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PALAP 9: energy analysis of agroecological practices for improving agricultural sustainability

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Short abstract *(50 words)*

Palap9 is a LTE started in 1995 on organic orange [*Citrus sinensis* (L.) Osbeck)] cultivation. Organic farming represent a feasible option for the new challenges of agro-ecological productions. In this study the introduction of agro-ecological practices (ASC and on farm compost) have been analyzed in an energetic perspective.

Extended abstract *(750-1000 words)*

European agriculture has undergone, over the past 60 years, a period of rapid intensification achieved through an increased application of chemical fertilizers and pesticides, combined with implementation of best management practices (Gaudino et al., 2014). Considering the amazing contribute of the agricultural activities in the environmental impact, in the last years, it has been evaluated the agricultural processes also from an environmental point of view. More recently increasing attention has been paid to assess the benefits arising from the implementation of mitigation strategies. In low input/organic farming systems, proper agro-ecological service crops (ASC) introduction and fertilization management can provide beneficial services to the agro-ecosystems, enhancing their environmental sustainability (Canali et. al., 2015). Effective energy use in agriculture is one of the conditions for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction (Pervanchon et al., 2002). The aims of this study are: (i) to evaluate, monitor and identify the environmental impact of the Palap9-LTE comparing the different management practices; (ii) to propose possible mitigation strategies paying particular attention to both on-farm organic fertilizers production and ASC introduction.

The research was carried out from 2012 to 2017 in a newly transplanted citrus orchard. The introduction of two different cultivation strategies were tested: 1. a mixture of vetch (*Vicia sativa* L.) and barley (*Hordeum vulgare* L.) (ASC) was cultivated in the winter period and compared to a NO-ASC control. 2. on-farm compost (OFC) compared to a mineral fertilizer (MF). To assess the environmental impacts due the introduction of this agroecological approach, an energy analysis was utilized. The total energy inputs and outputs for production unit (hectare), expressed in MJ, was established by multiplying each input by its own coefficient of equivalent energy (Alonso and Guzmán, 2010; Pergola et al., 2017; Pimentel and Pimentel, 1979; Rovira and Henriquez, 2008). The Namdari et al. (2011) methodology was used to determine the effects of energy input on citrus cultivations. The Energy ratio was calculated using the following formula: Energy output/Energy input. The energy inputs were further identified as direct and indirect intakes. In particular, both human labor and fossil fuels were considered as direct energy, whereas seeds, water, chemicals, fertilizers and machinery were accounted as indirect one.

The energy analysis showed that the ASC treatments consumed more energy inputs per hectare than the NO-ASC treatments (Table 1), whereas MF consumed less energy inputs than OFC management in orange production. These results are due to the higher energy used for fuels in the ASC management and the compost

spreading operations. The highest energy consuming inputs were the structures in plantation phase followed by fuels and electricity, fertilizers (5-6 and 10-11% for OFC and MF, respectively). In OFC thesis, 42 and 39% of total energy input for ASC and NO-ASC respectively resulted from direct energy. In MF, 38 and 34% of total energy input resulted from direct energy for ASC and NO-ASC respectively. The Net energy and the energy ratio in OFC were higher than MF, and greater in the ASC than NO ASC treatments. In fact the energy output were higher in the thesis were the agroecological techniques were utilized (OFC and ASC) and this result was due to the higher output derived from the carbon stocks in the soil. The net energy and energy ratio values in ASC in comparison with NO ASC, would indicate that it can be useful not only in providing agroecological services, but also in maintaining cropping system sustainability. The energy ratio results also suggest that OFC fertilizer was more efficient than MF in orange production. As regards the energy consumption for each crop operation, the plantation phase (trees plantation, irrigation system and structures installation) was the most energy consuming and impacting phase in all the analyzed systems. Moreover, especially in the ASC thesis, the ASC and soil operations consumed a consistent rate of energy.

Orchards involves different agricultural activities that produce several impacts on the environment but they may also reduce the pollution by stocking the CO_2. Moreover, organic productions systems are predictable to be virtuous systems under the environmental point of view. Among the strategies proposed to improve the environmental performance of organic orange production, the introduction of ASC and the substitution of mineral fertilizer with on-farm composts appear to carry a relevant environmental performance.

In conclusion, combined application of agroecological techniques is a viable strategy, sustaining yield of orange production, due to the increase of energy ratio. However, this study period could not be sufficient to draw general conclusions; therefore, more data will be analyzed in this ongoing research to validate the reported preliminary results, by extending the analysis to the whole production cycle of these orchard systems.

Table 1. Amounts of inputs and outputs (MJ ha^{-1}) in citrus production

	OFC-ASC	OFC-NO ASC	MF-ASC	MF-NO ASC
Total input	193877	173667	190566	170337
Total output	167943	75191	101830	55206
Net energy	-25934	-98475	-88736	-115131
Energy ratio	0.87	0.43	0.53	0.32
Direct energy	81944	68337	72347	58740
Indirect energy	111933	105330	118219	111597

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