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Could energy flow in agro-ecosystems be used as a "tool" for crop and farming system replacement?

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ABSTRACT

Energy flow in orchards can be used to determine first the best management practices and second the possibility of using those which have best environmental advantages. Conventional and organic peach and kiwi orchards were selected in order to (a) determine energy flow of the farming systems, and (b) reveal the importance of energy inputs in crop and farming system replacement. Fifteen farms (four conventional and three organic kiwi orchards; four conventional and four organic peach orchards) were selected with proportional stratified random sampling during the years 2010–2013. The Hierarchical Cluster Analysis (HCA) method was applied using nine production coefficients' variables (fertilizers, fungicides, insecticides, weed control, diesel, labor, irrigation, branches shoring, and machinery) and revealed three groups of the studied orchards. The highest contributors in cluster formation were weed control, branches shoring, labor, and machinery. The effect of the production coefficients on the grouping of the studied orchards reveals their importance for these crops and farming systems. Most of the production coefficients showed their lowest values in organic kiwi orchards (Group 3), so it could be said that they can play a key role in the replacement of the peaches, and conventional kiwi orchards. It seems that production coefficients can be used as a "tool" for decision makers who are seeking for crops and farming systems with low energy inputs and best environmental advantages in order to use them in crop replacement in agro-ecosystems.

1. Introduction

Continuous demand in increasing food production resulted in intensification of agriculture, a threat to the environment worldwide. Intensification resulted in growing concern about biodiversity conservation and its role in functional biosphere maintenance (Tilman et al., 2002). The risk of detrimental environmental effects could be reduced by using less intensive farming practices (Tilman et al., 2002; Müller et al., 2006; Dantsis et al., 2010).

Integrated and organic farming, low intensity farming systems, may contribute in diminishing energy inputs per ha (Michos et al., 2012; Zafiriou et al., 2012). The latter will minimize environmental problems such as greenhouse gas emissions (Litskas et al., 2011; Zafiriou et al., 2012) and confine the degradation of natural resources (Alonso and Guzmán, 2010). An environmental and an energy analysis of an agro-ecosystem could be combined to lead to the best management practices (Kaltsas et al., 2007; Franzese et al., 2009; Michos et al., 2012).

Energy resources are linked to the development of agriculture, which uses relatively small amounts of energy (IPCC, 2014). However, energy use in food production is often a large percentage of energy consumption in developed countries (Pimentel et al., 2002). Farming practices determine to a large extent the amount of energy inputs used in crops. The knowledge of energy use in crops is essential in developing sustainable production systems (Ziesemer, 2007). Although there are studies exploring the multifaceted sources and uses of energy inputs at farms (Venturi and Venturi, 2003; Meisterling et al., 2009; Kremen and Miles, 2012), there is still a lack in research due to the different farm production systems all over the world.

Several methods, including Life Cycle Assessment (LCA), have been widely used in bioenergy assessment studies (Schweinle et al.,

Abbreviations: KC, kiwi conventional orchards; KO, kiwi organic orchards; PC, peach conventional orchards; PO, peach organic orchards.

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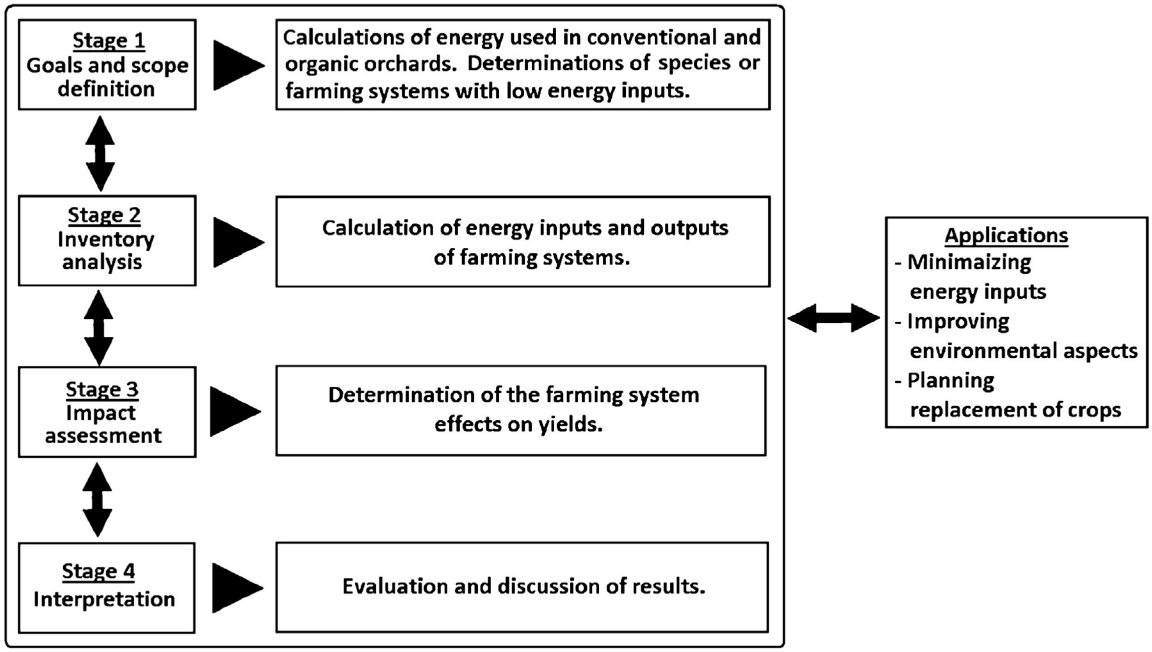

Fig. 1. An adjusted Life Cycle Assessment (LCA) with four stages.

2015; ARENA, 2016). A basic understanding of how these studies are conducted is imperative to determine how applicable the results are to a specific system. An appropriate approach to assess the energy costs of agriculture is the LCA method, which has been applied at the product, process and farm level (Haas et al., 2001; Cederberg and Flysjö, 2004). The true strength of an LCA is the total accounting of environmental impacts related to a specific system to determine areas for process improvements, create baseline data, or compare system alternatives (Schweinle et al., 2015).

In Europe, peaches (*Prunus persica* L.) and kiwi (*Actinidia deliciosa* L.) represent 27% and 48.8% of the world production, respectively (FAO, 2013). In Greece, peach and kiwi production is 760,200 and 161,400 Mg, respectively (FAO, 2013) and corresponds to 43,141 (peach) and 7890 (kiwi) ha (ELSTAT, 2013).

A complex of interacting factors can create replant problems in orchards. Peach trees replanted in peach orchards grow poorly (Willis, 2007). These replant problems in peach orchards were related to climatic changes (Lichtfouse, 2011), plant pathogens and pests (Kole, 2007), allelopathy (Ambika, 2013) and economic costs (Lichtfouse, 2011). Climatic changes affect the life cycle of plants and the production cost (Lichtfouse, 2011). Also, pathogens and pests (Kole, 2007) and several specific compounds (Willis, 2007) originating from plant parts can affect plant development. The compounds released by *Prunus* species are the cyanogenic glycosides (amygdalin and prunaxine; Selmar et al., 1988) causing autotoxisity and replant problems. Their release is enhanced by the presence of nematodes (Ambika, 2013).

Peaches are often a monoculture in mountainous areas, especially in the central part of northern Greece (ELSTAT, 2013). In this area, farmers are systematically occupied with peach production since the second half of the 20th century (Local Department of Agricultural Development, personal communication 2013). Low input farming systems, such as organic and integrated, can probably contribute in reducing production costs, using human labor efficiently, and protecting the environment (Michos et al., 2012; Zafiriou et al., 2012; Taxidis et al., 2015). Energy analysis can be a "tool" to determine which operations are using low amounts of energy for succeeding the sustainability of the agro-ecosystem (Funt, 1980; Reganold et al., 2001; Blanke and Burdick, 2005; Kehagias et al., 2015). Within the frame of this research, conventional and organic peach and kiwi orchards in Pella prefecture in northern Greece, were selected in order to (a) determine differences and similarities in energy inputs per ha (renewable, non-renewable) between the two farming systems, and (b) reveal the importance of energy inputs in crop and farming system replacement. Energy flow in peach and kiwi orchards can help to determine firstly the best management strategies for each species and secondly which one has best environmental advantages.

The paper was organized as follows: Introduction devoted to the presentation of a general aspect of energy use in agriculture and the aims of the study. Materials and methods, results and discussion referred to a research conducted in conventional and organic peach and kiwi orchards. Finally, concluded remarks were presented in order to aid decision makers seeking for crops and farming systems with low energy inputs and best environmental advantages.

2. Materials and methods

During the years 2010–2013, 15 farms [four conventional (KC1, KC2, KC3, KC4) and three organic (KO1, KO2, KO3) kiwi orchards; four conventional (PC1, PC2, PC3, PC4) and four organic (PO1, PO2, PO3, PO4) peach orchards] were selected in the central part of northern Greece (former Prefecture of Pella) with proportional stratified random sampling (Appendix A in Supplementary materials). Firstly, farms were stratified according to the two species (kiwi and peach) at their maximum fruit production age. Within this first stage, farms were stratified according to the two farming systems (conventional and organic). The selected orchards represent about the 10% of those with an age about 12–20 years. At this age both species reach their maximum fruit production (Janick and Simon, 1990). The canning peach variety "Andross" and the kiwi variety "Hayword" were grown in the respective orchards. The size of all studied orchards was about 1.0 ha. The plant density ranged from 389 to 692 individuals ha^{-1} in peach orchards and from 364 to 667 in kiwi orchards. All orchards had moderate slopes (8–10%) and were easily approached. Previous crops in the orchards were chestnut, sweet cherry, and apple trees. Organic farmers are applying the regulations EC 834/2007 and EC 889/2008. According to the