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Sustainability Assessment of Family Agricultural Properties: The Importance of Homeopathy

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Abstract: Family farming is a lifestyle and agricultural base that has ensured food for the world's growing population in addition to the family's own subsistence. However, the intensification of production processes to primarily generate exportable surpluses is based on the constant input of industrial inputs of low local socioeconomic viability. This study aims to evaluate the sustainability of family farms and their impact on the adoption of homeopathy instead of traditional/conventional intensification techniques. The study was conducted at six family farms located in the Serrana Mesoregion, Santa Catarina, Brazil, and include farms were classified according to the management and representativeness of their agricultural activity, i.e., conventional grains-cattle, milk-grains, grains and diversified, and according to their ecological basis, i.e., agroecological and organic. To discuss the sustainability of the family farms that were evaluated, the of metrics emergy synthesis, ecotoxicity potential and socioeconomic indicators are used. The results indicate that conventional diversified property has the best overall performance with regard to sustainability, including emergy yield ratio (EYR 1.88), emergy investment ratio (EIR 1.13), return on assets (1.22), hourly income of work (36.6 BRL/h) and income sufficiency (3.3). Agroecological and organic properties have better performance in renewability (76% and 75%), environmental load (ELR = 0.32 and 0.34), sustainability (ESI = 4.78 and 3.5) and potential ecotoxicity (1.736 and 1.579 kg 1.4 DCB-eq/ha). The contribution of homeopathy in an alternative scenario results in a 19% reduction in nonrenewable flows in conventional management properties and a decrease of up to 91% in ecotoxicity in grain + cattle properties. Using homeopathy, the return on assets and profit margin can be increased by up to 43% and income per hour of work and income sufficiency can be increased by 20% and 16%, respectively. This study contributes to discussions about the importance of using homeopathic therapies as a viable strategy that can be used in strategic public policy plans to improve the sustainability of family farms.

Keywords: agroecology; Brazil; ecotoxicity; emergy; organic

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1. Introduction

Small-scale agrosystems are a strategy for providing food for a growing population and for the food and nutritional security of a country [1]. Studies show that, globally, small farmers with properties that are up to 50 hectares in size produce between 62 and 66% of the food in 25% of the gross cultivated area, in addition to presenting the lowest postharvest losses compared to farmers with medium and large scale farms [2]. In this context, it is evident that small farmers characterized by developing small-scale family-type agriculture systems are essential for maintaining a country's food and nutritional security [3].

The intensification of food production after the "Green Revolution" has been based on the premise of productive maximization, with natural resources being infinite and without considering their recovery rate [4]. Thus, in recent decades, it has become evident that the intensification of food production systems, due to the increasing adoption of industrial inputs, is unsustainable from the point of view of the exhaustion of nonrenewable resources [5]. From the perspective of curbing and/or reversing environmental and social degradation in the agricultural sector, it is evident that, at the very least, the permanence of current family farmers and their strategic role in food production involves the formulation of public policies aimed at the socioeconomic viability of family farming based on the limit of the internal natural resources that are dependent on them [6]. Therefore, although family farming is considered to be an important pillar in global food production, its sustainability is generally vulnerable to the environmental and socioeconomic conditions of the country [2,7]. According to Dreby et al., the family farmer operates in a paradox of being socially valued and supported with minimal economic income, such as through maintaining a way of life based on low-environmental impact agriculture [8].

In the Serrana Mesoregion, which is located in the state of Santa Catarina, Brazil, and has typically occupied by extensive livestock farming in past decades, small-scale family farming still exists [9]. In contrast to the past, 65% of the farms in that are currently family farms and account for more than 50% of the region's agricultural production; however, these farms only cover 17% of the arable land [10]. The region also has high rates of productivity per area in relation to other Brazilian regions in crops such as beans and soybeans [11]. However, these productive values are the result of an intensification of production systems, where more than 70% of farms are dependent on industrial fertilizers and pesticides; this number increases to 75% in family farms, 2.2 times higher than the Brazilian average [10]. In this region, cultural aspects have influenced the development of family production systems, which are also characterized as having different agricultural activities, many of which are predominantly based on conventional production models [9]. However, the sustainability of these family farms becomes a topic of interest, given the current scenario of the collapse of production systems based on fossil sources. This makes it necessary to consider conceptual models of sustainability, which analyze the indicators that could represent the systemic performance of the sustainability of existing properties from the ecocentric and anthropocentric points of view [12].

For an anthropocentric approach, socioeconomic analyses are needed to show whether the system is economically viable and socially acceptable but also culturally acceptable with minimized impacts [13]. In this sense, economic indicators can offer a short-term perspective of the financial status of the system. Conversely, social indicators can be directed to identify possible problems such as insufficient income and cause farmers to migrate to another economic system because they consider it to be more profitable [14].

From the ecocentric approach, the medium- and long-term sustainability of production systems can be estimated through emergy synthesis (written with 'm') [15]. According to Odum, emergy is defined as "available energy of one kind previously used up directly and indirectly to make a service or product" [16]. This metric allows the different types of flows (mass, money and energy) that enter a given system and that become a single unit, called solar energy joules or "sej" [17]. Another indicator with ecocentric bases that is important to evaluatinge family farming systems is ecotoxicity, especially when the use of pesticides is an inherent part of the technological packages used. In this circumstance, it becomes critical to perform ecological risk assessments on the chemical substances that are introduced into a production system [18].

On the other hand, overcoming the problems caused by the current intensified production model requires seeking solutions with technologies and approaches that differ from those used for the development of current agricultural models, which are considered to be unsustainable. Thus, it is necessary to propose technologies that harmonize sustainable management in agrosystems and that replace the indiscriminate use of agrochemicals [4]. In this sense, the use of homeopathic preparations in agriculture has shown increasingly promising results; however, homeopathic preparations have a rationality that is different from those technologies that only seek to maximize production factors [19,20]. Homeopathic preparations work to reestablish the homeostasis of living organisms, performing the physiological functions of plants and animals without harmful effects to the environment [21]. Thus, in the scientific literature, it is possible to find satisfactory results when pesticides have been replaced by homeopathic treatments in terms of the yield (kg/ha) in crops such as beans, rice, and vegetables in addition to their potential in reducing and controlling diseases [22–25]. Despite the promising results, the implementation of homeopathy in agriculture presents difficulties because homeopathic remedies have their properties described in medical articles, describing their use in humans; therefore, their extension/use for cultivation systems requires reinterpretations and/or experiments [26]. Furthermore, no information highlighting the contribution of homeopathy to the sustainability of agrosystems, based on the results of a conceptual model that includes sustainability metrics/indicators, and that uses an anthropocentric and ecocentric approach has been found in the literature. In addition to the aforementioned factors, it is necessary to generate scientific information on the use of homeopathy in agricultural systems that aims to integrate and harmonize plant, animal, and human organisms among themselves and with the environment in which they live from the systemic perspective of sustainability, especially in family-based agrosystems.

This study aimed to evaluate the sustainability of different family-based production systems on farms located in the Serrana Catarinense Mesoregion, SC, Brazil, by considering the impact of implementing homeopathy, instead of traditional/conventional intensification techniques as alternative scenarios. The results of this study may contribute to reporting on the development of public policies that are aimed at promoting sustainable family farms.

2. Materials and Methods

2.1. Description of the Agricultural Systems Studied

The study was conducted using data that were obtained in loco from family farms located in the Serrana/Serra Catarinense Mesoregion, Santa Catarina state, Brazil (Figure 1). The region belongs to the Atlantic Forest biome and is, a mixed ombrophilous forest phytophysiognomy, with a predominant Cfb Köppen climate and average annual temperature of 16.5 °C and average annual rainfall of 1600 mm [27]. According to data from the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística-IBGE), in the Serrana Mesoregion, 65% of the farms are considered family farms and have an average area of 21 hectares [10]. The main agricultural activities correspond to temporary crops (81%), via the cultivation of corn, soybean and beans, while the rearing of beef cattle and milk is present on 90% of the farms.

Figure 1. Map of Brazil highlighting the location of the Serrana/Serra Catarinense Mesoregion, Santa Catarina State, Brazil.

For the present study, six family farms recommended by the extension service of the Agricultural Research and Rural Extension Company of Lages (Empresa de Pesquisa

Agropecuária e Extensão Rural de Lages) (Epagri-Lages) were considered, as they are representative of the main agricultural activities of the Serra Catarinense region. Family farms were classified according to Decree 9.0064/17, which regulates the Family Farming Law [28]. Data were collected through property visits and interviews with the owner with the support of Epagri-Lages extension workers. The farms were classified into six typologies as described in Table 1: Conventional farms based on technological packages dependent on agrochemicals and highlighting their main production foci (1) Conventional-Grains + Cattle, (2) Conventional-Milk + Grains, (3) Conventional-Grains, that with integration of different agricultural activities, (4) Conventional-Diversified, those with an ecological base with diversified production that integrate nutrient recycling practices, integrated pest management, and that comply with organic certification standards, (5) Agroecological, which considers social and cultural aspects and the diversification of agricultural activity, and (6) Organic, which includes farms that strictly meet the organic certification requirements.

Table 1. Description of the typologies and main characteristics of the family farms evaluated.

Property/Typology	Area in ha	Characteristics of Agricultural Activities
Conventional-Grains + Cattle	36	Temporary crops with grains (soybean, corn and beans). Livestock with beef cattle.
Conventional-Milk + Grains	27	Temporary crops with grains (soybean, corn, beans). Livestock with dairy cattle.
Conventional-Grains	9.5	Temporary crops with grains (corn, beans).
Conventional-Diversified	23	Temporary crops with grains (corn, beans). Horticulture. Livestock with beef cattle and bees (honey), fruit (pine nuts).
Agroecological	35	Temporary crops with corn and beans. Horticulture. Livestock farming with cattle for milk/cheese and bees (honey). Permanent crops with fruits (orange lemon, pine nut).
Organic	6	Horticulture. Temporary crops with beans, strawberry and garlic.

2.2. *Assessment of the Sustainability of the Properties Studied*

As family-based agrosystems are thermodynamic systems that are open to the input of energy and matter, the conceptual model of sustainability follows the logic of "Input-State-Output" (Figure 2). In this approach, indicators that are capable of representing the three aspects (environmental, economic and social) of sustainability are used, ensuring the informative and complementary capacity of each of them [29,30].

Figure 2. Conceptual model of sustainability ("Input-State-Output") showing the indicators used.

The importance of the adopted model is the possibility of choosing indicators that ultimately reflect the sustainability of the evaluated system Thus, an ecocentric perspective was considered in the evaluation through the use of emergy metrics that were complemented with ecotoxicity potential and anthropocentric analyses with socioeconomic indicators.

2.2.1. Synthesis in Emergy

The Synthesis in Emergy was developed by Odum, with contributions from Brown and Ulgiati, and Ortega et al., to include the partial renewability of some inputs [16,17,31].

The evaluation procedure consisted of three main steps: (1) the elaboration of the systemic diagram, which provides an overview of the inputs and direct and indirect connections between the natural and economic processes; (2) the elaboration of the emergy accounting tables, which account for all of the input flows and transform them into sej; and (3) the calculation of the emergy indicators support discussions on the performance of the properties. The indicators used in this study are described in Table 2. The data used to calculate the indicators are shown in the Supplementary Materials Tables S1 and S2 and in Appendix A.

Table 2. Emergy indicators used to evaluate the sustainability of family farms located in the Serrana Mesoregion, Santa Catarina, Brazil.

Indicator	Equation	Description
Unit Emergy Value (UEV)	UEV = Y/Output	Determines the emergy used in the system per unit of product.
Renewability (%R)	%R = 100 × (R + Mr + Sr)/Y	The proportion of renewable emergy in relation to the total use of emergy.
Emergy Yield Ratio (EYR)	EYR = Y/F	Ratio between the total use of emergy and the invested emergy of the economic system.
Emergy Investment Ratio (EIR)	EIR = F/(R + N)	Ratio between the resources of the economy by the emergy of nature.
Modified Environmental Loading Ratio (ELR)	ELR = (N + Mn + Sn)/(R + Mr + Sr)	Proportion of use of non -renewable emergy by renewable emergy.
Emergy Sustainability Index (ESI)	ESI = EYR/ELR	Defined as the ratio of EYR and ELR.

The emergy indicators were calculated, including family labor. According to Agostinho and Ortega, accounting for family labor is a complex subject but is necessary when evaluating the small properties that depend on family labor to produce [32]. This approach is important in the context of Serra Catarinense, because according to IBGE data, 65% of family farms are developed using family labor alone [10]. Other authors also emphasize the importance of estimating the contributions of labor in the agricultural production system [14,33,34].

The percentages of renewability that were used were derived from the scientific publications and are available in Supplementary Materials Table S1.2. In this analysis, the energy and material flows that crossed the boundaries of the system (properties) were converted into standard units called "solar joules" (sej) by multiplying each input stream by its unit emergy value (UEV), which are available in the literature, and do not include "labor and service". The UEVs that were selected were those that best represented the system under study (Supplementary Materials Table S1.4) and, if necessary, updated at the baseline 12.1×10^{24} sej [35].

The environmental performance of the studied properties, which generally describes the performance of family farms, is considered in the ternary diagram. The use of the ternary diagram for emergy evaluation was proposed by Giannetti et al. [36]. In the present study, the proportions of renewable emergent flows (R + Mr + Sr), nonrenewable natural resources (N), and nonrenewable materials and services (Mn + Sn) were plotted. The properties are represented by the points within the triangle, and their locations represent the ternary combinations of the relative proportion of the three components (R, N, and F).

2.2.2. Analysis of the Ecotoxicity Potential

The ecotoxicity potential (ETP) represents the potential contribution of a substance to the toxicity of the system in relation to a unit quantity of a reference substance [18]. The ETP includes the effects of the active ingredients (AI) in pesticides and the heavy metals in the mineral and organic fertilizers and in the pesticides entering the property. The information on the active ingredients was acquired directly from the insert from the pesticide package and is expressed in grams per hectare (g/ha). The heavy metal concentrations for the pesticide and mineral fertilizers were obtained from Zoffoli et al. [37] and Gonçalves et al. [38] and those for organic fertilizers (poultry litter) were obtained from Parente et al. [39] and Barros et al. [40]. The heavy metals considered in this study are cadmium (Cd), lead (Pb), copper (Cu), zinc (Zn) and chromium (Cr).

ETP calculations were performed according to Margni et al., in which the values of each AI and heavy metal are transformed into a reference substance through the multiplication of a characterization factor, which is estimated by taking into account their behavior in the medium, the toxic capacity, and the amount applied [41]. The reference chemical used in this study was 1,4-dichlorobenzene-equivalent (1.4 DCB-eq), and the results are expressed in kg of 1.4 DCB-eq. This chemical substance has been used as a reference for ecotoxicity in conventional and organic apple production, in conventional and organic tomato production and in wheat and corn production [42–44].

The values of 1.4 DCB-eq, for each chemical substance (active ingredient and heavy metals) are extracted from Huijbregts et al. and are available in Supplementary Materials Table S3.1 [45].

2.2.3. Socioeconomic Analysis

The financial performance of the properties is performed by the economic analysis of costs and revenues. The value (in BRL) of the inputs and sales were provided by the farmers themselves and correspond to the regional/national market prices (effective sale) in 2019. For analysis, the prices of all of the inputs used in the production system are considered. (fuels, electricity, seeds, fertilizers, pesticides, hired labor, and other services) and expressed in BRL ha^{-1} $year^{-1}$. The amount paid for family labor was estimated at BRL 90 per day, which is the amount that farmers pay when they hire labor from outside of the property. The annual costs include the annual depreciation values of fixed assets (machinery, infrastructure).

Economic Indicators

- Return on assets: Compares the final profit with the investments made. Return on assets = (Net revenue/Total costs) × 100.
- Profit margin (%): Compares the final profit of the company with the sales revenue. % Profit margin = (Net Revenue/Gross Revenue) × 100.

Social Indicators

The social criterion was referenced based on whether the farmers had sufficient income. Insufficient income leads to farmers being financially dependent on other economic systems and the migration of people from the countryside to cities. The same approach used by Jaklic et al. [14], who used the following indicators, was implemented:

- Income per hour of work (BRL/h): This indicator indicates the sufficiency of income for an acceptable standard of living. According to the Supplementary Law No. 771 of 17 March 2021, for the State of Santa Catarina in the category of agriculture and livestock, minimum wage is BRL 1281.00 per month. Calculation: Net revenue per working hours (own working hours).
- Income sufficiency was calculated using the ratio between fully paid family labor, with the revenue obtained from the sales and the total family labor invested in the property.

2.3. Comparative Analysis between Family Farms

To compare family farms, a radar chart containing the most representative indicators of the applied methods (emergy, ecotoxicity and socioeconomic) is used. Direct comparisons between the indicators were performed by normalizing their values with the Z Score formula, which transforms them into a common scale with a mean of zero ($\mu = 0$) and standard deviation of one ($\sigma = 1$). All of the indicators were considered to be equally important and were organized so that the highest value would reflect a more desirable performance. Thus, the largest area in the graph would represent the property with the best level of sustainability.

2.4. Alternative Scenario Optimized with the Use of Homeopathy

After the diagnosis (current situation) of each family property, scenarios of crop/livestock management are proposed through the use of homeopathic preparations to replace the pesticides and their adjacent impacts by, considering a 20% reduction in mineral and organic fertilizers. This decision was based on references from scientific publications showing that homeopathy in plants is effective in managing diseases and restoring their physiological processes, making them more efficient in the use of soil nutrients [46]. Thus, Santos Junior et al., obtained between 18 and 33% increases in grain yield (kg/ha) in bean crops that had been treated with homeopathic preparations compared to the control (without application) [22].

For the emergy analysis, the UEV (unit emergy value) of a homeopathic preparation was calculated by considering the rules of the homeopathic pharmacopoeia. The UEV was calculated from a mineral raw material to a dynamization of 12CH (centesimal Hahnemannian dilution order). The emergy spent/used until this dynamization was considered entry into the property. The amount of homeopathic matrix considered for inclusion in the system was estimated proportionally to the size of the agricultural activities taking place on each property. However, this was based on the fact that a characteristic of homeopathy is its influence on biological systems at highly diluted minimum doses [47]. This suggests that when small amounts of homeopathic matrix enter the property, it is possible to derive a large volume of the matrix when following the rules of dilution and suction outlined in the homeopathic pharmacopoeia of 1:100.

In these scenarios of homeopathy use, information is considered an important flow in the internalization of the principles of homeopathy in family farms. However, given the difficulty in quantifying 'information', it was decided to add 200 h per year within the family labor flows. The justification is because this would be the time spent by the farmer to train himself, reflect on the integration of homeopathy in his production system, and implement it correctly. The suggested time was based on consultation with experts in the field of homeopathy applied to agricultural ecosystems and in the course of Homeopathy in Agriculture of the CAV-UDESC.

Once the inputs were replaced, all the indicators of the metrics used (Emergy, Ecotoxicity, Socioeconomic) were calculated again in the sustainability analysis, now considering the use of homeopathic preparations.

3. Results and Discussion

3.1. Diagnosis of the Current Scenarios of the Family Farms Evaluated

3.1.1. Synthesis in Emergy

The energy diagram shown in Figure 3 shows the input and output flows of energy and matter in addition to the main subsystems, which are the agricultural activities of the six family farms in the Serra Catarinense region that were evaluated. The inputs of the local environmental resources are on the left side, and the economic inputs are arranged at the top of the diagram (Figure 3). The systems are characterized as being intensified through the use of family labor, which is eventually complemented by external labor. Within the system, forest and pasture plantations provide energy and biomass to the consuming subsystems (cattle and bees), and the flows have a greater interrelationship between the pasture, cattle, and crop subsystems. All of the farms are characterized by diversified production and produced different outputs of agricultural products and forested areas that producing ecosystem services. The red lines in the diagram represent the integration of homeopathy in the properties in an input substitution scenario; however, this approach will be discussed after the evaluation of the current scenario.

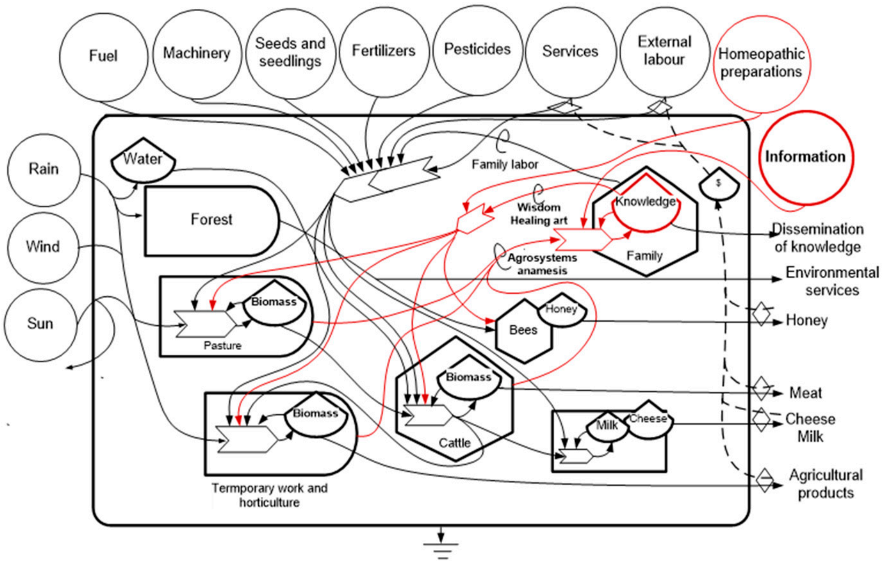

Figure 3. Energy diagram representing the family farms evaluated in the Serra Catarinense region with the integration of homeopathy for their management, highlighted in red.

Indicators in Emergy

With the data obtained during the evaluation and presented in Supplementary Materials Table S2, the calculation of the indicators in emergy compatibilized in Table 3 was performed. The values obtained from the current situation are discussed below, and the scenarios using homeopathy are discussed below.

Table 3. Emergy indicators of the family farms evaluated in the Serra Catarinense region in the current scenario and using homeopathic preparations (CH).

Indicator	**Agroecological**		**C. Grain/Cattle**		**C. Milk/Grains**		**C. Grains**		**[b] C. Diver.**		**Organic**	
	Current	**[a] CH**	**Current**	**CH**	**Current**	**CH**	**Current**	**CH**	**Current**	**CH**	**Current**	**CH**
UEV [c]	2.72	2.67	2.93	2.62	1.38	1.29	1.45	1.11	3.82	3.28	8.33	7.93
%R	76	77	42	49	34	37	40	47	50	55	75	76
ELR	0.32	0.30	1.35	1.05	1.98	1.71	1.49	1.12	1.01	0.82	0.34	0.32
EYR	1.51	1.52	1.48	1.57	1.31	1.34	1.28	1.32	1.88	2	1.21	1.21
EIR	1.98	1.92	2.08	1.76	3.22	2.95	3.56	3.15	1.13	1.00	4.75	4.87
ESI	4.78	5.13	1.09	1.50	0.66	0.78	0.86	1.18	1.86	2.45	3.56	3.73

[a] CH = Scenario with homeopathy. [b] Conventional Diversified. [c] UEV = Unit Emergy Value in 10^{12} sej/kg (system's total).

- Unit Emergy Value (UEV)

The unit emergy value (UEVs) of the family farms studied varied between 1.38×10^{12} sej/kg in the Milk + Grain typology (minimum) and 8.33×10^{12} sej/kg in the Organic typology (maximum). These values show that the organic system needs 6 times more emergy from the biosphere to produce one kg of product. The UEV is an indicator that evaluates the emergy ("Input") required to produce an output unit [48]. When comparing systems, high UEV values mean a lower efficiency per output unit [49,50].

In general, less technologically and ecologically based production systems require greater emergy flow per output unit. These flows are mainly incorporated into the workforce and constitute more renewable emergy than the others, which is noticeable in the other indicators (%R, ELR, EYR and ESI). On the other hand, systems with a high production efficiency (sej/kg), such as iin the case of the conventional family farms Grains + Milk and Conventional Grains, are highly dependent on nonrenewable resources, and their sustainability is limited by the availability of these resources. According to Martin et al., production systems that are centered on the use of fossil energies are more efficient but less sustainable over time because they are dependent on flows that are acquired outside of the system [51]. Bey studying different production systems in Mexico, the authors observed that the traditional agroecosystems of the indigenous Mayans have a higher transformity (1.37×10^6 sej/J) than those of corn (9.30×10^4 sej/J) and blackberry (2.32×10^5 sej/J) monocultures. However, the traditional agroecosystems of the indigenous Mayans demonstrated better performance in the other sustainability indicators (ELR and ESI).

- Renewability (%R)

Among the family farms that were evaluated, the ecologically based properties (ecological and organic) had renewability percentages of 76% and 75%, respectively. According to La Rosa et al., production systems with a high percentage of renewability (% R) are more likely to be environmentally sustainable and more successful [52]. The renewability indicator shows considerable differences between the properties. Among the conventional properties, the best renewability was found for conventional diversified properties, which achieved a value of 50% (Table 3).

The renewability of ecological-based systems is influenced by the degree of dependence on family labor and organic fertilizers, with renewable fractions of 90% and 70%, respectively (Supplementary Materials Table S1.2). The studies conducted by Albino and Callado also show that renewability in an agroecological production system (66%) differs from that of conventional monoculture systems (12%) [53]. Agostinho and Ortega showed a renewability level of 55% in small integrated production and family-based properties versus 26% in a large-scale monoculture for ethanol production [32].

It is noteworthy that the family farms that were evaluated with the best UEV efficiency had the lowest percent renewability. These rural properties are focused on the production of grains and milk (Milk + Grain and Grains), which are highly dependent on nonrenewable energy being incorporated into agrochemicals. According to Su et al., although the more technified systems have better performance, the intensification of the entry of nonrenewable energies such as chemical fertilizers, machinery and infrastructure makes them less environmentally renewable [54].

- Environmental Loading Ratio (ELR)

In general, all of the family farms evaluated show that their production system causes low local environmental stress. The main difference can be observed in the family farms of conventional management and those of ecological management, where in the conventional farms, the ELR shows values >1 and those of ecological base values <1.

It can be observed that those more diversified or integrated properties have lower ELR values (Table 3). In Brazil, studies on small farms with integrated production have values between 0.51 and 3.13 [53,55]. Ortega et al., in conventional systems of soybean production, found ELR values of 4.18, and Nakajima and Ortega, in the production of vegetables, found values of 4.77 for conventional systems and 1.54 for organic production [34,56].

- Emergy yield ratio (EYR)

The family farms evaluated presented an EYR ranging from a minimum of 1.21 (Organic) to a maximum of 1.88 (Conventional diversified) (Table 3). The EYR values in the comparison of different systems provide information to define the system with the greatest capacity to exploit local resources. The results obtained suggest that the "Conventional Diversified" family farm has better ability to exploit local resources by external investment of resources than all others. The results obtained here are endorsed by Cavalett et al., in integrated production systems in southern Brazil, where the EYR was equal to 1.44 [55]. According to Brown and Ulgiati, production systems make a good emergy contribution to the economy when the EYR value is between 2 and 5 [17]. This suggests that the studied systems do not have a good ability to exploit local sources of renewable resources by investment of resources, and their EYRs vary between 1.21 and 1.88. However, these results are influenced by the accounting of family labor in the calculation of the EYR, which has a representativeness of up to 53% of the total emergy of the system.

- Emergy Investment Ratio (EIR)

The best performance in the use of economic resources was observed in the "Conventional Diversified" family farm with a value of 1.88, while the organic family farm presented the EIR with a value of 4.75 (Table 3). This means that, per unit of emergy of nature, 1.88 units are needed from the economy. In the organic system, this ratio is 1:4.75. The EIR evaluates the efficiency of the system in using the emergy of the economy to boost its local development processes. In the comparison of production systems, low EIR values identify the one with the best efficiency in the allocation of economic resources [57]. In this sense, the "Conventional Diversified" family farm is more resilient to disturbances that may occur in the economy. The properties with higher EIR values are less likely to remain and less competitive. According to Asgharipour et al., current trends indicate that nonrenewable and low-cost energy will be increasingly restricted [58]. Therefore, in a scenario with scarcity of fossil sources, properties with lower efficiency and greater dependence on the use of the emergy of the economy would have less success in competing with those with lower demand and greater efficiency in the use of emergy of the economy system. This approach is applicable to conventional properties (Milk + Grains) and (Grains) with EIR 3.22 and 3.56, respectively, indicating that they are more susceptible and less competitive in the scarcity of resources from fossil sources. On the other hand, the EIR values in the ecologically based properties are more related to the emergy of labor. However, it remains a problem if we consider limitations in the availability of local labor in the coming times. In a study conducted by Agostinho and Ortega on small ethanol production properties, they showed values of 1.30 and 0.70, considering and disregarding family labor, respectively [32].

- Emergy Sustainability Index (ESI)

Ecologically based family farms have the highest sustainability (ESI), with 4.7 for agroecological farms and 3.5 for organic farms. Among the conventional family farms, Diversified and Grains + Cattle showed the highest ESI values of 1.86 and 1.09, respectively. The properties Conventional-Milk + Grains and Conventional-Grains are considered unsustainable because they have ESI values <1 (Table 3). According to Brown and Ulgiati, ESI values between 1 and 10 indicate that the system under study has net contributions to society without strongly affecting its environmental balance [17]. Thus, values lower than 1 indicate that the system is not well developed and will deplete resources quickly in addition to causing adverse environmental impacts. Properties with integrated production and with agro-ecological principles show greater energy sustainability than systems in monocultures or with the use of agrochemicals [58]. Some reference values can be found in studies conducted in Brazil by Agostinho et al. [59]. These authors found ESI values of 5 for agroecological-based properties and lower than 1 for conventional properties. In livestock systems, Agostinho et al., found ESI values for intensified and semi-intensified milk systems between 0.14 and 0.20, and for systems such as family management, the value was 0.70 [57]. David et al., for different tilapia farming systems, found better values in organic tilapia production systems than in conventional systems, with values between 0.85 and 0.17, respectively [60].

- Ternary Diagram

Figure 4 shows the proportion of emergy flows grouped into renewable resources (R + Mr + Sr), nonrenewable natural resources (N) and nonrenewable materials and services (Mn + Sn). The results show that the group of ecologically based properties is closer to the vertex of renewable resources and uses approximately the same proportion in percentage of emergy. On the other hand, the conventional properties are closer to the vertex of nonrenewable materials and services, with the conventional properties Milk + Grains being the most dependent on economic flows (64%).

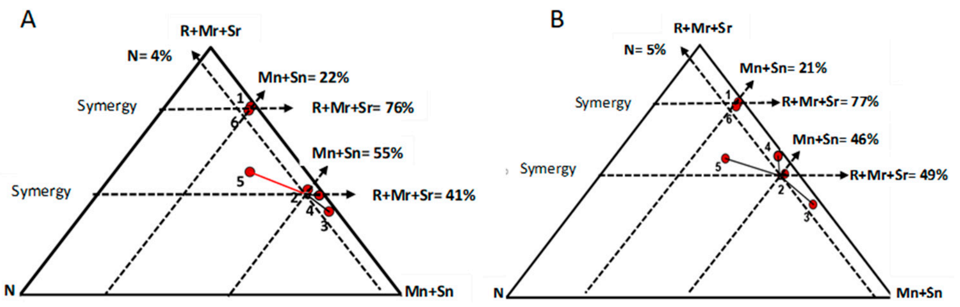

Figure 4. Ternary diagram showing the weighted performance (symergy) of the family farms evaluated in Serra Catarinense in the current scenario (**A**) and with the use of homeopathy (**B**). 1 = Agroecological, 2 = C. Grains Cattle, 3 = C. Milk Grain, 4 = C. Grains, 5 = C. Diversified, 6 = Organic.

The analysis of the symergy shows that the ecologically based properties have better emergy performance than the conventional ones. While agroecological and organic have a weighted symergy of renewable emergy of 76%, those of conventional management have a value of 41%. The opposite occurs in nonrenewable sources, with 22% for ecologically based sources and 55% for conventional ones. This suggests that in the conventional production model, there is less sustainability in the face of a scarcity of fossil sources. This makes it necessary for regional agricultural systems to use greener production technologies and integrate the agricultural system so that local renewable resources are more potentiated. According to Patrizi et al., in the face of a future with limited resources, the concept of "symbiosis" between agricultural and livestock production is necessary, in which a supply chain of renewable energy is implemented in a circular manner [61]. Cavalett et al., argue that integrated production systems have better efficiency in emergy conversion because they are able to exploit local resources and better use renewable internal emergy sources [55]. Additionally, they produce less ecosystem stress and pressure on the environment.

- Sustainability and Efficiency

Figure 5 shows the relationship between the ESI indicator and "overall efficiency" (the inverse of UEV). According to Bonilla et al., the system with the largest area, combining the two indicators (sustainability and efficiency), is the one with the best performance [62]. However, a large area value, by itself, is not balanced, unless it simultaneously combines satisfactory values of ESI and "overall efficiency" (OE). In this sense, the agroecological and conventional-diversified family farms are located in a better position within the graph, since they have an acceptable ratio between ESI and OE.

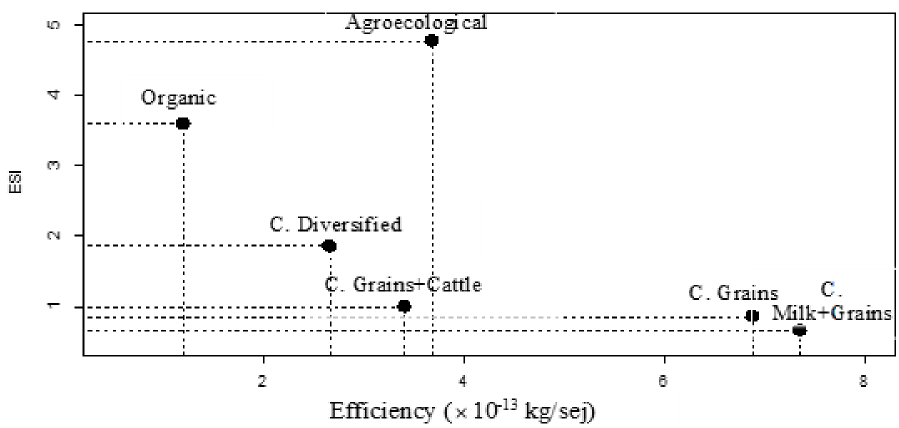

Figure 5. Relationship between ESI and overall efficiency of family farms evaluated in the Serra Catarinense region. Santa Catarina, Brazil.

On the other hand, the Conventional-Milk + Grains, Conventional-Grains + Cattle and Organic properties show a disproportionality in the relationship of the two indicators.

In times when the conventional Milk + Grains and Grains + Cattle have high values of OE, the product of large economic investments that result in an unsatisfactory ESI, Organic has low values of OE with high values of ESI, product of a greater dependence on renewable resources.

In general, farms with conventional management systems have better "overall efficiency" (kg/sej). However, there was low sustainability, with an ESI indicator between 0.66 and 1.86. The disproportionality between efficiency and sustainability is due to the high dependence on nonrenewable energy flows incorporated, especially in synthetic and pesticide fertilizers. According to Martin et al., a production system can be more efficient if we concentrate energies from fossil sources in its production process but less sustainable in time because they are dependent on flows acquired outside the system [52].

This type of analysis can help in making decisions about which type of system should be promoted and encouraged with public policies. From the point of view of productive efficiency and environmental sustainability, the agroecological property has better performance than the other properties. According to Asgharipour et al., small farms can benefit from the use of energy from renewable sources if they integrate ecological methodologies and agricultural and livestock activities [58].

3.1.2. Ecotoxicity Potential

The family farms evaluated that showed the greatest ecotoxicity potential (ETP) were the conventional Grains + Cattle, Grains, Diversified and Milk + Grains, with values of 9.277, 4.590, 4.351 and 4.323 kg 1,4-DCB-eq, respectively. On the other hand, ecologically managed properties have the highest ecotoxicity potential (ETP) values at the entry of heavy metals, with 1.791 kg of 1,4-DCB-eq for Agroecological and 1.579 kg 1,4-DCB-eq for Organic (Table 4).

Table 4. Ecotoxicity potential in kg of 1,4-dichlorobenzene-equivalent (1.4 DCB-eq) in the analyzed properties.

Category	Agroeco-Logical	C. Grains/Cattle	C. Milk/Grain	C. Grains	C. Diversified	Organic
	kg 1,4-DCB-eq/ha					
Glyphosate	0.032	0.232	0.135	0.152	0.022	0.000
Bifenthrin	0.000	0.738	0.377	0.459	0.000	0.000
Carbendazim	0.000	4.764	0.000	3.095	3.728	0.000
Mancozeb	0.000	2.844	3.319	0.000	0.000	0.000
Bentazon	0.000	0.083	0.000	0.089	0.259	0.000
Iprodione	0.000	0.000	0.000	0.000	0.003	0.000
* Heavy metals	1.736	0.616	0.495	0.796	0.340	1.579
Total	1.767	9.277	4.323	4.590	4.351	1.579

* Cd, Pb, Cu, Zn, Cr.

The high ecotoxicity potential observed in the family farms of Grains + Cattle and Grains may be directly related to the technological packages disseminated for the cultivation of soybean, corn and beans. In Brazil, the percentage of pesticide sales is distributed in 52% for soybeans, 10% for corn and 2% for beans, totaling 64% of the total marketed [63]. The results should be given special attention if we want more sustainable and pesticide-free agrosystems, since these crops represent 86% of the plant area with temporary crops in family farms of Serra Catarinense [10].

On the other hand, the heavy metals incorporated in poultry litter, which are commonly used in ecologically based systems, also have the risk of potentiating ecotoxicity in agrosystems. The results show that the agroecological and organic properties have a potential ecotoxicity of heavy metals of 1.736 and 1.579 kg of 1,4-DCB-eq/ha, being five and four times higher, respectively, than the Conventional diversified property, which presented the lowest value (0.340 kg 1,4-DCB-eq/ha) (Table 4).

In conventional properties, the use of pesticides with fungal action, such as carbendazim, has a higher value compared to other chemical substances. These values represent more than 51%, 67% and 85% of ETP in the Grain + Cattle, Grain and Diversified properties, respectively. Other chemical substances, such as glyphosate, have lower ETP, although they are emitted in larger quantities (Supplementary Material Table S3.3). These differences are related to the characterization factor. For example, carbendazim has a higher characterization factor in terms of ecotoxicity than glyphosate.

The use of pesticides in pest control has become one of the main problems of contamination of soil, water and food for human consumption [64]. However, the risk of ecotoxicity increases with the application of organic fertilizers such as poultry litter [43]. This type of fertilizer contains heavy metals that are released into the soil and accumulate in crops, representing a significant threat to the safety of the agrosystem and to human health [39,65]. The concentration of heavy metals in poultry litter is the result of supplementation with phosphorus, iron and metals (Mn, Zn, Cu and Se) in the feed of the chicken, which are necessary to stimulate their development, but of low complexity by the birds, which are expelled in the waste [39]. Zhu et al., also found greater ecotoxicity by heavy metals in organic systems of apple trees than in conventional cultivation systems [42]. However, the conventional system showed greater ecotoxicity by pesticides with a predominance of the active ingredient carbendazim.

3.1.3. Socioeconomic Analysis

The consideration of the monetary value of family labor in production costs significantly influences the results of economic performance in properties. This is evidenced mainly in organic family farms, which present all negative economic indicators. On the other hand, the conventional diversified property is the least affected and has the best return on assets (1.22) and profit margin (55%) performances (Table 5).

Table 5. Economic indicators of family farms evaluated in Serra Catarinense in the current scenario and using homeopathic preparations (CH).

	Return on Assets			Profit Margin (%)		
Properties	**Current**	**CH**	**Exchange Rate (%)**	**Current**	**CH**	**Exchange Rate (%)**
Agroecological	0.30	0.32	6.67	22	24.4	10.9
C. Grain/Cattle	0.27	0.35	29.63	20	26.1	30.5
C. Milk/Grains	0.43	0.59	37.21	30	37	23.3
C. Grains	0.16	0.23	43.75	13	18.6	43.1
C. Diversified	1.22	1.32	8.20	55	57	3.6
Organic	−0.25	−0.23	8.00	−33	−29	12.1

The importance of accounting for labor in the analysis of sustainability becomes clearer with the social approach. Based on income per hour of work and income sufficiency, the conventionally managed properties show better performance, with emphasis on the Conventional Diversified property with values of 36.61 BRL/h, compared to the organic property with a value of 7.4 BRL/h (Table 6). Considering the minimum acceptable value of 5.4 BRL/h, for the agricultural sector according to the complementary law no. 771 of 17 March 2021 for the State of Santa Catarina in the category of agriculture and livestock, the organic property would only satisfy the necessary minimum conditions if we consider that income should pay for family labor. The same occurs with the sufficiency of income, which is less than one.

Table 6. Social indicators of the family farms evaluated in Serra Catarinense in the current scenario and using homeopathic preparations (CH).

Properties	Income per Hour of Work			Income Sufficiency *		
	Current	CH	Change (%)	Current	CH	Change (%)
Agroecological	15.6	16.12	3.36	1.4	1.4	0.0
C. Grain/Cattle	20	22.17	10.76	1.8	2.0	9.5
C. Milk/Grains	27.6	31.36	13.81	2.4	2.8	16.1
C. Grains	15.9	17.44	9.85	1.4	1.6	10.8
C. Diver.	36.6	37.49	2.39	3.3	3.3	0.0
Organic	7.44	8.94	20.12	0.1	0.1	0.0

* Values ≥ 1 mean that the revenue received from sales can pay all the labor invested in the property and may even leave a positive balance when it is >1.

Although ecological management properties are more environmentally sustainable due to their use of renewable energy, they have lower social indicators. This approach is important when we consider the permanence of the farmer in the field. Production systems with insufficient income for the farmer tend to disappear. According to Dreby et al., family farming currently struggles with the paradox of increasing its social and economic values and a decrease in the viability of agriculture as a way of life [8]. Data from the IBGE show that between 2006 and 2017, family farms decreased by 9% and organic farms did not exceed 2% in Serra Catarinense [10]. According to Winck, low wages and the pursuit of a more stable life with fixed wages are the reasons for the reduction in the percentage of farms in the western region of Santa Catarina [66].

Estimating economic indicators is essential when making decisions about the performance of a food production system [67,68]. However, the contribution of family labor to production costs is often disregarded in such analyses. This approach is necessary if we want to identify social problems related to the permanence of the farmer in the field, since if the production systems do not reward financially, in relation to the number of hours worked, they will need to depend on another economic system.

3.1.4. Overall Performance of the Sustainability of Family Farms

The overall sustainability analysis included the emergy, ecotoxicity and socioeconomic indicators (Figure 2). Ecological-based properties (ecological and organic) are favored by environmental indicators and disadvantaged by socioeconomic indicators. However, the conventionally based properties (Grains + Cattle, Milk + Grains, Grains and Diversified) are favored by socioeconomic indicators (Figure 6).

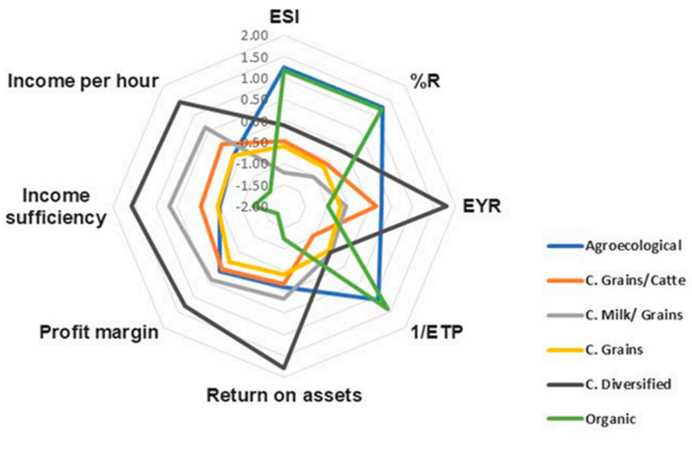

Figure 6. Comparative graph between family farms evaluated in Serra Catarinense, containing all sustainability indicators.

However, although conventional systems have advantages in terms of socioeconomic indicators, they exert strong pressure on the environment and are dependent on nonrenewable flows. However, the organic property, which is favored due to having more renewable flows, has low socioeconomic indicators, indicating the susceptibility of this property to being dependent on other alternative sources of income.

In general, considering the largest area of the polygon in the graph, the Conventional Diversified property has the highest level of sustainability. However, in the ESI, %R and ETP indicators it is surpassed only by the ecological properties. Properties with more diversified production systems tend to remain economically more competitive than those with simplified systems [69]. However, conventional models tend to put pressure on the local environment [70].

The use of multiple perspectives to evaluate the sustainability of family farms generates a broader view in both ecocentric and anthropocentric terms [14]. In addition, it provides information for solid and comprehensive regional agricultural planning in pursuit of the permanence of family farming [12].

3.2. Alternative Scenario with the Use of Homeopathic Preparations

This section seeks to evaluate a scenario where some of the inputs used by family farms were replaced by homeopathic preparations. However, since there is no UEV available in the scientific literature for homeopathic preparations and because it is an innovative subject, emergy synthesis was performed for the production of a homeopathic preparation, the UEV of which was then used in the substitution scenarios that were considered.

3.2.1. UEV of Homeopathic Preparation

The unit emergy value (UEV) of a homeopathic preparation was calculated from a mineral raw material. The calculation report can be found in Supplementary Material Table S4.1. The procedure follows the Hahnemannian centesimal method (CH) for insoluble drugs of the Brazilian Homeopathic Pharmacotechnics 3rd edition. The first step in the procedure is the grinding of a part of the mineral raw material into 99 parts of lactose (1CH). To prepare the second grind, one part of the primer ground with 99 parts of lactose is used, successively until obtaining the 4CH where the substance becomes soluble in ethanol. Consequently, the substance is diluted by taking one part of the 4CH with 99 parts of ethanol and succussing 100 times to obtain the 5CH. The process is repeated until obtaining the desired dynamization, in this case the 12CH, which is the homeopathic matrix that can later be used by farmers to make their respective derivations according to each case (Figure 7).

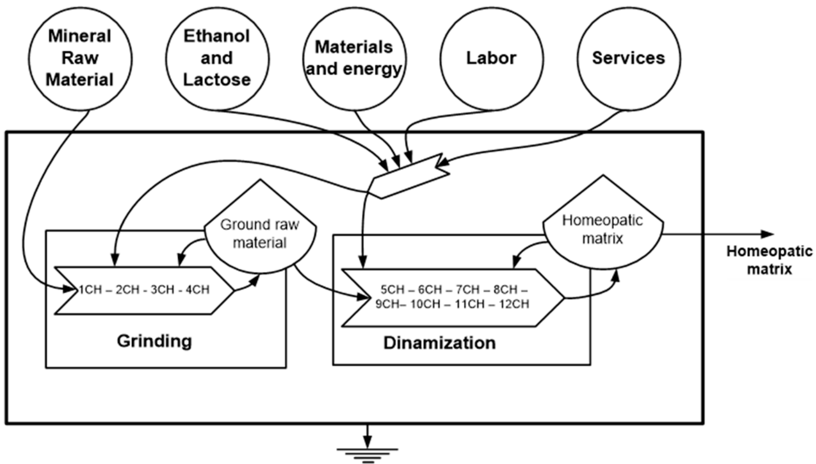

Figure 7. Energy diagram of the process of preparation of the homeopathic preparation from a mineral raw material up to 12CH (centesimal hahnemannian).

The emergy flows in the process of preparation of a homeopathic preparation, being used as reference material for Silicea (Silicea Terra), are shown in Table 7. The UEV of the homeopathic preparation was calculated as 2.66 × 10^{12} sej/mL, including the emergy of labor and services. With L&S being 98.11% of the total use of emergy for the preparation process until 12CH. This would be the amount of emergy per mL. of homeopathic preparation considered as input in the evaluations of family properties presented in the next item considering the replacement of some resources/inputs by homeopathic preparations.

Table 7. Assessment table in emergy for 100 mL of homeopathic preparation.

#	Item	Units	Input	seJ/Unit	References	Total Emergy	Y (%)
	Mineral raw material						
1	Silicon	g/proc **	3.00×10^{-1}	7.60×10^{8}	[71]	2.28×10^{9}	0.00
	Materials (M)						**1.89**
2	Ceramic (Laboratory)	g/proc.	1.30×10^{-1}	2.55×10^{7}	[72]	3.31×10^{6}	0.00
3	Lactose	USD/proc.	2.41×10^{-1}	4.26×10^{12}	[73]	1.03×10^{12}	0.39
4	Ethanol	J/proc.	1.80×10^{7}	3.68×10^{4}	[74]	6.63×10^{11}	0.25
5	Glassware (Laboratory)	g/proc.	2.33×10^{-1}	1.64×10^{9}	[71]	3.82×10^{8}	0.00
6	Equipment (Dynamiser)	USD/proc.	5.28×10^{-1}	4.26×10^{12}	[73]	2.25×10^{12}	0.84
7	Electricity	J/proc.	9.36×10^{6}	1.16×10^{5}	[74]	1.09×10^{12}	0.41
	Labor and Services (L & S)						**98.11**
8	Labor (Specialized)	J/proc.	1.00×10^{7}	8.74×10^{6}	[62]	8.78×10^{13}	32.87
9	Services	USD/proc.	4.07×10	4.26×10^{12}	[73]	1.73×10^{14}	64.29
	Total Emergy (Y)	**seJ**	$\mathbf{2.66 \times 10^{14}}$			$\mathbf{2.66 \times 10^{14}}$	
	Total Outputs (Ep)	**mL**	$\mathbf{1.00 \times 10^{2}}$				
	UEV (Sej/mL)	**mL**	$\mathbf{2.66 \times 10^{12}}$				

** process = 8 h. UEV = updated baseline of 12.1 × 10^{24} sej [35].

3.2.2. Potential of Homeopathic Preparations in the Sustainability of Family Farms

In Figure 3, the process of integrating homeopathy into family properties is shown in the emergy diagram and highlighted in red. This process is considered fundamental for the scenario proposed here to become plausible.

In this scenario, the information "input" refers to the basic principles and philosophies of homeopathy science that first need to be internalized by the rural family and transformed into knowledge. However, the anamnesis of the agrosystem, following analogies between the signs and symptoms of the Homeopathic Materia Medica in humans, interacts with knowledge, creating a flow of wisdom that determines the most appropriate homeopathic preparation that will later be applied in the agrosystem. The information-knowledge-wisdom flows remain constant, so that based on the farmer's praxis they can be adapted according to the circumstances.

While in other input measures, the input flow arrives as a technological package directly in the production systems, in this scenario, homeopathy makes the farmer the main manager of decisions and changes. According to Boff, an important step in the implementation of homeopathy in agrosystems is to provide the farmer with the necessary knowledge in choosing the most appropriate homeopathic preparations for the given case [75]. This favors knowledge for the farmer to manage and adapt their own technologies.

In this sense, this approach proposes knowledge-intensified agrosystems, which would replace the current production models characterized by being intensified in the use of chemical inputs. Orlando et al., suggest that the knowledge generated by a knowledge dialog between farmer-extension workers is a fundamental part of creating more sustainable technologies and without presenting universal standards [76].

On the other hand, replacing some inputs with homeopathic preparations to model the evaluated scenarios has a new emergy performance, calculation data available in Supplementary Material D. For the new scenario, the use of homeopathic preparations predicts that the renewable emergy will increase by 19% and nonrenewable will decrease by 16% in conventional management properties. This ratio is 1% in both cases in the ecologically based properties (Table 3). The small variation in emergy percentages is because homeopathic preparations are replacing pesticides, which have little contribution to the total input of emergy in the system.

Thus, it was possible to observe changes in the values of the indicators, which shows that the use of homeopathic preparations causes changes in the relationships of renewable and nonrenewable emergy flows. The C-Grain properties showed the highest rate of variation, decreasing its UEV from 1.45×10^{12} to 1.11×10^{12}, its ELR from 1.49 to 1.12 and increasing its % R from 40 to 47% and its ESI from 0.86 to 1.18 (Table 3). These results show that in an optimized scenario with the use of homeopathy, the property would be 23% more efficient in the use of emergy, and its production system would exert 23% less pressure on the environment with 17.5% more renewable energy and an increase in its environmental sustainability of 37%. The EIR indicator had the greatest variation in the C. Grains + Cattle property, from 2.08 to 1.76, which means that it would depend 15% less on the emergy from the economic system (Table 3).

Regarding the ecotoxicity potential, there was a reduction between 19.6% (lowest value) and 91.4% (highest value). The conventional management properties were the most favored, achieving lower final ecotoxicity values, and the ecologically based properties had the highest values. This is due to fertilization with poultry litter with a high content of heavy metals that are commonly used for these properties (Figure 8).

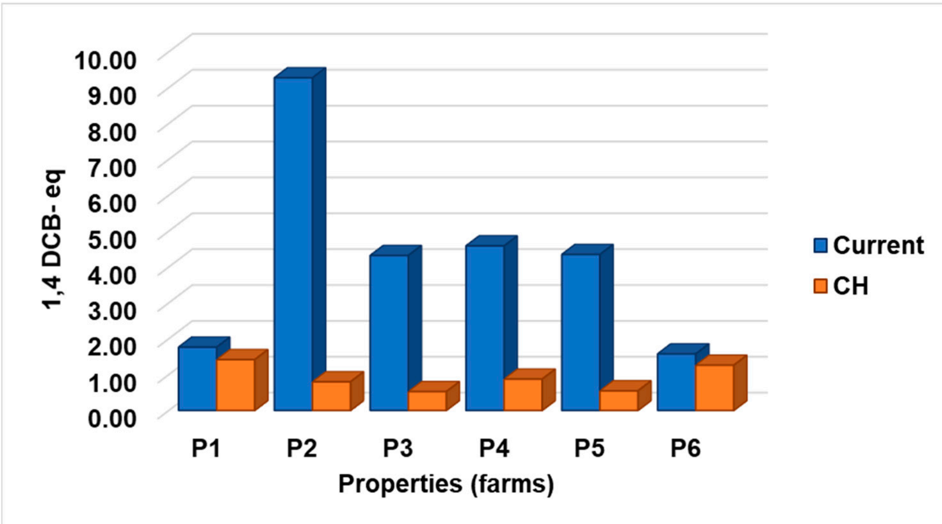

Figure 8. Comparison of current and optimized potential ecotoxicity with the use of homeopathy in family farms evaluated in Serra Catarinense. P1 = Agroecological, P2 = Cattle grains, P3 = Milk grains, P4 = Grains, P5 = Diversified, P6 = Organic.

The integration of homeopathy in the properties would also result in socioeconomic benefits. By replacing the pesticides and a portion of the fertilizers, the production costs would decrease, and consequently, the values of the indicators would change. The return on assets would increase between 6.7% in the agroecological property and 43.75% in C. Grains. However, profit margin would increase by 3.6% in C-Diversified and 43.1% in C. Grains (Table 6). On the other hand, the use of homeopathy would cause an increase in hourly income of 20% (Organic) and income sufficiency of 16% (C. Milk/Grains) (Table 7).

An advantage of homeopathy over other technologies is that it does not require a large amount of substance to cause an effect. Its influence on biological systems occurs through the use of small doses, infinitesimal, which work/act in the restoration of the vitality of the living organism [47]. This suggests a decrease in production costs and an improvement in the socioeconomic indicators of family farms.

In a general approach, the main exchange rates of the indicators are in family farms that cultivate grains and are characterized by being dependent on agrochemicals (Figure 9). Thus, homeopathy would make important environmental contributions, especially in those conventional systems with more intervention needs. According to Andrade and Casali, the science of homeopathy provides important technological solutions that are consistent with the perspective of building sustainable agrosystems [21]. In this sense, Moreno also argues that homeopathy as a nonresidual and environmentally friendly therapy represents a viable alternative to reduce the use of agrochemicals in agrosystems [19]. In addition, homeopathy has socioeconomic potential, decreasing production costs and increasing economic and social indicators. According to Abasolo-Pacheco et al., homeopathy is a viable and low-cost alternative that contributes to the financial return on assets of crops, and Moreno considers that homeopathy promotes a relative independence of farmers over their production system, in addition to promoting a free exchange of knowledge with society [19,77].

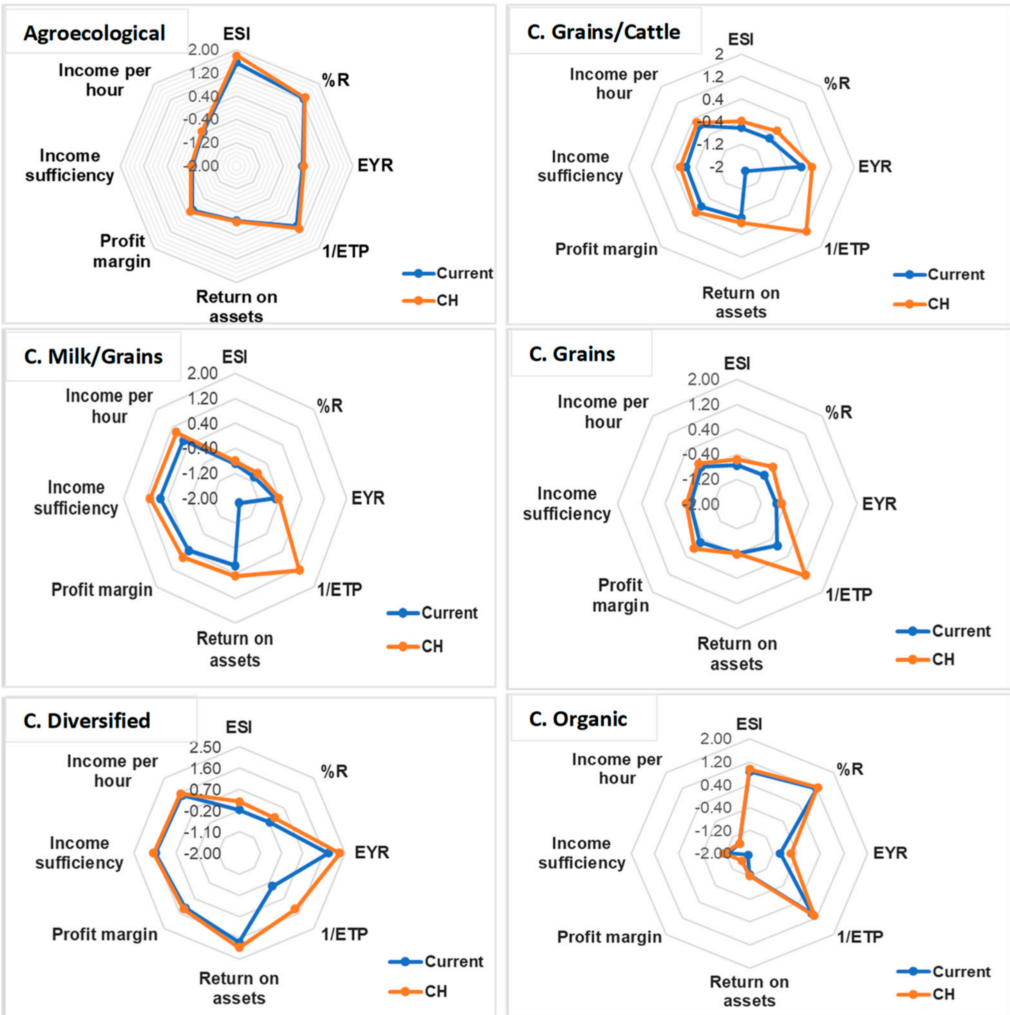

Figure 9. Comparison between the current and optimized scenarios as homeopathy (CH) of family farms evaluated in Serra Catarinense.

4. Conclusions

The evaluation of the sustainability of family farms in Serra Catarinense showed that ecocentric metrics indicate better performance for ecological management properties with integrated production, while anthropocentric metrics indicate better performance for conventional management properties.

The results show that in the Serrana Mesoregion, SC, family property with Conventional Diversified typology has the highest level of general sustainability. In general, they have the potential to make more emergy available to society through the emergence of the economy as well as better values in return on assets, profit margin, income per hour of work and income sufficiency. In addition, it presents the best values, in the conventional typologies, for the sustainability and renewability indicator in emergy. However, better prospects could exist in this system if it incorporated more renewable emergy.

On the other hand, the Agroecological and Organic properties showed the best environmental performances in the emergy indicators. Its production system depends, respectively, on 76% and 75% of renewable flows with low impact on the environment (ELR = 0.32 and 0.34), whose sustainability indicator in emergy is 4.78 and 4, for agroecological and organic properties, respectively. However, some considerations should be made in ecological-based management, especially in the input of inputs such as poultry litter. The amount of heavy metals in the ecological management properties is greater than that in the conventional properties, which constitutes a potential risk of ecotoxicity for the agrosystem.

The importance of quantifying family work is reflected in socioeconomic indicators. The ecological-based properties, which are more dependent on the work of the farmer, have the lowest return on assets and profit margin values, in addition to having the lowest income values per hour of work and income sufficiency. This shows that although they are more environmentally sustainable, they are more socioeconomically vulnerable than conventional properties and more susceptible to dependence on other economic systems.

The proposal of an alternative scenario, such as the use of homeopathic preparations, shows high potential to improve the environmental and socioeconomic performance of family farms in Serra Catarinense. The most relevant are the contributions to conventional management systems, which are characterized by the intensive use of agrochemicals. Therefore, the C. Grains property, where there were greater variations in the indicators evaluated, predicts that the implementation of homeopathy would increase environmental sustainability by 37% and reduce the potential for ecotoxicity by 91.4% in addition to increasing its benefits in socioeconomic indicators. In this sense, if the evaluated family properties adopt homeopathy in place of traditional/conventional intensification techniques, it could be more efficient in the use of emergy from external sources and could increase the capacity to exploit local resources in addition to focusing on a cleaner and healthier production with lower costs. Thus, the quantification of the contributions of homeopathy to the sustainability of family properties via a systemic approach from multiple perspectives provides important support in the planning of public policies and is aimed at developing agrosystems with less dependence on fossil fuels.

This study also provides innovative information regarding the Unit Emergy Value (UEV) of homeopathic preparations. This is important information for later studies that wish to analyze the contributions of homeopathy to the sustainability of agrosystems with a systemic approach of Synthesis in Emergy.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14106334/s1, Table S1: Calculation procedures, partial renewability and UEVs used in emergy synthesis; Table S2: Emergy tables of family farms located in the Serra Catarinense, Santa Catarina, Brazil; Table S3: Ecotoxicity data; Table S4: Data for emergy synthesis considering the replacement of conventional materials by homeopathy.

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Appendix A

Table A1. Production, energy and income from sales of agricultural products in family farms located in the Serra Catarinense region, Santa Catarina, Brazil.

Property	Production (kg/Year)	* Energy (J/ha/Year)	Income per Sale (BRL/Year)
Agroecology	69,195	2.80×10^{10}	131,044
Conventional: Grain/Cattle	73,000	3.15×10^{10}	106,760
Conventional: Grain Milk	151,600	5.88×10^{10}	132,490
Conventional: Grains	55,047	9.15×10^{10}	44,224
Conventional: Diversified	32,518	1.55×10^{10}	118,124
Organic	8525	2.75×10^{9}	37,837.50

* Energy (J/ha/year) = production (kg/year) × caloric value (kcal/kg) × 4186 (J/kcal)/ha of the property. Source: Brazilian food composition table/NEPA-UNICAMP. 2004. 42p.

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