Small, low cost systems for agricultural waste management at field level -the case of pistachio waste at Aegina island, Greece

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Technical University of Crete, School of Mineral Resources Engineering, 73100 Chania, Crete, Greece
AgroStrat

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

**LIFE11 ENV/GR/951**

1/10/2012-30/9/2017

Budget: 1,026,509 €

www.agrostrat.gr

With the support of:

- Region of Attiki, Greece
- Agricultural Association of Aegina Island
- Cooperative of Pistachio producers of Aegina island

During project lifetime:

- Region of Sterea Ellada, Greece
- Cooperative of Pistachio producers of Makri, Fthiotida prefecture
- Cooperative of Pistachio producers of Molos, Fthiotida prefecture

Athens 2017, Friday 23 June
Aims in brief……

1. Development, implementation of an integrated, recourse based scenario for the protection and improvement of serious degraded cultivated soils in the Mediterranean area.

2. Identification of pressures and practices that contribute to soil degradation, identification of soil quality indicators

3. Development of software monitoring tools for the sustainable management of intensively cultivated Mediterranean areas.

4. Development of a GIS-based Land Information System (GIS-LIS) and land suitability maps that will allow controlled and sustainable application of treated pistachio wastes and will guarantee preservation of soil quality.

5. Development of sustainable cultivation practices and re-use of treated agricultural wastes
Pistachio waste

- Pistachios are harvested between late August and early September.

- The nuts after harvest are transported to the processing facility where they are dehulled, and dried. Fresh water is used for the dehulling and from this process the main waste stream is produced, which apart from **hulls** contains also **pistachios, shells and water**.

- On average, **for 1tn of fresh nuts, 2 tn of waste are generated**.
Pistachio waste

- After the completion of the process, without separating solid waste from wastewater, farmers mainly dispose waste on soil, in sea or in wells and streams.

- **Wastewater** is dark colored, bad smelling, has high electrical conductivity and is rich in polyphenols and inorganics.

- The **solid waste**, which mainly consists of the nuts’ pericarps, is very rich in organic matter, polyphenols, and other constituents.

- Pistachio waste cannot be considered as hazardous, by the classical mean of hazardous waste definition, since it contains no heavy metals or pathogens, however, due to its very high content in polyphenols and its very high electrical conductivity (i.e. salts content) may cause significant detrimental effects on soil quality.
# Pistachio Wastewater

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average value</th>
<th>Parameter</th>
<th>Average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.22</td>
<td>Total Fe, mg L(^{-1})</td>
<td>0.51</td>
</tr>
<tr>
<td>EC, mS/cm</td>
<td>6.4</td>
<td>Total Zn, mg L(^{-1})</td>
<td>1.39</td>
</tr>
<tr>
<td>COD, g L(^{-1})</td>
<td>11.6</td>
<td>Total Mn, mg L(^{-1})</td>
<td>0.68</td>
</tr>
<tr>
<td>Polyphenols, g L(^{-1})</td>
<td>5.5</td>
<td>Total B, mg L(^{-1})</td>
<td>5.5</td>
</tr>
<tr>
<td>K, g L(^{-1})</td>
<td>1.04</td>
<td>NH(_4^+), mg L(^{-1})</td>
<td>9.0</td>
</tr>
<tr>
<td>Ca, % (w/v)</td>
<td>2.8 x 10(^{-2})</td>
<td>Cl(^-), mg L(^{-1})</td>
<td>1000</td>
</tr>
<tr>
<td>Mg, % (w/v)</td>
<td>1.24 x 10(^{-2})</td>
<td>NO(_3^), mg L(^{-1})</td>
<td>102</td>
</tr>
<tr>
<td>Na, mg L(^{-1})</td>
<td>180</td>
<td>PO(_4^{3-}), mg L(^{-1})</td>
<td>91</td>
</tr>
<tr>
<td>Total Cu, mg L(^{-1})</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Athens 2017, Friday 23 June
## Pistachio Solid Waste

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average value</th>
<th>Parameter</th>
<th>Average value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic matter, %</td>
<td>79</td>
<td>Total Cu, mg kg⁻¹</td>
<td>106</td>
</tr>
<tr>
<td>Total N, %</td>
<td>2.5</td>
<td>Total Fe, %</td>
<td>0.58</td>
</tr>
<tr>
<td>Moisture, %</td>
<td>60</td>
<td>Total Zn, mg kg⁻¹</td>
<td>99</td>
</tr>
<tr>
<td>pH</td>
<td>7.44</td>
<td>Total Mn, mg kg⁻¹</td>
<td>85</td>
</tr>
<tr>
<td>EC, mS/cm</td>
<td>3.8</td>
<td>Total B, %</td>
<td>0.13</td>
</tr>
<tr>
<td>Total Polyphenols, g kg⁻¹</td>
<td>4.5</td>
<td>Cl⁻, mg kg⁻¹</td>
<td>4,900</td>
</tr>
<tr>
<td>Total K, % (as K₂O)</td>
<td>2.9</td>
<td>NO₃⁻, mg kg⁻¹</td>
<td>1,200</td>
</tr>
<tr>
<td>Total P, % (as P₂O₅)</td>
<td>1.0</td>
<td>PO₄³⁻, mg kg⁻¹</td>
<td>50</td>
</tr>
<tr>
<td>Total Ca, % (as CaO)</td>
<td>5.5</td>
<td>SO₄²⁻, mg kg⁻¹</td>
<td>354</td>
</tr>
<tr>
<td>Total Mg, % (as MgO)</td>
<td>0.68</td>
<td>NH₄⁺, mg kg⁻¹</td>
<td>308</td>
</tr>
<tr>
<td>Total Na, %</td>
<td>0.69</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
What AgroStrat achieved at its pilot fields

1st case: 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 were constructed in one of the pilot fields and can be permanent or temporary.

- Protective media (geotextiles) were used to protect soil from leaching.
What AgroStrat achieved at its pilot fields

2nd case: Shallow Evaporation ponds

- The system was constructed in Aegina island by exploiting a former, almost destroyed, pig breeding area.
- The five stall places were reconstructed to form a sequential system of five reservoirs for waste collection.
- 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.

August 2016

October 2016

Athens 2017, Friday 23 June
....and here comes the question

Which is the correct dose to be applied on soil?

Materials

- Wastewater
- Solid waste
- Compost
### Measurement Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Matter (OM), %</td>
<td></td>
</tr>
<tr>
<td>Organic Carbon (OC), %</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
</tr>
<tr>
<td>Electrical Conductivity (EC)</td>
<td>mS/cm (dS/m)</td>
</tr>
<tr>
<td>Moisture, %</td>
<td></td>
</tr>
<tr>
<td>Dry Matter, %</td>
<td></td>
</tr>
<tr>
<td>Total Nitrogen (N)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Phosphorus Pentoxide (P2O5)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Potassium Oxide (K2O)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Foreign Matter, %</td>
<td></td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Iron Oxide (FeO)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Sodium (Na)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Boron (B)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Manganese (Mn)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Cadmium (Cd)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Chromium Total (Cr tot)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Hexavalent Chromium (Cr VI)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Nickel (Ni)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Arsenic (As)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Lead (Pb)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Molybdenum (Mo)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Fluoride (F)</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Ammonium (NH4)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Phosphate (PO4)</td>
<td>% (g/100g)</td>
</tr>
<tr>
<td>Sulfate (SO4)</td>
<td>% (g/100g)</td>
</tr>
</tbody>
</table>
### Evaluation Report

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6</td>
<td>The pH value is low and an expert advice is recommended. Low pH may cause problems to acid soils and also mobilization of heavy metals.</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>52%</td>
<td>Organic matter is considered satisfactory. In general materials with organic matter between 16-38% are suitable for field application while materials with organic matter higher than 19.4% are suitable for nursery application. Moreover, due to the high organic matter content, the material can be awarded with an ECO-label according to the COM Decision (EC) n° 799/2006 for soil improvers.</td>
</tr>
<tr>
<td>Electrical Conductivity</td>
<td>8 mS/cm (dS/m)</td>
<td>The electrical conductivity is high and the application of the material may cause salt accumulation, toxicities to plants and soil salinization. An expert advice is strongly recommended.</td>
</tr>
<tr>
<td>Moisture</td>
<td>50%</td>
<td>The moisture of the materials is within normal values range and satisfies also the COM Decision (EC) n° 799/2006 for soil improvers that can be awarded with an EU ECO label.</td>
</tr>
<tr>
<td>Total Nitrogen (N)</td>
<td>0.51%</td>
<td>Total nitrogen content is satisfactory and satisfies also the COM Decision (EC) n° 799/2006 for soil improvers that can be awarded with an EU ECO label. The lowest acceptable N concentration is 2%. Therefore a nitrogen content between 2 and 3% is acceptable.</td>
</tr>
<tr>
<td>Inorganic nitrogen content</td>
<td>0.065%</td>
<td>The inorganic form of nitrogen is lower than the 20% of the total nitrogen and the material is considered safe for soil application. However, all other</td>
</tr>
</tbody>
</table>
....but the software estimates also the correct dose to be distributed on soil

- For fertilizing pistachio trees
- Just to dispose off
Field Data

Add Field Information

Field Name: EXAMPLE
Field Description: ATHENS2017
Area: 2 stremma
Country: Greece
Latitude: 37.735328
Longitude: 23.438122

Select field's location:
(Double click on the map to insert pin location)

Cancel  Save
....but the software estimates also the correct dose to be distributed on soil

- For fertilizing pistachio trees
- Just to dispose off
Waste Disposal

Water Waste Disposal

For waste you should input the following parameters based on chemical analysis:

- **Get Mean Values**
  - Nitrates (NO₃): 103 mg/L (ppm)
  - Ammonium (NH₄): 9 mg/L (ppm)
  - Phosphorus (P): 0.1 % (g/100mL)
  - Phosphorus Pentoxide (P₂O₅): 0.68 mg/L (ppm)
  - Copper (Cu): 5500 mg/L (ppm)
  - Polyphenols: 5500 mg/L (ppm)

For soil you should input the following parameters:

- **Get GIS Values**
  - Total Nitrogen (N)
  - Available Phosphorus (Olsen-P)
  - Exchangeable Potassium (K)

Insert waste parameters

Insert soil parameters
### Water Waste Disposal

For waste you should input the following parameters based on chemical analysis:

#### Get Mean Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
<th>Value 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrate (NO₃)</td>
<td>102</td>
<td>mg/L</td>
</tr>
<tr>
<td>Ammonium (NH₄)</td>
<td>9</td>
<td>mg/L</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>1.94</td>
<td>g/L</td>
</tr>
<tr>
<td>Potassium Oxide (K₂O)</td>
<td>1.39</td>
<td>mg/L</td>
</tr>
</tbody>
</table>

#### Phosphorus (P)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus P₂O₅</td>
<td>0.02</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.68</td>
</tr>
<tr>
<td>Polyphenols</td>
<td>5500</td>
</tr>
</tbody>
</table>

For soil you should input the following parameters:

#### Get GIS Values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Nitrogen (N)</td>
<td>0.02</td>
</tr>
<tr>
<td>Available Phosphorus ( Olsen-P)</td>
<td>12</td>
</tr>
<tr>
<td>Exchangeable Potassium (K)</td>
<td>0.5</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>8.2</td>
</tr>
<tr>
<td>Available Zinc (DTPA-Zn)</td>
<td>1.6</td>
</tr>
<tr>
<td>Total Polyphenols</td>
<td>50</td>
</tr>
</tbody>
</table>

---

**Advisory**
The maximum amount of water waste that can be disposed of in soil is: 6.5 m³ distributed to the entire field.
....but the software estimates also the correct dose to be distributed on soil

- For fertilizing pistachio trees
- Just to dispose off
### Soil Advisory

<table>
<thead>
<tr>
<th>Element</th>
<th>Advisory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>Recommended dose 8.6Kg/1000m². Broadcast the fertilizer during orchard establishment and incorporate into soil. Apply 0.77 tons of the organic material on soil surface. It is suggested to broadcast the fertilizer and the organic material all over the field.</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>Apply the whole recommended phosphorus rate of 38Kg/1000m², before or during bud swelling period. Divide the recommended fertilizer amount according to the number of field trees, broadcast fertilizer under the canopy and incorporate into soil. Broadcast the organic material on soil surface all over the field. During the off-period it is recommended to use the half phosphorus fertilization rate.</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>The needed potassium amount can be provided by broadcasting 0.77 tons of the organic material. Therefore, no additional potassium fertilization is needed.</td>
</tr>
</tbody>
</table>

### Compost Advisory

In order to assess the suitability of the organic material for landsplading according to the national and the EU legislative framework, you must enter the concentrations of heavy metals contained in soil and organic material (total forms). The proposed consultancy have no legal basis.

Σύμφωνα με τα στοιχεία που δηλώσετε, η μέγιστη ποσότητα οργανικού υλικού, η οποία μπορεί να χρησιμοποιηθεί στα 1 στρέμματα του χωριού σας είναι 0.77 τόνοι.
What is behind the software
23 Soil Thematic Maps

Authors: Ch. Kolovos, S. Theocharopoulos
Soil Depth

**Yπομνήμα**

Βάθος Εδάφους (cm)

- 0-15
- 15-30
- 30-60
- 60-100
- 100-150
- >150
- URBAN

Συντάκτες:

Χ. Κολοβός, Σ. Θεοχαρόπουλος
Erosion Risk

**YΠΟΜΝΗΜΑ**

**ΔΙΑΒΡΩΣΗ**
- ΚΑΜΙΑ ΔΙΑΒΡΩΣΗ
- ΑΣΘΕΝΗΣ ΔΙΑΒΡΩΣΗ
- ΜΕΤΡΙΑ ΔΙΑΒΡΩΣΗ
- ΜΕΤΡΙΑ ΔΙΑΒΡΩΣΗ
- URBAN

Συντάκτες: Χ. Κολοβός, Σ. Θεοχαρόπουλος
Soil Map

Athens 2017, Friday 23 June
Soil Potassium

ΥΠΟΜΝΗΜΑ

K_MEO_100G

0.000

0.001 - 0.129

0.130 - 0.255

0.256 - 0.384

0.385 - 0.639

>0.639

URBAN

Συντάκτες:
X. Κολοβός, Σ. Θεοχαρόπουλος
Soil Organic Matter

Athens 2017, Friday 23 June

Συντάξαντες: Χ. Κολοβός, Σ. Θεοχαρόπουλος
...meaning that we know soil properties everywhere on the island

....then we evaluated soils as regards the suitability to accept wastes
  ...by applying the FAO evaluation methodology
  ...with which one can classify soils into suitability classes by rating pre-selected properties

LAND SUITABILITY MAPS FOR WASTE REUSE ON SOILS
Land suitability map for the disposal of pistachio processing solid waste

LEGEND
Areas characterization for solid waste disposal
- **S1**: Suitable
- **S2**: Moderately suitable
- **S3**: Marginally suitable
- **N1**: Temporarily unsuitable
- **N2**: Permanently unsuitable
- **URBAN**

Soil data processing, analysis and evaluation:
Dr. Maria Doula (Benaki Phytopathological Institute)

Soil sampling and soil characterization:
Dr. Sif Theoxaropoulos, Chronis Kolovos (ELGO DEMETER)
Water Waste Disposal

For waste you should input the following parameters based on chemical analysis:

- **Get Mean Values**
  - Nitrate (NO₃) 103 mg/L (ppm)
  - Ammonium (NH₄) 9 mg/L (ppm)
  - Potassium (K) 1.04 g/L
  - Potassium Oxide (K₂O) g/L
  - Zinc (Zn) 1.39 mg/L (ppm)

- Phosphorus (P) 0.1 mg/L (ppm)
  - Phosphorus Pentoxide (P₂O₅) mg/L (ppm)
  - Copper (Cu) 0.68 mg/L (ppm)
  - Polyphenols 5500 mg/L (ppm)

For soil you should input the following parameters:

- **Get GIS Values**
  - Total Nitrogen (N) % (g/100g)
  - Available Phosphorus ( Olsen-P) mg/kg (ppm)
  - Exchangeable Potassium (K) cmol(+)/kg

- Copper (Cu) mg/kg (ppm)
  - Available Zinc (DTPA-Zn) mg/kg (ppm)
  - Total Polyphenols mg/kg

Insert soil parameters
### Waste Disposal

#### Water Waste Disposal

To be considered, it is supposed that wastewater land spattering will take place by incorporation into an open depression.

For waste you should input the following parameters based on chemical analysis:

<table>
<thead>
<tr>
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<th>Unit</th>
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</thead>
<tbody>
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<td>9</td>
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</tr>
<tr>
<td>Potassium (K)</td>
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<td>g/L</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>0.02</td>
<td>% (g/100m)</td>
</tr>
<tr>
<td>Phosphorus Pentoxide (PO₄)</td>
<td></td>
<td>mg/L (ppm)</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>0.68</td>
<td>mg/L (ppm)</td>
</tr>
<tr>
<td>Polyphenols</td>
<td>5500</td>
<td>mg/L (ppm)</td>
</tr>
</tbody>
</table>

For soil you should input the following parameters:

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<tr>
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<th>Unit</th>
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<td>0.02</td>
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</tr>
<tr>
<td>Exchangeable Potassium (K)</td>
<td>0.5</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>8.2</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Available Zinc (DTPA-Zn)</td>
<td>1.6</td>
<td>mg/kg (ppm)</td>
</tr>
<tr>
<td>Total Polyphenols</td>
<td>50</td>
<td>mg/kg (ppm)</td>
</tr>
</tbody>
</table>

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CMMT: Agrostrat Default Server

Athens 2017, Friday 23 June
The maximum amount of water waste that can be disposed of in soil is: 6.5 m³ distributed to the entire field.
Authorities can monitor soil properties

Provide consultancy to the farmers
The application provides temporal evaluation of the cultivated areas through comprehensive charts, or statistical data analysis on a spatial scale analysis, potential to visualize the analysis results and produce local/regional maps. The platform allows individual users to communicate through the “Cultivation Management Software” with the responsible local/regional authority and request directives and guidance about their cultivated fields or discharge areas.
Strategy depends upon the ability to foresee future consequences of present initiatives

Thank you

Dr. Maria K. Doula

Benaki Phytopathological Institute
Greece