Energy flow analysis of irrigated pistachio production in Aegina, Greece

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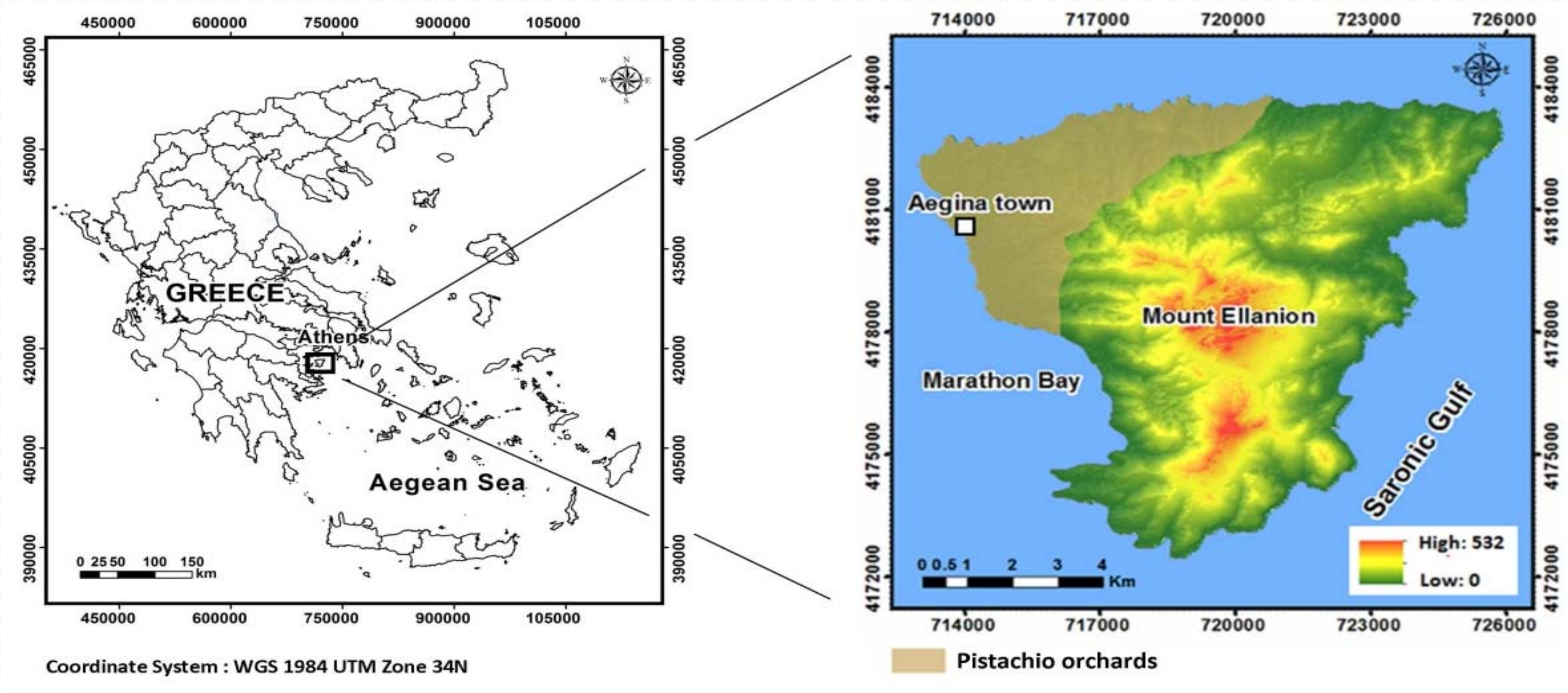
Outline of Presentation

- **Pistachio production in Greece**
- **Study area**
- **EFA methodology**
- **Statistical and Sensitivity analyses**
- **Results and Discussion**
- **Conclusions**

Pistachio production in Greece

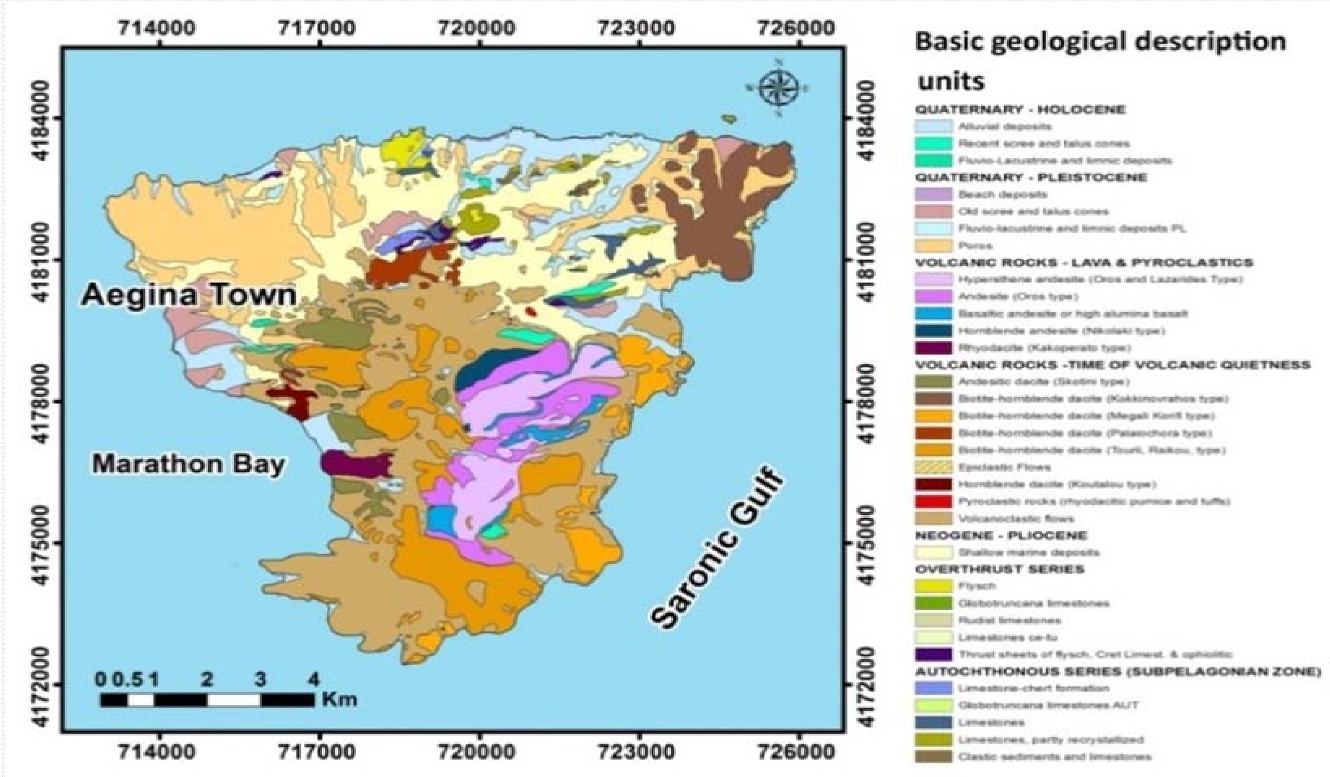
- **Among the EU-28 countries, Greece has the largest production (11 kt) followed by Italy (3.6 kt) and Spain (2.5 kt).**
- **Mainly produced in the regions of Attiki (Aegina island and Megara), Central Greece (Fthiotis, Veotia and Evia), Thessaly (Almyros) and North Greece (Chalkidiki).**
- **120,000 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)



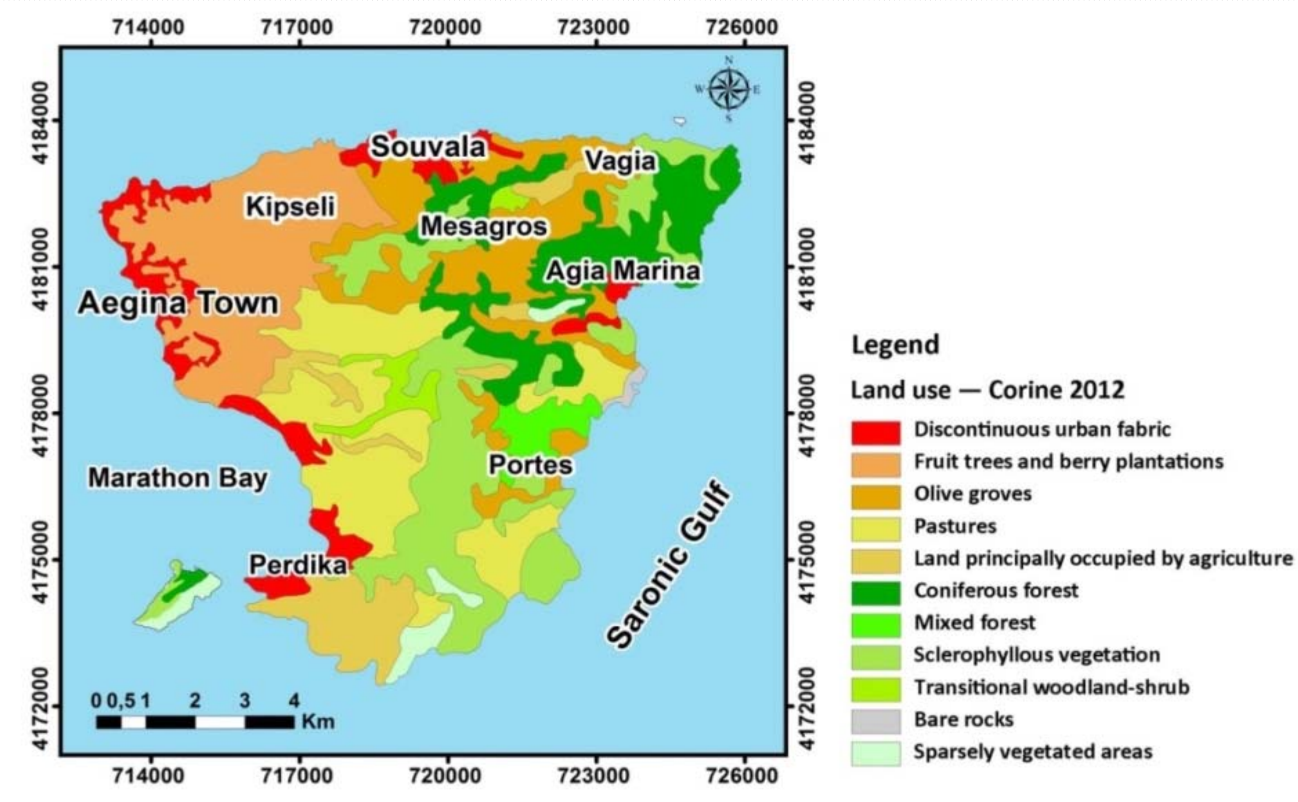
- **Aegina island is located approximately 16.5 miles south of Athens with a total surface area of 87 km² and a coastline of 57 km**
- **Characterized by semi-arid Mediterranean climate**
- **Typical topography, coastal plains and mountainous areas with hilly intermediate formations.**

Study area – Aegina island (2)



- **Plio-Pleistocene volcanic island with two geomorphological settings**
- **A permeable region (34%) located in the north and covered by Neogene lacustrine formations along with shallow marine sediments**
- **A less permeable region (66%) covered by large volcanoclastic dacitic flows and minor andesitic lava flows**

Study area – Aegina island (3)



Groundwater and soil contamination

- **intrusion of seawater**
- **overexploitation of coastal aquifers**
- **use of fertilizers /pesticides in agriculture and**
- **the uncontrolled disposal of wastewater /solid waste**

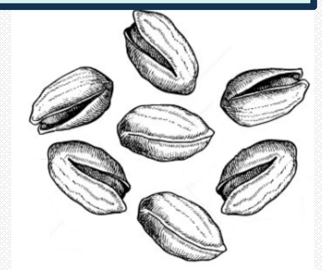
- **The north part of the study area is intensively cultivated and the major land uses include family orchards with pistachio trees scattered in the urban areas**
- **Main cultivations in the irrigated land are pistachios 63%, olive trees 20%, almond trees 7%, lemon trees 4%, vineyards 2% and others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

Goal and Scope definition

Determine the energy performance of irrigated pistachio (Pistachia vera. L) production in Aegina, Greece,

Quantify wasteful uses of energy and identify the target processes that offer promise in reducing energy requirements

Fill an important gap and **propose** guidelines for developing energy efficient, eco-friendlier and goal-oriented sustainable strategies



- **Input data obtained from different sources**

  a) **Primary: (on-site survey campaigns conducted in 36 pistachio orchards - AgroStrat project - 2012/2016)**

  b) **Secondary: (retrieved from various energy-related sources and databases)**

Main inventory data

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 2012-2016; ** refer to in shell pistachios

EFA Methodology (1)

Production process	Unit	Energy equivalents (MJ unit^{-1})
I. Direct energy inputs		
Human labor	h	1.96
Diesel fuel	L	47.8
Electricity	kWh	11.93
Water for irrigation	m^3	1.02
II. Indirect energy inputs		
N (as N)	kg	47.1
P (as P_2O5)	kg	15.8
K (as K_2O)	kg	9.28
Farmyard manure	kg	0.3
Herbicides	kg	238
Fungicides	kg	216
Insecticides	kg	101.2
Agricultural machinery	h	62,7
III. Output		
In shell pistachios	kg	11.80

EFA Methodology (2)

- A selected set of four energy indicators was calculated to evaluate energy performance based on the energy equivalents of the inputs and outputs.

Energy Indicator	Equation	Description
Energy use efficiency	$\frac{\text{Total energy output } (\text{MJ ha}^{-1})}{\text{Total energy input } (\text{MJ ha}^{-1})}$	Calculates the influence of inputs expressed in energy units for obtaining output energy
Net energy	$\text{Energy output } (\text{MJ ha}^{-1}) - \text{Energy input } (\text{MJ ha}^{-1})$	Displays the difference between the gross energy output produced and the total energy required
Energy productivity	$\frac{\text{Crop yield } (\text{kg ha}^{-1})}{\text{Total energy input } (\text{MJ ha}^{-1})}$	Describes the amount of a product obtained per unit of input energy
Specific energy	$\frac{\text{Total energy input } (\text{MJ ha}^{-1})}{\text{Crop yield } (\text{kg ha}^{-1})}$	Describes the amount of energy used to produce one kg of a product

Statistical and Sensitivity analyses

- **A principal component analysis (PCA) was conducted in order to identify the key drivers of the energy flow-analysis associated with the pistachio production in the study area.**
- **Sampling adequacy was tested by Kaiser–Meyer–Olkin's (KMO) criterion and Bartlett's test of sphericity (BTS) while reliability was checked by Cronbach's alpha**
- **Statistical analysis was performed using SPSS software package ver. 20.**

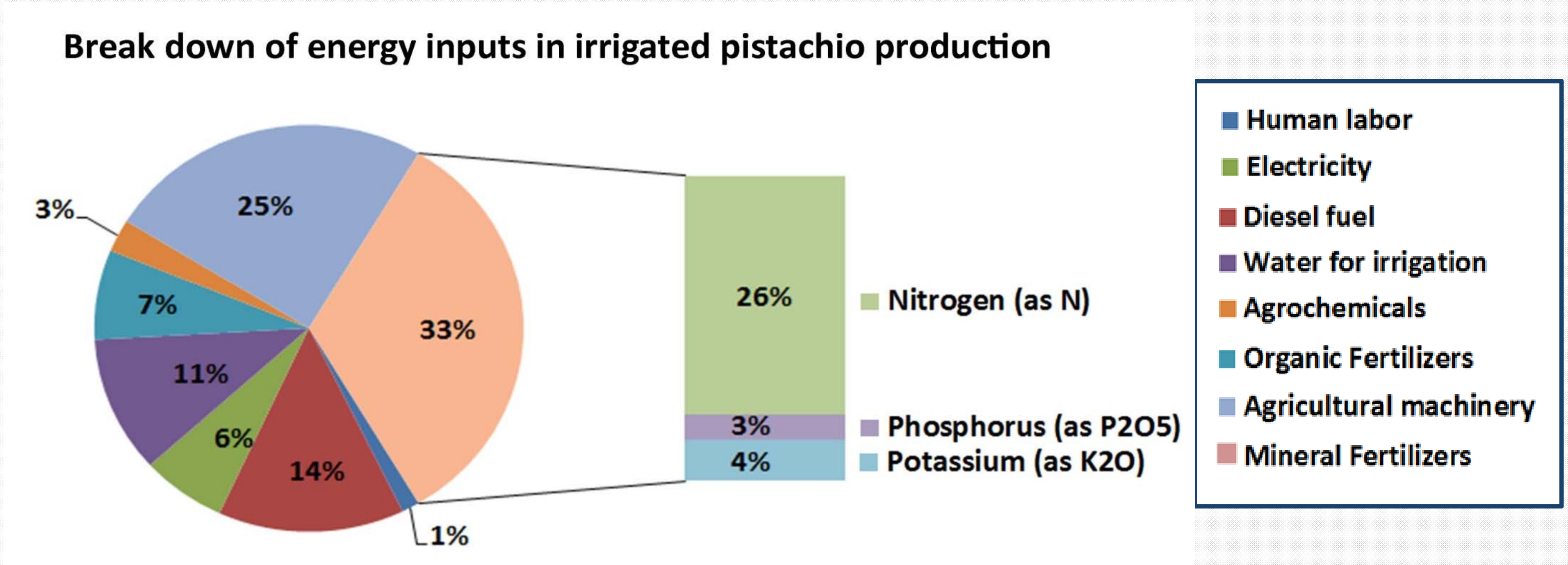
- **Sensitivity analysis was at last employed to quantify the direction and intensity of change in the output energy value and its related energy indicators due to changes to the various independent exogenous variables considered in the present study.**
- **With respect to the response coefficients of the energy inputs, the marginal physical productivity (MPP) method was applied using linear regression**

Overall EFA Results

Indicators	Unit	Mean	Share (%)	Min	Max	SD
Total Energy Input	MJ ha^{-1}	41,897	100	28,559	56,271	5,422
Total Energy Output	MJ ha^{-1}	29,500	–	13,617	42,350	6,667
Direct Energy	MJ ha^{-1}	13,669	32.63	7,125	23,971	3,600
Indirect Energy	MJ ha-1	28,228	67.37	21,434	35,218	2,727
Renewable Energy	MJ ha-1	8,105	19.35	5,507	11,526	1,526
Non-Renewable Energy	MJ ha-1	33,792	80.65	22,496	45,892	4,515
Energy use Efficiency	–	0.70	–	0.42	0.86	0.10
Net Energy	MJ ha^{-1}	-12,397	–	-20,848	-6,379	3,228
Energy productivity	kg MJ^{-1}	0.06	–	0.04	0.07	0.01
Specific energy	MJ kg^{-1}	16.76	–	11.75	26.35	3.33

- **On average, the indirect energy and non-renewable energy accounted for 81% and 67% of the total energy input consumed for the pistachio production, respectively.**
- **Energy use efficiency and energy productivity were 0.70 and 0.06 kg MJ^{-1}, respectively, thus indicating that there is a significant potential for improving energy efficiency of pistachio production in the study area.**

Contribution analysis



- **Nitrogen fertilization accounted for 79% of the total energy consumption associated to the use of mineral fertilizers, thus indicating that pistachio production in Greece is fully relied on this highly energy intensive input due to its manufacture process.**
- **The phase of agricultural machinery had the second highest contribution to energy consumption (25% of the total).**

Statistical analysis

Variable	Vari-Factors 1	2	3	4	5	Com.
Energy input for N-fertilizers (MJ ha^{-1})	0.95	-0.08	0.02	0.35	-0.02	0.97
Share of organic fertilizers (%)	0.83	-0.06	0.01	0.19	-0.01	0.86
Total energy input (MJ ha^{-1})	0.91	0.12	0.30	0.15	-0.02	0.95
Acreage of the farm (ha)	-0.52	-0.16	-0.18	0.03	0.83	0.56
Net energy (MJ ha^{-1})	-0.34	0.89	-0.11	-0.28	0.01	0.69
Pistachio yield (kg ha^{-1})	0.29	0.88	0.13	0.08	0.16	0.94
Energy input for machinery (MJ ha^{-1})	-0.04	-0.02	0.86	0.08	0.06	0.88
Number of tractor operations (n)	-0.12	-0.06	0.74	0.05	0.03	0.71
Horse power of operating tractors (n)	-0.09	-0.04	0.69	0.03	0.01	0.64
Energy input for irrigation (MJ ha^{-1})	-0.07	-0.06	-0.12	0.91	-0.01	0.86
Number of irrigation applications (n)	-0.15	-0.02	-0.07	0.78	-0.03	0.73
Water table depth (m)	-0.05	-0.04	0.16	0.68	0.61	0.63
Proportional explained variance (%)	26.34	20.24	15.45	12.09	6.59	
Cumulative share of explained variance (%)	26.34	46.58	62.03	74.12	80.71	

New PCA-defined factors: 1 = Nitrogen-fertilizer intensity, 2 = cultivation practices, 3 = machinery intensity, 4 = irrigation intensity and 5 = site characteristics.

Sensitivity analysis

Exogenous variables (Xi*): Energy from	Endogenous variable: Pistachio yield		
	ai	t-Ratio	MPP
1. Human labor	-0.06	-0.88	-0.005
2. Diesel fuel	-0.04	-0.39	-0.02
3. Mineral fertilizers	0.38	2.07**	0.17
4. Organic fertilizers	0.10	1.65	0.21
5. Agrochemicals	0.08	1.50	0.12
6. Agricultural machinery	0.24	2.02**	0.18
7. Electricity	0.21	1.74	0.19
8. Water for irrigation	0.19	0.52	0.13
Durbin-Watson	1.85		
R^2	0.90		
Return to scale	1.10		

*i=1,2,3,4,5,6,7,8; **Indicates significance at 5% probability level

- **Organic fertilizers, electricity and agricultural machinery exhibited the highest MPP values i.e. 0.21, 0.19 and 0.18, respectively, thus indicating that an increase of 10 MJ in each of aforementioned inputs would lead to additional increase in pistachio yield by 2.1, 1.9 and 1.8 MJ ha^{-1}.**

Conclusions (1)

- EFA can be used to identify opportunities to improve **energy efficiency** of the various processes and explore management practices for energy conservation at farm scale
- Present production of pistachios in Aegina is evaluated in terms of a set of **four energy indicators** along with different **forms of energy** (direct/indirect and non-renewable/renewable).
- EFA results obtained from the present study showed that pistachio production in Aegina is **fairly energy efficient** and is highly dependent on **indirect and non-renewable sources of energy**.
- The energetic impacts associated with the current production of pistachios in Aegina are mainly due to the single energy inputs of **nutrient management** (chemical and organic fertilizers), **agricultural machinery, diesel fuel consumption** and **irrigation**.

Conclusions (2)

- **Principal Component Analysis (PCA) showed that five crucial factors (nitrogen-fertilizer intensity, cultivation practices, machinery intensity, irrigation intensity and site characteristics) have proved to be statistically important on yield of pistachios and energy consumption**
- **Sensitivity analysis showed that more application of organic fertilizers, electricity and agricultural machinery will likely contribute to pistachio yield increase.**
- **Several options for improvement in terms of energy savings can been proposed, involving the efficient use of chemical fertilizers, agricultural machinery and irrigation water along with the promotion of the use of renewable sources of energy.**

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