Interreg
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Re-Source

RE-SOURCE PROJECT - PROVIDING SERVICES FOR MANAGEMENT OF NATURAL RESOURCES

D 5.1.1:

Operational evaluation of central system and inter-related subsystems

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AUTHORS

Name	Organisation
Kalopesa Eleni	**Aristotle University of Thessaloniki**
Tsakiridis Nikolaos	**Aristotle University of Thessaloniki**

TABLE OF CONTENTS

Table 1: Abraviations

Abbreviation	Full description
LP	Lead Partner
i-BEC	interBalkan Environment Center
CGAP	Codes of Good Agricultural Practices
OS	Operating System
WIMS	Web Information Management System
ISP	Internet Service Provider
DBMS	Database Management System
NDVI	Normalized Difference Vegetation Index
SEBAL	Surface Energy Balance Algorithm for Land
GIS	Geographical Information System
WMS	Web Mapping Services
XML	Extensible Markup Language
IMS	Internet Map Services
OS	Open Source
CGI	Common Getaway Interface
RDBMS	Relational Database Management System
DSS	Decision Support Systems

EXECUTIVE SUMMARY

This report is the thorough operational evaluation of the delivered services by LP (I-BEC) along with the system and related subsystems that constitute the system as a unified toolbox. The delivered systems were based on the existing capacity that LP has developed over the years, thus all actions can be considered as a partner-oriented customization of tools that have been developed and assessed over the last years by LP.

To that end, the performed actions are all focused on the evaluation in terms of system's stability, interoperability with other internal or external systems and the user friendliness. The components that have been taken into consideration along with the delivered services, contain the selection of the utilized tools and subsystems over which the services are operating and to propose possible modifications, aiming to secure and optimize the proper operation of the services.

In particular, the services delivered from LP during the implementation of RE-SOURCE project are:

- Precision irrigation: a digital model for the application of precise irrigation in space and time which is further upgraded, customized and applied within the Greek and Albanian territories,
- Application of Codes of Good Agricultural Practices (CGAP): a digital tool for the evaluation of the implementation of CGAP in Cyprus and North Macedonia territories
- Application of soil erosion risk assessment: a digital model for large-scale risk assessment of soil erosion is customized for use within the Bulgarian territory.

Precision irrigation application and CGAP service were delivered as web-services that can be publicly accessed, while the soil erosion digital model for use within Bulgarian territory was delivered as a standard GIS-compatible toolbox.

1. INTRODUCTION

As part of the RE-SOURCE project, a multidisciplinary toolbox was delivered from LP that aims to support administrative policies for sustainable resources management. To that end, a set of services that were part of LP's existing capacity were customized to meet project partners' needs. These services are meant to cover the need of accurate soil erosion risk assessment, to enable end users to apply precision irrigation and to efficiently assess the Codes if Good Agricultural Practices compliance of the applied practices.

This set of services was delivered to corresponding partners either as a web-based application (Application of Codes of Good Agricultural Practices and Precision irrigation tool), or as a GIS toolbox (Application of soil erosion risk assessment). The services are provided by a Central Database Management System that is located at LP's premises and consists of a physical server that hosts each service as a virtual machine, one for every service. The distribution of services is performed through the application of a Web-based Information Management System. The system's architecture is characterized from robustness and high speed service delivery, while all server-client communications are completed through security protocols, ensuring data integrity and privacy.

This report includes:

- A detailed description of every provided service
- The operational evaluation of every subsystem corresponding to each service, and the central system
- The identification of fine-tuning technical points that could provide further improvements

2. SYSTEM'S DESCRIPTION

2.1 Architecture

The three provided services are hosted from a dedicated data management system that is located at Central Macedonia, Greece, at LP premises. A physical server running Windows 2012 R2 hosts three Virtual Machines, one for each service. The selection of the abovementioned OS lies on the credibility that it ensured over the last decade, since it is widely accepted and most commonly used for such purposes. It is easy to install and maintain while it provides the installation of virtual machines with high performance that can employ:

- 64 processors
- A 1TB of RAM
- 1,024 active Virtual Machines
- 8,000 Virtual Machines per cluster
- 64TB Virtual Hard Disk with 256 disks per VM

The graphical interface of Windows based systems allows easy operation and maintenance and can easily be updated to most recent Windows Server 2019. This physical machine along with a developed central database management system plays the role of the system of systems which is fully operational and provides the three services in real time scale on constant basis. The central database is set to the core of the system is in total compliance with the protocol that is delivered to the partners regarding the data collection. The server and the database are interrelated with three virtual machines that host the following services and are delivered to the corresponding partners:

- VM 1. Precision irrigation – Application of precision irrigation model in Albania with the participation of local farmers by P5 and P6
- VM 2. Application of Codes of Good Agricultural Practices – Application of CGAP in specific areas of North Macedonia and Cyprus respectively by P5 and P6
- VM 3. Application of soil erosion risk assessment – Application of large-scale soil erosion risk assessment model in Bulgaria by P4

Three Web services were developed that namely are:

- A Web service that is a Web Information Management System and is dedicated to exchange georeferenced data between end users and concerning authorities. It handles data that are collections of georeferenced point observations accompanied with their corresponding metadata and description.
- The second Web service is associated to the CGAP service. It is a decision support application that handles data input of corresponding end users, and with the operation of a decision support system provides a final recommendation and compliance regarding the application of CGAP.
- The third Web Service concerns the precision irrigation tool, and its operation is based on the collection of meteorological, environmental and irrigation water usage data, to provide recommendations for irrigation policy by taking in consideration the provided crop coefficients and evapotranspiration in near real time.

As mentioned above, at the core of the second service lie the decision support systems and as well increase the speed and efficiency of decision-making activities making possible to collect and analyze real-time data.

The delivered system can be briefly sketched out at Figure 1:

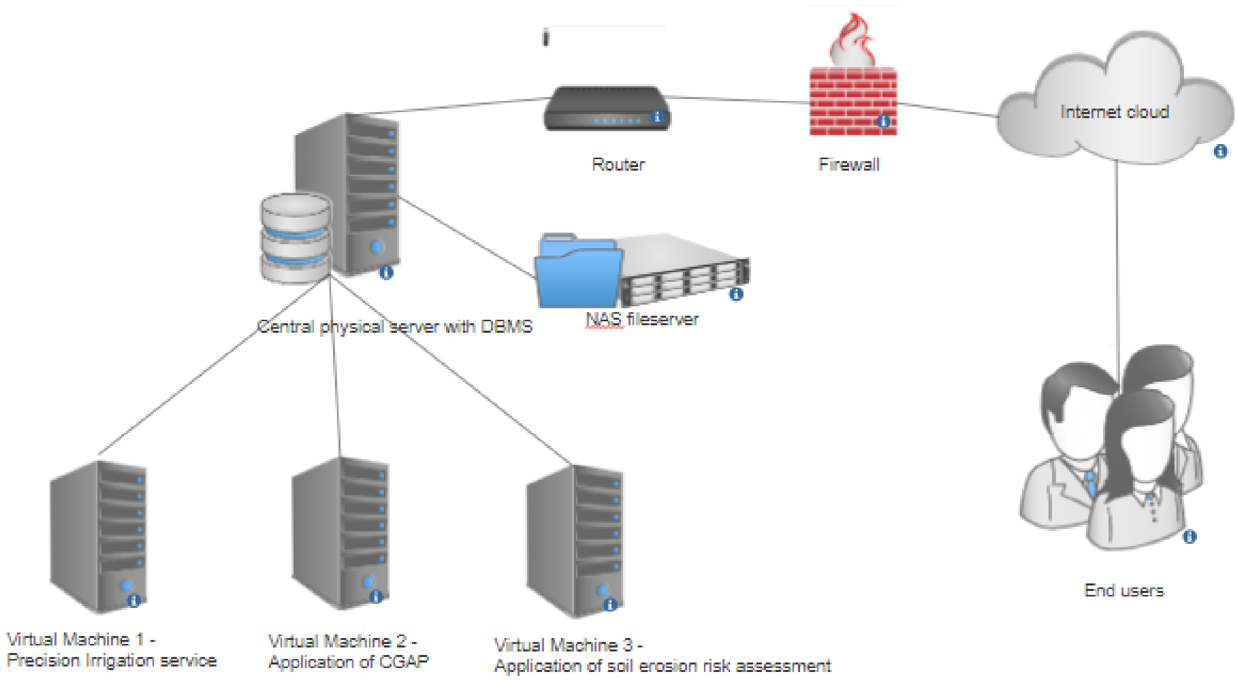

Figure 1: Architecture of central system

2.2 Hardware infrastructure assessment

The selection of hardware components was made aiming to support the existing technologies that LP had developed and to meet standard security requirements when it comes to hosting of large scaled data. To that end, the system involves the usage of physical firewall. This selection ensures that unwanted incoming and outgoing traffic will be avoided, thus data storage and integrity will be secured.

The physical server along with the installed Virtual Machines reassure that the hosted services will operate at their full potential, since sufficient processing power and memory is supplied. Furthermore, UPS units support uninterrupted operation of the server, even after long duration power outage. Internet connection is reassured also through the stable connection over two different ISPs, thus the probability of network malfunction is minimized.

Figure 2 - Server's rack close view

Figure 3 - Side view of physical server along with NASS, router, firewall and UPS

Figure 4 - Close view of Router (with switch) and Firewall

The data storage security is enhanced through the usage of a locally accessible NAS server that is responsible for regular backups of VMs and inflowing data. The available storage exceeds 20TB, ensuring sufficient space for the existing infrastructure to operate for more than 10 years. In extreme cases that data retrieval must be performed remotely, VPN tunneling has been installed (Open VPN) provisioning uninterrupted access to service administration.

The system is located at LP premises in a dedicated air-conditioned server room that has controlled temperature. Weekly maintenance is scheduled while extensive maintenance operations (i.e. dust removal from the cases' interior, heat conductors cleaning and paste replacement., system fans check, and UPS batteries check) are performed on a six-months basis.

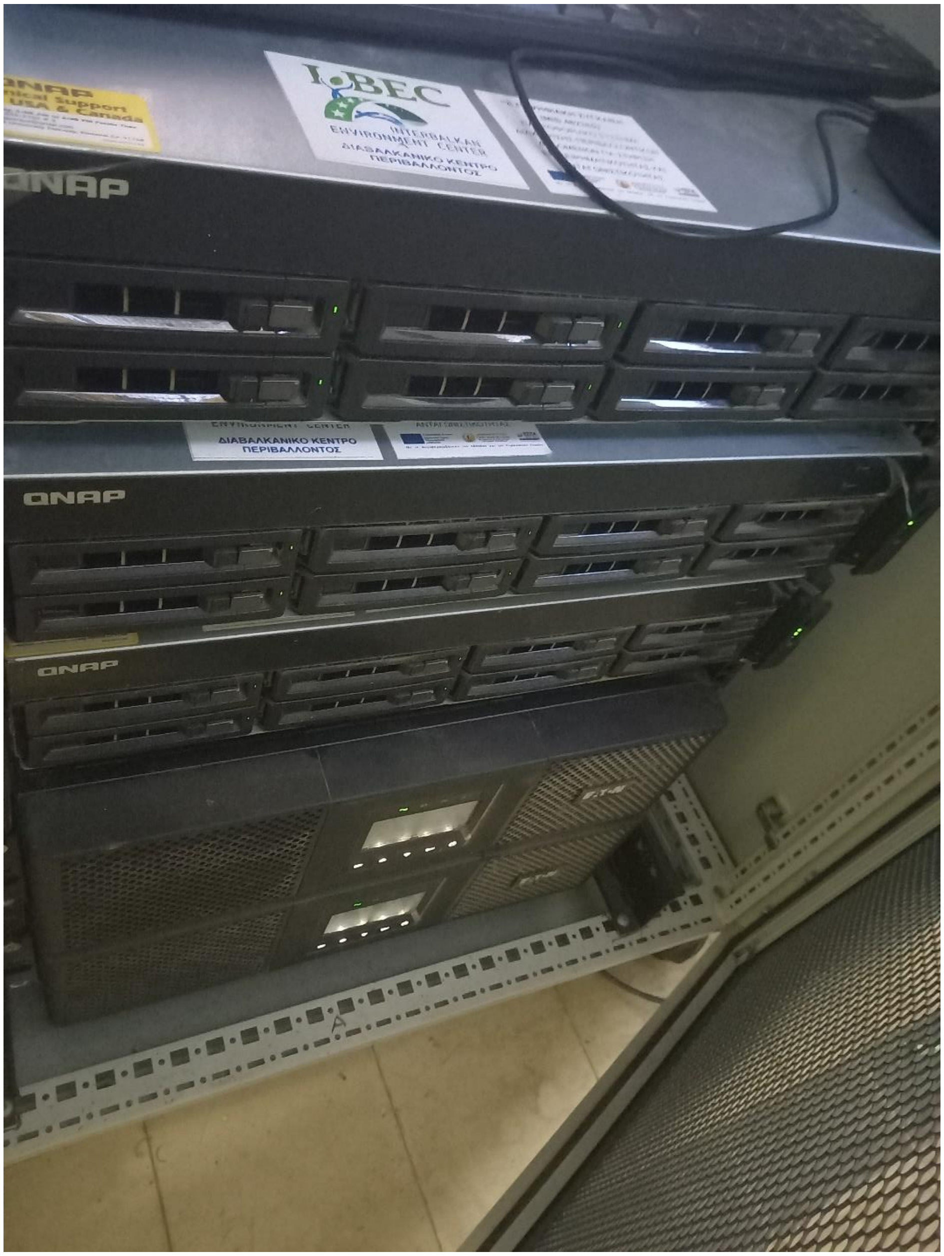

Figure 5 - NASS and UPS close view

Peripheral parts that are responsible for in situ data collection through telemetry protocols are standalone systems that are interconnected with the DBMS. The existing infrastructure contains mainly meteorological stations that are operated from concerning partners. The DBMS is constructed in such a way that can support installation of new meteorological or even updated versions of the existent through plug n play procedures. Thus, future operability of the system is secured while decommissioning risk due to peripherals outdating is minimized.

Figure 6 - Different types of meteorological stations that can be paired to the central DBMS

2.3 Software assessment

A combination of widely used software was employed for the formation of the central system. The core of the system is the OS. For this purpose, Windows Server 2012 R2 was selected. Even though the forth mentioned OS is not the newest version of Windows server OS and has entered mainstream support since October 2013, the extended support announced from Windows is January 2023. To that end and in order to avoid security issues that may arise after the extended support expiration, it is suggested to upgrade the OS to the latest version – Windows Server 2019. The dedicated virtual machines are configured to operate also over standard Windows Server 2012

The software choice was made in respect of the essentiality of the reliability and interoperability of the system. The software packages that were chosen are widely accepted and known for their reliability and their developers constantly release updated versions and provide their support so that the implementation and maintenance process will be properly supported. Additionally, such choices support the interoperability between the components of the system and meet the infrastructure criteria. Furthermore, the scalability of the system was taken into account so that it can easily support future upgrades and additions

The Internet Information Service runs ASP.NET, which is an open-source, server-side web-application framework designed for web development to produce dynamic web pages. It was developed by Microsoft to allow programmers to build dynamic web sites, applications and services.

It was launched in January 2002 with version 1.0 of the .NET Framework and is the successor to Microsoft's Active Server Pages (ASP) technology. ASP.NET is built on the Common Language Runtime (CLR), allowing programmers to write ASP.NET code using any supported .NET language. The ASP.NET SOAP extension framework allows ASP.NET components to process SOAP messages. ASP.NET is different than its predecessor in two major ways: it supports code written in compiled languages such as Visual Basic, C++, C#, and Perl, and it features server controls that can separate the code from the content. The choice of ASP.NET is a web development model with the following advantages:

1. Significant reduction of the amount of code required to build large applications.
2. Increased security through built-in Windows authentication and per-application configuration.
3. Early binding provides better performance, just-in-time compilation, native optimization, and caching.
4. The ASP.NET framework is complemented by a rich toolbox and designer in the Visual Studio integrated development environment.
5. Provides simplicity as common tasks are performed easily, ranging from simple form submission and client authentication to deployment and site configuration.
6. The source code and HTML are together therefore ASP.NET pages are easy to maintain and write. Also the source code is executed on the server. providing a lot of power and flexibility to the web pages.

7. All the processes are closely monitored and managed by the ASP.NET runtime, so that if process is dead, a new process can be created in its place, which helps keep your application constantly available to handle requests.
8. It is purely server-side technology so, ASP.NET code executes on the server before it is sent to the browser.
9. Being language-independent, it allows you to choose the language that best applies to your application or partition your application across many languages.
10. ASP.NET makes for easy deployment. There is no need to register components because the configuration information is built-in.
11. The Web server continuously monitors the pages, components and applications running on it. If it notices any memory leaks, infinite loops, other illegal activities, it immediately destroys those activities and restarts itself.
12. Easily works with ADO.NET using data-binding and page formatting features. It is an application which runs faster and counters large volumes of users without having performance problems

The data management is performed through the establishment of an SQL server that runs in the physical server. SQL, which stands for Structured Query Language and is a domain-specific language used in programming and designed for managing data held in a relational database management system (RDBMS). It is particularly useful in handling structured data, i.e. data incorporating relations among entities and variables. SQL offers two main advantages over older read–write APIs such as ISAM or VSAM. Firstly, it introduced the concept of accessing many records with one single command. Secondly, it eliminates the need to specify how to reach a record, e.g. with or without an index.

The key advantages of SQL are as follows:

- *High speed:* Using the SQL queries, the user can quickly and efficiently retrieve a large amount of records from a database.
- *No coding needed:* In the standard SQL, it is very easy to manage the database system. It doesn't require a substantial amount of code to manage the database system.
- *Well defined standards:* Long established are used by the SQL databases that are being used by ISO and ANSI.
- *Portability:* SQL can be used in laptop, PCs, server and even some mobile phones.

- *Interactive language:* SQL is a domain language used to communicate with the database. It is also used to receive answers to the complex questions in seconds.
- *Multiple data view:* Using the SQL language, the users can make different views of the database structure.

The SQL server that performs the above described tasks runs on open sourced MySQL Server 8.0, which is the latest version, ensuring database security.

2.4 Database architecture

The server handles a large amount of data, since telemetry data arrive near real time (in predefined time intervals according to in-situ telemetry system power consumption and specifications), thus their management is one of server's key roles. To that end, a relational database has been established which is dedicated to store, manage and analyze the collected information. A relational database is a type of database that stores and provides access to data points that are related to one another. Relational databases are based on the relational model, an intuitive, straightforward way of representing data in tables. In a relational database, each row in the table is a record with a unique ID called the key. The columns of the table hold attributes of the data, and each record usually has a value for each attribute, making it easy to establish the relationships among data points. Data points in this case are related via geographical reference. All data that come in spatial context are both stored in vector and raster format and are included in the database and presented through the WebIMS application are georeferenced in the same projection system, namely WGS '84[1].

Along with geographic data, non-spatial data that play the role of descriptive data, containing information about geographical data, are store to the same database. These data combined with explanatory metadata contain descriptive information that is stored in form of attribute tables and metadata. These tables are small databases that contain information regarding spatial features, where each row represent a unique feature in the context of space and time, while metadata metadata provide information that describes the content, quality, condition, origin, and other characteristics of data or other pieces of information.

[1] The Word Geodetic System (WGS) 84 is currently the reference system being used by the Global Positioning System and it is geocentric and globally consistent within ±1 m.

From a conceptual point of view, the project data will be classed into 3 main categories as sketched bellow

- Administrative data,
- (imagery and telemetry) relevant with irrigation
- Historical crop data.

The abovementioned categories are schematically depicted in Figure 7 - Relational Database depict

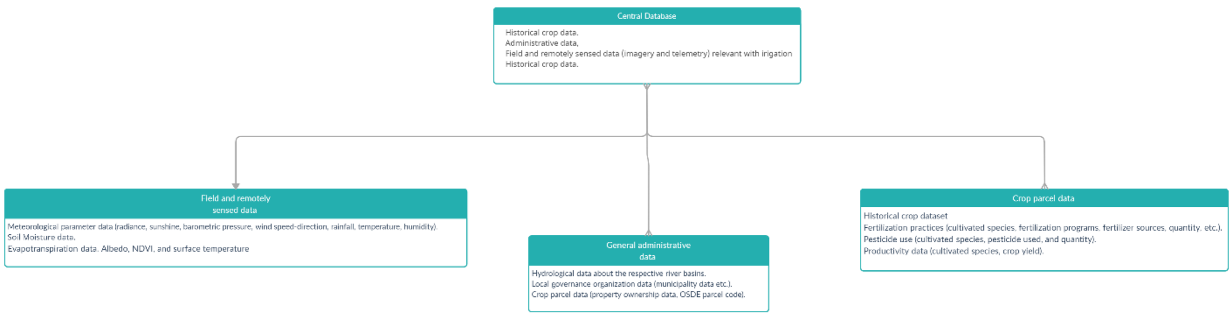

Figure 7 - Relational Database depiction

3. APPLICATIONS OPERATIONAL EVALUATION

This chapter contains the operational evaluation of delivered services. Each service was accessed remotely and assessed in terms of stability, user friendliness and whether they serve the objectives declared through Re-Source project.

3.1 Irrigation recommendation in the wider study area

The delivered service is based on an existing telemetry network of meteorological stations. This network represents a geo-referenced network of sensors that collects agro-meteorological data in near-real time. The collected data are inputs for a decision support system which is based on the proposed irrigation treatment, taking into consideration the crop, the irrigation period and the field's condition as assessed by the network of sensors. The measured variables contain the geographical reference of the station, the air and top-soil temperature in Celsius degrees, the wind speed, the relative humidity and the daily hours of sunshine.

The field's irrigation needs are estimated through the calculation of referenced evapotranspiration. Evapotranspiration is the most important variable in assessing the condition of the parcel, related to water needs.

The application is accessed via https://irrigation.re-sourcebalkanmed.eu . Through this interface, the user inputs a set of parameters concerning the irrigation water management and send it to the central DBMS. Then, in near real time, a recommendation is sent to the users e-mail with the volume of the water that need to be applied. The service can be used only by users that are registered to this service. This policy secures that unauthorized users will not have access to the results of the DSS that estimates the water needs. The service is stable, secure and easy to use. The methodology employed for the calculation of water needs is based on the estimation of evapotranspiration which is widely accepted, thus no changes are recommended.

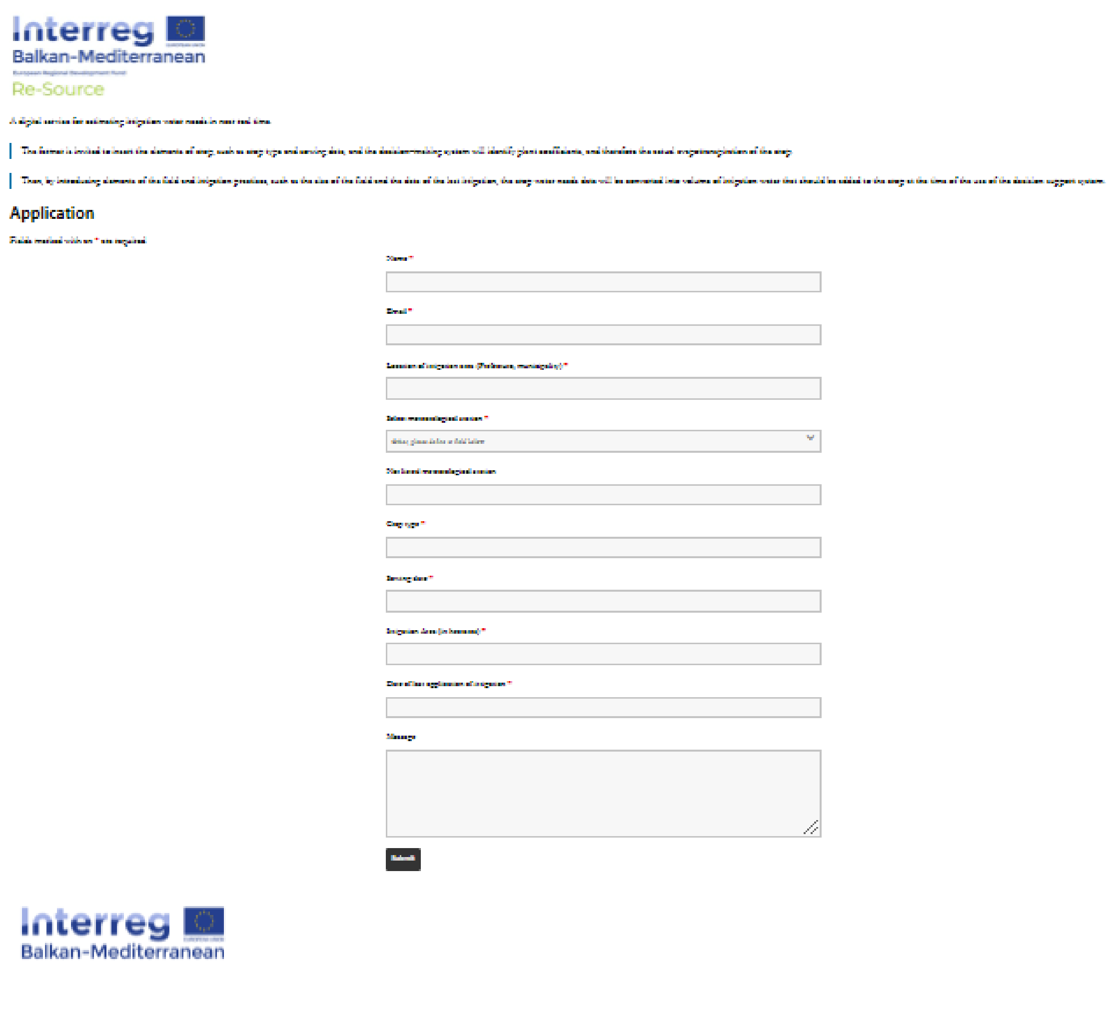

Figure 8 - Web service preview as accessed on 1st of December, 2020

3.2 Application of Codes of Good Agricultural Practices

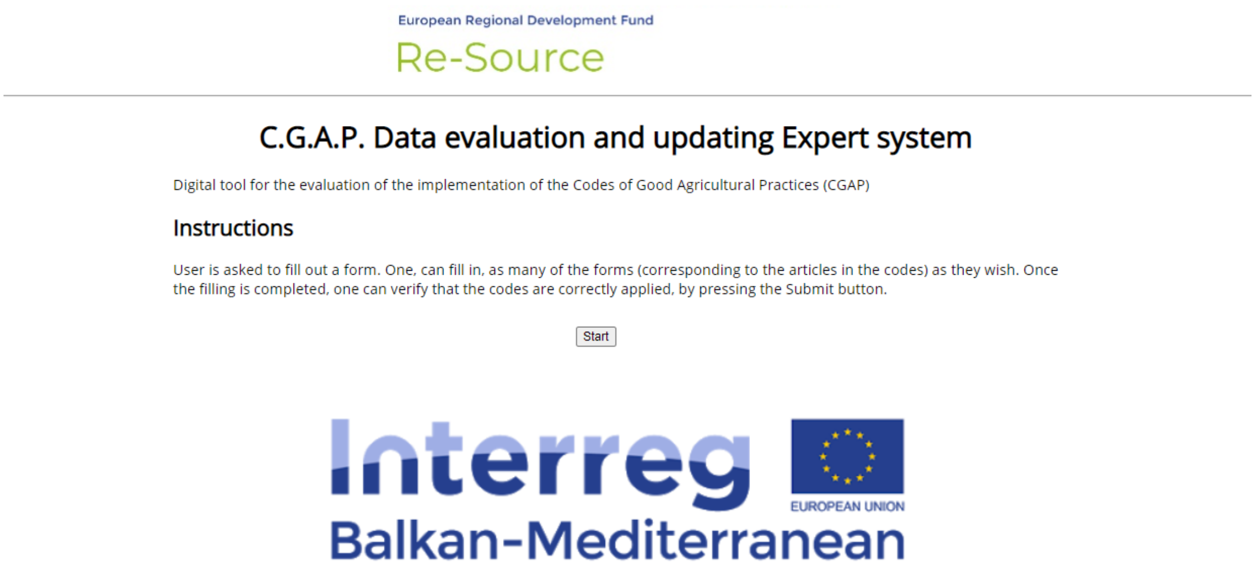

Figure 9 – Application of Codes of Good Agricultural Practices welcome screen

The online service can be accessed via https://cgap.re-sourcebalkanmed.eu/ . At first, the user navigates through the welcome screen to the main service. The tool evaluates the CGAP compliance in many layers, since the users is asked to input a variety of parameters. The first set of parameters that are input are the soil type and the crop type, which are mandatory for the assessment.

Figure 10 - Soil and crop type input

Then, the user input extends to a set of parameters that concern:

- ➢ Manage inputs
- ➢ Soil treatment
- ➢ Crop rotation
- ➢ Fertilizing
- ➢ Water resources protection
- ➢ Plant protection
- ➢ Management of native flora
- ➢ Crop residue management
- ➢ Waste management

Figure 11 - Second layer of inputs of CGAP application

This service is also a webservice, which does not present any stability or security issues. It is easy to use and in contrast with irrigation service, no registration needed.

3.3 Application of soil erosion risk assessment

The soil erosion risk assessment application was delivered as an ArcMap extension, which is significantly different from the delivered products of the other two services. Irrigation service and CGAP compliance service are openly accessed as a web platform, while the soil erosion risk assessment application requires ArcMap active license for each user. It is also publicly accessible via this link:

http://g2.re-sourcebalkanmed.eu/

The procedure for the installation is straightforward and is equivalent to typical installation of each ArcMap extension. Initially, the user is prompted to download a zipped file with the source code and associated files. These are then extracted and imported to ArcMap through the ArcCatalog after creating the path and connects the toolbox with the help of “Connect Folder” functionality of the ArcCatalog menu. The tool is ready for use.

1. The user opens the ArcCatalog (v10.1).
2. The user creates the path to find the decompressed toolbox through the Connect Folder found in the standard menu of ArcCatalog in the form of an icon.
3. The user finds the toolbox and double-clicks on it.

In order to be eligible for use, the following data perquisites must be met. The user must import as a raster format Rainfall erositivity, Soil erodibility, Topographic influence, Slope Intercept, The Corine_LandCover_2000 vector database and 3 raster layers from time series of years (with monthly time step) of the biophysical parameter FCover (Fractional Vegetation Cover) by the Modis satellite. As a result, the soil erosion is estimated through the application of G2 model, as proposed by (Karydas and Panagos, 2016, 2018). G2 is based on the empirical model RUSLE that calculates soil loss due to sheet and rill erosion, and is expressed as the product from five distinct factors that describe the main erosivity indicators (Panagos et al., 2015). This methodology is widely accepted and has been widely used over the last years to assess soil erosivity on large scale, extending from national to continental.

4. RECOMMENDATIONS

The development, delivery and operability of the services developed by the LP were thoroughly assessed and no significant drawbacks or omittances were recognized. The central system is well designed and set. All security standards are met, which reassures the uninterrupted operation of each component. Furthermore, the maintenance protocols are designed to secure that the quality of provided services will not decay to the future. From the scope of hardware assessment, a single recommendation is made concerning the UPS life expectancy increase.

In terms of software operability evaluation, the current state of the system is exceptional, and only a few future threads are recognized related to future support of selected software over which the central system is built. Especially, since Windows Server 2012 R2 is outdated and under mainstream support until 2023, it is recommended to update to a newer version of Windows Server (i.e. Windows Server 2019) to avoid future risks. This is a recommendation that does not need to be addressed immediately, but before the expiration of current version’s support.

Finally, the provided services are based on updated state of the art methodologies and updated CGAP, while their use is easy for the user. The precision irrigation tool has huge potential since new meteorological stations can be plug-n-play mounted. The soil erosion assessment service is based on G2 modeling, which can be used to model erosion of regions of national or even continental extend and is the most well-recognized methodology. To that end, even though it is input demanding, no modifications are suggested.

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