Life cycle analysis of pistachio production in Greece

Georgios Bartzas[1], Dimitra Zaharaki[2], Kostas Komnitsas[2]

[1] School of Mining and Metallurgical Engineering, National Technical University of Athens, Zografos Campus, 157 80 Athens, Greece

[2] School of Mineral Resources Engineering, Technical University of Crete, 73 100 Chania, Greece.

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Objective and Outline of Presentation

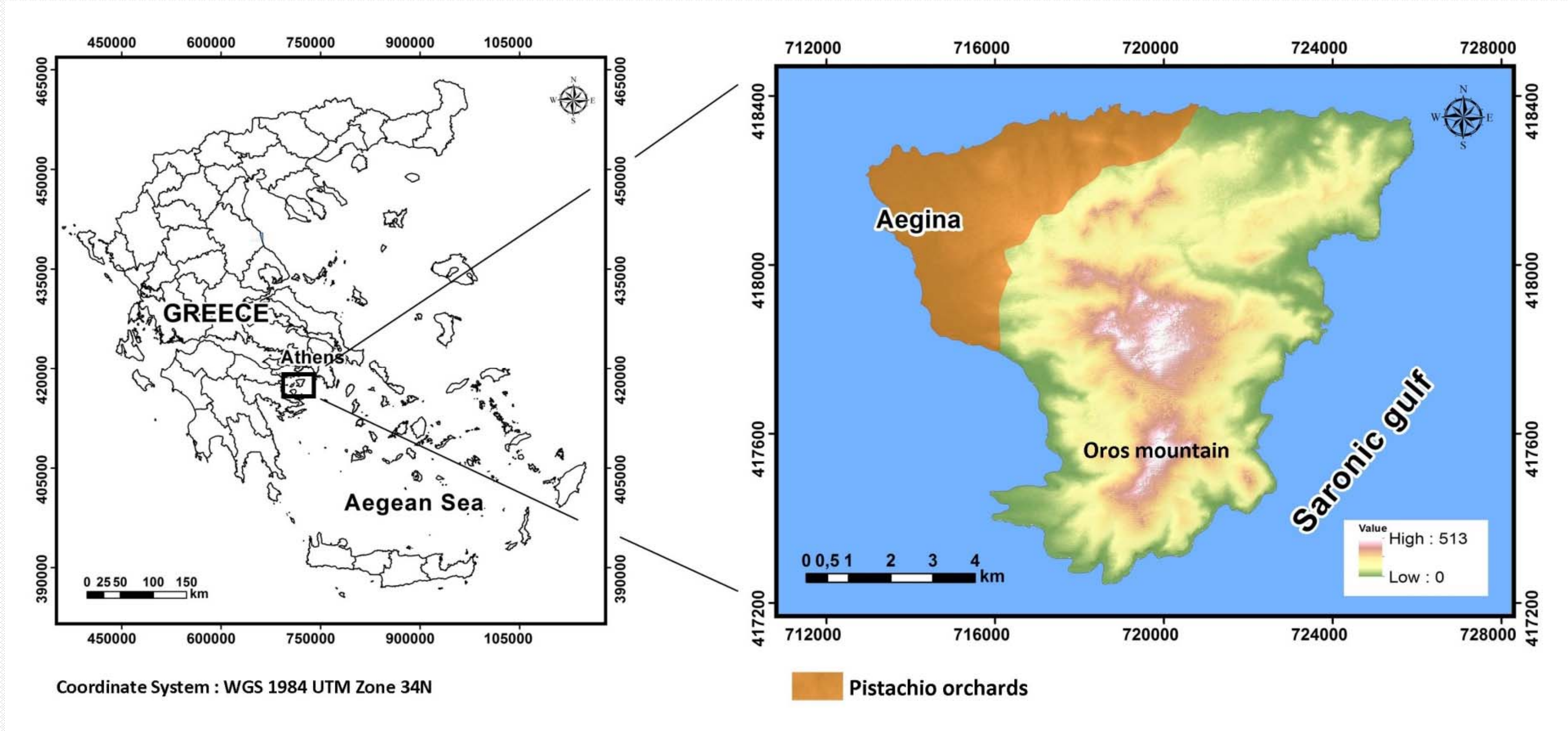
A life cycle assessment (LCA) approach to assess energy consumption and greenhouse gas footprints of the pistachio production in the island of Aegina

- **Pistachio production in Greece**
- **Study area**
- **Goal and Definition - LCA methodology**
- **Results and Discussion**
- **Conclusions**

Pistachio production in Greece

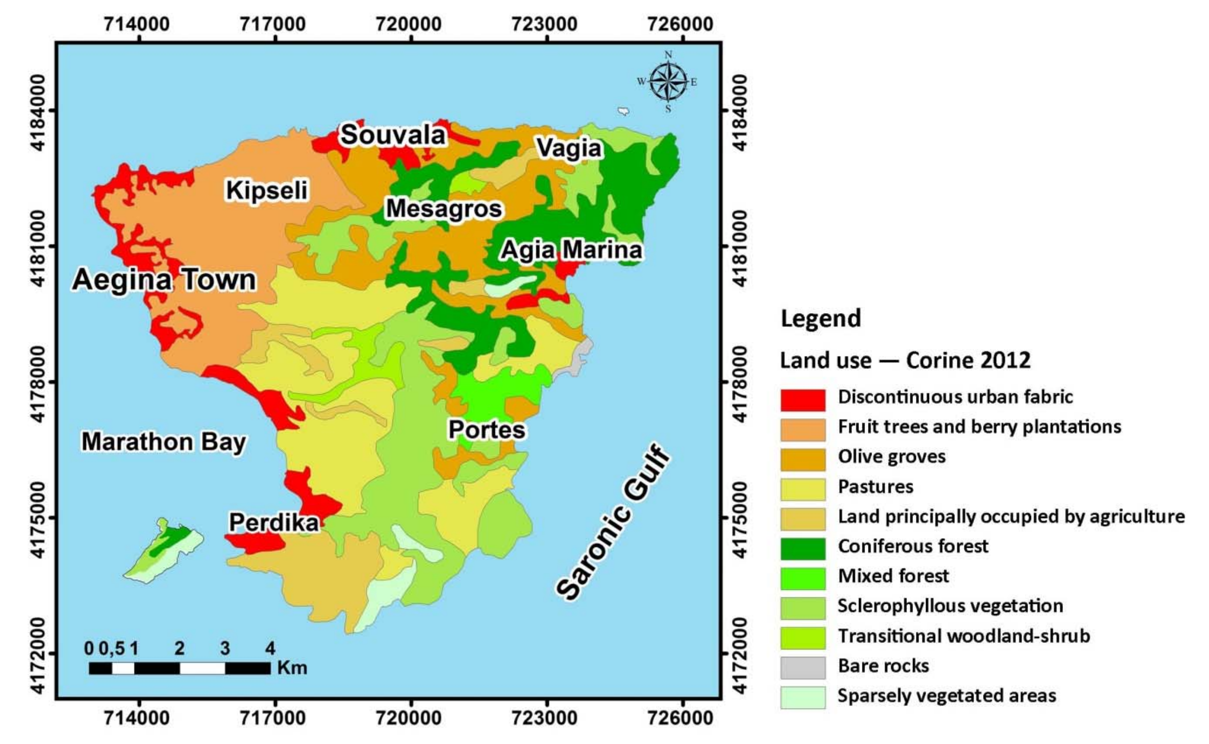
- **Among the EU-28 countries, Greece has the largest production (11 MT) followed by Italy (3 MT).**
- **Mainly produced in the regions of Attiki (Aegina island and Megara), Central Greece (Fthiotis, Veotia and Evia), Thessaly (Almyros) and North Greece (Chalkidiki).**
- **120,000 pistachio trees are cultivated in Aegina accounting for 11% of the total pistachio production in the country**
- **High quality Protected Designation of Origin (PDO) pistachios with premium pricing in the EU market, due to their particular organoleptic characteristics, excellent flavor and appeal**

Study area – Aegina island (1)



- **Aegina island is located approximately 16.5 miles south of Athens with a total surface area of 87 km² and a coastline of 57 km**
- **Characterized by semi-arid Mediterranean climate**
- **Typical topography, coastal plains and mountainous areas with hilly intermediate formations.**

Study area – Aegina island (2)



- **The north part of the study area is intensively cultivated and the major land uses include family orchards with pistachio trees scattered in the urban areas**
- **Main cultivations in the irrigated land are pistachios 63%, olive trees 20%, almond trees 7%, lemon trees 4%, vineyards 2% and others 4%.**

Goal and Scope definition

- **Goal: Quantify the energy consumption and greenhouse gas footprint of the existing life cycle of pistachio production and also explore more sustainable and eco-friendly practices that can be used in production/ processing stages.**
- **LCA was carried out using the commercial GaBi 6 software and related databases.**
- **Functional Unit: 1 t of dry in-shell pistachios**
- **Data types obtained from different sources**

  a) Primary: (Survey data – AgroStrat project)

  b) Secondary: (Literature data)

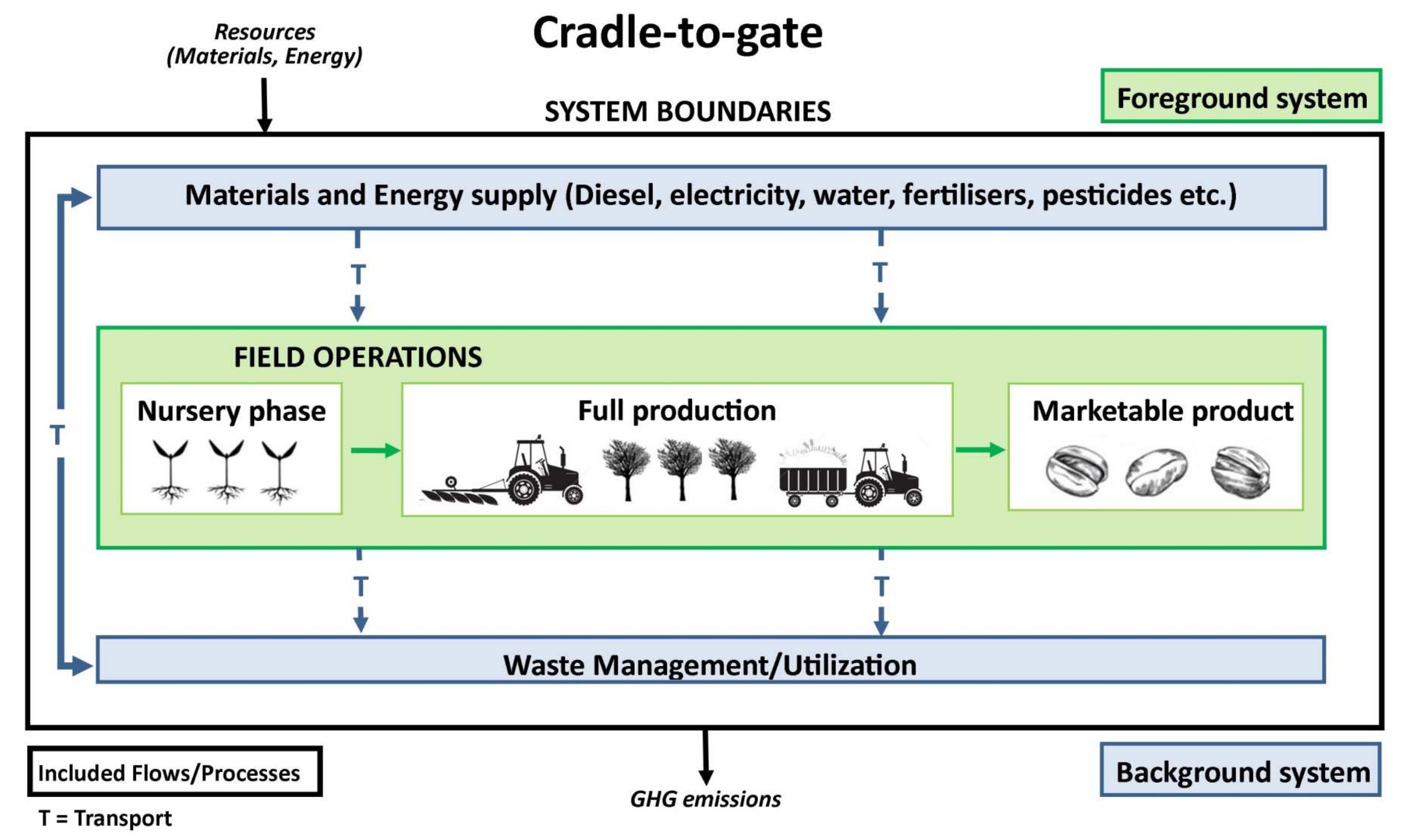
  c) Background: from available Gabi software databases (Ecoinvent, Professional)

LCA methodology

- **Cradle-to-gate LCA approach, considering all the production processes involved, from raw materials extraction (i.e the cradle) to the point where the final product (in-shell pistachios) is made available to the market (i.e the gate).**
- **Five impact categories were defined according to CML 2001 (Center of Environmental Science of Leiden University) and Cumulative Energy Demand (FU: Functional Unit, 1 t of dry in-shell pistachios)**

Impact category	Acronym	Units
Acidification potential	AP	t $SO_{2eq}\cdot FU^{-1}$
Eutrophication potential	EP	kg $PO_{4eq}\cdot FU^{-1}$
Global warming potential (100 years)	GWP	t $CO_{2eq}\cdot FU^{-1}$
Ozone depletion potential	ODP	kg CFC-$11_{eq}\cdot FU^{-1}$
Photochemical ozone creation potential	POCP	kg $C_2H_{4eq}\cdot FU^{-1}$
Cumulative energy demand	CED	GJ eq$\cdot FU^{-1}$

Pistachio production system boundaries



LCA scenarios main data

Baseline scenario (BL): Current situation

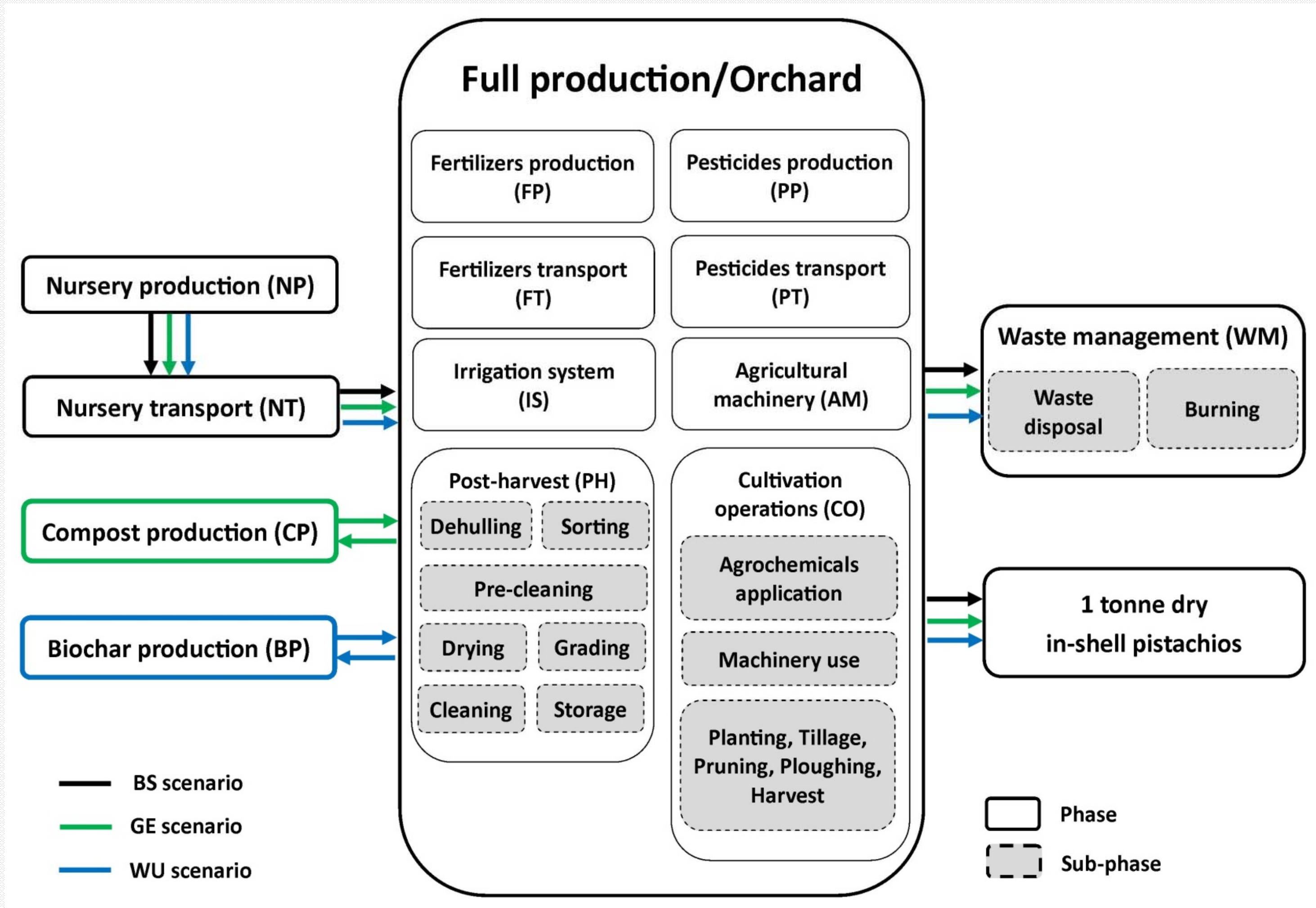
Stage	Output	Unit	Value	Management
Cultivation	Dead trees and orchard clearing	kg/ha	235	Burning material (100%)
	Prunings	kg/ha	1380	Uncontrolled disposal (35%) On farm burning (65%)
Post-harvest	Hulls	kg/ha	3290	On farm dumping/uncontrolled disposal (80%) Animal feed (20%)
	Culls	kg/ha	283	On farm dumping/uncontrolled disposal (100%)

A) **Baseline scenario (BL): Current situation (normal mode of field-works for pistachio production)**

B) **Green Energy scenario (GE): higher share of organic production - 50% (250 kg ha^{-1} per year) of the currently used N/P/K chemical fertilizers is replaced by compost (20 t ha^{-1}) produced on-site from organic solid wastes.**

C) **Waste Utilization scenario (WU): the production of biochar using 100% of the currently produced hulls and culls i.e. 3573 kg ha^{-1} per year and its use as soil amendment.**

System Boundaries: Scenarios



In all scenarios investigated, constant yield of pistachio production (2.5 t/ha) was considered.

Main agronomic characteristics and LCI data of the baseline scenario (BS)

Characteristics	Unit*	PDO Pistachios
Cultivar	-	Aegina
Orchard age	years	40
Density	trees ha^{-1}	250
Yield**	t ha^{-1}	2.5
Harvest period	-	1st week of September
Irrigation technique	-	Furrow, drip and sprinkler irrigation
Irrigation period	-	April to September
Fertilizers application rate		
N (as N)	kg ha^{-1}	230
P (as P_2O_5)	kg ha^{-1}	70
K (as K_2O)	kg ha^{-1}	200
Pesticides application rate		
Fungicides	kg ha^{-1}	3
Insecticides	kg ha^{-1}	2.4
Irrigation water	m^3 ha^{-1}	4450

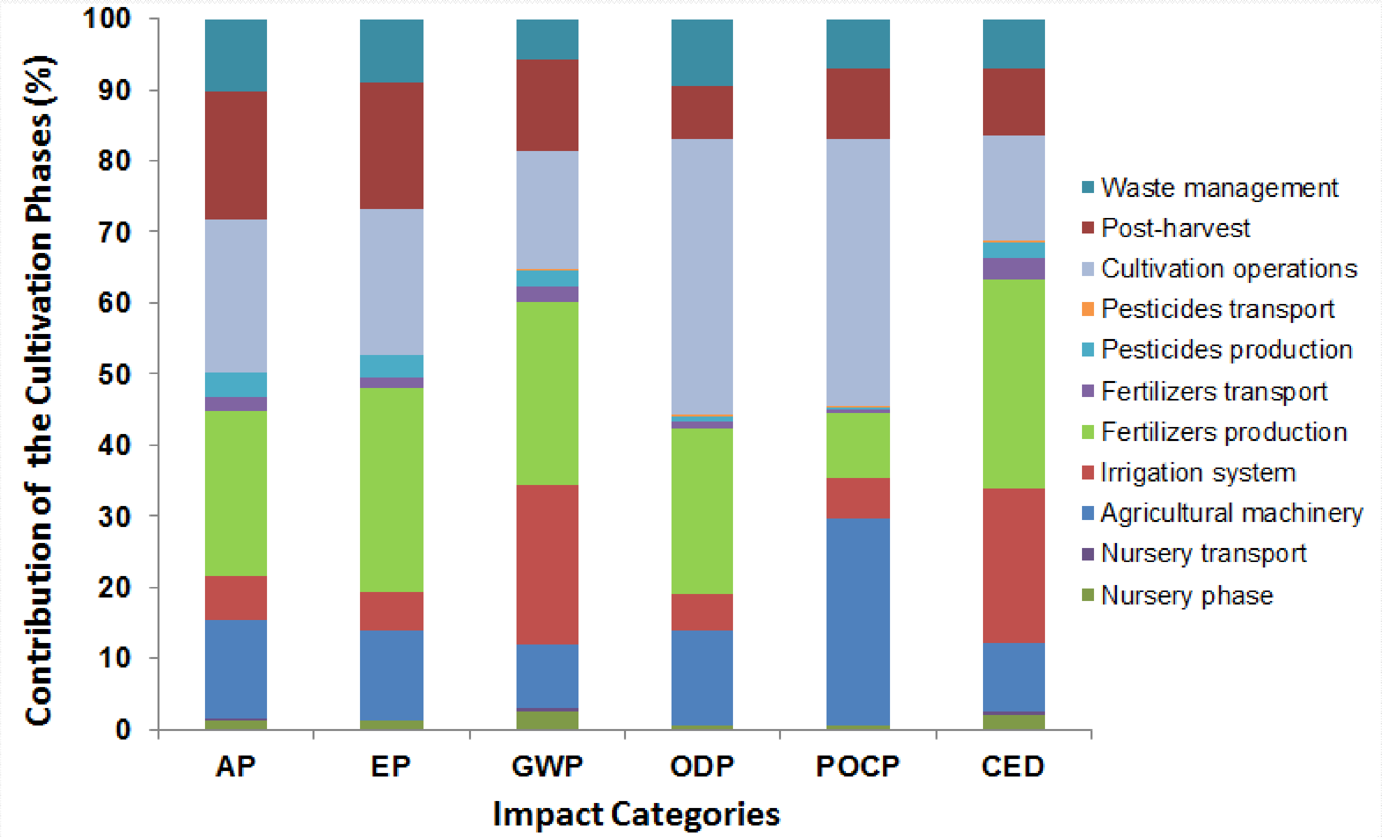
*Mean values refer to the period 2011-2015; ** refer to FU (functional unit)

Overall LCA Results

Impact Category	Scenario		
	BL	GE	WU
Acidification potential (AP) [kg SO_2-eq·FU^{-1}]	8.59E+00	7.95E+00	7.68E+00
Eutrophication potential (EP) [kg PO_4-eq·FU^{-1}]	3.69E+00	3.42E+00	3.29E+00
Global warming potential (GWP) (100 years) [kg CO_2-eq·FU^{-1}]	2.04E+03	1.86E+03	1.78E+03
Ozone depletion potential (ODP) [kg CFC-11-eq·FU^{-1}]	1.19E-04	1.06E-04	9.97E-05
Photochemical ozone creation potential (POCP) [kg C_2H_4-eq·FU^{-1}]	3.24E-01	3.01E-01	2.91E-01
Cumulative energy demand (CED) [GJ·FU^{-1}]	28.05E+00	25.39E+00	28.76E+00

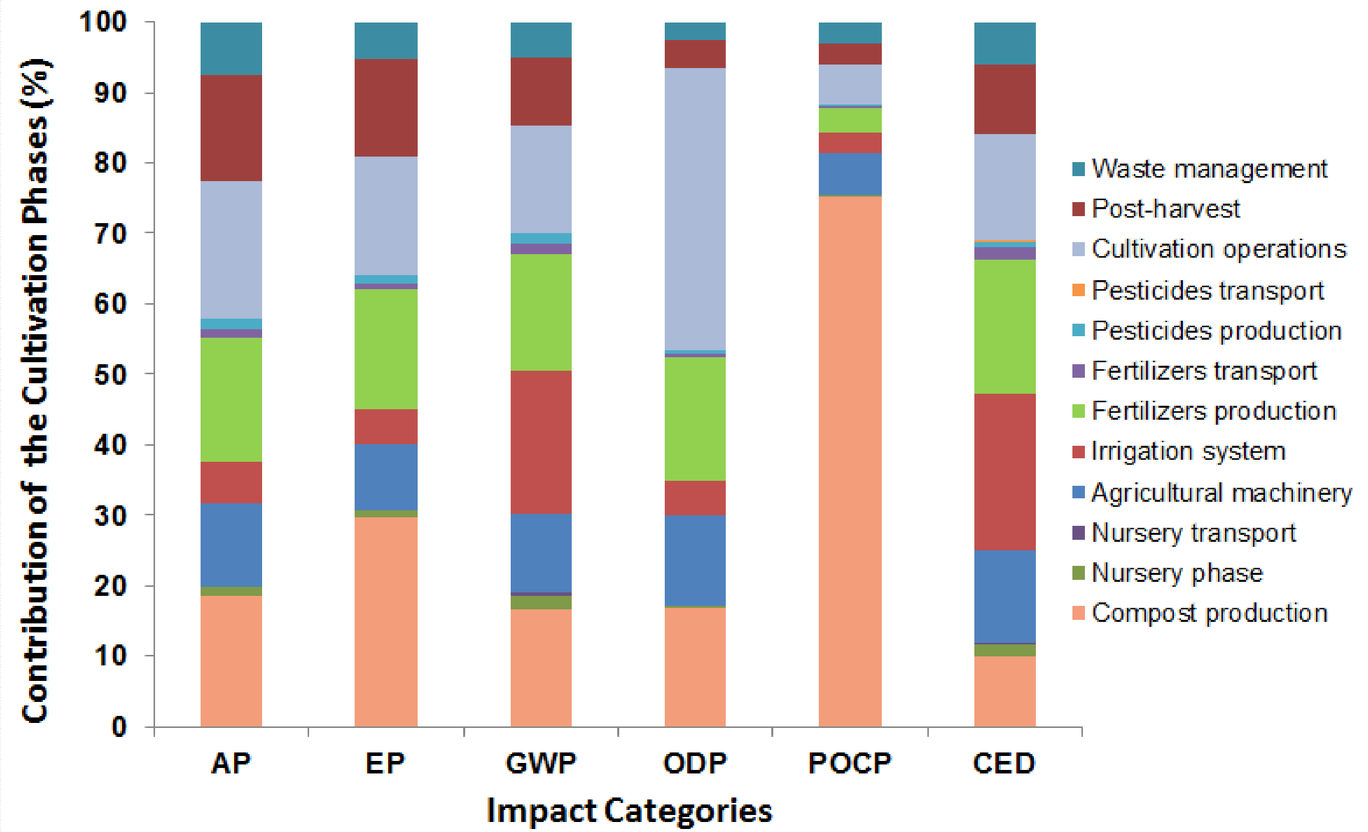
- **The WU scenario caused the lowest impacts per tonne of dry in-shell pistachios among the different scenarios assessed for almost all categories, except for CED, while the highest impact was assigned to the BL scenario.**
- **Environmental impacts caused by scenarios GE and WU are lower, from 4% to 17% depending on the impact category assessed, than those derived by the BL scenario**

Results for Baseline Scenario (BL)



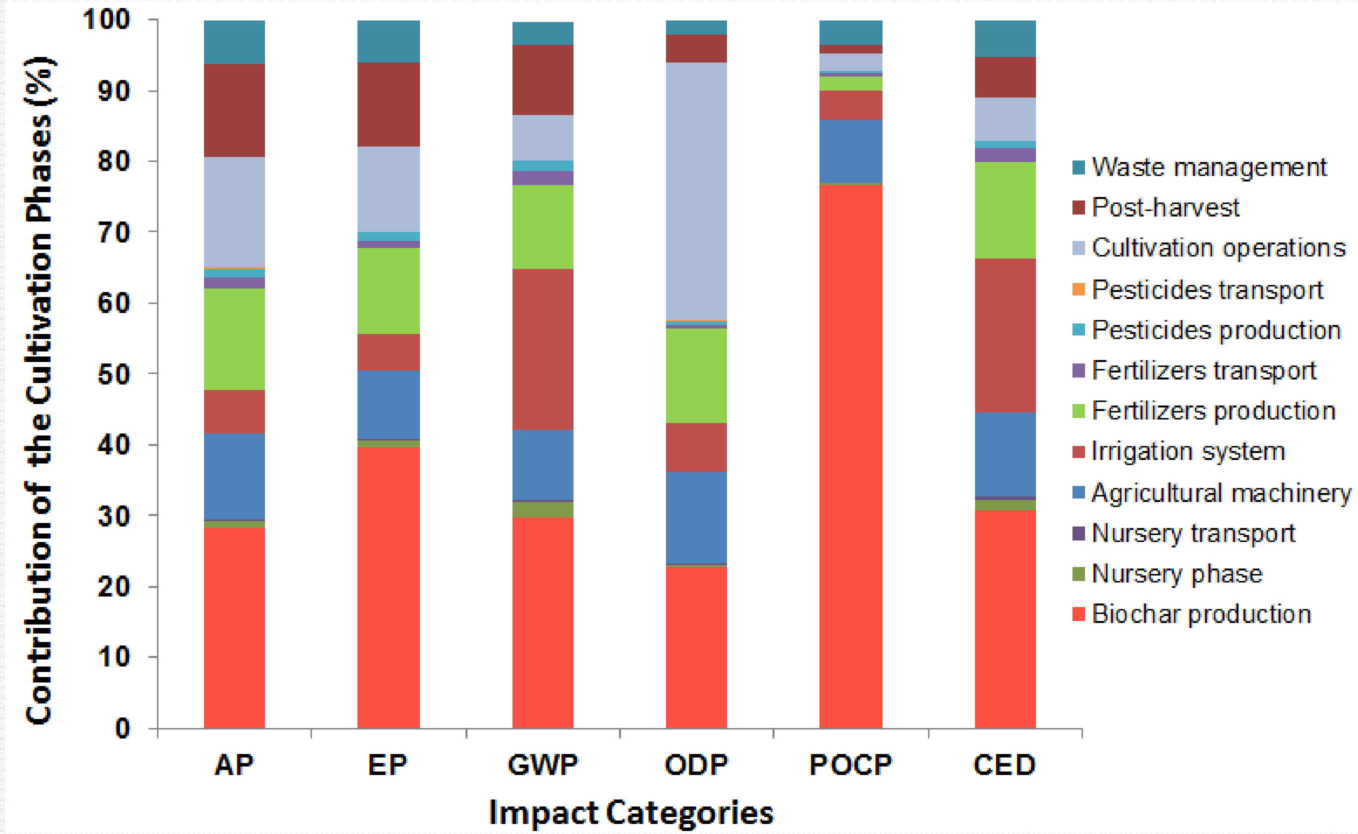
- **Fertilizers production (FP) is the major contributor, ranging from 23% to 29%, to the total single score for the impact categories of AP, EP, GWP and CED.**
- **The sub-phase of cultivation operations (CO) had the second highest contribution to all impact categories, except for GWP and CED**

Results for Green Energy Scenario (GE)



- **The highest contribution to impact categories GWP, ODP and CED for the GE scenario derived from compost production (CP), which contributes 10–75% to the cumulative impacts**
- **The fertilizers production (FP) phase represented the second highest burden, varying between 17% and 19% for all impact categories, except for POCP, for which its contribution was almost 4%.**

Results for Waste Utilization Scenario (WU)



- **Biochar production (BP) was the main source of emissions, ranging from 23 to 76%, to all impact categories, except for POCP**
- **Substitution of fertilizers with biochar reduced direct N_2O soil emissions in terms of AP and EP that could result from N-fertilizer application along with smaller GHG benefits associated with the elimination of open burning of solid pistachio waste**

Conclusions (1/2)

- **LCA can be used to identify opportunities to improve energy sustainability of the various processes and examine how they might be affected under different future scenarios**
- **Present production of pistachios in Aegina is evaluated in terms of energy consumption and GHG emissions.**
- **A baseline scenario representing the current operation and two alternative ones (Green energy and Waste Utilization scenarios) aiming at GHG emissions reduction, waste utilization and sustainability improvement were investigated.**
- **The environmental impacts associated with the current production of pistachios in Aegina are mainly due to the life cycle phases of fertilizers production (FP), irrigation system (IS) and cultivation operations (CO).**

Conclusions (2/2)

- The **Waste Utilization (WU) scenario**, involving combined use of biochar and chemical fertilizers, exhibited the best overall environmental performance, with lower contributions for most impact categories, except for CED, compared to the BL.
- Slightly lower environmental benefits were also derived from the GE scenario, when 50% of the currently used chemical fertilizers was replaced by compost produced on-site from organic solid wastes generated within the same cultivation system
- Application of compost and biochar, instead of chemical fertilizers, offers significant environmental benefits.
- More data obtained from additional field studies, pertinent to production and application of soil amendments would be extremely useful in order to minimize uncertainty of the obtained results.

Acknowledgments

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AgroStrat, www.agrostrat.gr

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