

Geospatial Tools for Olive Oil Mills' Wastes (OOMW) Disposal Areas Management

Angelos Chliaoutakis¹, Aris Kydonakis¹, Maria K. Doula²
Victor A. Kavvadias², Apostolos Sarris¹ & Nikos Papadopoulos¹

1. *Laboratory of Geophysical-Satellite Remote Sensing, Institute for Mediterranean Studies, Foundation for Research & Technology-Hellas (F.O.R.T.H.), Nik. Foka 130, Rethymno, 74100, Crete, Greece.*
2. *Soil Science Institute of Athens, Greek Agricultural Organization-DIMITRA, 1, Sof. Venizelou str, 14123 Likovrisi, Greece.*

Abstract. LIFE+ project “Strategies to improve and protect soil quality from the disposal of olive oil mills’ wastes (OOMW) in the Mediterranean-PROSODOL” aims towards the development and application of technologies for the protection, improvement and remediation of soils which are polluted from the disposal of olive oil mill's wastes. In this effort, several geospatial application tools were presented and implemented aiming to the effective monitoring of soil quality and wastes disposal areas management. The project was based on the collection of more than 1000 soil samples throughout the course of the project which were chemically analyzed in order to indicate the most significant soil parameters that could most suitable describe soil degradation due to OOMW disposal.

Based on the above results, a geospatial monitoring system application tool was implemented, where users (individuals or services) can enter measurements (spatial points) of these indicative chemical parameters at various time intervals and soil depths and monitor the fluctuation of the values through time. Results are indicated through predefined diagrams that have predefined zones (orange and red) depending on the degree of alert that needs to be signaled to the users. In addition, the soil parameters were mapped with respect to the depth, date and temporal variations of their spatial distribution (spatial surfaces). Furthermore, the diffusion of these parameters in the subsurface was also studied. Interpolated surfaces were created and integrated within another geospatial web based map application tool. Interpolated surface maps can be viewed simultaneously above topographic and satellite maps, providing a possible overview of the diffusion of the parameters in the subsurface and thus the risk-level in the vicinity of the waste disposal areas to the users.

A further verification of the diffusion of the underground pollution was also monitored through the application of electrical resistivity tomography (ERT) techniques. The geospatial monitoring tool application is available for free download from the Web site of the project (www.prosodol.gr).

The soil parameters and organic compounds content as well as other geological, hydrological and land use features, for all disposal sites of the three main areas of interest (former municipality of Nikiforos Fokas (Greece), Albenga region and Loano commune-municipality (Italy)), form the spatial background information provided by the PROSODOL project. A prototype (ArcGIS for INSPIRE) Geoportal integrating a Geodatabase with a Schema compliant with the INSPIRE Directive was employed for carrying out the whole mapping and transforming process of PROSODOL's spatial data information to compatible INSPIRE Map (View) Services.

Keywords. Olive Oil Mill's Wastes Disposals, Geospatial Tools, LIFE project, Rethymno, Surface Interpolation, Monitoring tool, Electrical Resistivity Tomography, INSPIRE Geoportal

1. Introduction

The Mediterranean region accounts for no less than 97% of the world's olive oil production due to the favorable climatic conditions. Greece holds the third place worldwide in olive oil production

and the island of Crete contributes approximately 5% to the total world olive oil production. The production procedure of olive oil generates large volumes of Olive Oil Mill Wastes (OOMW) with high organic load and rich inorganic constituents which lead to pollution of soil and water resources and therefore environmental degradation. The OOMW are usually disposed in evaporation ponds which are rarely of proper size and wastewaters often overflow affecting neighboring systems (soil, surface and groundwater) and other professional activities of the residents (agriculture, livestock farming). The base of the ponds is permeable and thus, the probability for groundwater and deep soil contamination is high. Consequently long-term disposal of waste, without necessary monitoring and protective measures may cause changes in the physico-chemical parameters of the surrounding ecosystems, with the risk of future non-tissue degradation of the environment.

The above issues are addressed by LIFE+ project "PROSODOL" which investigates the type and nature of the chemical residues of OOMW, explores technologies for the protection and monitoring of the soils' pollution and searches for means for the improvement and remediation of soils which are polluted from the disposal of olive oil mill's wastes. To achieve these goals, several geospatial tools were developed aiming towards the effective monitoring of soil quality and wastes disposal areas management. Moreover, older waste sites often lack reliable geological or artificial barriers and depositional information, to minimize the possibilities of further environmental damages. Among the diverse methodologies to monitor the OOMW pollution the geophysical method in terms of Electrical Resistivity Tomography (ERT) has been also used for monitoring the changes of the physical characteristics of the subsoil over time identifying the diffusion of the contaminants. The problem of environmental degradation and waste management are of major concern of earth scientists and the local authorities.

2. The Soil Monitoring System Application

In the PROSODOL project, the development and implementation of a soil monitoring system was necessary, in order to enhance the control of targeted areas, as well as others with similar activities, by monitoring several basic chemical parameters which reflect the wastes' disposal activity in the areas of interest. The aim of the Soil Monitoring System is to provide to the end users (public or private body) a handy tool for evaluating the degree of risk in the vicinity of the waste disposal areas. Below is a description of the functionality of this application tool.

The design process of the Soil Monitoring System Application tool consists of three basic principles.

- Need to specify the most important chemical parameters for evaluating the degree of risk of the waste disposal areas
- Need to specify the limits and range of risk levels (range of values), corresponding to "red" and "orange" flag zones.
- Design an interface that satisfies specific user needs, such as inserting, editing & searching functionalities of waste disposal areas chemical measurements, as well as graphically presenting the risk assessment results.

The whole application was designed and implemented with the Microsoft .NET framework enhanced with the capability of monitoring one or even more measurements on different waste dis-

posal areas, and capable of use for a larger scale services, rather than private use only (backing up and restoring measurements data via XML¹).

Eleven chemical parameters were selected in the end based on their ability to be used as indices to define soil's pollution (Table 1). Furthermore, the limits and the value range of the risk zones (red – high risk, orange – moderate risk) are denoted in the specific table columns (written references that contributed to estimate those ranges are presented to References section).

Table 1. Chemical parameters including their limits, red and orange zone ranges. Parentheses correspond to the bibliography.

Chemical Parameters	Orange zone	Red zone	Limits
Electrical Conductivity (mS/cm)	>2-4 ^[1]	>4 ^{[12] [16]}	0.2-40
Organic Matter %	> 5.0 ^{[12] [16]}	>20 ^[30]	0.05-55
Total phenols (mg/kg)	>40 ^[11]	>150 ^[31]	0.1-700
Total Kjeldahl Nitrogen (%)	> 0.3 ^{[12] [16]}		0.02-3.00
Available P-Olsen (mg/kg)	29-59 ^{[2] [3] [12] [16]}	> 60 ^[3] (potential high P mobility)	1-500
Exchangeable K (cmol/kg)	>1.2-2.0 ^{[12] [16]}	>2.0 ^[17]	0.1-30
Available (DTPA)-Fe (mg/kg)	>20-40 ^[9]	> 100 ^[5]	1-400
Total Cr (mg/kg)	64-200 ^{[6] [7]}	>200	5-1000
Total Ni (mg/kg)	30-100 ^{[11] [18] [19] [21] [24]}	>100	5-500
Total Mo (mg/kg)	3-4 ^{[11] [22] [24]}	>4	1-200
pH	>8.0 ^[1]	>8.5	4.0-9.5

In order to evaluate the degree of risk in the vicinity of a waste disposal area, a user needs to insert values to some or all of the above chemical parameters, and evaluate graphically the results upon an XY point diagram, where the red and orange risk zones are also presented. Since among European countries, but also worldwide, Spain and Italy are the two leaders in olive oil production, whereas Greece holds the third place, the monitoring system tool is designed and implemented in four languages, English, Greek, Italian and Spanish.

A user needs to insert measurement data, such as location properties, date recording information, area coordinates, as well as the chemical parameter values, and submit them to the system. Special provision has been made to secure the proper entry of data by disallowing the entry of values that exceed certain range limits or conditions. When input measurement information passes all constraints and preconditions, only then a user can submit the data to the system. Edits can take place according to all preconditions and constraints mentioned earlier for any measurement field attribute, value or text description, before applying the changes to the system. Moreover, the system provides the user the ability to delete a whole measurement from its database (or dataset). The user has also the ability to search for measurements data of targeted areas, submit selected information, configure certain measurement fields, and search for measurements that are stored in the system. The inserted chemical parameters values which are stored in the system's database can be viewed graphically on a XY diagram, presenting in the most meaningful way if the corresponding measurements exceed or are within the parameter limits (risk degree). A user not only can search measurements with certain

¹ <http://www.w3schools.com/xml/default.asp> (last date accessed: 22 Mar 2012)

criteria and needs, but he can also export the search results information (measurements found) in an Excel File Format document (Fig. 1).

Measurement Id	2	3
Area Code/Name	NF2	NF3
Date	16/12/2010 12:38:20 μμ	16/3/2011 12:00:00 μμ
Depth	50	60
Latitude	35.236987	35.236589
Longitude	25.145236	25.321458
Village	sdafa sdg	asd safta fhdshg
Prefecture	asdf asdf	asdgas fifa hsgdh ghgsdh
Description	asdgasdfgsdag	blablabla
Electrical Conductivity	40	37.62
Organic Matter	1	12.3
Total Phenols	56	58.3
Total Kjeldahl Nitrogen	2	2.8
Available P-Olsen	85	235.2
Exchangeable K	5	25.6
Available (DTPA)-Fe	48	368.3
Total Cr	73	452
Total Ni	421	12.3

Found 2 measurements.

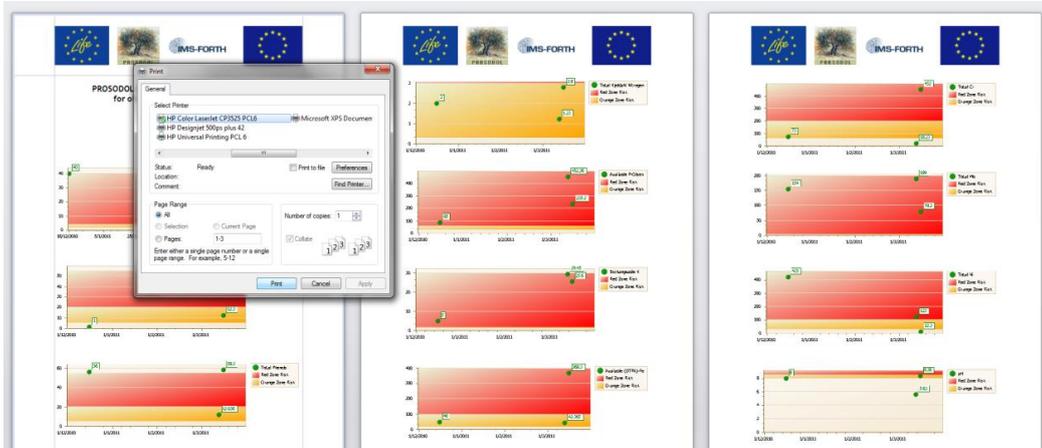


Figure 1: TOP: Inserting measurement data in the Monitoring System tool. MIDDLE: Searching measurements' information in the Monitoring System tool. BOTTOM: A graphic visualization of chemical parameter measurements stored in the database of the Monitoring System tool. Result of the search functionality.

3. Surface Analysis & Interpolation Methods

The soil monitoring system application concerns the monitoring of selected chemical indices at a specific location. How can one however monitor the dispersion of various chemical elements in a wider area? In order to address the specific issue, chemical parameters that were measured from various soil cores (with different depth penetration) were used to create surfaces of the distribution of different chemical parameters that represent the possible diffusion of them and the degree of risk in the vicinity of the waste disposal areas. The chemical parameters were mapped with respect to the depth and date of acquisition of the samples, allowing the study of the temporal variations of their spatial distribution and the diffusion of them in the subsurface.

The Inverse Distance Weighted (IDW) interpolation method produced the most satisfying results among the interpolation algorithms that were tested,. IDW calculates cell values by averaging the values of sampling points in the vicinity of each cell based on distance

$$Z_j = \sum_{i=1}^n \frac{z_i}{d_{ij}^2}$$

where: Z_j is the interpolated value at node j , d_{ij} is the distance between the grid node j and its neighboring node i and z_i are the neighboring points.

In order to have valid interpolated surfaces, the creation of surfaces was allowed only when more than 4 known values were available for interpolation. In cases where the measured values were less than 4 it was not possible to interpolate surfaces and therefore no results were produced.

Aiming towards the creation of an easy and understandable user interface, surfaces were implemented in the WEB_GIS application of PROSODOL web portal. In order to achieve such integration into a Map API such as Google API or Google Earth API, flash maps techniques (Flash Builder software) were employed, so that a user can view the interpolated surface area images simultaneously above a topographic/satellite map provided by those APIs. After consideration of the time based functionality, which a user can view the chemical parameters diffusion in a subsurface over time, Google Earth API was chosen as the most appropriate to use, since it handles integration of time tagged images via XML, a language designed to transport and store information data. Regarding the interpolation process ArcGIS Desktop was chosen to create the interpolated surface maps using the ArcGIS ModelBuilder tool.

Several steps and processes were studied carefully prior the design of the model construction of interpolated surfaces. The way to design a model is by building and connecting processes. A process is simply a tool plus its variables. A variable is either a data variable that references our data (layers, shape files of measurements information), or a value variable, which is anything else, such as numbers and text strings. Variables are connected to tool parameters. The ArcToolbox provides all the necessary tools that our model needs. Several processes (tools) need to be performed in order to achieve the resulted interpolation surfaces. The first step for the whole interpolation process is to define the date and depth of a measurement for the interpolated output map file. In the following step the interpolation process takes place. At this point it has to be noted that the interpolation of a surface, in other words, the diffusion of a chemical parameter in an area, has no meaning above a radius or a distance from the measurement points. For this reason a "mask" is necessary in order to determine the interpolated area boundaries. The mask is actually a polygon that surrounds the measurements' area and only inside this polygon the interpolation of the surface is going to take

place. The mask is provided to the Model as a layer or shape file. At this phase of the model building, the entire interpolated surface, with the corresponding mask areas, depending on the measurements (more than 4) according to depth, date and chemical parameter selection is materialized. Finally, a symbology layer file is needed to provide the tag of the range of values, which denotes the degree of risk with a color scheme as shown in the Fig. 2. Knowing the minimum and maximum variable limits, the red colors designate a high risk area of a certain chemical parameter, while the blue colors designate the low risk areas.

In every process step, ModelBuilder constructs the derived layers temporarily and only the final layer (the interpolated, masked, symbology accompanied layer) is stored, in order to provide it as an input to the *Layer to KML* process, which constructs our final KML file, namely an XML format file suitable for the Google Earth API application. The Google Earth API is a JavaScript API which allows embedding Google Earth, a 3D digital globe, into PROSODOL Web site. Using the API, KML files can be loaded, allowing us to build a 3D map application. The particular API allows the time plug-in, where time information contained to the derived KML files (as a feature), can be introduced to the plug-in and can be attached as a map view.

The implementation of the map application is quite straightforward; and it was handled with JavaScript over PHP pages of the PROSODOL web site. By selecting the user defined measurement, measurement's depth, and submitting the information to the application, the corresponding interpolated surface map is loaded. In Fig. 2, the interface of the map application is presented. These interpolated surface images are pre-rendered, in order to reduce the time cost of creating them on the fly.

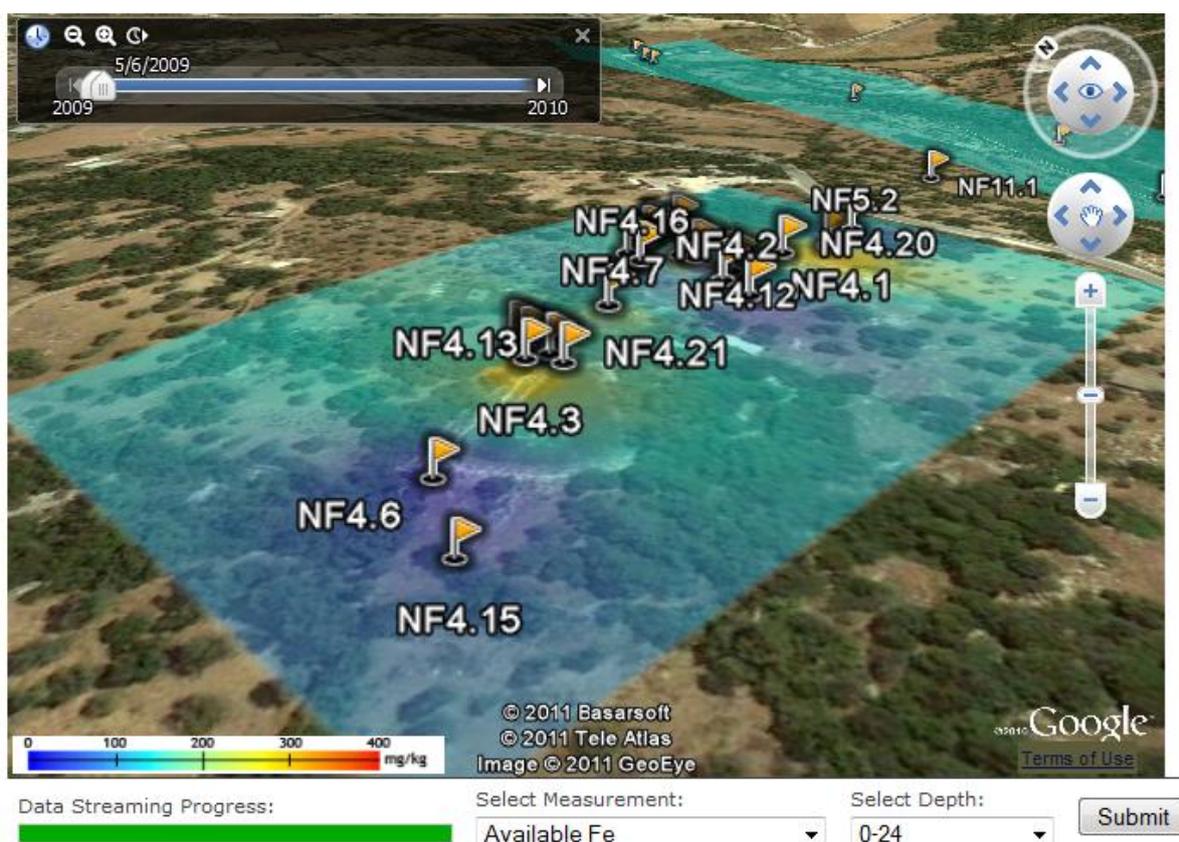


Figure 2: The User Interface of the 3D Google Map application indicating the surface distribution of the chemical parameters in terms of the date of sample acquisition and depth.

4. Geophysical Approaches: Electrical Resistivity Tomography

Except the frequent soil sampling and the subsequent chemical analysis of the samples, geophysical techniques were also tested as a faster way of monitoring the diffusion of the chemical constituents on and below the surface. The ERT monitoring experiment focused on a private property designated as the NF4 experimental site of PROSODOL (Fig. 3). The site is located along the road connecting Rethymno and Roustika in the Prefecture of Rethymno. The field measurements were conducted at the east of the larger of the two evaporation ponds which are used to store the olive oil mills' wastes.

A drill hole was opened close to the larger evaporation pond (Fig. 3) and a plastic piezometer was installed inside the borehole that reached the depth of 16 meters from the ground surface. A multi-clone cable was manufactured for the purposes of the measurements required, which could drive simultaneously up to 48 outputs. The cable was attached on the outer surface of the plastic piezometer, gradually during its installation in the borehole. The cable outputs were placed on the plastic tube in equal separations every 0.4m and the lead leaf covered each output by surrounding the tube. Each lead leaf was tightly fixed with plastic clamp ensuring the maximum connection between the cable output and the lead leaf. Totally 36 electrodes were placed inside the borehole starting from the depth of 2m below the ground surface and the reaching the bottom of the borehole.

The ERT monitoring measurements were made in terms of surface-to-borehole mode. Stainless steel electrodes were used for the surface measurements and the length of the surface branch of the survey was 18.8 meters. The surface electrodes were placed along two vertical lines at equal spaces every 0.4 meters. Dipole-dipole and gradient array configurations were employed to capture the surface, borehole and surface-to-borehole apparent resistivity measurements. The gradient data were measured in a forward and reverse mode to evaluate and assess the noise level of the measurements. The time lapse resistivity data from totally 5 monitoring phases were collected from January until May of 2011. The preliminary results indicate that level of noise of the measurements (based on the forward and reverse potential readings measured with the gradient array) is less than 2%. Based on this error level, during the pre-processing stage almost 6% of all the monitoring data were removed since they exhibited unrealistic high or low resistivity values.

Each phase of the ERT monitoring data were processed individually with a standard inversion algorithm that could account for the surface-to-borehole field measuring mode (32). Similar parameters were used in the inversion of the data where the software converged to a resistivity model after 5-7 iterations and a Root Mean Square (RMS) error of less than 4%. In general, for all the reconstructed models a thin high resistivity layer (~20cm/backfill material) seems to overlay a more conductive layer (clay and marl) and a deeper resistance layer (clay with sand). The image inside the borehole shows generally a conductive material. In order to have a better insight regarding the time-lapse variation of the subsurface resistivity, difference images were extracted between the first phase (reference phase) and the remaining ones based on the simple rule $\frac{T_x - T_1}{T_1}$, where T_1 is the

resistivity inverted model of the first phase and T_x the inversion models for phases 2, 3, 4 and 5. The ERT inversion models (Fig. 3) indicate a resistivity variation of +/-30% through the different monitoring phases. The decrease in resistivity values could be attributed to the movement of the conductive pollutant through the sandy marl of the area.

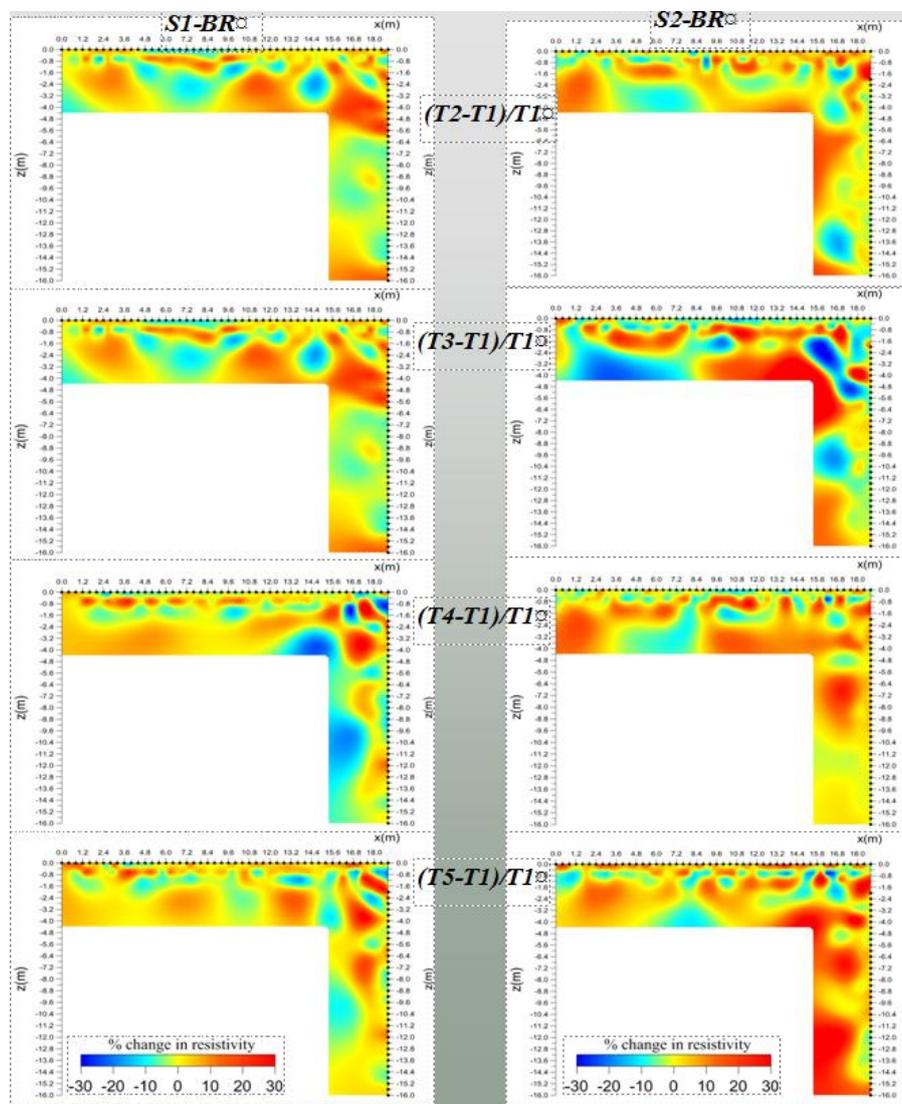


Figure 3: UP (left): Satellite image of the larger evaporation pond of the OOMW site where the geophysical ERT monitoring measurements were conducted. UP (right): The white arrow indicates the place where the borehole was drilled. DOWN: Preliminary results of the difference inversion of the ERT data collected along lines S1-BRH and S2-BRH for the five time phases. The results are plotted in terms of percentage relative change of the model resistivity of each phase with respect to the reference phase.

5. Spatial Data conformity to the INSPIRE Directive

PROSODOL is an environmental project of LIFE Programme, and as such, all spatial data concerning the project must be conformed to the INSPIRE Directive (EU). The INSPIRE Directive entered into force on the 15th May 2007, establishing an infrastructure for spatial information in Europe to support Community environmental policies, and policies or activities which may have an impact on the environment.

The INSPIRE Directive is based on the infrastructures for spatial information established and operated by the 27 Member States of the European Union. The Directive addresses 34 spatial data themes² needed for environmental applications, with key components specified through technical implementing rules. This makes INSPIRE a unique example of a legislative “regional” approach (33). To ensure that the spatial data infrastructures (SDI's) of the Member States are compatible and usable in a Community and trans-boundary context, the Directive requires that common Implementing Rules (IR) are adopted in a number of specific areas: Metadata, Data Specifications and Network Services. Metadata is information describing sets and services of geospatial data and make them possible to be found and used. For example, metadata for a geospatial set give us information on when it was created, who is the creator, what specifications might have been used to create the additional information. In the context of Metadata for spatial data and spatial data services, the standards EN ISO 19115, EN ISO19119, and ISO 15836 (Dublin Core) have been identified as important standards. Data Specifications must be governed by the 34 spatial data themes and are subdivided in the three Annexes of the directive (see INSPIRE Directive - Data Specifications). Annex-I is approved as an Implementing Rule while Annex-II and Annex-III data specifications are currently under construction. Finally, the Network Services are actually web services that need to be implemented.

The INSPIRE Directive requires a community geo-portal to be established and the Member States shall provide access to their infrastructures through the geo-portal as well as through any access points they themselves decide to operate. The current version of the *EU INSPIRE Geoport* is a prototype geo-portal and allows for discovery and viewing of spatial data sets and services. Its aim is to identify issues related to its implementation and accessing distributed INSPIRE services, to help towards the development of the operational geo-portal. The INSPIRE Geoport currently accesses a limited number of discovery and view services and therefore only a few metadata for spatial data sets and services may be found and viewed.

The *European Commission Metadata Editor* was designed to help the EU Member States to create metadata according to the INSPIRE implementing rules as mentioned in section Implementing Rules. One can fill in the necessary metadata fields and he is able to store the metadata in an XML file form. Thus, this file can be used to describe the metadata of various spatial data sets or even services according to the INSPIRE Directive. Certainly if the metadata already exists as such a file, then one can examine whether this file is compliant with the INSPIRE directive through the online *Metadata Validator*.

ArcGIS for INSPIRE provides a suitable solution including capabilities to ensure INSPIRE compliance supporting data, services, and metadata. Data are stored in the provided data models of the INSPIRE Annex-Themes implemented as an ESRI geo-database. This provides an ideal foundation for use and publication via ArcGIS Server. The core of the ArcGIS for INSPIRE is the “INSPIRE Services” component for ArcGIS Server. It is used for publishing Annex-Themes (currently only Annex-I Theme) as a geo-database. The extension expands the functions of an ArcGIS Server and integrates “INSPIRE View” and “INSPIRE Download” services as additional option into the existing service options.

² <http://inspire.jrc.ec.europa.eu/index.cfm/pageid/2/list/7>

The ArcGIS for INSPIRE Extension provides an essential element, the Geodatabase Schema, which implements the abstract INSPIRE data models (Annex-I Theme), in other words objects such as database tables, feature classes and domains that forms the creation of a Geodatabase for INSPIRE Annex-I data Models. Having the INSPIRE compatible geo-database schema, the next step is to create the corresponding INSPIRE layers for the PROSODOL spatial data and map services. INSPIRE data themes that are currently available are those that implements the Annex-I Theme data models (ex. "Geographical names", "Cadastral parcels", "Hydrography", etc). This limitation results in the need to map the PROSODOL's map services layers to those that are currently available from the Annex-I data theme. The spatial data information of PROSODOL map document layers is added manually to the appropriate INSPIRE geo-database tables in order to fill in the information of the corresponding INSPIRE Maps layers.

In the attempt to develop the IMS/FORTH INSPIRE Geoportal, several valid available tools were used, which can support the INSPIRE conformity of the PROSODOL Spatial Data information, as well as for the Metadata of the implemented data (view and discovery) services. The Geoportal currently represents metadata and services for the PROSODOL project but it is intended to be updated with more information over time. IMS/FORTH INSPIRE Geoportal is accessible either from the PROSODOL's website, or by addressing the URL <http://www.ims.forth.gr/geoportal> (last date accessed: 24 April 2012) (Fig. 4).

The IMS/FORTH INSPIRE Geoportal provides an easy and convenient way to find, view and share geospatial data and metadata within the framework of the Infrastructure for Spatial Information in the European Community (INSPIRE) Directive. The Geoportal is based on the ESRI Geoportal Server which is a free, open source product that enables discovery and use of geospatial resources. The ArcGIS for INSPIRE Extension also gives to the core of the ESRI Geoportal (thus the IMS/FORTH INSPIRE Geoportal) the ability to add an INSPIRE View Service Metadata network resource via the embedded (INSPIRE) Metadata Editor. The visiting user may access the Geoportal and search or browse the PROSODOL project's spatial data. In Fig. 4 the search functionality of the Geoportal is presented, including some of the available options like 1) free text search, 2) zoom to the corresponding map layer, 3) visualization of the results area, 4) detailed information of the geospatial data service that is in conformity with the INSPIRE Directive, 5) clearance of the search form field and 6) provision of the INSPIRE Metadata of the geospatial data service in an XML file.

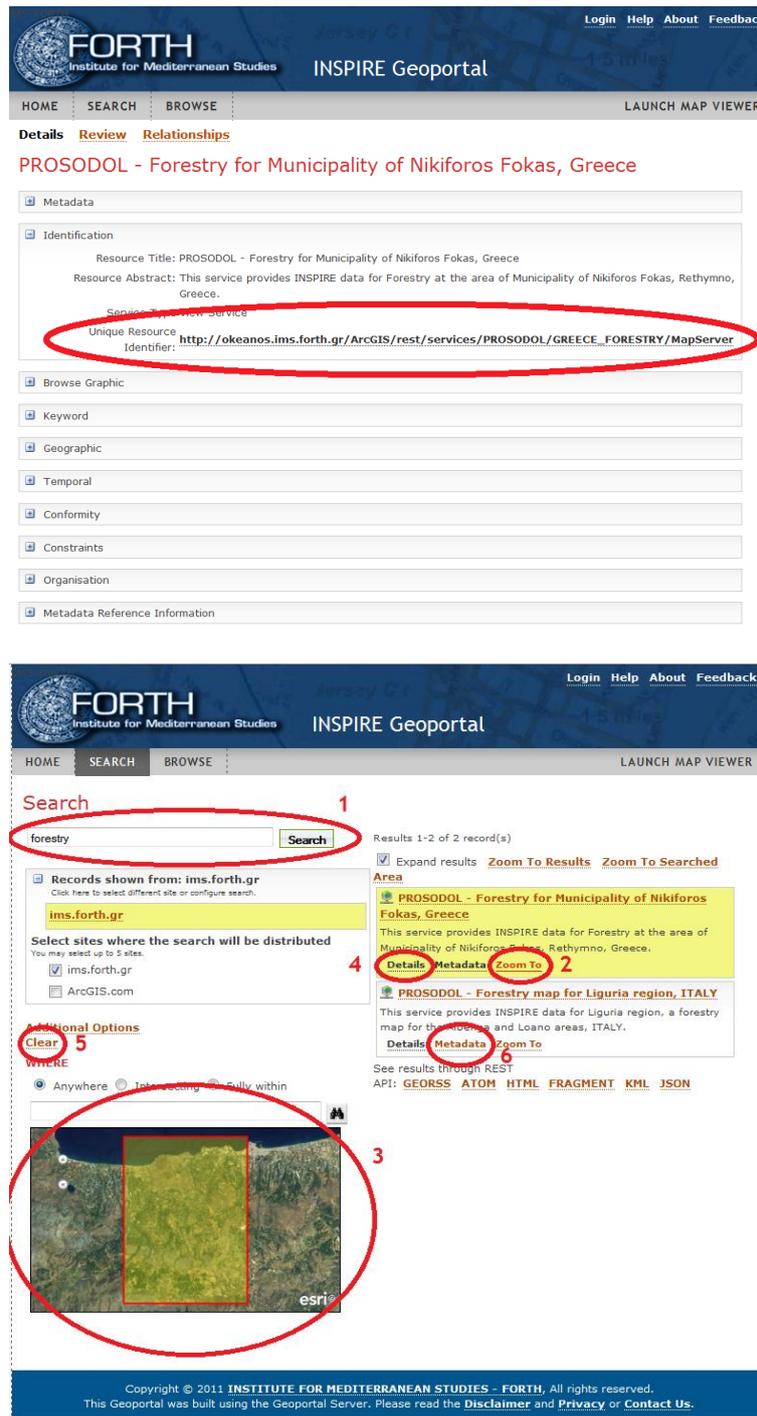


Figure 4: UP: Details of a web page of a resource in the IMS/FORTH INSPIRE Geportal. BELOW: The IMS/FORTH INSPIRE Geportal Search functionality.

6. Conclusions

A number of geospatial tools have been used for olive oil mills' wastes (OOMW) disposal areas management manifesting the potential of the particular technologies in an environmental issue which is of crucial importance especially in the Mediterranean area. Among the various techniques used, a freely distributed soil monitoring system application has been developed for monitoring the

several basic chemical parameters which reflect the wastes' disposal activity. The particular application is based on a regular analysis of the chemical constituents of soil samples and it can be used either from individual owners or by larger administration units. A much more specialized application was made for monitoring the distribution of different chemical parameters (in terms of depth and time) that represent the possible diffusion of them and the degree of risk in the vicinity of the waste disposal areas. The particular module has made use of the Google Earth API so that the particular results can be projected on the available topographic and satellite images provided by Google Earth.

In terms of the geophysical approaches, the ERT preliminary results signified that this geophysical method could be a modern alternative of mapping the environmental pollution in OOMW areas providing effective solutions to address such environmental problems. Future actions of this initiative will include the application of controlled ERT experiments in non-metallic tank simulating the real conditions of an OOMW and the geophysical modelling results could be complemented with flow modelling codes (employing stochastic models that calculate the pollutant diffusion).

Finally, all the GIS based cartographic products of the project PROSODOL together with their accompanied metadata were made available to the public through the development of IMS/FORTH INSPIRE Geoportal confronting the results of the project with the European Union INSPIRE Directive.

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