Re-Source

Re-Source - Providing services for management of natural resources

D3.1.3
Methodological guidelines & data collection protocols

WP3

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Summary

This report summarizes the guidelines, protocols and methodologies of the three digital services that will be already established within i-BEC and will be further develop in the context of “Re-source” project. The three tools/services are: 1) Precision irrigation: a digital model for the application of precise irrigation in space and time which will be further upgraded, customized and applied within the Greek and Albanian territories, 2) application of codes of good agricultural practices: a digital tool for the evaluation of the implementation of the CGAP (a set of more efficient, environmentally friendly practices in agriculture) will be customized and applied within the Cyprus and North Macedonia territories and 3) application of soil erosion risk assessment: a digital model for large-scale risk assessment of soil erosion will be customized for use within the Bulgarian territory.

Combining the three services the “Re-source” project seeks to leverage the results of two other projects “Digital Convergence” framework and the “AGRO-LESS” project (ETCP Greece-Bulgaria 2007-13) and to expand the implementation of digital services at the trans-Balkan level through the participation and cooperation of five Balkan countries. Emphasis will be placed on services related to the agricultural sector and the management of natural resources during agricultural practices.

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ACRONYMS

The following acronyms have been used in this document:

BMP	Best Management Practice
CGAP	Codes of Good Agricultural Practices
CWSI	Crop Water Stress Index
EPM	Erosion Potential Method
ESDAC	European Soil Data Centre
GIS	Geographical Information System
HDR	High Resolution Layer
JRC	Joint Research Centre
LUCAS	Land Use/Cover Area Frame Survey
i-BEC	interBalkan Environment Center
LP	Leader Partner
RUSLE	Revised-USLE
SDR	Sediment Delivery Ratio
SOC	Soil Organic Carbon
TDR	Time Domain Reflectometry
USLE	Universal Soil Loss Equation

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1 INTRODUCTION

The Re-Source project tackles the need for improved transnational governance capacity in relation to the following three fields:

1. Irrigational water management
2. Codes of good agricultural practices (CGAP) and
3. Soil erosion risk management

In agreement with the directions of the BMP framework, it aims to capitalize on results from past projects, namely digital tools/services produced within the "Digital Convergence" framework and the "AGRO-LESS" project (ETCP Greece-Bulgaria 2007-13) and expand/customize their use into the territories of five Balkan counties: Greece, Bulgaria, Albania, Republic of North Macedonia and Cyprus in order to promote governance capacity and legal framework delivery in the three aforementioned fields. During those two projects i-BEC has established a system of digital services/tools that are now being provided to a number of Greek Decentralized Administration Bodies including those of Aegean, Thessaly-Central Greece, Crete, Macedonia-Thrace, Peloponnese, Western Greece & Ionian. The successful delivery of services and digital applications within this wide Greek territory has encouraged i-BEC to further promote their potential upgrade and expansion with the present project "Re-Source".

The project exhibits a high level of transnational cooperation. The main co-operational channel among them will be brought forward by the LP (i-BEC) which aims to act as a transnational hub for the delivery of services, tools and know-how towards the rest of the partners and in close collaboration with them during all implementation phases (planning, analysis, customization, delivery of services – pilot operation, training and education). LP's role as a common reference point and the fact that the partnership consists of bodies with key roles on a policy level, in their respective territories, shapes a transnational partnership/consortium with the potential to bring changes on a wider-than national level, through the specification and development of common/harmonized definitions, methodologies and targets in the currently highly unspecified – in regulatory terms – environmental fields tackled by the project. The results and services of the project will be open to all, and will not be neither market oriented nor profit making.

The objective of the project was to provide guidelines as well as protocols and methodologies for data collection, debugging, processing and harmonization as guides for the application of each one of the above services/tools.

2 GENERAL GUIDELINES OF THE SERVICES/TOOLS

The main objective of the present material is to provide technical descriptions regarding the digital services and tools that LP has established. These services have successfully been provided to a number of Greek Decentralized Administration bodies, have been developed and reached the desired operational level, enabling LP to promote their use to an international extend. The promoted services cover a variety of applications that aim to enhance the capacity of public administration of the involved Balkan med countries. The main axes of the services' application are:

- Irrigational water management
- Soil erosion risk assessment
- Codes of Good Agricultural Practices (CGAP)

This action aims for the promotion and development of the products resulted from two past projects:

- "Environmental information system for the support of entrepreneurship and competitiveness - implemented within the framework of the operational programme "Digital Convergence"
- "Joint reference strategies for rural activities of reduced inputs- AGRO-LESS - implemented within the European Territorial Cooperation Programme "Greece-Bulgaria 2007-2013".

Table 1 Supply of equipment per partner (Re-source project)

Country	Public Body	Environmental field
Greece	Region of Thessaly, Soil and Water Resources Institute (Ministry of Rural Development and Food)	Irrigational water management
Albania	Ministry of Environment, Municipality of Berat	Irrigational water management
Bulgaria	Executive Forest Agency	Soil erosion risk management
North Macedonia	Municipality of Kocani	Codes of good agricultural practices
Cyprus	Agricultural Research Institute (Ministry of Agriculture, Rural Development and Environment)	Codes of good agricultural practices

The three (3) digital tools/services that will be used /provided in the Re-Source project (and which correspond to the three aforementioned environmental fields) are:

1. **Application of precision irrigation.**

Within the framework of the AGRO-LESS project a digital model was developed for the application of precision irrigation in space and time within Greek territory and applied in many different pilot areas with the involvement and cooperation of Greek farmers that were participating in the project.

Within the framework of the proposed "RE-Source" project this model will be customized and applied within the **Greek and Albanian** study areas.

2. **Application of Code of Good Agricultural Practices (CGAP).**

Within the Digital Convergence project a digital tool was developed, in the form of an interactive questionnaire, for the evaluation of the implementation of the *Code of Good Agricultural Practices* (CGAP) which is a code for more efficient, environmentally friendly practices in agriculture on a national basis (but also on a European).

Within the framework of the proposed "RE-Source" project this tool will be applied within the **Cyprus and North Macedonia** territories in order to evaluate the degree of compliance of current practices with CGAP.

3. **Application of soil erosion risk assessment.**

Within the Digital Convergence project a digital model was developed for soil erosion risk assessment.

Within the framework of the proposed "RE-Source" project this model will be customized for use within the **Bulgarian** territory to assess soil erosion potential.

2.1 Precision Irrigation

2.1.1 Generalities

In irrigated farms the precise estimation of water- requirements is one of the essential components of precision agriculture, leading in significant reduction of water wastage. Given the limited water resources, optimizing irrigation efficiency is considered very essential especially in the Mediterranean zone, characterized by high plant irrigation requirements.

Availability of irrigation water for agriculture is considered as a global challenge for the upcoming years, given its crucial role in plant physiology and production. The problem of agricultural water management is today in certain areas recognized as major well linked with their development issues. Agriculture consumes almost 70% of the fresh water i.e. 1,500 billion m^3 out of the 2,500 billion m^3 of water that is being used each year (Goodwin I, O'Connell MG. 2008). It is also estimated that 40% of the fresh-water used for agriculture in developing countries is lost, either by evaporation or drainage to the deeper layers of the soil, beyond the reach of plants' roots (Panchard et al. 2006). Thus, efficient water management is a major concern in many areas and crop systems. As a result, more and more planners as well as farmer associations are becoming conscious about irrigation water utilization efficiency as the water resources is getting more and more scarce.

Precision irrigation is worldwide a new concept in irrigation. Precision irrigation involves the accurate and precise application of water to meet the specific requirements of individual plants or management units and minimize adverse environmental impact. Commonly accepted definition of precision irrigation is sustainable management of water resources which involves application of water to the crop at the right time, right amount, right place and right manner thereby helping to manage the field variability of water in turn increasing the crop productivity and water use efficiency along with reduction in energy cost on irrigation. It utilizes a systems approach to achieve 'differential irrigation' treatment of field variation (spatial and temporal) as opposed to the 'uniform irrigation' treatment that underlies traditional management systems.

Without doubt precision irrigation is worldwide a new approach in irrigation. Drip irrigation is often regarded as epitomizing precise irrigation because of its ability to control application rate and timing. Some definitions in literature include:

- Precise application of water to meet specific requirements of individual plants or management units and minimize adverse environmental impact (Raine et al. 2007).
- Application of water to a given site in a volume and at a time needed for optimum crop production or other management objective (Camp, CR., Sadler, EJ., Evans, RG. 2006).
- Applying water in the right place with the right amount.
- Irrigation management based on crop need to defined sub-areas of a field referred to as management zones (King and He 2006).

The common element to all of these definitions is the 'differential irrigation treatment' of field variation as opposed to the 'uniform irrigation treatment' that underlies traditional irrigation. Essentially, this is a high-tech sensor-based irrigation water application method/approach with necessary flexibility.

Precision irrigation has the potential to increase both the water use and economic efficiencies. It has been reported that precision irrigation can improve application efficiency of water leading in water savings up to 50%. The potential economic benefit of precision irrigation lies in reducing the cost of inputs or increasing yield for the same inputs. It has been reported that variable rate irrigation could save 10 to 15% of water used in conventional irrigation practice. (Hedley et al. 2004) suggested water savings of around 25% are possible through improvements in application efficiency obtained by spatially varied irrigation applications.

2.1.2 Important components of precision irrigation service

According to (Sarma 2016) some characteristics of the precision irrigation system are:

- Optimal management of the spatial and temporal components of irrigation;
- Optimal performance of application system with crop, water and solute management;
- It is not a specific technology. It is a way of thinking, a systems approach.
- It is adaptive, it's a learning system; and
- It is applicable to all irrigation methods and for all crops at appropriate spatial and temporal scales.
- The system (s) therefore, would have the ability to apply water where it is needed, saving water and preventing excessive water runoff and leaching.

2.1.2.1 Data acquisition

A Precision Irrigation system requires ability to identify and quantify the variability i.e. spatial and temporal variability that exist in soil and crop conditions within a field and between fields. Existing technology is available to measure the various components of the soil-crop-atmosphere continuum many in real-time so as to provide precise and/or real-time control of irrigation applications.

2.1.2.2 Interpretation

Data has to be collected, interpreted and analysed at an appropriate scale and frequency. The inadequate development of decision support systems has been identified as a major difficulty for the interpretation of real time data and adoption of precision agriculture (McBratney et al. 2005).

2.1.2.3 Control

The ability to optimize the inputs and adjust irrigation management at appropriate temporal and spatial scales is an essential component of a precision irrigation system. Applying differential depths of water over a field will be dependent on the irrigation system. Automatic controllers with real time data should provide the most reliable and accurate means of controlling irrigation applications.

2.1.2.4 Evaluation

It is an important step in the precision irrigation process. Measuring the engineering, agronomic and economic performance of the irrigation system is essential for feedback and improving the system.

2.2 Soil erosion risk assessment

2.2.1 Generalities

Soil erosion caused by water has been addressed globally as one of the most critical soil degradation hazards. Erosion modelling is used in order to achieve a better understanding of erosion processes, provided that experimental conditions from which directly measured outcomes could be derived, are either impossible or impractical to create. The wide spreading of geographical information systems (GIS) and use of remote sensing data has accelerated erosion model development significantly, as it allows for data input from multiple sources, easy model structure modifications and unconditioned model rescaling. According to (Karydas, Tzoraki, and Panagos 2015)more than 80 erosion models have been developed for different purposes in half a century. With a view to support regular monitoring by decision-makers involved in environmental and agricultural policies, the **geoland2**[1] project had developed the **G2 erosion model**, in the framework of Copernicus Land Monitoring Service[2]. The development of a new erosion model was justified by the requirements for operational, standardized mapping solutions, raised by the new environmental policies in Europe, such as the Soil Thematic Strategy

[1] https://esdac.jrc.ec.europa.eu/projects/geoland2

[2] https://land.copernicus.eu/

(Montanarella and Alva 2015) and the Common Agricultural Policy (Panos Panagos et al. 2015),in the view of rapid land use changes and the climate change effects.

2.2.2 Important Components of G2 model tool

G2 was based on RUSLE and EPM heritage (for soil loss and sediment yield assessments, respectively), trying at the same time to overcome reported drawbacks of both models; for example, the questionable applicability in different areas from those where these models were developed or on a different temporal scale than annual, limitations to sheet and interill processes. Considering that G2 adopts fundamental empirical equations from RUSLE and EPM, it can be classified as an empirical model too.

G2 has been made available to interested parties, through the European Soil Data Centre (ESDAC) of the Joint Research Centre (JRC), with provision of guidance, datasets and technical support[3]. Up until now, the G2 model has been implemented in five different study areas in SE Europe and in Cyprus. In two of these cases (Crete and Cyprus), pre-existing field data were available either for calibration or rough verifications.

2.2.3 Model Overview

G2 is an empirical model for soil erosion rates on month-time intervals and has evolved with time into a quantitative tool with two distinct modules:

- One for soil loss and
- One for sediment yield.

The module for soil loss inherits its main principles and many of its formulas from the Universal Soil Loss Equation (USLE) (Wischmeier and Smith 1978) and the Revised-USLE (RUSLE)(Renard et al. 1997). (Ferro, Porto, and Yu 1999) argues that USLE is a robust empirical model with a logical structure regarding the variables used to simulate the physical erosion process. The input datasets of the G2 applications can be derived from geodatabases freely and regularly available by European or other international institutions.

The module for sediment yield (denoted as G2sed) adopts the sediment delivery ratio (SDR) formula from the Erosion Potential Method (EPM) (Gavrilovic 1988; Marques da Silva, R., Santos, C.A.G., Medeiros Silva, A. 2014). The main input dataset is a high resolution digital elevation model (DEM), from which the required topographic and

[3] http://esdac.jrc.ec.europa.eu/themes/g2-model

hydrographic properties can be derived. The G2sed module uses the outcome of the G2los module and the calculated EPM figures, to produce sediment yield maps (Karydas and Panagos 2018).

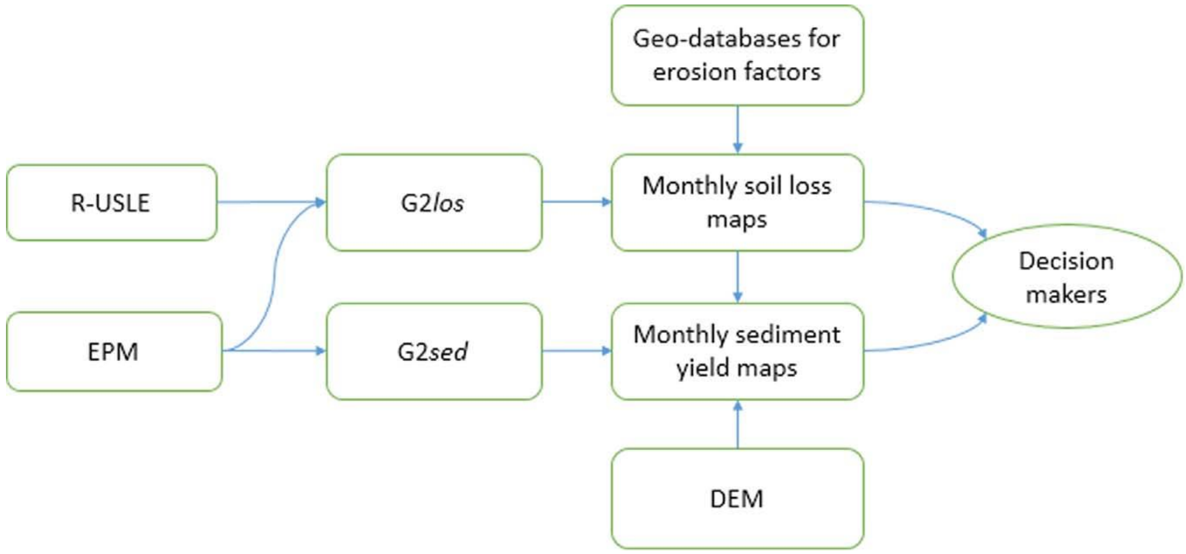


Figure 1 A flowchart of the contribution of R-USLE and EPM models to the modules of G2 and their relation to input and output data (Karydas and Panagos 2018).

2.3 Codes of Good Agricultural Practices (CGAP)

2.3.1 Generalities

In the past twenty years, a wide array of social, environmental and quality standards, codes of practices and certification programmes have appeared in agriculture and the food sector. Governments and their research and extension branches have traditionally developed production guidelines for specific commodities or systems. In recent years, especially in developed countries, governments have also established regulations on food safety and quality, voluntary standards on organic agriculture and sustainability assessments schemes.

Most of the codes and standards in agriculture are process standards (criteria for the way products are made) rather than product standards (specifications and criteria for the final characteristics of products). These process standards might or might not bot influence the characteristics of the end products. Codes developed to address product safety and quality tend to focus on the impact of production practices on the end-product, rather than on the impact of production practices on the environment, employment or local development.

2.3.2 Important Components of the CGAP

2.3.3 Protecting soils

Protecting the natural resources of water, soil and air is essential for a sustainable environment. The advice the CGAP tool recognizes that things farmers can do affect water, soil and air all at the same time. Most farmers recognize the importance of their soils for the sustainability of their business. However, small quantities of run-off and erosion, which may seem insignificant, can cause pollution and nuisance. Well manage soils with adequate organic matter can result in lower costs and pose less risk of erosion and run-off.

When organic matter is added to soils in organic manures, care should be taken to prevent heavy metals and persistent organic pollutants reducing the fertility of the soil in the long term or contaminating food crops so that they fail to meet legal standards.

2.3.4 Water pollution

Nitrogen and in some circumstances also phosphorus, may be lost from soil into groundwater and surface waters. These plant nutrients are also present in run-off from fields in soluble form, as well as in soil organic matter, organic manures and in the case of phosphorus, attached to soil particles from where they can be released into water.

Eroded soil may remain suspended in the water and reduce the quality of drinking water. Larger particles may settle (sedimentantion) in river gravels, causing serious damage to fisheries by smothering spawning grounds and reducing food supply. Such sediment can also support large growths of aquatic vegetation which may increase the risk of flooding. Agro-chemicals (pesticides, disinfectants, sheep dip and other veterinary medicines) and fuel oil are potential pollutants of water and must be managed accordingly.

2.3.5 Atmospheric Pollution

Ammonia and gases which cause unpleasant odours are released from organic manures and wastes during handling, storage and both during and after application to land. Local authorities have a duty to inspect their areas to detect any statutory nuisances and to take reasonably practical steps to investigate complaints of statutory nuisances which are made to them. Also ammonia in the air can cause human health problems. When it is re-deposited, it can acidify soils, natural habitats and fresh waters. By increasing the supply of nitrogen, it can reduce bio-diversity particularly in upland surface waters and natural and semi-natural habitats. Carbon dioxide is one of the gases which cause global warming. It is produced by the burning of fossil fuels such as coal and oil, by the breakdown of organic manures and by the loss of soil organic matter. Any loss of soil organic matter contributes to carbon dioxide emissions as well as making soils more difficult to manage. Protecting lowland and upland peat soils from degradation and anything that locks up carbon such as grassland or trees or that produces a bio-fuel is beneficial. In addition methane is produced directly by cattle and sheep and smaller amount is also release from livestock manures. Agriculture is responsible for about a third of all emissions of methane. It is possible to reduce methane emissions by optimizing livestock diets.

2.3.6 Protecting the wider environment

Farmers and land managers have a responsibility to protect the wider environment, especially designated areas such as Natura 2000 sites and many others. Some of the Hedges, surface waters and field margins are key habitats on farms. How they are cut, cleared or otherwise managed has a big effect on their value for wildlife. You should keep soil, organic manures, dirty water, fertilisers and pesticides out of these habitats and away from in-field trees during field operations. Leaving buffer strips or part of the headland untreated will provide additional benefits for ground nesting birds and natural predators of crop pestsese areas are particularly sensitive to nitrogen deposition from ammonia released by agriculture. By careful management of permanent pasture, including possible reducing stocking density and overall nutrient input, run-off and erosion can be reduced, nitrogen and phosphorus losses will decrease and in time the botanical composition of the sward will diversify with knock on benefits for insects and birds.

3 PRECISSION IRRIGATION TOOL

3.1 Development of guidelines, methodologies and best practices of the services for end users and stakeholoders

3.1.1 Technology associated with precision irrigation

Despite the fact that precision irrigation methods have played a major role in reducing the quantity of water required in agricultural and horticultural crops, there is still a need for new methods of automated and accurate irrigation scheduling and control. The early adopters found precision agriculture to be unprofitable and the instances in which it was implemented were few and far between. Further, the high initial investment in the form of electronic equipment for sensing and communication meant that only large farms could afford it. However, over the last several years, the advancement in sensing and communication technologies has significantly brought down the cost of deployment and running of a feasible precision agriculture framework. Despite the fact that a stand-alone sensor, due to its limited range, can only monitor a small portion of its environment, the use of several sensors working in a network seems particularly appropriate for precision agriculture. The technological development in Wireless Sensor Networks made it possible to monitor and control various parameters in agriculture. Emerging wireless technologies with low power needs and low data rate capabilities have been developed which perfectly suit precision agriculture (Wang, Zhang, and Wang 2006). Sensing and communication can now be done on a real-time basis leading to better response times.

Figure 2 Meteorological station for IoT based irrigation system - Young olive grove

3.1.2 Irrigation scheduling

In order to improve the efficiency of irrigation systems and prevent water losses, the first step is to develop an intelligent irrigation scheduling system, which will enable farmers to optimize the use of irrigation water.

The process of irrigation scheduling involves both the identification of the time to apply the water and the volume of water required to be applied. Volumetric inefficiencies in irrigation result largely from irrigating too often or applying too much water at each irrigation. Agronomic inadequacies occur when the plants are inappropriately stressed due to either insufficient water being applied frequently enough or excessive water application resulting in waterlogging or increasing the incidence of disease. The first step in improving both volumetric efficiencies and agronomic water productivity is knowing how much water to apply and when to apply it.

The plant response to irrigation is a function of the plant water status. Plant water status is influenced by a range of factors including the soil water potential (ie. the energy required to remove water from the soil), the interface (i.e. resistance and area) between the soil and plant roots, hydraulic conductivity within the plant and the evaporative demand (i.e. atmospheric conditions) to which the plant is exposed. Hence, methods commonly used to schedule commercial irrigations commonly involve measuring either (a) evapotranspiration (b) soil moisture or (c) plant stress.

The combination of two separate processes whereby water is lost on the one hand from the soil surface by evaporation and on the other hand from the crop by transpiration is referred to as **evapotranspiration (ET).**

Figure 3 Smart irrigation system for urban water management

3.1.3 The physics of evaporation

Evaporation is the process of a liquid changing into a gas. Consider an adiabatic system (one in which there is no heat exchange) containing dry air at a temperature T. Suppose a source of liquid water is added to the system, which is in contact with the air. As air molecules impinge on the liquid water molecules, some of the liquid molecules will gain enough energy to vaporize. The rate of vaporization will depend on the average speed and hence the temperature of the air molecules. As vaporization occurs, the sensible heat of the air is being converted to latent heat, so the air will cool.

Some of the vapour molecules in the air will condense into the liquid, and this rate of condensation will increase as the water vapour pressure increases. Eventually the rate of condensation will equal the rate of evaporation, and a dynamic equilibrium will have been. At this point the air is saturated, and the vapour pressure is called the saturation vapour pressure for the particular air temperature.

The net rate of evaporation depends on the temperature of the air and the water (for evaporation) and the vapour pressure in the air (for condensation). If the temperature of the air is increased, the rate of evaporation will increase and a new dynamic equilibrium will eventually form with a higher saturation vapour pressure. Hence, for soil-plant surfaces, the rate of evaporation depends on the temperatures of the evaporating surface and the air, as well as the vapour pressure of the air

3.1.4 Transpiration

Most of the water that evaporates from plant surfaces has passed through the plant. The water enters through the roots, passes through the vascular tissue to the leaves or other organs, and exits into the surrounding air primarily via stomata (but sometimes also through the cuticle). Evaporation of water that has passed through the plant is called transpiration. Since it is difficult to distinguish this water vapour from that caused by direct evaporation from soils, it is convenient to use the term evapotranspiration to describe the overall process.

The rate of water vapour loss from a crop and the underlying soil depends on: the physical and physiological properties of the crop; the relative heat flux to the crop and the soil; and the water content of the soil. The 'Leaf Area Index' (LAI) of a crop is used to define the effective surface area for water loss from the crop and the amount of shading of the ground surface below. LAI is defined as the ratio of the leaf area to the ground area; when LAI> 3 then transpiration dominates evapotranspiration, because most of the incoming radiant energy is captured by the crop canopy and the ground surface is almost fully shaded. For more sparse crop canopies (LAI < 3) a greater portion of incoming radiant energy reaches the ground surface and, if this is often wet, then soil evaporation will be a greater proportion of the total evaporation.

The physiological nature of the plant and the availability of water in the soil play an important role in evapotranspiration. For maximum evapotranspiration to occur, the plant must behave passively, acting as a wick for the transport of water from soil to air. This does not happen in all circumstances; sometimes the rate at which the plant sources water from the roots, or transports it through the vascular tissue, can limit evapotranspiration. The stomata ultimately control the rate of transpiration, and their resistance is affected by environmental factors including leaf temperature, light, and leaf water potential and possibly vapour pressure deficit, and by the physiology associated with CO_2 uptake.

The interconnected nature of water vapour loss (transpiration, λE) and CO_2 uptake (Fc) for photosynthesis through the stomata is described by the coupled expressions:

$$\lambda E = \left[\frac{\rho C_p}{\gamma} * (e_{sat}(T_s) - e_o)\right] / r_{st}$$

and

$$F = \frac{c_i - c_a}{r_c}$$

where Ts, e_o and c_a are the temperature, vapour pressure and CO_2 concentration near the leaf surface respectively and

ci is the internal CO_2 concentration. The stomatal resistance to CO_2 transfer is r_c and water vapour is r_{st}.

Maintenance of stomatal aperture to achieve maximum CO_2 uptake and minimal water loss, all within an optimum growth temperature range, requires a very sensitive and responsive system. If it were possible to either measure or estimate the critical influences of stomatal function, effective over a whole canopy, it would be possible to anticipate transpiration rates.

However, this is not yet achievable and so an aggregate expression of resistances in the transpiration flow path is attempted. The resistance of the plant and soil to evapotranspiration is sometimes described in terms of the 'surface resistance' and the 'aerodynamic resistance'. The surface resistance refers to the resistance of vapour flow through stomata, total leaf area and soil surface. On three other hand, the aerodynamic resistance describes the resistance from the vegetation upward and involves friction from air flowing over vegetative surfaces (Allen et al. 1998).

Evaporation can also occur from water on the leaves, which does not travel through the plant (i.e. intercepted water from rain or irrigation). Although this water still cools the plant, its release is not controlled by the plant. It is likely that the rate of evapotranspiration will increase when there is water lying on the leaves, and it could be higher even than free water evaporation because the leaf surface area can be greater than the ground surface area. (Wallace and Wallace 1994) notes that the evaporation rate can more than double when the leaves are wet, although this will very much depend on the type of crop and the weather conditions.

Thus, there are three contributions to evapotranspiration from the soil-plant system:

1. transpiration through the stomata

2. evaporation from the soil

3. evaporation of water on the plant leaves

3.1.5 Factors affecting evapotranspiration

Weather conditions

Evapotranspiration is dependent on weather. Precipitation, solar radiation, temperature, humidity, and wind all contribute to the rate of evapotranspiration. The huge quantities of energy consumed in evapotranspiration are supplied almost entirely from two sources: radiant energy and the energy associated with air movement. Both sources of energy are traceable to solar radiation.

Radiant energy

Radiant energy in both direct and diffuse forms, includes short-wave solar radiation and long-wave thermal radiation. Short wave radiation arriving in the Earth's atmosphere can be reflected or absorbed by both clouds and the ground. These in turn emit long-wave radiation according to Stefan's Law. A fraction of solar radiation is also absorbed by atmospheric components such as water vapour, liquid water, dust and pollutants. The presence of cloud results in most radiant energy being diffuse rather than direct.

Temperature

The temperature of both the air and the evaporating surface has a major influence on the rate of evapotranspiration. Temperature is particularly important because of its bearing on other meteorological variables such as saturation vapour pressure and outgoing long-wave radiation – which are critical to the rate of evapotranspiration.

Humidity

In general, evapotranspiration increases in response to an increasing difference between the vapour pressure at the evaporating surface and the vapour pressure of the air. Hence, as the absolute humidity of the air decreases, or air temperature increases, there is an increase in evapotranspiration.

Sensible heat advection

Advection is the "process of transport of an atmospheric property solely by the mass motion of the atmosphere". In the context of evapotranspiration, it can be considered as "the transport of energy or mass in the horizontal plane in the downwind direction" (Rosenberg, Norman J & Blad, Blaine L & Verma 1983).

Sensible heat (H) is an integral part of the surface energy balance as described by the equation:

$$R_n - G = H + \lambda E$$

Where R_n is net radiant energy,

G is soil heat flux and

λE is the latent heat associated with water vapour

Normally, the ground and vegetative surface is warmer than the immediately overlaying air and so sensible heat transfers from the surface into the atmosphere. When adventive conditions occur, sensible heat, over and above that generated at the point of reference, moves in from a surrounding (upwind) area. Hence the energy available for evaporation is greater than that which is generated by the net radiant energy at the point of reference. This process is described as advection.

Wind

Wind plays an important role in the evapotranspiration process. Strong winds enhance turbulence, removing the water vapour from the plant canopy more quickly and mixing it into the surrounding drier air. In sub-humid and arid climates, wind can also transport sensible heat from dry surroundings into wet fields.

While wind primarily responds to atmospheric pressure differences, local turbulence can be strongly influenced by topographic features. Hence abrupt elevation changes and equivalent effects such as wind barriers can cause increased local turbulence and increased evapotranspiration.

3.1.6 Evapotranspiration – based irrigation scheduling

Evapotranspiration (ET) is also known as water requirement of the crops. The water requirement can be supplied by stored soil water, precipitation, and irrigation. Irrigation is required when ET (crop water demand) exceeds the supply of water from soil water and precipitation. As ET varies with plant development stage and weather conditions, both the amount and timing of irrigation are important. The rate of ET is a function of four critical factors i.e. weather parameters, soil moisture, plant type and stage of development (Allen et al., 1998). Different crops have different water-use requirements under the same weather conditions. The evapotranspiration rate from a reference surface is called the reference crop ET and denoted as ETo. The reference surface is hypothetical grass reference crop with an assumed crop height of 0.12 m, a fixed surface resistance of 70 sec m-1 and an albedo (reflectance of the crop-soil surface i.e. fraction of ground covered by vegetation) of 0.23, closely resembling the evapotranspiration from an extensive surface of green grass of uniform height, actively growing, well-watered, and completely shading the ground" (Allen et al., 1989). The grass is specifically defined as the reference crop. The crop coefficients appropriate to the specific crops are used along with the values of reference ET for computing the actual ET at different growth stages of the crop. The modified Penman and Moneith model was used to calculate the reference evapo-transpiration. The calculation procedures of ETo by means of the FAO Penman-Monteith equation are presented by (Allen et al. 1998):

$$ETo = \frac{\left\{0.408\, \Delta(Rn - G) + \gamma \left(\frac{900}{(T + 273)}\right) U2(es - ea)\right\}}{\{\Delta + \gamma(1 + 0.34U2)\}}$$

Where:

ETo	Reference evapo-transpiration [mm day^{-1}],
Rn	Net radiation at the crop surface [MJ m^{-2} day^{-1}],
G	soil heat flux density [MJ m^{-2} day^{-1}],
T	Air temperature at 2 m height [°C],
U2	Wind speed at 2 m height [m s^{-1}],
es	Saturation vapour pressure [kPa],
ea	Actual vapour pressure [kPa],

es - ea Saturation vapour pressure deficit [kPa],

Δ Slope of vapour pressure curve [kPa °C^{-1}],

γ Psychrometric constant [kPa °C^{-1}],

The crop evapotranspiration (ETc) differs distinctly from the reference evapotranspiration (ETo) as the ground cover, canopy properties and aerodynamic resistance of the crop are different from grass. The Kc component of equation integrates the characteristics of the crop (e.g., crop height, fraction of net radiation absorbed at the land surface, canopy resistance, and evaporation from bare soil surface) into the ETc estimation equation, to account for the difference in transpiration between the actual crop and the reference grass. The effects of characteristics that distinguish field crops from grass are integrated into the crop coefficient (Kc). In the crop coefficient approach, crop evapotranspiration is calculated by multiplying ETo by Kc.

$$ETc = Kc \times ETo.$$

Where:

ETc Crop evapo-transpiration [mm day^{-1}],

Kc Crop coefficient [dimensionless],

ETo Reference crop evapo-transpiration [mm day^{-1}].

3.1.7 Overview of evapotranspiration from crops

Plant growth and productivity are directly related to the availability of water(Rosenberg, Norman J & Blad, Blaine L & Verma 1983). Only about 1% of the water taken up by plants is actually involved in metabolic activity; most of the water is vaporised into the air, cooling the plant and preventing overheating. Since large quantities of energy are required to change phase from liquid to vapour (2.45MJ/kg for H_2O at 20°C), transpiration is a very effective means for the dissipation of heat.

Where the water available to crops is limited, growth can be impaired and yields reduced. In low rainfall areas, crops are often irrigated to achieve greater productivity. In such regions, the water available for irrigation is often limited, so it is important to be able to predict how much water is potentially required. Estimating the water requirements by estimating evapotranspiration provides quantification for planning and operational purposes. The rate of evapotranspiration depends on a number of interlinked factors, including but not limited to:

- the physiological and morphological nature of the crop;
- local and regional climate;
- soil properties;
- local topography and
- regional land use

The effects of many of these factors are difficult to measure. For this reason the estimation of evapotranspiration is a semi-empirical science, with predictions being made using a small subset of these variables. When modeling evapotranspiration, it is important to understand the assumptions and limitations of the method being used. Use of a method should ideally be justified, as a method giving valid estimates in one region may not necessarily do the same in another, particularly if empirical fitting has been used.

3.1.8 Soil moisture monitoring

Soil moisture monitoring is widely used for scheduling irrigations and involves measurements of either soil water potential (i.e. tension) or soil water content. Most soil moisture monitoring involves a single point measurement of soil moisture within the plant root zone. These measurements are useful in understanding the changes in soil moisture within the root zone and relating these observed changes to both the volume of irrigation water applied and the extraction of water by the plant. It is also possible to identify the time to irrigate and, with either trial and error or infield sensor calibration, the volume of water to apply.

A major limitation with using soil moisture monitoring for irrigation scheduling is that plant water uptake and stress does not only respond to the soil water content or potential. A range of other factors including atmospheric conditions (ie. radiation intensity), nutrient availability, root zone salinity, incidence of pests or disease and previous crop stress history all impact plant water uptake. Another limitation is that most soil moisture measurements are often only taken at a single point. The accuracy and appropriateness of the irrigation schedule developed using this data is therefore reliant on the selection of representative monitoring sites within each management zone and/or is based on the assumption that the field is homogeneous in terms of both soil characteristics (i.e. moisture content and water holding capacity) and crop characteristics (i.e. growth and rooting depth).

Not all of the water held within a soil can be extracted by plants. An estimate of the volume of soil water that is accessible to the plant without imposing an unacceptable level of crop stress is required to identify appropriate irrigation intervals and application volumes. The acceptable level of crop stress will vary between crops and even within a season depending on the crop management target. For example, lettuce crops have a smaller water potential stress limit compared to lucerne crops. Similarly, it is often desirable to impose a relatively large moisture stress prior to flowering in perennial tree crops but a smaller stress during fruit filling periods. Hence, the maximum acceptable crop stress value should be viewed as a management variable that is determined by the grower.

The volume of soil water able to be readily utilized by the crop (termed the "readily available water" or RAW) may be estimated from texture-based soil water characteristic data (Table 1) and the maximum acceptable crop stress. The active crop rooting volume may be used to convert the tabulated RAW (in mm/m) into a volume appropriate to the individual plant or unit crop area. The irrigation interval may then be calculated from the ETc and RAW values using:

Irrigation interval (in days) = RAW (mm) / ETc (mm/day)

Table 2 Effect of soil texture on readily available water

Soil Texture	Readily Available Water (mm_{water} per m_{soil}) between field capacity and:				
Crop stress level	-20 kPa	-40 kPa	-60 kPa	-100 kPa	-200 kPa
Sandy	30	35	35	40	45
Loamy Sand	45	50	55	60	65
Sandy Loam	45	60	65	70	85
Loam	45	65	75	85	105
Sandy Clay Loam	40	60	70	80	100
Clay Loam	30	55	65	80	105
Light Clay	27	46	57	70	90
Medium Clay	24	43	55	65	83
Heavy Clay	21	40	53	60	81

Irrigation schedules developed using atmospheric measurements are widely used. However, there are a number of limitations, particularly as the spatial scale of discrimination required for management decreases. For example, while the crop coefficient can be adjusted for a range of factors (e.g. crop age, canopy cover) appropriate values for different crop cultivars and management conditions (e.g. deficit irrigation, partial root zone drying) are not normally available. Similarly, the soil water characteristic data commonly used for estimating the soil water volumes is often based only on the soil textural properties. However, the readily available water content of a particular soil will also be strongly influenced by the soil structure and organic matter content. Hence, the cultivation and crop management history of the soil will affect the readily available water content. Estimates of rooting volume are also commonly based on a small sample of point measures, which may not adequately reflect the variation observed in the field. The technique is also not suited for differential (i.e. variable rate) irrigation at small spatial scales as the atmospheric measurements are normally obtained from a single local weather station and assumed constant over the surrounding area.

In order to improve confidence when using soil moisture monitoring devices, growers often deploy multiple sensors at different depths within the root zone and/or a range of locations within the fields.

3.1.9 Plant stress monitoring

Measurement of plant water stress has been a topical issue for a number of years and there are now a range of plant sensing tools available for both research and commercial crop irrigation scheduling. Plant based sensors can be broadly classified into either contact or non-contact sensors. Contact sensors are those that are physically mounted so that they are in direct contact with the plant. By their nature, contact sensors normally provide single plant or point source data. Non-contact sensors are further divided into either proximal (i.e. near to the crop) or remote (i.e. aerial and satellite based data acquisition) sensors depending on how close to the crop the sensor is located. Proximal sensors can be either hand-held, fixed or vehicle mounted.

Plant based sensors have also been classified (Remorini and Massai 2003) according to whether they measure a direct physiological indicator (e.g. plant water status) or an indirect physiological plant response induced by changes in plant water status (e.g. leaf temperature, plant organ diameter or growth). Plant water status sensors measure either the plant water content (e.g. stem micro-variation sensors, dendrometers, leaf thickness sensors) or the plant water potential within the root, stem or leaf (e.g. pressure chamber and psychrometer). Plant response sensors include those which measure a change in the plant that is related to the change in water status and include tools such as sap-flow sensors, porometers (ie. measures stomatal conductance) and thermal infrared guns (ie. measures canopy temperature).

3.2 Development of protocols, methodologies for data collection, debugging, processing and harmonization

3.2.1 Necessary input data for the precision irrigation system

A digital model for the application of precision irrigation in space and time has developed and applied in many different pilot areas in Greek territory. This model will be customized and applied within the Re-source project.

The requirements of the model in terms of input data are summed up in the following categories:

3.2.1.1 Pilot areas

The model can be applied in every type of irrigational crop under any type of irrigation method. It is obvious that under highly-controlled irrigation systems (i.e drop irrigation) the efficiency results can be higher, but that doesn't mean that other methods of irrigation are excluded.

The pilots can be at any area and there is no limitation regarding the size of each area.

In regard with the pilot areas, the following input data are needed:

- The **outline of each pilot area**. Within a google map, or any other sort of mapping application, the selected pilot areas need to be identified. There is no need to identify the specific parcels containing irrigational crops in the wider area.

3.2.1.2 Meteorological data

The model runs with the current daily meteorological data. Meteorological data need to be provide from meteorological stations in proximity with the pilot areas. This proximity isn't a defined distance, so the closest meteorological station to the pilot areas need to be taken into account whether they can fulfil the demands of the model. The geographic point of those meteorological stations, (via google maps) need to be provided.

The control room, where the model runs needs to have direct access to the meteorological data via internet or telemetry. If there isn't such option, then daily data needs to be sent via e-mail, on daily basis. The time frequency of the available data can be quite detailed (i.e data every 10 min, or 30min) but the model works with the daily averages, so daily averages and not timely detailed data can be given as well. The parameters to be included in this datasheet are the following:

- Temperature max (^{0}C) per day

- Temperature min (^{0}C) per day
- Temperature mean (^{0}C) per day
- Relative Humidity mean (per day)
- Wind mean (m/sec) per day
- n (sunshine) (h/day)
- Rain (mm/day)

3.2.1.3 Crop data

In regard with the crops the only necessary input data, is **a list containing the type of crops** in the selected area.

4 SOIL EROSION RISK ASSESSMENT TOOL

4.1 Development of guidelines, methodologies and best practices of the services for end users and stakeholoders

G2 erosion model is a quantitative model for mapping soil loss and sediment yield on month time intervals. As it mentioned above it resulted from the cooperation of Joint Research Centre/SOIL project and the Lab of Forest Management and Remote Sensing, School of Agriculture, Forestry and Natural Environment of Aristotle University of Thessaloniki.

G2 erosion model designated to produce soil loss maps as raster layers at a DEM dependent resolution and sediment yield maps as vector layers. The model inherits experience of R-USLE and EPM and has been developed and revised through five consecutive case-studies:

- Cyprus: 9251 km^2 – pixel size: 100m including sediment module
- Crete island: 8336 km^2 (Greece) – Pixel size: 300m, temporal coverage: 2011-2012
- Ishmi-Erzeni watershed: 2200 km^2 (Albania) – Pixel size: 300, temporal coverage: 2011-2012
- Korce: 1960 km^2 (Albania): 1690 km^2 – Pixel size: 30m
- Strymonas / Struma: 14500 km^2 (Greece/Bulgaria) – Pixel size: 300m, temporal coverage: 2003 – 2006

with a steady view to serve as an effective decision-making tool based on harmonized datasets and procedures.

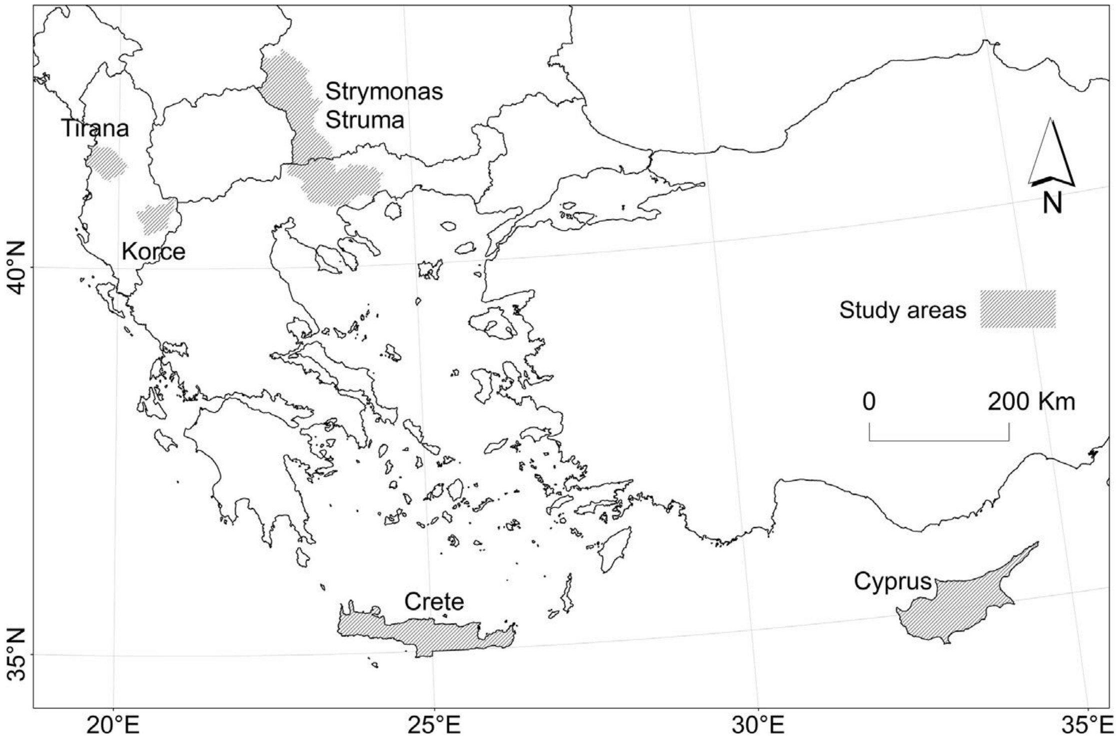


Figure 4 The study areas of the G2 model applications (Karydas & Panagos)

4.1.1 Model Description

G2 model is designed to run in a GIS environment, as it adopts modifications made by (Moore and Burch 1986) for spatially distributed soil loss assessments. G2 produces soil loss maps as raster layers at a 100-m resolution and sediment yield maps as vector layers at a 100-ha minimum mapping unit (MMU), on a month-time step.

The spatial scale of application in G2 is affected mainly by the terrain dataset, which has been proved to cause tremendous effect on erosion outputs. As therefore, the cell size of the erosion maps is determined by the resolution of the terrain dataset, taking also account of its positional accuracy. For example, a DEM of 25-30m resolution, will allow to map erosion features at a 100-m cell size. Bringing the dataset closely to model specifications, or (inversely) adapting a model to the particularities of the available dataset can be understood as “hidden calibration” of a model, a process inevitable in empirical modelling. Temporal scale of G2 is set by default to month-time intervals, instead of yearly assessments originally provided by USLE or EPM; a month is the first time-step, for which rainfall data could be made available for long periods and wide areas.

G2 consists of a set of algorithms (adopted, revised or developed) for producing month-time step maps and statistics of soil loss caused by sheet and interill erosion processes. Inherited by RUSLE, five input erosion parameters are combined by G2 in a multiplicative equation, to estimate a quantitative erosion output:

$$E = \frac{R}{V} \times S \times \frac{T}{I} \quad (1)$$

where E is the predicted soil amount removed from an area during a specific time period (t ha^{-1}); R is the rainfall-runoff erosivity factor for a specific time period (MJ mm ha^{-1} h^{-1}), which quantifies the impact of raindrop and runoff energy; S is the soil erobility factor (t ha h $MJ^{-1}ha^{-1}mm^{-1}$), identical to USLE's K-factor, which reflects the ease of soil detachment by raindrop splash or surface flow; T is the topography factor (dimensionless and analogous to the LS-factor of the USLE) which represents the effects of all interrelated cover and management variables; and I is slope-intercept factor (dimensionless and partially analogous to the USLE's P-factor), which is corrective of *T.*

Equation (1) is a redefined version of the original formula ($E = R \times V \times S \times T \times I$) implemented in the Strymonas application (Panos Panagos et al. 2012). In the revised formula of G2, the V and I factors have been moved to the denominator in order to reflect their protective role in the erosion process. Appropriate modifications have also taken place for each equation factor. The parenthesis in Equation (1) emphasize the (methodological) categorization of input factors into groups of counteracting actions, i.e. rain on vegetation (R vs. V) and the slope intercept of the terrain (T vs. I).

Table 3 A summary of all mathematical properties of the G2 module (Karydas and Panagos 2018)

Factor	Role	Character	Units	Range	Dimensionality (P:Power; L:Length; M:Mass)
R	Erosive	Dynamic	MJ mm ha^{-1} h^{-1}	$[0, +\infty)$	$[P][L^{-1}]$
V	Protective	Dynamic	-	$[1, +\infty)$	0
S	Erosive	Static	t ha h MJ mm ha^{-1} h^{-1}	(0,0.1)	$[M]$ $[L^{-1}]$ $[P^{-1}]$
T	Erosive	Static	-	(0,20)	0
L	Protective	Static	-	[1,2]	0
E	Erosion	Dynamic	t ha^{-1}	$[0, +\infty)$	$[M][L^{-2}]$

4.1.1.1 Erosion factors

Rainfall erosivity (R)

According to (Wischmeier and Smith 1978), rainfall erosivity (R) is defined as the numerical measure of the erosive potential of rainfalls within a specific period of time. In physical terms, R indicates how particle detachment and transport capacity are combined in the erosive processes. The experimental research conducted by the USLE developers has proved that soil loss is directly proportional to R, although with moderate correlation.

The R-factor is the product of the kinetic energy of a rainfall event and its maximum 30-min intensity (Brown and Foster 1987):

$$R = \frac{1}{n}\sum_{j=1}^{n}\sum_{k=1}^{mj}(EI_{30})_k$$

where R is the average monthly rainfall erosivity (MJ mm ha^{-1} $h^{-1}(y/12)^{-1}$); n is the number of years recorded; mj is the number of erosive events during a given month j; and EI_{30} is the rainfall erosivity index of a single event K. The event erosivity EI_{30} MJ mm ha^{-1} h^{-1} is defined as:

$$EI = EI_{30} = \left(\sum_{r=1}^{0} e_r v_r\right) I_{30}$$

where e_r is the unit of rainfall energy (MJ ha^{-1} mm^{-1}); v_r is the rainfall volume (mm) during a time period r; and I_{30} is the maximum rainfall intensity of the event during a period of 30 min (mm h^{-1}). The unit of rainfall energy (e_r) is calculated for each time interval as follows:

$$e_r = 0.29[1 - 0.72\exp(-0.05 i_r)]$$

where i_r is the rainfall intensity during the time interval (mm h^{-1}).

Vegetation retention (V)

The vegetation retention factor (analogous to the USLE's C-factor) is the degree to which vegetation cover and management is expected to protect soil from erosion (Wischmeier and Smith 1978). C-factor values can be found in empirical tables or alternatively can be estimated from land use maps or satellite images when details of land-use management are not available (Vrieling 2006). In the G2 model, V is a dynamic factor which combines input from time series of vegetation layers and a constant empirical land-use parameter, and is defined as follows:

$$V = e^{(LU*Fcover)}$$

where V is the vegetation retention (normalized; dimensionless) with V=1 for bare, heavily managed agricultural land and V>1 for land under better management conditions; Fcover is a vegetation layer normalized in the range [0-1]; LU is an empirical land-use parameter (constant for a specific location) ranging from 1 to 10, that corresponds to different management and treatments of land cover.

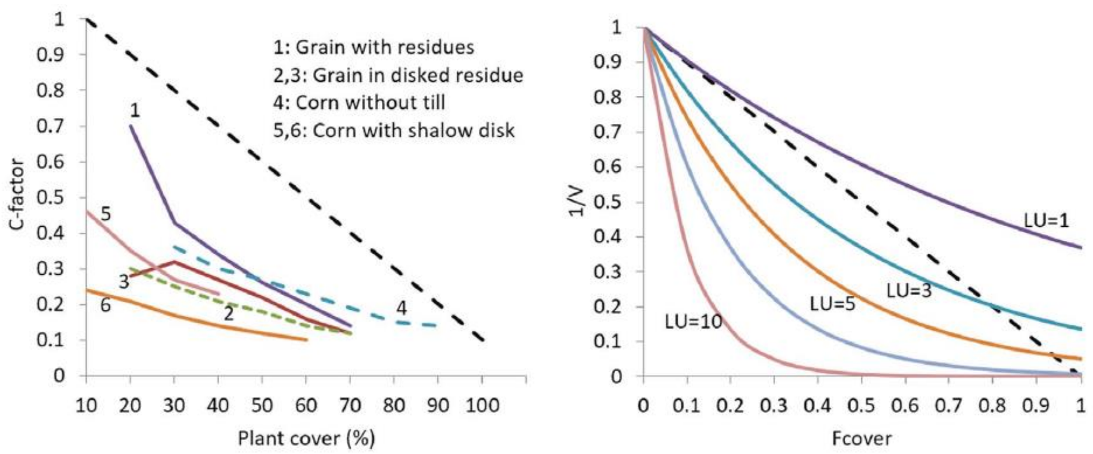


Figure 5 Extraction of exponential equation family of V-factor vs. Fcover for different LU values by G2 (right), according to C-factor values derived from USLE experimental data for indicative crop management practices (left). (Karydas & Panagos)

<u>Soil erodibility (S)</u>

Soil erodibility is a lumped parameter that represents an integrated annual value of the soil profile's reaction to the process of soil detachment and transport by raindrop and surface flow. Soil erodibility (denoted as the K-factor in the USLE and S-factor in the G2 model) is the best estimated from direct measurements of natural plots. As this is not financially sustainable at the regional/national level, the S-factor relates to soil properties as proposed for the USLE model by:

$$S = K = \left[\frac{2.1 \times 10^{-4} M^{1.14}(12 - OM) + 3.25(s - 2) + 2.5(p - 3)}{100}\right] \times 0.1317 \qquad (2)$$

where M is the textural factor defined as percentage silt+fine sand fraction content multiplied by (100-clay fraction); OM is the organic matter content (%); s is the soil structure class (s=1:very fine granular, s=3 medium or coarse granular, s=4: blocky, platy or massive); and p is the permeability class (p=1: very rapid,...,p=6:very slow). S (or K) is expressed in SI units of t ha h ha^{-1} $MJ^{-1}mm^{-1}$. Equation (2) has been used to estimate soil erodibility at the European scale based on the LUCAS topsoil dataset (P. Panagos et al. 2012).

Topographic influence (T) and slope intercept (I)

To estimate the influence of topography on erosion risk (T; or LS as denoted by the USLE), the G2 model uses an equation developed by (Moore and Burch 1986) and proposed by (Desmet and Govers 1997) that is used by most of the USLE-family models:

$$T = \left(\frac{A_s}{22.13}\right)^{0.4} \times \left(\frac{sin\beta}{0.0896}\right)^{1.3}$$

where T is the topographic influence (≥ 0; dimensioless), A_s is the flow accumulation (m) and β is the slope (rad).

Flow accumulation is defined as the accumulated flow to a cell from all upslope cells. It is calculated using a Digital Elevation Model (DEM). The original calculated values are given as the numbers of cells flowing into the specific cell. When a DEM is used as input for calculating A_s and β, accuracy errors inherent in the DEM are propagated to the erosion outputs. In order to compensate for this kind of uncertainty, the G2 model:

- Pays particular attention in the strict implementation of the terms under which the Moore-Burch equation (and the USLE-plot conditions in general) should be applied.
- Has developed a corrective parameter for slope length, namely the *I*-factor, which accounts for land use alterations (on a local basis), thus resulting in the proportional reduction of influence of the T-factor on erosion risk.

4.2 Development of protocols, methodologies for data collection, debugging, processing and harmonization

4.2.1 Necessary input data for the soil erosion risk assessment tool

Data requirements of G2 are becoming more and more possible to be met, as long as appropriate geodatabases are made available to decision makers by European or other international institutions. Indicative examples of free, regularly updated, validated, and ready-to-use geospatial datasets, for the preparation of the erosion factor layers for G2, include

- FCover from BIOPAR layers available by the Copernicus Land
- Monitoring Service (CLMS); BIOPAR layers are created with the SAIL/PROSPECT baseline vegetation model (Verhoef 1985).
- CORINE Land Cover (CLC) available by CLMS;
- Imperviousness layer from the High Resolution Layers (HRL) available by CLMS;
- Land Use/Cover Area frame Survey (LUCAS) (the soil component) available by ESDAC;
- ASTER-GDEM and EU-DEM (elevation raster data) available by METI/NASA and Eurostat, respectively; and
- Sentinel-2 (S2) satellite imagery available by the European Space Agency (ESA).

Furthermore JRC has developed GIS-ready layers of rainfall erosivity on month-time intervals, at different resolutions for the European Union (500 m) and the Globe (1 km), namely the Rainfall Erosivity Database at European Scale (REDES) and the Global Rainfall Erosivity Database (GloREDA), respectively, available by the European Soil Data Centre (ESDAC). JRC has also developed the soil erodility layer at a 500-m resolution and the terrain influence layer on a 25-m resolution covering the European Union; both datasets are available in ESDAC.

Among the erosion layers, quality of R and S depend strongly on original point data, irrespectively whether or not the interpolated geospatial layers were already available (JRC) or were created by the model users.

As far as V-surfaces are concerned, use of FCover layers from different satellites (such as MERIS, PROBA-V, and SPOT-VGT) and for many consecutive years (five or more) is highly recommended. Variance in FCover sources allows to eliminate gaps from cloudiness and also to compensate for inter-annual discrepancies (usually detected in agricultural lands).

In the same direction, the contribution of a high resolution FCover layer is also encouraged. Apart from filling the gaps, high resolution FCover layers could be used to effectively downscale the final FCover outputs. Sentinel-2 imagery could be considered as an appropriate solution in this direction. Calculation of FCover values from this image type can be realised using empirical equations (Verger et al. 2015). The LU values can be taken from a matrix developed by G2, where the most common CORINE categories at Level 3 are interpreted in terms of a degree of land use influence on erosion. Recently, this matrix was revised in accordance with a new C-factor dataset elaborated by the JRC for the entire European Union (Panos Panagos et al. 2015). However, for several land uses, the values of the two sources remain different (Table 4). The selected LU values will be assigned to the corresponding CORINE or other equivalent layer polygons. G2 treats all the CORINE categories originally as erosive, although some of them are considered to be non-erosive, e.g. artificial surfaces or water bodies. This is due to the possibility of mixed pixels in the available raster data, i.e. the existence of heterogeneous surfaces contained in a single pixel (usually found at the boundaries of the categories). Taking, therefore, all the categories as erosive by default, the risk of neglecting an erosive surface (contained in a mixed pixel) is avoided; the V value of this surface will be judged by the rest contributing parameters, i.e. fraction of vegetation cover (FCover) and imperviousness degree (imp).

The high resolution imperviousness-degree layers can be derived from Copernicus Land Monitoring Service, as HRLs (at a 20-m cell size). These layers indicate the degree of sealed soil within every pixel in a range [0−1] (corresponding to 0–100% of soil sealing). It is suggested to mask out cells with a value of 0 (if any) or convert them to no-data in order to ensure the arithmetical integrity of the V-function (possible null imperviousness values would render zero V and thus the denominator). Complementarity of the geospatial layers contributing to Vsurfaces (FCover, LU, and imp) is considered to improve overall accuracy of V-factor.

For S-factor, Texture, Organic Matter, Soil Structure, and Permeability layers can be derived from the European Soil Data Centre (ESDAC) of the JRC for the EU at 500-m resolution grids. If extra local soil datasets are available, these can be used to correct, refine, or downscale the original rough S estimations. In case of lack of the above data, the method introduced by (Knijff et al. 1999) and improved by and (Panagos et al., 2012) could be applied as an alternative.

For T-factor and the SDR estimations use of ASTERGDEM or EU-DEM, both validated and with a spatial resolution better than 30 m, is recommended.

For L-factor, a recent satellite image of medium-high resolution, such as Sentinel-2, is considered appropriate to capture up-to-date landscape alterations. Use of the near-infrared (NIR) band of the image is recommended, as this band is sensitive both to vegetation and water variations. Furthermore, use of images from different dates –if available- and extraction of an averaged L is welcomed. On the contrary, extraction of a principal component of the image bands is not recommended.

For optimum consistency of the input geospatial layers, the UTM WGS84 projection system is suggested. Also, a buffer zone of 1 km from the coastline (or other known discontinuities) should be masked out from the final erosion outputs. This would help to avoid biases implied from spatial interpolation or extrapolation methodologies implemented on R or S point data or possible existence of tiny coastline watersheds.8) and(Panos Panagos et al. 2015) could be applied as an alternative.

4.2.1.1 Digital Elevation Model (DEM)

DEM is a common data source for developing topography dependent models such as G2. DEM's spatial analysis affects directly G2 accuracy, hence the suggested resolution should be less than 30m.

4.2.1.2 Meteorological Data

Meteorological data mined from open access stations or delivered by national meteorological Services shall be collected describing the following variables:

- Daily rainfall (mm/day)
- Maximum and minimum daily temperature (^{o}C)
- Daily solar radiation (W/m^2)
- Daily average relative humidity
- Daily average wind speeds (m/sec)

Full spatial and temporal description should accompany forth mentioned data. Specifically, latitude and longitude of each source shall be delivered and a time series of length at least of 30 years.

4.2.1.3 Land Cover/Use

Digital land use map provides the spatial extent and classification of various land use classes of the study area. This information, if is as updated as possible, can enhance G2 model's ability to map more accurately the erosion of the study area.

4.2.1.4 Soil Data

Soil data as required by G2 including Soil Organic Carbon (SOC) and Organic Matter, Soil Texture and permeability class (rapid, very rapid, very slow). Information about coordinates (Latitude, Longitude and Elevation) for each soil sample is a necessary should be provided.

5 CODES OF GOOD AGRICULTURAL PRACTICES – ENVIRONMENTAL DATA INFORMATION SYSTEM

5.1 Development of guidelines, methodologies and best practices of the services for end users and stakeholoders

Protecting the natural resources of water, soil and air is essential for a sustainable environment. The advice in this CGAP tool recognizes that things farmers do can affect water soil and air simultaneously.

Some examples of good practice which can benefit water, soil and air

- Careful management of livestock manures can:
    - Reduce losses of ammonia and other gases to the atmosphere
    - Limit nitrate leaching to groundwater
    - Avoid excessive buildup of nutrients and contaminants in soil; and
- Following a nutrient management plan will ensure efficient use of fertilisers (and organic manures) and can:
    - Limit nitrate leaching to surface and groundwater's
    - Prevent the unnecessary accumulation of phosphorus in the soil which will also reduce impact on the water environment and
    - Reduce the risk of nitrous oxide (a greenhouse gas) being lost to the atmosphere.

5.2 Development of protocols, methodologies for data collection, debugging, processing and harmonization

5.2.1 System information

The system allows the user to retrieve personalized information regarding the degree of user compliance with the Codes of Good Agricultural Practices (CGAP). The user is prompted to fill out a form, the result of which is the degree of compliance. At the same time, the system shows in detail the points where the user does not comply.

5.2.2 Parcel selection

The user is initially connected to the web-based service (see Figure 6) they select their CGAP according to their location. In the popup window, they select the link next to "CGAP". The link redirects the user to the form that the user will fill.

5.2.3 Form completion

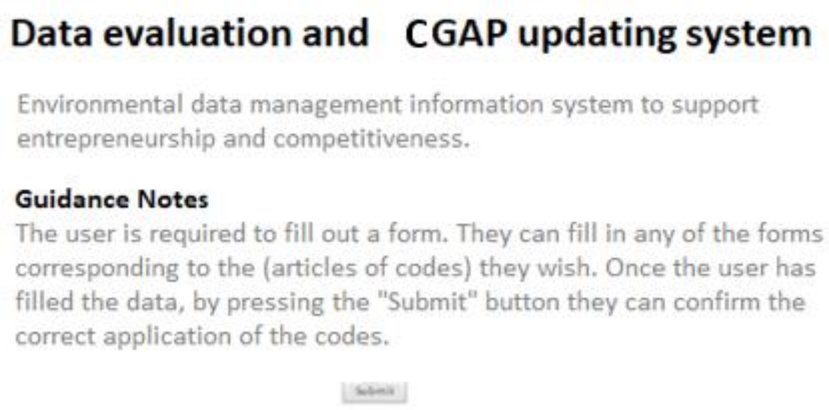


Figure 6 CGAP tool welcome screen

The user, after reading the text and instructions, selects the "Start" button (left click). The user fills in the fields "Soil class" and "Cultivation" and then presses the "Submit form" button so that they can be redirected to the main form.

Figure 7 Parcel information

At this phase, the user is asked to fill in the form. Initially, it is noted that the user can fill in any and all of the individual tabs, which correspond to the individual articles of the CGAP. However, in each tab, it is mandatory to fill in all the individual fields correctly. In case the user tries to submit the form, without completing all the fields, appropriate messages will appear on his screen (Figure 8).

In case the user wants to change the tab, while they have not completely completed the current tab, an appropriate appears. In case the user selects "Yes" the data in the current tab is deleted.

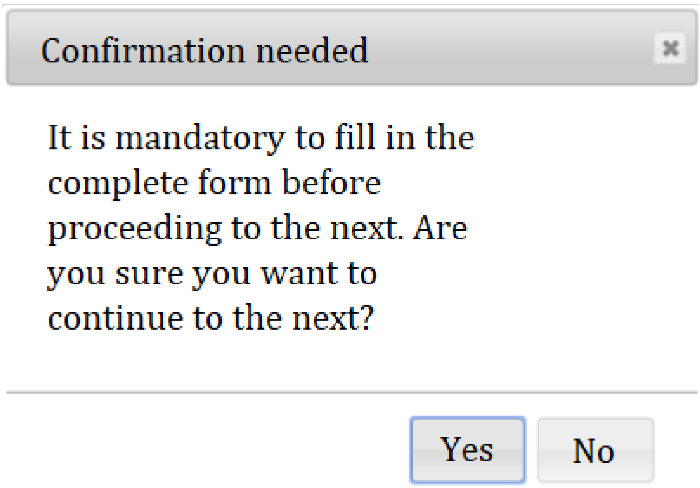
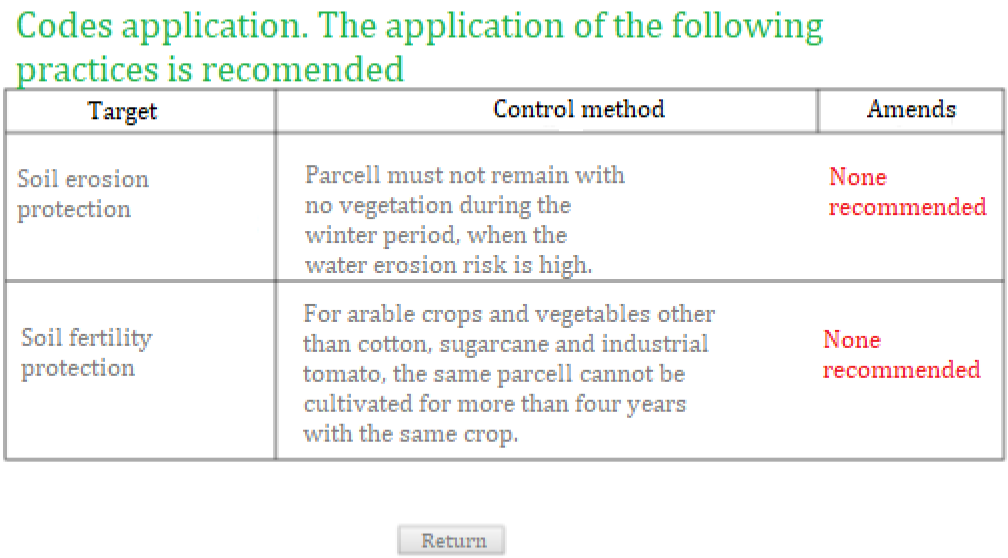


Figure 8 Confirmation screen

If the user has successfully filled a complete tab, and submitted it, then the result of the degree of compliance of the user with the CGAP is calculated. The result can be positive Figure 9 or negative Figure 10.



Codes application. The application of the following practices is recomended

Target	Control method	Amends
Soil erosion protection	Parcell must not remain with no vegetation during the winter period, when the water erosion risk is high.	None recommended
Soil fertility protection	For arable crops and vegetables other than cotton, sugarcane and industrial tomato, the same parcell cannot be cultivated for more than four years with the same crop.	None recommended

Return

Figure 9 Example of compliance report

Target	Control method	Amends
Protection of aquifiers - Irrigation	Irrational water use in terms of over-irrigation, leveling of neighboring fields or defeceit irrigation systems must be avoided.	None recommended
	Cultivation of land formerely covered by lakes	100%
	Avoid field leveling with slope higher than 3%	None recommended
	Surface irrigation is not recommended as an irrigation system, due to high water requirements, nutrients runoff and uneven water distribution.	None recommended

Not complied to codes. Total amends of: 110%

Return

Figure 10 Example of compliance report

With the "Return" button, the user can return to the form and fill in the remaining tabs or make corrections to those that he has already completed.

6 I-BEC'S GEOTATABASE

6.1 Data and meta-data management system

i-BEC's geo-database was developed according the main axis of serving as a methodological system that stores and organizes data of different spatial and temporal origin (i.e. hydrological, soil, etc.). In such context, data created in geographic information systems (GIS) and are routed to i-BEC's geo data-base for storage are based on a specific data and metadata structure. This structure is shaped under the following set of guidelines:

- Users use and share common and valid data
- The generated thematic maps are uniform

- Instant data search and find is supported
- Already existing data do not take over extra storing space
- User can combine heterogeneous data through simple and easy steps
- Is compatible with international data storage and retrieval standards
- Any update or edit to the initial datum is logged
- Data are accompanied with required metadata

The data is stored in a data management system consisting of individual information systems that will be interconnected with appropriate communication channels, allowing on the one hand the direct and uninterrupted interconnection of the systems and supporting on the other hand the use of appropriate spatial or descriptive search queries.

6.2 Geospatial information database

The sets of data that i-bec's geo-database manages, processes, produces and homogenizes are spatial referenced, resulting to the general characterization of these set as spatial datasets. A typical example is a telemetry dataset, which has as spatial component the coordinates of the measuring station and as a descriptive component the parameters (temperature, rainfall, pH, turbidity, etc.) recorded in the time-unit that the corresponding sensor is set. However, the most important information extracted from the telemetry stations is the sensor recordings and not the station's location. For this reason, the categorization of data into the following general categories is based on the information embedded in that spatial data. Therefore, all data contain at least the spatial reference to a proposed coordinate system and the description / recording of the information to which are related.

According to these statements, the spatial information database contains the following categories:

- **Spatial data**: This category contains vector data or raster data that
    1. Are obtained from national (i.e. geodata.gov) or international databases (i.e. earthexplorer.usgs.gov)
    2. Are created within the framework of various research projects (through digitization or other prost processing works).

- **Laboratory or sampling data:** This category contains all data that come from sampling at specific geographical points and then their properties that are analyzed under chemistry or laboratorial conditions. Each entry is accompanied by at least one unique characteristic number, the samples corresponding coordinates, as well as and the results of the analyses (i.e. pH, nitrates, temperature, or other measurements). Data retrieval is achieved through the GIS-ArcMap geolocation interface. After connecting to the SQL database and then by querying (search by location or attributes), the sampling point is first reached and then the results of the chemistry are displayed.

The geo database is focused on measurements derived from water samplings or soil sampling, or data related to plant tissue or land use.

- **Telemetry data:** This category applies to all data received via telemetry from monitoring stations that are equipped with appropriate sensors and automatic transmission systems of the sensed parameters. This category of data is stored to an MS SQL Server. For specific categories of data, such as water quality data, debugging algorithms are applied and then the corrected data are stored in a new-formed table of the SQL database. Data Search and parameters' visualization can be performed in three ways:

    1. Through a WebGIS application where the station is searched spatially and then through a special application a "drop down menu" is displayed for selecting a parameter and displaying the measurements in the form of a table and diagram presenting additional basic statistical characteristics.

    2. Through the dashboard, where the station is selected and then the parameter is selected in order to display the data in a tabular or graphical form (virtual meters or diagram).

    3. Through the working environment of GIS-ArcMap, where through connection to the corresponding SQL database and then after a series of queries, the station is initially searched and then all the measurements performed by the corresponding sensor are displayed.

At this point it should be emphasized that in all three ways of displaying data described above there is the possibility of exporting them in .txt, .csv and .xls form.

- **Metadata:** Metadata are the main data description tool and can be understood as the “abstract” of any type of data, as well as a very important tool for searching data through keywords

Geodatabase management operations.

The main management functions performed in the database are for the most part:

- Data Management System navigation
- Data import to the Data Management System.
- Data export for every kind of use and edit.
- Metadata population for each ontology class.

Geodatabase navigation and other operations as well is performed through the ArcGIS software, and specifically by its explorer, ArcCatalog. The basic operations of the system are considered known by the administrator. For further information regarding the operations of ArcGIS v10.1, refer to (Zeiler 1999).

- Data import

As can be seen from the analysis of the geospatial data categories, the data can be classified into:

- Background mapping data that cannot be changed
- Spatial reference data of the project
- Data sampling and field measurements

Data import to the Data Management System is related only to the population of the third category of data, which can be conducted in the following steps:

- Spatial data import through GPS
- Code and primary key extraction, and export to spreadsheet.
- Population of excel spreadsheet (separate for each table class) with the results of field analyses and measurements, retaining the created coding.
- Re-import spreadsheet data to database table classes.

7 CONTRIBUTION OF REMOTE SENSING AND PROXIMAL SENSING

7.1 Introduction to remote sensing

7.1.1 Definitions

Remote sensing is defined as the acquisition of information for the field or crop in question without being in physical conduct with it. In other words, valuable information on various parameters can be acquired with air-photographs or satellite images, without visiting the field or with sampling the minimum number of locations.

7.1.2 History of remote sensing

Remote sensing was developed in the last century following the technological development of photography, flight, and computers. As soon as photography was developed, air-photographs from hot air balloons and later from airplanes were acquired. The development of digital photography allowed easy storage and transmission of digital images acquired from unmanned satellites orbiting the earth, and recently from unmanned aerial vehicles (UAVs).

7.1.3 Current trends

The current trends of remote sensing focus on developing higher resolution satellites, however not below 0.5m due to restrictions related to defence and personal data. Also, dedicated bands have been used in wide coverage as well as very high resolution satellites, such as coastal and red edge on WorldView-2. Finally, the user friendliness and timely delivery of the acquired images is a sector under development for wider accessibility of the data.

7.2 Available remote and proximal sensors used in precision farming

7.2.1 Development sensors

The early photographic sensors gave way to digital sensors in the 1970's. Since then, several handheld, airborne and satellite sensors have been designed to acquire digital images in various sections of the electromagnetic spectrum. Their spatial resolution has increased from 79m of the Landsat 1 MSS in 1972 to 0.41m of the GeoEye-1 in 2008. They are usually designed to acquire data in the visible (blue, green, red) and near infrared parts of the electromagnetic spectrum, and some extend their acquisition to the middle infrared and thermal infrared wavelengths. They are usually designed as broad-band multispectral sensors, and very few are hyper-spectral or have dedicated narrow bands, such as the coastal and red edge of the WorldView-2 satellite.

7.2.2 Active – Passive

Most are passive sensors, i.e. they record the sun's light reflected from the target, as they tend to be lower cost and simple in their construction. Active sensors have the source of the electromagnetic radiation as well as the receiver which is recording the reflected part of the radiation. The satellite active sensors are restricted to the microwave parts of the spectrum (e.g. ENVISAT/ASAR, TerraSAR-X). There are several active optical handheld instruments developed to emit and record radiation (Unispec DC of PP Systems Inc., N-sensor ALS of Yara International ASA).

7.2.3 Platforms used

Several platforms have been used to carry the remote sensing and proximal sensors. Handheld sensors are used often in precision farming as they are of low cost, they offer specific information on demand and can be integrated easily on farming machinery. Handheld global positioning system (GPS) sensors are used to record the position of on the field measurements and agricultural applications. Airborne sensors offer the advantage of wider coverage on demand and multifold of information (especially with hyper-spectral sensors), however the costs are higher. A lower cost option of aerial platform are the unmanned aerial vehicles (UAV), which are robotic fixed wing airplanes or vertical take-off and landing helicopters. They usually offer sufficient coverage for precision farming applications, however they can carry certain low weight sensors as their payload is limited. Satellite platforms orbit the Earth at various heights (>400km) and offer various options of spatial and spectral resolutions. They are the most cost-effective option for large areas, but have the disadvantage of being influenced by cloud coverage and not being always available on demand.

7.2.4 Sensors

Several remote sensing sensors have been used in precision farming applications (Lee et al. 2010).

- **Multispectral** imaging sensors usually acquire data in 3-6 bands in the visible (400-700nm), near infrared (700-1200nm) and shortwave infrared (1200-2400) parts of the spectrum. Most often they include the red (600-700nm) and near infrared bands which are used for the calculation of vegetation indices and generally for monitoring the quantity and quality of green vegetation. The main reason is that healthy green vegetation is characterized: (i) by low reflectance in the visible wavelengths with a small peak at green, due to the strong absorption by the photoactive pigments (chlorophylls, anthocyanins, carotenoids), and (ii) by high reflectance in the near infrared wavelengths due to multiple scattering in the space among the cells in the leaf internal tissue. Most of the commercially available sensors collect data multispectral data at these parts of the spectrum.

- **Hyper-spectral** imaging sensors acquire data in the same parts of the spectrum as the multispectral sensors, but in many more bands (usually dozens to a few hundred). This array of almost continuous data provides information that might be originally missed by the multispectral sensors. Thus, very specialized vegetation indices have been developed for vegetation (Haboudane et al. 2002). Hyper-spectral data have successfully been used for the identification of appropriate bands for specific applications, such as the red edge band (650-750nm) which is sensitive to subtle changes in green vegetation health. The red edge has recently gained preference and has been included in a commercial remote sensing satellite (WorldView-2). A few hyper-spectral satellite sensors are available (Hyperion, Proba), however mainly for research applications. Airborne hyper-spectral data have also been used extensively, such as the CASI camera (Compact Airborne Spectrographic Imager).

- **Thermal** imaging sensors acquire data in the thermal infrared parts of the spectrum (3000-15000nm) where radiation is emitted by all bodies with a temperature >0oK, according to their thermal properties. Due to the high water content (emissivity between 0.97 and 0.99), healthy vegetation haves much like "black bodies" and emit radiation in the thermal infrared band (TIR~10000nm) according to their temperature(Lee et al. 2010; Ribeiro da Luz and Crowley 2007). Thermal images have been used for the estimation of water consumption of cultivated land, as they can provide valuable constituents of the energy balance which governs evapotranspiration (Alexandridis et al. 2009). Moreover, they have been used in counting of fruits (Stajnko, Lakota, and Hočevar 2004) and in the detection of foliar diseases, as stress can induce stomatal closure resulting in an increase in leaf temperature (Lee et al. 2010; Lindenthal et al. 2005).

- **Microwave** imaging sensors are mostly active (SAR), and have the unique advantage of not being influenced by weather patterns and sun location. Thus, they are very useful in locations or seasons of frequent cloud cover, such as the tropics or monsoon season. They have been related to soil moisture, soil electrical conductivity, and soil surface roughness, as well as various vegetation parameters. However, their limited spatial resolution and difficulty in processing restrict their use in precision farming applications.

7.3 Advantages and services offered by remote sensing in precision farming

Several reviews outline the advantages offered by the various forms of remote sensing in precision farming (Brisco et al. 1998; Hall et al. 2002; Moran, Inoue, and Barnes 1997). The following advantages are highlighted:

- **Full coverage** of the examined field at relatively low cost. Remotely sensed images provides wall-to-wall coverage (full coverage of the examined fields / areas), as compared to the sampled locations usually provided by in-situ and automatic measurements stations. Considering the coverage of each image, the cost of acquisition is relatively low compared to other methods.

- **Multispectral** nature of the information. Remote sensing provides data in multiple wavelengths in addition to the ones that are visible by human eyes. This is an advantage, as early detection of plants stress (e.g. infestation or water deficiency) may not be evident in the visible wavelength.

- **Timely information**. Remote sensing information is collected on demand (from handheld, airborne or UAV platforms), after ordering a pre-scheduled acquisition (very high resolution satellites, e.g. IKONOS), or following a pre-determined schedule (for wide coverage satellites, e.g. every 16 days for Landsat). In any case, it is available for processing a few hours or days after acquisition.

- **Integration of results** in a farm management system. Being in digital raster or vector format, the outputs from remote sensing algorithms are easily incorporated in an integrated farm management system, which will help in the decision making process.

There are three basic types of information required for precision crop management: (i) information on seasonally stable conditions, (ii) information on seasonally variable conditions, and (iii) information required to diagnose the cause of the crop yield variability and develop a management strategy (Moran, Inoue, and Barnes 1997). Remote sensing can contribute to the above mentioned information types by offering the following services:

- Mapping **crop yield**. Mapping of crop yield is performed in-situ using sensors mounted on combine harvesters. The location of the yield variation is recorded with a GPS, after corrections due to delay in response to the vehicle movement. The resulting point location dataset is usually converted into a continuous surface for the whole field with a spatial interpolation technique, such as Inverse Distance Weighted, simple kriging, and co-kriging (Arslan and Colvin 2002; Blackmore and Moore 1999). Most important, remote sensing images have been used for the prediction of crop yield before harvesting. This is usually performed using simple regression equations that connect the expected yield with vegetation indices of single date observation, or monitoring the growth profile during the crop's development stages (Aparicio and Aparicio-Ruíz 2000). More complex techniques involve growth models that incorporate time series from meteorological stations and satellite images in the visible, near and thermal infrared (Basso et al. 2001; Bastiaanssen and Ali 2003; Chemin and Alexandridis 2006).

- Mapping **soil fertility** parameters. Mapping of soil variability is performed with laboratory analysis of soil samples, or with proximal sensors pulled above bare soil. The location of the soil variation is recorded with a GPS, after corrections due to delay in response to the vehicle movement, and the resulting point location dataset is usually converted into a continuous surface for the whole field with a spatial interpolation technique, depending on the soil parameter under investigation. Surface soil conditions have been assessed with remote sensing using microwave, multispectral, or hyper-spectral sensors (Alexandridis et al. 2009; Kimes, Kerber, and Sellers 1993; Shepherd and Walsh 2002). The list of agriculturally-important soil properties (including texture, organic and inorganic carbon content, macro- and micro-nutrients, moisture content, cation exchange capacity, electrical conductivity, pH, and iron) were quantified with remote and proximal sensing with variable success, using laboratory analysis of soil samples with a bench-top spectrometer to field-scale soil mapping with satellite hyper-spectral imagery.

- Monitoring **soil moisture** content. Accurate estimation of volumetric soil moisture content is done with laboratory analysis of undisturbed soil samples. A faster way is to use soil moisture probes, such as the time domain reflectometry (TDR), installed in strategic locations in the field and recording frequent measurements in a data logger. To have a full coverage of the field or site, satellite remote sensing has been used with microwave or thermal infrared images (Alexandridis et al. 2009; Goetz et al. 2003). However, microwave signal only captures the first few centimeters of surface soil, and is strongly influenced by the presence of vegetation, thus it may not be useful in operational monitoring.

- Determining **fertilization applications** in the spatial domain. Remote or proximal sensing is being used in real time for determining the spatial distribution of fertilizer applications. Alternatively, the spatial distribution of nutrients requirements of the crop is determined using the yield map of the previous cropping season, from satellite images or harvested yield flow sensors. This is based on the assumption that chlorophyll content of the green parts of the plant are directly related to the nitrogen (N) content. Thus, several indices have been developed to assess the N content, often using specialized narrow wavelengths, and dedicated sensors have been operational (Jasper, Reusch, and Link 2009; Miao et al. 2009; Patil et al. 2013).

- Monitoring **crop growth**. Remote or proximal sensing has been used for the assessment of crop growth in relation to fertilization or other farming activities. The ability of vegetation indices to correlate to the quality and quantity of green vegetation has been utilized to identify the crop's development stages using regression equations (Aparicio and Aparicio-Ruíz 2000). Physical parameters, such as the fraction of photosynthetically active radiation (fPAR) have been routinely estimated from wide coverage satellite images, such as MODIS. More promising is the combination of remote sensing with crop growth models, which incorporate meteorological data (Basso et al. 2001; Moran, Inoue, and Barnes 1997).

- Monitoring **water use and irrigation requirements**. The time to irrigate and amount of water to apply in various parts of the field is information that can be derived from strategically positioned soil moisture sensors or plant stress sensors (e.g. sap flow). Remote or proximal sensing can identify water stress using specialized indices, such as the crop water stress index (CWSI) (Alchanatis et al. 2010; Jackson et al. 1981). Moreover, the amount of irrigation water can be estimated from meteorological and soil data using the modified Penman-Montieth equation (FAO56) or more advanced models that utilize satellite images to account for the crop development stages and spatial variability, such as SEBAL.

- Detecting **crop diseases**. Remote and proximal sensing of crop diseases is based on the observation that green leaves' colour is changing after an infection is set, often before a change is visible by naked eyes (Nilsson 1995). Hyper-spectral remote sensing has an advantage over multispectral, as various disease symptoms are evident by specific wavelengths (Muhammed 2005). Thermal sensing has also been used in various applications of detection and mapping of crop diseases (Lee et al. 2010).

- Mapping **weed infestations**. Identification of the presence and density of weeds has been performed with remote and proximal sensing in order to guide the flow of variable rate herbicide chemicals. Delineation of weed patches has been performed with success, while the removal of the influence of the fully grown crop or the soil background remain a challenge (Thorp and Tian 2004). Specific management of weeds in specialty crops can be achieved with machine vision and specific herbicide applications (Lee et al. 2010). The main challenges in this task is the discrimination of the weed within the crop, and the identification of the weed type in order to spray the appropriate chemical.

- Mapping **insect infestations**. Direct mapping of insect infestations is possible with remote and proximal sensing, as decreased leaf chlorophyll concentration and change of colour are some of the main symptoms (Yang and Cheng 2001). Alternatively, the favourable conditions for insects breeding can be modelled in a farm management information system (Moran, Inoue, and Barnes 1997).

8 CONCLUSIONS

The overarching objective of this project was to provide a detailed description of the three tools/digital services that will be utilize and improve in the "Re-source" project and to give all the necessary information to all partners regarding the use of each tool as well as general guidelines and protocols for data collection in order to make the tools efficient in their application in the respective pilot area.

The successful delivery of services and digital applications of the three tools in pilot areas can give the ability to i-BEC to make a good use of the tools in order to emphasize the agricultural sector and the management of natural resources during agricultural practices.

More specifically, precision irrigation and soil erosion tools can provide without doubt smart solutions for agriculture as well as innovative monitoring and simulate techniques from the effects of agricultural practices.

Furthermore, in this project the CGAP tool will be used as a guide to support farmers and land managers to protect the environment within the framework of the post CAP 2020 regulations. The code describes very useful key actions that farmers can take to protect and enhance the quality of water, soil and air. In some cases farmers can also achieve cost saving for their business using this tool or in future with CAP and greening action[4]. Also it can help farmers to meet their legal obligations including those relating to cross compliance. In this project the CGAP tool is a manual on how farmers can manage their farms or holding. Can help farmers to select the appropriate actions for their individual situation. It is true that many farms and holdings are already delivering a good standard of environmental protection, but there are some where it can improved. Most can do something better. It should be mention that the CGAP tool in its prototype version created based the Greek legislation regarding the Good Agricultural Policy. In the context of this project this tool will be modified based on the legislation of the countries Cyprus and North Macedonia to which it will be applied.

[4] https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/income-support/greening_en

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