Energy analysis of organic horticultural farms in Italy

P. MIGLIORINI[1], M. CHIORRI[2], C. PAFFARINI[2], F. GALIOTO[2]

Abstract

The aim of this research is to evaluate energy efficiency of organic horticultural farms in Italy at both surface (GJ/GJ ha^{-1} year^{-1}) and product (kg MJ^{-1}) level. The methods used is the Output/Input balance at farm level using energy equivalents of the three phases: production, transformation/conservation and marketing. The methodology have been applied to 8 case studies of the organic horticultural Italian sector. The results show that the energy input is low but also the energy efficiency is not high especially if compared to other study of the arable sector. However they show very positive aspects in the commercial phase.

Keywords: *energy analysis; energy efficiency; organic; horticultural; Italy.*

Introduction

Sustainability in agriculture is declined according to the economic, ecological and social aspects. In a scenario where more and more energy resources are limited is thus well place the energy assessment as part of the sustainability assessment. The organic horticultural farm is usually an intensive sector in terms of labour and external inputs and has high energy consumption both during production phase (raw materials, irrigation and processing), transformation/conservation phase (energy for machinery and cold storage) and the marketing stage (long transport and packaging material). One of the goal of organic horticulture is to reduce the use of external inputs, especially those non-renewable like fossil fuels. Inefficient energy use can result in severe environmental impacts (i.e. GHGs emission). The development of energy efficient agricultural systems – with a low input of energy compared to the output of products – should therefore help to reduce agricultural emissions of greenhouse gasses (Dalgaard et al., 2001).

However, as well as for conventional products, the production of organic horticultural products requires a considerable use of energy for irrigation, soil preparation, transportation and refrigeration. But the largest consumer of energy in agricultural production, i.e. the synthetic nitrogen fertilizers and pesticides are prohibited in organic farming and organic gardening, saving large amounts of energy.

On farms, energy is consumed in a 'direct' and an 'indirect' way. Direct energy is used on farm for agricultural activities, the use is directly measurable and it comprises mainly diesel, fuel and electricity. The energy that is used to produce farm inputs such as mineral and organic fertilisers, seeds, pesticides, concentrates, other materials and machines is indirect energy. Energy use efficiency (EUE) is often expressed on an area basis (MJ ha^{-1}). The energy inputs per unit area required for organically grown crops are typically 50% of those for conventional crops because of the lower fertilizer and pesticide input, and in spite of the fact that saving is partially offset by greater investment of energy in cultivation (Topp et al. 2007). Energy use efficiency is also expressed by the 'energy price' (EP) of agricultural products (Corré et al., 2003) that is the amount of energy needed for the production of one unit of product (MJ kg^{-1}). This method is my be better for the organic systems that generally produce less than conventional one. A good solution is thus to present the data of energy efficiency both per hectare and per kg of product. Few works dealing with the relative EUE of organic horticultural crops were published during the last 20 years. While the majority of the studies refers to arable crops and they demonstrate the higher efficiency of organic sector compare to the conventional one (Pimentel et al., 2005).

But what is the energy efficiency of the organic horticultural sector in Italy? In this paper we evaluate energy use efficiency, comparing energy input to production output, of 8 organic horticultural farms.

Material and Methods

Data and farm characteristics

The case study approach is often used in socio-economic analysis (Laws et al., 2003; Yin, 2002). The selection of case studies was preceded by a survey carried out in the first half of 2010 involving 65 organic farms, mainly horticultural, located in Emilia Romagna, Marche and Abruzzo. The questionnaire concerned the general organization of the farm and has allowed to highlight the salient features and the compliance of the farm to the project. Referring on these information, we selected 8 case studies (6 are located in Emilia Romagna, 1 in Marche and 1 in Abruzzo) among those that are converted since more than ten year using agroecological approach with commercial innovation and

[1] University of Gastronomic Sciences, Piazza Vittorio Emanuele, 9 – Frazione Pollenzo – 12042 Bra (CN), Italy. E-mail: p.migliorini@unisg.it; Internet: www.unisg.it
[2] University of Perugia, DSEEA, Borgo XX Giugno 74 - 06121 Perugia, Italy. E-mail: mchorri@unipg.it; Internet: www.agr.unipg.it

short chain channel of distribution (on farm, farmers market, buying groups supportive).

In the first half of 2011, through direct interviews, detailed information on agronomic and socio-economic aspects of the farms have been collected and processed (Chiorri et al., 2012).

System boundaries

The method used in our study corresponds to 'process analysis', where all energy inputs (direct and indirect) to an agricultural system are considered, based on physical material flows (Meul et al., 2007). Are not counted among the external inputs, the solar energy and human labour. The energy use in the analysis involves all energy used directly and indirectly for: 1. farm production phase; 2. sorting and packaging phase; 3. marketing phase. The phase 1 and 2 consider the process up to the moment that the products leave the farm ('farm gate approach'). The phase 3 implies the analysis of the distribution of the products to the different market channels, with the calculation of the transport cost (fossil fuel). The description of production processes is done through the identification of cultivation techniques and quantification of inputs: agricultural operation (type), the machine and operator used (type), use time of the machines (hours/ha), fuel consumed (kg/ha), seeds used (kg/ha), fertilizer use (kg/ha) and their titles (N, P, K), pesticide treatments (type), the active substance used (kg or l/ha), irrigation (type), volume of water used (l /ha); and outputs: the main product yields (kg/ha).

Energy input and output parameters

In our study, we considered direct energy input as the energy used on the farm for field operations, comprising diesel fuel, lubricants and electricity. The accounted energy included the caloric energy content (this is the amount of energy released when the fuel is combusted) and the energy used for mining, transformation and transport of the energy carrier. Indirect energy input to the farm included the energy needed for the production of manure and compost, seeds and plantlet, pesticides, other materials (e.g. plastic bags) and field machinery (tractors and implements). For indirect energy inputs, the accounted energy included the energy for their manufacturing, processing and transporting. The consumed amounts of inputs where multiplied by their corresponding energetic values, summarize in tab. 1.

Table 1 - *Energy equivalents used for inputs.*

Input	Units	Value	Reference
Diesel oil and lubricants	MJ kg^{-1}	45,3	Dalgaard et al., 2001
Tractors (1)	MJ kg^{-1} mass	139,7	Mazzoncini et al. 2011
Implements	MJ kg^{-1} mass	69,0	Baldi et al., 1986
Manure and compost	MJ kg^{-1}	0,30	Biondi, 1989
Seeds and Plantlet (2)	MJ kg^{-1}	(2)	Vazzana et al, 1997;
Herbicides (3)	MJ kg^{-1}	91,3	Dalgaard et al., 2001
Insecticides (3)	MJ kg^{-1}	52,7	Dalgaard et al., 2001
Fungicides (3)	MJ kg^{-1}	55,7	Dalgaard et al., 2001
Plastic materials (box and bag)	MJ kg^{-1}	100	Vazzana et al, 1997
Cartboard (box)	MJ kg^{-1}	5	Vazzana et al, 1997
Energy	MJ kw^{-1}	10	Vazzana et al, 1997

(1) manufacturing and maintenance; (2) 0,3 horticultural plantlet; 3,3 potatoes; 54 fruit plant; .8-6,8 wheat, barley; 5,6 pigeon bean; (3) formulated agents.

As output we considered the annual production of vegetable fresh farm products, multiplied for their energy value (tab. 2).

Table 2 - *Energy equivalents used for outputs.*

Output	Units	Value	References
Vegetables	MJ kg1 d.w.	2.1	USDA, 2004
Fruit	MJ kg1 d.w.	3,1	USDA 2004
Basil seed	MJ kg1 d.w.	15	Vazzana et al, 1997;
Alfa alfa hay	MJ kg1 d.w.	10	Vazzana et al, 1997;
Potatoes	MJ kg1 d.w.	3,36	Hülsbergen et al. 2001
Legumes grain (beans, field beans, chickpea)	MJ kg1 d.w.	16,7	Koga, 2008;
Wheat* (grain)	MJ kg1 d.w.	18,6	Koga, 2008;
Barley (grain)	MJ kg1 d.w.	15.4	Nguyen 1995
Maize (grain)	MJ kg1 d.w	14.6	Mazzoncini et al. 2011

d.w.= dry weight; * both durum and winter wheat.

Output/Input: Energy Efficiency and Energy Productivity

In our study, we expressed the energy use both as efficiency (EE) and productivity (EP). The EE is the ratio of output/input in energy value (GJ/GJ) of one hectare. The EP is the amount of product produced with one unit of energy (kg/MJ), and this fits the definition of ecoefficiency: produce more (output) from less (input).

Results and discussion

Table 3 show the average energy input, output and efficiency referred to one hectares of the 8 organic horticultural farms analysed.

Energy input

Regarding the input, these results demonstrate that the amount of energy inputs used by these organic horticultural farms are low (13,93 GJ ha^{-1} $year^{-1}$ as average for the production phase, 29,21 GJ ha^{-1} $year^{-1}$ for the shortening phase and 16,99 GJ ha^{-1} $year^{-1}$ for the marketing phase) especially if compared with 53 GJ ha^{-1} $year^{-1}$ of dairy farms inputs of only farm production (Meul et al., 2007). Moreover demonstrate the importance of the phase 2 – sorting and packaging: it comprise about 46% of the total average input. It must be said that in phase 2 is attributed the direct energy purchased by the farm which is used not only for the sorting and packaging but for every production need (i.e., irrigation and heating greenhouses, where it exists) but weighs only 13% of total input. Particularly the materials used (box and bag) both of plastic and cardboard accounted for a high share of the total farm energy use (33%). The other two phases use almost the same amount of energy: the farm production phase 1, account the 29% of the total input and the marketing phase 3 the 26%. Although there is great variability within the case studies, the macro trend are the same: the phase 2 vary from 70% to 23%; the phase 1 from 50% to 15%; the phase 3 to 53% to 6%. The energy use by these organic farms for fertilizer and pesticide are only the 3% of the total input. These data are in line with other results that have analysed the EUE of fruit organic farms (Raviv, 2010) and arable organic farms (Mazzoncini et al., 2011) where the input of the experimental farm production phase are between 10 and 5 GJ ha^{-1} $year^{-1}$. At the same time these results are strongly in contrast with the EUE analysis of the conventional arable sector: Meul (et al., 2007) refers

Table 3 – *Result of energy analysis of the organic horticultural farms (GJ/ha) and calculation of the indicator (EE: Energy Efficiency; EP: Energy productivity; UAA: Utilized Agricultural Area).*

Case study	A		B		C		D		E		F		G		H		Min	Max	Aver.
UAA	18,88		40,89		1,98		12,65		3,25		1,63		12,56		2,15				
	GJ/ha	**%**	**GJ/ha**	**%**	**GJ/ha**	**%**	**GJ/ha**	**%**	**GJ/ha**	**%**	**GJ/ha**	**%**	**GJ/ha**	**%**	**GJ/ha**	**%**	**GJ/ha**	**GJ/ha**	**GJ/ha**
INPUT																			
1. Farm production phase:	**6,42**	**48**	**7,14**	**15**	**19,47**	**21**	**15,70**	**40**	**15,23**	**22**	**18,12**	**17**	**14,68**	**50**	**14,66**	**17**	**6,42**	**19,47**	**13,93**
Machinery use	***3,65***	***27***	***2,84***	***6***	***5,16***	***6***	***1,97***	***5***	***5,19***	***8***	***6,04***	***6***	***5,49***	***19***	***0,76***	***1***	***0,76***	***6,04***	***3,89***
Tillage and seed bed prep.	2,70	20	0,88	2	1,87	2	0,48	1	2,75	4	3,80	4	1,88	6	0,23	0	0,23	3,80	1,82
Sowing/transplanting	0,11	1	0,57	1	0,00	0	0,15	0	0,55	1	0,61	1	0,11	0	0,18	0	0,00	0,61	0,28
Fertilization	0,69	5	0,23	0	1,48	2	0,21	1	0,54	1	1,64	2	0,45	2	0,19	0	0,19	1,64	0,68
Crop protect. and weed contr.	0,00	0	0,55	1	0,75	1	0,55	1	0,00	0	0,00	0	1,42	5	0,00	0	0,00	1,42	0,41
Cultivation	0,14	1	0,59	1	1,06	1	0,57	1	1,36	2	0,00	0	1,63	6	0,16	0	0,00	1,63	0,69
Harvesting	0,00	0	0,02	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0	0,00	0,02	0,00
Technical means	***2,78***	***21***	***4,30***	***9***	***14,31***	***15***	***13,73***	***35***	***10,04***	***15***	***12,07***	***11***	***9,19***	***31***	***13,90***	***16***	***2,78***	***14,31***	***10,04***
Seed	2,13	16	3,94	9	12,11	13	13,13	33	8,69	13	7,87	7	6,81	23	13,68	16	2,13	13,68	8,54
Fertilizer use	0,60	4	0,19	0	1,45	2	0,16	0	0,90	1	3,75	4	2,34	8	0,01	0	0,01	3,75	1,17
Pesticides use	0,05	0	0,17	0	0,76	1	0,45	1	0,45	1	0,46	0	0,03	0	0,21	0	0,03	0,76	0,32
2. Sorting and packaging:	**3,91**	**29**	**36,32**	**79**	**55,02**	**60**	**8,90**	**23**	**27,86**	**41**	**32,01**	**30**	**10,08**	**34**	**59,55**	**70**	**3,91**	**59,55**	**29,21**
Materials	1,62	12	21,22	46	48,37	52	6,26	16	25,92	38	21,78	20	6,10	21	47,01	55	1,62	48,37	22,28
Energy	2,30	17	15,11	33	6,65	7	2,63	7	1,94	3	10,23	10	3,98	14	12,54	15	1,94	15,11	6,92
3. Marketing phase:	**3,04**	**23**	**2,64**	**6**	**17,95**	**19**	**14,84**	**38**	**25,28**	**37**	**56,28**	**53**	**4,54**	**16**	**11,38**	**13**	**2,64**	**56,28**	**16,99**
Gas oil for transport	3,04	23	2,64	6	17,95	19	14,84	38	25,28	37	56,28	53	4,54	16	11,38	13	2,64	56,28	16,99
TOT.INPUT	**13,38**	**100**	**46,10**	**100**	**92,44**	**100**	**39,44**	**100**	**68,37**	**100**	**106,40**	**100**	**29,30**	**100**	**85,59**	**100**	**13,38**	**106,40**	**60,13**
OUTPUT																			
Commercial output	11,02	100	66,98	100	51,46	100	16,83	100	21,34	100	45,71	100	29,84	100	22,17	100	11,02	66,98	33,17
TOT.OUTPUT	**11,02**	**0**	**66,98**	**100**	**51,46**	**100**	**16,83**	**100**	**21,34**	**100**	**45,71**	**100**	**29,84**	**100**	**22,17**	**100**	**11,02**	**66,98**	**33,17**
EE (GJ/GJ)	**0,82**		**1,45**		**0,56**		**0,43**		**0,31**		**0,43**		**1,02**		**0,26**		**0,26**	**1,45**	**0,66**
EP (kg/MJ)	**1,94**		**7,84**		**0,49**		**2,99**		**0,55**		**0,40**		**4,71**		**0,23**		**0,23**	**7,84**	**2,39**

that in arable Flanders farms nearly 35% of total energy input in 2000-2001 could be attributed to the used mineral fertilisers. With in the farm production phase 1, the use of energy for seeds and plantlets is relatively high (16% as average, 7% and 33% as min and max) if compare with others sectors. In fact in arable the machine use are higher than in horticulture if compare with technical means, that are higher in horticultural farms. But in general the production process is extremely simplified and the total costs are controlled as it evidenced in the economic analysis conducted in the same farms (Chiorri et al., 2012).

Energy use efficiency

Results in tab.3 show that these farms have a low Energy Efficiency (EE: 0,66 average, 0,26 min and 1,45 max) but are in line with others researchs of the same farming systems in Italy (Migliorini et al., 2008). This in fact is due to the low energy content of the vegetable products if compared to the cereals grain and not to the low yield level of production that is good. The farms show an homogenous energy balance. The Energy Productivity is positive (EP: 2,39 average, 0,23 min and 7,84 max), showing that some farms are much better than others (case study B and G) managing to produce a high amount of vegetable products (and also cereals in case of B) with a low energy inputs. These data are far from the high efficiency of the arable crop that show an average output/input ratio of 11 in case of organic farming and 7,5 of conventional farming (Mazzoncini et al., 2011) or 5,5 in Flemish conventional arable farms (Meul et al., 2007) but still show a positive situation.

Conclusion

The organic horticultural sector in Italy show a low use of energy for input and are especially virtuous for the reduction use of both machinery and external inputs (except seeds and plantlets). All farms cultivate a large number of horticultural species and use different forms of marketing with a short chain (about three per company) to meet the needs of a loyal and satisfied customers. Increased organizational complexity is comforted by the relatively simplified cultivation phase, but with an increase in need during processing, packaging and marketing.

Acknowledgment

This study was carried out in the framework of the "ORT.BIO" Project funded by the Ministry for Agricultural Food and Forestry Policies (MIPAAF). Coordinator: University of Bologna Partners: CRPV Cesena, Bologna PROBER, CRA CRA-ORA Monsampolo del Tronto, D-SEEA University of Perugia.

References

Baldi, F., Spugnoli, P., Zoli, M. (1986): Analisi energetica di aziende agricole toscane a prevalente indirizzo viti-olivicolo: primi risultati e confronti. Proceeding of the 2nd International Conference on Energy and Agricolture, Sirmione, 13-16 ottobre 1986.

Biondi, P., Panaro, V. e Pellizzi, G. (1989): Richieste di energia nel sistema agricolo italiano. PFE, Roma, 389 pp.

Chiorri, M., Paffarini, C., Galioto, F. (2012): I canali commerciali "corti" nell'orticoltura biologica: caratteristiche strutturali e primi risultati economici di casi studio in Emilia Romagna, Marche ed Abruzzo. GRABIT Ist International Workshop, Ancona May 10-11 2012 "Organic farming. A sustainable model for transition in the Mediterranean" (in ita).

Corre, W., Schroder, J. and Verhagen, J. (2003): Energy use in conventional and organic farming systems. Proc. Intl.

Fert. Soc. 511: 1-24.

Dalgaard, T., Halberg, N., Porter, J.R. (2001): A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. Agric. Ecosyst. Environ. 87: 51-65.

Koga, N. (2008): An energy balance under a conventional crop rotation system in norther Japan: perspectives on fuel ethanol production from sugar beet. Agric. Ecosyst. Environ. 125: 101-110.

Laws, S. et al. (2003): Research for development, a practical guide, Sage Publications, Trousands Oaks.

Mazzoncini, M., Migliorini, P, Belloni, P., Moschini, V., Barberi, P., Vazzana, C. (2011): Maggiore efficienza energetica dai sistemi bio applicati in Toscana in ricerche di lungo periodo. In: L'agricoltura biologica in risposte alle sfide del futuro: il sostegno della ricerca e dell'innovazione.. Catania, 7-8 Novembre 2011, ROMA:ENEA. Agenzia nazionale per le nuove tecnologie, p52, ISBN: 978-88-8286-250-3.

Migliorini, P., Chiorri, M., Moschini, V., Galioto, F., Vazzana, C. (2008): Quella biologica è sostenibile? BioAgricoltura sett./ott. 2008, pag. 30-36 Roma.

Meul, M., Van Passel, S., Nevens, F., Dessein, J., Rogge, E., Mulier, A., Van Hauwermeiren, A. (2008): MOTIFS: a monitoring tool for integrated farm sustainability. Agron. Sustain. Dev. 28: 321–332.

Nguyen, M.L., Haynes, R.J. (1995): Energy and labour efficiency for three pairs of conventional and alternative mixed cropping (pasture-arable) farms in Canterbury New Zealand. Agric. Ecosyst. Environ. 52: 163-172.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., and Seidel, R. (2005): Environmental, energetic, and economic comparisons of organic and conventional farming systems. Bioscience 55: 573–582.

Raviv, M. (2010): Sustainability of organic horticulture. Horticultural Reviews, Hoboken (New Jersey) Willey-Blackwell, vol.36.

Topp, C., Stockdale, C., Watson, and Rees (2007): Estimating resource use efficiencies in organic agriculture: a review of budgeting approaches used. J. Sci. Food Agr. 87(15): 2782–2790.

USDA (2004): USDA National Nutrient Database for Standard Reference. United States Department of Agriculture. Accessd on: http://www.nal.usda.gov/fnic/foodcomp/search.

Vazzana, C., Raso, E., Pieri, S. (1997): Una nuova metodologia europea per la progettazione e gestione di agroecosistemi integrati ed ecologici: applicazione in un'area agricola toscana, Rivista di Agronomia, 31 (2): 423-440.

Yin, K.R. (2002): Case Study Research, Design and Methods, 3 rd Ed. Newbury Park, Sage Publications, Trousands Oaks.