it has the following differences:

- The user can select which layers are queryable (only the ones visible are shown in the "current position" window.
- External layers that are provided in a classical WMS server that are declared queryable are shown here (the current position only shows the layers that are requested as binary arrays)
- The information shown refers to all bands of a multiband dataset and not to the bands shown in the screen.

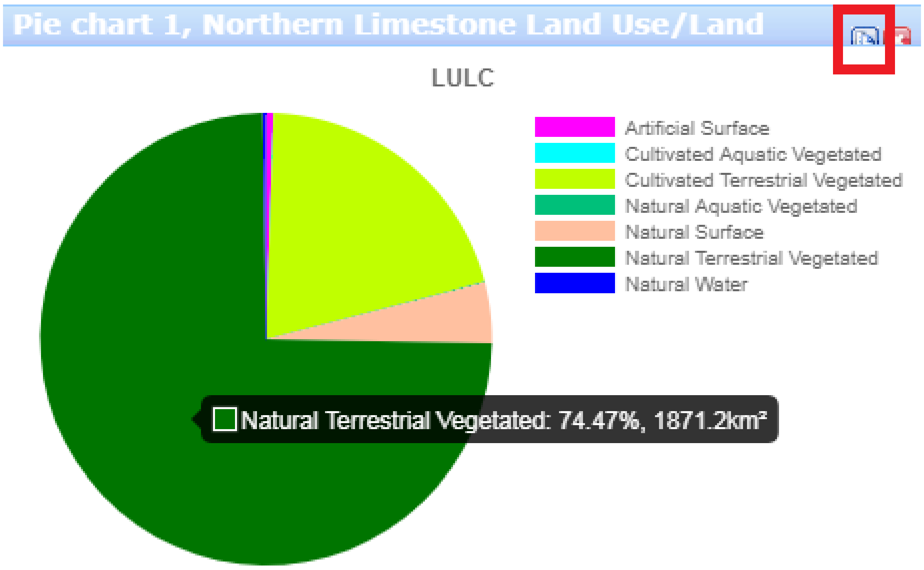
3.9.2 Statistics, histograms and pie charts



By clicking in a layer name in the legend that is active in the view you will get a context menu which includes the "histogram/pie chart" option. This will give you a graphical representation of the distribution of the values or categories seen in the current view (Figure 8). The platform permits to keep the histogram window open and frozen, and open additional histogram windows to be able to visually compare them.

The numerical values used to elaborate this graphic can be copied and pasted into a text file or spreadsheet (e.g. MS Excel) by using the small icon in the blue bar of the histogram window. Note that the clipboard information is enriched by statistics about these values (mean, standard deviation, range, etc).

According to the type of layer the graph displayed will be a histogram or a pie chart, for discrete or categorical data respectively.



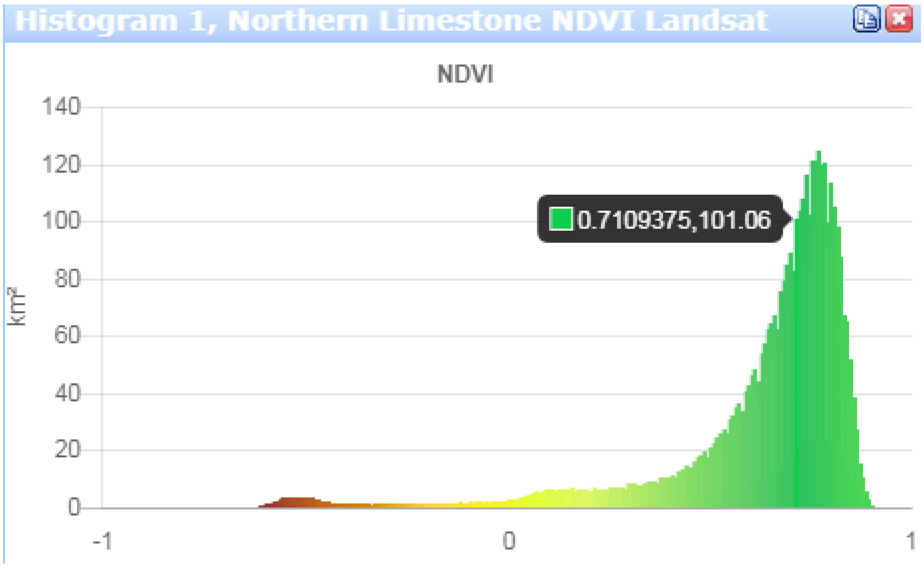


Figure 8. Histograms and pie charts can be requested for the current view

3.10 Analytical functions

The browser incorporates the capability to create new layers (or new styles for an existing layer) that are the results of an analytical expression.

IMPORTANT: please be aware that these calculations are performed at screen resolution. Layers and styles that result from a calculation are evaluated on the flight each time that the view changes by effect of a zoom or a pan. The results of these calculations (including statistics) are done at the screen resolution and the might change as a result of a zoom. Analytical functions provide a fast way to try and error your ideas and immediate results. Even if the results can be a reasonable approximation, when you are ready to take conclusions we highly recommend that you download the datasets and repeat the calculations at full resolutions with a GIS application to increase accuracy and reduce uncertainty.

3.10.1 Selection by condition

The app allows user to perform analysis such as determine distributions of variables in a given area. This can be made through the "Selection by condition" function (left click on a layer) (Figure 9). User will be able to select one of the layers visible at the moment and apply the conditions to be explored. The operators supported in the tool are 6 (=, =/=, >, <, >=, <=). Once the result is displayed as a new layer, data can be copied and paste to a spreadsheet and save it. An example of these types of selections is: “Determine the distribution of height inside Gran Paradiso National Park. In particular report the mean altitude and standard deviation”.

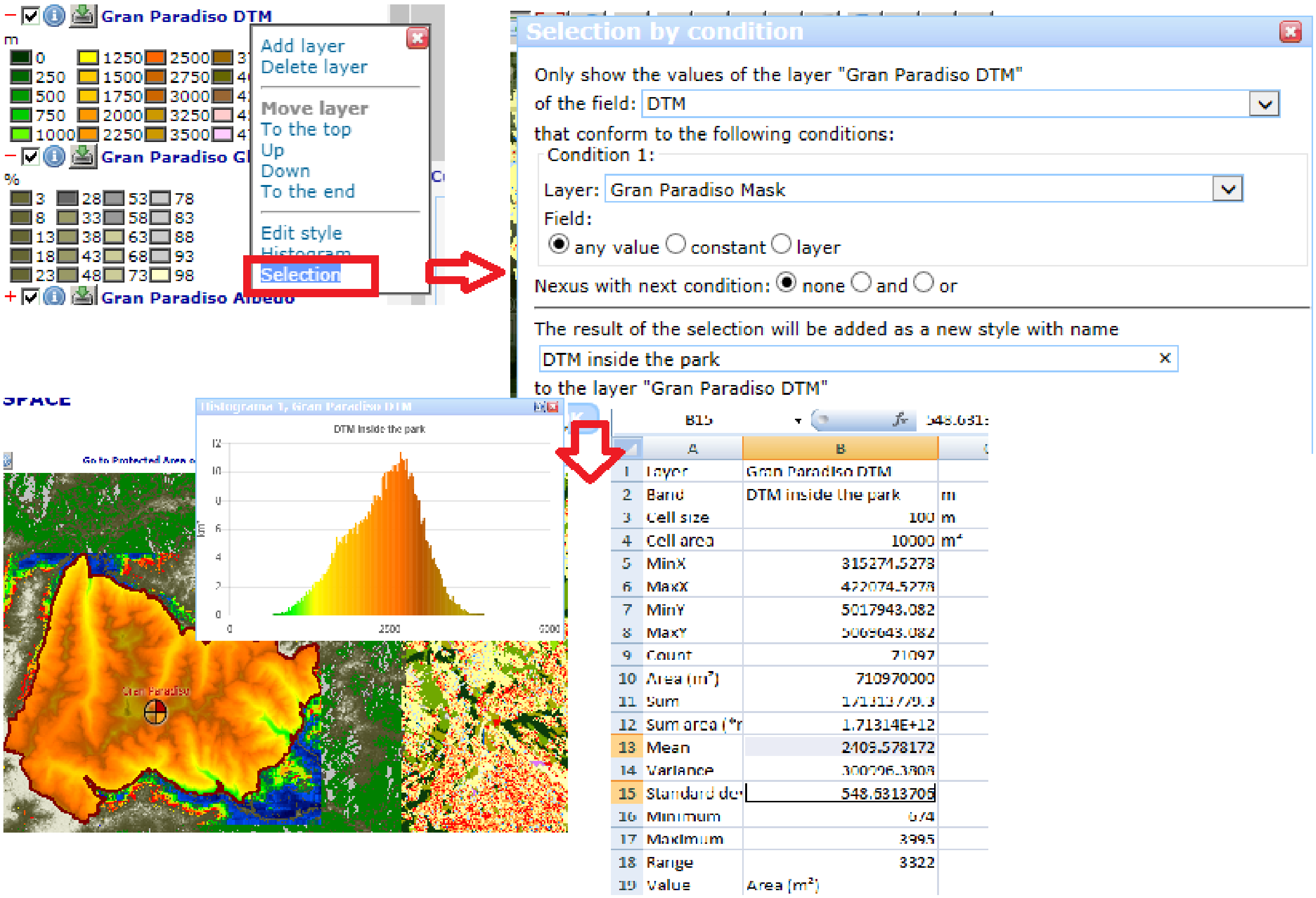


Figure 9. Selections by contention create new styles for a layer. Histograms and statistics can be extracted from any styles and in particular form the selections.

Additionally, the tool allows select by condition using more than one layer (Figure 10), and therefore, limiting the analysis to a previous selection. For instance: “Determine which habitats in Gran Paradiso National Park dominate the same range of elevations than “Formazioni erbose acidofile subalpine ed alpine”. In this case, the selection is done only for areas that belong to the condition specified by the user.

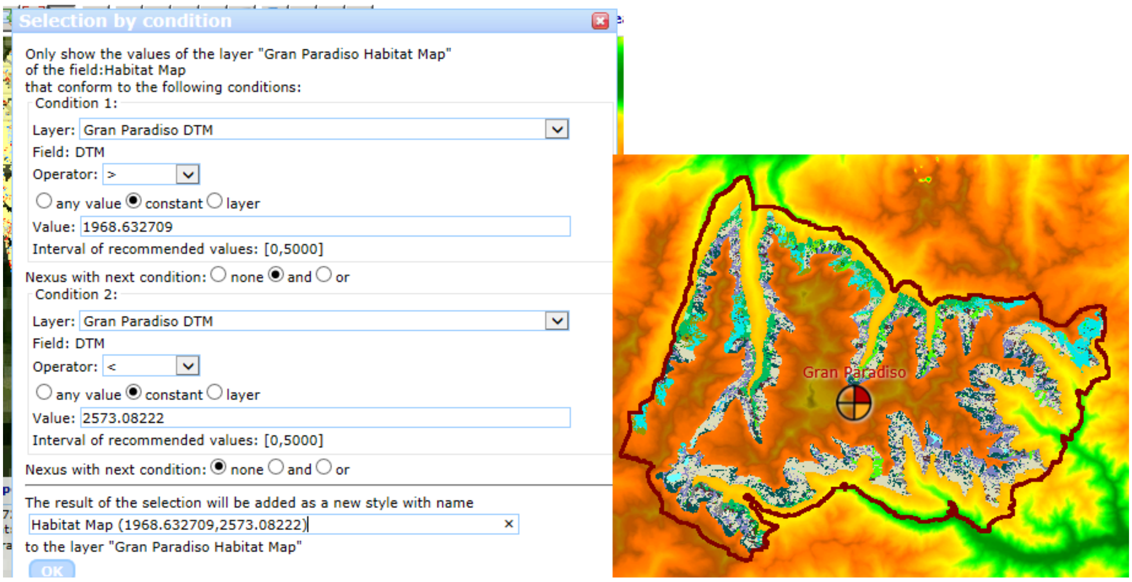


Figure 10. Selections can have more than one condition involving other layers

3.10.2 Identify differences between layers

The selection by condition tool also allows users to compare in-situ different layers and obtain the changes between them as a new layer. For instance, user can compute the difference of Non-wet snow over Gran Paradiso between two different dates (Figure 11).

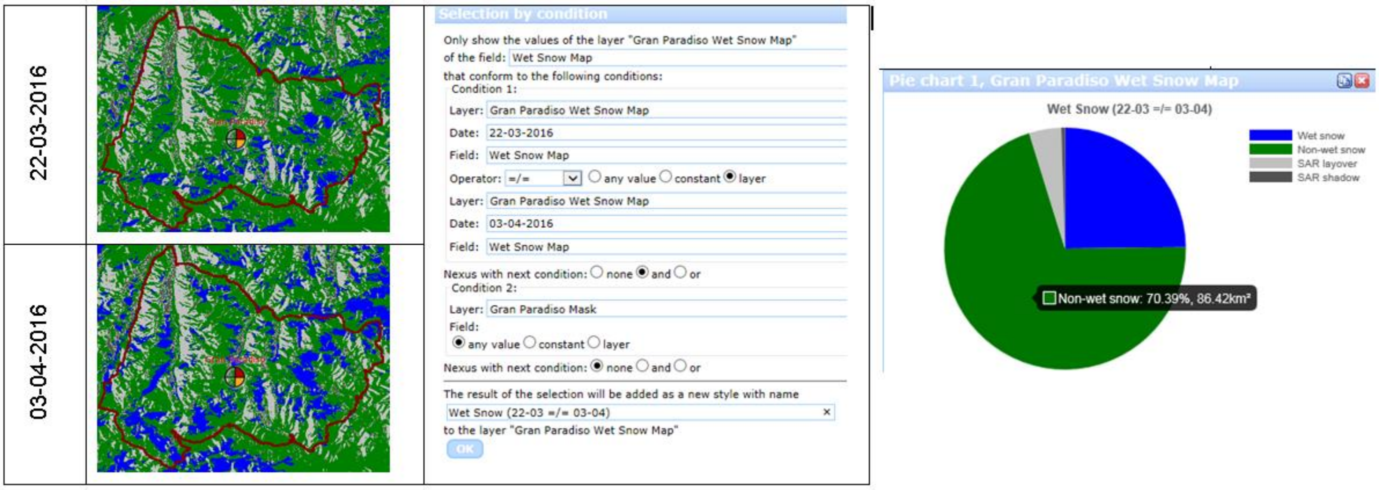


Figure 11. We can select what is different in time and know statistics of what have been lost or gained.

3.10.3 Layer calculator

The browser includes a layer calculator. A layer calculator performs the same operation than a scientific calculator but some of the numbers in the expression can be substituted by layers (Figure 12). The result of a calculation is a layer where each pixel is the result of the operational calculation of the original layer pixel values.

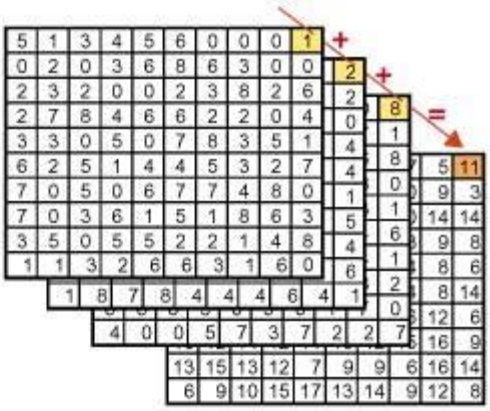


Figure 12. Layer calculator concept

One of the common applications of the layer calculator is the remote sending indices. The fact that the data used in remote sensing are the reflectance at some specific bands of the electromagnetic spectrum (i.e. frequencies) makes them most suitable for operations between bands. The principle of such operations is to perform more or less complex mathematical operations to enhance some spectral response that is characteristic of a given type of feature. For examples the Normalized Difference Vegetation Index (NDVI) enhances de difference between the infrared and the red bands that is useful for emphasizing active vegetation. Vegetation has a very singular spectral signature with a very marked peak in the near-infrared band and less reflectance in the red band[4](Figure 13).

Many specific indices may be found at web pages such as https://www.sentinel-hub.com/eotaxonomy/indices or https://www.indexdatabase.de.

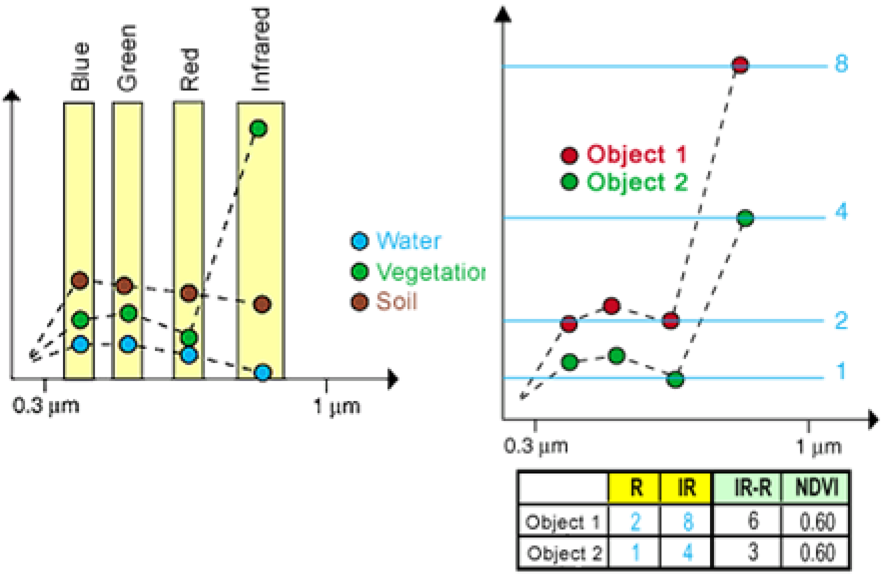


Figure 13 A layer calculator can be used to generate a NDVI index.

3.11 Screenshots

At any time is it possible to freeze a fragment of the view by using the camera button of the toolbar. After drawing the rectangle representing the Area of Interest, a new window with the same view will appear. Its content

[4] Illustrations from http://eoedu.belspo.be/en/guide/indices.asp?section=3.9. Explanatory video at: https://youtu.be/rxOMhQwApMc

is not changed and it can be move around (Figure 14). You can keep as many screenshots opened as you like. This is useful if you want to compare different layers, areas or times.

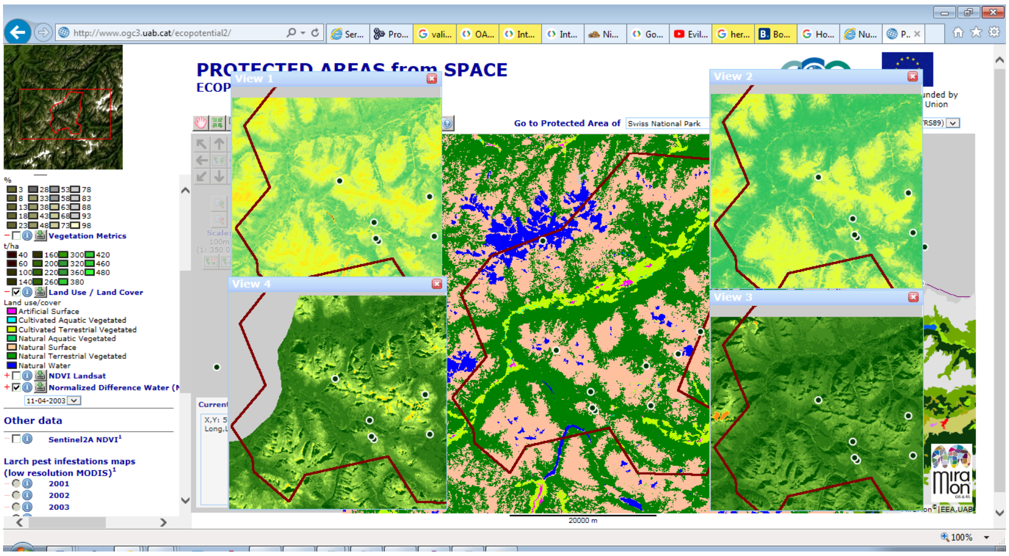


Figure 14. Screenshots can be used to illustrate changes in time

3.12 Metadata

An option in the context menu of the layer or the style called "metadata" opens a window with information describing the data in the ISO 19115 metadata standards following the INSPIRE profile (Figure 15). Actually the metadata has been elaborated with the INSPIRE metadata editor (http://inspire-geoportal.ec.europa.eu/editor/) and styled with a template specifically elaborated for ECOPotential (http://maps.ecopotential-project.eu/metadades/0_stylesheet/xml-to-html-iso.xsl)

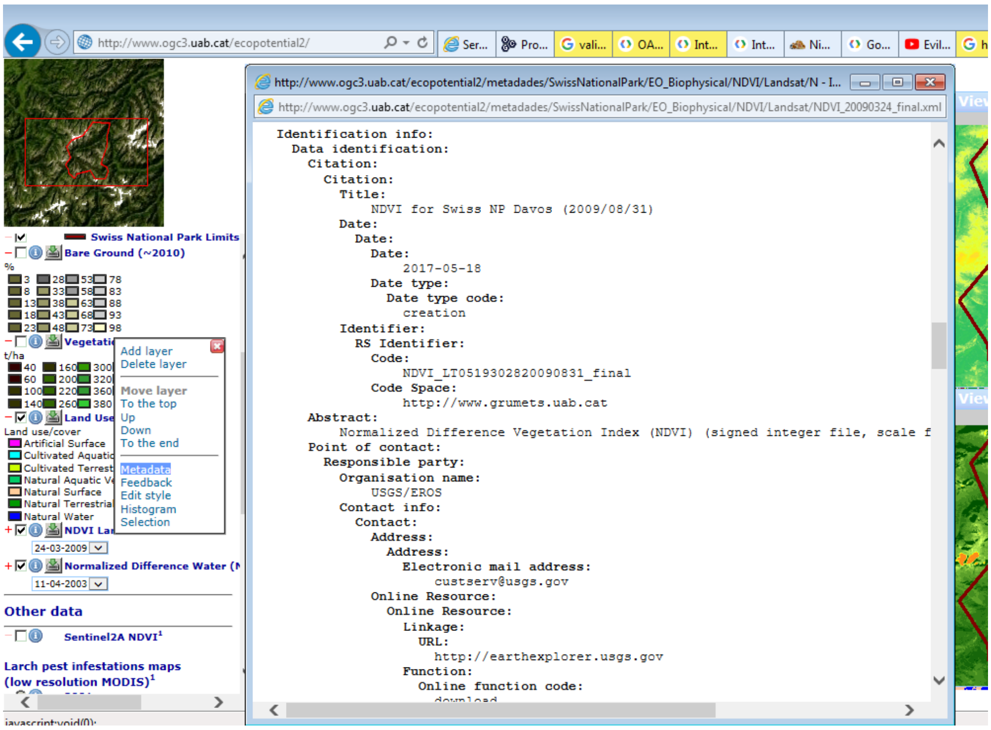


Figure 15. Metadata about an NDVI dataset

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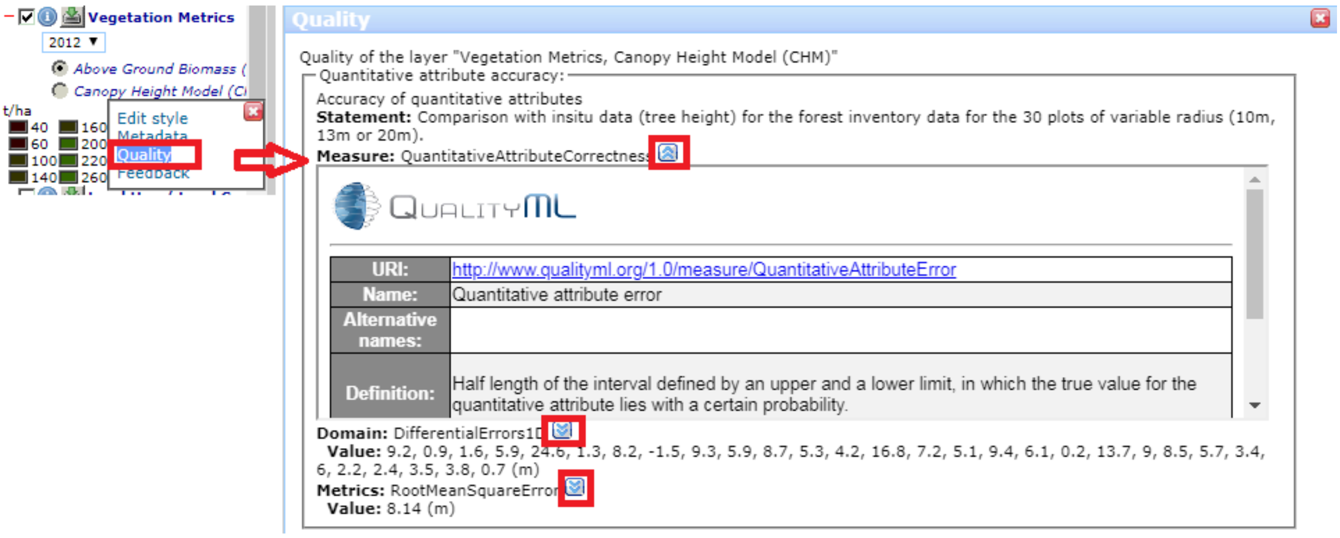
3.13 Data Quality

Data quality is available for those layers for which data quality has been provided by the producer. The app allows the producer to carefully document the data quality of a dataset using QualityML, as stated in the DoA Task 4.6. Essentially, producer can report the dimension of the data quality measured, the indicator used, the type of measurement done, the errors of uncertainties computed (the domain) and the statistical expression (the metrics) used to summarize it. User can access this information through the context menu: right click on the layer and selecting the option "Quality" (Figure 16). In the dedicated window, each attribute is linked to the corresponding QualityML reference by clicking on the double blue arrow.



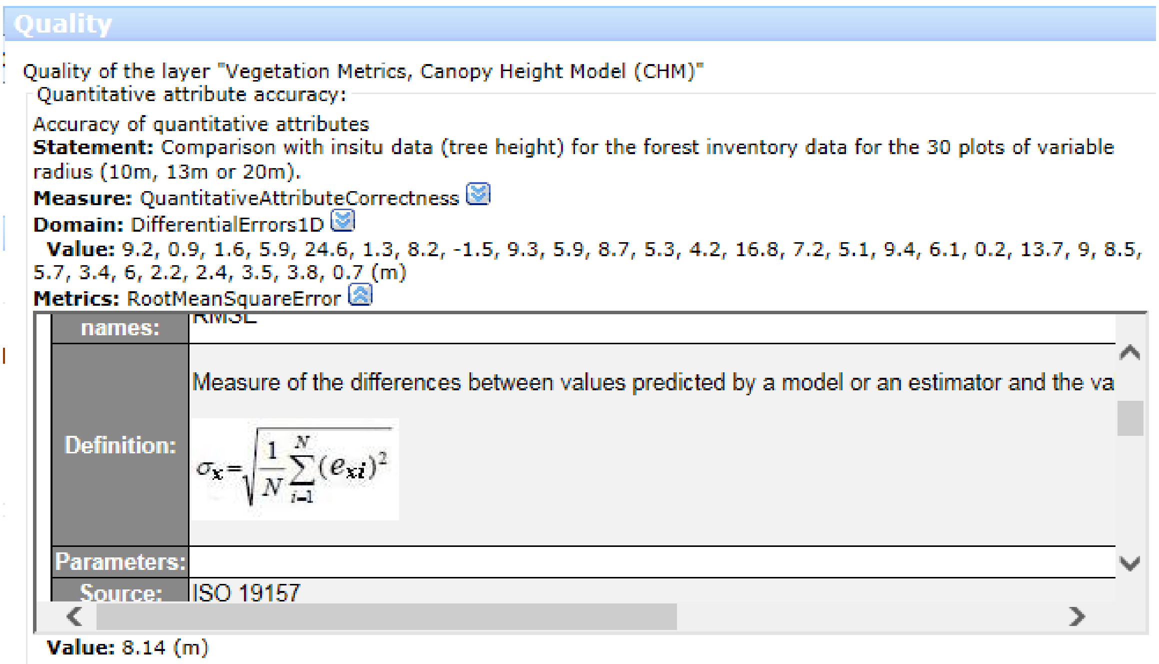


Figure 16. Data quality statements and indicators associated to QualityML

3.14 Geospatial User feedback - NiMMbus

We do our best to communicate with our users but sometimes mistakes or misinterpretations happen. In other cases, users may find something interesting to comment in the data or may have a question. For these reasons we have introduced a Geospatial User Feedback system. All layers can be evaluated by the users through the User feedback option (context menu, right click on the layer name) (Figure 17 and Figure 18). The user feedback is implemented through the NiMMbus solution developed in the context of H2020 NextGEOSS project. The system implements the Geospatial User Feedback (GUF) standard developed in the OGC www.opengeospatial.org/standards/guf (and started in the FP7 GeoViQua project). The user feedback allows to provide comments, ratings and questions associated to a given geospatial dataset, in this case, the selected layer.

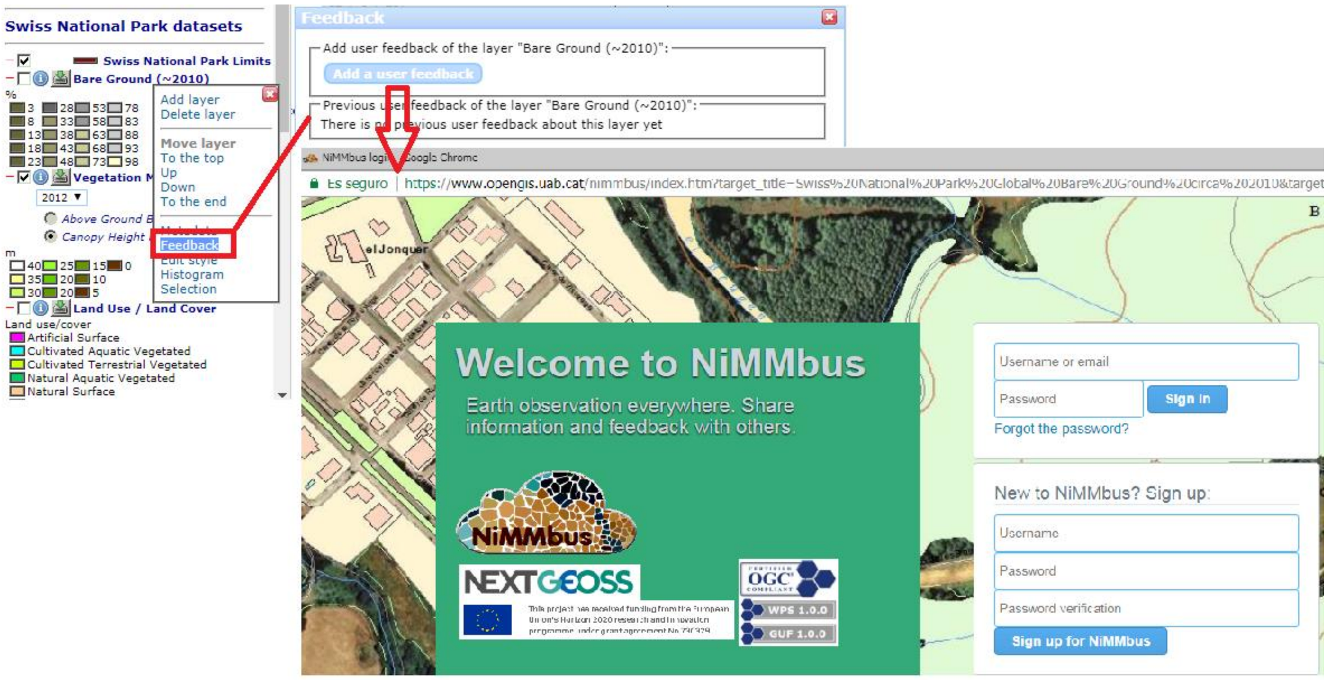


Figure 17. Adding new Geospatial User Feedback about a dataset

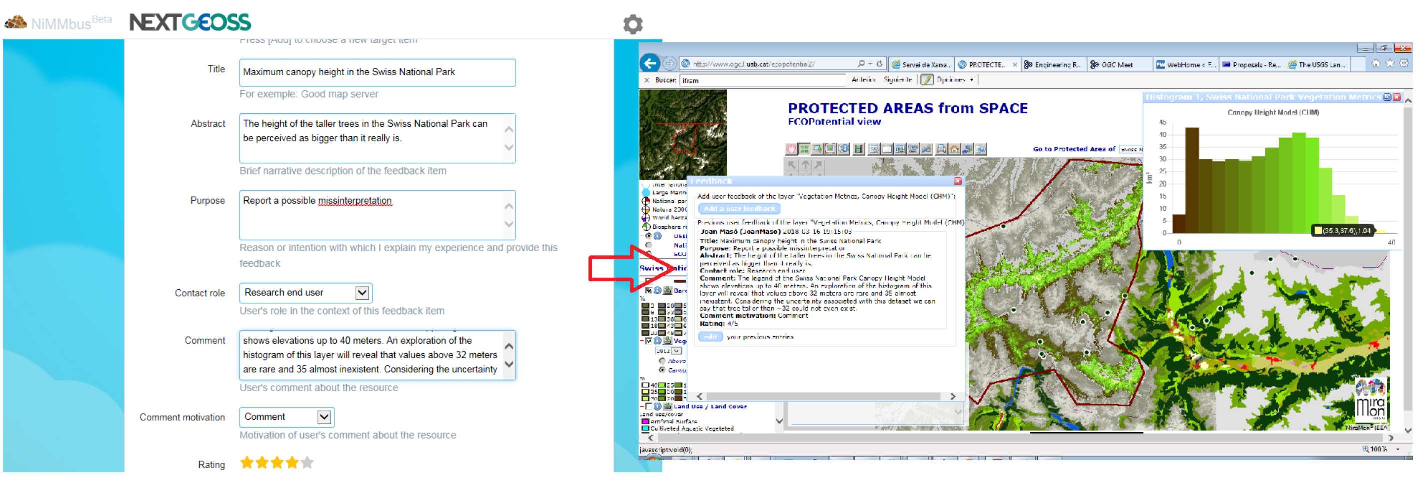


Figure 18. Showing Geospatial user Feedback about a dataset.

3.15 Configuration

When you press the Options button, this dialog box appears and allows you to configure a series of browser functions (Figure 19):

Width and height: These allow you to define the size of the viewer when the automatic mode (fill the window) is deactivated. If this option is enabled, the width and height values are resized so that the view fills as large an area as possible.

Magnitude of jump (Jump Perc): indicates the percentage of the image that moves when the movement arrows of the viewer are used

Coord: this allows you to configure different aspects of the coordinates that are displayed on the browser.

Number of figures: This is the number of decimal figures that is used to present coordinates.

Corners: allows you to configure the viewing format of the coordinates that appear at the corners of the viewer. This may be: any, determined by the projection, or in longitude/latitude. In the last case, it is possible to choose between decimal degrees or sexagesimal (degrees, minutes and seconds) degrees (º ' '').

Current: refers to the coordinates of the position of the cursor over the view or over the location map. This parameter allows you to configure the viewing format of the coordinate frame. In this case, the viewing formats may be determined by the projection, in longitude/latitude or in both. For longitude/latitude, it is possible to choose between decimal degrees or sexagesimal (degrees, minutes and seconds) degrees (º ' '').

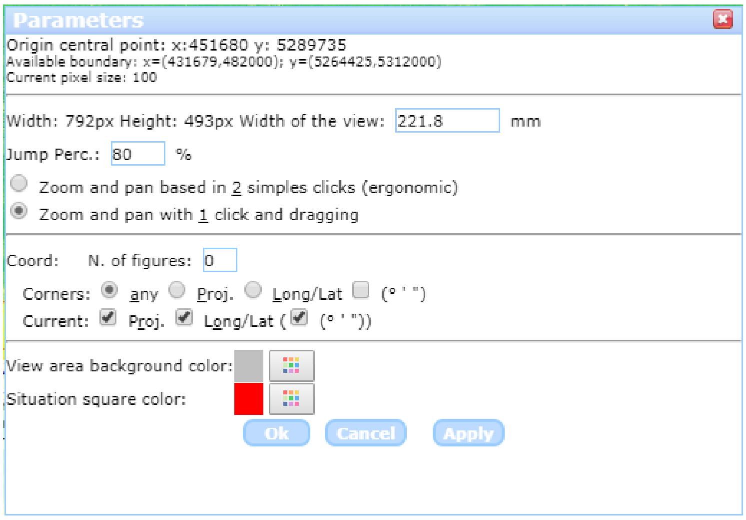


Figure 19. Map Browser configuration window.

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4. The Land Cover Classification System (LCCS) Mobile App

4.1 Introduction

Within the Earth Observation Data for EcoSystem Monitoring (EODESM) system developed through the EU Horizon 2020 ECOPotential Project, the Food and Agriculture (FAO) Land Cover Classification System (LCCS) is used as the basis for the classification of land covers and change as well as evidence-based change alerts from Earth observation (EO) data. The LCCS classifications of land cover and change are generated by combining both thematic and continuous environmental layers, which can be broadly associated with cultivated and managed lands, vegetation, urban environments, bare surfaces and water. Within each category, the information from the different layers is combined to produce comprehensive descriptions of land cover and, when temporal datasets are available, the individual components of the LCCS classes as well as environmental layers external to the classification are compared to generate maps of change events and processes.

The aim of this project was to develop a mobile application (App) that could be used to support the EODESM system by validating classifications of land covers and change for any location and assisting the development of algorithms for retrieving environmental layers (e.g., soil moisture, above ground biomass) and assessing uncertainty.

4.2 Background

4.2.1 The FAO Land Cover Classification System (LCCS-2)

The FAO LCCS-2 consists of a dichotomous and modular hierarchical phase (Figure 20). The dichotomous phase consists of three levels, with these discriminating between primarily vegetated and non-vegetated (Level 1), terrestrial and aquatic covers (Level 2) and cultivated and managed and (semi) natural vegetation and natural or artificial bare surfaces and water (Level 3). The modular hierarchical phases then provides more detailed information for each of these categories based on a range of thematic and continuous variables. As an example, vegetation is described on the basis of life form, canopy cover, canopy height, leaf type, phenology and the number of layers, including the structural characteristics of these (Figure 21). Additional information can also be included, such as plant species composition, biomass (Mg ha-1) and Leaf Area Index (LAI, m2 m-2). As an example, a forest stand can be described as “Continuous tall (14-30 m) broad leaved evergreen trees with a closed canopy (>70-60 %) and a 2nd layer supporting an open canopy that is 7-3 m in height”, with this obtained by combining the codes in a sequence (i.e., A3.A10.B2.C1.D1.E1.F2.F9.G7). By generating and/or referencing other layers, additional descriptors such as biomass (e.g., 125 Mg ha-1), dominant species (e.g., Quercus or oak) and LAI (e.g., 3.2 m2 m-2) can be also included.

4.2.2 Detecting change in LCCS component categories and environmental variables

The EODESM system detects change by retrieving the different layers from EO data for one period (Period 1) in time (a baseline) and combining these to automatically generate spatial representations of the LCCS classes (Figure 20). This is then repeated for a nominated second period (Period 2) that is time-separated by hours, days, weeks, years, decades or simply satellite observations (e.g., every 16 days for the Landsat sensors). Change is then detected by comparing both the LCCS component codes but also environmental variables that are measured to defined units such as metres (e.g., height, depth), percentage (e.g., cover) and time (e.g., starts and ends of leaf fall, flowering or crop management). The change event or process is then determined on the basis of evidence from these different sources and these are then used to create change alerts (e.g., deforestation activity) or monitor longer-term processes such as forest growth or dieback.

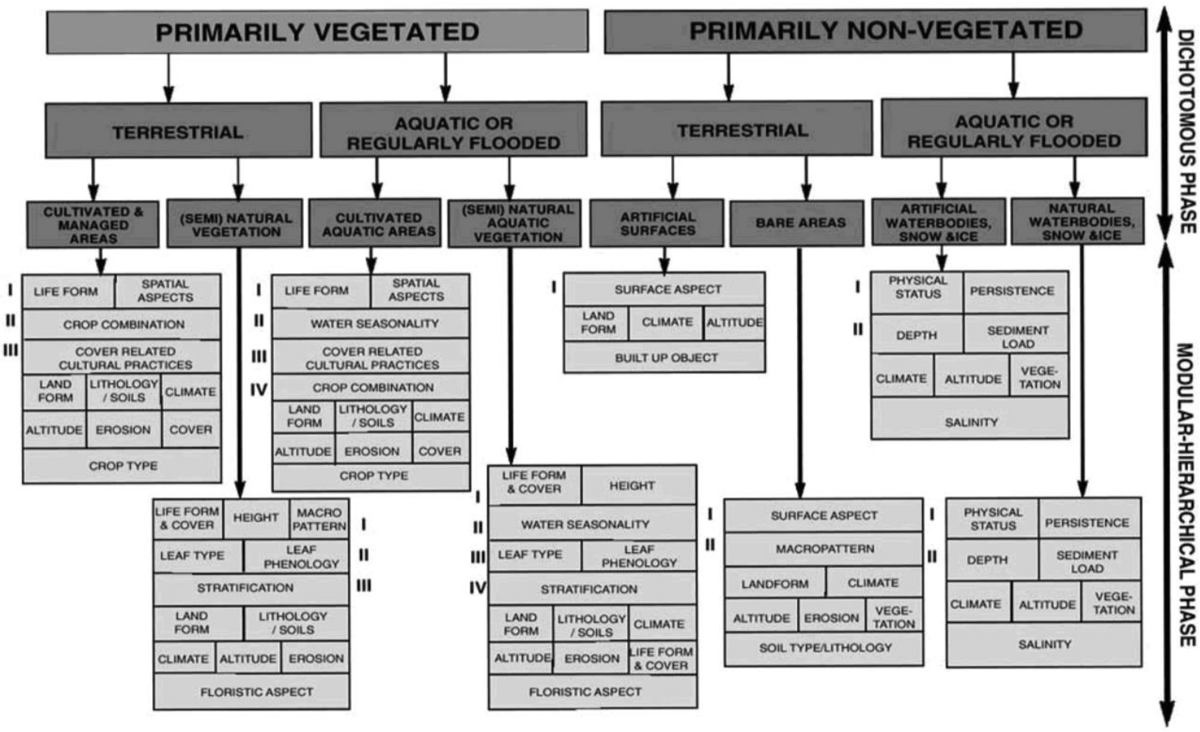

Figure 20. The FAO LCSS-2 taxonomy

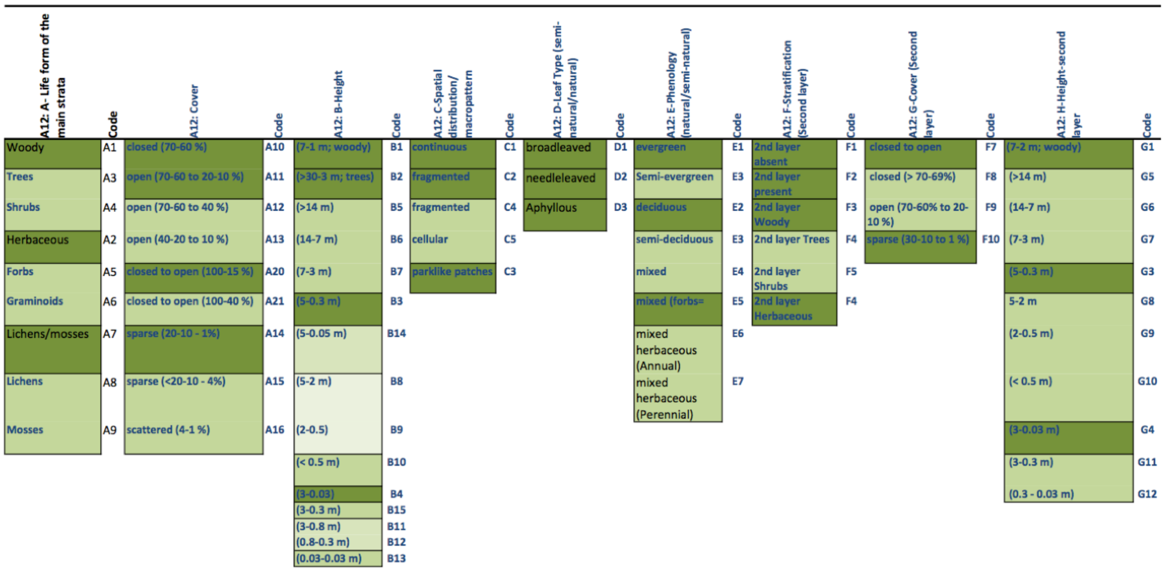

Figure 21. An example of the layers used within LCCS-2 to classify vegetation

4.2.3 Mobile applications

A wide range of mobile applications are available to support the collection of field data, with these including FieldGB, ArcGIS and Cybertracker. The Open Data Kit (ODK) has also been developed and has been adopted by Australia's Terrestrial Environment Research Network (TERN) in collecting a diverse range of environmental information. These application allow for in-field recording of thematic and continuous information but also delivery (in near real time or on return to a home base) to a centralised storage.

4.3 Study areas

The study focused initially on protected areas associated with the ECOPotential project, with these located across Europe but also including South Africa (Kruger National Park, NP) and Israel (Har Negev NP) (Figure 1). However, initial trials were undertaken for the Camargue NP (France), Doñana NP (Spain) and Murgia Alta (Italy) and Hardangervidda (Norway).

4.4 Methods

4.4.1 LCCS App development

The mobile application for collecting land cover information was developed in conjunction with TERN AusCover (Peter Scarth, University of Queensland) and examples of the interface are provided in Figure 22. The code was written such that the sequences of steps followed in the LCCS were mirrored with no modification. Additional information such as dates, times, recorder name and position (determined through access to Global Positioning System (GPS) data with pre-determined accuracies. Photographs for the different LCCS categories were also uploaded to guide the users. Instructions for downloading and using the App are provided in Box 1 and these are still valid for current use.

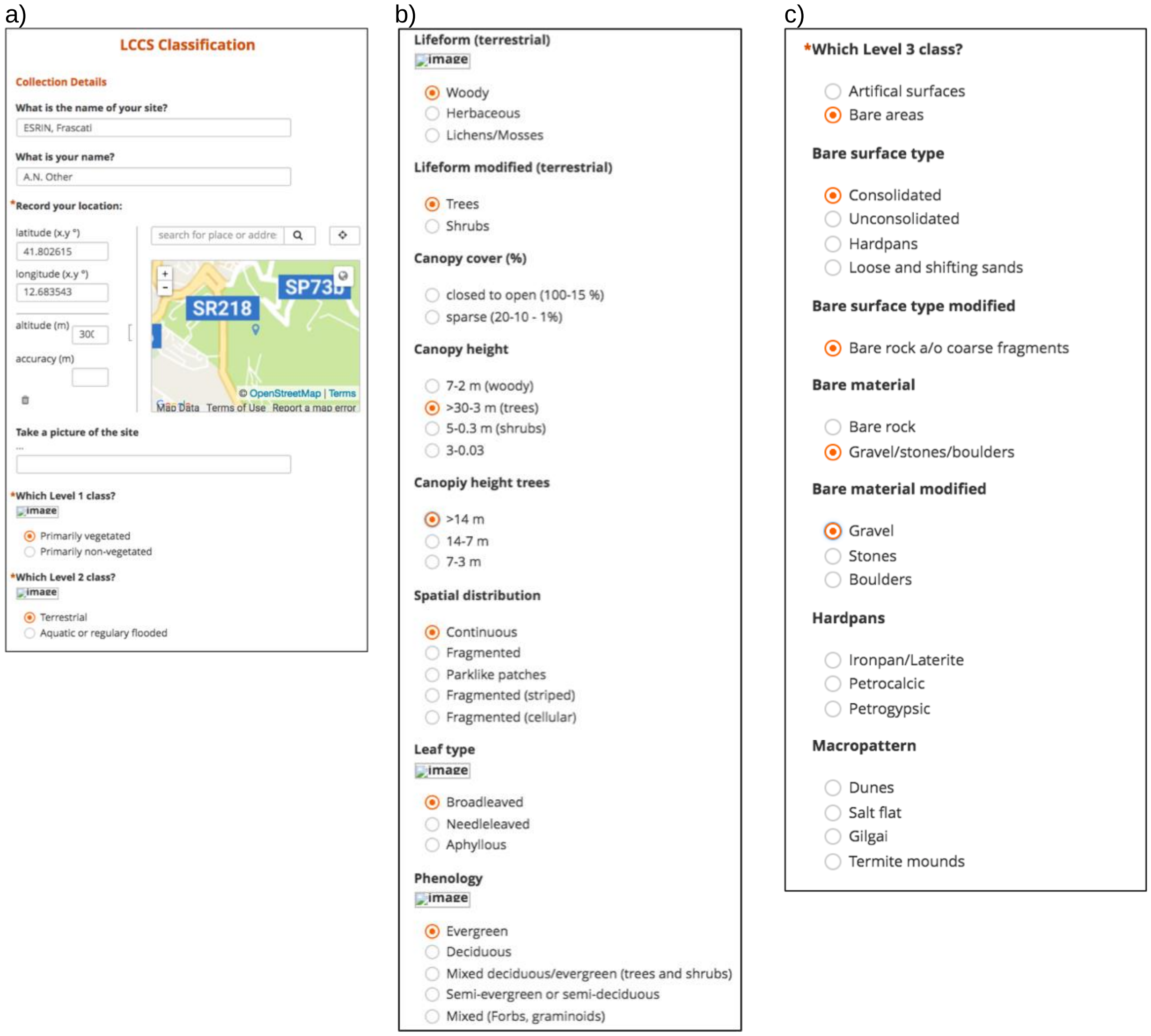

Figure 22. The LCCS App interface showing a) the front page and initial classifications of LCCS Level 3, b) lifeform categories and c) bare surface categories

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4.4.2 Trialing and data collection

Following development, the mobile application was trialed in Australia, Greece and the UK and was validated by CNR - Institute of Biosciences and BioResources (Valeria Tomaselli). This same group validated the maps in Murgia Alta (Italy) and this was followed by similar field campaigns in the Camargue, Doñana and Hardangervidda (Figure 23). The collection was undertaken by professional scientists and land managers associated with the protected areas. Additional data were collected from sites that were used to simply trial the App, with these including Africa (Senegal, Tanzania) and Australia. Data were collated within a centralised ODK database (landcover-app) from which comma separated values (.csv) and keyhole markup language (.kml) files could be downloaded.

Box 1: Instructions for downloading the mobile App.

If you have an android phone, install ODK Collect Version 1.4.16

Download from Google Play

- From your device's application drawer, choose the Play Store.
- Search for "ODK" and choose "ODK Collect" from "Open Data Kit".
- https://play.google.com/store/apps/details?id=org.odk.collect.android
- Select that result and click the Install button. Click OK after viewing the security settings.
- Open the application
- Go into 'General Settings' by pressing the option button on your phone (on phone try button lower left of home button - main button) and selecting 'General Settings'
- Click Configure platform settings
- Under 'URL' connect to the server using this web address: *https://land-cover.appspot.com*)
- Username: rscDataUser Password: tlsIsCool
- Select autosend (does automatic upload - optional) OR upload manually.

Before going into the field, select “Get Blank Form” which will show every form that is available.
Get the LCCS form (LCCS Classification V2; select OK).

Then when in field “Fill Blank Form” and go Start GeoPoint. You need to wait for the accuracy to be < 5 m. Note that you have to get a GPS reading before taking the picture. When you get your reading (on Android) select the arrow pointing to a small circle.

Submit your data and we will provide a summary of what you have collected.

You can change the version in settings and upload the new xml with new form ID (e.g., Version 2) and then turn downloadable for the old form (so one form at a time).

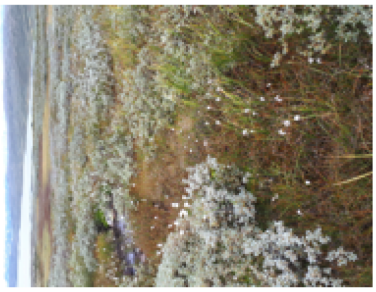
a)

start	Fri May 26 09:16:11 UTC 2017
site_details:siteName	AAlta Murgia
site_details:observer	Giuseppe
location:Latitude	40.89044618933313
location:Longitude	16.459520712605936
location:Altitude	525.6013544853777
location:Accuracy	5.0
site_details:image	View
level_1	isVeg
level_2	terrestrial
level_3	seminaturalTerrestrial

b)

start	Mon Aug 14 09:19:30 UTC 2017
site_details:siteName	EMSC 05
site_details:observer	SON
location:Latitude	43.39192306
location:Longitude	4.61909112
location:Altitude	56.0
location:Accuracy	4.0
site_details:image	View
level_1	nonVeg
level_2	aquatic
level_3	naturalWater

c)



start	Thu Aug 24 13:27:02 UTC 2017
site_details:siteName	Hardangervidda
site_details:observer	Tessa Bargmann
location:Latitude	60.35004842095077
location:Longitude	7.900119675323367
location:Altitude	1266.800048828125
location:Accuracy	4.5
site_details:image	View
level_1	isVeg
level_2	terrestrial
level_3	seminaturalTerrestrial

d)

start	Wed Apr 05 09:52:08 UTC 2017
site_details:siteName	Doñana
site_details:observer	Fran Ramirez
location:Latitude	36.991972225
location:Longitude	-6.516954082
location:Altitude	90.35567474365234
location:Accuracy	4.0
site_details:image	View
level_1	isVeg
level_2	terrestrial
level_3	seminaturalTerrestrial

Figure 23. Photographs and Level 1 to 3 classifications of locations in a) Murgia Alta, b) Camargue, c) Hardangervidda and d) Doñana NPs in Italy, France, Norway and Spain respectively. Note that the surveyors recorded the actual location where they were standing and these photographs represent the landscape view

4.5 Results

4.5.1 Field campaigns

During 2017, LCCS field data were collected from 710 locations, with the majority located in Europe (Figure 24). Additional data were collected in early 2018 and are ongoing, Recordings were mainly from vegetated areas (Table 1), which dominated the protected areas of the Camargue, Doñana, Hardangervidda and Murgia Alta. Many of the records for cultivated areas were from Wales.

Figure 24. The location of field campaigns using the LCCS App. Additional locations were also visited by partners' trialing the App

Table 1. The number of thematic categories recorded at 710 sites distributed primarily in Europe

LCCS Category	Number of records
Cultivated/Managed	954
(Semi) natural vegetation	4000
Artificial surface (urban)	63
Bare surface	91
Water	316
TOTAL	**5424**

4.6 Discussion

4.6.1 Uptake and use

The LCCS App was made available to several ECOPotential scientists and land managers and basic instructions were provided. The App was quick to install (typically < 10 minutes) and data were able to be collected immediately thereafter. Once the sequence was completed and the data were submitted, these were uploaded to the central ODK store within 5 minutes. Directions for changing location and collecting further field data were able to be phoned through to the surveyor with an instant response, with this demonstrating the capacity for remote planning, organisation and implementation of field surveys in any location worldwide and from any location.

4.6.2 Consistency of classifications

For all sites, a consistent classification of land covers was obtained as all surveyors followed the LCCS2 taxonomy. When each button was pressed on the LCCS App, this led also to the provision of data that could be used to validate the EO-derived LCCS classification obtained for each site and for all sites combined. In effect, this provided the potential for local to global validation of the classification and identification of areas where EODESM performed well or where further improvements could be undertaken.

4.6.3 Improvements

Several improvements to the LCCS App are being considered, with these including:

a) Shortcuts that allow population of LCCS codes on submission of a generic description. As an example, an arable field would automatically be associated with the accumulated LCCS Level 3 category of a vegetated terrestrial cultivated/managed land cover.
b) Repeats, that allow access to previous assignments.
c) Inclusion of actual physical measures (e.g., canopy cover %) alongside the LCCS category (e.g., open (70-60 to 40 %).
d) Selection based on images rather than text.
e) Further development of modules relating to change categories (e.g., deforestation, ploughing) and translation to other taxonomies.

These will be provided as regular updates to the App to ensure that improvements are continual.

4.6.4 Modular development

The EODESM system uses both the LCCS Taxonomy and environmental variables (and changes in these) over defined time-separated periods. The environmental variables are used both in the classifications (e.g., as descriptors of canopy cover and height, size of unconsolidated bare surface materials) and external to these (e.g., soil moisture and acidity, foliar chemistry, above ground biomass). These latter variables require *in situ* measurements across a range of landscapes but, in all cases, a land cover recording can be made prior to collection. Hence, the LCCS App will be developed to as a modular system (renamed as the EODESM App), with this allowing a range of environmental variables to be collected subsequently. A broad overview of this approach is provided in Figure 25.

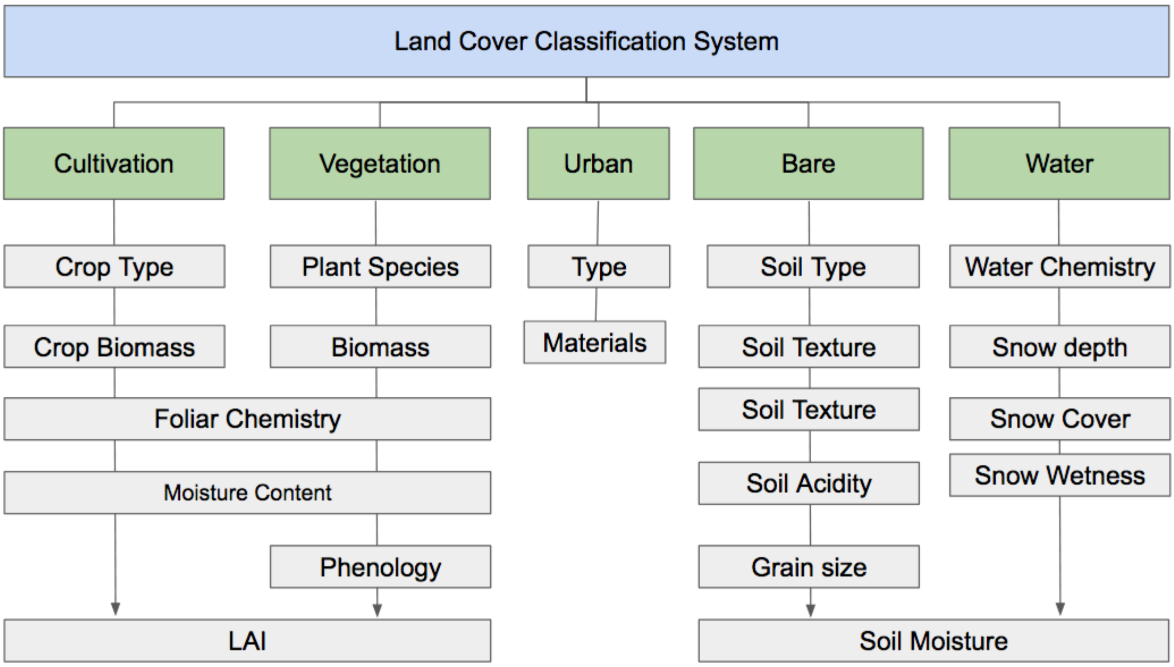


Figure 25. Overview of the proposed modular system for the EODESM App

5. Future work

5.1 Integrate the *Protected Areas from Space* map browser app in the ECOPotential VLAB.

The following sections describe a potential approach to the integration of the Protected Areas from Space (PAfS) as an app for the ECOPOtential VLAB providing access to DEIMS catalog and other information.

5.1.1 Provide a WMS endpoint for the Virtual Laboratory runs.

The second release of the ECOPotential VLAB is offering the results of models as a downloadable file or as an overlay on a map viewer. Currently, the provided map browser is a simple interface that permits to view the result overlaid with some common base map such as, Google maps or OSM maps.

In order to get the advantages of the PAfS functionalities we propose to make the model output accessible to the PAfS Map Browser. That can be simply achieved by making the VLAB data and products accessible with the WMS interface in EPSG:4326 (and eventually the UTM projection of each park) supported by the PafS browser. By doing so, the VLAB data and products will be immediately visible in the PAfS Browser. This has the advantage that users can see their results combined with the other remote sensing products.

5.1.2 WMS endpoint of the Virtual Laboratory runs in IMG format

If the VLAB was able to support the IMG format, VLAB model output would not only be visible but also would be available for further analysis in the PafS browser. The support of IMG format with no compression could be implemented using the right GDAL library that is able to produce RAW data with no headers as a result. The Run-length encoding (RLE) support would require an extra development.

5.1.3 Using the GetCapabilities of the MiraMon Map server as a catalogue

CNR-IIA is the organization responsible of the design and development of the ECOPotentialVLAB, but also of the Discovery and Access Broker (DAB). Currently, the ECOPotential VLAB includes a DAB instance to support harmonized discovery and access to heterogeneous in-situ and remote sensing datasets. While the data query is not supported by the VLAB interface, it will be provided in the third release of the VLAB (expected on June 2018).

We propose that CNR-IIA brokers the FTP data source (data from FTP and from WMS service) through the WMS GetCapabilities operation provided by the PafS WMS server. A prerequisite is, of course, the provision of metadata by producers of data and products stored in the FTP server.

5.1.4 Using the *Protected Areas from Space* WPS processing client to start VLAB processes.

The MiraMon map browser was used in the past to execute WPS processes. The client supports WPS 1.0 but does not expose it for the *Protected Areas from Space* map browser. The support for WPS is NOT implemented in a general way but requires the definition an interface for each process.

It should be possible to adapt the current interface and use the VLAB API instead of the WPS interface. This way, the virtual lab could be called from the map browser.

5.1.5 Using the MiraMon WMS Server as data source for the VLAB

The use of a WMS with IMG images allow for using them as inputs for the processing. The advantage of this is that the process can be easily executed using low resolution imagery to obtain a first preview of the results before spending the time required for processing the whole dataset. Alternatively, the WMS can be used to generate a small portion of the high resolution data allowing for checking the detailed results of a small region before spending the time required for processing the whole dataset. This integration would require the support of WMS/IMG format in the DAB instance provided in the ECOPotential VLAB.

5.1.6 Complete integration of the Map Browser and the VLAB.

The combination of some of the steps described above could achieve the complete integration of the VLAB and the PAfS map browser. Figure 26 shows the different mechanism that we are considering achieving the full integration.

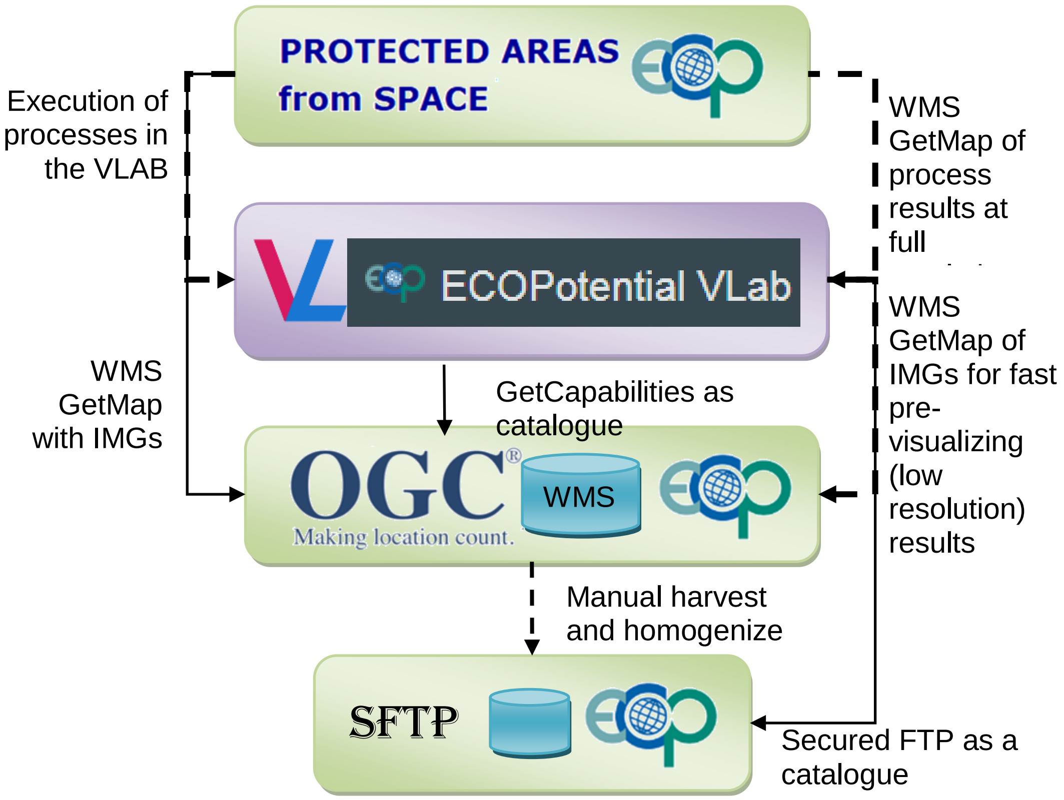


Figure 26. Data sources, map browser and virtual lab integration diagram

5.2 Adding new processes in the VLAB

5.2.1 Preparation of a sentinel 2 image covering the protected area

One of the main problems with the ESA sentinel data hub is cutting and mosaicking the scenes the sentinel 2 images for each protected area. We suggest developing a simple process that takes 2-4 scenes of the sentinel data hub and creates a mosaic.

Inputs:

- The protected area border (already available in the FTP). Could be selected from a list
- A date
- The percentage of admissible clouds
- The preferred orbit

Output

- A zip file with all the bands of the date that is closer to the requested one mosaicked.

5.3 Integrating EODESM source datasets as layers in maps browser

The EODEMS software requires the preparation for several layers that can be useful for the protected areas. The preparation of this datasets is a tedious manual process that has been mainly done by Richard Lucas for each protected area. Most of this datasets are already prepared in the ftp as KEA files. The idea is to incorporate them as layers in the map browsers and then show the result of the result of the EODESM run. It will be a very practical way to show how the EODESM works in practice.

6. Conclusions

The web app is a map browser that allows the visualization, analysis and download of all datasets elaborated in WP4 in addition to the DEIMS sites in WP5. The full integration of the web app with the ECOPotential Virtual Laboratory platform has been discussed and alternatives have been presented. The map browser adopts the standards recommended by GEO in term or metadata and map creation. The map browser allows for providing user feedback (using the GUF OGC standard originated in the FP7 GeoViQua project) and reporting data quality indicators based on QualityML vocabulary. The map browser is incorporating a new approach that uses WMS standards to transmit arrays of values that can be transformed into visualizations. This approach has the advantage of also allowing the execution of simple analytical operations as well as richer interactions with the data. This way, some preliminary analysis can be done without downloading the full dataset into the user computer. The evolution of the WMS based on binary arrays has been described in this document and will be broad to the attention of the Open Geospatial Consortium for its eventual standardization.

The LCCS mobile App provides an easy and freely available approach to acquired information on land cover and land cover change that can support the validation of classifications using the same LCCS taxonomy as that generated through the EODESM system. The LCCS App (Version 1) has been distributed to scientists and land managers linked with four protected areas in Europe (Camargue, Doñana, Hardangervidda and Murgia Alta) and have been evaluated also for Wales in the UK. The resulting data are delivered and stored within a centralised system and are currently available as .csv or .kml files. Future developments of the App will focus on developing capacity for the inclusion of environmental data as well as change.

7. ANNEX 1: Proposed extension of WMS standard implemented in MiraMon Map Browser

7.1 The IMG format extension

MiraMon uses simple raw formats to be able to process data very fast. MiraMon uses the *.img* extension to save these files and identifies them as IMG formats. Normally, the IMG file is accompanied by a metadata files in with **I.rel* extension but other arrangements are possible (e.g. in the past Idrisi 2.0 used IMG formats and paired them with DOC formats; that are nothing to do with the MSWord format). These formats basically consist on arrays of binary encoded numbers without any header. Further description of the structure and variants of the files will be found bellow.

The MiraMon Map Server (MiraMon.cgi) is now able to serve IMG formats as a response of a WMS request. The MIME time is application/x-img. The IMG format cannot be presented directly in a web browser using an *<img src=>*. Instead, the IMG format can be requested by the common asynchronous request coming from the AJAX *(XMLHttpRequest())* activating the *responseType = "arraybuffer"*.

```
var xhr = new XMLHttpRequest();
xhr.onreadystatechange = function() {}  //TBD by the app
xhr.open("GET", path, true);
xhr.responseType = "arraybuffer";
xhr.send();
```

Modern JavaScript APIs are ready to manipulate binary arrays using simple function to transform and *array_buffer* received by the asynchronous request into a dataview and extract bytes one by one. See the following code:

```
dv=new DataView(array_buffer);
dv.getUint8(byte_position, true);
```

The implementation of the dataview this is surprisingly fast allowing the web browser to manipulate big quantities of binary data in real time. To visualize this data in the user screen canvas functions needs to be used. In particular the combination of *createImageData* to get a RGBA array, the population of the RGBA array and the return of it with *putImageData* will show the image in the screen.

There are several subtypes of IMG formats. However, at this moment, there is no way to get any metadata information that allows identifying the subtype. This means that clients need to know the subtype in advance for each layer[5]. In ECOPotential that is possible by looking inside the MiraMon map browser configuration file (config.json) that has this information in the values property of each layer. In essence, you need to know:

- The encoding of the individual numbers that represent the cells of the raster
- The compression format (if any)
- The number of rows and columns (that should be de same that was requested in the *GetMap* request)

7.2 Advantages of the IMG format extension

In a normal WMS, we get an image (e.g. a PNG) where the values of the cells represent colors in the screen. The advantage of the IMG format is that we are getting data values that represent physical properties. The client has full control on how to represent that as colors (or transparent) by applying transformations to it. The client is also

[5] The need for having more metadata about the return of a GetMap requests has been repeatedly discussed by WMS.SWG in the past. A new GetMetadata operation or the use of the "Link" mechanism in the headers (https://tools.ietf.org/html/rfc5988) are to possible solutions. Another alternative for this case could be to extend the GetCapabilities layer description.

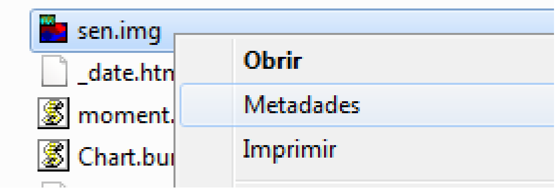
able to create RGB combinations of 3 requests or make calculations among data coming from different layers on the fly.

7.3 Testing the a IMG format

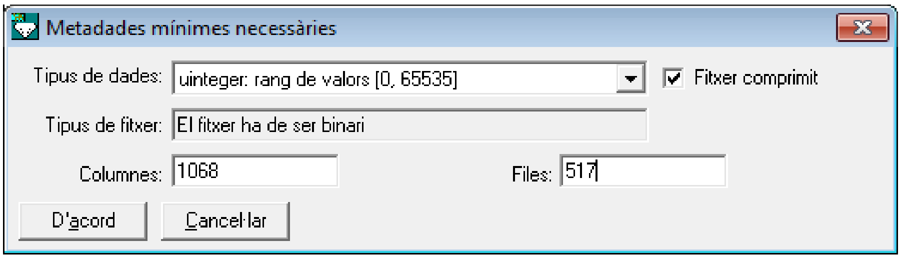
The following request shows how to use a standard *GetMap* request to get a IMG format. The only particularity is the use for *FORMAT=application/x-img*:

http://maps.ecopotential-project.eu/cgi-bin/MiraMon.cgi?SERVICE=WMS&VERSION=1.3.0&REQUEST=GetMap&CRS=EPSG:4326&BBOX=30.557982333333335,34.351614500000025,30.98881566666665,35.24161449999999&WIDTH=1068&HEIGHT=517&LAYERS=HarHaNegevSentinel36RXV&FORMAT=application/x-img&TRANSPARENT=TRUE&STYLES=&TIME=2016-12-02&DIM_BAND=B01

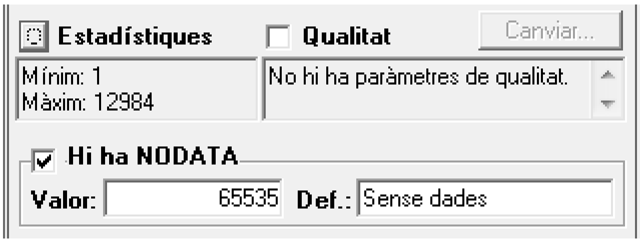
If we cut and paste this UR in a web browser we will be ask to save the file. We should save it as an IMG file. In a Windows machine with MiraMon installed, you will be able to create a metadata file:



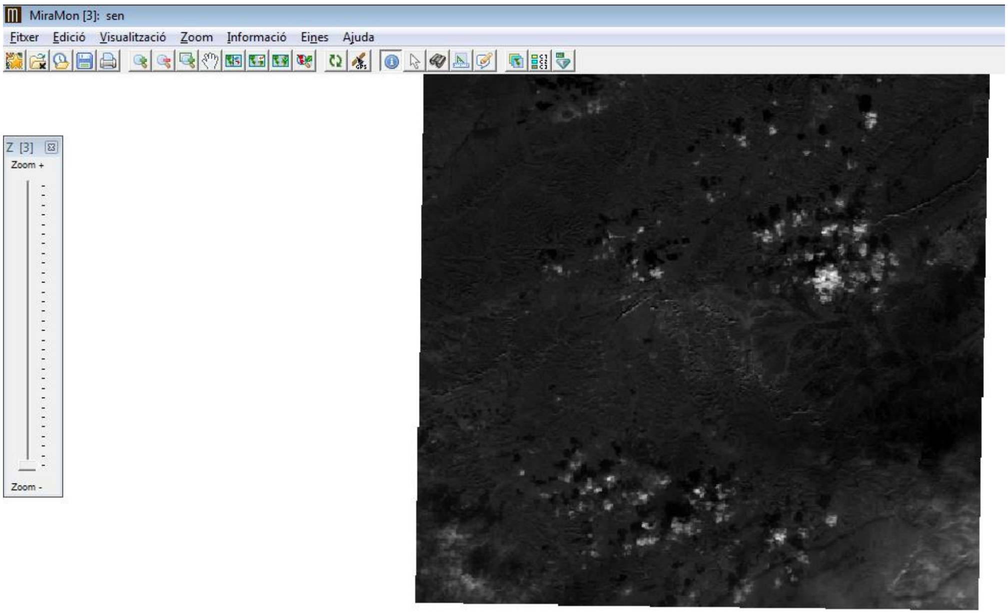
If we accept the message saying that there is no metadata and if we want to create it we will get the following dialog box. The subtype we know in advance and the columns and rows can be found in the URL request:



After that, we can specify the nodata value and calculate the value range:



After that, we can check the image with MiraMon:



7.4 Particularities of the IMG format: Encodings

The IMG format represents sequences of values encoded in binary. In some encodings, bytes are grouped to allow for longer integer values of floating point numbers. In the case of grouping the order of the bytes is *little endian* (Intel order). The following table indicates the 10 encodings accepted by MiraMon for the IMG format:

encoding	**bits by pixel**	**bytes by pixel**	**type of value**	**whole values**	**use**
bit	1	1/8		[0,1]	mask image
byte	8	1		[0,255]	thematic cartography until 256 categories, aerial photographs (black and white or color) or until 256 grey levels or 256 colours.
integer	16	2	integer	[-32768, 32767]	thematic cartography of ups to 256 categories, several types of DEM, photographs (black and white or colour) of up to 256 grey levels or 256 colours.
long	32	4		[-2147483648, 2147483647]	thematic cartography with links to databases.
real	32	4		(»-3.4E+38, »3.4E+38)	several types of DEM that need single real precision (6 significant figures) as temperature maps.
double	64	8	real	(»-1.7E+308, »1.7E+308)	several types of DEM that need double real precision (15, 16 significant figures). In practice, double format is only used to intermediate calculations in which you need too much precision, and not for final layers.

7.5 Particularities of the IMG format: Compression

In many occasions, contiguous pixels in an image repeat the same number. In this case, the use of a simple encoding that reduces the number of repetitions is convenient. IMG uses the RLE compression strategy.

In the format, the following pattern is repeated: The first byte is the number of repetitions. Next bytes are the value that is repeated. If the special case that the number of repetitions is zero, the following byte specifies the number of non repeated numbers so there will be n byte groups representing the n values in the file. The number of repetitions is a single byte and cannot exceed 255. The start of a row shall be a number of repetitions (rows are compressed independently).

7.6 Particularities of the IMG format: Compression with indexing

In a RLE compressed file, the position where row start in the array of bytes cannot be anticipated. This means that to read a row, the previous rows should be reed first. To overcome that problem, MiraMon introduced a new section that provides the position where each row starts.

The description of this section is out of scope of this document.