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ScienceDirect
Journal of Cleaner Production 16 (2008) 1907–1914
Journal of Cleaner Production
www.elsevier.com/locate/jclepro

Emergy evaluation of Sicilian red orange production. A comparison between organic and conventional farming

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Received 29 March 2007; received in revised form 11 January 2008; accepted 15 January 2008
Available online 4 March 2008

Abstract

This study examines, by using emergy analysis, the production of red orange in Sicily in order to evaluate resource use, productivity, environmental impact and overall sustainability. Four different sicilian farms were studied in order to compare conventional with organic production. Several indices derived from the emergy evaluation were used: the emergy yield ratio (EYR); the environmental loading ratio (ELR); the index of sustainability (SI). Organic orange production appears to use more renewable resources and less purchased energy and materials.

Keywords: Blood oranges; Emergy method; Sustainability index; Organic agriculture

1. Introduction

Modern agricultural production systems are dependent upon large quantities of increasingly scarce non-renewable resources to maintain their high yields. Simultaneously, there is evidence that many modern, highly mechanized systems of food production can degrade soil, water and genetic resources. Recognition of the fact that conventional modern agriculture deviates from ecological principles has inspired a new generation of scientists and agricultural practitioners who are working to reintegrate the principles of ecology into agriculture [31,32]. While the goal of farming in a manner that is more mimetic of natural systems may be firmly incorporated into the tenets of the alternative agriculture movement, measuring the sustainability of agricultural systems by the criterion of how closely their function resembles natural systems is a relatively new area of research, and understanding how ecological principles translate into agricultural practice remains an important task. This paper is an attempt to evaluate the sustainability of the production of Sicilian red oranges, by using the emergy analysis [15] as a methodological platform.

2. Methodology

2.1. An overview on Sicilian red oranges

The best quality of the Sicilian orange supply is represented by the production of pigmented oranges, best known as "red" (blood) oranges, "Tarocco", "Moro" and "Sanguinello" [28].

They provide some special flavours and organoleptic characteristics that cannot be found outside Sicily, and in particular outside the east side of Sicily and in the south and south–west of Mount Etna. It is in this part of the island – nowhere else in the Mediterranean or in America – that these oranges have found the right environmental conditions to best show their genetic characteristics, such as their intense red colour and the perfect acid/sugar ratio [19]. Red orange growing in Sicily is extremely important in some areas (Map 1), which are specifically suitable for their pedological and weather conditions. Temperature ranges between morning and night, sometimes of beyond 20 °C, contribute to the synthesis of

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0959-6526/$ - see front matter
doi:10.1016/j.jclepro.2008.01.003

anthocyanins [26]. Anthocyanins that do not exist in blonde varieties, not only give an essential sensory contribution, as they help to typify the product and promote its image, but they also play a more important biological role. In fact, they are used in ophthalmologic therapy as active principles; they contribute to the regeneration of the visual purpura in the treatment of ulcers and in angiology, thanks to their epithelium-repairing and capillary-permeability modulating properties. They are also used in those physiopathological conditions characterized by an excessive production of free radicals [2,6,10,13,20]. The prevailing anthocyanin in blood oranges is the cyanidin-3-glucoside, which has a powerful antioxidant action and is therefore useful in preventing cardiovascular diseases and the development of some types of cancer [1]. They also reduce the effects of ageing and help to prevent hypercholesterolemia. The characteristics of the land and climate are essential for producing the pigments that give red oranges their characteristic colour in some Sicilian territories. The essential factor is, indeed, whether the above-mentioned sudden change in temperature occurs when oranges ripen. This phenomenon, a characteristic of the Mediterranean, does not exist in tropical areas from which citrus fruits come. This provides fruits with valuable, unique organoleptic characteristics. With respect to their peculiar biological characteristics and their unique geographical origin, Sicilian blood oranges have gained the PGI EU recognition (Protected Geographical Origin), according to the EC Regulation n. 1107/96 and the consequent ‘‘Disciplinare di Produzione Arancia rossa di Sicilia" (Circolare del Ministero per le Politiche Agricole – Gazzetta Ufficiale Repubblica Italiana n. 240 on 14th October 1997). The production of ‘‘red’’ oranges in Sicily brought back from Italian official statistics (National Institute of Statistics – ISTAT) has only recently overcome 1000 tons. Although a great increase in production has been registered, the product exportation seems to be very limited. Exportation growth seems to be stable or slightly declining. It can be traced back mainly to the growing presence of other countries (Spain, Greece, Morocco, Turkey) on main citrus markets. These countries are able to compete thanks to a price policy, which is fostered by their extremely low cost factors. On the other hand, there is no appropriate and effective policy aimed at promoting those productions, even if Sicilian productions have nearly unrivalled qualities. Italian goverment has not done enough to develop organisation models fit for carrying out adequate policies for product differentiation [27]. Finally, as regard to the Sicilian red oranges, some tourists consider their holidays in Sicily an opportunity to eat typical and traditional agricultural products, which remind them of Sicily’s ‘‘nature, sun and landscape’’ and the ‘‘authenticity, quality and taste’’ of its local products. Their most appreciated products are, therefore, ‘‘sicilian blood oranges’’ [22,23].

2.2. Emergy analysis and sustainability

Emergy is defined as the sum of all inputs of energy directly or indirectly required by a process to provide a given product when the inputs are expressed in the same form (or type) of energy, usually solar energy. Most often, inputs to a process are the result of another process (or a chain of processes), in which energy has been concentrated and upgraded [24]. Thus, the total emergy input is derived by summing up all inputs, as previous defined (expressed in equivalent energy of a single form, such as solar energy) used in the chain of processes that yielded the output in question. The total solar emergy of an item can be calculated as the product of its available energy content by its solar transformity. It is usually measured in solar emergy joules (sej), while solar transformity is expressed as solar emergy joules per joule of product (sej/J). When an item is expressed in units different than joules, for instance as grams, the quality factor is emergy/mass (sej/g).

The solar transformity gives a measure of the concentration of solar emergy through a hierarchy of processes or levels. Transformity can be considered a quality indicator, according to Lotka-Odum’s maximum power principle (Odum and Pinkerton, 1955).

Once the total number of input flows has been identified and the total emergy driving a process has been evaluated, a set of indices and ratios can be calculated.

Three main emergy flows can be recognized when evaluating a system:

- renewable flows from within (R);
- non-renewable flows from within (N); and
- flows imported from outside the system (feedback flows, F).

Sometimes referred to as purchased flow (other works have widely described these concepts, see Refs. [24,25,33,34]).

The renewable flows (R) are: flow limited, free and locally available. The non-renewable flows (N) are: stock limited, not always free and locally available.

The feedback flows (F) may be: stock limited, never free, never locally available, always imported.

The above characteristics of emergy flows make it possible to calculate different and useful indices. In the present study we apply three main indicators, that have been widely discussed elsewhere, and we shortly describe below.

- The environmental loading ratio (ELR) is the ratio of purchased (F) and non-renewable indigenous emergy (N) to free environmental emergy (R). It is an indicator of the pressure of the process on the local ecosystem and can be considered a measure of the ecosystem stress due to production activity.
- The emergy yield ratio (EYR) is the ratio of the emergy of the output (Y), divided by the emergy of those inputs (F) to the process that are fed back from outside the system under study. It is an indicator of the yield compared with inputs other than local inputs and gives a measure of the ability of the process to exploit local resources accounting for the difference between local and imported. The higher the EYR, the higher this ability, which is not a negligible factor in economic systems.

- The index of sustainability (SI), defined as the ratio of the above EYR to the ELR, globally indicates if a process provides a suitable contribution to the user with a low environmental pressure.

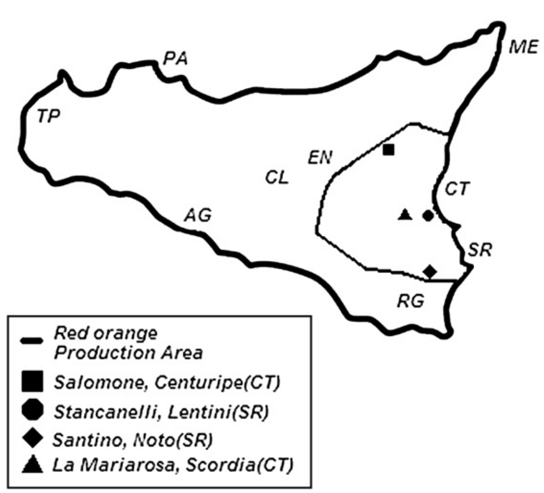
2.3. Site descriptions

Field studies were conducted in several farms that use both systems of orange production, organic and conventional. They are located inside the geographic boundaries, according to the EC Regulation n. 1107/96, from the east side of Sicily and in the south and south–west of Mount Etna, as traced in Map 1. The conventional system is characterized by the use of chemical pesticides, herbicides, fertilizers and petroleum fuel. The organic system is intensive in the use of natural inputs, organic manure and permanent workers.

The first farm is called La Mariarosa [30] and is located in the municipal district of Scordia (CT) (see Map 1). It occupies a total area of 100 ha planted with conventional red orange cultivars. The second farm, a small size farm, is called Stancanelli and is located in the municipal district of Lentini (SR), in the south border. It occupies a total area of 30 ha, planted with organic red orange cultivars. Other two organic farms were considered in order to compare other parameters such as the size, the productivity and the management choice within the organic productivity: the farm Santino [29], a 6 ha small family agricultural plantation located in the district of Noto (SR), and the Salomone farm, with 1.8 ha, located in the municipality of Centuripe (CT) in the northern border.

3. Results

The results of the analyses are given in diagrammatic and in tabular forms. Figs. 1 and 2 are, respectively, the energy flow diagrams of the conventional farm La Mariarosa and the organic farm Santino. They give a general picture of the orange production systems and illustrate the connections between the various components. Fig. 1 shows more purchased inputs including pesticides, fertilizers (phosphorous, potash, nitrogen), electricity, human labor. Santino's farm instead (Fig. 2) uses, no electricity, no external human labor, organic manure and no pesticide (this choice enhances local biodiversity).



Map 1. Map of Sicily including the geographical boundaries of red orange production and the location of the four studied farms.

Tables 1–4 are samples of emergy evaluation tables. Column 1 of the tables gives the line number of each item and is a footnote reference for the emergy calculations that are listed below the table. The name of the item and the units of raw data for that item – usually joules, grams or euros – are recorded in column 2. Column 3 gives the quantity of the component recorded in joules, grams or euros. The energy, material or currency flow for each item is then multiplied by its respective transformity, which is given in column 4. The product of the raw data and the transformity equals the total emergy contribution of that component to the system. The majority of the transformities used in this study were gathered from previously published analyses (e.g., [5,11,15,16,25]). The emergy contributions of the components to the system are listed in column 5 and the emergy contributions per hectare are listed in column 6.

Table 1 gives the results from the emergy analysis of the conventional farm La Mariarosa. A full description of the evaluation of all the items involved in the emergy accounting of the orange production of La Mariarosa farm is given as footnote to Table 1. For the other farms only the final results are reported in Tables 2–4.

The emergy inputs from sun, wind and rain (items 1, 2, 3) are by-products of the same global flow. To avoid double counting only the largest of these components was counted. The percentage of renewable and non-renewable emergy supporting labor was determined based on previous studies [25,17,21]. In Italy, 90% of supporting labor was due to non-renewable sources. Irrigation water was considered in part renewable (the fraction of rain water collected in a pond, as explained in note to item 5) and in part purchased (the fraction purchased from the municipal water distribution system, as reported in note to item 13).

4. Discussion

Data reported in Table 5 give a clear description of the analysis results. The total emergy flows are very similar for all the systems but the transformity values differ considerably. The highest transformity value (2.2E9 sej/g) was calculated for the farm Santino (a family run organic farm); the lowest value (0.6E9 sej/g) was found for the farm Salomone (considered an intensive organic farm because of the great orange yield). The lower transformity and the greater orange yield per ha indicate that Salomone farm concentrates renewable energies across time and space to produce yields. The high transformity of Santino farm indicates that more area is required to concentrate lower quality energies (Santino farm does not use electricity nor external human labor) for a smaller harvest.

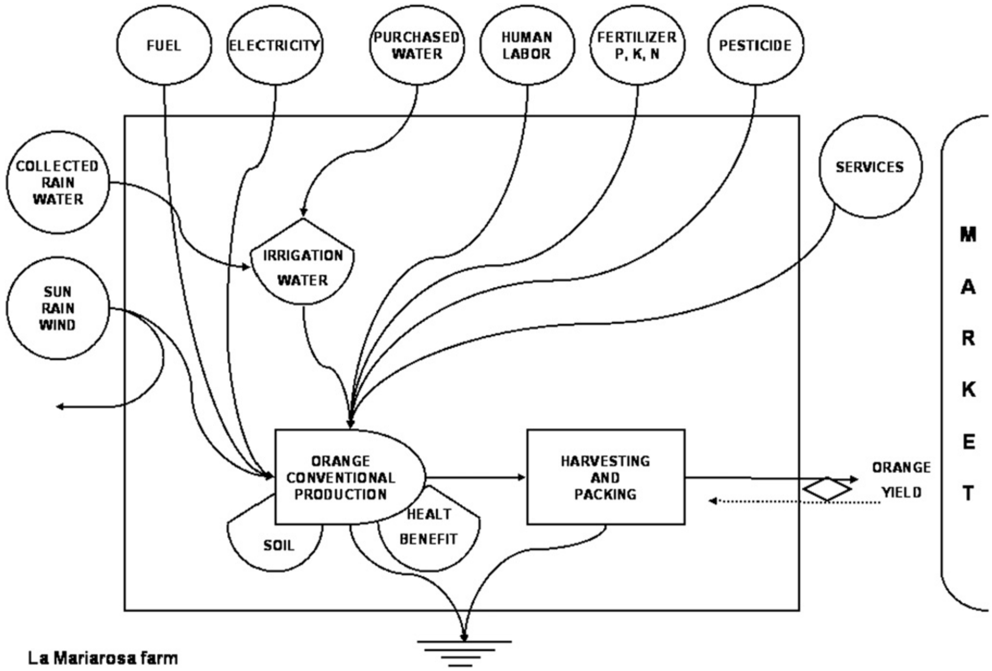


Fig. 1. Energy systems diagram of the conventional orange production of La Mariarosa farm.

The analysis of the emergy indices indicates that EYR is higher for the farm Santino and lower for the conventional farm La Mariarosa. EYR calculates the amount of renewable energy utilised per investment of non-renewable energy. The low EYR for the conventional system indicates that a small amount of renewable energy was utilised per investment of non-renewable energy [12] as demonstrated by the low fraction renewable value reported in Table 5. The average EYR for Italian conventional agriculture is 1.43 [25]; the values found for the three organic systems under study (Stancanelli 2.6; Santino 11.7; Salomone 1.6) are higher than the Italian average, demonstrating the higher amount of renewable energy utilised by the organic agriculture.

The environmental loading ratio is greater for the conventional system La Mariarosa ELR = 43; for the organic farms the ELR value was: Stancanelli 30, Santino 3.8, Salomone

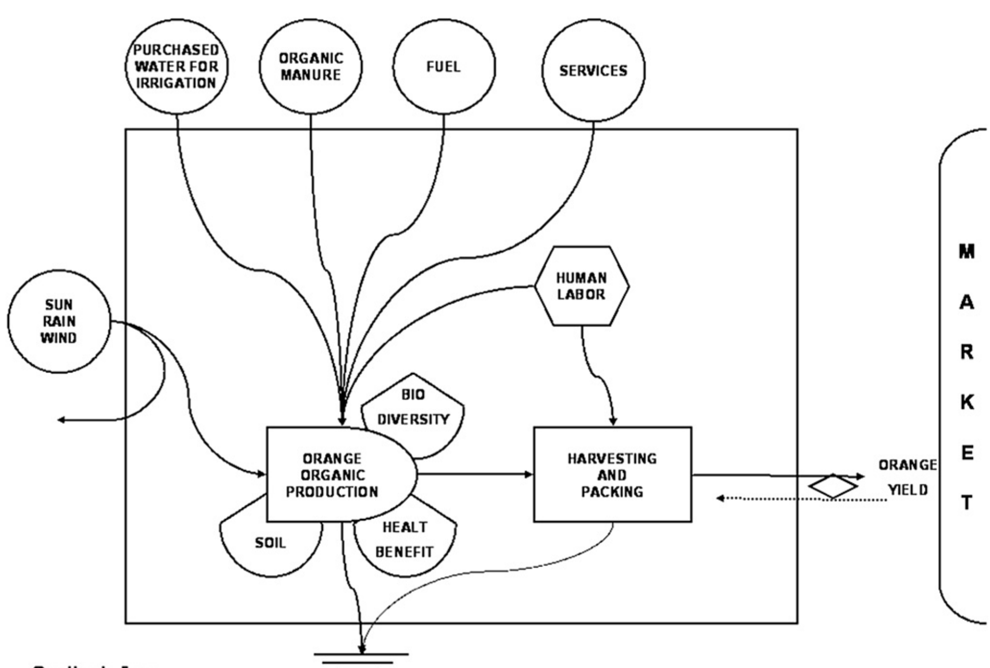


Fig. 2. Energy systems diagram of the organic orange production of Santino's farm.

Table 1
Farm La Mariarosa, Scordia (ct); conventional production; surface area 100 ha

Note	Item	Data (unit/yr)	Transformity (sej/unit)	Emergy (sej/yr)	Emergy/ha/yr
Renewable resources (*R*)					
1	Sunlight	3.2E15 J	1E00 sej/J	3.2E15	3.2E13
2	Rain	9.7E11 J	18 199 sej/J	1.7E16	1.7E14
3	Wind	2.54E9 J	1496 sej/J	3.8E12	3.8E10
4	Labor (10%)	1.75E9 J	7.38E6 sej/J	1.3E16	1.3E14
5	Irrigation water	9.88E11 J	18 199 sej/J	1.8E16	1.8E14
Sum of renewable				5.2E16	5.2E14
Non-renewable resources (*N*)					
6	Net top soil loss	6.24E12 J	1.24E5 sej/J	7.74E17	7.74E15
Purchased resources (*F*)					
7	Gasoline J	5.3E11 J	1.1E5 sej/J	5.83E17	5.83E15
8	Electricity J	6.42E11 J	1.43E5 sej/J	9.1E16	9.1E14
9	Phosphate	1.12E6 g P	3.69E10 sej/g	4.13E16	4.13E14
10	Potash	2.36E7 g K	3.01E9 sej/g	7.1E16	7.1E14
11	Nitrogen	3.01E6 g N	4 E10 sej/g	1.2E17	1.2E15
12	Pesticide	1.79E6 g	1.48E10 sej/g	2.6E16	2.6E14
13	Irrigation water	8.E11 g	5.12E5 sej/g	4.1E17	4.1E15
14	Services	3.01E4€	1.4E12 sej/€	4.2E16	4.2E14
15	Labor (90%)	1.57E10 J	7.38E6 sej/J	1.16E17	1.16E15
Sum of purchased				1.5E18	1.5E16
Product evaluation					
16	Total emergy	2.3E18 sej		Total emergy/ha/yr 2.3E16 sej	
17	Orange yield	2E9 g		Orange yield/ha/yr 2E7 g	
18	Orange emergy per mass	1.2E9 sej/g			

1. Sunlight = $A \times I \times$ absorbed percentage
   (*Handbook of Emergy evaluation* (3) M.T. Brown, E. Bardi, p. 59)
   A = surface area E6 m^2
   I = average solar radiation of Priolo (SR) = 101.5 W/m^2 (average summer insulation 137.7 W/m^2; average winter insulation 65.3 W/m^2, CIPA)
   Absorbed percentage = 70%
   Evaluation = E6 m^2 × 101.5 J/s m^2 × 3.1536E7 s/yr × 0.7 = 3.2E15 J/yr.
2. Rain, chemical potential energy = $A \times p \times d \times \Delta G$
   ΔG = Gibbs free energy (4.94 J/g) (*Environmental Accounting* H.T. Odum, p. 42)
   p = yearly precipitation (58% of 340 mm/yr) (evapotranspiration rate 58%, T. Rydberg, 2002)
   d = water density (1E6 g/m^3)
   Evaluation = E6 m^2 × 0.197 m/yr × 1E6 g/m^3 × 4.94 J/g = 1.76E12 J/yr.
3. Wind kinetic = $r \times c(\mathrm{vg})^3 A$
   r = air density (1.23 kg/m^3)
   c = drag coefficient (1E-3)
   v = average annual wind velocity (2.42 m/s)
   vg = geostrophic wind (10/6v)
   A = surface area (E6 m^2)
   (*Handbook of Emergy evaluation* (3) M.T. Brown, E. Bardi, p. 39)
   Evaluation = 1.23 kg/m^3 × 1E-3(10/6 × 2.42 m/s)^3 × 31 536E3 s/yr × E6 m^2 = 2.5E9 J/yr.
4. Transformity for human labor is 7.38E6 sej/J [25]
   11 employees working 10 h/day; (11 persons × 10 h = 110 ph); (110 ph/24 h = 4.6 persons × day) (4.6 p/day × 365 days/yr = 1679 persons/yr) 1679 persons/yr × 2500 kcal/person × 4186 J/kcal = 1.75E10 J. In Italy, 90% of supporting labor is considered due to non-renewable sources and 10% to renewable.
5. Transformity for renewable irrigation water 18 199 sej/J. Renewable water is rain water collected in a pond. Total use of renewable water (2E11 g × 4.94 J/g) = 9.88E11 J/yr.
6. Net top soil loss transformity for organic soil is 7.38E4 sej/J [15] corrected by factor of 1.68 = 1.24E5 sej/J [16]. Erosion rate estimated at 690 g/m^2/yr [8,14,18] with 0.04% organics in soil. The energy content in organic soil is 5.4 kcal/g [35].
   The net loss of topsoil is (farmed area) (erosion rate) = (E6 m^2) (690 g/m^2/yr) = 6.9E8 g/yr.
   The energy of soil used, or lost = (net loss topsoil) (% organic) (5.4 kcal/g) (4186 J/kcal) = (6.9E8 g/yr) (0.04%) (5.4 kcal/g) (4186 J/kcal) = 6.2E12 J/yr.
7. Fuel includes diesel, gasoline and lubricants and uses petroleum products transformity 6.6E4 sej/J [15] corrected by factor 1.68 [16]. Transformity = (6.6E4 sej/J × 1.68) = 1.1E5 sej/J.
   Yearly cost for fuel consumption 1000€/yr; cost of agricultural fuel in 2005 = 0.646€/l.
   Volume of fuel consumption (10 000€/yr:0.646€/l) = 15 480 l; fuel density 0.82 kg/l.
   Fuel weight (15 480 l × 0.82 kg/l) = 12 693 kg/yr.
   Heat content (4.19E7 J/kg). Total joules in fuel consumption 4.19E7 J/kg × 12 693 kg/yr = 5.3E11 J/yr.
8. Transformity from Italian electricity is 1.43E5 sej/J (Sviluppo di un modello di analisi emergetica per il sistema elettrico nazionale, 2000 – contabilità ambientale, Bastianoni, p. 72). Total cost for electricity consumption 25 000€/yr; price of electricity in Italy = 0.14€/kWh; Electricity consumption in joule (25 000€/0.14€) = 178 571 kWh = 6.42E11 J/yr.

9. Transformity for phosphorus 2.2E10 sej/g P [3] corrected by factor 1.68 [16]; Transformity = 3.7E10 sej/g P.
Phosphate use for orange orchards = 1.12E4 g P/ha/yr [4 p. 12]. Total phosphate use (E6 m^2) (1.12E4 g P/E4 m^2) = 1.12E6 g P.
10. Transformity for potash (K_2O) 1.74E9 sej/g K [15] corrected by factor 1.68 [16]; Transformity = 3E9 sej/g K.
Potash use for orange orchards = 2.36E5 g K/ha/yr [4 p. 12].
Total potash use (E6 m^2) (2.36E5 g K/E4 m^2) = 2.36E7 g K.
11. Transformity for nitrogen 2.41E10 sej/g N [3] corrected by factor 1.68 [16]; Transformity = 4.05E10 sej/g N. Nitrogen use for orange orchards 3.01E4 g N/ha/yr [4 p. 12]. Total nitrogen use (E6 m^2) (3.01E4 g N/E4 m^2) = 3.01E6 g N.
12. Pesticides also include fungicides and herbicides. Transformity for pesticides 1.48E10 sej/g [5]. Pesticides use for orange orchards 1.79E4 g/ha/yr [4 p. 12]. Total pesticides use (E6 m^2) (1.79E4 g/E4 m^2) = 1.79E6 g/yr.
13. Transformity for purchased water 5.12E5 sej/g, calculated for the Italian territory by Tiezzi et al., in Analisi di sostenibilità ambientale della Provincia di Modena e dei suoi distretti, Siena, 1998). Total use of purchased water 8E11 g.
14. Services for oranges include cost of tree stock, land, buildings and management divided over estimated life of operation. Transformity 1.4E12 sej/€ (Tiezzi et al., Analisi di sostenibilità ambientale della Provincia di Modena e dei suoi distretti, Siena, 1998).
15. Purchased labor transformity usually will be higher than local labor transformity. Because of lack of more precisely local data, in this study we use the same transformity on item 4 and item 15 (see no. 4).
16. Total emergy is sum of all components.
17. Orange yield is given as fresh weight of oranges produced.
18. Orange transformity is given by dividing the total emergy by the orange yield.

24. This ratio is related to the fraction of renewable resources and is considered a measure of ecosystem stress due to production [24]. According to the ELR found for the farms under study, the ecosystem stress involved in the organic orange production is lower than in conventional production.

The SI was studied and proposed by Ulgiati and Brown [24]. According with their results, an SI < 1 appears to be indicative of consumer products or processes, and an SI > 1 is indicative of products that have net contributions to society. A low SI (<1) is indicative of highly developed consumer oriented economies, and high SI (>10) is indicative of economies that have been termed undeveloped. SI ratios between 1 and 10 are indicative of developing economies. The SI calculated for Italy in 1989 [25] was SI = 0.17. This indicates a massive use of non-renewable energy, large imports of purchased energy and materials, and large environmental stress. In the present study the farm Santino, with an SI = 3.1 and an ELR = 3.8 appears to be the most sustainable of the four systems. Nevertheless, the high transformity value due to the low

Table 2
Stancanelli, Lentini (SR), organic production; surface area 30 ha; five workers

Note	Item	Data (unit/yr)	Transformity (sej/unit)	Emergy (sej/yr)	Emergy/ha/yr
Renewable resources (*R*)					
1	Sunlight	9.6E14 J	1E00 sej/J	9.6E14	3.2E13
2	Rain	2.9E11 J	18 199 sej/J	5.3E15	1.7E14
3	Wind	2.5E9 J	1496 sej/J	3.8E12	1.3E11
4	Labor (10%)	8E8 J	7.4E6 sej/J	5.9E15	1.9E14
5	Irrigation water	–	–	–	
Sum of renewable				1.2E16	3.9E14
Non-renewable resources (*N*)					
6	Net top soil loss	1.8E12 J	1.24E5 sej/J	2.2E17	7.3E15
Purchased resources (*F*)					
7	Gasoline	3.4E9 J	1.1E5 sej/J	3.7E14	1.2E13
8	Electricity	2.4E11 J	1.43E5 sej/J	3.4E16	1.1E15
9	Organic manure	6E6 g	1.13E8 sej/g[a]	1.1E14	3.7E12
13	Irrigation water	7.2E10 g	5.12E5 sej/g	3.7E16	1.2E15
14	Services	9.1E3€	1.4E12 sej/€	1.2E16	4.0E14
15	Labor (90%)	7.2E9 J	7.38E6 sej/J	5.3E16	1.8E15
Sum of purchased				1.4E17	4.5E15
Product evaluation					
15	Total emergy	3.8E17 sej		Total emergy/ha/yr 1.2E16 sej	
16	Orange yield	2.4E8 g		Orange yield/ha/yr 8E6 g	
17	Orange emergy per mass	1.6E9 sej/g			

[a] [7].

Table 3
Farm Santino, noto (SR); surface area 6 ha, no electricity, one worker

Note	Item	Data (unit/yr)	Transformity (sej/unit)	Emergy (sej/yr)	Emergy/ha/yr
Renewable resources (*R*)					
1	Sunlight	2.3E14 J	1E00 sej/J	2.3E14	3.8E13
2	Rain	5.8E10 J	18 199 sej/J	1.05E15	1.75E14
3	Wind	7.5E8 J	1496 sej/J	1.1E12	1.8E11
4	Labor (100%)	1.6E9 J	7.38E6 sej/J	1.2E16	2E15
5	Irrigation water	–			
Sum of renewable				1.33E16	2.2E15
Non-renewable resources (*N*)					
6	Net top soil loss	3.7 E11 J	1.24 E5 sej/J	4.5 E16	7.5E14
Purchased resources (*F*)					
7	Gasoline	3.4E10 J	1.1E5 sej/J	3.7E15	
8	Electricity	–			
9	Organic manure	2E5 g	1.13E8 sej/g*	2.26E13	
12	Pesticide	–			
13	Irrigation water	1.4E7 g	5.12E5 sej/g	7.1E12	
14	Services	1.01E3€	1.4E12 sej/€	1.4E15	
Sum of purchased				5.1E15	8.5E14
Product evaluation					
15	Total emergy	6.3E16 sej		Total emergy/ha/yr 1.05E16 sej	
16	Orange yield	3E7 g		Orange yield/ha/yr 5E6 g	
17	Orange emergy per mass	2.2E9 sej/g			

Table 4
Salomone organic production; surface area 1.8 ha

Note	Item	Data (unit/yr)	Transformity (sej/unit)	Emergy (sej/yr)	Emergy/ha/yr
Renewable resources (*R*)					
1	Sunlight	5.7E13 J	1E00 sej/J	5.7E13	
2	Rain	1.7E10 J	18 199 sej/J	3.1E14	
3	Wind	1.5E8 J	1496 sej/J	2.2E11	
4	Labor (10%)	1.6E8 J	7.38E6 sej/J	1.2E15	
5	Irrigation water	–	–	–	
Sum of renewable				1.5E15	8.6E14
Non-renewable resources (*N*)					
6	Net top soil loss	1.2E11 J	1.24E5 sej/J	1.4E16	7.7E15
Purchased resources (*F*)					
7	Gasoline	3.4E9 J	1.1E5 sej/J	3.7E14	
8	Electricity	2.9E10 J	1.4E5 sej/J	4.1E15	
9	Organic manure	4E5 g	1.13E8 sej/g	4.52E13	
10	Irrigation water	9E9 g	5.12E5 sej/g	4.6E15	
11	Services	2.01E3€	1.4E12 sej/€	2.8E15	
12	Labor (90%)	1.44E9 J	7.38E6 sej/J	1.08E16	
Sum of purchased				2.3E16	1.3E16
Product evaluation					
15	Total emergy	3.8E16 sej	Total emergy/ha/yr		2.1E16 sej
16	Orange yield	6.4E7 g	Orange yield/ha/yr		3.5E7 g
17	Orange emergy per mass	0.6E9 sej/g			

product yield makes this system not the most efficient under the socio-economic point of view. A good compromise could be the farm Salomone, a 2 ha organic farm with a great orange production per year, a low transformity value and better emergy indices values compared with the indices related to the conventional agriculture and with the indices related to the Italian agriculture. A limitation of our application is the use of the same transformity for human labor. Labor usually will have different transformities, the transformity from outside (purchased labor) will be higher than local. A further improvement of this study could be to gather more precise local data in order to evaluate the tranformities for local human labor.

5. Conclusion

This paper demonstrated that, in the four studied farms, better results could be achieved when the small producers make larger use of their renewable natural resources. In terms of public policies, organic orange growing is the best alternative for small-scale producers, enabling them to maintain their economic profitability. Small conventional producers should take the opportunity offered by increasing international demand and start using the organic techniques. The organic production system matches the aim of avoiding the use of synthetic chemical compounds, limiting the intensity of production and providing controls along the entire chain of production. In organic farming, the biodiversity of the native habitats enables the control of pests and preservation of water springs and soil. Thus, the organic system improves local sustainability, whereas the effect on global sustainability is not easily assessable. Organic agriculture is based on a set of principles that can also serve as guidelines for the development of conventional agriculture. But there are a number of problems in organic agriculture that must be solved before it is really sustainable [9]. Emergy is an appropriate methodology to evaluate this systems, because each type of flow, such as monetary or information flows could be taken into account for the evaluation. For a more comprehensive work it could be useful to compare the results obtained in this study with other common methodologies, such as exergy and Life-Cycle Analysis (LCA) that are often used to evaluate materials flows, but not services or information.

Table 5
Category totals and indices calculated for the four systems under study

		La Mariarosa (conventional, 100 ha)	Stancanelli (organic, large extension, 30 ha)	Santino (organic, family farm, 6 ha)	Salomone (organic, intensive, 2 ha)
Category totals					
Emergy yield (sej/ha/yr)	*Y*	2.3E16	1.2E16	1E16	2.1E16
Orange yield (g/ha/yr)	*O*	2E7	8E6	5E6	3.5E7
Transformity (*Y*/*O* sej/g)	*T*	1.2E9	1.5E9	2.2E9	0.6E9
Total renewable (sej/ha/yr)	*R*	5.2E14	3.9E14	2.2E15	8.6E14
Total non-renewable (sej/ha/yr)	*N*	7.7E15	7.3E15	7.5E15	7.7E15
Total purchased (sej/ha/yr)	*F*	1.5E16	4.5E15	8.5E14	1.3E16
Indices					
Fraction renewable	$R/(R+N+F)$	0.026	0.03	0.2	0.04
Emergy yield ratio (EYR)	Y/F	1.5	2.6	11.7	1.6
Environmental loading ratio (ELR)	$(F+N)/R$	43	30	3.8	24
Emergy sustainability index (SI)	EYR/ELR	0.03	0.08	3.1	0.07

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