HERCULES

Sustainable futures for Europe's HERitage in CULtural landscapES: Tools for understanding, managing, and protecting landscape functions and values

GA no. 603447

D7.4 Web-based GIS system for modelling, visualisation, dissemination and further use of resulting data

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Executive summary

Deliverable 7.4 "Web-based GIS system for modelling, visualisation, dissemination and further use of resulting data" wraps up the *Knowledge Hub for Good Landscape Practice*, a joint platform for interaction with the wider landscape community.

Work package 7 aimed to provide a toolkit that would ensure efficient collecting, archiving, using, sharing, and distributing of data and project results amongst project partners, stakeholders and the general public without any regional or feature-type limitations. Figure 1 shows how it acts as a major toolkit for communication of HERCULES insights and at the same time provide the means for collecting feedback and input through crowdsourcing tools.

Figure 1: Illustration of what is Knowledge Hub and how it can connect various target audiences.

Following the gathered requirements from other work packages the web GIS platform with underlying repository was built allowing processing and storing of large amounts of spatial data. The architecture implements current state-of-the-art in cloud computing. The data can be visualized, modelled, and accessed through three viewports:

- Knowledge Hub web GIS application via http://kh.hercules-landscapes.eu/
- Use-case-centric mobile applications, created on demand.
- HERCULES Labs – simplified web applications providing interactive exploring of project's results, available at http://labs.kh.hercules-landscapes.eu.

Additionally, Sentinel-2 satellite imagery from Copernicus' missions has been added to Labs, as earth observation is providing new means to monitor and access the status and changes in land and land-use. A demo web application with advanced analysis tools is available at http://labs.kh.hercules-landscapes.eu/herculesSL/index.html.

Table of contents

Abbreviations

API	Application programming interface
EO	Earth observation
ESA	European Space Agency
GIS	Geographic Information System
HERCULES	HERitage in CULtural landscapES
KH	Knowledge Hub
NDVI	Normalised vegetation density index
RGB	Red Green Blue
WP	Work Package

1 Introduction

Within work package 7, "Development and testing of a Knowledge Hub for Good Landscape Practice", we have designed and implemented the *Knowledge Hub for Good Landscape Practice*, assigned to ensure efficient collecting, archiving, using, sharing, and distributing of data and project results amongst project partners, stakeholders and the general public.

A multitude of regional or feature specific approaches have already been developed to protect and develop heritage values in cultural landscapes. The Knowledge Hub is meant to be unrestrained: it is not limited to region and scale, nor does it impose a constraint on feature or data types, as long as they do carry a locational information. It provides the means for collecting feedback and input from both general public and professionals (landscape practitioners, managers and policymakers), and can act as a toolkit for communication of (HERCULES) insights between various parties, as shown in Figure 1. The general public for the Knowledge Hub represents both main stakeholders as well as the knowledge base of the underlying questions: what is happening with cultural landscapes and how do you perceive these changes, thus representing the focus group of the citizen science in the HERCULES project.

In order to fulfil the objectives of such endeavour from the data management point of view, we have gathered requirements from other work packages (WP), analysed user requirements and current state-of-the-art in GIS and cloud community. Based on that knowledge we have defined hardware and software specifications, set up a data repository and implemented its access through three main viewports:

- **Knowledge Hub web GIS application**, implementing a powerful cloud web GIS editor and viewer with advanced GIS tools, is available at http://kh.hercules-landscapes.eu and is the main access point to the data repository. A screenshot of the web application is shown in Figure 2.

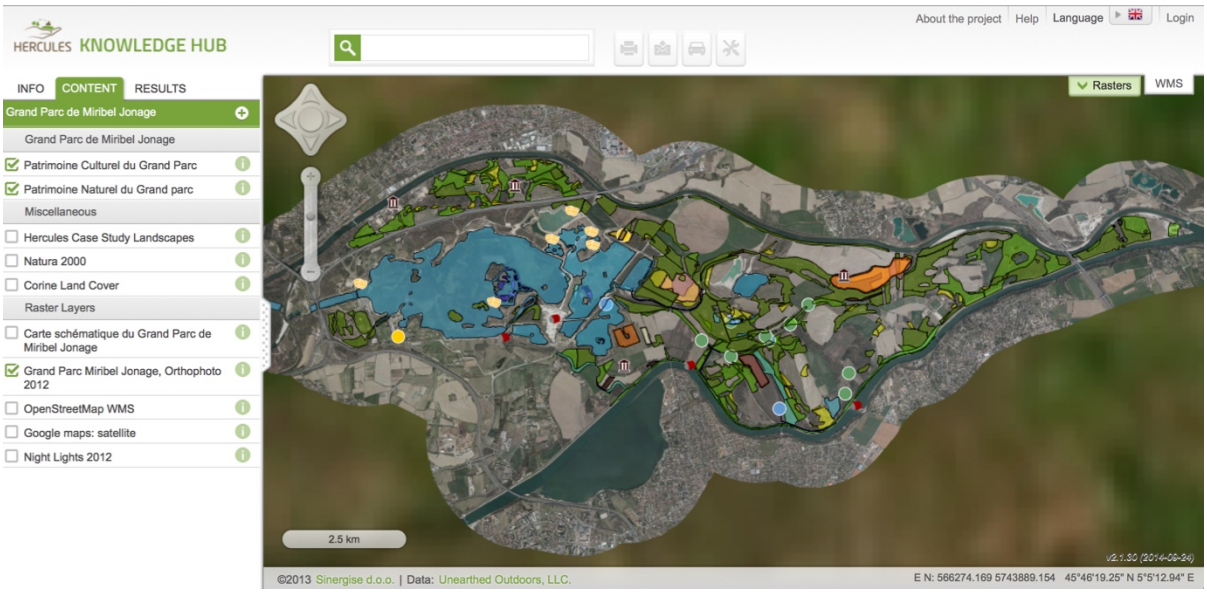

Figure 2: Grand Parc Miribel Jonage - one of HERCULES' study landscapes - on the Knowledge Hub web GIS application.

- **Mobile applications**, which are use-case-centric, provide means to crowdsource data collection in an organised and simple-to-use way. Since the data model (e.g., for the data collection) is defined from the web GIS application, the platform allows for fast deployment of new use-case-centric mobile applications. "My landscape ratings", shown in Figure 3 on the left, was configured in collaboration with University of Freiburg (HERCULES partner) to be a part of "European-scale survey on landscape practices" (deliverable 6.1 within work package 6). Another application, shown in Figure 3 on the right, is a demo offline data repository related to agriculture that was prepared as a showcase for "Forum For Agriculture 2015" conference.

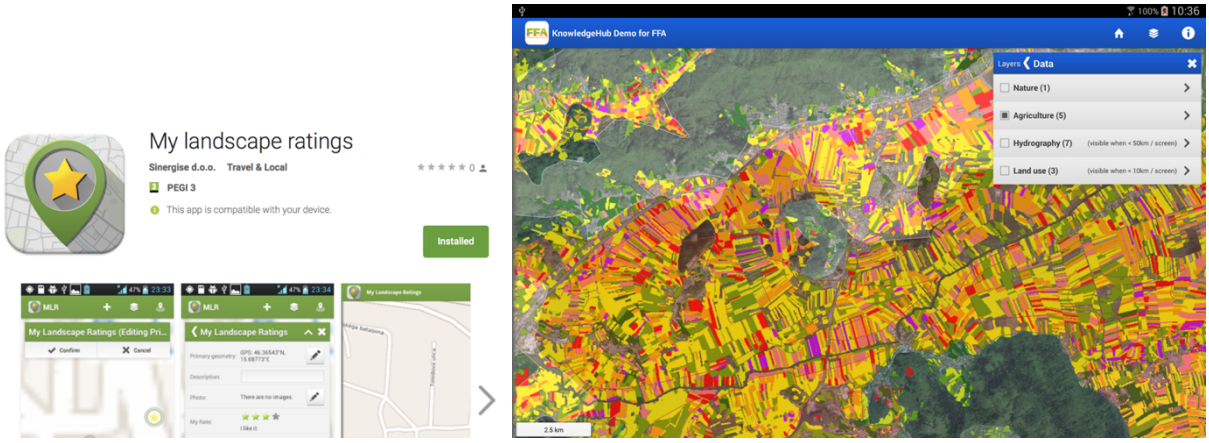

Figure 3: "My landscape ratings" on Google Play is shown on the left; a demo of an application with an offline data repository on a tablet is shown on the right.

- **HERCULES Labs – data explorers**, http://labs.kh.hercules-landscapes.eu. In order to facilitate showcasing the results to the general (non-expert) public, the concept of "data explorers" has been included in the Knowledge Hub platform. The Labs can be seen as the basic version of the Knowledge Hub, while the web GIS application remains as the expert version. Labs can also easily be integrated in other existing web pages, facilitating dissemination and re use of HERCULES results elsewhere. Info tiles describing a few of many available Labs are shown in Figure 4.

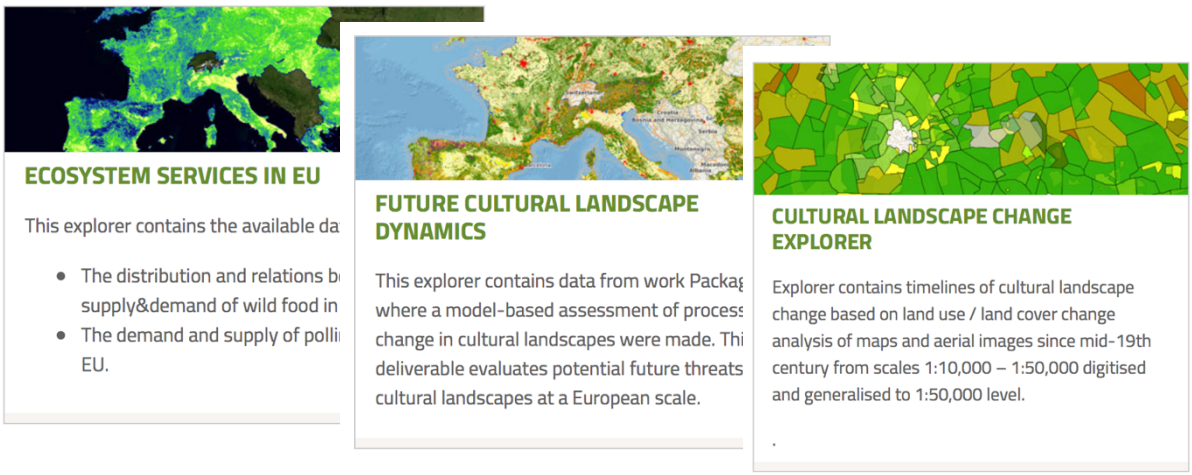

Figure 4: A few of the available Labs.

- Satellite imagery has been identified valuable for achieving the goal of mapping and assessing landscape changes. With the **introduction of Sentinel-2 data** – a free public dataset from the earth observation programm Copernicus' (European Commission in partnership with the European Space Agency) missions – it has become possible to add it to the KH. A web application with advanced satellite data analysis tools and means to measure and visualize the changes through time is shown in Figure 5. The application is available through Labs at http://labs.kh.hercules-landscapes.eu/herculesSL/index.html. Primarily targeted to the study landscapes of the HERCULES project, users will be able to pinpoint and mark the changes they feel mostly affect the cultural landscapes.

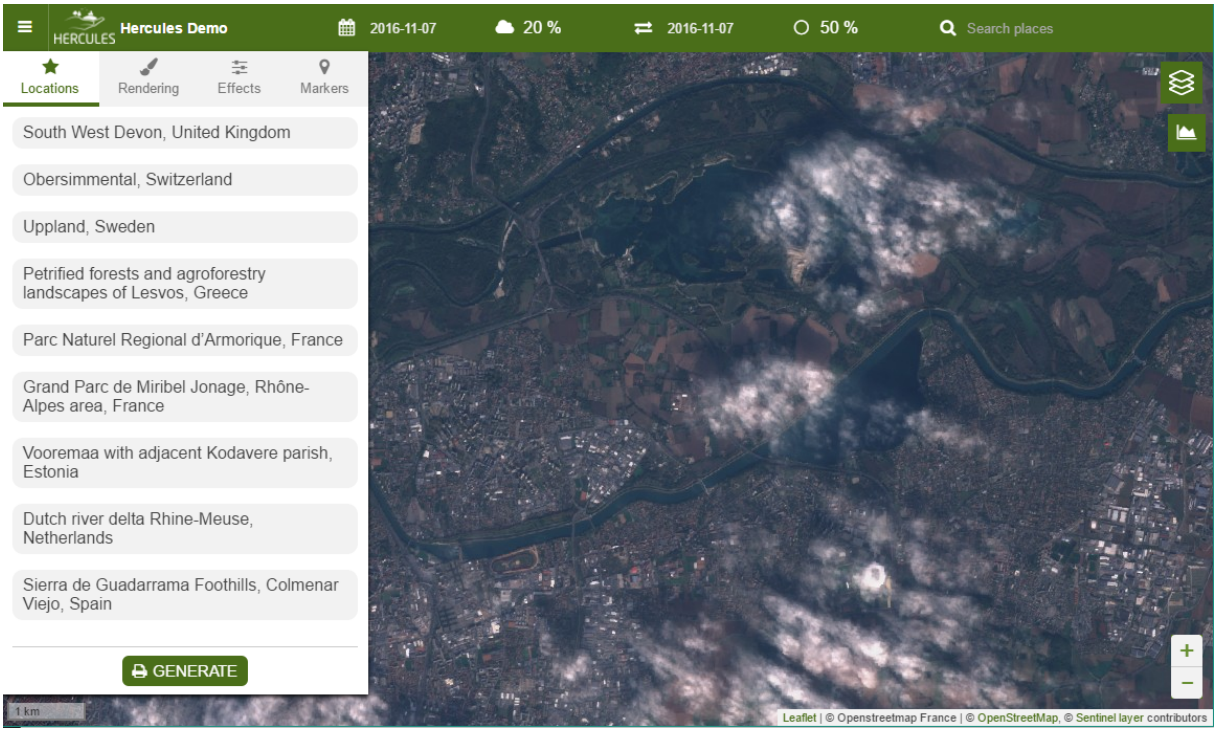

Figure 5: A demo web application to analyse and visualize the land changes with Sentinel-2 satellite imagery.

The three viewports of the Knowledge Hub platform, web GIS application, mobile applications and Labs, together with the Sentinel-2 satellite data toolkit and the underlying (spatial) data repository infrastructure combine into the *Knowledge Hub for Good Landscape Practice*, a platform for efficient collecting, archiving, using, sharing, and distributing of data and project results amongst project partners, stakeholders and the general public and thus resolve the efforts of the work package 7.

2 The three viewports into the Knowledge Hub

The overall idea of the Knowledge Hub (KH) is to act as a general repository of data in all forms. These datasets could then be used by different stakeholders to present their stories in a quick and efficient way, as shown in Figure 6. The main point of the central repository is to allow use and re-use of the datasets and therefore increase their reach and, through re-using, improve their quality.

Figure 6: Illustration of Knowledge Hub as data repository and web GIS portal providing a platform for HERCULES project.

Current report is the pinnacle of the efforts in the work package 7. The (spatial) data infrastructure together with the first glimpse of the web GIS application was described in deliverable D7.1 "Repository of spatial and alphanumerical datasets". Deliverable D7.2 "Smartphone based application for crowdsourcing powered data collection" described the means to crowdsource data collection in an organised and simple-to-use way using mobile application "My landscape ratings" as an example. Shortly afterwards, the deliverable D7.3 "Web-based GIS application for crowdsourcing powered data collection" was presented in order to ensure the KH usefulness to HERCULES project.

Since then, the KH and smartphone application(s) have been tested and used on multiple occasions, both with stakeholders and HERCULES partners, in order to gain the feedback that could be used to further refine the KH. Foremost objection was the usability for non-GIS experts: users without GIS background could not exploit all the functionalities implemented in web GIS application due to lack of expertise and knowledge. In order to bring KH closer to such public, the "Labs – explorers to the KH" have been implemented and made accessible through a dedicated web page (http://labs.kh.hercules-landscapes.eu). The process of refinement was described in deliverable D8.3 "Report on pilot applications of the Knowledge Hub in case study sites, including detailed feedback for refining the Hub".

The following chapter will shortly describe both new functionalities within the KH platform as well as means to expose HERCULES results and other data collected within the project to be accessed, visualized, reused and shared. The focus will be on the new functionalities, particularly on modelling and powerful visualization, and ways to bring the data closer to general, non GIS expert public.

2.1 Web GIS application

Deliverable D7.1 reported the hardware and software specifications, gathered from WPs and current state-of-the-art in GIS and cloud community. Based on that knowledge the spatial and alphanumerical data repository of KH platform was implemented and deployed, together with the web GIS application. The application was extended with additional functionalities, focused on scalability, extensibility, configurability and integration of the system within D7.3.

This report emphasises on new functionalities on the KH web GIS application, providing exciting new capabilities to the KH platform, namely:

- Powerful visualization engine,
- Computational operations and query tools on raster data,
- Raster data modelling using scripting language.

2.1.1. Visualization engine

Some of the vector data styling options have been shortly described in chapter 4.4.3. of deliverable D7.1. The basic symbol styling options can be seen in Figure 7. There are more then 250 different symbols, covering most aspects of pictograms needed in (thematic) mapping. Colour, size, rotation and opacity of the symbol can be defined as well.

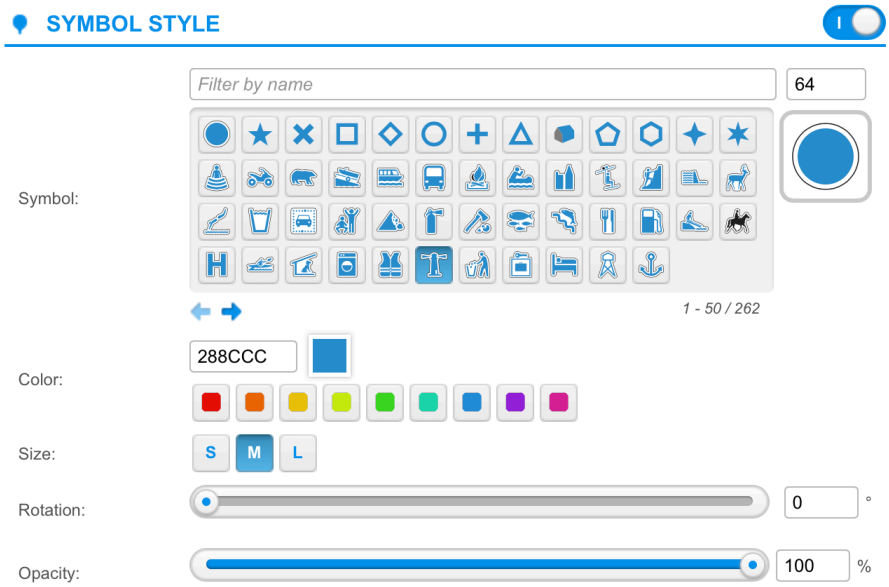

Figure 7: Basic symbol styling options for visualization of point-like features on KH.

For visualization of linear elements, line style, width, colour, opacity, join and cap type can be specified, as shown in Figure 8.

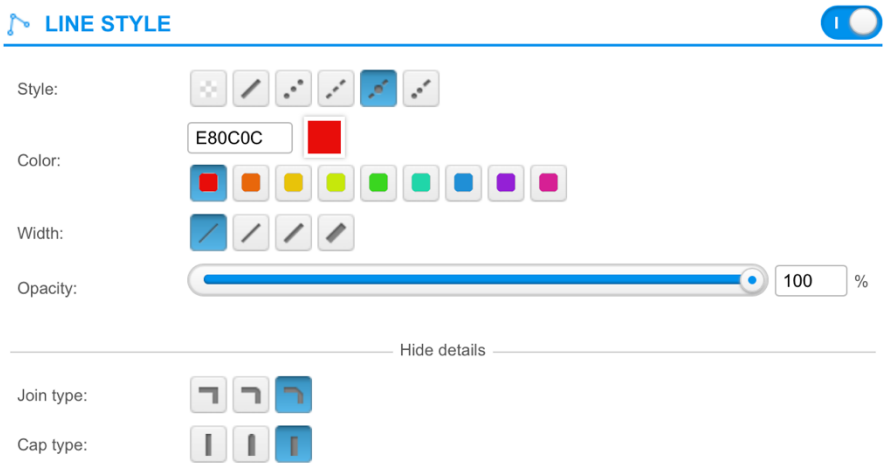

Figure 8: Basic styling options for linear elements.

Styling polygons is usually two-fold: styling borders equals to styling linear elements, while styling the "fill" of the polygons, shown in Figure 9, allows defining background fill colour and opacity, hatching style (empty, solid, and various hatching patterns) and foreground colour when using patterned fills.

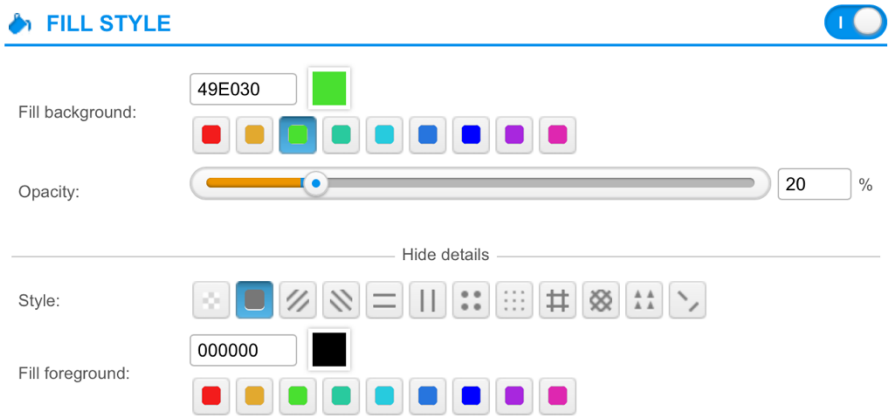

Figure 9: Basic styling options for polygons.

Text, which can be added to any kind of vector data, can be styled with a plethora of specific options. Besides the typical ones, like font, size, colour and opacity, also glow settings and text placement with respect to the feature geometry are available in basic settings, shown in Figure 10. Note that text label can be value of any of the feature's attributes.

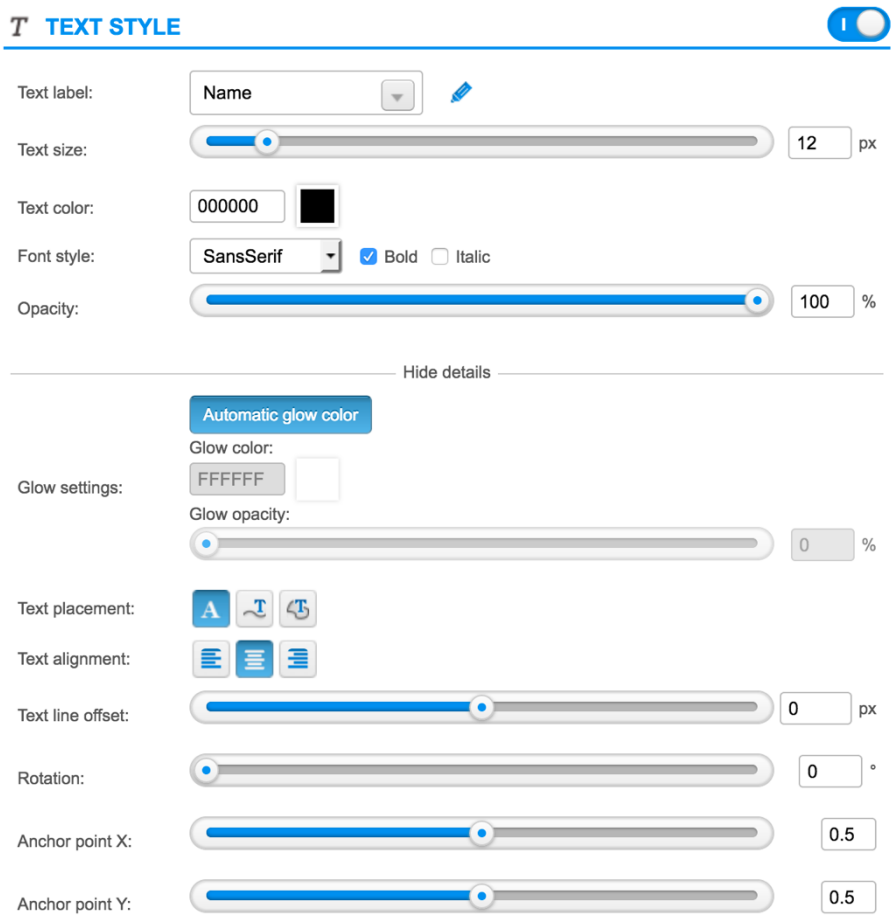

Figure 10: Text styling options.

Although basic settings provide a wide array of possibilities for visualization of data, the real advantage of KH over many other GIS editors is the versatile styling that can be achieved with the "Advanced editor", with advanced scripting, as can be seen in Figure 11. Here, the attribute f2144 ("Elevation" field of the corresponding layer data model) value is conscripted to variable elevation, and then a simple if-else chain is employed to set the colour variable according to elevation variable. At the end, fill parameter of the symbol (with id 617) is set to the value of colour variable, resulting in legend as shown in Figure 12.

Layer editor

General | Fields | Style | Reverse references | Copyrights | Mobile

Validate

```
var elevation = f2144;
var color = 0xff003399;

if (elevation <= 0){
  color=0xff23cf0c;
} else if (elevation >= 0 && elevation <= 500){
  color=0xff4feb11;
} else if (elevation >= 501 && elevation <= 1000){
  color=0xff91eb11;
} else if (elevation >= 1001 && elevation <= 2000){
  color=0xffcaeb11;
} else if (elevation >= 2001 && elevation <= 3000){
  color=0xffebde11;
} else if (elevation >= 3001 && elevation <= 4000){
color=0xffebbf11;
} else if (elevation  >= 4001 && elevation <= 5000){
color=0xffeba611;
}else if (elevation >= 5001 && elevation <= 6000){
color=0xffeb8c11;
} else if (elevation >= 6001 && elevation <= 7000){
  color=0xffeb6d11;
} else if (elevation >= 7001 && elevation <= 8000){
color=0xffe6340b;
} else if (elevation > 8000){
color=0xffd10000;
}

return sf.Symbology([
    sf.PaintingPass([
        sf.PointSymbolizer({
            opacity: 1,
            displacementX: 0,
            displacementY: 0,
            size: 18,
            rotation: 0,
            symbolId: 617,
            fill: color,
        })
    ])
]);
```

Simple editor | Edit legend

Ok | Cancel | Delete

Figure 11: Advanced style editor is a placeholder for a script that defines the symbology.

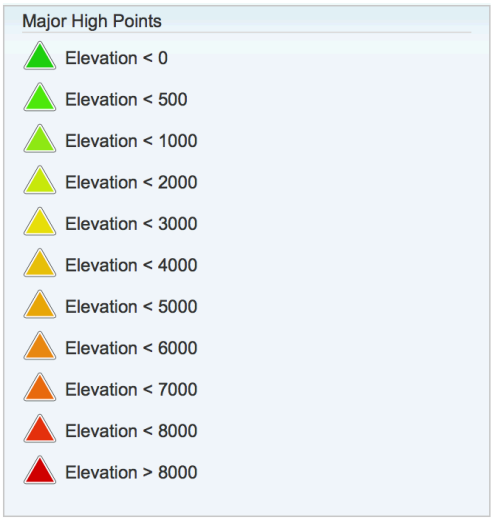

Figure 12: Legend resulting from the style script defined above.

This way, data can be visualized based on some sort of categorization, and rules are defined in simple, yet powerful programmatic way. Symbols can change with scale; part of data can be

hidden without the need for filtering etc. The same applies to both linear and polygonal features, as well as text styling. The possibilities are many.

So far the advanced styling has been implemented by Sinergise whenever deemed appropriate. Instructions on vector data styling will be added to KH help pages shortly.

2.1.2. Computational operations and query tools on raster data

During the lifetime of the HERCULES project we have identified that the majority of data we get as an input to KH from partners (e.g. results of various deliverables), are of raster type. Presenting raster data on a map is in general trivial; it has to be geographically referenced and usually tiled to get better performance, but that is the gist of it.

In order to bring new possibilities to KH, we have implemented an advanced raster data querying tool, which we call raster data “feature info”. It allows three types of queries:

- point-like query,
- query on area,
- query on either point or area defined as a feature in another (vector) data layer on KH.

Users can switch between the three options by clicking on the appropriate icon, as shown in Figure 13. Upon selecting one of the options, the user is asked to either click somewhere on the map, draw a polygon or select a feature from the currently visible layers (again by clicking on the map). The third option is particularly useful for getting information on data, pertaining to some predefined entities, e.g. countries, municipalities, etc.

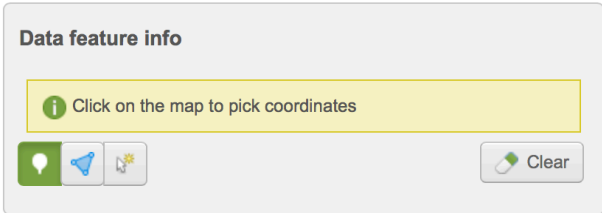

Figure 13: Raster data "feature info".

The side effect of this tool is the opportunity to perform calculations and simple statistical analysis on top of raster data, as we make it possible for users to define what will be the result of such query. As with advanced styling, this is achieved using (JavaScript) scripting language, where variable names `c0`, `c1`, … are raw pixel values by channel/band. Hence, if the raster data was a GeoTiff file with 6 bands, and one would like to display an average value of the last 5 bands, the script shown in Figure 14 would do.

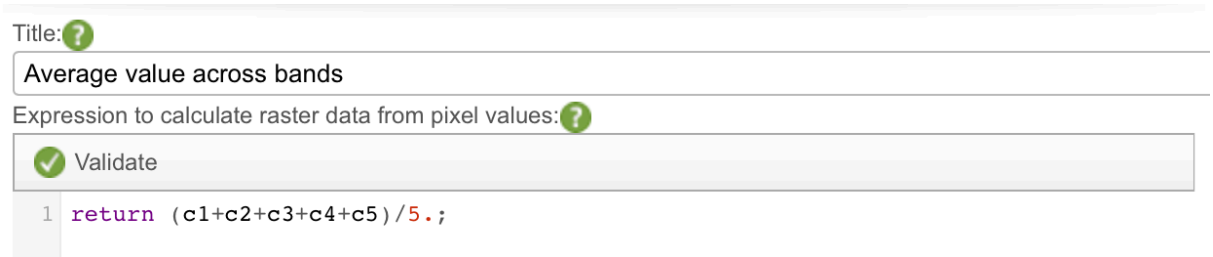

Figure 14: Scripting the raster data feature info calculation.

When all this functionality is paired with temporal dataset it brings time series spatial analyses to KH as a by-product. To allow users to incorporate such results into their own

visualization or modelling tools, we have made it possible to download the values from queries as simple comma separated values (CSV) file.

As an example we show feature to retrieve NDVI value from some satellite test imagery for single time over a drawn polygon and for time series for a single point. The example is shown in Figure 15 and Figure 16.

Figure 15: Raster data feature info example – get NDVI values over a plot of land from raster data that has red, green, blue and near infra-red bands. Histogram with basic statistics is shown in upper right corner of the image.

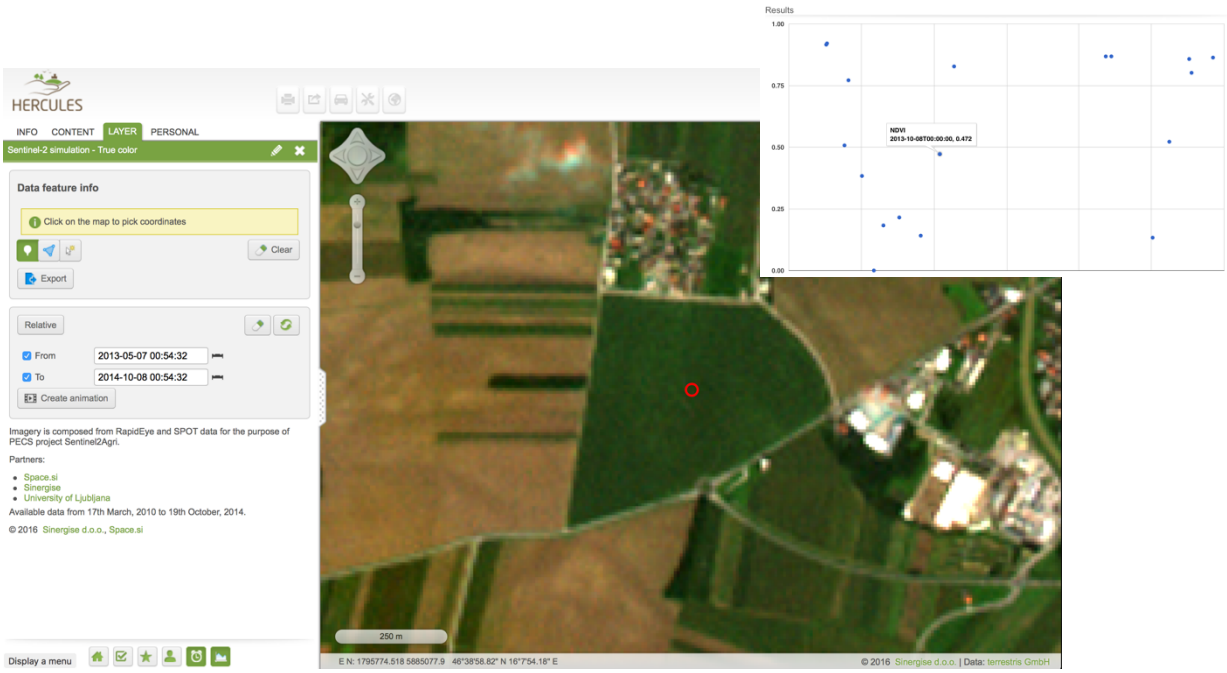

Figure 16: Raster data feature info example – get NDVI values for a point (inside a field) for all data that is available between two set dates. A plot over time is shown in upper right corner of the image.

2.1.3. Raster data modelling

As stated above, a lot of data we acquired from HERCULES project are in raster data format. Quite often the data was either a classification of sort, or data that would be used to derive that classification. That usually meant that some colour was defined (and often redefined) for each category. As that typically means reprocessing the raster data into a new tiled pyramid, the first thing we implemented was so called "raster image transform", which allows defining a matrix, mapping the raster data values in some way to the resulting output red-green-blue (RGB) image with possible transparency, as shown in Figure 17.

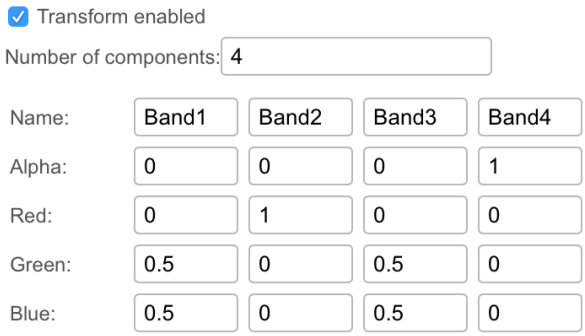

Figure 17: Raster image transform matrix is basic raster data modelling tool, mapping input data into a RGB image.

In the example above, the resulting visualization would be calculated from four input components. Fourth component is an alpha mask channel, "Band2" would be mapped to red colour while "Band1" and "Band3" represent the equal mixture of blue and green colour.

This principle has immediately been extended with advanced option of scripting, as it translates into a set of mathematical equations in any case. The above matrix can be rewritten to advanced settings as shown in Figure 18.

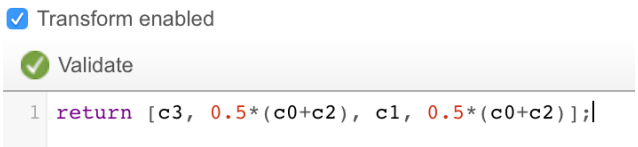

Figure 18: Specifying alpha + RGB values from Figure 17 in mathematical expression for advanced settings.

Reusing definition from query tools on raster data, the component numbering starts from 0 and has a "c" prepended (`c0` for Band1, `c1` for Band2, etc.).

Although it might seem unpractical, this kind of scripting allowed us to build up classification visualization for the "Cultural Landscape Characterisation and Typology" (Tieskens et al. "Characterizing European cultural landscapes: accounting for structure, management intensity and value of agricultural and forest landscapes") done within work package 4. The data for three indicators (management intensity, landscape structure and social value/meaning) is classified according to defined threshold values for each into Figure 19 (with the model shown in Figure 20). This functionality is even more powerful when used within Labs, as will be shown in Chapter 2.3.

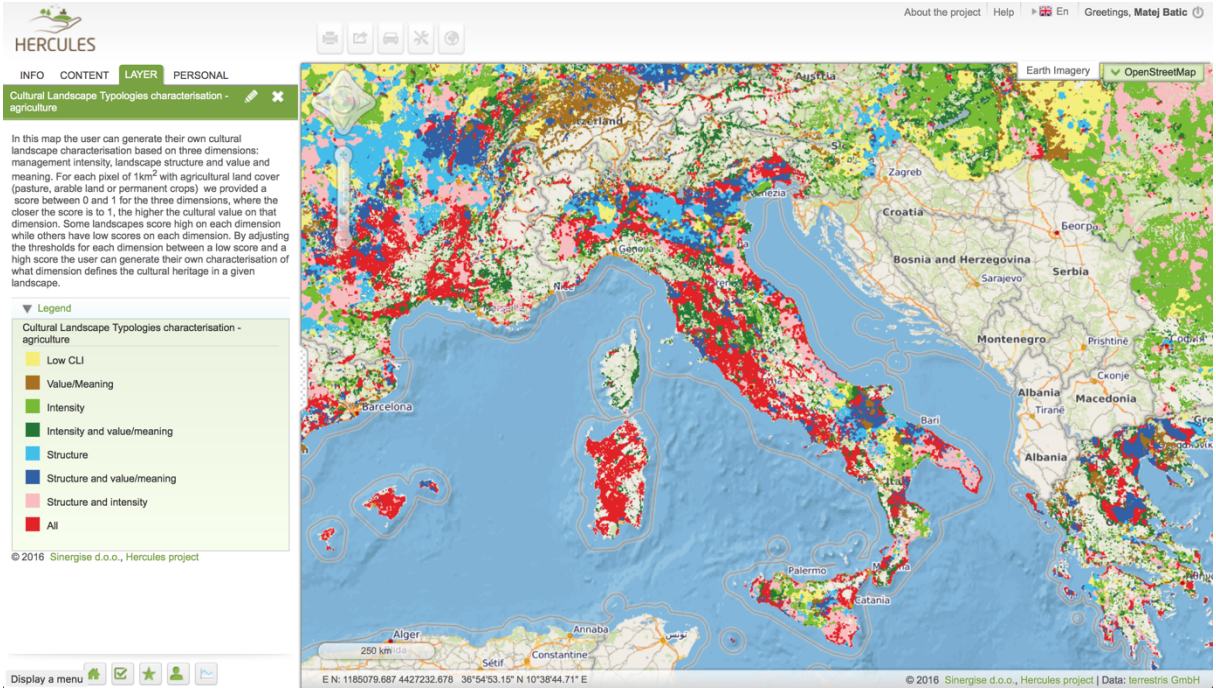

Figure 19: Result of raster data classification based on script in Figure 20.

Transform enabled

Validate

```
//band 1 = intensity
//band 2 = value
//band 3 = structure

if (c0 < 0.000001 && c1 < 0.000001 && c2 < 0.000001) { //nodata value
  return [0, 0, 0, 0];
}

var intensity_threshold = 0.494;
var value_threshold = 0.29;
var structure_threshold = 0.348;
var opacity = 1;

var val = (c0 > intensity_threshold) ? '1' : '0';
val += (c1 > value_threshold) ? '1' : '0';
val += (c2 > structure_threshold) ? '1' : '0';

var colorTable = {
  "000" : [opacity, 244/255, 238/255, 122/255 ],  //Low CLI
  "010" : [opacity, 167/255, 113/255, 33/255],    //Value/meaning
  "100" : [opacity, 120/255, 186/255, 53/255],    //Intensity
  "110" : [opacity, 37/255, 118/255, 54/255],     //Intensity and value/meaning
  "001" : [opacity, 66/255, 190/255, 233/255],    //Structure
  "011" : [opacity, 50/255, 96/255, 164/255],     //Structure and value/meaning
  "101" : [opacity, 247/255, 189/255, 192/255],   //Structure and intensity
  "111" : [opacity, 225/255, 35/255, 40/255]      //All
};

return colorTable[val];
```

Figure 20: Classification script for Figure 19.

2.2 Mobile applications

One of the most important underlying concepts of the KH platform is a flexible data modelling. The structure of the data that will be integrated in the KH can be specified (field names, field types, etc., in general an alpha-numerical and spatial data attributes of specific record) using the web GIS application. This ensures the ability to improve methodology and models of the project, as well as overall quality assurance of the data (e.g. by requiring mandatory fields, cross-checking of data on entry etc.).

This data modelling capability of the platform is most important for the mobile applications, as they were primarily intended for (crowd-sourcing) data collection. The mobile applications

are use-case-centric, as was shown with "My landscape ratings" application within D6.2, meaning each application is tailored to the specific use-case. As the majority of the customisation is in fact defining the data model, which can be done by the requestor of the application, it allows for very fast deployment of new applications.

As mentioned, a survey-like mobile prototype application was deployed on Google Play marketplace as a part of D7.2 (see Figure 3). The application has been configured in collaboration with ALU-Freiburg, allowing users to take a photo, choose predefined answers to few questions and add comments, as can be seen in Figure 21. The application is a part of "European-scale survey on landscape practices" (described in D6.1), collecting geolocated data (geotagged photos) and gathering additional information on how users perceive their landscapes.

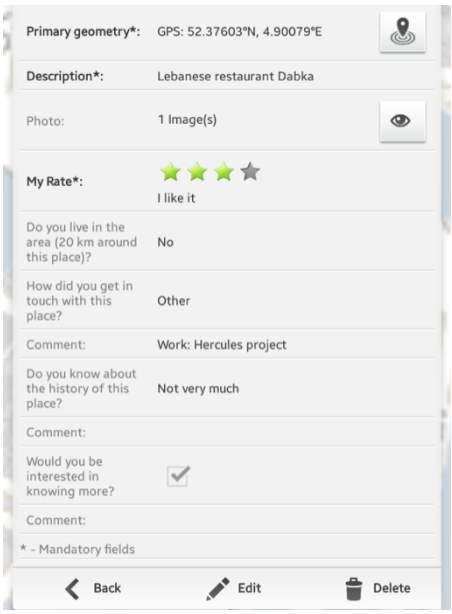

Figure 21: Survey-like questionnaire is easy to use, as majority of the questions provide multiple-choice answers.

The mobile applications work in two ways: either connected to the internet (mandatory to download the application and synchronise the local data with remote content on the KH), or in offline mode when network coverage is weak, expensive or not available at all. Since the mobile applications can include any data that is available on the KH, they may provide an easy to use resource (atlas) of use-case based data.

A dedicated application, showcasing the KH capabilities to compile an offline atlas for mobile application, has been prepared as an example for an exhibition at Forum for Agriculture 2015 (with around 1600 participants from policy makers, civil society and scientific community), taking place on 31 March 2015 in Brussels. The application consisted of a GIS viewer (without editing capabilities) with content focused to agriculture/landscape. The main point for the end-user is to be able to browse/visualize the spatial data, related to limitations/suggestions for agriculture, shown in Figure 22 and Figure 23.

Following (additional) data has been added to the KH to facilitate such application:

- Hydrology

- information about protected areas
- water streams

– Agriculture (agriculture related layers from the application are shown in Figure 22)
  - land use
  - agriculture parcels
  - pedology (not very detailed but still useful: nitrate balance, drought related data)

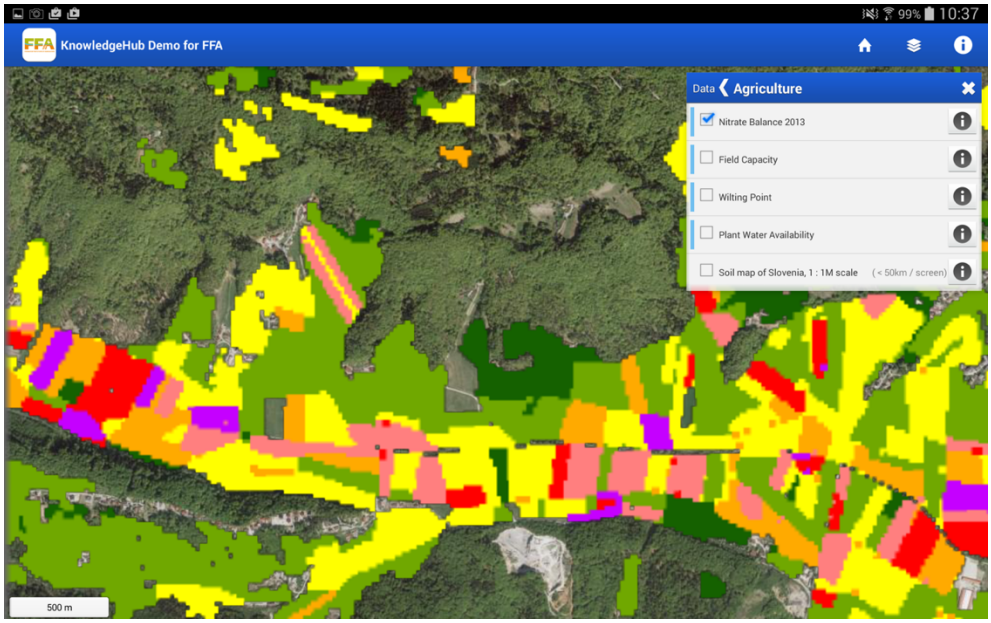

Figure 22: Smartphone application for demonstrating KH in offline mode at Forum for the Future of Agriculture. "Nitrate Balance 2013" layer, a part of "Agriculture" group of layers, is turned on.

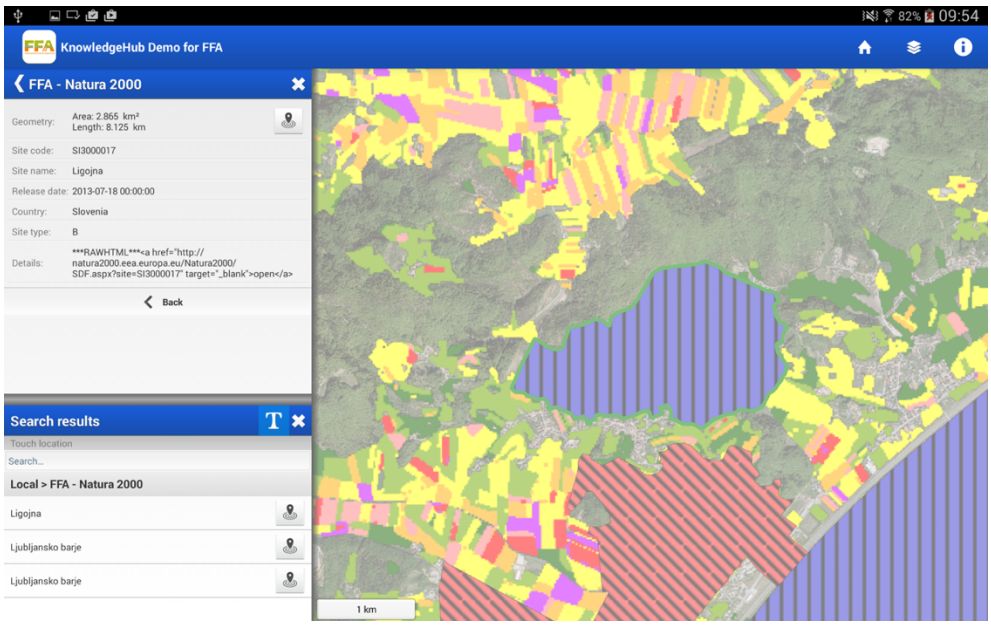

Figure 23: Additional data is shown by clicking on the map; here data about Ligojna Natura 2000 site is shown.

The data has been added on smaller scale (part of Slovenia, south-west of Ljubljana), to showcase how a farmer (practitioner) could use the KH for his/her farm (practice) management: e.g. upon clicking on map he/she can see where there are Natura 2000 areas (limitations), water protected areas (limitations), but also access to water for irrigation (suggestion).

The mobile applications' viewport into the KH platform does not support modelling of the data, but its strengths are in data collection and dissemination. It supports the powerful visualization possibilities of the KH, as well as easy-to-use data input methods. As shown in the examples the use-case specific mobile applications could be used in a very wide scope of ranges: from crowd-sourced data acquisition to providing landscape practitioners, managers and policymakers with insights from HERCULES project they can use in the field.

2.3 HERCULES Labs

2.3.1 The formation of the data explorers

Almost immediately after the KH web GIS application was available online, the distinction between users with various GIS knowledge became obvious. The differences in expertise resulted in a number of personalized requests to change this icon, that title, etc. in order to make the application easier to use. However, the requests, even implemented, would still not help with the main problem discerned: that the KH web GIS application is too complex to use for the majority of users.

The first response to overcome this problem was the implementation of online KH help portal, with descriptions on how to use the map, an introduction to KH terminology (what is a layer, theme), basic functionalities and tools of the KH and how to use them, as well as a few introductory videos:

- an overview of KH and quick walk through its basic features;
- quick tutorial on how to create a new layer and
- quick tutorial on how to create a new theme.

We quickly realized that users who are not motivated to use the KH do not bother to use help either; something simpler was needed to facilitate showcasing our results. Thus the concept of "HERCULES Labs" – a proposal for the integration of the KH to the HERCULES website for multiple use cases – was born. HERCULES Labs should be the entry point for the general public, allowing them to easily select different thematic explorers of the KH. Linkage of HERCULES main web site with KH and Labs is shown in Figure 24.

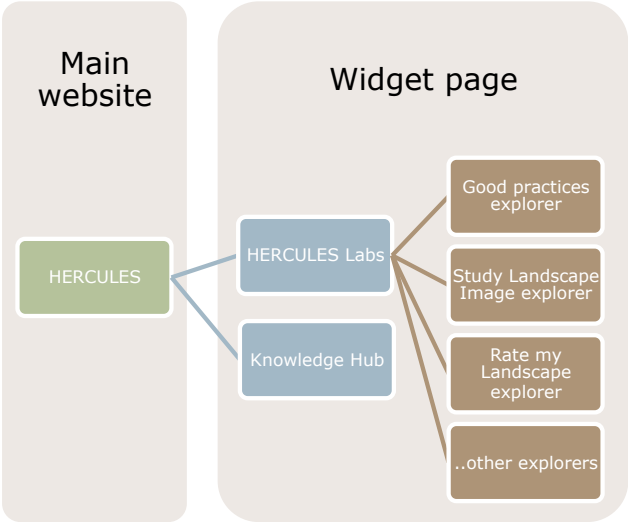

Figure 24: Hierarchy of web pages on HERCULES website following the distinction between full web GIS application and HERCULES 'Explorers'.

2.3.2 Embedding a Lab into a web page

Following this idea, we have provided the possibility to implement the KH into (any) web page, so that users can easily show the data from KH in one simple (map) widget. The widget provides many powerful tools and visualization of a standalone KH web GIS application, yet is not burdened with plethora of functionalities and complexities. The Labs can be thus seen as the **basic version**, while the web GIS application remains as the **expert version** of the KH.

Each such widget is a window into a theme set up on the KH, and any theme can have its own widget. For instance, the theme "Hercules - Landscape dynamics", available on KH here (http://kh.hercules-landscapes.eu/#T107) is accessible as a widget through URL http://kh.hercules-landscapes.eu/?widgetId=LandscapeDynamicsWidget. The `widgetId` parameter is given to users upon request to provide a safeguard. A user controls what is shown on a map on the web GIS application, and the Lab immediately reflects the change.

To include the lab on a web page, in principle just the following code has to be added to the HTML:

```
<iframe
frameborder="0"
height="100%"
scrolling="no"
src="http://kh.hercules-
landscapes.eu/?widgetId=LandscapeDynamicsWidget"
width="100%">
</iframe>
```

There are additional parameters to control the look and feel of the widget, which will be shortly added to the help portal.

The results of the Landscape Dynamics lab are shown in Figure 25.

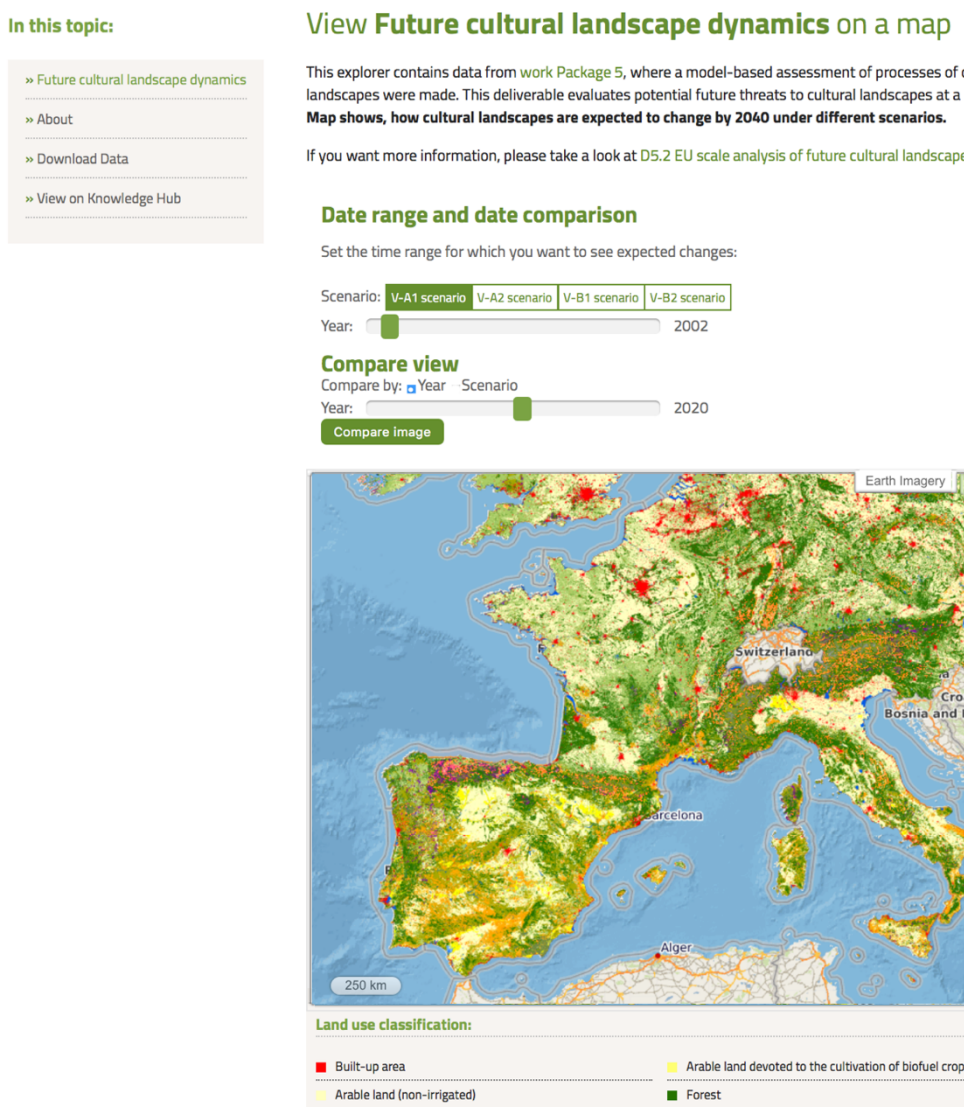

Figure 25: Future landscape dynamics Lab showcases the results of deliverable D5.2. The Lab is set up with a short description of what is shown, with an interactive map (widget), and an application controls where users can compare the implications of various scenarios over time.

The Labs are communicating with the KH using Application programming interface (API), which enables manipulation of GIS data that is stored inside the KH. As the Labs are primarily meant as explorers of data, their main objective is to provide a viewport into particular KH themes. Nevertheless, to facilitate crowdsourced data collection with an easy interface, it is possible to use the Labs to add (and edit) the data to the KH.

2.3.3 HERCULES project results on a dedicated Labs page

Since July 2015, Labs with HERCULES insights and results are available on a dedicated web page: http://labs.kh.hercules-landscapes.eu. The number of Labs is continuously growing as additional explorers are added to facilitate showcasing the results from various HERCULES deliverables. A list of implemented Labs (at the time of writing this report) is shown in Figure 26. At the moment the Labs are added as they come, but a review process to organize (and rename) them appropriately is under way.

Following recent trends in data visualization, Labs allow for so called "geospatial storytelling" – where sharing the results is wide-scoped in a sense that the results are presented both for experts and untrained public. One such Lab (Rhine Roman Land Use Case Study Lab) is currently being implemented from the results of deliverable D2.3 "Dynamic models for the analysis long-term landscape change using archaeology data and the landscape biography framework in the case study sites" and is expected to be published shortly.

Figure 26: Labs available in November 2016. The number of explorers is growing with more HERCULES deliverables providing data input to the KH.

2.3.4 Modelling and temporal data visualization with Labs

The difficult mechanisation to apply advanced styling options, described in chapter 2.1.3. can be nevertheless given to non-expert public within Labs, as both visualization engine for vector data and raster data modelling and query tool can be configured via the API, allowing users to interact with the KH platform in an unprecedented way.

Following table represents which Lab showcase which capability.

Table 1: Labs and their capabilities

Lab name	Description and Capabilities
Ecosystem services in EU (L1)	This theme contains data about wild food spatial distribution and demand and supply of pollination in EU. – Raster data classification modelling
Future cultural Landscape Dynamics (L2)	This explorer contains data from WP5, where a model-based assessment of processes of change in cultural landscapes were made. This deliverable evaluates potential future threats to cultural landscapes at a European scale. – Spatiotemporal raster data (raster data with temporal dimension showing the possible future scenarios) – Raster data modelling visualization (model specified on web GIS app) – Raster data feature info (on web GIS app) – Comparison tool for assessment of data from different times
Cultural Landscape Change Explorer (L3)	This explorer contains timelines of cultural landscape change for the HERCULES' study landscapes. – Historical vector data (geometries changing over time) – Comparison tool for assessment of data from different times
Cultural Landscape Characterization explorer (L4)	The explorer contains an interface in which the user can generate their own European-wide cultural landscape characterization based on three dimensions: management intensity, landscape structure and value and meaning. – Interactive and user-friendly raster data modelling within the Lab – Raster data feature info
Modelling past land use change (L5)	An interactive story telling web GIS application is the result of research performed in the context of the HERCULES project in which the history, current state and future of the European cultural landscape is being studied (WP2). – Geospatial storytelling for general public – Historical raster and vector data that was used as input for

	modelling within WP2 as well as the resulting (raster and vector) data – Advanced styling

Most important and interesting capabilities that make the KH platform such a powerful tool to model, visualise and share resulting data will be outlined in this chapter.

Temporal data comparison tool is available for both vector and raster data. It is used in L3 with vector data and in L2 for raster data and allows user to quickly discern changes over time by imposing two data "frames" on top of each other. Switching between the two is than possible by either moving the slider to (un)cover the underlying image or changing the opacity of the image on top, as shown in Figure 27.

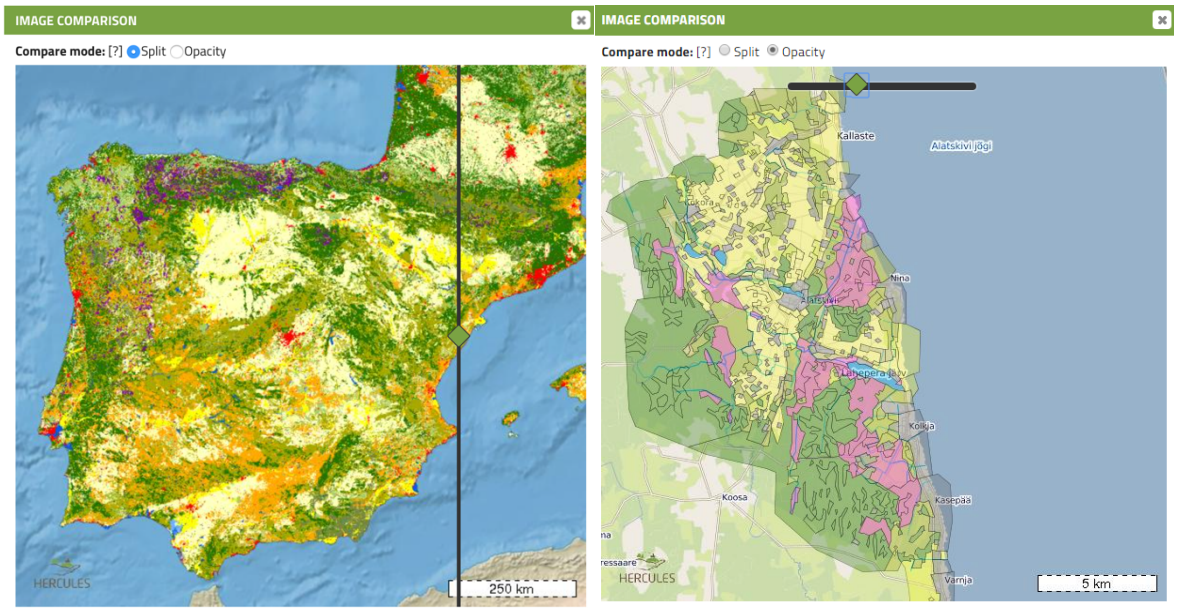

Figure 27: Two time comparison tool options: split mode on right and opacity mode on left. Data on left is raster data from L2, vector data on right is from L3.

Raster data modelling is employed in most of the Labs. On top of having real data (and not just coloured visualization), which can be extracted over areas and time, it also allows us to quickly re-colour the data without the need to reprocess the tiled pyramids. An example is shown in Figure 28, where colours for classification were taken from the article Schulp et al. (2014) "Wild food in Europe: A synthesis of knowledge and data of terrestrial wild food as an ecosystem service", Ecological Economics, 105, 292–305.

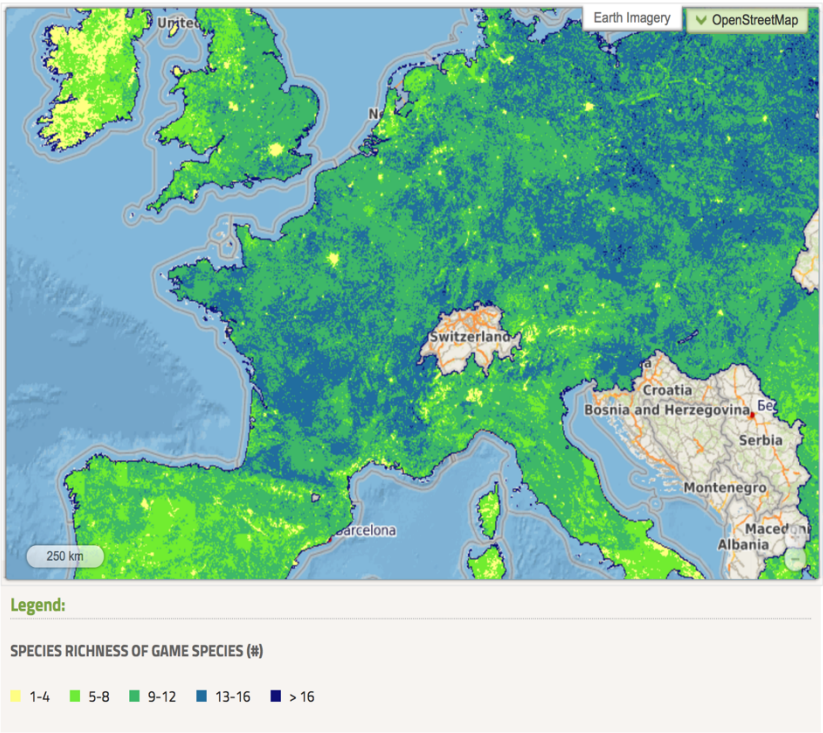

Figure 28: Raster data classification with colouring from the original article. Underlying data is written in multi-band GeoTiff file format.

More important for both visualisation and modelling as well as for interaction with general (non-expert) public is Cultural Landscape Characterization explorer (L4), which showcases interaction of simple user interface with complex modelling capabilities of KH platform.

The controls, together with rendered map and legend, are shown in Figure 29.

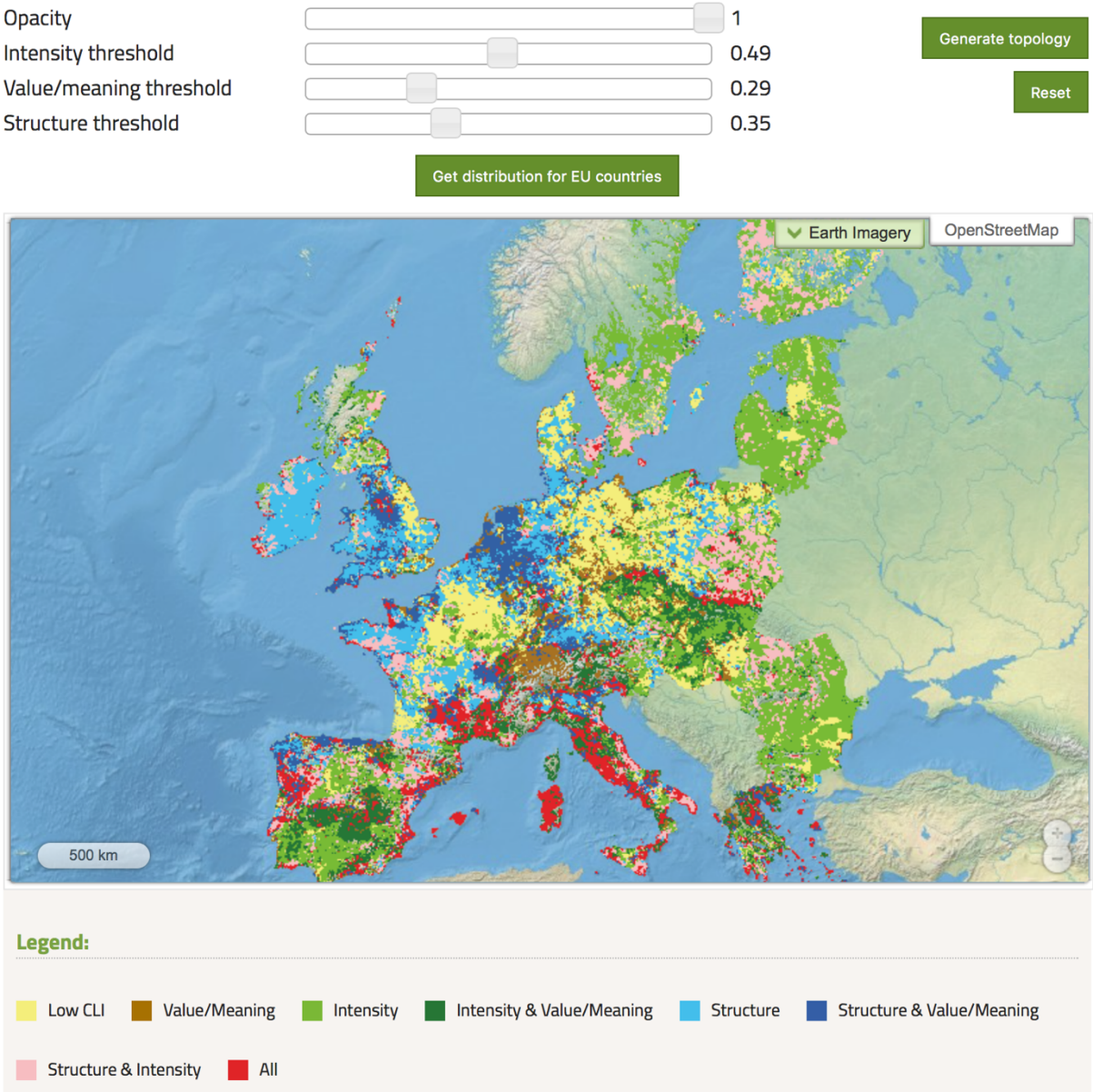

Figure 29: Confluence of simple user interface with powerful modelling engine of KH, showcased on HERCULES results from D6.4.

By changing the threshold values for the three dimensions (Intensity, Value/Meaning and Structure), the user is able to model their personal characterisation of cultural landscapes. Additionally, on clicking the "Get distribution for EU countries", the calculation over the countries' areas is performed, with the parameters set by the user, and results are displayed on a stack bar plot. The results for two different thresholds settings are shown in Figure 30.

The possibility to hide the advanced options of the KH platform with the simple user experience of the Labs renders the Labs into an efficient toolkit to visualise, share and distribute project results to everyone.

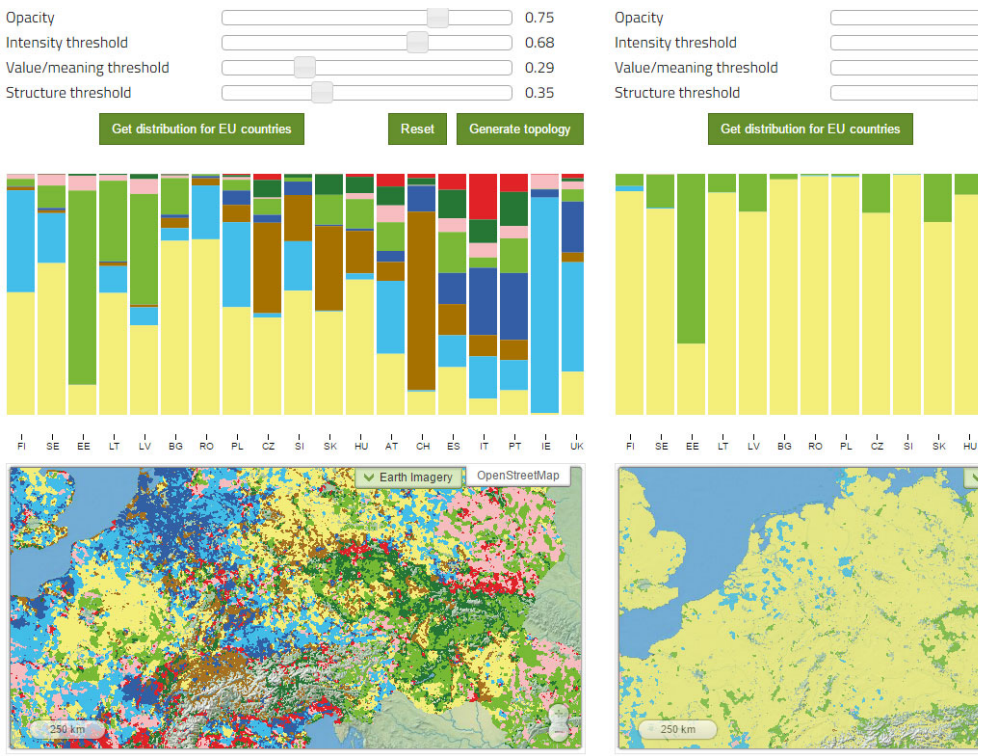

Figure 30: By changing parameters users can model their own perception of cultural landscapes over EU countries and get resulting distributions for each country.

The storytelling GIS lab, shown in Figure 31, is currently being implemented from the results of deliverable D2.3 "Dynamic models for the analysis long-term landscape change using archaeology data and the landscape biography framework in the case study sites". The Lab focusses on the land use in the Lower-Rhine delta of the Low Countries during the first millennium AD and presents the results of a dynamic modelling framework to simulate past landscape change. It provides an innovative example on how complex modelling research can be published, allowing authors to share all their research data in a more comprehensible way.

Instead of printed static maps generally used in reports and academic papers and articles, it allows presenting the research in interactive environment, giving the readers to have a detailed look into their areas of interest, overlay various data layers on a single map and get additional information about the data itself with the use of feature info functionalities of the KH. Since the Lab presents the main story line in a way that is suitable for non-expert public, it is also usable to present the research to a broader public and heritage and landscape managers. The research details which are of interest to experts are available as well, but in a way that does not obstruct the general story line, thus allowing the research to be publish in a more scientifically transparent way and interesting for general public at the same time.

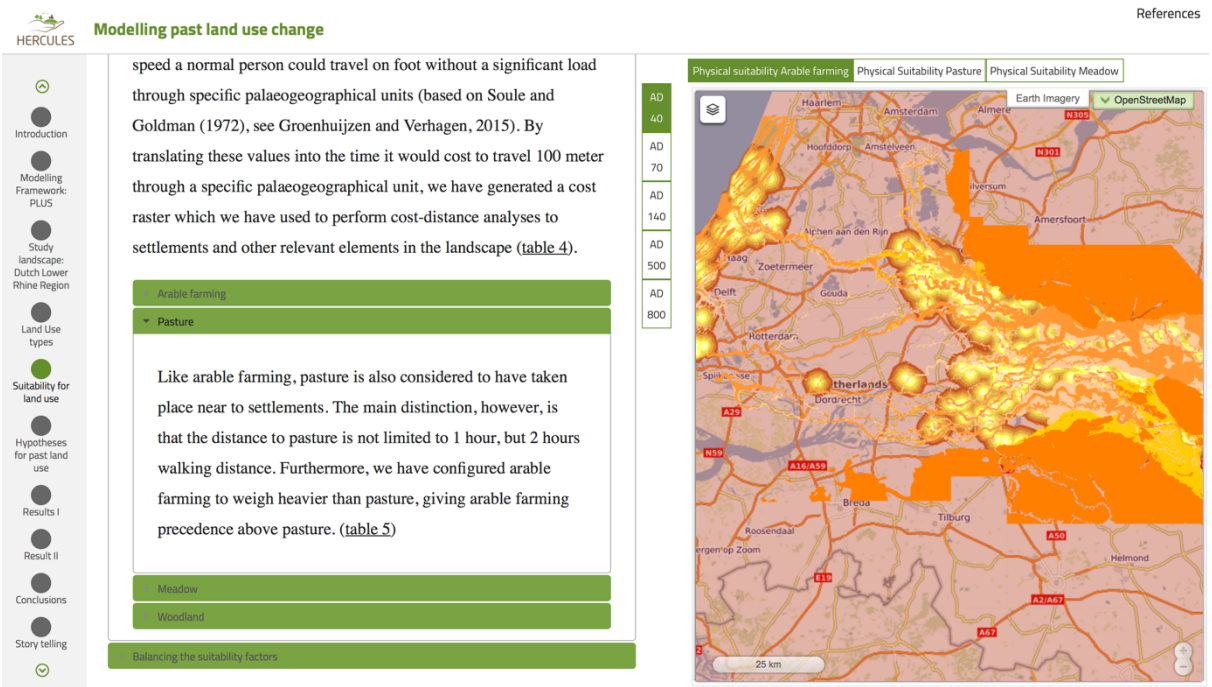

Figure 31: Screenshot of a storytelling lab, showing the "slide" selection on the left, textual story in the middle and a map, supporting the text, on the right.

2.4 Sentinel-2 satellite data

One of the goals of the KH is to provide means to map, assess, protect, and manage the functions, services, and values of cultural landscapes at local scale. We believe that visualization and analysis of land changes in time is playing a crucial role here as well. Sentinel-2 data - a free public dataset from Copernicus' missions - is perfect for observation of land changes through time. This data (satellite multi-spectral imagery of 10-meter resolution) makes it possible to identify different land-uses (e.g. built-up areas, forests, arable land, waters, etc.) and fits well with landscape change observation.

Sentinel-2 imagery has been integrated into the KH using Sentinel Hub service (http://www.sentinel-hub.com), provided by Sinergise. The service revolutionizes access to Earth observation satellite imagery, reducing the time required to visualize and exploit the data from hours down to seconds. Sentinel Hub triumphed in the 2016 Copernicus Masters Competition organised by AZO on behalf of the European Space Agency (ESA).

Sentinel Hub uses Amazon Web Services cloud and innovative methods to efficiently process and distribute data in a matter of seconds. It can be integrated into any mapping application for web application allowing for any easy-to-use and cost-effective way to exploit the data. It removes the major hassle of downloading, archiving and processing petabytes of data and simply makes the full and global archive easily available immediately via web services. Application developers can focus on added value services and end-user applications rather than having to deal with the complexity of remote sensing data.

A demo application with advanced satellite data analysis tools and means to visualize and measure the changes through time has been added to the HERCULES Labs. It provides an easy-to-use land monitoring service primarily targeted to the study landscapes of HERCULES

project, where users will be able to pinpoint and mark the changes they feel mostly affect the (cultural) landscapes. Screenshot with a selection of study landscapes is shown in Figure 5.

Users can switch between a predefined set of earth observation (EO) products, as can be seen in Figure 32, or write his own rendering of multiband data from Sentinel-2 imagery, which enables advanced data modelling and manipulation.

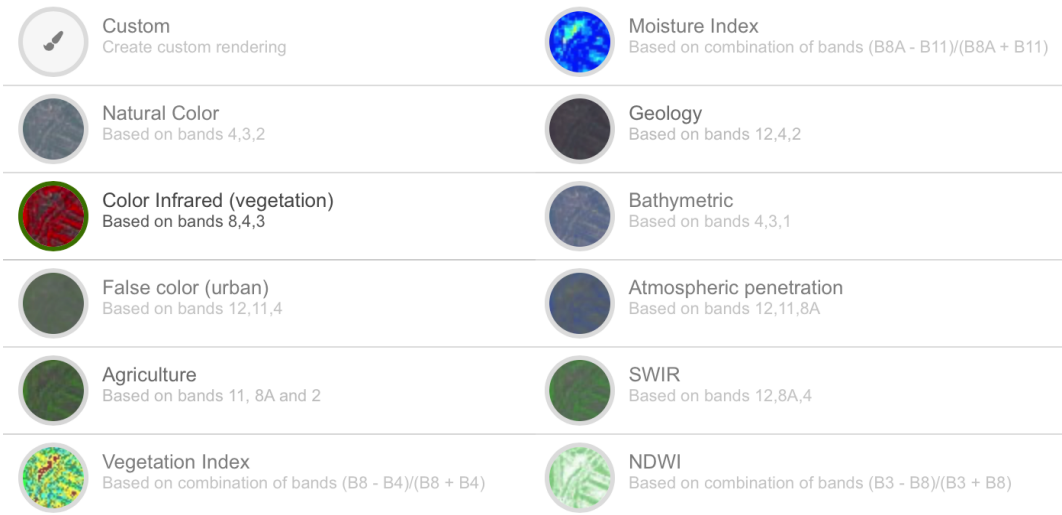

Figure 32: Predefined set of EO products, together with custom script that allows for advanced data manipulation.

The custom script provides means for general public to interact with data via dragging and dropping the channels available from Sentinel-2 satellite as well as powerful scripting mode for experienced users. Both modes are shown in Figure 33.

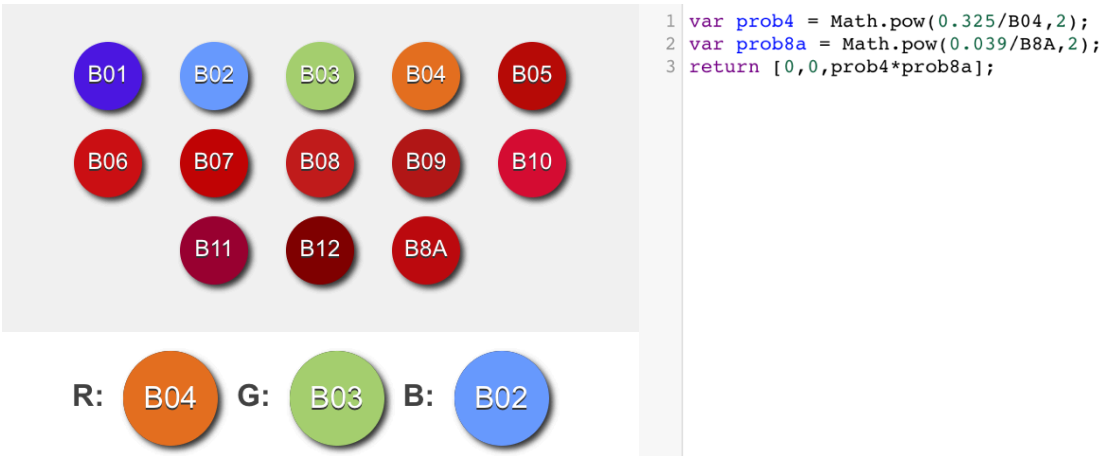

Figure 33: Custom script mode for both general and expert users. The equation on the right will show water bodies' probability in blue shades. Equation is adapted from Hollstein et al., Ready-To-use Methods for the Detection of Clouds, Cirrus, Snow, Shadow, Water and Clear Sky Pixels in Sentinel-2 MSI Images", Remote Sensing, submitted 4/2016.

By enabling atmospheric correction filter available through "Effects" tab, it is possible to obtain a good estimation of bottom-of-the-atmosphere reflectance as opposed to top-of-the-atmosphere reflectance (which is the default). This filter is a runtime-optimised version of

ESA's provided Sen2Cor processor. Additionally, by enabling cloud correction, the service will try to replace the clouds with older, but cloud-free imagery.

In the top banner users can find the location of their interest, choose date of the imagery, and set maximal cloud coverage percentage when they are still interested in seeing the data. Upon entering the second date, they can compare the two images by means of changing opacity of the second image with the slider, shown in Figure 34.

To provide some quantifiable data as well, user can select the icon and then click anywhere on the map to get the graph of normalized difference vegetation index (NDVI) values through time, as shown in Figure 35. Implementation to get other indices and values plotted through time are also being considered and will be added at later time.

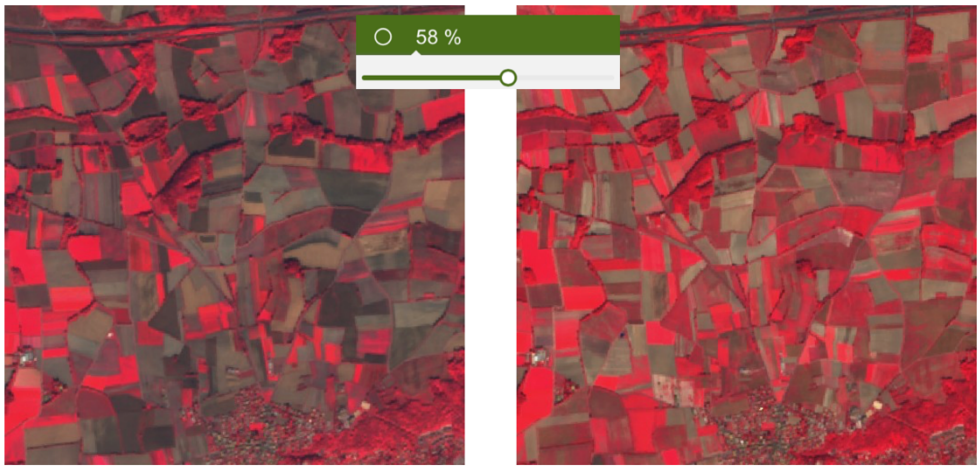

Figure 34: With opacity slider user can see the differences between two dates superimposed one on another. The images below the slider show differences in colour infrared product of the same area.

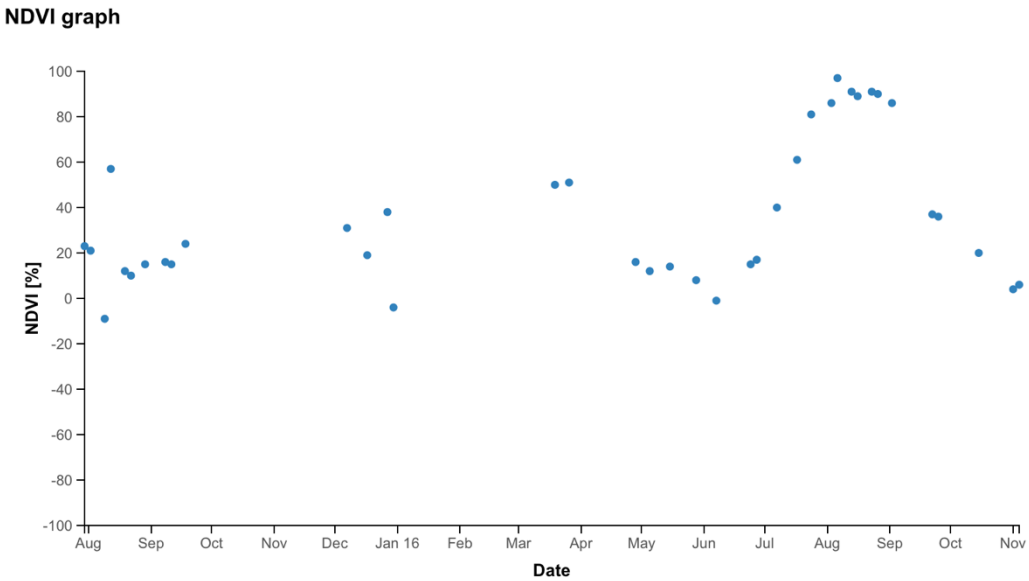

Figure 35: Plot of normalized difference vegetation index through time, clearly showing dense vegetation in August and possible harvest sometime in September 2016. Please note that data was obtained from a farmland area.

Users can also mark the locations (both temporally and spatially) they feel influenced (cultural) to landscape changes, thus providing the KH with citizen observatory functionality. The user interface to add marker (shown in Figure 36) is simplistic in order to make users more inclined to contribute.

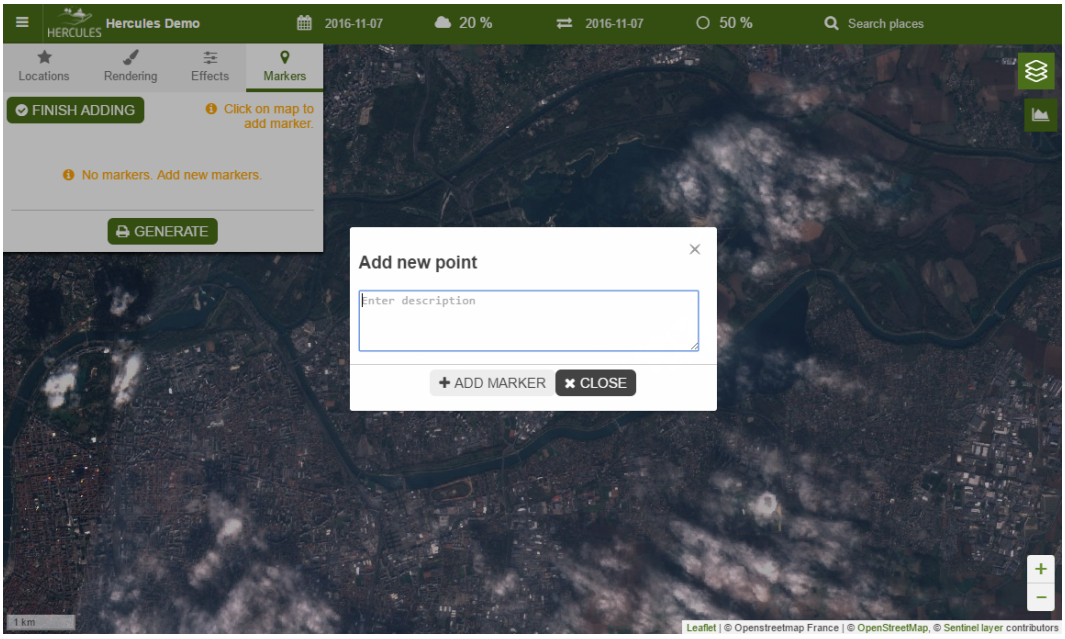

Figure 36: Users can mark discovered changes they feel contribute to (cultural) landscape changes.

3 The longevity of the Knowledge Hub

From the beginning of the HERCULES project it has been established that the KH will continue its operation after the lifetime of the project. In order to achieve this longevity, a plan has been outlined in milestone MS9.6 "Business plan to ensure the longevity of the Knowledge Hub". As the permanency of the KH is crucial for the dissemination purposes of the HERCULES project, the most important parts have been added to this deliverable as well.

3.1 Keys to success

There are three cornerstones relevant for longevity of the KH:

- Maintenance of the system from infrastructure point of view,
- Relevant and up-to-date data,
- Users using the system.

In addition to the above, further improvements of the platform are relevant to keep the KH interesting and state-of-the art in the cloud GIS field. In the following subsections, we try to address each of these separately.

3.1.1. Long-term maintenance of the Knowledge Hub system

Sinergise will provide non-interrupted operation of the KH and patch it with possible bug fixes. The same goes for

- KH spatial and alphanumerical database,
- KH web GIS application,
- Mobile applications developed within the timeframe of the project,
- Labs web page(s).

To ensure sustainability of the KH it has been designed to be integrated with Sinergise's Geopedia platform (http://www.geopedia.world). This keeps the costs of maintenance low and provides Sinergise with an option to commit to maintain the KH for at least 5 years after the end of the project, even if there is no additional budget available.

In case the additional (even if small) maintenance costs prove to be a burden after 5 years, Sinergise will incorporate KH within Geopedia itself. This will incorporate all the data and results from the KH, which will continue to be available through means of widgets (Labs), provided some small changes (changing the URL to access the widget). The role of web GIS will also be taken by Geopedia web GIS, thus providing the KH with up-to-date web cloud GIS tool. The mobile applications will also be integrated within Geopedia.

The Labs webpage will be kept as is even after a period of 5 years, with necessary changes implemented by Sinergise.

3.1.2. Relevance of data on the Knowledge Hub

This proved to be most important factor, which is why all partners have committed to contribute results of their tasks within the project to KH. To reach even wider scope, we have provided ways for external users to add their data as well.

All project partners were recommended to use the KH for dissemination of their research results even after the end of the project.

Two additional actions will hopefully make the platform interesting for a long-term period:

- The HERCULES data are being disseminated through Geopedia platform as well. Similarly, all Geopedia data are available within the KH. For both options the privacy and data protection remains the important factor – data are available only to users, who have appropriate privileges (unless the data permissions are set to public).
- In addition to Sentinel-2 data, Landsat-8 data will be included to KH as well. Both represent free public datasets (part of the USGS' and Copernicus' missions) and are perfect for observation of a land change. Landsat data are available for the time period of more than 20 years and both Landsat and Sentinel missions are committed to produce data for at least next 10 years. These data (satellite multi-spectral imagery of 10/30-meter resolution) make it possible to identify different land-uses (e.g. built-up areas, forests, arable land, waters, etc.) and fit well with landscape change observation. The ingestion of these data will be done in as automatic way as possible, which means the data will be updated even after end of the Hercules project, ensuring the relevance of overall data in the platform.

3.1.3. Engagement of the users

Dissemination of the HERCULES data and overall KH platform is a task for all HERCULES partners. They have committed themselves to disseminate content residing in the KH and the platform itself at as many occasions as possible.

To ensure as efficient dissemination as possible, we have implemented an option to embed (integrate) KH in other webpages in a form of the widgets (KH Labs are exemplary implementation). This makes it possible to spread the data beyond the scope of the original project.

3.2 Target audience

The target audience for the KH consist of GIS experts (landscape practitioners, policy makers and managers) and interested general public, as shown in Figure 1.

The KH utilizes powerful GIS tools which helps GIS professionals to collect, model, analyse and distribute spatial data. The targeted audience is thus firstly made up of the GIS expert community and landscape practitioners. But since the traditional approach to publishing maps on the Internet "by GIS experts, for GIS experts" is ineffective, as web mapping becomes more and more mainstream, the applications need to be designed for ease of use. To bring the KH closer to the general public we have implemented an option to integrate the KH in other web-pages in a form of the widgets – KH Labs are exemplary implementation (http://labs.kh.hercules-landscapes.eu/). In this way we want to offer useful services to a wider range of users and so expand the target audience to the general public.

3.3 Challenges

Across Europe, a multitude of approaches have already been developed to protect and develop heritage values in cultural landscapes. However, they are mostly localized to a particular region, or concerned with a specific feature (type). The KH is meant to be completely open in this concern: it is not limited to region and scale, nor does it impose a constraint on feature or data types, as long as they do carry a locational information.

The KH acts as a toolkit for communication of (HERCULES) insights while at the same time provides the means for collecting feedback and input from general public, not only professionals (landscape practitioners, managers and policymakers). One of the challenges for the KH here is how to provide tools and services which will be equally useful for presentation and collection of data. Following this requirements, we have built a powerful web GIS platform with underlying repository allowing processing and storing of large amounts of spatial data. The architecture implements current state-of-the-art in cloud computing and allows efficient collecting, archiving, using, sharing, and distributing of data amongst project partners, stakeholders and the general public.

3.4 Value Proposition

The KH can provide benefit to an extremely wide range of audiences – does not limit its usage to professionals, but strives for the empowerment of both public and private actors. It allows its users not only to access, use, archive, share and distribute data produced throughout the study, but by being freely accessible to all, also enables anyone to contribute their own data. It thus provides the means for collecting input and feedback and can act as a toolkit for the communication of (the project's) insights between various parties. Not being limited to data and feedback gathering, it will also allow making available research analyses (automatic or semi-automatic modelling, supported by change detection, pattern recognition, time series analysis and future dynamics forecasting).

3.5 Promotion Strategy

- Advertising: We will utilise direct mail and face-to-face promotional activities to raise awareness about the KH.
- Internet: We will have a content heavy website maintained for 5 years beyond the project that will be linked to the KH.
- Alliances: Dissemination of the HERCULES data and overall KH platform is a task for all HERCULES partners. They have committed themselves to disseminate content residing in KH and the platform itself at as many occasions as possible.

To ensure as efficient dissemination as possible, we have implemented an option to embed (integrate) KH in other web-pages in a form of the widgets – KH Labs are exemplary implementation (http://labs.kh.hercules-landscapes.eu/). This makes it possible to spread the data far beyond the original project.

3.6 Opportunities

The optimal option to ensure longevity of the KH is to use it within other (EU, Horizon 2020, etc.) projects. This can provide funding for upgrades of both functionality and data.

We have investigated several opportunities:

- All project partners and project stakeholders will keep their access credentials and be able to use the platform, view, edit and manage the data within, even after the end of the project.
- Project partners were asked to consider using the KH in their future research proposals.
- Due to tight integration with Geopedia, the KH will more or less automatically receive updates whenever Geopedia platform is updated.

3.7 KH maintenance

Sinergise has a plan to maintain the KH for at least the next 5 years. During this period the developers will keep track of bug reports, monitor the potential application failures, upgrade GIS tools and improve overall user interface of the system.

Support to users will be provided through the Help and support centre (http://kh.hercules-landscapes.eu/help/index.html), which will be regularly updated. Use cases of potential new functionalities will be presented there as well.

3.8 KH as a source of revenues

The best option to ensure longevity of the platform is when it is bringing revenues directly – e.g. subscription based model, pay-per-use, etc. The partners, especially SMEs, were looking for these kinds of options throughout the project and they have identified several possible opportunities:

- Landscape practitioners using it as a guideline for their work, with all the necessary rules and data being on disposal. This would significantly reduce the effort required, thus increasing the added value of their services.
- Landscape related institutions (e.g. municipalities, ministries, other public bodies) using it as a platform for dissemination of their data.
- NGOs focused to demonstrate their actions - e.g. for preventions of significant changes in the landscape (new industry areas, melioration and power generation related changes in the water flow, etc.).

Several of these options require detailed and localized datasets, which are updated regularly. EU-wide solutions are therefore not feasible and partnerships are required on local/country levels.

Further more, from the beginning of the project until now, the landscape of IT solutions has changed significantly – where there were just a few web GIS tools available few years ago, there are now plenty. And even more importantly, the model has changed from applications covering wide use to specialized micro-services, each covering individual case only. Therefore, the feasibility of using KH as it is for commercial purposes is quite limited and would require additional investments.

4 Conclusions

Deliverable 7.4 "Web-based GIS system for modelling, visualisation, dissemination and further use of resulting data" wraps up the Knowledge Hub for Good Landscape Practice.

We have presented the new functionalities of the web GIS application, inclusion of the Labs to the list of viewports and addition of satellite imagery to the Knowledge Hub platform using the Sentinel Hub services, provided by Sinergise.

The three viewports together with the Sentinel-2 satellite data toolkit and the underlying (spatial) data repository infrastructure assemble the Knowledge Hub platform. The versatility of the web application, adaptability of mobile applications to use-case scenarios and possibility to hide the advanced tools with simple user experience of the Labs make the Knowledge Hub platform an efficient toolkit to collect, archive, use, share and distribute project results to everyone.

The Knowledge Hub strives to protect, manage, and plan for sustainable landscapes at local, national, and Pan-European scales. It provides the means for combining information on landscape practice, land use, land cover, biodiversity, soils & geology, social issues & existing policies, legal constraints, history, archaeology, etc., from both experience-based local insights and scientific knowledge. The platform serves researchers as a powerful suite of analysis and modelling GIS tools, ranging from small "building blocks" that you can use to construct a sophisticated work-flow, to completely self-contained analysis programs.

We have identified three main factors, which will contribute to long-term sustainability of the platform:

- **Data, residing in the platform** proved to be the most important factor, which is why all partners have committed to contribute results of their tasks within the project to Knowledge Hub. To reach even wider scope, we have provided ways for external users to add their data as well.
- **Storytelling applications,** focused to a single use-case and embedded in the wider web-page describing wider context. These "stories" will also contribute most to further development of the functionalities of the Knowledge Hub.
- **Dissemination** - in today's world, where there is too much of information available everywhere, it is extremely important to spread the news about specific content and Knowledge Hub is no different. HERCULES' partners have committed themselves to disseminate content residing in Knowledge Hub and the platform itself at as many occasions as possible.

Due to the research nature of the overall HERCULES project, the primary focus was to develop the tools to support research activities with the idea generate actual market opportunities only as an addition. Therefore, the future of the Knowledge Hub is first and foremost in research projects. Hopefully there will be similar projects where the Knowledge Hub will continue to serve its purpose, guaranteeing its continuous operation and upgrades for the next several years. However, the longevity of the Knowledge Hub does not depend only on these projects as Sinergise has committed resources to maintain the platform for at least next 5 years.