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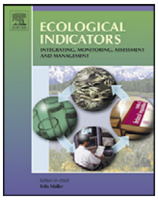

Energy inputs, outputs and greenhouse gas emissions in organic, integrated and conventional peach orchards

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ABSTRACT

Energy analysis in peach orchards is useful to decide best management strategies. The objectives of this study were to evaluate (a) the energy flow among conventional, integrated and organic farming systems and (b) the effect of farming system to greenhouse gas-emissions. Sixteen farms (four conventional, nine integrated, three organic) at six locations in northern Greece were selected randomly during the years 2008 and 2009. Multidimensional data analyses were used to detect (a) clusters of farming systems and (b) associations between farming systems and production coefficients variables. Three groups of farming systems and three groups of variables were revealed. Farming systems in the same group respond more or less similarly to the production coefficients variables. Non-parametric tests concerning external variables (outputs, energy efficiency, fruit production, CO_2, CH_4 and N_2O) showed that the variables in organic farming cluster were at average significantly lower. Similarities and/or dissimilarities among farming systems, can probably be related to farm topography, production coefficients and local farming practices. The results showed that organic farming could reduce inputs and gas-emissions.

1. Introduction

Energy use in agriculture has been increasing in response to population growth, to diminishing of arable land and a desire for higher standards of living. Continuous demand in increasing food production resulted in intensification, a threat to the environment worldwide. Intensification has also led to growing concern about conserving biodiversity and its role in maintaining functional biosphere (Tilman et al., 2002). It can have negative local consequences, such as increased erosion, lower soil fertility, and reduced biodiversity as well as negative regional consequences, such as pollution of ground water and eutrophication of rivers and lakes; and negative global consequences, including impacts on atmospheric constituents and climate (Raviv, 2009; Müller et al., 2006). The risk of adverse environmental effects is lower with less intensive farming methods (Tilman et al., 2002; Dantsis et al., 2010; Sattler et al., 2010). Low intensity agriculture, such as integrated and organic farming, may contribute to biodiversity maintenance (Hole et al., 2005; Gibson et al., 2007) in agricultural land besides the economic benefits. Generally, efficient use of energy will minimize environmental problems and prevent degradation of natural resources.

Energy use for crop production is generally correlated with greenhouse gas emissions and depletion of natural resources. In order to reduce both, potentials for energy saving in farming activities have to be identified (Bechini and Castoldi, 2009). This may lead to site specific optimised energy intensities in production. Fossil energy in agricultural sector must be used in a sustainable manner (Brown et al., 1998) considering that fossil fuels are a limited source of energy and a source of CO_2 emissions in the atmosphere (IPCC, 1997). An environmental and energy analysis combination of a production system may be more useful for the application of best management practices (Kaltsas et al., 2007; Franzese et al., 2009; Kavargiris et al., 2009; Liu et al., 2010a). Development of agricultural systems with low inputs of energy could lead to reduction of agricultural CO_2 emissions (Pimentel and Pimentel, 1996; Dalgaard et al., 2001; Smith et al., 2008; Muller, 2009; Schneider and Smith, 2009). On a global basis the agricultural sector consumes about 5% of the total fossil energy used (Pinstrup-Andersen, 1999). To reduce environmental impacts of agriculture, methods to understand and assess the impact on nature need to be employed (Cuadra and Björklund, 2007). One of the methods suggested is the Life Cycle Assessment (LCA) method (SETAC, 1993; ISO, 1997, 1998).

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Greece has a suitable climate for growing many crops, vegetables and fruits. Among fruits, peach is important for the Greek economy (Minagric, 2011). In 2009, peach (*Prunus persica* L. Batsch) was grown in Europe in an estimated area of 282,482 ha and produced 22.1% of the total world production, mainly in Italy, Spain, and Greece (FAO, 2011). In Greece, peach was cultivated in a total area of 36,900 ha, with a production of 734,000 Mg year^{-1} in 2009 (FAO, 2011). It is well suited for conventional, integrated and organic production in Greece, especially in Prefecture of Pella, northern Greece, where there is a long tradition in peach production (Minagric, 2011). The development of energy efficient farming systems should help to reduce the greenhouse gas emissions of agricultural production (Dalgaard et al., 2001).

The objectives of this study were to evaluate, by selecting conventionally, integrated and organically cultivated peach areas in northern Greece, (a) the differences and similarities in energy flow among conventional, integrated and organic farming systems, and (b) the effect of farming system on greenhouse gas (CO_2, CH_4 and N_2O) emissions based on the used fossil energy and fertilizers. This study also focuses on the possibility of some feasibility agri-environmental indicators being used in comparisons.

2. Materials and methods

Four conventional, nine integrated, and three organic peach orchards were selected randomly in six areas in the Prefecture of Pella, northern Greece (see Appendix A) during the years 2008 and 2009. The canning peach variety “Andross” was grown in all farms. The size of all studied peach orchards was about 0.8 ha. All orchards were previously cultivated with chestnut, sweet cherry and apple trees. The age of the cultivated peach orchards in the selected areas was about 12 years for all farming systems. Mean annual temperature, precipitation and relative humidity (means ± 1 SD; $n = 13$ years) were 15 ± 4 °C, 600 ± 51 mm and 70 ± 15%, respectively for Loutrochori, Mavrovounio, and Sevastiana and 13 ± 4 °C, 805 ± 37 mm and 65 ± 15%, respectively for Arnisa, Xanthogia, and Zervi.

Agricultural practices in conventional, integrated and organic peach orchards during the study period are presented in Table 1. The calculation of the energy sequestered by the crop was based on the farmers' work schedule, the time required for each operation, the number of laborers and machines, all inputs used as field operations (fertilizer application, irrigation, harvesting, etc.) and production coefficients (fertilizers, plant protection products, etc.). To calculate this energy, material and fuel consumption used, as well as time needed to complete each operation, were recorded. Using the conversion factors of Table 2, the embodied energy of machinery and human labor was determined. Total energy embodied in machinery equaled 142.7 MJ kg^{-1} (Pimentel et al., 1973; Fluck, 1985). This included energy for manufacturing (86.38 MJ kg^{-1} of mass; Pimentel et al., 1973), energy for repairs and maintenance (0.55 times the energy for manufacturing; Fluck, 1985) and energy for transportation (8.8 MJ kg^{-1}; Bridges and Smith, 1979). Total energy embodied in machinery was adapted according to machinery life spans (15–20 years), weight and the technology as used in Greece. The energy required for each operation was estimated by summing up the embodied energy, which was calculated as mentioned above, plus the energy of fuel used by machinery and human labor.

The amount of fossil energy used was estimated by the litres of diesel needed to refill the reservoir. The greenhouse gas emissions (CO_2, CH_4, N_2O) were computed for soils according to Küstermann et al. (2008), for fuel according to the CO_2-equivalent factors by IPCC (1997, 2006) and for fertilizers according to IPCC (1997) and EMEP/EEA (2009).

Principal component analysis (PCA) was initially used as a biplot graphing tool (Gabriel, 1971; Jacoby, 1998) to visualize (a) general grouping patterns among farming systems, (b) relationships among production coefficients variables, and interactions between farming systems and production coefficients. In this study, instead of one biplot, two separate but comparable plots were drawn for better interpretation of the graphical outputs. In order to confirm the groupings of the farming systems, hierarchical cluster analysis (HCA) was applied on the corresponding of the production coefficients variables (Mojena, 1977; Sharma, 1996). Cluster formation was based on the Ward's minimum variance criterion (Ward, 1963) while the Euclidian distance was used as a dissimilarity index (Sharma, 1996) between the farming systems. The statistical significance of the resulted cluster solution was tested with the upper tailed rule (Mojena and Wishart, 1980). The contribution of each variable in cluster formation was assessed by examining the magnitude and the statistical significance of the corresponding coefficients of determination R^2 computed from a series of one-way ANOVAs; cluster membership was used as the independent variable and production coefficients variables as the dependents. The value of R^2 indicates the percentage of variance of the examined variable accounted by the differences between the clusters (Sharma, 1996). In the frame of one-way ANOVA, R^2 is computationally and conceptually equivalent with the statistic “eta squared”, a measure of the independent's variable, the cluster membership in our case, effect size (Cortina and Nouri, 2000). Eta squared is computed by the formulae $\eta^2 = R^2 = (SS_{Between\ groups}/SS_{Total})$, where SS denotes the corresponding sum of squares. Prior to PCA and HCA variable values (X) were transformed according to the transformation $\log(X+1)$ in order (a) to smooth and homogenize the heavily skewed distributions of some variables containing many zero values (Mucha et al., 2008) and (b) to validate the significance testing of the coefficients of determinations R^2 through ANOVA. PCA and HCA were used for revealing latent structures among variables and farming systems without making any a priori assumptions about the mechanism (the type of farming system in this study) by which the data were generated (Lebart et al., 1984; Benzécri, 1992). Finally, a series of non parametric Mann–Whitney (M–W) tests were performed for testing the differences between the resulted clusters concerning the untransformed production coefficients variables and six external variables not included in the cluster analysis. The external variables were energy outputs, efficiency, fruit production, and CO_2, CH_4 and N_2O-emissions. The observed significance levels (P-values) of all M–W tests were computed by the Monte-Carlo simulation method (Mehta and Patel, 1996) utilizing 10,000 random samples in each testing.

PCA were performed by means of the SPSS ver. 15.0 software package enhanced with the module Exact Tests. HCA was performed using SPSS, Clustan ver. 5.27, and XLSTAT ver. 7.5.3. The input order stability and validity of the resulted cluster solution was checked and verified by applying the bootstrap methodology (Spaans and Van der Kloot, 2004) implemented in the PermuCLUSTER v.1.0 software (an addin of SPSS). The significance level of all statistical hypotheses testing procedures was predetermined at $P < 0.05$.

3. Results

PCA plots are illustrated in Figs. 1 and 2. A clear separation of three groups for farming systems and production coefficients was observed. The first principal component (Dimension 1) explained 38.21% of the total variance and the second (Dimension 2) 21.69%. Consequently, a significant portion (59.90%) of total variability is depicted on the presented factorial planes 1 × 2 (Figs. 1 and 2). The first group (Group 1) was consisted of seven farming systems

Table 1
Agricultural practices for conventional, integrated and organic peach farms in the study locations.

Agricultural practices	Frequency – comments		
	Conventional	Integrated	Organic
Fertilizer application	Applications of synthetic fertilizers (11% N, 15% P_2O_5, 15% K_2O; 0.9 Mg ha^{-1} ± 0.1 or 20% N, 20% P_2O_5, 20% K_2O; 1.4 Mg ha^{-1} or 21% N 0.7 ± 0.1 Mg ha^{-1}). The fertilizers are applied 1 or 2 times/year.	Applications of synthetic fertilizers (11% N, 15% P_2O_5, 15% K_2O; 0.9 Mg ha^{-1} ± 0.1 or 20% N, 20% P_2O_5, 20% K_2O; 0.1 Mg ha^{-1} or 21% N 0.5 ± 0.1 Mg ha^{-1} or 34.5% N 0.1 Mg ha^{-1}). Applications same with conventional.	Agrobiosol (8% N, 0.5% P_2O_5, 0.5% K_2O; 0.7 ± 0.1 Mg ha^{-1}), Poultry manure (1.4% N, 1.1% P_2O_5, 0.6% K_2O; 0.8 Mg ha^{-1}) sheep and goats manure (0.8% N, 0.23% P_2O_5, 0.7% K_2O; 0.95 Mg ha^{-1}). Applications 1 time/year.
Weed control	Farmers are cutting weeds (5–10 times/year) by using machinery (lawn mower).	Farmers are cutting weeds (5–10 times/year) by using machinery (lawn mower). Also, some farmers use herbicides 1–2 times/year (Glyphosate, Glufosinate-ammonium). The used quantities range from 0.9 to 4 kg ha^{-1} totally.	Farmers are cutting weeds (1–5 times per year) by using machinery (lawn mower) or by hand.
Fungicides	Farmers apply (2–7 times/year) quantities of S, Captan, Myclobutanil, which range from 10 to 16 kg ha^{-1} totally.	Farmers apply (2–7 times/year) quantities of S, Cu, Captan, Myclobutanil, which range from 5 to 10 kg ha^{-1} totally.	Farmers apply (6–11 times/year) quantities of Copper hydroxide, S, which range from 1.5 to 30.0 kg ha^{-1} totally
Insecticides	Farmers apply at the end of May (2–3 times/year) quantities of lambda-cyhalotrin, Bifenthrin, Imidacloprid, which range from 1.0 to 1.5 kg ha^{-1} totally	Farmers apply at the end of May (2–3 times/year) quantities of Karate, Bifenthrin, Imidacloprid, which range from 1.0 to 1.5 kg ha^{-1} totally.	Farmers apply at the end of March until May (3–8 times/year) quantities of pyrethrum, S, *Bacillus thurigiensis*, which range from 0.5 to 3.0 kg ha^{-1} totally.
Insect traps	Not applied	Not applied	Farmers use pheromone traps; 40 traps ha^{-1}.
Pruning	One time/year from late November until February with aero-scissors.	One time/year from late December until March with aero-scissors.	One or two times/year from late February until May with aero-scissors.
Irrigation	From June to September 4–10 times with sprinkler heads functioning.	Same practices.	Same practices.
Fruit thinning	From May to June by hand	Same practices	Same practices
Harvesting	3–4 times during the August by hand.	3–4 times from August to September by hand.	3–4 times from mid July to September by hand.

(C1, C2, C3, C4, I1, I2 and I3), the second (Group 2) contained six farming systems (I4, I5, I6, I7, I8 and I9), and the third one (Group 3) had three members, namely farming systems O1, O2, and O3. Farming systems in the same group responded more or less similarly to the production coefficients variables. These three groups are clearly distinct, taking into account the quality of the representation in Fig. 1 (59.9% of total variance). Specifically, the first dimension, with the greatest variability, separates Group 2

Table 2
Energy content of inputs.

Item	Unit	Content energy (MJ/Unit)	Mass (kg)	Life (h)	References
Fertilizer					
Nitrogen	kg	74.2			Lockeretz (1980), Tsatsarelis (1993)
Phosphorus	kg	13.7			Lockeretz (1980), Tsatsarelis (1993)
Potassium	kg	9.7			Lockeretz (1980), Tsatsarelis (1993)
Agrobiosol	kg	6.5			Kavargiris et al. (2009)
Poultry manure	kg	8.4			White and Taiganides (1971)
Sheep and goat manure	kg	23.5			Makhijani and Poole (1975)
Insecticides	kg	363.6			Kaltsas et al. (2007)
Fungicides	kg	99.0			Kaltsas et al. (2007)
Herbicides	kg	418			Kavargiris et al. (2009)
Petroleum (diesel)[a]	l	47.3			Cervinka (1980)
Electric energy	kWh	12.1			Jarach (1985)
Machinery					
Tractor 48 kW	h	41.4	4350	15,000	Tsatsarelis (1992) adapted
Pump	h	2.4	200	12,000	Tsatsarelis (1992) adapted
Irrigation system	h m	0.092	–	15,000	Tsatsarelis (1992) adapted
Field cultivator	h	17.1	300	2500	Tsatsarelis (1991) adapted
Rotary tiller	h	17.7	310	2500	Tsatsarelis and Koundouras (1994) adapted
Tank	h	23.8	250	1500	Tsatsarelis (1992) adapted
Sprayer	h	19.1	200	1500	Tsatsarelis and Koundouras (1994) adapted
Lawn mower	h	1	10	1500	Tsatsarelis (1993) adapted
Transportation	h	48.9	1500	15,000	Genitsariotis et al. (1996) adapted
Platform	h	57.1	1000	15,000	Tsatsarelis (1992) adapted
Aero-scissors	h	0.035			Genitsariotis et al. (1996) adapted
Insect traps	h	0.002	0.3	18,000	Tsatsarelis (1993) adapted
Labor	h	2.2			Pimentel and Pimentel (1996)
Peach fruit	Mg	1588.4			Pimentel (1980) adapted
Shoots	Mg	18.4			Pimentel (1980) adapted

[a] Energy content + energy for production.

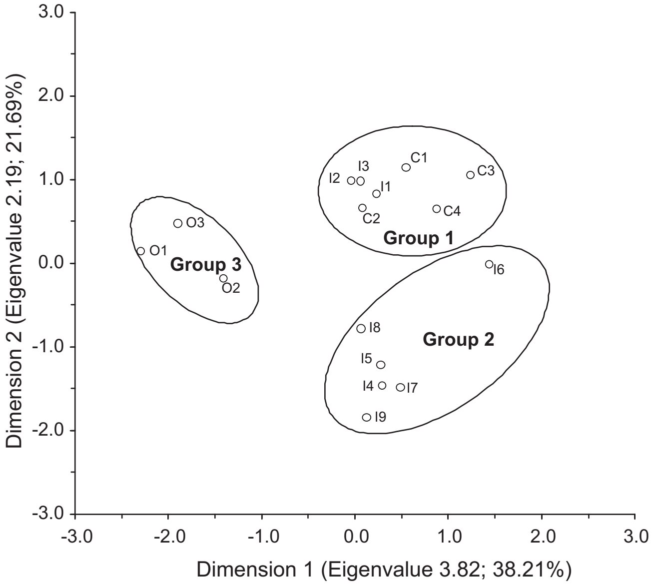

Fig. 1. PCA factorial plane 1 × 2 based on the farming systems components' scores.

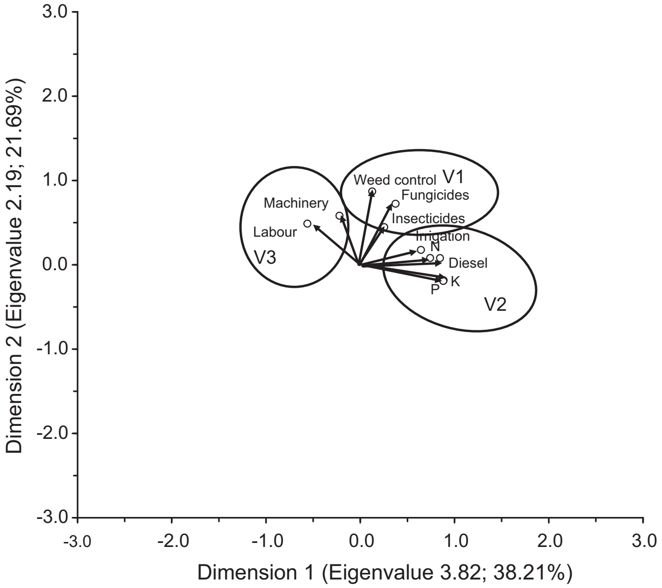

Fig. 2. PCA factorial plane 1 × 2 based on production coefficients components' scores.

from Group 3 and the second dimension separates Group 1 from the other two.

Three groups containing more or less inter-correlated production coefficients variables were apparent in Fig. 2. Group V1 was structured by the variables weed control, insecticides and fungicides. Group V2 contained the variables N, P, K, irrigation and diesel. Group V3 was consisted of the variables labor and machines. Dimension 1 was structured mainly by the V2 and V3 variables. Dimension 2 was mainly correlated with the V1 variables. Considering the relative positions of farming systems and variables' groups by superimposing Fig. 2 onto Fig. 1 it is concluded that variability in Group 1 is related mainly to the values of V1 variables, variability in Group 2 is related mainly to the values of V2 variables and variability in Group 3 is related mainly to the values of V3 variables.

Hierarchical cluster analysis revealed the same three main groups of farming systems (Fig. 3) and confirmed, to a high degree, the results extracted from the previous PCA. The upper tail rule showed that the solution with three clusters is significant ($t(14) = 4.24$, $P < 0.001$) and the relatively high value of cophenetic correlation coefficient ($r_c = 0.75$, $P < 0.001$) indicates that the dendrogram illustrated in Fig. 3 preserves in an adequate degree the exact pairwise distances between the original unmodeled variables. Table 3 presents the centroids (mean values) of the three groups of farming systems relative to the production coefficients variables, and the corresponding R^2 values. Fertilizers (N, P, K), fungicides, weed control, diesel, labor and irrigation have the greatest contribution on cluster formation. This is evident from their high (minimum $R^2 > 0.496$) and statistically significant ($P < 0.05$) R^2 values. Mean values for production coefficients N, P, K, diesel and irrigation for the Group 3 were statistically significantly lower (Table 3). Mean values for labor were significantly higher for the Group 3, intermediate for the Group 1 and lower for the Group 2. For the machinery-tools mean values were statistically significantly lower (Table 3). Finally, mean values for fungicides and weed control were statistically significantly higher for the Group 1.

The dissimilarity indices (di) between the 16 peach orchards are shown in Appendix B. These indices ranged from 0.3 to 1.6 for Group 1, from 0.7 to 2.0 for Group 2, and from 1.1 to 2.9 for Group 3. Peach orchards (I1, I2) and (I2, I3) were the most similar (di = 0.3) while C3 and O3 were the most dissimilar (di = 2.9). Group 3 (Fig. 3) compared to the other two groups, seems to be the most homogeneous cluster of farming systems since it shows the smallest cluster linkage distance (1.16). On the contrary, Group 1 shows the greatest variability between its members (linkage distance = 2.12). Group 1 is consisted of two sub-clusters (first sub-cluster includes farming systems C1, C2, C3 and C4 and the second I1, I2 and I3) both showing great homogeneity among their members, with the second sub-cluster containing the most homogeneous peach orchards (linkage distance = 0.10). These two sub-clusters are combined at next clustering stage to form Group 1. Group 2 is consisted of two sub-clusters too (first sub-cluster includes farming systems I4, I5 and I6 and the second I7, I8 and I9) with the second sub-cluster showing high degree of homogeneity among its members (linkage distance = 0.34). Groups 1 and 2 are combined at linkage distance 3.86 to form a bigger separate cluster as regards Group 3. Group 3 joints the other two groups at a relative distant stage (linkage distance = 7.04).

Taking into account the six external variables, namely outputs, energy efficiency, fruit production, CO_2, CH_4, and N_2O it can be noted that the three groups are statistically different at $P < 0.05$ (Table 4). All variables of Group 3 were at average significantly lower.

Means averaged over all orchards ($n = 16$) for production coefficients, energy outputs, energy efficiency, fruit production and gas emissions with the accompanying descriptive statistics (maximum, minimum and standard deviations) are shown in Appendix C. Detailed values for every individual orchard, for energy inputs, energy outputs, energy efficiency, fruit production and gas emissions are provided in Appendix D.

4. Discussion

The ranking order of means averaging from all farming systems of most important production coefficients was machinery-tools (33.4%), irrigation (27.5%), fuels (23.5%), fertilizers (8.8%), plant protection products (4.0%) and labor (2.9%). Machinery-tools, fuels, irrigation and fertilizer in conventional (29.2, 25.2, 23.7 and 14.0%, respectively) in integrated (18.8, 28.8, 39.9 and 8.8% respectively) and in organic peach orchards (52.1, 16.4, 18.8 and 3.6%, respectively) were the highest energy inputs. In other crops, fuels were the main energy input ranging from 22 to 71%, second in order was electric energy (42–44%), followed by fertilization (15–45%) and machinery (21–25%) (Tsatsarelis, 1991, 1992, 1993; Tsatsarelis

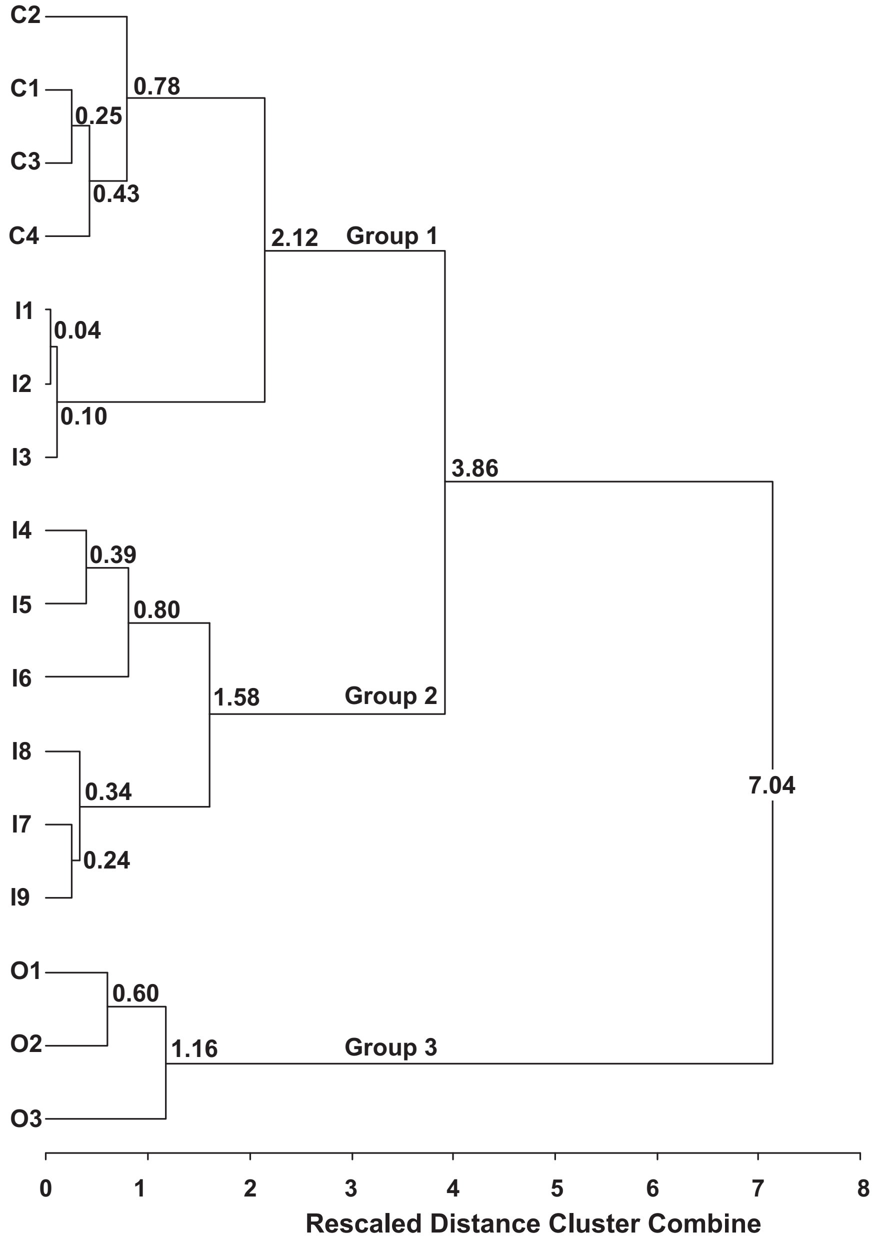

Fig. 3. Dendrogram of HCA. Numbers indicate the rescaled cluster linkage distance.

Table 3
Group centroids (untransformed mean values) relative to production coefficients and respective R^2 coefficients from transformed data.

Production coefficients	Group 1 (MJ ha^{-1})	Group 2 (MJ ha^{-1})	Group 3 (MJ ha^{-1})	R^2	P
N	13,098.4^{a*}	9101.9^{a}	2572.3^{b}	**0.664****	0.001
P	1548.6^{a}	1578.8^{a}	230.2^{b}	**0.598**	0.003
K	1096.4^{a}	1152.8^{a}	122.9^{b}	**0.663**	0.001
Fungicides	4821.4^{a}	1010.8^{b}	1217.1^{b}	**0.524**	0.008
Insecticides	1811.2^{a}	1340.1^{a}	1633.4^{a}	0.144	0.363
Weed control	11,733.4^{a}	3889.9^{b}	5757.2^{b}	**0.568**	0.004
Diesel	29,926.4^{a}	33,210.6^{a}	11,430.8^{b}	**0.496**	0.012
Labor	2401.4^{b}	993.8^{c}	4551.6^{a}	**0.571**	0.004
Irrigation	48,817.1^{a}	41,776.2^{a}	15,316.0^{b}	**0.496**	0.012
Machinery	34,284.0^{a}	17,546.7^{b}	38,585.3^{a}	0.334	0.071

[*] Means in the same row followed by different exponential letters are statistically significant different at significance level $P < 0.05$ according to as series of Mann–Whitney tests.

[**] Statistically significant R^2 ($P < 0.05$) are boldfaced.

Table 4
Comparison of three groups of farming systems relative to the mean values of energy outputs, efficiency, fruit production and CO_2, CH_4 and N_2O-emissions.

	Outputs ($MJ\,ha^{-1}$)	Energy efficiency	Fruit production ($Mg\,ha^{-1}$)	CO_2 ($Mg\,ha^{-1}$)	CH_4 ($kg\,ha^{-1}$)	N_2O ($kg\,ha^{-1}$)
Group 1	51,738.1^{a,*}	0.35^{a}	32.56^{a}	4.98^{a}	1.05^{a}	0.06^{a}
Group 2	76,250.7^{a}	0.84^{a}	47.99^{a}	4.73^{a}	0.99^{a}	0.06^{a}
Group 3	17,943.0^{b}	0.25^{a}	11.30^{b}	1.78^{b}	0.37^{b}	0.02^{b}

[*] Mean values in the same column followed by different exponential letters are statistically significant different at significance level $P < 0.05$ according to as series of Mann–Whitney tests.

and Koundouras, 1994; Strapatsa et al., 2006; Kaltsas et al., 2007; Kavargiris et al., 2009).

Farming systems formed three groups. Group 1, which consisted of the four conventional and three of the integrated farms (C1, C2, C3, C4, I1, I2, I3), was associated mainly with high values of the production coefficients of weed control, insecticides and fungicides. Group 2, which contained the rest six integrated farms (I4, I5, I6, I7, I8, I9), was characterized mainly by medium to high values of the production coefficients of irrigation, diesel, N P and K. Group 3, which consisted of the three organic farms (O1, O2, O3), was highly responded to the productions coefficients of labor and machinery. These three groups of farming systems were clearly distinct. Group 1 was consisted of two sub-clusters. First sub-cluster included all the conventional peach orchards while the second sub-cluster included the integrated peach orchards. Group 2 was consisted of two sub-clusters. In Group 3 the variability between its members, can be possibly related with the different types of fertilizers, plant protection products and machinery-tools used by farmers. Moreover in Group 3, fertilizers, plant protection products were applied at different quantities and times per year and the used fuel and labor were diverse. The results showed that farming systems varied. Farming systems (I1, I2) and (I2, I3) were the most similar, while C3 and O3 were the most dissimilar. These similarities and/or dissimilarities among farming systems can probably be related to farm topography, production coefficients and local farming practices. Similar results for other crops have been reported by other researchers (Tsatsarelis, 1991, 1992, 1993; Tsatsarelis and Koundouras, 1994; Reganold et al., 2001; Kaltsas et al., 2007; Kavargiris et al., 2009). In Group 3 energy outputs, energy efficiency and fruit production were statistically lower than in the other two groups. Analogous results have been reported from surveys carried out at farms located in Spain (Alonso and Guzmán, 2010).

The CO_2, CH_4, and N_2O-emissions of Group 3 (three organic) were at average significantly lower than those of the other two groups. The different use of fossil energy and fertilizers led to lower CO_2, CH_4 and N_2O-emissions in organic than in other farming systems. Kavargiris et al. (2009) found similar results comparing conventional and organic vineyards. Also, organic olive groves in Thasos island tended to have lower CO_2-emmisions than the conventional ones (Kaltsas et al., 2007). Organic farming can significantly reduce greenhouse gas emissions, since it uses significantly less fuel than conventional agriculture (Kotschi and Müller-Sämann, 2004; Kaltsas et al., 2007; Kavargiris et al., 2009; Raviv, 2009; Liu et al., 2010b). Farming management is in many respects different in organic systems, and this affects both soil carbon storage and gas emissions (CO_2, CH_4 and N_2O) (IFOAM, 2009; Scialabba and Müller-Lindenlauf, 2010). When losses and gains of soil carbon deposits (mineralization or sequestration) are embodied in the calculations, the global warming potential is considerably reduced for organic farming (Küstermann et al., 2008). Organic farming could be included as a high-benefit/low-cost CO_2 reduction system in the future climate agreement.

5. Conclusions

Different management practices in peach cultivation formed three groups of farming systems and three groups of production coefficients. Organic peach orchards were well distinguished from the others, while integrated peach orchards were scattered (or spilled) in two groups. One group consisted of the three integrated peach orchards along with the conventional ones and the other group with the rest of integrated. Farming systems in the same group responded more or less similarly to the production coefficients variables. There were similarities and/or dissimilarities among farming systems, which can probably be related to farm topography, production coefficients and local farming practices. Non-parametric tests concerning external variables (outputs, energy efficiency, fruit production, CO_2, CH_4, N_2O) showed that the variables in organic farming cluster were at average statistically significantly lower. Organic farming holds an especially favourable position, in reducing energy inputs and greenhouse gas-emissions in an efficient way.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ecolind.2011.05.002.

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