



# AgroStrat

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

LIFE11 ENV/GR/951

## AgroStrat for Farmers



Department of Soil Science  
of Athens-Hellenic  
Agricultural Organization  
DEMETER



Institute for Mediterranean Studies -  
Foundation for Research and  
Technology



Technical University of  
Crete

**Edited by Maria K. Doula**

With the support of the Region of Attiki-Regional Union of Islands, the Agricultural Association of Aegina and the Agricultural Cooperative of Aegina's Pistachio Producers

# What is in this document

## Contents

Theme	Page
Objectives and Innovations	3
The Integrated Management scenario	4
Chapter 1: Integrated fertilization practices for pistachio trees	5
Chapter 2: Environmental footprint of pistachio cultivation	9
Chapter 3: Addressing Soil Threats	10
Chapter 4: Development of soil thematic maps-Definition of soil indicators	13
Chapter 5: Pistachio waste management	15
Chapter 6: The decision-making tools of AgroStrat	24
Chapter 7: The IMaS in Eight Steps	29
Implementation of IMaS by farmers	33
Contact details	40

This document was developed to assist farmers in understanding Agrostrat project and its outcomes, with the aim of identifying preconditions of implementation, the necessary 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, to the environment and mainly to farmers, also as regards their economic growth through agricultural environment protection.

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. farmers and their associations as well as 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 with the potential of exploitation by farmers

- 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 composting methodology for pistachio waste with very high electrical conductivity with the addition of natural zeolite as additive to the feedstock.
- 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

## A tool for policy makers and farmers

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 soil 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

### ...a chapter for pistachio trees

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.

## Fertilization

### Basic Rule of fertilization

Fertilization must follow the natural cycle of the tree and be done in such doses as to meet its needs

#### Nutritional needs of pistachio trees

At the beginning of the blooming period, nutrient needs are met, at least partially, by the consumption of transportable forms of nutrients stored in the branches and roots, later the growing fruits also get nutrients from the fully grown leaves. Therefore, fertilization must be applied not earlier than mid-end of April to fulfill the demands.

#### 1<sup>st</sup> demand (March-May)

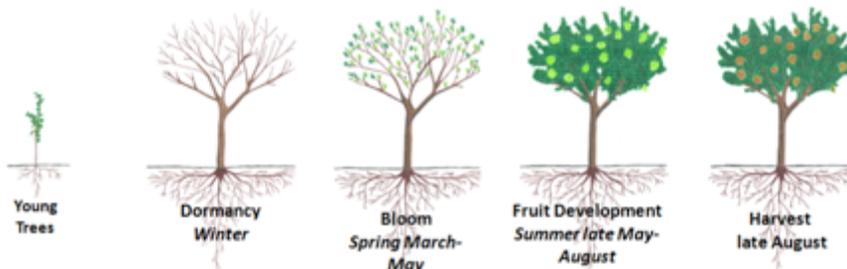
needs of spring vegetation for the formation of new shoots and pericarps

#### 2<sup>nd</sup> demand (June-September)

Needs for pistachio nuts growth

According to the anticipated yield, the appropriate amount of Nitrogen, Phosphorus and Potassium should be estimated, considering:

<b>Needed amounts of nutrients per 100 kg of fresh nuts</b>	22.5 Kg of Nitrogen / ha
	5.0 Kg of Phosphorus / ha
	12.55 Kg of Potassium / ha



#### For example:

If the anticipated yield is 1 tn/h nuts, then the needed amounts of nutrients per hectare, are:

- **225 Kg Nitrogen**
- **50 Kg Phosphorus**
- **125.5 Kg Potassium**

Always keep in mind that for Nitrogen and due to losses after application, the dose proposed should be discussed with local advisors or agronomists and conformed according to the system of application and the climatic conditions.

The estimated nutrients amount should be applied in doses as seen in the following tables and according to the fertilization practice, i.e. surface application or fertigation.

**Surface application of fertilizers**

Month	Nitrogen	Phosphorus	Potassium
Mid-End April	20%	100%	-
End May	40%	-	50%
End June	40%	-	50%

**Fertigation**

Month	Nitrogen	Phosphorus	Potassium
Mid-End April	20%	100%	-
End May	30%	-	40%
End June	30%	-	40%
End July	20%	-	20%

It is of great importance to understand that the negative effects of current practices mainly include the following:

- Decline in soil productivity which can be due to soil compaction, loss of soil organic matter, reduced water retention capacity, and salinization of soils.
- Water pollution as a result of using fertilizers (nitrates and phosphorus), pesticides, manures and other organic amendments.
- Water scarcity in many places is due to overuse of surface and ground water for irrigation.

An appropriate pistachio nutrient management plan determines the nutrient needs of the crop, takes into consideration factors like crop tissue analyses, soil type, time of year, soil moisture, crop load (e.g. alternate bearing), etc. as well as the actions that have to be taken in order to protect soil and water quality.

**Leaf sampling and analysis**

- If orchard is variable, then divide orchards into uniform blocks and take separate samples for each block. Sample 10-20 trees in each orchard block and collect 4-10 leaves per tree.
- Leaf tissue is taken and analyzed at least once a season (from late July through August) and used to help assess crop nutrient needs and assess the impact of the nutrition management program.
- Non-bearing branches should be sampled to eliminate the effect of variable crop level or mineral-element composition. Randomly collect fully expanded sub-terminal leaflets at about six feet from the ground.
- Do not sample leaves that have received in-season foliar nutrient applications for the elements of interest.

**Nutritional ranges usually found in leaf analyses from pistachio trees**

Element	Range over which normal growth with healthy leaves occurred		
	<i>Percent of dry weight</i>		
Nitrogen (N)	25	-	29
Phosphorus (P)	0.14	-	0.17
Potassium (K)	1.0	-	20
Calcium (Ca)	1.3	-	4.0
Magnesium (Mg)	0.6	-	1.2
Sodium (Na)	0.002	-	0.007
Chloride (Cl)	0.1	-	0.3
		<i>ppm</i>	
Manganese (Mn)	30	-	80
Boron (B)	55	-	230
Zinc (Zn)	7	-	14

## Recommendations for pistachios cultivation, and not only...

### Soil sampling

Soil samples for nutrient analysis should be taken periodically, to update soil nutrients requirements, from the main root zone. Most of the water and nutrients are taken up from the top 60 cm of the profile; especially in orchards with small but frequent irrigation water. When the soil samples are also used to assess soil salinity, sampling to a depth of 120 cm may be required.

### Fertilization practices

Prepare a fertilizer budget based on expected tree nutritional needs for each growing season and considering the anticipated yield. Excessive application of nutrients is economically inefficient, can lead to lush growth that is more susceptible to diseases and pests and can cause ground and surface water contamination. Long-term records for the orchards should be kept regarding the application program, including application of fertilizers and soil amendments, pesticides-herbicides-insecticides used, results of soil and leaf analyses and also yield.

### Quality of irrigation water

- The water source has to be monitored, sampled and evaluated for its quality. Monitor the total salinity of the irrigation water during growing period by using a cheap portable electrical conductivity (EC) meter. When the total salinity increases about 20%, then you have to analyze water and assess the sources of this change.
- Irrigation water has to be sampled and analyzed annually during summer period, including all chemical parameters and, if this is possible, biological parameters (e.g. E.coli). Chemical contaminants such as nitrates may indicate excess fertilizer is leaching into the water supply and the amounts applied to the crop should be accounted for in a nitrogen nutrition budget
- Quality of water in distribution reservoirs should be also tested.
- Carefully assess water quality with the assistance of experts and address potential sources of contamination and degradation.

### Organic amendments

- 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.
- Consider that when using organic amendments there is a high risk of nitrates leaching water bodies. Therefore, avoid excess application and calculate the appropriate amount by following a nitrogen nutrition budget.
- Untreated or improperly treated organic amendments may contain pathogens that could contaminate plants and crops and pose food safety concerns.
- When planting new trees spread the organic material two weeks before planting
- Application of organic materials has to take place at the end of the season, preferably when soils are warm no saturated and/or cover- cropped.
- Incorporate organic materials into the soil immediately after application to minimize drift, water runoff and nitrogen loss in the atmosphere. If incorporation is not possible or practical under your management plan, it is strongly recommended to use only adequate organic materials.



Recommendations for pistachios cultivation, and not only...

**Irrigation scheduling and salinity control**

- Under-irrigation reduces growth and yield, whereas over-irrigation can cause root rot, salinization, leaching of nutrients, and water bodies degradation.
- Use drip irrigation whenever possible. Fertilization via micro-sprinklers or drip irrigation allows for frequent application and reduce water losses and water use efficiency is maximized.
- Always consider soil sodium, since high exchangeable sodium levels can cause structural deterioration to soils that lead to water infiltration problems and general soil degradation.
- One-time application of large water quantities tends to percolate rapidly through the larger cracks and pores in soil. Small water quantities (25-50 mm depth per application), applied frequently over several days, is more effective for maintaining soil moisture and also moving salts below the root zone.
- Post harvest irrigation should be limited to meet the needs of specific operations only (70 - 75% reduction in irrigation water).
- Sprinkler and micro irrigation or rainfall allow much more time for salts to diffuse out of the small pores and into the water moving through the big pores and ultimately leach out of the rootzone. Leaching by this method is most effective during the winter when surface evaporation from soil and crop transpiration is the lowest.
- It is essential leaching to be done when soil nitrates levels are low and crop nitrogen needs have been satisfied. Soils should never be intentionally leached within 72 hours after the application of pesticides.

For pistachio trees

- Critical periods when pistachio should not be under-irrigated are: (1) from nut filling to hull slip, and (2) from bloom to end of shell expansion
- If water is limited, regulated deficit irrigation scheduling approach (up to 50% of water reduction, between the time the shell has expanded and the initiation of rapid kernel growth) can be used to save water while having a minimal impact of sustained tree productivity.

In case of excess soil salinity, apply soil washing to reduce salts. To calculate the needed water amount for washing, use the following formula:

$$\text{Leaching Fraction (LF)} = \frac{\text{Electrical Conductivity of irrigation water}}{5(\text{Soil Electrical Conductivity}) - \text{Electrical Conductivity of irrigation water}}$$

NOTE: the Soil Electrical Conductivity appears in the above formula is the theoretical amount of soil EC that causes yield reduction. For each plant, search for the specific table that provides these values. For pistachio trees, the respective table is seen below

Pistachio trees					
Decrease in yield	0%	10%	25%	50%	100%
Soil Electrical conductivity, dS/m	4.7	5.8	7.5	10.4	16

**Example of LF calculation:** lets consider that the electrical conductivity of available irrigation water is 8 dS/m. If the acceptable yield decrease is 10%, then soil electrical conductivity is 5.8 (from the table). By replacing these values in the LF formula above, then the LF is 0.38, meaning that we need to irrigate with 38% more water for salts removal.

## 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

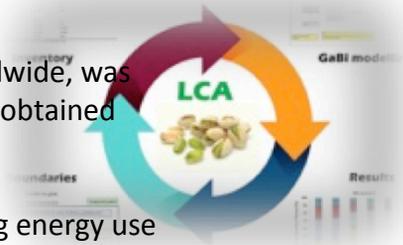
### For the first time,

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:

- Always consider of efficient use of irrigation water and chemical fertilizers along with recycling of agricultural wastes and the use of renewable sources of energy.
- Produce compost and biochar and use them for partially replacement of chemical fertilizers
- Implement good cultivation and waste management practices.
- Use of eco-friendly farming practices for greenhouse gases emissions reduction and energy conservation.



AgroStrat estimated that the production of 1 tn of dry pistachios consumes 2,05 GJ of energy and emits 2,04 kg CO<sub>2</sub>-eq.

**A new car emits 120.1gCO<sub>2</sub>/km, meaning that 1 tn of pistachios corresponds to 17Km driving a new car**



## 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 Organic Matter** is a key component of soil, controlling many vital functions, is a source of food for soil fauna and contributes to soil biodiversity.

Soil organic matter provides the physical environment for roots to penetrate the soil and for excess water to drain freely from soil.

### Practices for Soil Organic Matter increase

- Incorporation of plant residues (after harvest)
- Addition of organic materials such as manure, compost or other organic substances
- Mulching
- Crop rotation that includes pasture and fodder species
- Less or minimal soil cultivation, especially during dry and hot periods (no till farming may also be adopted)
- Maintaining high soil humidity levels

### Soil Threats

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



**Salinisation** is the result of the accumulation of salts and other substances from irrigation water and fertilizers and is regarded as one of the major causes of desertification.

**Sodification** is the process by which the exchangeable sodium content of the soil is increased and sodium ions accumulate in the solid and/or liquid phases of the soil. High levels of salts will eventually make soils unsuitable for plant growth.

### Early signs of soil salinity

- Increased soil wetness in semiarid and arid areas to the point that the soil does not support equipment
- the growth of salt-tolerant weeds
- Irregular patterns of crop growth and lack of plant vigor

### Advanced signs of soil salinity that require emerge action

- white crusting on the surface
- a broken ring pattern of salts adjacent to a body of water
- white spots and streaks in the soil, even where no surface crusting is visible
- the presence of naturally growing, salt-tolerant vegetation

## Addressing soil organic matter, salinization and sodification

- To keep the soil productive, its nutrient levels need to be replenished on a regular basis.
- Crop residues should be returned to soil to maintain or even increase their organic matter status.
- A sufficiently high organic matter level is important to increase soil stability, soil water holding capacity and the nutrient holding capacity and supply. However, additional organic and/or inorganic fertilization is inevitable to restore and maintain the optimal productivity of the soil.
- Loss of organic matter and soil biodiversity and consequently reducing soil fertility are often driven by unsustainable agricultural practices such as overgrazing of pasturelands, over intensive annual cropping, deep plugging on fragile soils, cultivation of erosion-facilitating crops (e.g. maize), continuous use of heavy machinery destroying soil structure through compaction, unsustainable irrigation systems contributing to the salinisation and erosion of cultivated lands.
- Summer fallow management practices may cause increased salinization by increasing the soil moisture content to the point that water moves to seeps on hill slopes. Salts accumulate as the water evaporates from these seeps.
- Drainage is essential for reclaiming degraded soils since soluble salts can be leached (washed) and move through the soil, (rather than run off the surface). The purpose is to leach salts below the plant root zone. If the soil is poorly drained because of compaction, drainage potential should be ensured first, for example by adding an amendment like organic matter.

**Compaction** can detrimentally affect a number of soil functions by reducing the pore space between soil particles, increasing bulk density and reducing or totally destroying the soil's absorptive capacity. Reduced infiltration increases surface run-off and leads to more erosion while decreasing groundwater recharge.

Heavy loads on the soil surface that cause compaction in the subsoil are cumulative and cause the bulk soil of the subsoil to increase significantly



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

**Desertification:** A combination of some of soil threats can ultimately lead arid or sub-arid climatic conditions to desertification. Therefore, desertification is caused by a combination of threats and conditions.

**Soil erosion** is recognized as one of the most important soil degradation process worldwide

Bulgaria, Cyprus, Greece, Hungary, Italy, Latvia, Malta, Portugal, Romania, Slovakia, Slovenia and Spain consider themselves affected by desertification and are included in the list of United Nation Convention to Combat Desertification.



## Activities that contribute to desertification

### Arable Lands

- Removal of the vegetation cover
- Unsustainable agricultural practices (deep ploughing and destruction of soil structure)
- Loss of soil organic matter (e.g. soil wash due to rainfall)
- Compaction-heavy machinery
- Nutrients loss-monocultures (e.g. wheat, vineyards), non-native plants cultivation. Intensive agriculture exhausts the soil's nutrients and minerals needed to sustain plant life.
- Pollution/contamination

### Irrigated areas

- Excessive use of water - water erosion
- Insufficient irrigation system
- Salinization-formation of salt layers on soil surface

### Pastures

- Overgrazing-excessive use of the same pastures. Overgrazing removes the grass and other vegetation that protects the soil from erosion.
- High density of animals per area

## Actions against desertification

- Land restoration and fertilization. Use of organic amendments, like composts to increase soil organic matter.
- Combating wind effects by constructing barriers and stabilizing sand dunes with local plants.
- Reforestation. Trees play several roles, i.e. fix soil, act as windbreakers, enrich soil in nutrients and adsorb water during rainfall.
- Adoption of sustainable agricultural practices (i.e. development of Codes of "Good Farming Practices). Agriculture diversity must be preserved. Soil "breathing" during certain-time periods (no-cultivation, no grazing) should be ensured.
- Development of integrated scenarios for changing societal behaviors (modern and traditional) of every-day life (social, commercial, professional etc.) that affect and intensify desertification.
- Education and training of local communities.

## 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

## Soil Thematic Maps-Land Suitability Maps

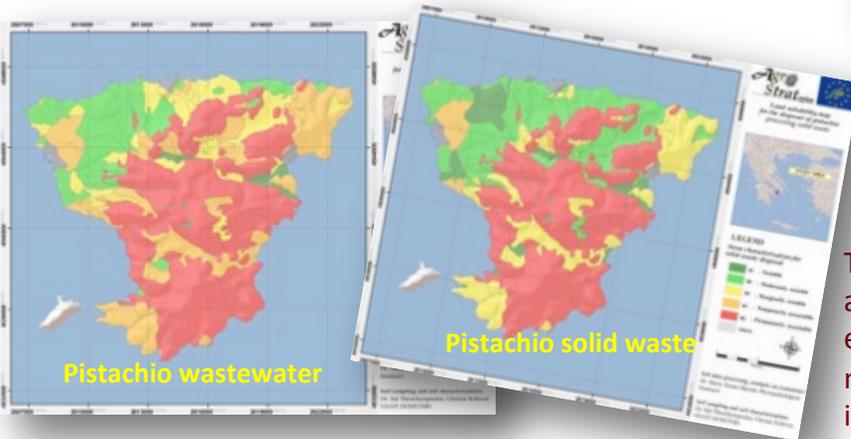
AgroStrat developed a system for assessing soil quality as regard physical and chemical properties and an evaluation system for land suitability for waste distribution or reuse for nutrients valorization.

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.

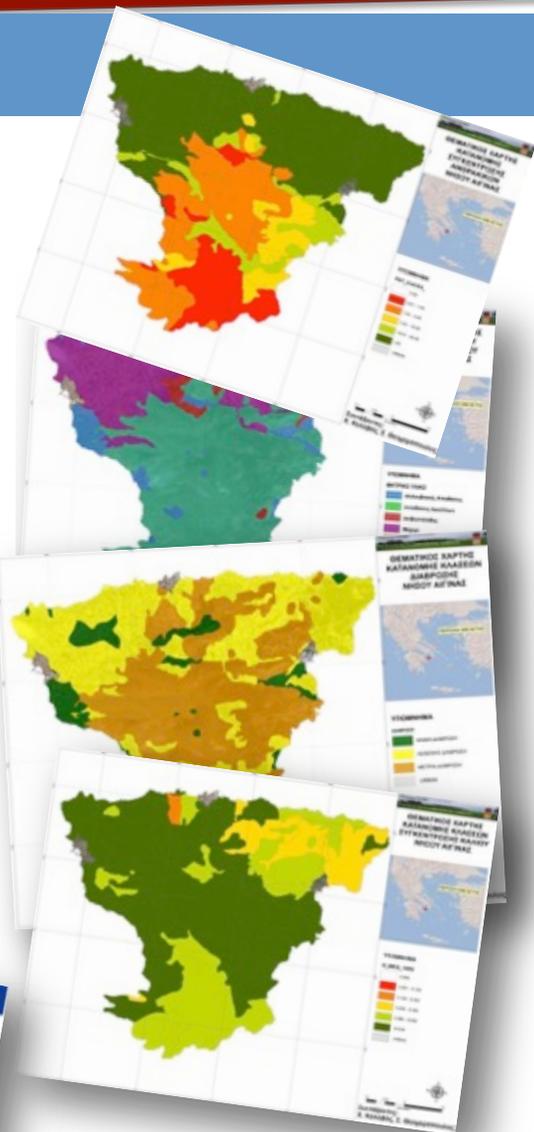
Thereafter, soil properties and areas characteristics were evaluated according to FAO land evaluation system. The GIS soil thematic maps were also exploited in order to develop Land Suitability Maps for agricultural waste distribution on soil, considering also legislative restrictions.

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



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. **It is not possible for farmers to use the maps directly, but it is possible to have indirect access through web tools of Agrostrat.**



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.



## 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<sup>3</sup>/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<sup>3</sup>. 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:** Be aware that before any action or waste application on soil, the authorized competent authority must be informed and provide the appropriate permission.

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 <sup>-1</sup>	106
Total N, %	2.5	Total Fe, %	0.58
Moisture, %	60	Total Zn, mg kg <sup>-1</sup>	99
pH	7.44	Total Mn, mg kg <sup>-1</sup>	85
EC, mS/cm	3.8	Total B, %	0.13
Total Polyphenols, g kg <sup>-1</sup>	4.5	Cl <sup>-</sup> , mg kg <sup>-1</sup>	4,900
Total K, % (as K <sub>2</sub> O)	2.9	NO <sub>3</sub> <sup>-</sup> , mg kg <sup>-1</sup>	1,200
Total P, % (as P <sub>2</sub> O <sub>5</sub> )	1.0	PO <sub>4</sub> <sup>3-</sup> , mg kg <sup>-1</sup>	50
Total Ca, % (as CaO)	5.5	SO <sub>4</sub> <sup>2-</sup> , mg kg <sup>-1</sup>	354
Total Mg, % (as MgO)	0.68	NH <sub>4</sub> <sup>+</sup> , mg kg <sup>-1</sup>	308
Total Na, %	0.69		

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 <sup>-1</sup>	0.49
EC, mS/cm	6.1	Total Zn, mg L <sup>-1</sup>	1.25
Polyphenols, mg L <sup>-1</sup>	1,500	Total Mn, mg L <sup>-1</sup>	0.68
K, mg L <sup>-1</sup>	1,050	Total B, mg L <sup>-1</sup>	0.062
P, mg L <sup>-1</sup>	38	NH <sub>4</sub> <sup>+</sup> , mg kg <sup>-1</sup>	60
Ca, % (w/v)	0.04	Cl <sup>-</sup> , mg L <sup>-1</sup>	710
Mg, % (w/v)	0.02	NO <sub>3</sub> <sup>-</sup> , mg L <sup>-1</sup>	5.0
Na, mg L <sup>-1</sup>	347	PO <sub>4</sub> <sup>3-</sup> , mg L <sup>-1</sup>	52
Cu, mg L <sup>-1</sup>	0.13	SO <sub>4</sub> <sup>2-</sup> , mg L <sup>-1</sup>	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 proposes 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

...because prevention is better than addressing impacts of disposal



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.



### Composting Pistachio Waste

#### Step by Step

##### Feedstock

- 10 parts of solid pistachio waste (after dehulling)
- 5 parts of well-digested manure
- 1 part straw
- 1 part clinoptilolite (natural zeolite, can be found in market)



**1/ Apply the materials in layers, one above the other, alternately, and prepare a pile or a windrow**



Maximum height of pile/windrow 1.5m

**2/ Repeat the procedure and add more layers of materials**

**3/ Good mixing and wetting**

**4/ Protect the mixture using composting textiles**



**WINDROW TURNING FREQUENCY**  
First 3-5 days Turn daily  
Next 3-4 weeks Turn 1-3 times/week  
Week 5 to End Turn once/week (max)

##### During composting

- Aerate the mixture often by turning (for 2-3 months)
- Keep mixture temperature below 65°C and moisture between 45 and 60%. Wet the mixture periodically
- Frequent temperature and moisture monitoring
- During maturity phase (the last 2 months) the compost must be kept at a protected area

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

Composition of compost prepared by the addition of zeolite (Agrostrat compost) and without

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 <sup>-1</sup>	0.24	0.34	In soil < 40 mg kg <sup>-1</sup>
Total K, % (as K <sub>2</sub> O)	1.1	1.6	0.5-1.8
Total P, % (as P <sub>2</sub> O <sub>5</sub> )	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 <sup>-1</sup>	100	20	Table 5
Total Fe, mg kg <sup>-1</sup>	1340	3,545	
Total Zn, mg kg <sup>-1</sup>	122	139	Table 5
Total Mn, mg kg <sup>-1</sup>	119	199	
Total As, mg kg <sup>-1</sup>	1.3	2.7	Table 5
Total Cd, mg kg <sup>-1</sup>	0.23	0.25	Table 5
Total Pb, mg kg <sup>-1</sup>	11	18	Table 5
Total Ni, mg kg <sup>-1</sup>	1.4	1.7	Table 5
Total B, %	0.04	0.04	
Cl <sup>-</sup> , mg kg <sup>-1</sup> (in mg L <sup>-1</sup> )	3,850 (385)	2,350 (235)	< 500 mg L <sup>-1</sup> (in water extract) <sup>#</sup>
NO <sub>3</sub> <sup>-</sup> , mg kg <sup>-1</sup> (in mg L <sup>-1</sup> )	10,500 (1050)	5,800 (580)	< 1000 mg L <sup>-1</sup> (in water extract) <sup>#</sup>
PO <sub>4</sub> <sup>3-</sup> , mg kg <sup>-1</sup>	660	795	
SO <sub>4</sub> <sup>2-</sup> , mg kg <sup>-1</sup>	1,800	245	
NH <sub>4</sub> <sup>+</sup> , mg kg <sup>-1</sup> (in mg L <sup>-1</sup> )	40 (4)	60 (6)	< 300 FW (Switzerland limit) Lower than 50 mg L <sup>-1</sup> (in water extract) <sup>#</sup>
NH <sub>4</sub> <sup>+</sup> / NO <sub>3</sub> <sup>-</sup>	0.004	0.01	

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 <sup>-1</sup>			
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 <sub>tot</sub>	70-200	510	-	250	100
Cr <sub>VI</sub>		10	3	-	-
Pb	70-1,000	500	280	150	100
As	10-25	15	-	-	10
Hg	0.7-10	5	3	2	1



## Working with waste at your field

There are no always safe ways of dealing with any waste, while any waste can be hazardous to human health or the environment if it is wrongly managed. Therefore, prior any action, the following issues should be defined/clarified:

- does the waste need a special container to prevent its escape or to protect it;
- what type of container suits it and what material can the container be made of;
- can it safely be mixed with any other waste or are there wastes with which it should not be mixed;
- can it safely be crushed and transferred from one vehicle to another;
- is it likely to change its physical state during storage or transport?
- Waste must be kept safely against:
- corrosion or wear of waste containers;
- accidental spilling or leaking or inadvertent leaching from waste unprotected from rainfall;
- accident or weather breaking contained waste open and allowing it to escape;

## Why to compost organic waste from your field...

Use of composts on cultivated land enriches soil with organic matter and nutrients, which otherwise would have been lost. Therefore, compost application on the poor and eroded Mediterranean soils, will significantly improve their quality and fertility and will strengthen their resilience capacity against impacts of the climate change.

Use of the compost from your own materials may have economic benefits, as it reduces the need for chemical fertilizers, improves soil fertility and therefore yield.

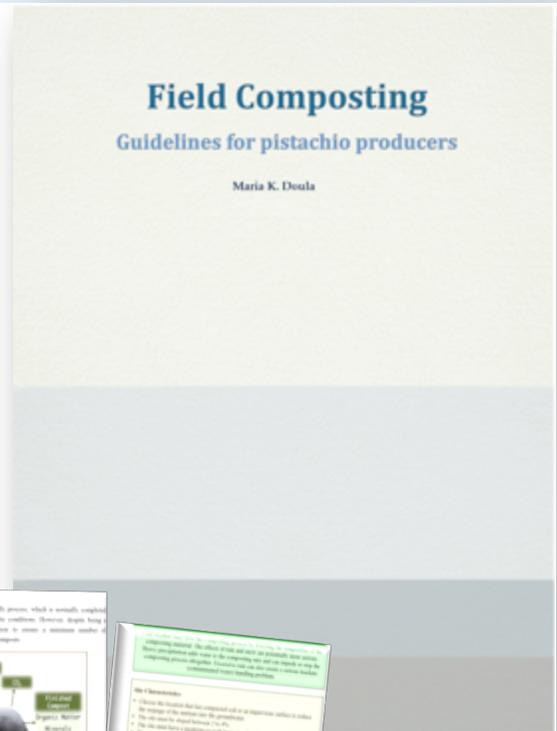
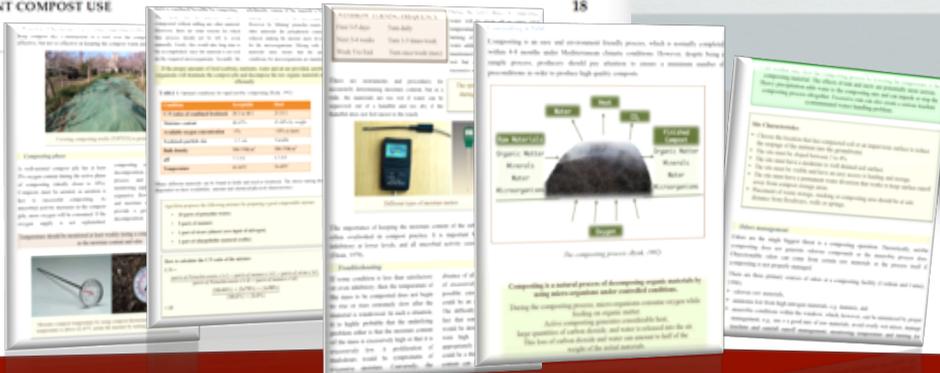
**AgroStrat released a very useful guide for composting pistachio wastes which also provides composting details and other important information for handling and managing organic wastes.**

**Visit AgroStrat website and download the Field Composting Guide**

### Content

<b>PREFACE</b>	<b>3</b>
<b>PISTACHIO DEHULLING WASTES</b>	<b>4</b>
<b>WHY TO COMPOST PISTACHIO WASTES</b>	<b>5</b>
<b>COMPOSTING AT FIELD</b>	<b>6</b>
<b>AEROBIC VS. ANAEROBIC COMPOSTING</b>	<b>7</b>
<b>ANAEROBIC COMPOSTING</b>	<b>7</b>
<b>AEROBIC COMPOSTING</b>	<b>7</b>
<b>WINDROW COMPOSTING</b>	<b>8</b>
<b>COMPOSTING STAGES</b>	<b>8</b>
<b>COMPOSTING PHASES</b>	<b>9</b>
<b>AREA SELECTION</b>	<b>10</b>
<b>ODORS MANAGEMENT</b>	<b>11</b>
<b>WASTE HANDLING AND PRE-TREATMENT</b>	<b>12</b>
<b>HOW TO SELECT FEEDSTOCK MATERIALS AND PREPARE THE COMPOSTABLE MIXTURE</b>	<b>12</b>
<b>PREPARATION OF THE COMPOSTABLE MIXTURE</b>	<b>14</b>
<b>COMPOSTING PHASE</b>	<b>15</b>
<b>TROUBLESHOOTING</b>	<b>16</b>
<b>WHEN IS THE COMPOST READY?</b>	<b>17</b>
<b>EFFICIENT COMPOST USE</b>	<b>18</b>

### REFERENCES



## 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,  $N-NO_3$ ,  $N-NH_4$ , 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 by 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,  $N-NO_3$ ,  $N-NH_4$ , 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 and 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.



### 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.



**Raw solid pistachio waste**

## 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 ( $N_{avail}$ ):

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

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.

## 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-A useful tool for farmers

#### 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.

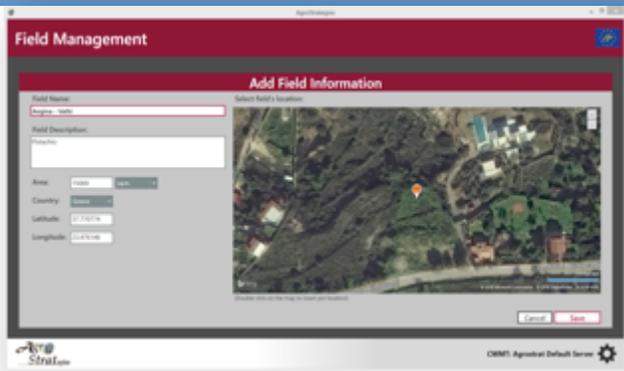
#### CONSULTANCY

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.

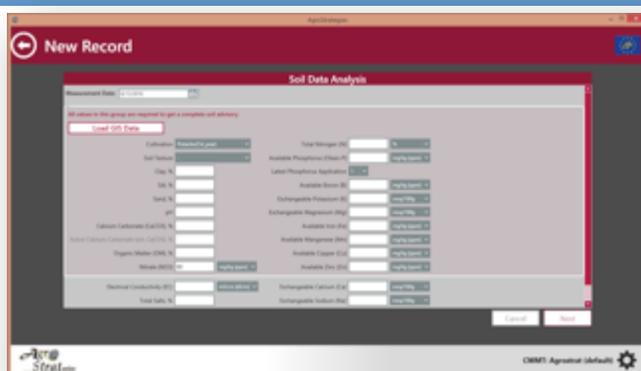
#### CONNECTION WITH THE REGIONAL AUTHORITY

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.

## The Cultivation Management Software



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



To receive consultancy 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.



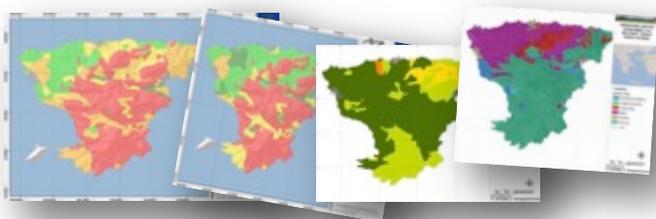
**The Software of AgroStrat**

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

**Visit AgroStrat web site and use the software for free**



### 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.

## 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.*

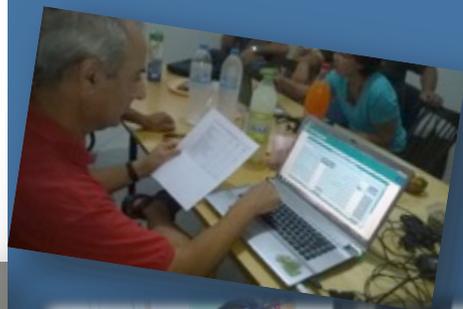
*The Cultivation Management Software aims to provide consultancy and by no mean to substitute authorized competent authorities. Therefore, farmers and individuals are informed by specific note on the AgroStrat page and also on the different software page to consult national competent authorities in case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



## 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  
A tool for authorities and farmers associations that connects them with farmers on line**

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.



## The field device that connects field measurements with the AgroStrat Software



### 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.

**For the moment, four such devices have been constructed and given to farmers associations in Greece. More will be constructed shortly**



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 for 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.

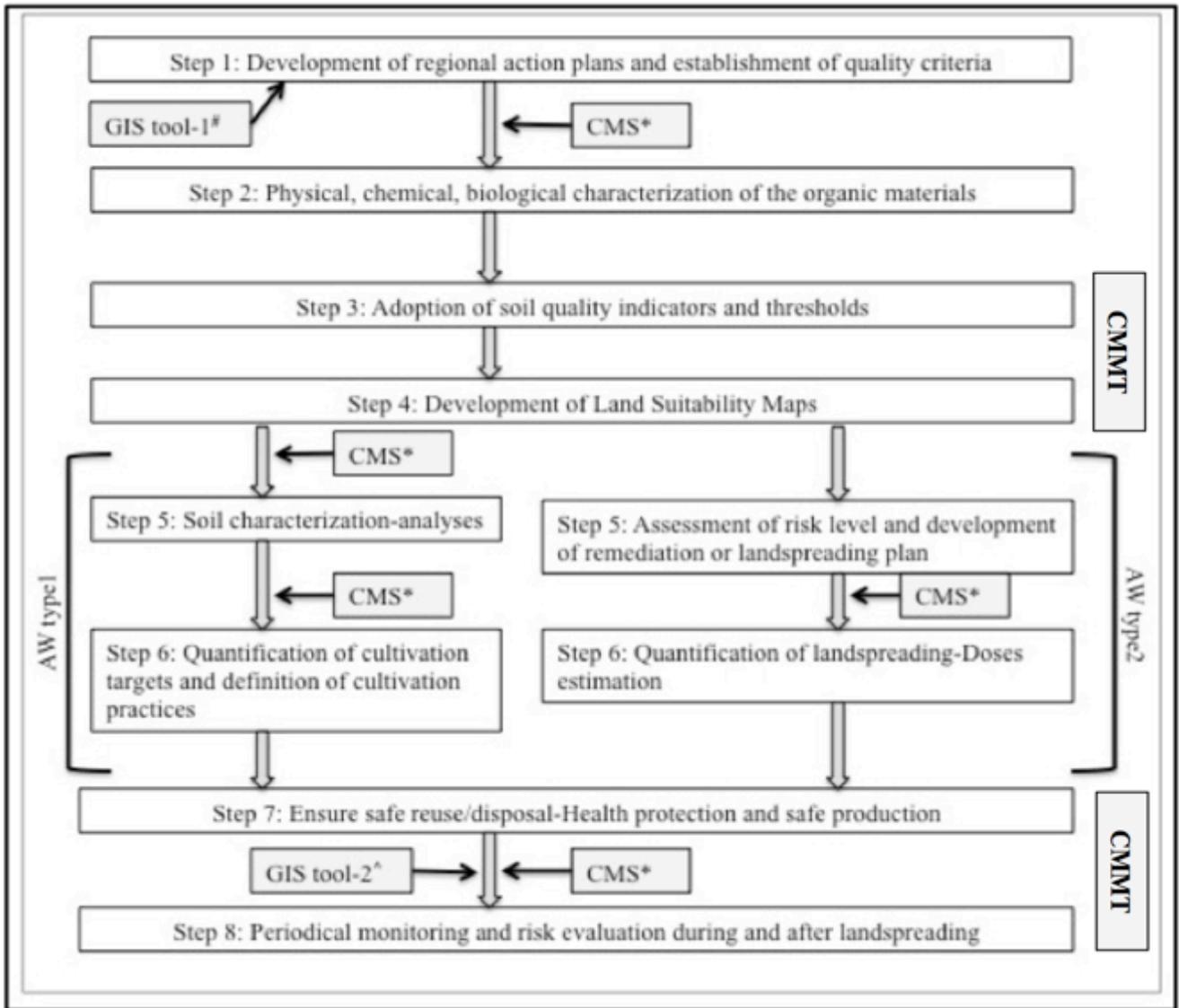
Potentially-hazardous or hazardous wastes (i.e. AW-type2) are mainly wastewater but also solid waste, e.g. Olive Mills Waste, waste from livestock farming, wastewater and sludge from food processing, and others. These types of AW may contain a plethora of potential hazardous constituents, as for example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

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

Traditionally used wastes (AW-type1)	Potentially-hazardous or hazardous wastes (AW-type2)
<ul style="list-style-type: none"> <li>• Step 1: Development of regional action plans and establishment of quality criteria</li> <li>• Step 2: Physical, chemical, biological characterization of the organic materials</li> <li>• Step 3: Adoption of soil quality indicators and thresholds</li> <li>• Step 4: Development of Land Suitability Maps</li> </ul>	<ul style="list-style-type: none"> <li>• Step 5: Assessment of risk level and development of remediation or landspreading plan</li> <li>• Step 6: Quantification of landspreading-Doses estimation</li> </ul>
<ul style="list-style-type: none"> <li>• Step 5: Soil characterization-analyses</li> <li>• Step 6: Quantification of cultivation targets and definition of cultivation practices</li> </ul>	<ul style="list-style-type: none"> <li>• Step 7: Ensure safe reuse/disposal-Health protection and safe production</li> <li>• Step 8: Periodical monitoring and risk evaluation in relation to thresholds and targets</li> </ul>

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

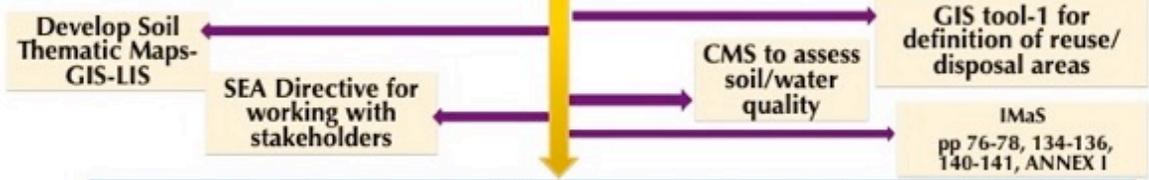
**GIS-Tool-1:** A GIS application developed during LIFE PROSODOL for evaluating location suitability for waste reuse or disposal considering several anthropogenic, environmental and geological criteria-factors.

**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.

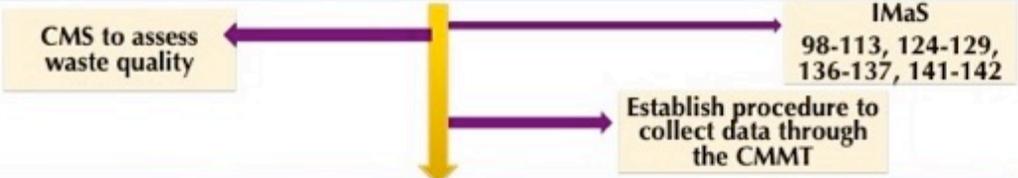
How to implement IMaS in 8 Steps for AW-type 1 and where to find supporting data

**THE INTEGRATED MANAGEMENT SCENARIO for AW-type1**

**Step 1: Development of regional action plans, set quality criteria, priorities, indicators and targets,**



**Step 2: Physical, chemical, biological characterization of the organic materials**



**Step 3: Adoption of soil quality indicators and thresholds**



**Step 4: Development of Suitability Maps**



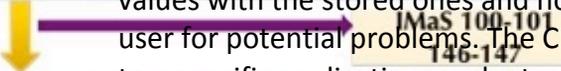
**Step 5: Soil characterization-analyses**



**Step 6: Quantification of cultivation targets and definition of cultivation practices**



**Step 7: Ensure safe reuse/disposal-Health protection and safe production**



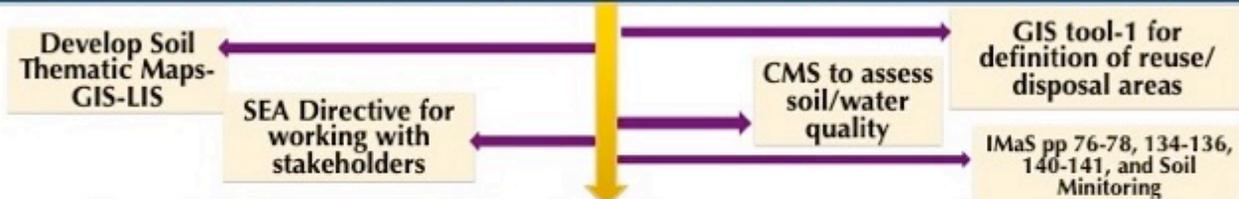
**Step 8: Periodical monitoring and risk evaluation during and after land-reuse**



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.

## THE INTEGRATED MANAGEMENT SCENARIO for AW-type2

### Step 1: Development of regional action plans, set quality criteria, priorities, indicators and targets,



### Step 2: Physical, chemical, biological characterization of the organic materials



### Step 3: Adoption of soil quality indicators and thresholds



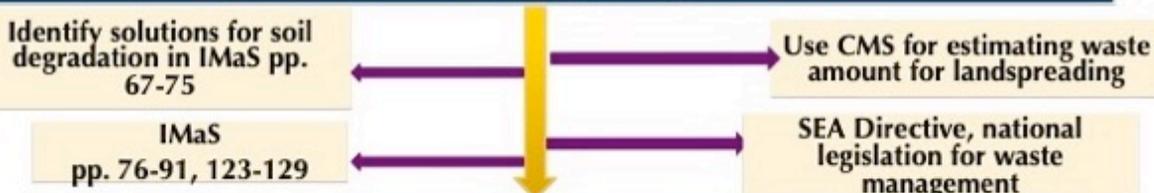
### Step 4: Development of Suitability Maps



### Step 5: Assessment of risk level and development of remediation or landspreading plan



### Step 6: Quantification of landspreading-Doses estimation



### Step 7: Ensure safe reuse/disposal-Health protection and safe production



### Step 8: Periodical monitoring and risk evaluation during and after landspreading

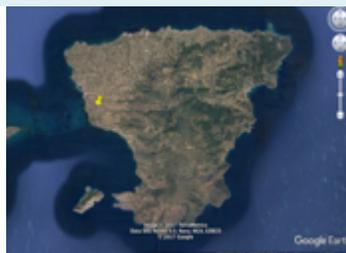


## Implementation of IMaS by farmers

Although IMaS seems to have been developed to assist authorities and policy makers in protecting the environment and controlling environmental quality, however there are steps and actions that can be implemented by individual farmers.

**IMaS has already been implemented at three pilot fields in Greece in close cooperation with farmers**

### EXAMPLE: A pilot field in Aegina



- A field of 0,1 ha
- 30 trees/0,1ha
- 70 years old trees
- Mean annual yield 180 Kg/0,1ha



### Results of soil chemical analysis before IMaS implementation

Soil depth	N mg/g	K cmol/kg	P mg/kg	Fe mg/kg	Mn mg/kg	B mg/kg	Mg cmol/kg	Zn mg/kg	Cu mg/kg	pH	OM* %	EC mS/cm
0-30cm	1,3	1,1	70	5,3	5,3	0,8	4,5	7,2	22	7,6	4,1	3,45
30-60cm	0,8	1,4	45	4,4	4,1	0,7	4,3	4,1	12	7,7	2,2	5,65
60-90cm	0,46	1,5	15	2,2	3,4	0,8	3,7	1,3	8,5	7,6	1,8	8,76

OM\* : Organic Matter

According to the analysis, soil is characterized by high electrical conductivity (EC), which increases with soil depth (the threshold for soil EC is 2mS/cm while values above 4mS/cm indicate saline soils, with high degradation level).

As regard nutrients and metals, the soil has:

- satisfactory nitrogen concentration at the upper soil layer (0-30 cm),
- high phosphorus concentration for the two upper layers
- high potassium concentration in all three soil depths,
- low boron concentration in all three soil depths
- low iron and manganese concentration in all three depths
- very high concentrations of magnesium, copper and zinc in all three depths
- satisfactory organic matter content

**Fertilization program is seen in the table below as well as the respective cost**

Fertilizers	€/kg	Rate, (kg/0.1 ha)	Cost, (€/0.1 ha)
Ammonium sulfate (21-0-0)	0.31	40	12.4
Urea (46-0-0)	0.32	8	2.56
Potassium Sulfate (0-0-50)	1.22	25	30.5
Potassium nitrate (13-0-46)	1.5	15	22.5
<b>Total cost</b>			<b>67.96</b>

Considering the yield, the fertilization cost-return index is  $180:67.96 = 0.38 \text{ €/kg}$  of pistachio

As regards irrigation water, the farmer uses water from a drilling, which is of bad quality, mainly as regard the electrical conductivity, total hardness,  $\text{HCO}_3^-$  and  $\text{Cl}^-$  content and Lime Deposition Potential. The high soil electrical conductivity is owed to the bad irrigation water quality, the excess use of fertilizers and the disposal of waste on soil.

The farmer has his own dehulling machine and processes pistachio nuts in summer, between 20 August and 5 September. Waste stream generated from pistachios is mainly disposed on soil, between the tree lines, at the pilot field or at other fields belonging to him.

## How IMA<sub>S</sub> was implemented at the pilot field

### THE INTEGRATED MANAGEMENT SCENARIO for field No 1

Step 1: Development of regional action plans, set quality criteria, priorities, indicators and targets,

Step 2: Physical, chemical, biological characterization of organic materials

Step 3: Adoption of soil quality indicators and thresholds

Step 4: Development of Suitability Maps

Step 5: Soil characterization-analyses

Assess soil/water/  
waste results with  
CMS

Step 6: Quantification of cultivation targets and definition of cultivation practices

Proposed solutions for soil  
EC-soil washing

Estimate waste and mineral  
fertilizations using the CMS

Manage waste in field

Waste composting

Produce biochar

Use pistachio wastes for  
supplementary fertilization

Step 7: Ensure safe reuse/disposal-Health protection and safe production

Step 8: Periodical monitoring and risk evaluation during and after landspreading

Use of CMMT to upload data  
and communicate with the  
monitoring authority

## How IMaS was implemented at the pilot field

Steps No 5, 6, 7 and 8 of the IMaS were implemented at the pilot field, and in specific:

- Evaluation of soil quality by using the CMS
- Fertilization consultancy by using the CMS
- Waste management at field (wastewater evaporation, composting, biochar production)
- Evaluation of compost quality using the CMS
- Evaluation of land suitability for waste and compost reuse
- Provision of cultivation practices to reduce erosion risk
- Soil washing instructions to reduce soil salts and the EC.
- Recording the results in the CMS and uploading on the CMMT

### Activities and Achievements

#### *Waste management*

As regards waste management, the farmer implemented:

- Collection of wastewater and evaporation into sequential ponds in field
- Composting
- Biochar production

### Collection of wastewater and evaporation into sequential ponds in field

Wastes were separated into solid and wastewater immediately after their production by using a simple separation equipment (metal grids). The solid part was collected and composted while wastewater was transferred into three shallow ponds (each of 5m x 5 m x 40 cm) and left to evaporate. Evaporation, given the Mediterranean conditions, was completed within 2 months. The system constructed was temporary. Protective media (geotextiles) were used to protect soil from infiltration of wastewater.



Shallow evaporation ponds



Shallow ponds immediately after waste production (August 2016)



Solid residues after wastewater evaporation (September 2016)

### Biochar production

The pilot farmer used part of the solid residues to produce biochar.



## How IMaS was implemented at the pilot field

### Composting

The solid waste part (after dehulling) and the residues of the evaporation ponds were mixed with manure, straw and zeolite according to the methodology developed by Agrostrat and were composted. The compost was of very good quality and also met the standards for ECO labeled products

#### Composition of compost produced at the pilot field

Parameter	Compost With zeolite	Threshold
Organic matter, %	27.8	16-38 (field application) > 19.4 (nursery application)
Total N, %	4.3	> 2
C/N	6.5	< 15
Moisture, %	58	40 - 50
pH	7.90	7.2 - 8.5
EC, mS/cm	2.6	< 4.0
Polyphenols, g kg <sup>-1</sup>	0.34	In soil < 40 mg kg <sup>-1</sup>
Total K, % (as K <sub>2</sub> O)	1.6	0.5-1.8
Total P, % (as P <sub>2</sub> O <sub>5</sub> )	0.81	0.5-2.8
Total Ca, % (as CaO)	12	> 2.0
Total Mg, % (as MgO)	1.2	0.3-3
Total Na, %	0.35	< 2.0
Total Cu, mg kg <sup>-1</sup>	20	100 for ECO labeled products
Total Fe, mg kg <sup>-1</sup>	3,545	
Total Zn, mg kg <sup>-1</sup>	139	300 for ECO labeled products
Total Mn, mg kg <sup>-1</sup>	199	
Total As, mg kg <sup>-1</sup>	2.7	10 for ECO labeled products
Total Cd, mg kg <sup>-1</sup>	0.25	1.0 for ECO labeled products
Total Pb, mg kg <sup>-1</sup>	18	100 for ECO labeled products
Total Ni, mg kg <sup>-1</sup>	1.7	50 for ECO labeled products
Total B, %	0.04	
Cl <sup>-</sup> , mg kg <sup>-1</sup> (in mg L <sup>-1</sup> )	2,350 (235)	< 500 mg L <sup>-1</sup> (in water extract)
NO <sub>3</sub> <sup>-</sup> , mg kg <sup>-1</sup> (in mg L <sup>-1</sup> )	5,800 (580)	< 1000 mg L <sup>-1</sup> (in water extract)
PO <sub>4</sub> <sup>3-</sup> , mg kg <sup>-1</sup>	795	
SO <sub>4</sub> <sup>2-</sup> , mg kg <sup>-1</sup>	245	
NH <sub>4</sub> <sup>+</sup> , mg kg <sup>-1</sup> (in mg L <sup>-1</sup> )	60 (6)	< 300 FW (Switzerland limit) Lower than 50 mg L <sup>-1</sup> (in water extract)
NH <sub>4</sub> <sup>+</sup> / NO <sub>3</sub> <sup>-</sup>	0.01	



## How IMaS was implemented at the pilot field

### Fertilization

The farmer used the CMS and uploaded soil analysis in order to receive an evaluation of soil quality and fertility level. Similarly, he uploaded the analyses of the produced compost. However, although the compost was of very good quality, thus, the CMS suggested that it couldn't be dispersed on soil despite the fact that the field was located at a "suitable area" according to the "land suitability maps" for using solid waste use on soil. The reason for this output was the very high soil electrical conductivity and the very high Cu and Zn content. Therefore, only mineral fertilization was suggested according to the outputs of the CMS and the cultivation targets set by the farmer, which was at least 180 tn/0,1ha mean annual production.

Considering soil analysis, the following consultancy was provided by the CMS and also validated by fertilization experts:

#### Spring period (April-May 2017)

- Needed nitrogen 14 kg/ 0.1ha, added to soil at three doses:
  - 3kg N /0.1 ha in the form of ammonium sulfate (15 kg/str) during bud swelling. Ammonium sulfate was incorporated the sooner possible to prevent ammonia volatilization losses.
  - 5.6 kg N /str in the beginning of May and 5.6 kg N /str in the beginning of June. N will be added to soil in the form of ammonium nitrate (17 kg/str + 17 kg/str), which must be incorporated as soon as possible to prevent ammonia volatilization losses.
- Needed iron 0.4 kg/0.1 ha, given in the form of Fe-EDDHA (6,5 % Fe) and in combination with ammonium sulfate during bud swelling.
- Needed Boron 4.5 kg Borax /0.1 ha, added as Borax (11% B) in combination with ammonium sulfate during bud swelling. The suggested dose was 150 gr Borax per tree.

#### Fertilization costs a for the period April-May 2017

Fertilizers	€/kg	Rate, (kg/0.1 ha)	Cost, (€/0.1 ha)
Ammonium sulfate (21-0-0)	0.3	15	4.5
Ammonium nitrate (34-0-0)	0.4	34	13.6
Fe SO <sub>4</sub> (20%)	0.7	2	1.4
Boron (11%)	0.8	4.5	3.6
<b>Total cost</b>			<b>23.1</b>

In June 2017 and after fertilizers applications during the period April-May 2017, new soil samples were collected and analyzed. The results are seen below

#### Values of soil parameters in July 2017 of field No 1 after the 1<sup>st</sup> fertilization program

Soil depth	N mg/g	K cmol/kg	P mg/kg	Fe mg/kg	Mn mg/kg	B mg/kg	Mg cmol/kg	Zn mg/kg	Cu mg/kg	pH	OM %	EC mS/cm
0-30cm	2,3	1,6	54	4,3	8,7	1,5	5,3	11	26	7,29	5,7	6,39
30-60cm	0,94	1,8	28	3,2	8,6	1	4,5	2,4	12	7,32	3,2	6,51
60-90cm	0,69	1,6	2,1	3,6	8,4	1,1	4,4	0,73	7,5	7,37	1,1	7,91

Soil EC was still very high, while as regard nutrients and metals, the soil has:

- high nitrogen concentration at the upper soil layer (0-30 cm),
- satisfactory phosphorus concentration , lower than initially
- still high potassium concentration in all three soil depths,
- satisfactory boron concentration in all three soil depths
- still low iron and somehow higher manganese concentration in all three depths
- still very high concentrations of magnesium, copper and zinc in all three depths
- satisfactory organic matter content

## How IMaS was implemented at the pilot field

### Fertilization

Considering soil results, the new fertilization program was retrieved by the farmer using the CMS. Moreover, in order to address the high EC, it was decided to suggest soil washing. For this, irrigation water increased by 12%, percentage which was calculated by using the *Leaching Factor* theory, as described in the previous pages.

The suggested fertilization program for the summer period was:

#### Summer period (July 2017)

- Needed nitrogen 14 kg N/ 0.1 ha added to soil at three doses:
  - 3kg N/0.1 ha in the form of ammonium sulfate (15 kg/0.1 ha) during bud swelling. Ammonium sulfate was incorporated as soon as possible to prevent ammonia volatilization losses.
  - 5.6 kg N /str in the beginning of May and 5.6 kg N /str in the beginning of June, The N will be added to soil in the the form of ammonium nitrate (17 kg/0.1 ha + 17kg/0.1 ha) which must be incorporated as soon as possible to prevent ammonia volatilization losses.
- Needed Boron 4.5 kg Borax /0.1 ha, added as Borax (11% B) in combination with ammonium sulfate during bud swelling. The suggested dose was 150 gr Borax per tree

#### Fertilization costs for the 1<sup>st</sup> pilot field in Aegina for the summer period (July 2017)

Fertilizers	€/kg	Rate, (kg/0.1 ha)	Cost, (€/0.1 ha)
Ammonium sulfate (21-0-0)	0.3	15	4.5
Ammonium nitrate (34-0-0)	0.4	34	13.6
Boron (11%)	0.8	4.5	3.6
<b>Total cost</b>			<b>21.7</b>

### Benefits in terms of yield increase and reduction of fertilization costs

#### Increase in yield

An average pistachio yield in 2016 and 2017 was about 234 kg/ 0.1 ha, **increased by 30%**.

#### Reduction in fertilization costs

The Fertilization cost-return index is  $234:44.8 = 0.19 \text{ €/kg}$  of pistachio.

Under the sustainable fertilization program using the CMS, the fertilization cost-return index was reduced by **50%**, compared to a conventional fertilization program. Net fertilization costs =  $(67.96 \text{ €/0.1 ha} \times 10) - (44.8 \text{ €/0.1 ha} \times 10) = 232 \text{ €/ha}$ . Therefore, when considering the production parameters of the pilot field, the implementation of the IMaS reduced fertilization costs at about **232 € per ha**.



## How IMA<sub>S</sub> was implemented at the pilot field

### Fertilization

#### Improvement of soil properties

By the end of the second fertilizers application, and after the soil-washing program, soil samples were collected again and analyzed. An improvement in soil properties were recorded as it can be seen in the following table.

Values of soil parameters after the 2<sup>nd</sup> fertilization and washing programs for the pilot field.

Soil depth	N mg/g	K cmol/kg	P mg/kg	Fe mg/kg	Mn mg/kg	B mg/kg	Mg cmol/kg	Zn mg/kg	Cu mg/kg	pH	OM %	EC mS/cm
0-30cm	1,9	1,3	45	5,7	7,9	1,3	3,8	10	18	7,22	4,3	3,04
30-60cm	1,0	1,5	23	4,5	8,1	1,1	2,1	3,0	7,6	7,36	3,1	3,41
60-90cm	0,61	1,0	3,0	3,9	7,0	0,6	2,0	0,6	6,5	7,21	1,0	3,76

By comparing the values of soil parameters after the implementation of IMA<sub>S</sub> with the initial, i.e. before the implementation, soil quality seems improved as regard:

- the EC, which was significantly reduced after soil washing program
- phosphorus, the concentration of which returned between the normal values (phosphorus was not added to the cultivation due to its high concentration in soil)
- manganese, which was increased (although still low)
- boron, the concentration of which is now satisfactory
- magnesium, although still high, thus it was significantly decreased

No significant change was recorded for potassium, iron, copper and zinc within the period of the pilot demonstration. However, better results also for these elements are anticipated for the coming years if the farmer continues to implement AgroStrat results.

**It should be highlighted that the benefits mentioned corresponds to the application of IMA<sub>S</sub> over a short period of time.**

**However, they were extremely positive and, in addition to improved soil quality, they also reduced production costs.**

**It is therefore expected that its systematic implementation will result in more significant and consistently measured benefits for both the environment and the economic development of the producers.**



# AgroStrat

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

**We remain on the Web!**

**Visit us at:**

<http://www.agrostrat.gr>



## Contact us

Dr. M. K. Doula (project coordinator): [mdoula@otenet.gr](mailto:mdoula@otenet.gr)

Dr. A. Sarris: [asaris@ret.forthnet.gr](mailto:asaris@ret.forthnet.gr)

Prof. K. Komnitsas: [kknmitsas@isc.tuc.gr](mailto:kknmitsas@isc.tuc.gr)

Dr. S. Theocharopoulos: [sid\\_theo@otenet.gr](mailto:sid_theo@otenet.gr)