Emergy analysis of organic horticultural systems

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Abstract

The industrial agriculture depends on a constant flow of non-renewable natural resources, which will not be able to meet the growing demand. The emergy analysis quantifies the sustainability of production systems, and its indicators are useful for the planning of agroecosystems and public policy. This research's objective is to reveal the emergy diagnosis of five horticultural systems under organic management. A studied production unit (number 1) is a system of production and marketing of a small family-business type, in short chain. The other productive units (numbers 2, 3, 4 and 5) are family production systems, where the products are marked by intermediaries, in long chains. The performance evaluation of the emergy production systems followed the three recommended methodological stages: (i) elaboration of a systemic diagram; (ii) constructing emergy tables to calculate total emergy, and (iii) discussion of emergy indicators. Emergy flow analysis indicated the following: total emergy (Y) ranging from 1,72 to 6,24 E+17 seJ ha^{-1} $year^{-1}$; Transformity (Tr): 6.72 E+06 to 3.14 E+07 seJ/J; high renewability (%R = 60 to 85%); Emergy Exchange Ratio (EER) ranging from 1,93 to 12,09; high benefit/cost (ESI - Emergy Sustainability Index) ranging from 3,54 to 39,71. These indicators show that the studied production systems can contribute to economic growth without causing serious disturbance to the environmental balance. The greater energy transformation efficiency in the organic production chain can be achieved by increasing commercialized production; but, to improve long term sustainability, the development strategies for commercialized production must restrict investments in non-renewable energy resources.

Key words: Sustainability; emergy analysis; organic horticulture

Introduction

The availability of food produced by the industrial agriculture depends on constant flow of non renewable natural resources, mainly fossil energy. When the pick of oil extraction is achieved, soon its derivatives will not be capable of achieving the increasing demand, and, as a consequence, the agricultural and industrial production will decrease, and the production of food will be more subordinated to the availability of renewable resources and to the local workforce (GLIESSMAN, 2005; ODUM and ODUM, 2006).

The concept of sustainability applied to the agriculture was evidenced in Agenda 21. The systems of agricultural production of the ecological type, as organic agriculture, have presented satisfactory results from the economical, environmental and social points of view (ASSIS, 2002). In addition, the emergy analysis – sometimes referred as energetic memory – is a method of integral and systemic evaluation of the sustainability, with useful indicators for the planning of the agroecosystems and of public policies for the development of sustainability systems of production, based on the principles of Agroecology.

The solar energy is the most abundant energetic source on Earth, which, by being disperse, in time and space, presents low quality when compared to the quality of other sources of energy derived from it. At each transformation of the energy in another different type, a certain amount is degraded (2^{nd} law of thermodynamics), and the quantity of remaining energy (exergy) is lower, however, the quality of the energy increases (emergy) in relation to the previous step. In general, a lot of Joules of the solar energy are required to produce one Joule of organic matter, a lot of Joules of organic matter are used to produce one Joule of fossil fuel, and so on, a lot of Joules of a low concentrated energy are previously used to produce one Joule of the most concentrated energy. Thus, it is convenient to express all the types of energy in terms

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of equivalent solar energy.

The emergy is defined as the quantity of energy previously available, direct or indirectly, to generate a resource, product, service or information; therefore, it is an universal measure of the work of the nature and the society in a common base, expressed in Joules of solar energy equivalent (seJ, emJoule), to distinguish it from the Joule (ODUM, 1996; BROWN and ULGIATI, 2004). It is clear that to make a resource valuable it is necessary the work of the nature and the man.

The real value of a resource is given by its transformity (Tr), which is a quotient similar to the energetic intensity, but which goes beyond the commercial energetic expense (AGOSTINHO, 2009). The transformity is defined as the ratio of the emergy per unit of potential energy (exergy), and it is expressed in terms of emjoule per joule (seJ J^{-1}); also, it may be expressed in terms of specific emergy, defined as the emergy per mass (seJ g^{-1}); or, still, in terms of emergy per monetary unit (seJ $US\$^{-1}$), which is the total emergy used in the territory of nation divided by the gross national product (GNP) expressed in dollars[1]. The transformity of the solar energy absorbed by the land, by definition, is equal to 1 seJ J^{-1} (ODUM, 1996; BROWN and ULGIATI, 2004).

For the emergy evaluation, it is necessary to know the studied production system, the main compounds, the internal relations and quantify the flow of energy and mass that income and outgo. The budget of the income flow must account the free contributions of the nature (I) and those acquired from the economy (F).

1 Transformity or Emergy Intensity (Unit emergy values); therefore there are three types of Emergy Intensity (seJ J^{-1}, seJ g^{-1} e seJ $\$^{-1}$).

Usually, the flow of the natural resources (I) and the economical (F) are informed in different units (J $year^{-1}$, kg $year^{-1}$ or \$ $year^{-1}$); and, cannot be counted. The solution of the emergy analysis is to convert them in terms of emjoules (seJ). For the conversion, the number value of the flow express in its usual unity is multiplied by the respective value of transformity (seJ J^{-1}, seJ kg^{-1}, seJ $\$^{-1}$). Thus, transformed all the income flow in terms of equivalent solar energy (seJ), the resources used in the production system may be accounted.

The main emergy indicators are ODUM, 1996; ORTEGA et al., 2002; BROWN and ULGIATI, 2004): total emergy (Y), transformity (Tr), emergy yield rate (EYR), renewability (R%), emergy investment rate (EIR), environmental load (ELR), emergy sustainability index (ESI) and exchange rate (EER).

The objective of this work is to evaluate the sustainability of five systems of production of oleiriculture under the organic management, in family business, in the mountain region of the state of Rio de Janeiro, trough the emergy analysis, assuming that the production and commercialization systems must present satisfactory global performance, in long term period.

Material and methods

For the emergy evaluation of the olericultural production systems under organic management, it was selected five (5) units certified by the Associação de Agricultores Biológicos do Estado do Rio de Janeiro (ABIO - Biological Farmers ssociation of the State of Rio de Janeiro), in the highland region of Rio de Janeiro (Table 1)

Table 1. Characteristics of the olericultural productive systems under organic management.

Code	Latitude	Longitude	Altitude	Rainfall	UAS [(1)] (ha)	Production [(2)]	
						kg ha^{-1},$year^{-1}$	US\$ ha^{-1} $year^{-1}$
1	22º 16' (S)	43º 02'(W)	926 m	1500 mm	0.7	18,604	64,304.00
2	22º 15'(S)	42º 58'(W)	1081 m	1500 mm	0.7	14,886	8,607.00
3	22º 15'(S)	42º 58'(W)	1065 m	1500 mm	0.8	23,966	14,934.00
4	22º 11'(S)	42º 55'(W)	722 m	1400 mm	0.3	36,828	13,189.00
5	22º 11'(S)	42º 55'(W)	719 m	1400 mm	0.4	25,596	10,961.00

(1) Used agricultural surface. (2) Commercialized fresh matter. US\$ 1 = R\$ 1.71,

System 1 is a family-business establishment, formed by the partnership of one family of farmers and another family of land properties. It is a diversified system of production and commerce (herbaceous vegetables, tubers and fruits), with home delivery and delivery in hotels, stores and restaurants, which configures it as a productive arrangement in short chain of marketing. Systems 2 and 3 are family establishments of diversified olericultural production, in which the products are sold to intermediates, configuring arrangements in large chain. Systems 4 and 5 are family properties specialized in the production of fruit vegetables, specially chayote - *Sechium edule*, in long chain of commerce.

The emergy analysis observed the three methodological steps: (i) elaboration of a systemic diagram; (ii) construction of a table of the calculation of the total energy; and, (iii) discussion of the emergy indicators (ODUM, 1996; ORTEGA et al. 2002; BROWN and ULGIATI, 2004).

The income and outgo flow of the production systems were quantified trough the information of the farmers, data of the literature, measures of the field, sampling of income and product, accompaniment and monitoring of the production units, during the period from January to December 2008.

The emergy performance was evaluated trough the classic indicators (ODUM, 1996; BROWN and ULGIATI, 2004) and the modified which include the concept of partial renewability (renewable fraction) of each income flow (ORTEGA et al., 2002; AGOSTINHO, 2005; TAKAHASHI et al., 2008).

For the graphical representation of the results of emergy performance it was made a ternary diagram (BARRELLA et al, 2005; GIANETTI et al., 2007)[1]; considering the three flows aggregated in: (i) environmental resources, including renewable and non-renewable free natural resources; (ii) financial renewable resources (Fr); and, (iii) financial non-renewable resources (Fn).

In the following items it is provided a description of the emergy indicators:

a) Transformity (seJ J^{-1}) – is the total emergy (Y= I + F) in seJ, divided by the produced energy (E) in Joule (ODUM, 1996). It evaluates the system efficiency (Tr = Y / E). The lower value indicates higher efficiency of the transformation of the energy. And, high transformity indicates that the system occupies a superior position in the hierarchy of the energy in the biosphere. The transformity of the system indicates, also, the real value of the product.
b) Renewability (R%) – is the percentage of renewable emergy. Systems with high renewability prevail, in long-term period. Equations: R = (R / Y) x 100 (ODUM, 1996); Rm = $[(R+M_R+S_R) / Y] \times 100$ (ORTEGA et al., 2002).
c) Yield Rate (EYR) – indicates the hability of the system in explore the local resources and make them available as products, as a response to external investments. When EYR is equal to one (EYR=1), it indicates that the emergy of the local resources is exactly equal to the quantity of emergy which is provided to the economy; therefore, the system has no potential of contribution to the economical growth. According to BROWN and ULGIATI (2004), the net energy of contribution is low when $1 < EYR < 2$; moderated: $2 < EYR < 5$; and, high: EYR > 5. Systems with EYR > 5 have significant potential of contribution for the socioeconomical growth. Equations: EYR = Y / F (ODUM, 1996); EYRm = $Y / [M_N+S_N]$ (ORTEGA, et al., 2002).
d) Investment rate (EIR) – evaluates the efficient use of the emergy of the investment in resources of the economy. The lower value of EIR indicated lower cost of non renewable emergy, mainly, condition which reduces the cost of production and provides better development in the market. It can be interpreted as index of competitiveness: lower EIR, higher competitiveness (EIR ↓ = competitiveness ↑). Equations: EIR = F / I (ODUM, 1996); EIRm = $[M_N+S_N] / [R+N + M_R+S_R]$ (ORTEGA et al., 2002).
e) Environmental load (ELR) – indicates the stress that the system exercises over the environment. Theoretically, ELR = 0 indicates mature natural ecosystems. The higher the ELR, due to the use of non-renewable resources, higher is the distance between the systems of production and the local ecosystems. According to BROWN and ULGIATI (2004), ELR < 2 indicates low

1 The graphic was drwan with ProSim Ternary Diagram (http://www.prosim.net/en/index.html).

environmental load. Moreover, the stress is moderately low when: $2 < ELR < 3$; moderate: $3 < ELR < 10$; and, high: $ELR > 10$. Equations: $ELR = (N + F) / R$ (BROWN and ULGIATI, 2004); $ELRm = [N+M_N+S_N] / [R+M_R+S_R]$ (ORTEGA et al., 2002).

f) Sustainability index (ESI) – evaluated the contribution of the system to the economy per unit of environmental load. $ESI < 1$ indicated non sustainable system. Systems with $ESI > 1$ contribute to the economical growth, without grave environmental perturbation; however, intermediate values ($1 < ESI < 5$) characterize sustainability in medium term period. $ESI > 5$ indicates sustainability in long term period. Equation: $ESI = EYR / ELR$ (BROWN and ULGIATI, 2004).

g) Exchange rate – is the ratio of the emergy of the product by the emergy of the money. When $EER = 1$, the producer and the consumer have the same amount of emergy, indicating that no commercial partner has relative advantage over the other. When $EER = 1$, the producer and the consumer obtain relative advantage over the other. When $EER < 1$, the producer has advantage over the consumer. And, $EER > 1$, the producer looses emergy, impoverishes, i.e., the emergy rate is in benefit of the consumer. Equation: $EER= Y/ [\$ x (seJ/\$)]$ (ODUM, 1996).

In this work, the transformity of money (seJ $\$^{-1}$, Emdollar, Em$) was calculated by the equation: $EM\$ = \{[248.0 + 878.16*EXP(-1* ((year-1981) / 9.49))] /100\} *10^{12} * 1.68$ (AGOSTINHO, 2005). The value of the estimated Emdollar (Em$) was 5.02E+12 seJ US^{-1}, for the year 2008. The same way, the transformities used were corrected by the factor 1.68 – considering the global emergy (baseline) equivalent to 15.83E24 seJ year^{-1} (BROWN and ULGIATI, 2004).

Results and discussion

The overall diagram of the agroecosystems under organic management, in the highland region of the state of Rio de Janeiro, shows that they are systems of production and commerce of oleiriculture and husbandry of small animals for the self-consumption. (Figure 1)

The value of the emergy flow and the total emergy of the system of production are presented in Table 2, 3, 4, 5 and 6.

The total emergy (Y) of the five systems

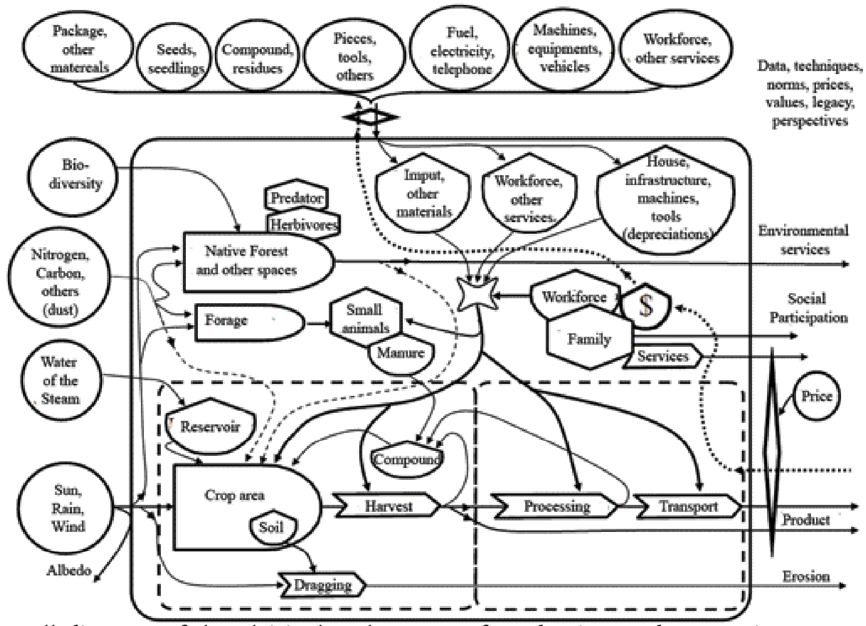

Figure 1. Overall diagram of the oleiricultural system of production under organic management, in the highland region of the state of Rio de Janeiro.

Table 2. System of production and commerce of oleiriculture, in short chain, in family-business establishment. System 1 (flow in unit ha^{-1} $year^{-1}$).

Note [a]	Value		FR [b]	Transformity		Emergy (seJ)			US$
						R [c]	NR [d]	Total	
1. Rainfall	7.50E10	J	1	3.06E4	seJ/J	2.30E15	0.00E00	2.30E15	456.81
2. Irrigation	1.50E10	J	1	2.96E5	seJ/J	4.44E15	0.00E00	4.44E15	882.81
R [e]						6.73E15	0.00E00	6.73E15	1,339.62
3. Erosion	2.50E08	J	0	1.24E5	seJ/J	0.00E00	2.16E13	2.16E13	7.23
N [f]						0.00E00	2.16E13	2.16E13	7.23
I = R + N [g]						6.73E15	2.16E13	6.75E15	1,346.84
4. Compound	2,019.95	US$	0.60	5.02E12	seJ/US$	6.08E15	4.05E15	1.01E16	2,019.95
5. Seeding	3,325.40	US$	0.70	5.02E12	seJ/US$	1.17E16	5.01E15	1.67E16	3,325.40
MR [h]						1.78E16	9.07E15	2.69E16	5,345.35
6. Depreciation I	5,071.57	US$	0.05	5.02E12	seJ/US$	1.27E15	2.42E16	2.55E16	5,071.57
7. Depreciation II	1,547.51	US$	0.05	5.02E12	seJ/US$	3.89E14	7.39E15	7.77E15	1,547.51
8. Fuel	3.68E10	J	0.01	1.86E05	seJ/J	6.86E13	6.80E15	6.86E15	1,366.42
9. Tools	3,797.42	US$	0.05	5.02E12	seJ/US$	9.54E14	1.81E16	1.91E16	3,797.42
10. Seeds	1,136.01	US$	0.23	5.02E12	seJ/US$	1.31E15	4.39E15	5.71E15	1,136.01
MN [i]						4.00E15	6.09E16	6.49E16	12,918.94
M = MR + MN [j]						2.18E16	7.00E16	9.18E16	18,264.30
11. Workforce I	1.12E10	J	0.9	1.85E07	seJ/J	1.86E17	2.07E16	2.07E17	41,243.64
12. Workforce II	3.74E09	J	0.6	1.85E07	seJ/J	4.14E16	2.76E16	6.91E16	13,747.88
13. Workforce III	8.97E09	J	0.6	1.85E07	seJ/J	9.95E16	6.63E16	1.66E17	32,994.92
SR [k]						3.27E17	1.15E17	4.42E17	87,986.44
14. Electricity	2.06E10	J	0.5	5.64E05	seJ/J	5.80E15	5.80E15	1.16E16	2,309.04
15. Freight	8,513.83	US$	0.01	5.02E12	seJ/US$	4.28E14	4.23E16	4.28E16	8,513.83
16. Mechanization	467.43	US$	0.01	5.02E12	seJ/US$	2.35E13	2.32E15	2.35E15	467.43
17. Mowing	1,151.04	US$	0.6	5.02E12	seJ/US$	3.47E15	2.31E15	5.78E15	1,151.04
18. Telephone	1,051.71	US$	0.5	5.02E12	seJ/US$	2.64E15	2.64E15	5.28E15	1,051.71
19. Taxes	3,155.13	US$	0.05	5.02E12	seJ/US$	7.93E14	1.51E16	1.59E16	3,155.13
SN [l]						1.32E16	7.05E16	8.36E16	16,648.17
S = SR + SN [m]						3.41E17	1.85E17	5.26E17	104,634.61
F = M + S [n]						3.62E17	2.55E17	6.17E17	122,898.91
Y. Emergy [o]						3.69E17	2.55E17	6.24E17	124,245.75
O. Energy [p]		J						1.99E10	

[a] Explanatory notes in appendix. [b] FR: fraction renewable [c] R: renewable emergy [d] NR: non renewable emergy [e] R: renewable natural resources [f] N: non renewable natural resources [g] I: natural resources [h] MR: renewable material of the economy [i] MN: non renewable material of the economy [j] M: materials of the economy [k] SR: renewable material of the economy [l] SN: non renewable services of the economy [m] S: services of the economy [n] F: resources of the economy [o] Emergy (Y) = I + F [P] Energy available from the produced food.

Table 3. System of production of oleiriculture and commerce in long chain, in family establishment, with seasonal hiring of local workforce. System 2 (Flow in unit ha^{-1} $year^{-1}$).

Notes [(a)]	Value		FR [(b)]	Transformity		Emergy (seJ)			US$
						R [(c)]	NR [(d)]	Total	
1. Rainfall	7.50E10	J	1	3.06E04	seJ/J	2.30E15	0.00E00	2.30E15	456.81
2. Irrigation	1.50E10	J	1	2.96E05	seJ/J	4.44E15	0.00E00	4.44E15	882.81
R [(e)]						6.73E15	0.00E00	6.73E15	1,339.62
3. Erosion	5.77E08	J	0	1.24E5	seJ/J	0.00E00	7.15E13	7.15E13	23.92
N [(f)]	5.77E08	J	0	1.24E5	seJ/J	0.00E00	7.15E13	7.15E13	23.92
I = R + N [(g)]						6.73E15	7.15E13	6.80E15	1,363.53
4. Compound	701.14	US$	0.60	5.02E12	seJ/US$	2.11E15	1.40E15	3.52E15	701.14
5. Seeds I	0.71	kg	0.42	1.68E12	seJ/kg	5.04E11	6.96E11	1.20E12	0.24
6. Seedlings	801.30	US$	0.7	5.02E12	seJ/US$	2.82E15	1.21E15	4.03E15	801.30
MR [(h)]						4.93E15	2.62E15	7.55E15	1,502.68
7. Fuel	1.55E10	J	0.01	1.86E05	seJ/J	2.90E13	2.87E15	2.90E15	576.93
8. Seeds II	0.71	kg	0.23	1.68E12	seJ/kg	2.76E11	9.24E11	1.20E12	0.24
9. Depreciation I	365.87	US$	0.05	5.02E12	seJ/US$	9.19E13	1.75E15	1.84E15	365.87
10. Depreciation II	1051.71	US$	0.05	5.02E12	seJ/US$	2.64E14	5.02E15	5.28E15	1,051.71
11. Tools	479.95	US$	0.05	5.02E12	seJ/US$	1.21E14	2.29E15	2.41E15	479.95
MN [(i)]						5.06E14	1.19E16	1.24E16	2,474.70
M = MR + MN [(j)]						5.44E15	1.45E16	2.00E16	3,977.38
11. Workforce I	1.19E10	J	0.9	1.85E07	seJ/J	1.98E17	2.20E16	2.20E17	43,718.26
12. Workforce II	7.77E08	J	0.6	1.85E07	seJ/J	8.62E15	5.75E15	1.44E16	2,859.56
SR [(k)]						2.06E17	2.77E16	2.34E17	46,577.82
14. Electricity	6.85E09	J	0.5	5.64E05	seJ/J	1.93E15	1.93E15	3.87E15	769.68
SN [(l)]	6.85E09	J	0.5	5.64E05	seJ/J	1.93E15	1.93E15	3.87E15	769.68
S = SR + SN [(m)]						2.08E17	2.96E16	2.38E17	47,347.50
F = M + S [(n)]						2.13E17	4.36E16	2.57E17	51,093.98
Y. Emergy [(o)]						2.20E17	4.43E16	2.65E17	52,688.41
O. Energy [(p)]		J						1.59E10	

[a)] Explanatory notes in appendix. [(b)] FR: fraction renewable [(c)] R: renewable emergy [(d)] NR: non renewable emergy [(e)] R: renewable natural resources [(f)] N: non renewable natural resources [(g)] I: natural resources [(h)] MR: renewable material of the economy [(i)] MN: non renewable material of the economy [(j)] M: materials of the economy [(k)] SR: renewable material of the economy [(l)] SN: non renewable services of the economy [(m)] S: services of the economy [(n)] F: resources of the economy [(o)] Emergy (Y) = I + F [(P)] Energy available from the produced food.

ranged from 1.72E+17 to 8.01E+17 seJ. The contribution of the workforce to the total emergy ranged from approximately 70 to 90% (S1 = 71% < S3 = 84% < S2 = 88% < S5 = 91% < S4 = 92%). The intensive use of the family workforce, mainly, was a characteristic of the studied systems.

The classic emergy indicators (EYR, EIR, R, ELR, EIS e EER) and the modified indicators (EYRm, EIRm, Rm, ELRm e EISm) which were calculed present very distinct values (Table 7).

It can be verified, by the simple observation of the values, that the modified indications express better the reality of the agroecosystems studied. According to ORTEGA et al. (2002), the modified indicators allow a most appropriated evaluation of the emergy performance of the production systems.

Table 4. System of production of oleiriculture and commerce in long chain, in family establishment, with permanent hiring of local workforce. System 3 (Flow in unit ha^{-1} $year^{-1}$).

Notes [a]	Value		FR [b]	Transformity		Emergy (seJ)			US$
1. Rainfall	7.50E10	J	1	3.06E4	seJ/J	2.30E15	0.00E00	2.30E15	456.81
2. Irrigation	1.50E10	J	1	2.96E5	seJ/J	4.44E15	0.00E00	4.44E15	882.81
R [e]						6.73E15	0.00E00	6.73E15	1,339.62
3. Erosion	2.50E08	J	0	1.24E5	seJ/J	0.00E00	3.10E13	3.10E13	10.38
N [f]						0.00E00	3.10E13	3.10E13	10.38
I = R + N [g]						6.73E15	3.10E13	6.76E15	1,350.00
4. Compound	920.25	US$	0.60	5.02E12	seJ/US$	2.77E15	1.84E15	4.62E15	920.25
5. Seeds I	0.25	kg	0.42	1.68E12	seJ/kg	1.76E11	2.44E11	4.20E11	0.08
6. Seedlings	613.50	US$	0.70	5.02E12	seJ/US$	2.16E15	9.25E14	3.08E15	613.50
MR [h]						4.93E15	2.77E15	7.71E15	1,533.83
7. Fuel	4.29E09	J	0.01	1.86E05	seJ/J	8.01E12	7.93E14	8.01E14	159.42
8. Seeds II	2.44	kg	0.23	1.68E12	seJ/kg	9.42E11	3.15E12	4.10E12	0.82
9. Depreciation I	331.09	US$	0.05	5.02E12	seJ/US$	8.32E13	1.58E15	1.66E15	331.09
10. Depreciation II	920.25	US$	0.05	5.02E12	seJ/US$	2.31E14	4.39E15	4.62E15	920.25
11. Tools	409.00	US$	0.05	5.02E12	seJ/US$	1.03E14	1.95E15	2.05E15	409.00
MN [i]						4.26E14	8.72E15	9.15E15	1,820.57
M = MR + MN [j]						5.36E15	1.15E16	1.69E16	3,354.39
11. Workforce I	3.92E09	J	0.9	1.85E07	seJ/J	6.53E16	7.25E15	7.25E16	14,435.28
12. Workforce II	3.92E09	J	0.6	1.85E07	seJ/J	4.35E16	2.90E16	7.25E16	14,435.28
SR [k]						1.09E17	3.63E16	1.45E17	28,870.55
14. Electricity	5.81E09	J	0.5	5.64E05	seJ/J	1.64E15	1.64E15	3.28E15	652.23
SN [l]						1.64E15	1.64E15	3.28E15	652.23
S = SR + SN [m]						1.10E17	3.79E16	1.48E17	29,522.78
F = M + S [n]						1.16E17	4.94E16	1.65E17	32,877.18
Y. Emergy [o]						1.23E17	4.94E16	1.72E17	34,227.18
O. Energy [p]		J						2.56E10	

[a] Explanatory notes in appendix. [b] FR: fraction renewable [c] R: renewable emergy [d] NR: non renewable emergy [e] R: renewable natural resources [f] N: non renewable natural resources [g] I: natural resources [h] MR: renewable material of the economy [i] MN: non renewable material of the economy [j] M: materials of the economy [k] SR: renewable material of the economy [l] SN: non renewable services of the economy [m] S: services of the economy [n] F: resources of the economy [o] Emergy (Y) = I + F [P] Energy available from the produced food.

The transformity (Tr) of the systems ranged from 6.72 E+06 to 3.14 E+07 seJ/ J. The ordering of the transformity of the systems was the following: S3 = 6.72 E+06 < S2 = 1.67 E+07 < S5 = 2.32 E+07 < S4 = 3.06 E+07 < S1 = 3.14 E+07. Two groups are still noteworthy: system 1, which presented higher Tr (6,24 E+17); and, the group of the systems 2, 3, 4 and 5, considering that system 3 presented the lowest transformity. According to COMAR (1998) and CUVILLIER (2005), the transformities of the production systems of organic and conventional vegetable crops are, in average, 2.37E+5 and 6.3E+6 seJ/J, respectively; therefore, these authors obtained values lower than those found in this work. However, the difference is explained mainly by the variation of the volume of the product commercialized. The ratio of the emergy by the exergy produced is sensitive to the amount of energy available which was considered

Table 5. System of production of chayote and commerce in long chain, in family establishment. System 4 (Flow in unit ha^{-1} $year^{-1}$).

Notes [a]	Value		FR [b]	Transformity		Emergy (seJ)			US$
						R [c]	NR [d]	Total	
1. Rainfall	7.00E10	J	1	3.06E04	seJ/J	2.14E15	0.00E00	2.14E15	426.36
2. Irrigation	9.00E09	J	1	2.96E05	seJ/J	2.66E15	0.00E00	2.66E15	529.68
R [e]						4.80E15	0.00E00	4.80E15	956.04
3. Erosion	2.11E08	J	0	1.24E05	seJ/J	0.00E00	2.61E13	2.61E13	8.73
N [f]						0.00E00	2.61E13	2.61E13	8.73
I = R + N [g]						4.80E15	2.61E13	4.83E15	964.77
4. Compound	1.67E11	J	0.8	4.45E04	seJ/J	5.96E15	1.49E15	7.45E15	1,483.77
5. Seeds	9.56E08	J	1	1.75E05	seJ/J	1.67E14	0.00E00	1.67E14	33.26
MR [h]						6.13E15	1.49E15	7.62E15	1,517.03
6. Depreciation I	3,947.80	US$	0.05	5.02E12	seJ/US$	9.92E14	1.88E16	1.98E16	3,947.80
7. Depreciation II	579.35	US$	0.40	5.02E12	seJ/US$	1.16E15	1.75E15	2.91E15	579.35
8. Tools	116.86	US$	0.05	5.02E12	seJ/US$	2.94E13	5.58E14	5.87E14	116.86
9. Fuel	3.18E09	J	0.01	1.86E05	seJ/J	5.93E12	5.87E14	5.93E14	118.09
MN [i]						2.19E15	2.17E16	2.39E16	4,762.09
M = MR + MN [j]						6.76E17	1.20E17	7.96E17	158,438.88
10. Workforce	3.98E10	J	0.90	1.85E07	seJ/J	6.61E17	7.35E16	7.35E17	146,277.46
SR [k]						6.61E17	7.35E16	7.35E17	146,277.46
11. Electricity	1.70E10	J	0.5	5.64E05	seJ/J	4.80E15	4.80E15	9.59E15	1,909.17
12. Taxes	3,973.12	US$	0.05	5.02E12	seJ/US$	9.98E14	1.90E16	2.00E16	3,973.12
SN [l]						5.79E15	2.38E16	2.96E16	5,882.30
S = SR + SN [m]						6.67E17	9.72E16	7.64E17	152,159.76
F = M + S [n]						6.76E17	1.20E17	7.96E17	158,438.88
Y. Emergy [o]						6.80E17	1.20E17	8.01E17	159,403.65
O. Energy [p]		J						2.62E10	

[a] Explanatory notes in appendix. [b] FR: fraction renewable [c] R: renewable emergy [d] NR: non renewable emergy [e] R: renewable natural resources [f] N: non renewable natural resources [g] I: natural resources [h] MR: renewable material of the economy [i] MN: non renewable material of the economy [j] M: materials of the economy [k] SR: renewable material of the economy [l] SN: non renewable services of the economy [m] S: services of the economy [n] F: resources of the economy [o] Emergy (Y) = I + F [P] Energy available from the produced food.

in the study.

The renewability (R%) indicates the durability, only systems with high renewability are sustainable, in long term period; mainly due to the increasing scarcity of non renewable natural resources (fossil fuel, agrochemicals, minerals). In general, the studied systems presented lower renewability (Rm = 60%), is a productive arrangement in short chain of commercialization. The minimum process of the vegetables and the direct deliveries imply in a high dependence of material and services (non renewable); however, the renewability of 60% is high, compared to the renewability of approximately 30% of the conventional agro-industrial systems (ODUM, 2001).

The emergy yield (EYRm) of the studied systems present rates ranging from 2.45 to 6.82. The ordering of the EYRm of the systems was the following: S1 = 2.45 < S3 = 3.48 < S2 = 5.99 < S4 = 6.65 < S5 = 6.82. Commonly, the valued of the yield

Table 6. System of production of chayote and other fruits, with commerce in long chain, in family establishment. System 5 (Flow in unit ha^{-1} $year^{-1}$).

Notes [a]	Value		FR [b]	Transformity		Emergy (seJ)			US$
						R [c]	NR [d]	Total	
1. Rainfall	7.00E10	J	1	3.06E04	seJ/J	2.14E15	0.00E00	2.14E15	426.36
2. Irrigation	9.00E09	J	1	2.96E05	seJ/J	2.66E15	0.00E00	2.66E15	529.68
R [e]						4.80E15	0.00E00	4.80E15	956.04
3. Erosion	2.29E08	J	0	1.24E05	seJ/J	0.00E00	2.83E13	2.83E13	9.48
N [f]						0.00E00	2.83E13	2.83E13	9.48
I = R + N [g]						4.80E15	2.83E13	4.83E15	965.52
4. Compound	1.67E11	J	0.60	4.45E04	seJ/J	4.47E15	2.98E15	7.45E15	1,483.77
5. Seeds	9.56E08	J	1	1.75E05	seJ/J	1.67E14	0.00E00	1.67E14	33.26
MR [h]						4.64E15	2.98E15	7.62E15	1,517.03
6. Depreciation I	2,982.76	US$	0.05	5.02E12	seJ/US$	7.49E14	1.42E16	1.50E16	2,982.76
7. Depreciation II	579.35	US$	0.40	5.02E12	seJ/US$	1.16E15	1.75E15	2.91E15	579.35
8. Tools	116.86	US$	0.05	5.02E12	seJ/US$	2.94E13	5.58E14	5.87E14	116.86
9. Fuel	2.39E09	J	0.01	1.86E05	seJ/J	4.45E12	4.40E14	4.45E14	88.56
MN [i]						1.95E15	1.70E16	1.89E16	3,767.53
M = MR + MN [j]						6.59E15	2.00E16	2.65E16	5,284.56
10. Workforce	2.08E10	J	0.90	1.85E07	seJ/J	3.46E17	3.84E16	3.84E17	76,506.96
SR [k]						3.46E17	3.84E16	3.84E17	76,506.96
11. Electricity	1.27E10	J	0.5	5.64E05	seJ/J	3.60E15	3.60E15	7.19E15	1,431.88
SN [l]						3.60E15	3.60E15	7.19E15	1,431.88
S = SR + SN [m]						3.50E17	4.20E16	3.92E17	77,938.84
F = M + S [n]						3.56E17	6.20E16	4.18E17	83,223.40
Y. Emergy [o]						3.61E17	6.20E16	4.23E17	84,188.92
O. Energy [p]								1.82E10	

[a] Explanatory notes in appendix. [b] FR: fraction renewable [c] R: renewable emergy [d] NR: non renewable emergy [e] R: renewable natural resources [f] N: non renewable natural resources [g] I: natural resources [h] MR: renewable material of the economy [i] MN: non renewable material of the economy [j] M: materials of the economy [k] SR: renewable material of the economy [l] SN: non renewable services of the economy [m] S: services of the economy [n] F: resources of the economy [o] Emergy (Y) = I + F [P] Energy available from the produced food.

Table 7. Classic and modified indicators of the systems of production.

Indicator [1]		Unit	System of Production				
			1	2	3	4	5
1	TR	seJ J^{-1}	3,14E+07	1,67E+07	6,72 E+06	3,06E+07	2,32E+07
2	R	%	1,08	2,54	3,91	0,60	1,14
3	Rm	%	59,13	83,28	71,25	84,95	85,34
4	EYR	Without dimension	1,01	1,03	1,04	1,01	1,01
5	EYRm	Without dimension	2,45	5,99	3,48	6,65	6,82
6	EIR	Without dimension	91,45	37,91	24,43	164,83	86,54
7	EIRm	Without dimension	0,69	0,20	0,40	0,18	0,17
8	ELR	Without dimension	91,75	38,32	24,55	165,73	87,06
9	ELRm	Without dimension	0,69	0,20	0,40	0,18	0,17
10	ESI	Without dimension	0,01	0,03	0,04	0,01	0,01
11	ESIm	Without dimension	3,54	29,82	8,63	37,53	39,71
12	EER	Without dimension	1,93	6,12	2,29	12,09	7,68

rate (EYR) of the agricultural systems range from 1 to 4 (ORTEGA et al., 2001). According to the classification of BROWN and ULGIATI (2004), system 1 (EYRm = 2.45) and system 3 (EYRm = 3.48) presented moderated net emergy; and, systems 2, 4 and 5 (EYRm > 5) presented high potential of contribution for the economical growth.

The investment rate (EIRm) evaluated the amount of non renewable resources acquired from the economy, in relation to the renewable natural resources used. The investment rate ranged from 0.17 to 0.69. The ordering of EIRm was the following: S5 = 0.17 < S4 = 0.18 < S2 = 0.20 < S3 = 0.40 < S1 = 0.69. The higher rate presented by system 1 is justified (EIRm = 0.69) mainly due to the investments performed in the structure of commercialization. In general, the studied organic systems show efficiency in the investment in non renewable emergy, and, in consequence, its products and services may be considered competitive in market, in long term period.

The environmental load indicated the degree of environmental stress caused by the agroecosystems. The systems presented ELRm from 0.17 to 0.69. The ordering of the ELRm was the following: S5 = 0.17 < S4 = 0.18 < S2 = 0.20 < S3 = 0.20 < S5 = 0.69. The ELR < 2 indicates low environmental load (BROWN and ULGIATI, 2004). In general, the studied organic systems present very low load, therefore, are considered sustainable. Notwithstanding, the lower environmental load indicates more sustainability, in long-term period.

The index of sustainability evaluates the relation benefit/cost of the productive systems, the great use of the environmental resources and investments of the echonomy with the lower environmental load (ESI = EYR / ELR). The ESIm ranged from 3.54 to 39.7. The ordering of the ESIm was the following: S1= 3.54 < S3 = 8.63 < S2 = 29.82 < S4 = 37.53 < S5 = 39.71. The intermediate values of ESI (1 < ESI < 5) characterize systems with sustainability in medium term periods; and, systems with EIS > 5 are sustainable, in long term period (BROWN and ULGIATI, 2004). The system of production and commerce in short chain (S1) presented medium average, while the long chain systems (systems 2, 3, 4 and 5) are sustainable in long term periods. However, the studied systems were capable to contribute significantly for the economical growth, without severe environmental damage.

The exchange rate (EERm) indicated the relative advantage between the commercial partners (producer and consumer). The exchange rate ranges from 1.93 to 12.09. The ordering of the EERm of the systems was the following: S1 = 1.93 < S3 = 2.29 < S2 = 6.12 < S5 = 7.68 < S4 = 12.09. From the farmer viewpoint, the closer the EER is to one (EER ≈ 1), the better is the economical development (ODUM, 1996). In general, it is verified that the organic products and services presented to the society may not be considered expensive (EER > 1). The development of system 1 (EERm = 1.93) suggests improvement on the exchange rate of the organic systems trough the higher commercialized diversification and production, aggregation of value to products trough the minimum processing of the vegetables, shortening of the commercialization chain and meeting the demand of closest markets.

The task of interpreting the indicators may become exhaustive with the increase of the number of variables that are being studied. So, for the graphical representation of the system development, the normalized flow were joint in three classes: environmental resources (I), renewable economical resources (F_R) and non renewable (F_N) (Table 8).

The systems which presented the highest and lowest index of sustainability, system 1 (EIS = 3.54) and system 5 (EIS = 39.71), respectively, presented the same percentage of use of environmental resources (I = 0.011); however, used different percentages of renewable economical resources (S1: F_R= 0.75 and S5: F_R = 0.92) and non renewable (S1: F_N= 0.23 and S5: F_R = 0.06) (Table 8).

The ternary diagram separated the five systems in two groups (Figure 2): the group of the system of production and commerce in short chain (system 1) and the group of the systems in long chain (systems 2, 3, 4 and 5).

As strategy of developments of the studied systems it is suggested the orientation of the investments in renewable material and services, as the use of local workforce; on the other hand, it must decrease the percentage of costs with non renewable economic resources (F_N), as restrict investment

Table 8. Absolute and relative values of the environmental (I) and economic flow which are renewable (FR) and non renewable). (Absolute values in seJ ha^{-1} year^{-1}).

Flow	Production system				
	1	2	3	4	5
	Absolute values				
MR	2.69E+16	7.55E+15	7.71E+15	7.62E+15	7.62E+15
SR	4.42E+17	2.34E+17	1.45E+17	7.35E+17	3.84E+17
F_R = (MR + SR)	4.69E+17	2.42E+17	1.53E+17	7.43E+17	3.92E+17
MN	6.49E+16	1.24E+16	9.15E+15	2.39E+16	1.89E+16
SN	8.36E+16	3.87E+15	3.28E+15	2.96E+16	7.19E+15
F_N = (MN + SN)	1.49E+17	1.63E+16	1.24E+16	5.35E+16	2.61E+16
R	6.73E+15	6.73E+15	6.73E+15	4.80E+15	4.80E+15
N	2.16E+13	7.15E+13	3.10E+13	2.61E+13	2.83E+13
I = (R + N)	6.75E+15	6.80E+15	6.76E+15	4.83E+15	4.83E+15
Y = (R + N + MR + MN +SR + SN)	6.24E+17	2.65E+17	1.72E+17	8.01E+17	4.23E+17
	Relative Values				
	6.24E+17	2.65E+17	1.72E+17	8.01E+17	4.23E+17
F_N% = (F_N / Y)	0.238	0.061	0.072	0.067	0.062
F_R % = (F_R / Y)	0.751	0.913	0.888	0.927	0.927
I % = (I / Y)	0.011	0.026	0.039	0.006	0.011
Y normalized = (F_N% + F_R% + I%)	1.00	1.00	1.00	1.00	1.00

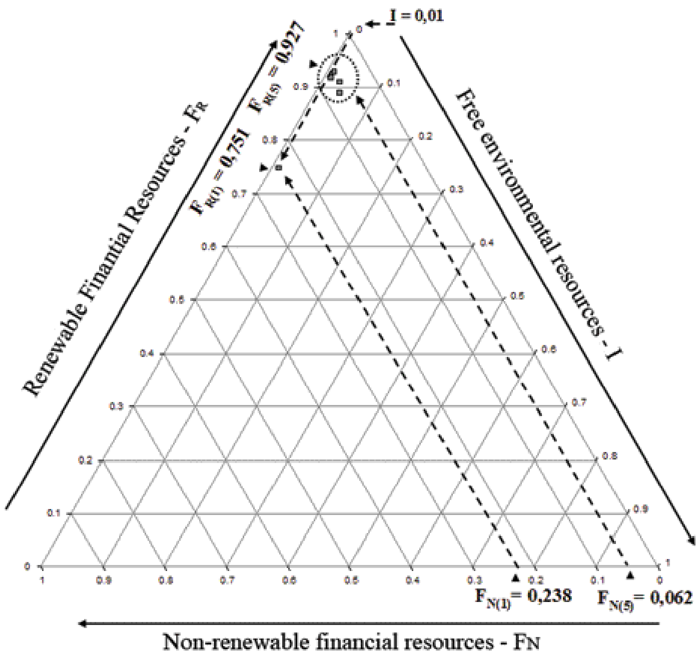

Figure 2. Diagram showing the group from the system 1 and the group of the systems 2, 3, 4 and 5, respectively, the lowest system and those which presented highest index of sustainability.

in greenhouses and achieve the closest consumer markets, to improve the sustainability, in long term period.

Conclusions

The modified emergy indicators were more appropriated than the classic formulations for the emergy analysis of systems of production of oleiriculture under organic management, in family units, in the highland region of Rio de Janeiro.

The highest efficiency of transformation of the energy in the chain of organic products may be reached trough the increase of the commercialized production; however, the increase of the investments in the system of production and commercialization must restrict the use of non renewable economic resources.

The systems of production of oleiriculture under organic management studied contribute to the economic growth, with low environmental charge, therefore, from the emergy point of view, are sustainable, in long term period.

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Appendix

In this appendix, it is presented the calculation records of the emergy flow references in the column Notes of the tables of emergy analysis (Tables 2, 3, 4, 5 and 6); and, also, it is presented information and references about transformities and the renewable fractions used.

Notes from Table 2 – System of Production 1

1. Rainfall. The value of the energy of the rain (E), in J ha^{-1} $year^{-1}$, was calculated for the annual average rainfall of 1500 mm, trough the equation: E (J ha^{-1} $year^{-1}$) = rainfall (mm) * Free energy of Gibbs (J kg^{-1}) * 10.000 (m^2); therefore, E = 1500 (mm) * 5000 (J kg^{-1}) * 10000 (m^2) = 7.50 E+10 J ha^{-1} $year^{-1}$. Transformity, Tr = 3.06 E+4 seJ J^{-1} (BROWN and ULGIATI, 2004). Renewable fraction, FR = 1 (TAKAHASHI et al., 2008).

2. Water of the stream. To calculate the energy of the water of the stream used in the irrigation, it was considered the application of the flow of 2 mm, during 150 days per year. The equation used: E = amount of water (m^3 ha^{-1} $year^{-1}$) * 1000 (kg m^{-3})*5000(J kg^{-1}), therefore: E = 3000 (m^3 ha^{-1} $year^{-1}$) * 1000 (kg m^{-3}) * 5000 (J kg^{-1}) = 1.50E+10 J ha^{-1} $year^{-1}$. Transformity, Tr = 1.76E+5 seJ J^{-1} (ODUM, 2000), was corrected by the factor 1.68 (BROWN and ULGIATI, 2004), therefore, Tr = 1.76E+5 seJ J^{-1} x 1.68 = 2.96E+5 seJ J^{-1}. The renewable fraction, Fr = 1.

3. Erosion. The erosion was calculated by the universal soil loss equation (USLE), E = R. K. L. S. C. P (BERTONI and LOMBARDI NETO, 2008), which had the following values of the factors: R = 11000, K = 0.019091; LS = 0.006774; C = 0.5; P = 0.40. Therefore, E = 0.284504 t ha^{-1}. $year^{-1}$. To calculate the energy, in J ha^{-1} $year^{-1}$, referent to the losses of organic matter caused by the soil erosion, it was considered the percentage of organic matter of the soil of 0.0271 (MOS= 2.71%), and used the equation: E = Losses (kg ha^{-1} $year^{-1}$) * MOS (%) * 5400 (kcal kg^{-1}) * 4186 (J $kcal^{-1}$); therefore, E = 284504*0.0271* 5400*4186 = 1.74E+8 J. ha^{-1} $year^{-1}$. Tranformity, Tr = 1.24E+5 seJ J^{-1} (BROWN and ULGIATI, 2004). The renewable fraction, FR = 0.

4. Compound. The price of the compound was R$ 440.00 per truck (R$ 440.00 * 7 m^{-3}), placed in the establishment. It was used 5.5 trucks of compound (38.5 m^3), applied in the area of 0.7 hectares. Therefore, the emergy value of the compound: E = quantity (m^3 $year^{-1}$) * Price (US$ m^{-3}) / Area (ha) = US$ 2.019,95 ha^{-1} $year^{-1}$. Transformity, Tr = 5.02397E+12 seJ US$$^{-1}$ (estimated). The renewable fraction, FR = 0.6 (common sense), considering that the organic compound (residues of poultry slaughterhouse and horse 'bed') is bought in the municipality of São José do Vale do Rio Preto (SJVRP), distant 30 km from the establishment.

5. Seedlings. The shopping was US$ 3.325,40 ha^{-1} $year^{-1}$. The transformity, Tr: 5.02397E+12 seJ US$$^{-1}$ (estimated). The renewable fraction, FR = 0.70 (common sense), considering that the seedlings are bought from specialized nursery located 15 km from the establishment.

6. Depreciation of the infrastructure. The accounted infrastructure was: (i) dwelling house (masonry); (ii) office (masonry); (iii) compost; (iv) greenhouses (wood); dams (land); and, (vi) hangar (masonry). The depreciation was calculated in US$ 5.071,57 ha^{-1} $year^{-1}$. The transformity, Tr = 5.02397E+12 seJ US$$^{-1}$ (estimated). The renewable fraction, Fr = 0.05 (ORTEGA et al., 2002).

7. Depreciation of machines and equipments. The establishment has: (i)micro-tractor (rotary tiller); (ii) system of irrigation (spraying) per gravity; (iii) light vehicle (called Pracha) for the internal transport of the production; and, (iv) equipments for the

packing of products (weight, capping machine and plastic bags). The depreciation was calculated in US$ 1.547,51 ha^{-1} $year^{-1}$. The transformity, Tr = 5.02397E+12 seJ $US\$^{-1}$ (estimated). The renewable fraction, Fr = 0.05 (ORTEGA et al., 2002).

8. Fuel (diesel). The annual consumption of fuel (diesel) amount ot 771 liters per hectare per year, used mainly in the micro-tractor for the preparation of beds. To calculate the energy it was used the equation: Energy (J) = **771** (L ha^{-1} $year^{-1}$) * 1.14 E+4 (kcal L^{-1}) * 4186 (J $kcal^{-1}$) = 3.68E+10 J ha^{-1} $year^{-1}$. Tranformity, Tr = 1.86E+5 seJ J^{-1} (ORTEGA et al., 2001). The renewable fraction, Fr = 0.01 (ORTEGA et al., 2002).

9. Pieces, tools and other materials. The expenses with pieces for the machines (micro-tractor, vehicle), irrigation, tools, packaging and other materials were calculated in US$ 3.797,42 ha^{-1} $year^{-1}$. Transformity, Tr = 5.02397E+12 seJ $US\$^{-1}$ (estimated). The renewable fraction, Fr = 0.05 (ORTEGA et al., 2002).

10. Seeds. The shopping of the seeds certified were US$ 1.590,43 ha^{-1} $year^{-1}$. The transformity. Tr = 5.02397E+12 seJ $US\$^{-1}$ (estimated). The renewable fraction, Fr = 0.23 corresponds to the percentage of renewability of conventional systems of grain production (ORTEGA et al., 2002).

11. Familiar workforce. The family workforce was composed by three people: the heads of the family (man and woman) with ages between 18 and 59 years, plus one son with age between 7 and 13 years. For the adults, it was considered the workforce equal to one (1); i.e., each adult correspond to one (1) work unit (UT) and the work of the son is equal to 0.50 UT. Each work unit (UT) corresponds to 300 days of work per year, with average journey of 8 hours per day. For the calculation of the energy of the workforce it was used the equation: E (J ha^{-1} $year^{-1}$) = 2.5 (UT) * 300 (days $year^{-1}$) * 2500 (kcal day^{-1})*4186 (J $kcal^{-1}$) / Area (ha); therefore, the energy of the family workforce: E = 1.12E+10 J ha^{-1} $year^{-1}$. Transformity, Tr = 1.85E+7 seJ J^{-1} correspond to the value of the transformity of 1.1E+7 seJ J^{-1} (ODUM, 1996) multiplied by the factor of correction 1.68 (BROWN and ULGIATI, 2004), i.e., Tr = 1.1E+7 x 1.68 = 1.85 seJ J^{-1}. The renewable fraction, FR = 0.90 (common sense), for the family workforce.

12. Worforce from partners. It was accounted the workforce from two adults, which are the land properties, who dedicate 50 days per years, in the administration of the business, and, still, an auxiliary of the administration (under the age of 17) during 150 days per year. The workforce from partners, therefore, corresponds to 0.83 UT. To calculate the energy from the workforce from partners it was used the equation: E (J ha^{-1} $year^{-1}$) = 0.83 (UT) *300 (days $years^{-1}$) * 2500 (kcal day^{-1}) *4186 (J $kcal^{-1}$) / Area (ha) = 3.74E+09 J ha^{-1} $year^{-1}$. Transformity, Tr = 1.85E+7 seJ J^{-1}, corresponds to the value of the transformity of 1.1E+7 seJ J^{-1} (ODUM, 1996) multiplied by the factor of correction 1.68 (BROWN and ULGIATI, 2004). The renewable fraction, FR = 0.60 (TAKAHASHI et al., 2008), for the local workforce.

13. Permanent workforce. It was accounted two adult workers (2 UT), therefore, we have: E (J $ha^{-1}$$year^{-1}$) = 2 (UTF) *300 ($dayyear^{-1}$) * 2500 (kcal day^{-1}) * 4186 (J $kcal^{-1}$) / 0,7 (ha) = 8.97E+09 J ha^{-1} $year^{-1}$.

14. Permanent workforce. It was accounted two adult workers (2UT), therefore, we have: E (J ha^{-1} $year^{-1}$) = 2 (UTF) *300 (days $year^{-1}$) * 2500 (kcal day^{-1}) * 4186 (J $kcal^{-1}$) / 0,7 (ha) = 8,97E+09 J ha^{-1} $year^{-1}$. Transformity, Tr = 1.85E+7 seJ J^{-1} corresponds to the value of transformity of 1.1E+7 seJ J^{-1} (ODUM, 1996), multiplied by the factor of correction 1.68 (BROWN and ULGIATI, 2004). The renewable fraction, FR = 0.60 (TAKAHASHI et al., 2008), for local workforce.

15. Electricity. The electric energy used is referent to the residential consumption of 111 kWh/year and, besides that, it was considered equal consumption of energy in the administrative office and warehouse of expedition. To calculate the energy it was used the equation: Energy (J ha^{-1} $year^{-1}$) = Total consumption (kWh $year^{-1}$) *1000 (w kW^{-1}) * 3600 (s h^{-1}) / Area (ha); therefore, Energy = 111 (kWh $year^{-1}$) *3* 1000 (w kW^{-1}) *3600 (s h^{-1}) / 0.7 (ha) = 2.06E+10 J ha^{-1} $year^{-1}$. Transformity, Tr = 5.64E+5 seJ J^{-1}, corresponds to the value of 3.36E+5 seJ J^{-1} (ODUM, 1996) multiplied by the factor of correction 1.68 (BROWN and ULGIATI, 2004). The renewable fraction, FR = 0.50 (TAKAHASHI et al.; 2008).

16. Freight. The accounted services of freight were, mainly, for the transport of the products from the farm to the urban area (District of Posse, Petrópolis), and, later, to the city of Rio de Janeiro. The sped with freight to Posse was R$ 150.00 $month^{-1}$; and, to Rio de Janeiro, R$ 700.00 $month^{-1}$; therefore, the total expense with freight was calculated by the equation: F = [Posse (R$ $month^{-1}$) + Rio (R$ $month^{-1}$)] * 12 (months) / dollar (R$ $US\$^{-1}$) / Area (ha) = US$ 8,513.83 $ha^{-1}$$year^{-1}$.Transformity, Tr = 5.02E+12 seJ $US\$^{-1}$ (estimated). The renewable fraction, FR = 0.01 (ORTEGA et al.; 2002).

17. Mechanization (cleaning of the area). For the implantation of the crop it was hired services of mechanization for stump removal and cleaning of the area correspondent to one hectare (1 ha) in the total value of R$ 800.00; therefore, it was spent US$ 467.43 $ha^{-1}$$year^{-1}$ [US$ 467.43 = R$ 800.00 / 1.71 (R$ $US\$^{-1}$)]. Transformity, Tr = 5.02E+12 seJ $US\$^{-1}$ (estimated). The renewable fraction, Fr = 0.01 (ORTEGA et al.; 2002).

18. Mowing and natural windrowing. For the implementation of the crop it was hired services of workforce for mowing and windrowing of one hectare (1 ha), in the value of R$ 1,970; therefore, it was spent US$ 1,151.04 ha^{-1} $year^{-1}$, [US$ 1,151.04 = R$ 1,970.00 / 1.71 (R$ $US\$^{-1}$)]. Transformity, Tr = 5.02E+12 seJ $US\$^{-1}$ (estimated). The renewable fraction, FR = 0.60 (TAKAHASHI et al., 2008).

19. Telephone. It was accounted the monthly expense with telephone of R$150.00 (contact with the clients) and it was considered that this values does not change for an area of one hectare, therefore, we have the expense of US$ 1,051.71 ha^{-1} $year^{-1}$, [US$ 1,051,71 ha^{-1} $year^{-1}$ = R$ 150.00 *12 / 1.71 (R$ $US\$^{-1}$)]. Transformity, Tr = 5.02E+12 seJ $US\$^{-1}$ (estimated). The renewable fraction, FR = 0.05 (TAKAHASHI et al., 2008).

20. Produced energy available. The commercialized production was calculated in 18,604 kg ha^{-1} $year^{-1}$; and, the average calorie for the assortment of vegetables was 255 kcal kg^{-1}. Thus, to calculate the produced energy available it was used the equation: Produced energy (J ha^{-1} $year^{-1}$) = Production (kg ha^{-1} $year^{-1}$) * 255 (kcal kg^{-1}) * 4186 J $kcal^{-1}$; i.e., E = 18,604* 255 * 4186 = 19,858,771,676 J ha^{-1} $year^{-1}$ = 1.99E+10 J ha^{-1} $year^{-1}$

Notes from Table 3 – System of production 2.

1. Rainfall. Equal to Table 2 (System 1).

2. Water of the stream. Equal to note 2 from Table 2 (System 1)

3. Erosion. The erosion was calculated by the universal soil loss equation (USLE), using the following factors: R = 11000, K = 0. 025521; LS = 0. 007917; C = 0.5; P = 0.40. Therefore, E = 0.444530 t ha^{-1}. $year^{-1}$. The percentage of organic matter of the soil was 0.0574 (MOS= 5.74%). From that, the MOS energy used was calculated in 5.77E+08 J ha^{-1} $year^{-1}$. The equation, transformity (Tr = 1.24E+5 seJ J^{-1}) and renewable fraction are equal to note 3 from Table 2 (System 1)

4. Compound. The price of the compound was R$420.00 per truck (R$ 420.00*7 m^{-3}), placed in the local. It was used 14 m^3 per year (2 trucks), i.e., US $ 701,14 ha^{-1} $year^{-1}$ (R$ 420.00 * 2 / 1.71 / 0.7). Transformity and renewable fraction, equal to note 4 from Table 2 (System 1)

5. Own seeds. It was used 500 g per year in 0.7 hectares; therefore, 0.714 kg ha^{-1} $year^{-1}$. Transformity, Tr = 1.68E+12 kg ha^{-1} $year^{-1}$, corresponds to the transformity 1.00E+12 kg ha^{-1} $year^{-1}$ (ODUM, 1996 *apud* ORTEGA et al, 2002), corrected by the factor 1.68 (BROWN and ULGIATI, 2004). The renewable fraction – FR = 0.42 – is referent to the percentage of renewability of organic and ecological systems of grain production (ORTEGA et al., 2002).

6. Seedlings. The annual expense with seedlings was US$ 801.30 per hectare. The transformity and renewable fraction are equal to note 5 from table 2 (System 1).

7. Fuel. The annual consumption of fuel (diesel) completes an amount of 228 liters, being 72 liters in the micro-tractor and 156 liters in the irrigation motor pump. Considering the useful agricultural surface of 0.7 ha, we have: 325.71 liters ha^{-1} $year^{-1}$. Equation to calculate energy (in Joules), transformity (Tr) and renewable fraction, equal to note 8 from Table 2 (System 1).

8. Certified seeds. It was accounted 0.714 kg ha^{-1} $year^{-1}$. Transformity, Tr = 1.68E+12 kg ha^{-1} $year^{-1}$ (see note 5, appendix A1). The renewable fraction – FR = 0.23 – is referent to the percentage of renewability of conventional systems of grain production (ORTEGA et al., 2002).

9. Depreciation of machines and equipments. It was accounted: (i) micro-tractor (collective); and, (ii) irrigation system (spraying, joint pump system with diesel motor). The total depreciation was calculated in US$ 365.87 ha^{-1} $year^{-1}$. Transformity, Tr = 5.02397E+12 seJ $US\$^{-1}$ (estimated). Renewable fraction = 0.05 (ORTEGA et al., 2002).

10. Depreciation of the infrastructure. It was accounted: (i) House (masonry); (ii) Composting; and (iii) cover for product management (wood). The depreciation was calculated in US$ 1,051.71 ha^{-1} $year^{-1}$. Transformity = 5.02397E+12 seJ $US\$^{-1}$ (estimated). Renewable fraction = 0.05 (ORTEGA et al., 2002).

11. Pieces, tools and other materials. The expenses were calculated in US$ 479.95 ha^{-1} $years^{-1}$. Transformity = 5,02397E+12 seJ $US\$^{-1}$ (estimated). Renewable fraction = 0.05 (ORTEGA et al., 2002).

12. Family workforce. It was composed by three people: the family heads (man and woman), with ages between 18 and 59 years, and a son with age between 14 and 17 years, completing 2.65 units of work (UT). Equation of the energy used, transformity and renewable fraction, equal to note 11 from Table 2 (System 1).

13. Workforce (diarist). One diarist (adult) was hired for 52 days. To calculte the energy of the workforce it was used the equation: E (J ha^{-1} $year^{-1}$) = 1 (UT) * 52 (days $year^{-1}$) * 2500 (kcal day^{-1}) * 4186 (J $kcal^{-1}$) / 0.7 (ha) = 7.77 E+08 J ha^{-1} $year^{-1}$.

14. Electricity. It was accounted the home consumption of 111 kWh $year^{-1}$, which corresponds to 6.85E+9 J ha^{-1} $year^{-1}$. Equation, transformity and renewable fraction used, equal to note 14 from Table 2 (System 1)

15. Produced energy available. The annual commercialized production was 14,881.21 kg ha^{-1} $year^{-1}$. The average calorie of the assortment of vegetable was 225 kcal kg^{-1}. Therefore, the produced energy: E (J ha^{-1} $year^{-1}$) = 14,881.21 (kg ha^{-1} $year^{-1}$) * 225 (kcal kg^{-1}) * 4186 (J $kcal^{-1}$) = 1.59E+10 J ha^{-1} $year^{-1}$.

Notes from Table 4 – System of Production 3.

1. Rainfall. Equal to note 1 from Table 2 (System 1).

2. Water of the stream. Equal to note 2 from Table 2 (System 1).

3. Erosion. Calculated by USLE, whose values of the factors were: R = 11,000, K = 0.025572; LS = 0.005449; C = 0.5; P = 0.40. Therefore, E = 0.282578 t ha^{-1} $year^{-1}$.The percentage of the organic matter of the soil of 0.0392 (MOS= 3.92%). Thus, the energy used was calculated in 2.50E+8 J ha^{-1} $year^{-1}$. Equation, transformity and renewable fraction, equal to note 3 from Table 2.

4. Compound. The price of the organic compound was R$ 420.00 per truck (R$ 420.00*7 m^{-3}) placed in the local. It was spent 21 m^3 per year (3 trucks per year), referent to R$ 1,260.00 or US$ 920.25 ha^{-1} $year^{-1}$ (US$ 920.25 = R$ 1,260/1.71 /0.8). Transformity, Tr = 5.02397E+12 seJ US$$^{-1}$ (estimated). The renewable fraction (FR = 0.60) equal to note 4 from Table 2 (System 1).

5. Own seeds. It was used 0.250 kg ha^{-1} $year^{-1}$. Transformity, Tr = 1.68E+12 kg/ha $year^{-1}$; and, the renewable fraction – FR = 0.42 – equal to note 5 from Table 3 (System 2).

6. Seedlings – The annual spent was US$ 613.50 per hectare. Transformity, Tr = 5.02397E+12 seJ US$$^{-1}$ (estimated). The renewable fraction (FR = 0.70), equal to note 5 from Table 2 (System 1).

7. Fuel. The annual consumption of fuel (diesel) completes an amount of 90 liters ha^{-1} $year^{-1}$. Thus, the energy used was 4.29E+9 J ha^{-1} $year^{-1}$. The equation used, transformity (Tr = 1.86E+5 seJ J^{-1}) and renewable fraction (FR = 0.01), equal to note 8 from Table 2 (System 1).

8. Certificated seeds. It was used 2.44 kg ha^{-1} $year^{-1}$. Transformity, Tr = 1.68E+12 kg ha^{-1} $year^{-1}$ (see note 5 from Table 4). The renewable fraction (FR = 0.23) is referent to the percentage of renewability of the conventional systems of grain production (ORTEGA et al., 2002).

9. Depreciation of machines and equipments. It was accounted: (i) micro-tractor (collective); and, (ii) system of irrigation (spraying, joint pump motor with electric motor). The total depreciation was calculated in US$ 331.09 ha^{-1} $year^{-1}$. Transformity, Tr = 5.02397E+12 seJ US$$^{-1}$ (estimated). The renewable fraction – Fr = 0.05 – (ORTEGA et al., 2002).

10. Depreciation of the infrastructure. It was accounted: (i) House (masonry); (ii) Composting (wood); and (iii) cover for product management (wood). The total depreciation was calculated in US$ 920.25 ha^{-1} $year^{-1}$. Transformity = 5.02397E+12 seJ US$$^{-1}$ (estimated). Renewable fraction = 0.05 (ORTEGA et al., 2002)

11. Pieces, tools and other materials. The expenses were calculated in US$ 409.00 ha^{-1} $year^{-1}$. Transformity = 5.02397E+12 seJ/US$ (estimated). Renewable fraction = 0.05 (ORTEGA et al., 2002)

12. Famility workforce. Represented by the head of the family, therefore: E (J/ha $year^{-1}$) = 1.00 (UTF) *300 (day/year) * 2500 (kcal/day)*4186 (J/kcal) / Area (hectare) = 3.92E+09 J ha^{-1} ano^{-1}. Transformity (Tr = 1.85E+7 seJ/J) and the renewable fraction (FR = 0.90), are equal to the note 11 from Table 2 (System 1).

13. Workforce (monthly wage earner). It was accounted the workforce of one man (1 UT); therefore, E (J/ha $year^{-1}$) = 1 (UT)* 300 (days $year^{-1}$) * 2500 (kcal/day) *4186 (J/kcal) / 0.8 (ha) = 3.92 E+09 J/ha $year^{-1}$. Transformity (Tr = 1.85E+7 seJ/J) and the renewable fraction (Fr = 0.60), equal to note 13 from Table 2.

14. Electricity. It was accounted the annual consumption in irrigation (electric motors) plus the residential use, completing 1.290 kWh. From this, the energy used was calculated in 5.81 E+09 J ha^{-1} $year^{-1}$. The equation used, the transformity (Tr = 5.64E+5 seJ J^{-1}) and the renewable fraction (FR = 0.50) are equal to note 14 from Table 2 (System 1).

15. Produced energy available. The annual production commercialized was calculated in 23,966.21 kg ha^{-1} $year^{-1}$. The average calorie of the assortment of the vegetables was 255 kcal kg^{-1}. From that, the energy produced was: E (J $ha^{-1}year^{-1}$) = 23,966.21 (kg ha^{-1} $year^{-1}$) * 255 (kcal kg^{-1})* 4186 (J $kcal^{-1}$) = 2.56E+10 J ha^{-1} $year^{-1}$.

Notes from Table 5 – System of Production 4.

1. Rainfall. For calculate the energy (E) it was considered the average annual rainfall of 1400 mm. From this, E = 7.00E+10 J ha^{-1} $year^{-1}$. The equation, the transformity (Tr = 3.06 E+4 seJ J^{-1}) and the renewable fraction (FR = 1) are equal to note 1 from Table 2 (System 1).

2. Water of the stream. It was considered the application of 2 mm, during 90 days per year (180 mm $year^{-1}$), then E = 9.00E+9 J ha^{-1} $year^{-1}$. The equation, transformity (Tr = 2.96E+5 seJ J^{-1}) and the renewable fraction (FR = 1) are equal to note 2 from Table 2 (System 1).

3. Erosion. Calculated by USLE, whose values of the factors were: R = 11,000, K = 0.017623; LS = 0.0023443; C = 0.5; P = 0.20. Therefore, E = 0.454455 t ha^{-1}. $year^{-1}$. The percentage of organic matter of the soil of 0.0205 (MOS = 2,05%). From this, the energy used was calculated in 2.11E+8 J ha^{-1} $year^{-1}$. The equation, transformity (Tr = 1.24E+5 seJ J^{-1}) and the renewable fraction (FR = 0) are equal to note 3 from Table 2 (System 1).

4. Compound. It was used 8,000 kg ha^{-1} of organic compound prepared trough the poultry 'bed', in the property. The energy of the compound was calculated by the equation: E (J $ha^{-1}year^{-1}$) = Amount (kg ha^{-1} $year^{-1}$)* 5000 (kcal kg^{-1})*4186 (J $kcal^{-1}$) = 1.674E+11 J ha^{-1} $year^{-1}$. The transformity (Tr = 4.45E+4 seJ J^{-1}), is referent to the transformation of the manure Tr = 2.65 E+4 seJ J^{-1} (AGOSTINHO, 2005), multiplied by the factor of correction 1.68 (BROWN and ULGIATI, 2004). The renewable fraction – FR = 0.8 (common sense) – is justified since it is the composed manually elaborated, in the property.

5. Seedlings and own seeds. It was used 3,360 fruit-seeds (planting and replanting) selected in the property, for annual renovation of the plants. The average weight of the fruits was 400 g. The caloric value of the chayote was 170 kcal kg^{-1}. Therefore, to calculate the energy of their own seedlings we have: E (J ha^{-1} $year^{-1}$) = number of seeds * 0.4 (kg $fruit^{-1}$) * 170 (kcal kg^{-1}) * 4186 J $kcal^{-1}$ = 9.56E+08 J. Transformity (Tr = 1.75E+5 seJ J^{-1}) is equal to the transformity of the food raw product, Tr = 1.04E+5 seJ J^{-1} (ORTEGA, 2001) multiplied by the factor of correction 1.68 (BROWN and ULGIATI, 2004). The renewable fraction – FR = 1 (common sense) is justified since they are seedling of their own.

6. Depreciation of the infrastructure. It was accounted: (i) house (masonry); (ii) irrigation warehouse (wood); (iii) goat-house (wood); (iv) hen-house (wood); reservoir (land); (vi) irrigation system (dropping, by gravity); and (vii) others (machines and equipments). The total depreciation was calculated in US$ 3,947.80 ha^{-1} $year^{-1}$. Transformity, Tr 5.02397E+12 seJ US$$^{-1}$ (estimated). The renewable fraction – FR = 0.05 (ORTEGA et al., 2002).

7. Depreciation of the trellis. The chayote is cultivated in structures called trellis. The depreciation was calculated in US$ 579.35 ha^{-1} $year^{-1}$. Transformity, Tr = 5.02397E+12 seJ US$$^{-1}$ (estimated). The renewable fraction – FR = 0.40 (common sense) is justified since 40% of the cost of the trellis were renewable material (eucalyptus and bamboo).

8. Pieces, tools and other materials. It was accounted the expense of US$ 116.86 ha^{-1} $year^{-1}$. Transformity, Tr = 5.02397E+12 seJ US$$^{-1}$ (estimated). The renewable fraction – FR = 0.05 (ORTEGA et al., 2002).

9. Fuel. It was accounted 66.66 liters of diesel per hectare per year; therefore: E = (J) = X liter (ha^{-1} $year^{-1}$) * 1.14 E+4 (kcal L^{-1}) * 4186 (J $kcal^{-1}$) = 3.18 E+09 J ha^{-1} $year^{-1}$. Transformity, Tr = 1.86E+5 seJ J^{-1} (ORTEGA et al., 2001).

10. Family workforce. It was accounted two head of the family (man and woman, with ages from 18 to 50 years), two sons (ages between 14 and 17 years) and one son (age from 7 to 13 years), resulting in the total of 3.8 units of work (UT). From that, the energy used was 3.98E+10 J ha^{-1} $year^{-1}$. The equation, transformity (Tr = 1.85E+7 seJ J^{-1}) and the fraction – FR = 0.90 (common sense), are equal to note 11 from Table 2 (System 1)

11. Electricity. It was accounted the residential consumption of 1,416 kw $year^{-1}$. From that, the energy used was calculated in 1.70E+10 J ha^{-1} $year^{-1}$. The equation used, the transformity (Tr = 5.64E+5 seJ J^{-1}) and the renewable fraction (FR = 0.50) are equal to note 14 from Table 2 (System 1).

12. Taxes. It was accounted the social contribution from two adults in the total of R$ 2,040.00 per year, so: Taxes (US$ ha^{-1} $year^{-1}$) = R$ 2,040.00 / 1.71 (R$ US$$^{-1}$) / Area (ha) = US$ 3,973.12 ha^{-1} $year^{-1}$. Transformity, Tr = 5.02397E+12 seJ US$$^{-1}$ (estimated). Renewable fraction – FR = 0.05 (TAKAHASHI et al., 2008).

13. Produced energy available. It was accounted the annual production of 36,828 kg $ha^{-1}year^{-1}$, and considered the calorie of the chayote of 170 kcal kg-^{1}; therefore, the energy produced: E (J ha^{-1} $year^{-1}$) = 36,828 (kg ha^{-1} $year^{-1}$)*170 (kcal kg^{-1})* 4186 (J $kcal^{-1}$) = 2.62 E+10 J ha^{-1} $year^{-1}$.

Notes from Table 6 – System of Production 5.

1. Rainfall. To calculate energy (E) it was considered the average annual rainfall of 1400 mm. From that, E = 7.00E+10 J ha^{-1} $year^{-1}$. The equation, transformity (Tr = 2.96E+5 seJ J^{-1}) and the renewable fraction (FR = 1), equal to note 1 from Table 2 (System 1).

2. Water of the stream. It was considered the application of 2 mm, during 90 days per year (180 mm year-1); then, E = 9.00E+9 J ha^{-1} $year^{-1}$. The equation, transformity (Tr = 2.96E+5 seJ J^{-1}) and renewable fraction (FR = 1) are equal to note 2 from Table 2 (System 1).

3. Erosion. Calculated by USLE, with the following values: R = 11,000, K = 0.017509; LS = 0.0023443; C = 0.5; P = 0.20. Therefore, E = 0.451498 t ha^{-1} $year^{-1}$. The percentage of organic matter of the soil of 0.0224 (MOS= 2.24%). From that, the energy used was calculated in 2.29E+8 J ha^{-1} $year^{-1}$. The equation, transformity (Tr = 1.24E+5 seJ J^{-1}) and the renewable fraction (FR = 0), equal to note 3 from Table 2 (System 1).

4. Compound. It was used 8,000 kg ha^{-1} of organic compound. The energy of the compound was calculated by the equation: E (J ha^{-1} $year^{-1}$) = Amount (kg ha^{-1} $year^{-1}$) * 5000 (kcal kg^{-1})*4186 (J $kcal^{-1}$) = 1.674E+11 J ha^{-1} $year^{-1}$. Transformity (Tr = 4.45E+4 seJ J^{-1}), is referent to the transformity of the manure, Tr = 2.65 E+4 seJ J^{-1} (AGOSTINHO, 2005), multiplied by the factor of correction 1.68 (BROWN and ULGIATI, 2004). The renewable fraction – FR = 0.6 (common sense) is justified since it is the compound bought in the local market.

5. Seedling and own seeds. Equal to note 5 from Table 5 (System 4).

6. Depreciation of the infrastructure. It was accounted: (i) house (masonry); (ii) breeding shed (wood); (iii) goat-house (wood); (iv) hen-house (wood); (v) reservoir (land); (vi) irrigation system (dropping, by gravity); and, (vii) others (machines and equipment). The total depreciation was calculated in US$ 2,982.76 ha^{-1} $year^{-1}$. Transformity, Tr 5.02397E+12 seJ US$$^{-1}$ (estimated). The renewable fraction – FR = 0.05 (ORTEGA et al., 2002).

7. Depreciation of the trellis. Equal to note 7 from Table 5 (System 4).

8. Pieces, tools and other materials. Equal to note 8 from Table 5 (System 4).

9. Fuel. It was spent 50 liters of diesel per year. From that, the energy accounted was 2.39E+09 J ha^{-1} $year^{-1}$. The equation used, the transformity (Tr = 1.86E+5) and the renewable fraction (FR = 0.01) are equal to note 9 from Table 5 (System 4).

10. Family workforce. It was accounted two adults (man and woman, with ages between 18 and 59 years) and one son (with age between 14 and 17 years), making a total of 2.65 UT. From that, the energy used was calculated in 2.08E+10 J/ha $year^{-1}$. The equation used, the transformity (Tr = 1.85E+7 seJ J^{-1}) and the renewable fraction – FR = 0.90 (common sense) are equal to note 11 from Table 2 (System 1).

11. Electricity. It was accounted the residential consumption of 1.416 kw $year^{-1}$. From that, the energy used was calculated in 1.27E+10 J ha^{-1} $year^{-1}$. The equation used, the transformity (Tr = 5.64E+5 seJ J^{-1}) and the renewable fraction (FR = 0.50) are equal to note 14 from Table 2 (System 1).

12. Produced energy available. It was accounted the annual production of 10,238 kg ha^{-1} $year^{-1}$. And, considering the calorie of the raw chayote of 170 kcal kg-^{1}; then, the produced energy: E (J ha^{-1} $year^{-1}$) = 10,238 (kg ha^{-1} $year^{-1}$)*170 (kcal kg^{-1})* 4186 (J $kcal^{-1}$) = 1.82 E+10 J ha^{-1} $year^{-1}$.