AgroStrat

Sustainable Strategies for the improvement of seriously degraded agricultural areas: The example of *Pistachia vera* L.

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AgroStrat for Policy Makers

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What is in this document

Contents

This document was developed to assist policy makers in understanding Agrostrat project and its outcomes, with the aim of identifying which of these can be implemented and in which areas, as well as the implementation conditions, the necessary human resources and infrastructure and also the expected benefits.

Through the presentation of the project and its achievements, this documents illustrates the short and long-term benefits that AgroStrat achievements can bring to the local communities and the environment.

The project, during the 5 years of its duration, produced many innovative results, i.e. methodologies, web decision-making tools and strategic plans that have significant transferability potential. Focusing on the sustainability of intensively cultivated Mediterranean areas, AgroStrat addressed the issues of soil and water bodies protection, the promotion and adoption of good agricultural practices, the sustainable management of agricultural waste, as well as the sustainability of the rural environment as a whole, by working with those who are directly interested, i.e. the farmers and their associations as well as the local and regional authorities.

Objective and Innovations

The Main Objective

Development of sustainable cultivation practices at Mediterranean areas under desertification risk, which include sustainable management of soil, water and nutrients, valorization of agricultural waste streams and reduction of cultivations' environmental footprint

Innovations

- An Integrated Management Scenario for intensively cultivated areas to address specific issues (e.g. waste management at field, soil erosion) or as holistic approach to support regional plans.
- A set of soil indicators suitable for pistachio cultivation practices and wastes disposal for the determination of soil quality, degradation and desertification risk.
- A composting methodology for pistachio waste with very high electrical conductivity with the addition of natural zeolite as additive to the feedstock.
- A unique system for land evaluation for waste landspreading, which considers soil physical and chemical properties, geological and hydrological characteristics.
- A Cultivation Management Software (CMS) that provides consultancy to farmers for soil and water quality, fertilization according to soil properties and crop needs, evaluation of the soil suitability for waste/organic materials landspreading or use for fertilization.
- A Central Management and Monitoring Tool (CMMT) that allows network development between farmers and local authorities and establishment of a center of monitoring/ management cultivated areas.
- Construction of a practical, easy to use, field equipment for rapid measurement of soil pH, moisture and electrical conductivity which could be used by individual farmers.
- Analysis of pistachio production sustainability considering the three pillars of sustainability (environmental, economic and social)-Life Cycle Analysis of pistachio production.

The Integrated Management Scenario

The Integrated Management Scenario (IMaS) is the overall deliverable of LIFE AgroStrat project, which includes all project achievements and integrates them into a strategy for pistachio cultivation, soil management, waste exploitation and reuse, management and treatment.

The Seven Chapters of IMaS

Chapter 1: Integrated fertilization practices for pistachio trees
Chapter 2: Environmental footprint of pistachio cultivation
Chapter 3: Addressing soil threats
Chapter 4: Development of sol thematic maps-Definition of soil indicators
Chapter 5: Pistachio wastes management
Chapter 6: The decision-making tools of AgroStrat
Chapter 7: The IMaS in eight steps

The scenario is a document of seven chapters, accompanied by

- An Implementation Guide,
- A techno-economic analysis, and
- A supporting guide manual for developing soil monitoring plans

The project, through its actions, demonstrated how local/regional communities (farmers and authorities) can cooperate between each other and with scientists to develop and promote sustainable integrated management of resources and wastes; continuously monitor effectiveness of their actions while at the same time, ensure and advance environment protection and increase productivity.

Not only for pistachio trees cultivation

The IMaS although it was developed using the example of pistachio trees cultivation, it was developed in a such a way that can be also implemented for other cultivation types and at other Med countries.
This is because the scenario proposes sustainable cultivation practices for Mediterranean areas under degradation/desertification risk, for sustainable soil and water monitoring and management, nutrients use, proper management of agricultural wastes (recycling, disposal, composting and use in agricultural sector, potential use of wastewater for irrigation, production of biochar) as well as, practices for minimizing soil salinization risk and erosion while promoting soil protection.

Chapter 1: Integrated fertilization practices for pistachio trees

Briefly…

The chapter provides guidance on sustainable cultivation of Pistacia vera L. cultivation under Mediterranean climatic conditions. All relevant issues are discussed and presented in an easy and understandable way in order to be easily adopted by the farmers. Guidance on soil and leaf sampling, analysis and fertility assess in relation to pistachio trees needs are provided together with detailed description of nutrients application at field. Specific instructions for fertilization scenario for young trees, for mature trees, as well as for the appropriate practices before tree establishment.

Some recommendations for pistachios cultivation, and not only…

- Periodic nationwide soil sampling and analyses to update the soil nutrient requirements and thematic maps in Pistachio orchards for the various regions in the country are necessary. Farmers shall be engaged in this action and encouraged and motivated through gaining site specific fertilizer recommendations
- Agroecological characteristics for pistachio orchards could be categorized and stored in a database which can be linked to GIS, as it is anticipated that agroecological characteristics will be utilized for policymaking. This will provide valuable information to farmers and agronomists, while it will extensively contribute to policymaking in order to define the suitable areas for producing pistachio
- Composting and/or reuse of available bio-waste and crop residues (prunings, hulls and shells) at orchard level is a feasible and low-cost approach to minimize extensive use of chemical fertilizers.
- Updated fertilizer recommendations shall be provided to fertilizer sector for improving fertilizer technology
- Better education and instructions for the members of the extension service and the local farmers will improve the fertilizer use efficiently. Education for training and improving professional skills of agronomists (e.g. distance learning courses) could be used for such trainings.
- Farmers should attend field day seminars organized by extension services and sectors of agronomical institutes/universities.
- Extension services should provide farmers templates to promote documentation of implemented practices that will assist assessment of soil sustainably, as well as definition of areas where improvements might be possible. It may include a) basic knowledge of soil properties, b) soil management practices, and c) nutrient management
- Qualified agronomists and/or agronomical institutes should advise on irrigation scheduling and estimating of the leaching requirement for
- maintaining soil salinity at acceptable levels (in case of irrigation with saline waters)
- Adding value to green water management: Support localized storage of rainfall water for a more sustainable agricultural water management

- Policy makers should pay attention to farmer's supply response for crops whose production is "aggressive" to environment. On the other hand, policy makers need to assess any possible negative impact of fertilizer reduction on farm incomes
- Policy makers should determine the appropriate strategies to enhance pistachio exports based on analyzing environmental threats due to inappropriate cultivation practices. as well as domestic weaknesses and strengths and opportunities and drawing SWOT matrix

By Konstantinos Komnitsas and George Bartzas

Chapter 2: Environmental footprint of pistachio cultivation

Briefly…

The chapter evaluates the environmental footprint of Pistacia vera L. cultivation under different cultivation practices applied and waste management methods developed during the AgroStrat project. In this context, a holistic Life Cycle Analysis (LCA) in terms of raw materials consumption, energy use, transportation and greenhouse gas (GHG) emissions was carried out for all processes considered in accordance with the "cradle to gate" approach. Critical processes that are energy intensive and cause most environmental impacts were identified and alternative cultivation practices and modern waste management options, applicable at farm level, were fully analyzed, discussed and valorized. Finally, viable actions for eco-improvement were suggested based on measures that promote energy conservation and minimization of GHG emissions, as well as local acquisition of raw materials

For the first time,

the environmental footprint of pistachio production in Greece and worldwide, was assessed through a detailed life cycle analysis using mostly primary data obtained from local surveys in AgroStrat pilot area, i.e. Aegina island.

Five environmental impact categories as well as one indicator concerning energy use were assessed to

(i) identify the cultivation activities, which cause the highest impacts during the production of 1 ton of dry in-shell pistachios, and

(ii) explore more environmentally friendly management practices at farm scale.

Results and Recommendations

Analysis revealed that the environmental impacts associated with the current production of pistachios in Aegina are mainly due to:

- the life cycle phases of fertilizers production,
- irrigation system and
- cultivation operations

Therefore, AgroStrat proposes:

- Measures for efficient use of irrigation water and chemical fertilizers along with the promotion of recycling of agricultural wastes and the use of renewable sources of energy.
- Promotion of compost and biochar use for partially replacement of chemical fertilizers
- Support of pistachio farmers for adaptation of good cultivation and waste management practices using ad-hoc expert groups of agronomists, experts/scientists and representatives of the official authorities.
- Improvement of collaboration between farmers and other stakeholders for the design, development and implementation of environmental plans, policies and legislation.
- Use of eco-friendly farming practices for GHG mitigation, energy conservation and efficiency improvement, promotion of local acquisition of raw materials, risk reduction and proper waste management.
- Continuesly monitoring and reporting of the environmental status of pistachio production using measurable and reliable indicators that will enable efficient decision making.
- Development and implementation of educational and training programmes, in the form of seminars, workshops and distant learing courses to raise awareness of farmers and other interested stakeholders on environmental problems and adoption of good cultivation and zero-waste practices in the frame of circular economy.

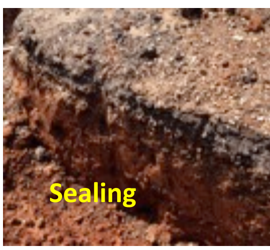
Chapter 3: Addressing Soil Threats

Briefly...

The chapter begins with the theoretical basis of soil degradation and the parameters that accelerate desertification. Findings and assessment of pilot area soil data are also discussed. Finally, technical and scientific measures in a form of a strategy to mitigate degradation and desertification and to promote sustainable land use are provided and explained.

Soil degradation is a very slow process that may occur many years without giving obvious consequences or with consequences that may be easily underestimated (e.g. reduced fertility, need of more intense fertilization), but when at the last stage then degradation is non-reversible

Desertification is *land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities*



Soil Threats

- Erosion
- Decline in organic matter
- Contamination
- Sealing
- Compaction
- Decline in biodiversity Salinization and Sodification
- Floods
- Landslides

Management practices should be implemented aiming to improve and protect soil sustainability, as for example :

- Activities for restoring soil functions
- Practices to improve ecosystem services
- Activities that restore and enhance soil chemical and physical fertility
- Soil conservation techniques mainly in sloping areas
- Activities that Increase and maintain soil cover, if possible throughout the year

Some measures ...

Planning ecological focus areas, strip crop rotation along the contour lines, annual crops should alternate with legumes, simultaneous cultivation of different crops on the same land unit, use of winter crops, minimum or no tillage, if ploughing then along the contour lines, sustainable management of weeds and pests, no residues burning, all areas, presenting a high slope should be ascribed to stock raising with controlled grazing, no heavy machinery in slopping land, crop rotations and intercropping, limitation of stored soil water evaporation through mulching, implementation of cultivation practices that reduce water losses and increase stored soil water, increase soil organic matter by recycling organic materials on soils, soil washing to reduce salts content in case of using irrigation water with salt content.

In Europe, an estimated 115 million hectares are subject to water erosion and 42 million hectares are affected by wind erosion.

Chapter 4: Development of soil thematic maps-Definition of soil indicators

Briefly…

A methodological approach is presented in order to assist stakeholders and policy makers to develop maps for land suitability to accept waste using as example the case of agricultural waste and specifically pistachio waste. The theoretical background used for the development of the evaluation system was that of FAO which conformed to the particularities of pistachio waste landspreading. Drainage; slope; soil depth; infiltration rate; erosion level; on-site waste management (i.e. parameter that considers drainage, clay content, depth and surface gravel); salinity; exchangeable sodium percentage and cation exchange capacity were considered in order to classify land/soil of the pilot area into the five suitability classes of FAO evaluation system. An additional set of soil indicators which are parameters that are mostly affected by the disposal of pistachio waste were also considered for the categorization of soils into suitability classes. Finally, GIS land suitability maps were produced while details on how the interested stakeholders can develop such maps are provided.

Soil Indicators, what are they and how can be exploited for soil monitoring

An indicator may be easy to measure and summarize in shorthand the effects of complex processes that are more difficult to measure or observe. Its purpose is to show how well or bad a system is working. If there is a problem, an indicator is useful in determining what direction to take to address the issue.

Indicators should be useful to: (a) determine the condition of, and change in, the environment in relation to society and the development process; (b) diagnose the actual causes and effects of existing problems that have been detected, in order to elaborate responses and actions, and (c) predict future impacts of human activities on the environment and society to determine future and/or alternative strategies and policies.

Soil quality/degradation indicators are usually classified as physical, chemical, and biological.
Physical indicators include: soil texture, depth of soil, topsoil and rooting, bulk density, infiltration rate, and water retention characteristics.
As **chemical indicators** could be used many chemically measured soil parameters, such as: organic matter, nitrogen, pH, electrical conductivity , phosphorus, potassium, etc.
The basic **biological indicators** are: microbial biomass, carbon and nitrogen content, potentially mineralizable nitrogen, soil respiration, water content and soil temperature.

The identification of soil indicators are case-specific, since the soil parameters that will be selected are different for the different studied systems. **For example,**

Soil Indicators for pistachio trees cultivation and waste disposal on soil (defined during Agrostrat)

- Electrical conductivity
- Organic matter
- Total nitrogen
- Available phosphorus
- Exchangeable potassium
- Available copper
- Available zinc
- Total polyphenols

Soil Indicators for olive mills waste disposal on soil (defined during LIFE PROSODOL)

- Electrical conductivity
- Organic matter
- pH
- Total nitrogen
- Available phosphorus
- Exchangeable potassium
- Available iron
- Total polyphenols

Table 1 Proposed indicators and the respective thresholds for pistachio waste disposal areas

Soil Indicator	Low	Normal	High	Very high	Excessive
Electrical Conductivity, mS/cm	<2	2-4	4-8	>8	
Total nitrogen, %	<0.1	0.1-0.3	>0.3		
Available phosphorus, mg/kg	<10	10-28	28-40	40-59	>59
Exchang. Potassium, cmol/kg	<0.26	0.26-1.2	1.2-2.0	>2.0	>2.0
Available copper, mg/kg	<0.8	0.8-3.0	3.0-20	>20	
Available zinc, mg/kg	<2,9	2.9-8.1	8.1-13	>13	
Total polyphenols	<50			>50	

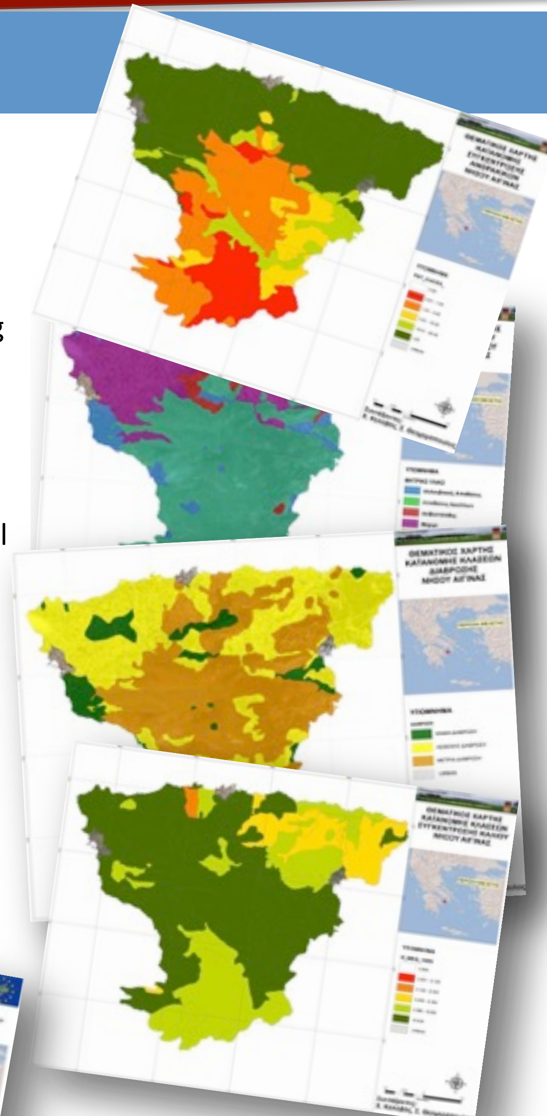
Steps for the identification of soil indicators

1. Identification of background levels of key soil parameters of the area of interest. For this, an initial regional soil survey should be performed. Soil sampling should take place at three depth increments (0-30 cm, 30-60 cm and 60-90cm) in order to define the current situation in representative, benchmark soils of the area. Emphasis should be given to identify control soils i.e. soils that have never accepted waste as well areas, where have been disposed for long time. By considering also legislative restrictions and literature data, a list of thresholds for soil parameters (through statistical processing) can be established, which will be the most appropriate for the specific region.
2. Definition of the soil parameters that are most likely to be affected by waste reuse/disposal. These parameters can be used as indicators for soil quality monitoring. This, however, requires the collection of additional soil data from areas that already accept waste. Soil sampling from these areas should be performed every 2-3 months for almost one or two years in order to ensure that all activities, which could have a detrimental effect on soil parameters will be recorded and assessed. Changes in soil quality can be assessed by measuring the soil indicators and comparing them with critical limits or thresholds at different time intervals, for a specific use in a selected area-system.

Consider that…

If such a methodological study could not be performed, then it is recommended to identify the most appropriate soil parameters by assessing quality parameters of the surrounding area and start monitor them over time.
Some common and sensitive soil parameters can be used in this case, as for example, soil pH, electrical conductivity, polyphenols, total organic carbon, nitrogen, phosphorus, zinc and copper.

Soil Thematic Maps-Land Suitability Maps



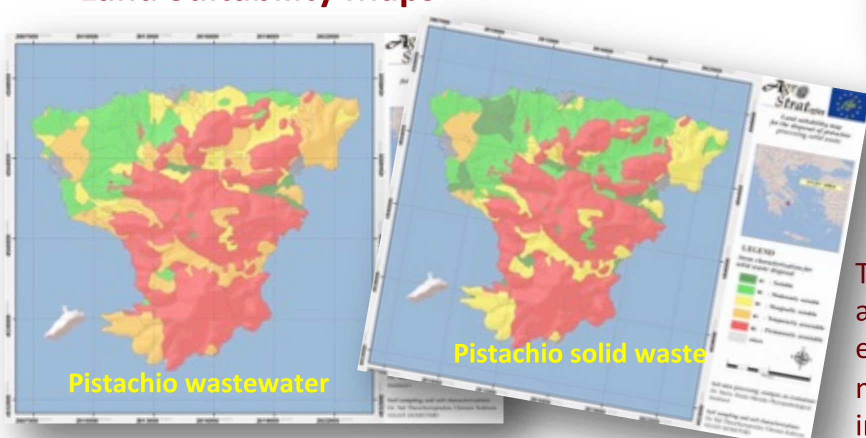
AgroStrat developed a system for assessing soil quality as regard physical and chemical properties and an evaluation system for land suitability for waste distribution or reuse for nutrients valorization.

After a two years soil characterization, sampling and analyzing campaign, and by using Aegina island as pilot area, a series of GIS soil thematic maps were developed for soil depth, texture, nutrients content, erosion risk and others.

Thereafter, soil properties and areas characteristics were evaluated according to FAO land evaluation system. The GIS soil thematic maps were also exploited in order to develop Land Suitability Maps for agricultural waste distribution on soil, considering also legislative restrictions.

Land was categorized according to the suitability for pistachio waste (solid and wastewater) into four classes, i.e. highly suitable (S1), moderately suitable (S2), marginally suitable (S3), currently not suitable (N1) and not suitable (N2).

Land Suitability Maps



The methodology can be used also for any type of organic material. For example, by implementing AgroStrat methodology and considering the soil indicators for olive mill waste derived from LIFE PROSODOL project, the respective Land Suitability Maps for olive mill landspreading can be derived.

By using these maps it is now possible for policy makers and other stakeholders to know which areas are suitable for waste disposal or recycling on cultivated land, and also to calculate the appropriate dose of these materials taking into account soil chemical composition (from the thematic maps), the thresholds of soil indicators that should not be exceeded and also legislative restrictions.

Chapter 5: Pistachio waste management

Briefly…

In the beginning, the chapter deals with nowadays management and use of pistachio wastes as these practices were recorded at the pilot area by the beginning of the project. After summarizing the main restriction and the guidelines of the European legislative framework and considering the results obtained by the experimentations during the project, the chapter provides knowledge regarding the impacts on soil of the uncontrolled disposal or reuse of agricultural wastes. Instructions for exploitation of pistachio waste to produce compost by implementing the methodology developed by Agrostrat (i.e. with the addition of the natural zeolite clinoptilolite) are provided, as well as low cost and easy to implement practices for waste management at field. Finally, instructions are given for the calculation of the appropriate waste amount to be distributed on soil.

Pistachio waste

Worldwide, pistachios harvest normally begins in late August and may continue through late October. In Greece, pistachios are harvested between late August and early September and the pistachios are harvested mainly by hand. In other areas with larger produced amounts, e.g. in California, pistachios are mechanically harvested.

The nuts after harvest are transported to the processing facility where they are dehulled, and dried.

Apart from the mechanical processing, water is used also during dehulling. From this process, the main waste stream is produced, which apart from hulls contains also pistachios, shells and water.

On average, $2m^3/h$ of water are required for 1 tn fresh nuts during dehulling, while almost 1tn of nuts can be processed within an hour. Therefore, if we consider 40 tn of fresh nuts as mean farm production, the anticipated water consumption is almost $80m^3$. For the entire Aegina island it is estimated that for an average production of 1,500 tn of fresh nuts, almost 3,200 tn of water are used during dehulling. Moreover, considering that an average of 35-50% of the fresh nuts' weight will be recharged as waste, then one can estimate that almost 600 tn of hulls are produced, which in addition to the 3,200 tn of water, make an overall of almost 3,800 tn of sludge.

IMPORTANT INFORMATION: Farmers were informed that before any action or waste application on soil, the authorized competent authority must be informed and provide the appropriate permission.

Table 2 Composition of solid pistachio wastes collected from different producers from Aegina island.

Parameter	Average value	Parameter	Average value
Organic matter, %	79	Total Cu, mg kg^{-1}	106
Total N, %	2.5	Total Fe, %	0.58
Moisture, %	60	Total Zn, mg kg^{-1}	99
pH	7.44	Total Mn, mg kg^{-1}	85
EC, mS/cm	3.8	Total B, %	0.13
Total Polyphenols, g kg^{-1}	4.5	Cl^-, mg kg^{-1}	4,900
Total K, % (as K_2O)	2.9	NO_3^-, mg kg^{-1}	1,200
Total P, % (as P_2O_5)	1.0	PO_4^{3-}, mg kg^{-1}	50
Total Ca, % (as CaO)	5.5	SO_4^{2-}, mg kg^{-1}	354
Total Mg, % (as MgO)	0.68	NH_4^+, mg kg^{-1}	308
Total Na, %	0.69		

Table 3 Chemical parameters of pistachio wastewater collected from different producers from Aegina island.

Parameter	Average value	Parameter	Average value
pH	5.68	Total Fe, mg L^{-1}	0.49
EC, mS/cm	6.1	Total Zn, mg L^{-1}	1.25
Polyphenols, mg L^{-1}	1,500	Total Mn, mg L^{-1}	0.68
K, mg L^{-1}	1,050	Total B, mg L^{-1}	0.062
P, mg L^{-1}	38	NH_4^+, mg kg^{-1}	60
Ca, % (w/v)	0.04	Cl^-, mg L^{-1}	710
Mg, % (w/v)	0.02	NO_3^-, mg L^{-1}	5.0
Na, mg L^{-1}	347	PO_4^{3-}, mg L^{-1}	52
Cu, mg L^{-1}	0.13	SO_4^{2-}, mg L^{-1}	135

What happens to waste generated from pistachios processing?

So far little is known regarding the fate of pistachio's waste in Greece and in other Mediterranean countries. Moreover, international scientific literature is rather poor, especially in issues regarding the management of pistachio waste.

In the framework of the LIFE AgroStrat project, the beneficiaries contacted producers from Aegina island and other Greek areas in order to collect data and information regarding management of pistachio waste.

According to farmers' description and to visits at wastes disposal areas, wastewater is either disposed on soil, mainly where pistachio trees or vegetables are cultivated, or is disposed in wells and streams.

Solid wastes are sometimes left to be naturally composted and further used as supplement to fertilizers or are disposed untreated on soil or in streams.

In other Greek areas, disposal lagoons are used for the disposal of both wastewater and hulls, however these are poorly constructed (i.e. simple soil excavation without using protective materials to prevent leaching) and of high depth (up to 5 m) that, apart from adverse impacts on soil quality, inhibit the evaporation process.

AgroStrat proposed to farmers to manage pistachio wastes at their field, and stop disposing on soils or discharging in water bodies.

Two practical methodologies, a temporary and a permanent were proposed to farmers, that can be implemented at their field level to manage pistachio waste.

Waste Management at field

Simple waste management systems were developed and implemented at two pilot fields in Aegina island. The first one by constructing three shallow evaporation ponds and the second one by building four sequential wastewater collection reservoirs.

The systems aim to assist separation of pistachio waste into solid waste and wastewater at field.

Shallow evaporation ponds

Wastes are separated into solid and wastewater immediately after their production by using a simple separation equipment. The solid part is composted while wastewater is collected into three shallow ponds and left to evaporate. The ponds can be permanent or temporary. Protective media (geotextiles) must be used to prevent infiltration of wastewater into soil.

Sequential Collection Reservoirs

The system was constructed by exploiting a former, almost destroyed, pig breeding area.

In the case of the sequential system, wastes are not separated after production. Instead, they are collected into the five reservoirs. The solid part is left to precipitate and then used for composting. Wastewater is left to evaporate.

The five stall places were reconstructed to form a sequential system of five reservoirs for waste collection.

Composting pistachio waste

Composting pistachio wastes and reuse for agricultural purpose is a challenging issue, as this matter has not been extensively studied so far, especially as regards the development of specific methodology to address the very high electrical conductivity of the waste and, consequently, of the produced compost. AgroStrat developed a methodology for composting pistachio wastes by using clinoptilolite as additive (a natural zeolite) mainly in order to address the high salinity of pistachio wastes.

Compost composition: The AgroStrat compost is rich in nutrients and meet the EU standards for ECO labeled composts

Table 4 Proposed indicators and the respective thresholds for pistachio waste disposal areas

Parameter	Ordinary Compost without zeolite	Agrostrat Compost With zeolite	Threshold
Organic matter, %	34.4	27.8	16-38 (field application) > 19.4 (nursery application)
Total N, %	3.2	4.3	> 2
C/N	11	6.5	< 15
Moisture, %	48	58	40 - 50
pH	8.10	7.90	7.2 - 8.5
EC, mS/cm	6.3	2.6	< 4.0
Polyphenols, g kg^{-1}	0.24	0.34	In soil < 40 mg kg^{-1}
Total K, % (as K_2O)	1.1	1.6	0.5-1.8
Total P, % (as P_2O_5)	0.53	0.81	0.5-2.8
Total Ca, % (as CaO)	12	12	> 2.0
Total Mg, % (as MgO)	1.3	1.2	0.3-3
Total Na, %	0.28	0.35	< 2.0*
Total Cu, mg kg^{-1}	100	20	Table 5
Total Fe, mg kg^{-1}	1340	3,545	
Total Zn, mg kg^{-1}	122	139	Table 5
Total Mn, mg kg^{-1}	119	199	
Total As, mg kg^{-1}	1.3	2.7	Table 5
Total Cd, mg kg^{-1}	0.23	0.25	Table 5
Total Pb, mg kg^{-1}	11	18	Table 5
Total Ni, mg kg^{-1}	1.4	1.7	Table 5
Total B, %	0.04	0.04	
Cl^-, mg kg^{-1} (in mg L^{-1})	3,850 (385)	2,350 (235)	 < 500 mg L^{-1} (in water extract)#
NO_3^-, mg kg^{-1} (in mg L^{-1})	10,500 (1050)	5,800 (580)	 < 1000 mg L^{-1} (in water extract)#
PO_4^{3-}, mg kg^{-1}	660	795	
SO_4^{2-}, mg kg^{-1}	1,800	245	
NH_4^+, mg kg^{-1} (in mg L^{-1})	40 (4)	60 (6)	< 300 FW (Switzerland limit) Lower than 50 mg L^{-1}(in water extract)#
NH_4^+/ NO_3^-	0.004	0.01	

Table 5 Concentration range of heavy metals for the final product of the composting process within EU and European pistachio producing countries and the metals concentration

Metal	Range within EU	Greece	Italy	Spain (Class AA)	EU ECO Label
	mg kg^{-1}				
Zn	210-4,000	2,000	1,000	400	300
Cu	70-600	500	300	300	100
Ni	20-200	200	100	100	50
Cd	0.7-10	10	3	2	1.0
Cr_{tot}	70-200	510	-	250	100
Cr_{VI}		10	3	-	-
Pb	70-1,000	500	280	150	100
As	10-25	15	-	-	10
Hg	0.7-10	5	3	2	1

By Maria K Doula

Irrigation – Fresh water vs Wastewater from pistachio processing

Reuse of wastewater for irrigation is a challenging topic that has been extensively studied by many researchers worldwide, mainly as regards the reuse of treated municipal wastewater. Another type of wastewater that has been considered for irrigation is olive mill wastewater. Without doubt the reuse of wastewaters in agriculture may provide benefits, as for example conservation of fresh water, but it can also cause adverse effects to soil quality, underground water, and also to human and animal health, if no stringent measures for safe use are not taken.

The comparison between irrigation water from drillings/well, which is used by many farmers and the wastewater from pistachio processing, showed that although both are unacceptable for irrigation, thus, pistachio wastewater seems to be less harmful than the water from drillings. Both samples have low risk for soil permeability hazard, while the mean value for electrical conductivity and total hardness are almost the same for both effluents. The concentration of chlorides in wastewater is the one-third of that in irrigation water, however, very restricted factors for pistachio wastewater are the low pH and the very high polyphenols content.

In Aegina farmers use drilling water to irrigate pistachio trees. The water is of bad quality and has very high concentration of chlorides, sodium and extremely high electrical conductivity. As a result, soil electrical conductivity was increased significantly. Salts are concentrated on soil surface but mainly at higher depths, where values as high as 10-12 mS/cm were measured.

Results for soil electrical conductivity from twelve pistachio orchards in Aegina island.
Almost all exceed the threshold of 4mS/cm and many even the threshold of 8mS/cm for degraded soils. Green columns illustrate the electrical conductivity of soils collected from non-cultivated areas.

Irrigation water that contains certain ions at concentrations above threshold values can cause plant toxicity problems. Toxicity normally results in impaired growth, reduced yield, changes in the morphology of the plant and even its death. The degree of damage depends on the crop, its stage of growth, the concentration of the toxic ion, climate and soil conditions.
The most common phytotoxic ions that may be present in municipal sewage and other wastewater types in concentrations such as to cause toxicity are: boron (B), chloride (Cl) and sodium (Na). Heavy metals are also a significant threat for soil, cultivated plants and, in turn, human and animals health.

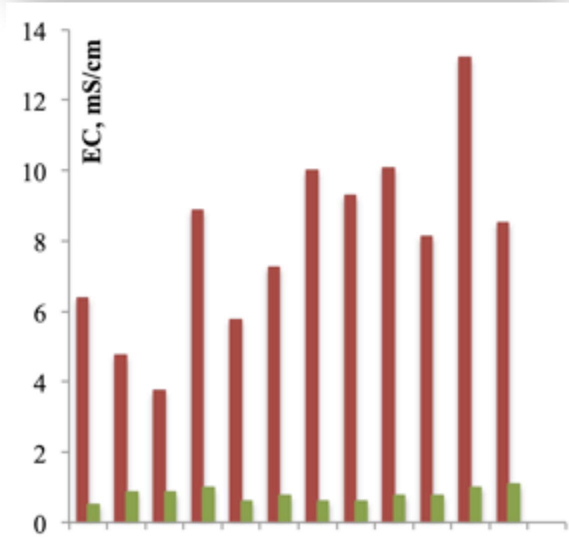


Table 6 Mean values and the respective evaluation for irrigation use of drilling and well water parameters measured, between 2013 and 2014 in Aegina island.

Parameter	Mean value	Evaluation
pH	7.14	Within normal range
Electrical Conductivity, dS/m	6.08	High hazard. The water is unacceptable for irrigation, except for very salt-tolerant plants where there is excellent drainage, frequent leaching an intensive management. The risk for soil salinity is very high.
Total hardness, ppm $CaCO_3$	1,979	Unacceptable high hardness
HCO_3^{2-}, meq/l	4.7	Slight to moderate restriction on use
Cl^-, mg/l	2,118	Chlorides concentration is very high and can cause severe damages to plants
$N\text{-}NO_3^-$, mg/l	12	Slight to moderate restriction on use
SAR	8.8	Low risk for sodium hazard
RSC, meq/l	-34	The residual sodium carbonate is low. No calcium deposition and infiltration decrease problems are anticipated
LDP, meq/l	4.7	Very high risk for lime deposition on leaves, fruits and trees roots.

Table 7 Mean values and the respective evaluation for irrigation use of wastewater originated by pistachios processing

Parameter	Mean value	Evaluation
pH	5.68	Very low, out of the normal range
Electrical Conductivity, dS/m	6.10	High hazard. The water is unacceptable for irrigation, except for very salt-tolerant plants where there is excellent drainage, frequent leaching an intensive management. The risk for soil salinity is very high.
Total hardness, ppm $CaCO_3$	1,820	Unacceptable high hardness
HCO_3^{2-}, mg/l	1.1	None restriction on use
Cl^-, mg/l	710	Chlorides concentration is very high and can cause severe damages to plants
$N\text{-}NO_3^-$, mg/l	1.1	None restriction on use
SAR	3.5	Low risk for sodium hazard
RSC, meq/l	-35	The residual sodium carbonate is low. No calcium deposition and infiltration decrease problems are anticipated
LDP, meq/l	1.1	No risk for lime deposition on leaves, fruits and trees roots

1: SAR: $\frac{(Na\frac{meq}{l})}{\sqrt{0{,}5\ x\ [(Ca\frac{meq}{l})+(Mg\frac{meq}{l})}}$, 2: RSC (meq/l): =$(HCO_3^{2-})+(CO_3^{2-})-(Ca^{2+})-(Mg^{2+})$

3: LDP (meq/l) is the lower between the two sums (a) $(HCO_3^-)+(CO_3^{2-})$, or (b) $(Ca^{2+})+(Mg^{2+})$

Estimation of waste doses for landspreading

For using pistachio or in general agricultural waste for fertilization purposes, it is strongly recommended to take specific care on maintaining soil quality and avoid polyphenols contamination and nutrients overloading. For this reason, Land Suitability Maps should be always considered in order to identify the appropriate areas for reuse and also the potential restrictions for each one of them. The second important aspect, when fertilization is the final goal, is to ensure nutrients balance, i.e. to calculate the amount of waste to be added by considering soil nutritional status as well as trees nutritional demands.

Waste dose estimation that ensures soil sustainability and economic benefits for farmers

A. Definition of soil, waste and irrigation water parameters

1. Soil fertility parameters should be measured by performing soil analysis. Fourteen soil parameters, at least, should be measured, i.e., texture, pH, electrical conductivity, organic matter, total nitrogen, $N\text{-}NO_3$, $N\text{-}NH_4$, exchangeable potassium and magnesium, available phosphorus, available metals (zinc, iron, copper, manganese) and boron. Apart from these parameters and in order to be in line with legislation, total forms of cadmium, lead, mercury, copper, zinc, chromium, nickel and arsenic should be measured, to ensure that soils of the area contain these heavy metals in concentrations lower than the limits defined by the law and therefore, can accept wastes. Specific care should be taken to design the appropriate sampling strategy, which will ensure that the collected samples are representative of the area and the cultivation practices, and well conserved against temperature, humidity and other environmental factors.

2. History of the area should be known as regards use of organic materials/composts. This is significant in order the residual amounts of organic matter and nitrogen due to past years application to be calculated. Since these materials can release NO_3^- and NH_4^+ for two years, nitrates and ammonium content of the materials distributed in the past two years as well as, the amount of materials distributed should be known.

3. Irrigation water quality should be defined be performing water analysis, especially when water from drillings or wells is used for irrigation. Nutrients that are likely to be found in high concentrations in irrigation water are potassium, nitrates and boron. However, depending on the environmental status of the area, metals, such as iron, could also be found in irrigation water. Therefore, the sampling strategy and the constituents to be measured are depended on the specific local conditions. The amount of irrigation water added annually to the orchard should be defined, as well.

4. Waste to be added should be analyzed for pH, electrical conductivity, moisture, organic matter, total nitrogen, $N\text{-}NO_3$, $N\text{-}NH_4$, potassium, sodium, magnesium, calcium, chlorides, phosphorus, polyphenols, boron, zinc, iron, copper, manganese, cadmium, lead, arsenic, chromium total (and/ or Cr(VI) depending on the legislative restrictions) mercury and nickel. The analysis must be performed annually or prior any landspreading if new materials are going to be used.

Estimation of waste doses for landspreading

B. Ensuring legislation's restrictions fulfillment

Having characterized the soil of the area and wastes to be distributed, the next step is to ensure that the restrictions imposed by the national or the European legislation framework are respected.
For this, the suitability of the waste and the receptor (i.e. the soil) should be assessed in relation to the current Acts ad laws. For this, an extensive evaluation of national legislative framework should be performed in order to assess potential restrictions for landspreading. Therefore, it would be possible to assess if heavy metals content of soil and waste permit waste landspreading
The amount of waste to be distributed on land, in case of heavy metals existence, can be defined by using the following relationship:

$$M\ (\text{Tons of material}) = (C \times L)/K \quad [1]$$

where:
C: Limit values of heavy metals which may be added annually to agricultural land, based on a 10 year average (kg/ha/y);
L: area for disposal in ha;
K: concentration of heavy metals in wastes in mg/kg.

C. Assessing wastes nutritional and general quality status

Wastes for distribution should be assessed as regards their physical and chemical properties. Although such standards are limited in the legislative frameworks to only some parameters, e.g. pH, electrical conductivity, C/N ratio and others, and also are different among the European countries, literature data can provide thresholds and range of values that can be used to assess if a material is of the appropriate quality level and nutritional status to be distributed without risk to cause environmental hazards.

Raw solid pistachio waste

D. Definition of trees' nutritional needs

The nutritional needs of the cultivated trees are depended on many factors, such as age of the trees, soil quality, local climatic conditions, and water quality. In any case, the local responsible agronomist may provide information to the farmers for the amounts of the different nutrients that are required considering, however, the results of the soil chemical analysis. In addition, there are many different software available in the market which calculate the kg of each nutrient that is required to be applied per unit area.

Estimation of waste doses for landspreading

D. Calculation of waste amount to be applied on soil (Doula et al.,2017).

Calculation for fertilization purposes

Considering the needed amount per unit area of each nutrient, the amount of waste that is theoretically needed to fulfill each nutrient need can be calculated. The process for calculating the appropriate waste amount is as in the following:

- Estimation of maximum permissible amount (= M) according to the legislative framework in force (Eq. [1])
- Setting yield targets for the season or/and for longer period
- Calculation of the nutrients amount to be supplied in order to achieve the defined targets, considering also the concentration of the nutrients in soil.
- Calculation of the waste amount that is theoretically needed to fulfill each nutrient requirement.
- The calculation is repeated for each one of the nutrients (e.g. N, P, K). The amount for distribution is the lowest among these (=L).
  - ✓ **For Nitrogen** the following relationship should be used to calculate the Available Nitrogen to plants (N_{avail}):

$$N_{avail} = (NO_3\text{-}N) + K_{vol}\,(NH_4\text{-}N) + K_{min}\,(\text{Organic N}) \qquad [2]$$

    where

    K_{vol} is the rate of NH_4-N that is not released to the atmosphere as NH_3. For surface disposal this is 0,7 (i.e. 70% of NH_4-N remains in soil). If waste is incorporated into soil then K_{vol}=1.

    K_{min} is the mineralization factor for organic nitrogen, i.e. how much of the organic nitrogen will be available to plants. For the first year after application K_{min}=0.2, for the second K_{min}=0.10 and for the third K_{min}=0.05.
  - ✓ **For the calculation of phosphorus** it has to be considered that 50% of the phosphorus is available to plants, **while potassium** is 100% available.
- If the nutrients-calculated amount (=L) is lower than the metals'-calculated amount (=M), then L is the amount that can be spread on soil. Otherwise, the optimum amount is the one calculated according to the legislation (=M).
- After selection between L and M amounts, then all nutrients contained in the selected waste amount should be recalculated and compared to trees nutritional needs. If any of the nutrients is not covered by this waste amount, then mineral fertilizers are applied, in application rates according to the defined nutrients needs.

Calculation for waste amount for using as soil improver or just disposal

- Calculation of the optimum waste amount by considering soil indicators, as described previously.
- The optimum waste amount is the one that ensures that the upper thresholds of the soil indicators will not be exceeded.
- Calculation of the maximum waste amount that is required to increase each soil indicator up to its threshold.
- Between all these calculated amounts (for each soil indicator), the lowest one is selected and compared to the amount *M* derived from the legislation. Among these two, the lowest is the optimum amount to be applied on soil.

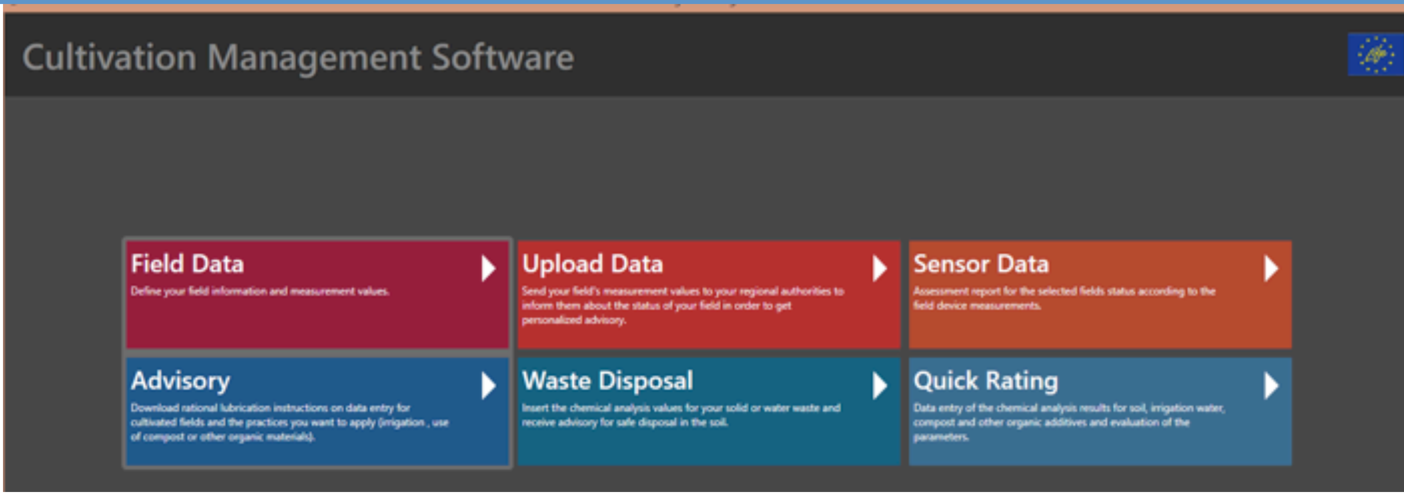
Doula, M.K., Kouloumbis, P., Sarris, A., Hliaoutakis, A., Papadopoulos, N.S., Kydonakis, A. 2017. "Reuse of Sewage Sludge on Soil: Terms, Preconditions and Monitoring", In: Municipal Solid Waste: Management Strategies, Challenges and Future Directions, Tzortzakis, N. (Ed.), NOVA SCIENCE, Chapter 13.

Chapter 6: The decision-making tools of AgroStrat

Briefly…

This chapter presents the tools that were developed during AgroStrat project to assist farmers and policy makers in implementing the IMaS and especially information provided in chapters 1 and 5. Thematic maps and land suitability maps of chapters 3 and 4 were incorporated into these decision-making tools. These tools are (1) the Cultivation Management Software, and (2) the Central Management and Monitoring tool Moreover, a field device was designed and developed to assist farmers in monitoring periodically soil pH, electrical conductivity and moisture content.

The Cultivation Management Software



The project developed a software that can be used in the entire Mediterranean region and promotes sustainable agricultural practices for *Pistachia vera* L. cultivation but also to other cultivations.
The software provides consultancy on:

- Quality of soil, irrigation water, composts and waste
- Mineral fertilization in combination with organic materials
- Use of composts and wastes for fertilization
- Use of composts for soil improvement

Evaluation

By inserting results of the chemical analysis, the software provides a fast evaluation of the quality of soil, irrigation water, composts or organic wastes.

Consultancy

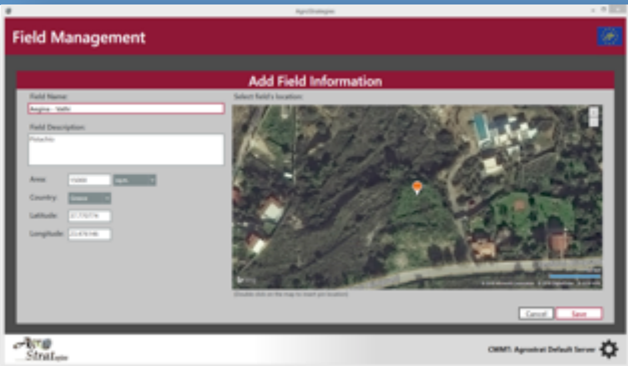
The end-user indicates the exact position of the cultivated field of interest by inserting field coordinates or by finding the field on Google Earth. In case of Aegina island, the software considers the results of the chemical analysis of soil, water and composts provided by the user and in case of missing soil properties, data from the thematic maps are automatically inserted. Fertilization consultancy and sustainable use of composts and organic waste are provided. For other areas, the software considers the results of the chemical analysis.

Connection with the Regional Authority

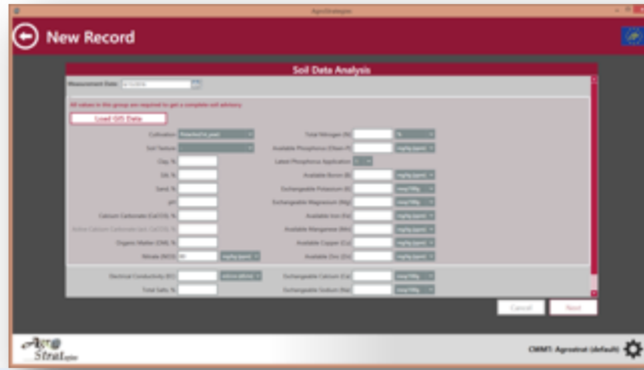
This unique software feature connects farmers with the Regional Authority via Internet. The farmers may receive additional consultancy by the scientists of the Authority. It also supports networking between farmers, authorities and citizens.

By Angelos Hliaoutakis, Nikos S. Papadopoulos, Aris Kydonakis, Maria K Doula and Apostolos Sarris

The Cultivation Management Software



The user identifies the field of interest by inserting the coordinates or by searching the relevant map



To receive concultancy on fertilization and use of organic materials, farmers input the results of the chemical analysis for soil and organic materials. If there is a chemical analysis for irrigation water, then the results can be also inserted in order to be considered for the development of the fertilization scenario.

By choosing "REPORT", the software provides evaluation of the data inserted by the user. The evaluation includes texts with explanations, descriptions, as well as an easy understandable chromatic scale to facilitate the evaluation of soil, water and waste "at a glance".

For the consultancy, the Software uses also data from soil thematic GIS maps an Land Suitability Maps. The overall scope is to propose a fertilization scenario by taking into account the most of the soil parameters and therefore, to ensure sustainable use of mineral fertilizers and soil amendments.

Field data and fertilization proposals are saved and can be retrieved for future use. A specific application uses the stored data and permits the periodical monitoring of soil parameters' change, providing early warning of potential soil degradation risk

The Software of AgroStrat

A Dynamic Decision-Making Tool for the entire Mediterranean region

Because…

- after slight modifications, the software can provide consultancy for other cultivation types, in addition to pistachio trees
- the software allows the incorporation of soil thematic maps of other areas in Greece and in other countries, providing therefore the potential to be fully exploited for farmers consultancy throughout the Mediterranean region and Europe.
- not only agricultural waste, but many different waste types can be considered for landspreading evaluation, taking into account national and European legislative frameworks.

By Angelos Hliaoutakis, Nikos S. Papadopoulos, Aris Kydonakis, Maria K Doula and Apostolos Sarris

Use of organic materials and wastes in cultivation

The Software includes also a specific application that provides evaluation of the suitability of an area to accept waste, ensuring safe disposal of pistachio dehulling waste (solid and wastewater). The results of the waste's chemical analysis are inserted in the software.
Different types of organic materials can be inserted, as for example, pistachio waste, olive mill waste, manures, a.o.
As a first step, the software evaluates the appropriateness of the material for soil disposal, considering the European and the national legislative frameworks.
If landspreading is permitted, then the appropriate amount is calculated considering soil nutritional status, irrigation water quality and trees needs, following the methodology as described previously.
Detailed instructions are provided to the user on how to use and apply the materials in combination with mineral fertilizers.

Note: The terms "organic materials", "wastes" and "agricultural wastes" that are mentioned and evaluated by using the CMS and the CMMT of Agrostrat, mean all the types of materials, high in organic matter, produced by different agricultural and livestock practices and also during plants, crops and nuts processing while they do not include any kind of animal debris or industrial wastes. They are exclusively originated by the agricultural and livestock sectors, as for example pistachio waste, olive mill wastes, manures.

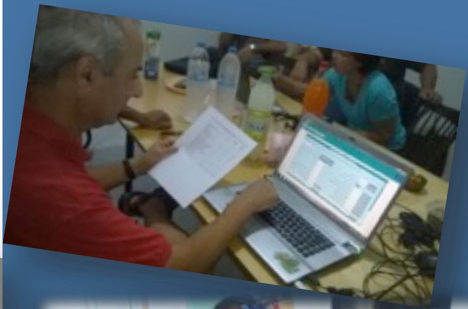
The Cultivation Management Software aims to provide consultancy and by no mean to substitute authorized competent authorities. Therefore, farmers and individuals are informed by specific note on the AgroStrat page and also on the different software page to consult national competent authorities in case of waste disposal on soil.

A special application enables connection via internet between farmers and Centers of Monitoring that can be established by associations, and authorities, collection of soil and cultivation data and mapping of the collected parameters at local or regional level.

Waste landspreading

The Software uses Land Suitability Maps and evaluates areas under interest for their suitability to accept solid waste or wastewater. For the suitable areas, the recommended amount of waste that is allowed to be spread, is calculated considering the level of suitability, soil properties and waste's composition.

Many farmers have been already trained on the use of Cultivation management Software and are able to upload data and get consultancy. Similarly, pistachio and other associations have been informed and trained on the use of software.



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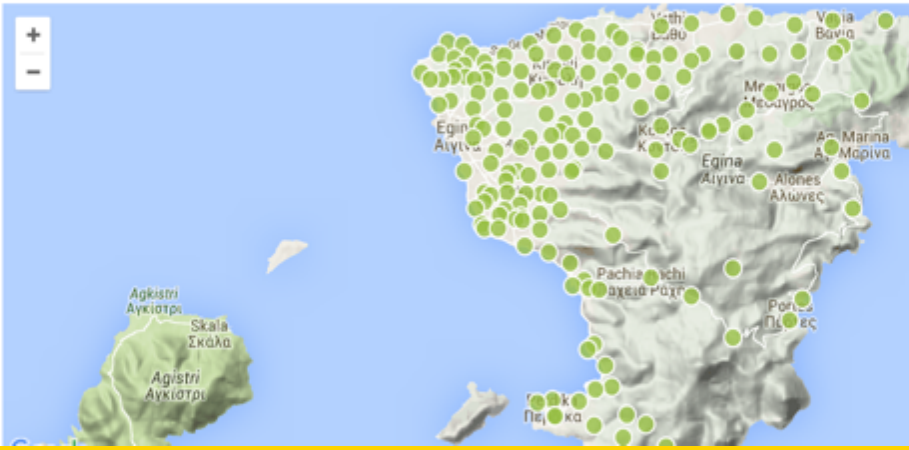
Central Management & Monitoring Tool-CMMT



THE CENTRAL MANAGEMENT MONITORING TOOL (CMMT) OF AGROSTRAT IS A UNIQUE WEB GIS-BASED APPLICATION THAT WILL ASSIST LOCAL AND REGIONAL AUTHORITIES TO MONITOR SOIL QUALITY AND AGRICULTURAL PRACTICES AT LOCAL AND REGIONAL SCALE

Field monitoring, measurement, spatial analysis and visualization

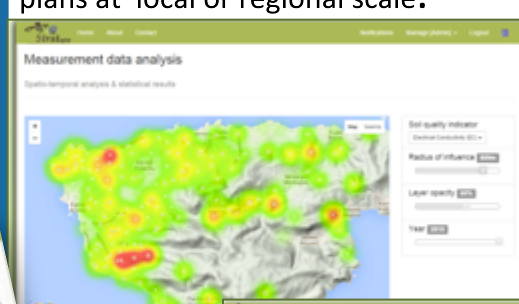
CMMT system is a web app for the management and monitoring of cultivation fields using soil, water and organic waste parameters, integrated within a Geographical Information System (GIS).
The Central Management & Monitoring Tool supports the establishment of a Monitoring Centre, which could be located, for instance, at the premises of a Regional Service/Agency, farmers' association or of a Municipality, and enhances the continuous monitoring of cultivated areas or areas where wastes are disposed.

Connection with the Monitoring Authority

This unique web application provides the option for the farmers to inform the Monitoring Authority for their field and cultivation status by uploading soil, water and wastes analysis on CMMT Server and may receive additional consultancy afterwards by the scientists of the Authority

The cultivated fields or the waste disposal areas are presented on maps. The user may select which soil property wishes to monitor and for which period. The results are presented on the maps, while special features provide the authorities with the potential to screen all data sent by the farmers as well as to assess statistical evaluation of the collected data at regional scale.

The CMMT enhances authorities to screen cultivated areas rapidly, identify potential risky conditions and proceed to detailed monitoring, if necessary. The tool strongly promotes the implementation of resources monitoring at field, municipal or regional scale.
Data can be uploaded by local farmers through the Cultivation Management Software or by the Authorities through the CMMT.
Therefore, the CMMT can collect, store and process soil and cultivation data allowing short and long term evaluation of the agricultural environment as well as, the development of strategies and plans at local or regional scale.



By Angelos Hliaoutakis, Nikos S. Papadopoulos, Aris Kydonakis, Maria K Doula and Apostolos Sarris

Measurement at field by farmers using a small, flexible, "smart" device

In order farmers to be able to monitor the most critical soil parameters, i.e. soil moisture, pH and electrical conductivity, by their own and therefore evaluate the existence of potential problems at field, AgroStrat developed a field equipment that can be used by farmers to measure these parameters easily and rapidly.

The device provides a fast, simple and accurate way for measuring those most critical soil characteristics. The values are stored in an SD stored card along with the coordinates of the point where the measurements were taken, stored by the instrument's integrated GPS.

Data from the SD card can be then transferred to the PC of the farmer and inserted in the Cultivation Management Software and assigned to the specific field.

The software then compares the inserted values with the stored ones and notifies the user for potential problems. The CMS, thanks to a specific application, evaluates the measurements and provides a rapid report regarding these soil parameters, acting, thus, as an early warning system, especially for soil electrical conductivity.

Chapter 7: The ImaS in Eight Steps

Briefly…

The last chapter presents the IMaS in an easy-to-implement way in order to be implemented in different areas and for different local or regional condition and circumstances. To this end, the IMaS is presented as a generic 8-Steps Strategy, based however, on the theoretical basis and also on the Agrostrat results, as described in all previous chapters. Since the IMaS is *an umbrella-scenario*, it is possible to implement only some of the described eight steps to address specific local or regional problems, e.g. soil erosion in Mediterranean islands, or terms and preconditions to apply organic waste on soils, and others. Since waste management is a crucial aspect of the IMaS and considering the different waste types produced in the Mediterranean and in Europe, the 8-Steps Strategy has been developed around the waste type to be managed and considers and develops all other relevant practices, measures and means to be decided, implemented and assessed at rural agricultural areas.

A strategy built around waste management at rural agricultural areas

To build the eight steps, two approaches are considered; one when **hazardous or potential hazardous** waste streams have to be managed; and the other one, when authorities have to consider **non-hazardous/ traditionally used** waste streams in their plans.

Traditionally used wastes (i.e. AW-type1) are applied and used mainly as soil improvers/additives. This category includes mainly solid waste and especially manures (after stabilization or not) and composts, which are traditionally used by farmers for thousands of years. Some types of wastewater of low organic load, as for example water used for washing crops before or during processing, are also included in this category.

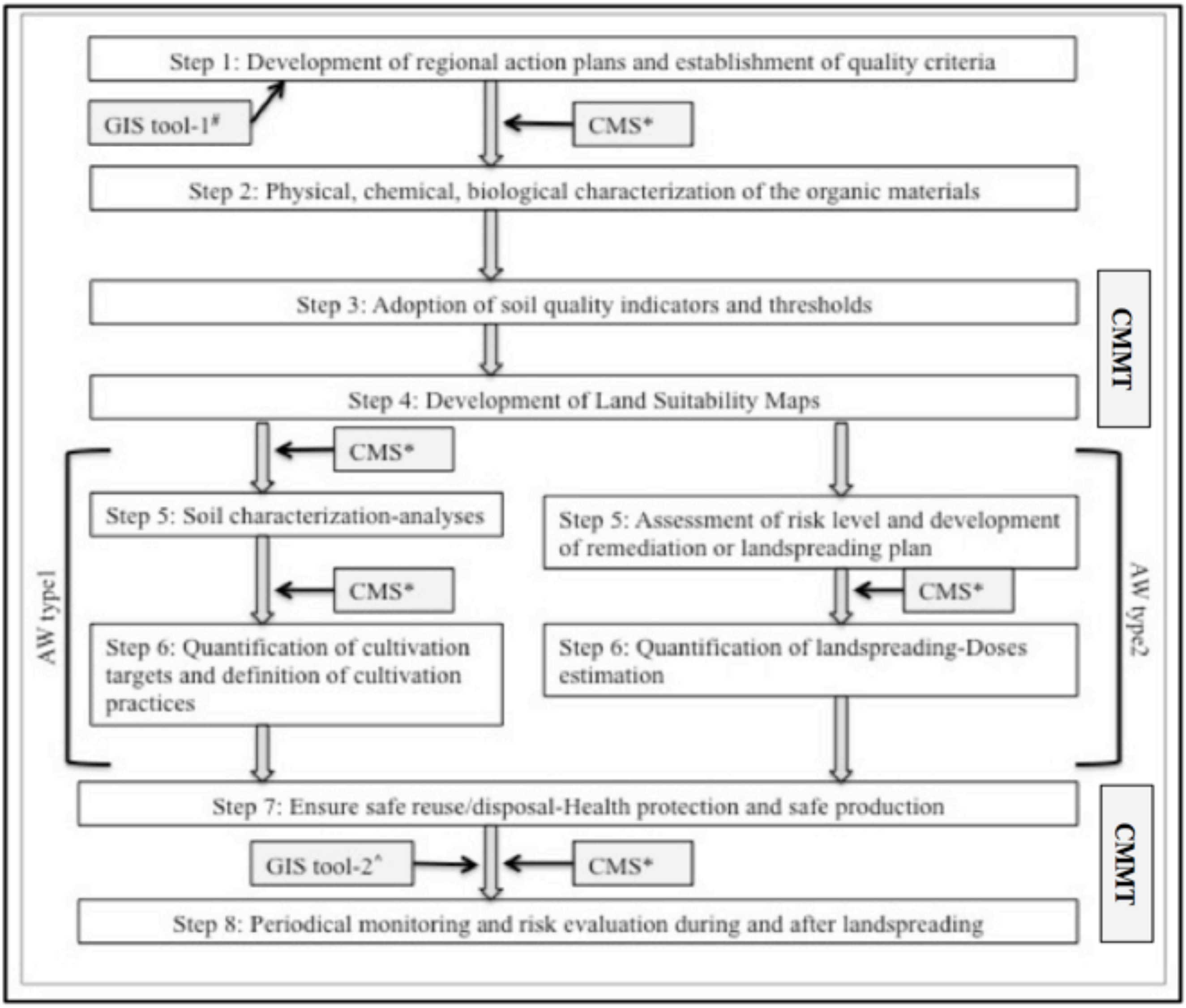
Potentially-hazardous or hazardous wastes (i.e. AW-type2) are mainly wastewater but also solid waste, e.g. Olive Mills Waste, waste from livestock farming, wastewater and sludge from food processing, and others. These types of AW may contain a plethora of potential hazardous constituents, as for example polyphenols, pesticide residues, heavy metals and also pathogens.

Table 8 The eight steps of the strategic framework proposed for sustainable management of rural areas

<table>
<tr><th>Traditionally used wastes (AW-type1)</th><th>Potentially-hazardous or hazardous wastes (AW-type2)</th></tr>
<tr><td colspan="2">• Step 1: Development of regional action plans and establishment of quality criteria
• Step 2: Physical, chemical, biological characterization of the organic materials
• Step 3: Adoption of soil quality indicators and thresholds
• Step 4: Development of Land Suitability Maps</td></tr>
<tr><td>• Step 5: Soil characterization-analyses</td><td>• Step 5: Assessment of risk level and development of remediation or landspreading plan</td></tr>
<tr><td>• Step 6: Quantification of cultivation targets and definition of cultivation practices</td><td>• Step 6: Quantification of landspreading-Doses estimation</td></tr>
<tr><td colspan="2">• Step 7: Ensure safe reuse/disposal-Health protection and safe production
• Step 8: Periodical monitoring and risk evaluation in relation to thresholds and targets</td></tr>
</table>

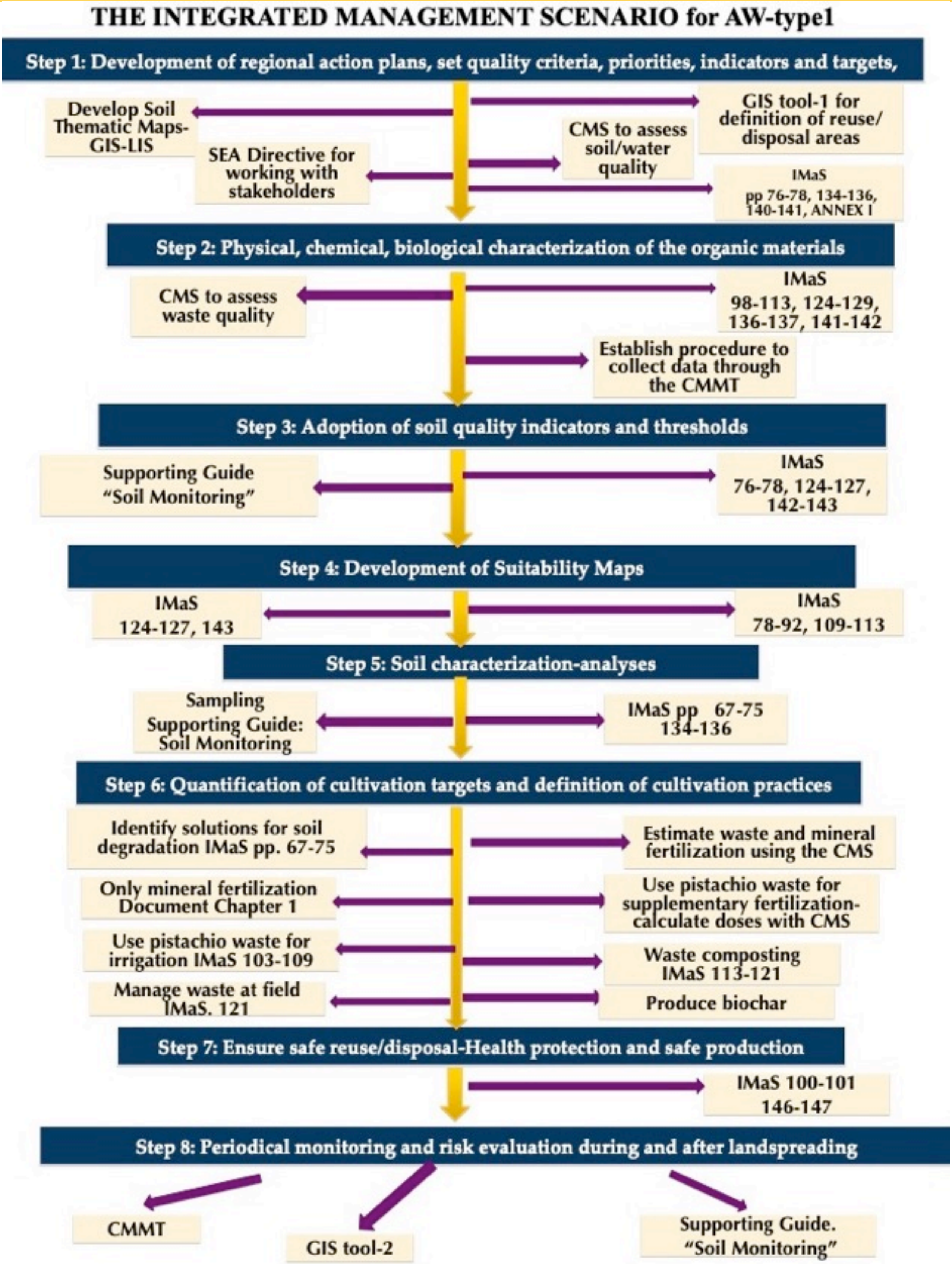
Methodologies and decision-making tools developed by the project are proposed to be used for the implementation of the 8-Steps Strategy. Agrostrat developed also an Implementation Guide that aims to provide additional information in a form of practical and concrete steps that will assist the implementation and mainly the replication of the Integrated Management Scenario (IMaS)

The flowchart of the Eight-Step Strategy for IMaS implementation by using decision-making tools

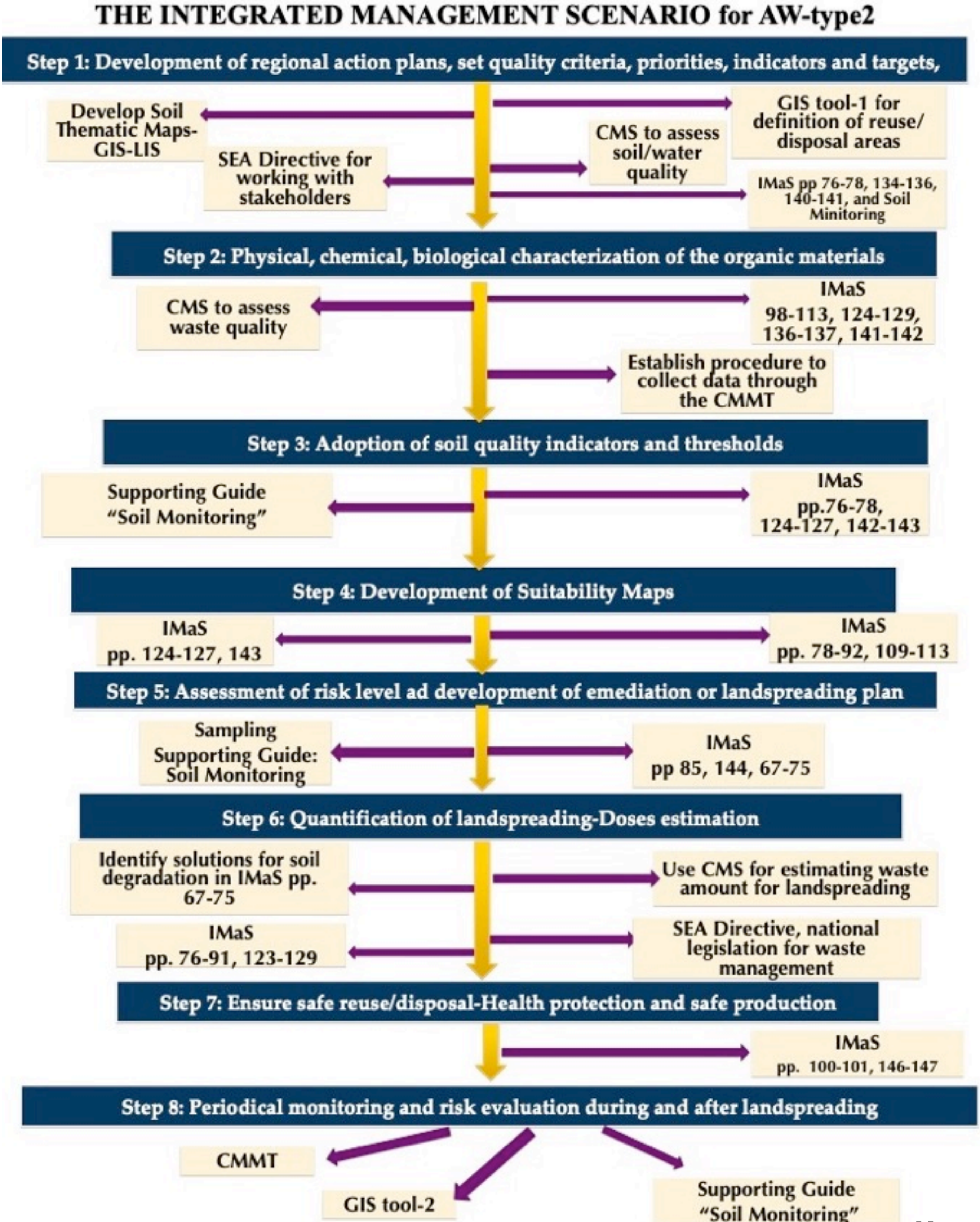


CMS: The Cultivation Management Software
CMMT: The Central Management and Monitoring Tool
GIS-Tool-1: A GIS application developed during LIFE PROSODOL for evaluating location suitability for waste reuse or disposal considering several anthropogenic, environmental and geological criteria-factors.
GIS-Tool-2: A web based GIS tool developed by LIFE-PROSODOL project, which presents soil constituents' distributions vs. time, and depth. Through this tool, local and regional authorities have the opportunity to map and screen disposal areas rapidly, identify potential risky conditions, carry out systematic monitoring of the areas of interest and facilitate decision making on the appropriate measures to be taken at field or regional scale.

How to implement IMaS in 8 Steps for AW-type 1 and where to find supporting data



How to implement IMaS in 8 Steps for AW-type 2 and where to find supporting data



By Maria K Doula

Techno-economic aspects

1 Definition of soil indicators

For the purposes of Agrostrat project, many soil physicochemical parameters were monitored for 1,5 years by analyzing soil samples collected from different sites at Aegina island, which was the pilot area, bimonthly. For this, 15 pilot fields were selected and monitored periodically between January 2013 and June 2014. The fields were selected considering different aspects as regards cultivation and waste management practices, waste incorporation in soil, irrigation type and quality of irrigation water. For each sampling site, control sample from three depth intervals were collected (0-30 cm, 30-60 cm and 60-90 cm). Five sampling campaigns took place on 29-30 January 2013, 1-5 July 2013, 18-23 November 2013, 18-22 March 2014, and on 9-14 June 2014 (20 days in total).

Almost 700 soil samples is required to be collected, from three depth intervals, i.e. 0-30cm, 30-60 cm and 60-90 cm, categorized relative to soil classification method and analyzed for: % clay, % silt, % sand, texture, moisture, pH, electrical conductivity, total salts, water holding capacity, organic matter, $CaCO_3$, active $CaCO_3$, total N, available P, water soluble Na, exchangeable cations (K, Ca, Mg, Na), available metals (Cu, Fe, Mn, Zn), polyphenols, boron, Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-} and NH_4^+ (25 parameters). Methods for analyses are the same as mentioned above.

Techno-economic aspects

1 Definition of soil indicators

Technical requirements

To design a sampling strategy and ensure that representative soil samples will be collected, deskwork is initially required. For this, the consortium collected data from the pilot area regarding cultivated areas, waste characteristic, irrigation practices and others. The main fieldwork concerned collection of soil samples. After analysis of the samples at the lab, a statistical processing is required and then the procedure is completed by results evaluation and selection of the indicators among the measured soil parameters. Therefore, for the definition of a set of oil indicators, the followings are required:

- At least two scientists (soil scientists, environmentalist, chemists)
- A car, preferably a jeep for reaching also difficult accessible areas
- At least two augers for collecting soil samples along with other necessary accessories, like sampling knifes, spade, samples bags, etc.

Table 9 Costs for implementing activities to define soil indicators (pilot `area: Aegina island)

Action	Cost per item, €	Cost, €
Two Scientists: fieldwork for 20 days	100 (salary of 2.500€)	4.000
Traveling for 2 persons/20 days	150 per day per person	6.000
Fuel	200	200
Chemical analyses of 700 soil samples for 26 parameters	100 (minimum price without VAT)	70.000
A scientist: One month deskwork for statistical processing and evaluation of the results	2.500	2.500
Equipment, accessories for soil sampling	1000	1000
Total		**83.700**

Techno-economic aspects

2 Soil Thematic Maps and Land Suitability Maps

Theoretical basis

For the development of the soil thematic maps and the land suitability maps, the first step is to design and perform soil-sampling campaigns, collect the appropriate number of samples and analyze them for the appropriate soil parameters. This procedure took place during Agrostrat project by following already developed knowledge on mapping of cultivated areas.

The following guidelines were followed:

- The target area was designated.
- Existed soil surveys, studies and reports of the area were collected, studied and evaluated.
- A reconnaissance soil survey took place in order the geomorphology, hydrogeology and the bioclimatic conditions to be studied by soils experts.
- Preliminary investigation in combination with the reconnaissance soil survey in order to take representative soil and water samples.
- Study, description and classification of the soils of the pilot fields and soils of Aegina. This was carried out by soil profile description and sampling. The profiles were classified according to the WRB, 2015 system.
- Soil permeability monitoring in representative soil mapping units of Aegina.
- Measurement of soil water infiltration rate in the representative soil types of the area.
- Soil sampling in order to determine soil physical and hydraulic properties in representative soil mapping units of Aegina
- Field investigation of soil degradation-desertification risk.
- Development of a Resources Data Base in order to store and process data
- Geostatistical techniques like kriging was used
- Thematic maps were produced
- Field validation of the thematic maps

Sampling sites for mapping the pilot island (green marks)

After the implementation of the above 1-5, the pilot activities were designed, which took place during 5 visits to Aegina island and for 20 days in total.

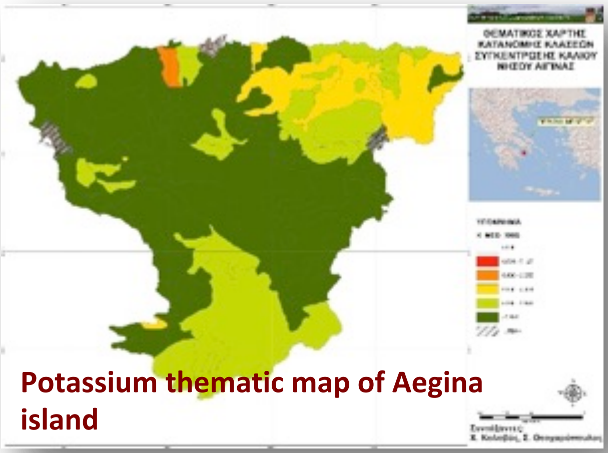
Soil samples were collected from 168 sampling points and samples from 16 profiles. The total number of samples was about 435 (samples were collected from three depth intervals, i.e. 0-30 cm, 30-60 cm and 60-90 cm where possible). The samples were analysed for % clay, % silt, % sand, texture, moisture, pH, electrical conductivity, total salts, water holding capacity, organic matter, $CaCO_3$, active $CaCO_3$, total N, available P, water soluble Na, exchangeable cations (K, Ca, Mg, Na), available metals (Cu, Fe, Mn, Zn), polyphenols, boron, Cl^-, SO_4^{2-}, NO_3^-, PO_4^{3-}, NH_4^+ .

In total, about 11.300 chemical analyses were performed.

Techno-economic aspects

2 Soil Thematic Maps and Land Suitability Maps

After the completion of soil analyses, a database was developed in XML language in order the interoperability as demanded by the INSPIRE directive to be ensured. The thematic soil maps that were developed are for textural class (sand, silt, clay), exchangeable cations (K, Na, Mg, Ca), organic matter, pH, carbonates, total N, P, electrical conductivity, bulk density, soluble salts, sodium saturation, macro and micronutrients, soil water infiltration, soil permeability, as well as bulk density.



Potassium thematic map of Aegina island

The development of such soil thematic maps requires scientific work to be done while the implementation of the mapping-strategy need to be undertaken by soil experts, cartographers and chemists for soil analyses.
For the development of the **land suitability maps**, the soil indicators and all above collected soil data were processed.

Technical requirements

To perform mapping of an area, the followings are needed and must be available (also used during Agrostrat):

- At least four scientists (soil scientists, cartographers)
- A car, preferable a jeep for reaching also difficult accessible areas
- At least two augers for collecting soil samples along with other necessary accessories, like sampling knifes, spade, samples bags, HCl for $CaCO_3$ determination at field, etc.

Table 10 Costs for mapping Aegina island

Action	Cost per item, €	Cost, €
Four Scientists: fieldwork for 20 days	100 (considering a salary of 2.500€)	8.000
Travel costs for 4 persons and for 20 days	150 per day per person	12.000
Fuel	500	500
Chemical analyses of 435 soil samples for 26 parameters	100 (minimum price without VAT)	43.500
A scientist: 2 months desk work for developing the databases and the maps	2.500	5.000
Equipment, accessories for soil sampling	1000	1000
Total		**70.000**

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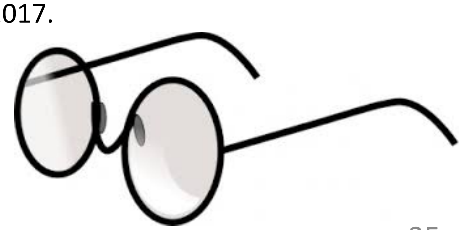

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