Scientific Paper

Evaluation of food and energy production in animal husbandry farms of Matanzas province, Cuba

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Abstract

A study was conducted in five animal husbandry farms located in the region of the Yumurí Valley –Matanzas province, Cuba–, in order to evaluate the sustainability and energy efficiency of their productions. As main tool the agroecological diagnosis of the systems was used; the species and individuals and their productivity, as well as the agroecological practices developed by the farmers, were identified, and the production biodiversity index and energy efficiency of the agroecosystem were determined as sustainability indicators. The utilization of the area, agrobiodiversity and implementation of agroecological practices influenced positively the productivity and sustainability of the farms, and indicated that they were in transition towards the agroecological production model. The farm Fortuna reached the best productive results, while in La Primavera and Uso Colectivo the energy efficiency and food production capacity were low; while in Las Delicias and Riera, all these indicators had a favorable performance.

Keywords: biodiversity, diagnosis, sustainability

Introduction

Conventional agriculture, emerged with the Green Revolution, concentrated large land extensions in the hands of few owners, especially transnational enterprises, which implied the transformation of agriculture into a profitable industry through the commerce of chemical inputs, machinery, genetically enhanced varieties and technological packages. Its initial effects were positive, but it soon showed fragility, vulnerability and risks for the environment, human health and agroecosystems.

As viable and sustainable alternative, traditional agriculture is innovative and has the capacity to adapt to the varied existing environmental and social conditions, by propitiating to a large extent the balance of the agroecosystem. Agroecology, which has its roots in agricultural sciences, the environment protection movement, ecology, the analysis of traditional agroecosystems and rural development, has integrated these ideas and methods of doing agriculture, giving it a scientific basis with a common objective: the sustainability of agroecosystems (Funes-Aguilar, 2015). In this context the agroecological movement emerges in Latin America, and Cuba becomes one of its greatest examples.

The agroecological movement throughout the country, and especially in the Matanzas municipality since the late 1980's, has been developed mainly by non-state farmers at the scale of farms or small family production units, where biodiversity, integration and utilization of their components, among other measures, guarantee the sustainability of productions (Benavides, 2011).

At present, when this trend is enhanced and the transition towards a sustainable production model becomes evident, the development of the agroecological diagnosis has facilitated the characterization of many farming systems. The use of this tool, in recent years, has allowed to obtain valuable data about the main components of agroecosystems and their relations, which permits a better utilization of them in the search for higher productive results (Funes-Monzote *et al*., 2009a; Hernández and López, 2011; Márquez *et al*., 2011; Álvarez *et al*., 2012).

The challenge of food production with the use of sustainable practices has motivated the need to develop integral and diversified productive systems, which are characterized by the more efficient use of inputs and energy, based on the principles of agroecological science (Funes-Monzote *et al*., 2012; Sarandón and Flores, 2014). In that sense, the objective of this study was to evaluate the sustainability and energy efficiency of productions in five animal husbandry farms in the region of the Yumurí Valley.

Materials and Methods

The zone of study is located in the Yumurí Valley, belonging to the Matanzas municipality, Matanzas province, Cuba; where Brown soils prevail, with agroproductive category between II and III, characterized by a good natural fertility. In this zone a mean annual temperature of 23,8 ºC, rainfall values between 900 and 1 600 mm, and mean annual relative humidity of 79 %, are recorded.

The selected farms are neighboring; and have food crops as main production, although in most of them animal rearing takes place in lower scale.

The studied indicators were:

- Species richness: the plant species and their individuals were identified and counted, to determine the biodiversity indicators; for such purpose the following documents were consulted: *Diccionario botánico* (Roig, 1969), *Plantas medicinales, aromáticas o venenosas de Cuba* (Roig, 2012), and *Especies de frutales cultivadas en Cuba en la agricultura urbana y suburbana* (Rodríguez and Sánchez, 2010); in addition, the experiences accumulated by the farmers and researchers linked to these studies were taken into consideration.
- Determination of the agroecological practices present in the farms: the evaluation system to declare farms as agroecological, instrumented by the National Association of Small Farmers (ANAP, for its initials in Spanish), was consulted in order to evaluate the sustainability of the studied systems.
- Diversity of the production: it was determined through different ecological indexes that were calculated through the software programs DIVERS and Programs for Ecological Methodology version 6.1.1 (Krep, 2003), in order to know the agrobiodiversity of the systems and their contribution to sustainability.
- Energy efficiency of the agroecosystem: the corresponding indicators were determined, using the program Energía 3.01 (Funes-Monzote *et al*., 2009b); the plant and animal production obtained and the external inputs used during the evaluated period were taken into consideration.

Results and Discussion

Table 1 shows the characterization of the studied farms regarding the available area and its utilization in crop and animal production.

From the studied systems, 80 % combined agricultural with animal production, which is beneficial because higher utilization of the productive area and better integration is established among the different species present. This allows a better use of the available resources and nutrient recycling, which in turn improves the economic and energy efficiency; this supports the criterion that the development of integrated agriculture-animal husbandry systems allows to balance energetically the benefits from animal and plant production, by achieving higher efficiency and productivity, which respond to the nutritional, existential and functional needs of men (Funes-Monzote, 2015).

The utilization of the total area constitutes an indicator to measure sustainability in farms, because it indicates a better exploitation of them and higher production is guaranteed. Among the studied cases, only the farms Fortuna and Riera used 100 %

Table 1. Distribution and use of the total area of the farms.

Land use	Farm				
	La Primavera	Las Delicias	Fortuna	Riera	Uso Colectivo
Total area (ha)	26,84	13,42	12,56	10,37	13,42
Cultivated area (ha)	4,5	8,8	9,5	7,7	2,07
Food crops (ha)	2,5	6,5	8,4	6,2	1,64
Fruits (ha)	1,0	2,3	1,1	1,5	0,43
Forestry trees (ha)	1,0	-	-	-	-
Uncultivated area (ha)	22,34	4,61	3,06	2,67	11,35
Grazing (ha)	9,0	-	3,06	2,67	6,0
Unproductive (ha)	13,34	4,61	-	-	5,35
Proportion of the crop: animal husbandry area (%)	70:30	100:0	75:25	75:25	90:10

of the available area. Las Delicias and Uso Colectivo had 34 and 40 % of the area unproductive, respectively; while in La Primavera 50 % of the land was unutilized, mainly affected by the presence of the invasive weeds *Acacia farnesiana* L. Willd. and *Dichrostachys cinerea* Wight & Arn. This indicator influences remarkbly the total productivity of the farms, as can be observed in figure 1.

The productive result is supported by the soil use in each studied system. In the farms Fortuna and Riera, where the land was totally exploited, productive values of 14,5 and 7,48 t ha^{-1}, respectively, were obtained. Las Delicias showed favorable results (5,11 t ha^{-1}), although part of the area was unproductive; this could be associated to the intensive use of the arable land, good productive diversity and higher yields, as will be explained below. La Primavera and Uso Colectivo showed the worst productive indicators, with 0,85 and 0,96 t ha^{-1}, respectively.

On the other hand, the higher proportion of cultivable area in the farms Fortuna and Riera was not associated to the higher values in the agrobiodiversity indexes, which differs from the results obtained by Funes-Monzote *et al*. (2009a). This situation is due to the fact that in the farms with lower cultivable area (La Primavera and Las Delicias), practices of crop association and intercropping which guarantee a higher number of species in space-time were used. This result coincides with the report by Leyva and Jürgen (2003), about the fact that the utilization of the available resources in the farm leads to the protection of the environment and soil conservation. It is proven in general that the farms, after choosing the agroecological production model, have higher variety of available genetic resources.

The diversity, in general, can be considered acceptable. La Primavera showed the highest value of specific richness; nevertheless, Las Delicias was the

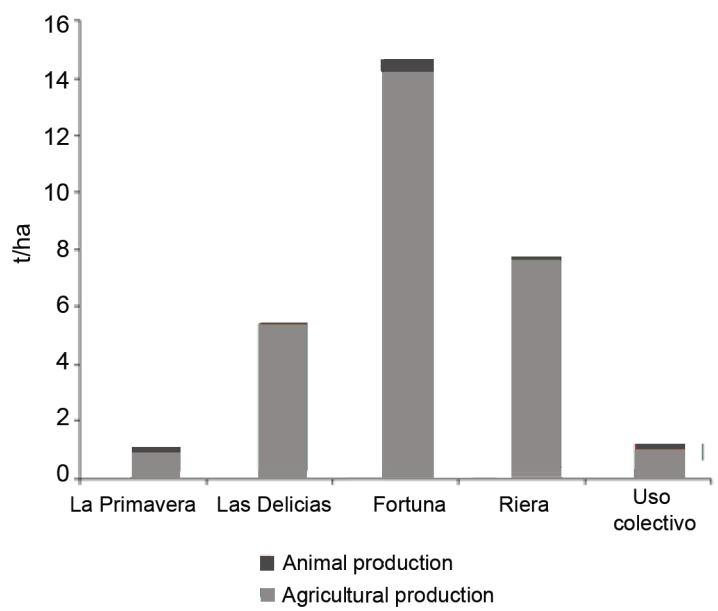


Figure 1. Productive evaluation of the farms (t ha^{-1}).

Table 2. Production biodiversity indicators.

Index	La Primavera	Las Delicias	Fortuna	Riera	Uso Colectivo
Specific richness (S)	24	20	13	19	10
Equitability (E)	0,72	0,82	0,77	0,64	0,84
Shannon-Wiener diversity (H´)	2,30	2,46	1,98	1,89	1,93
Maximum diversity (Hmax)	3,19	2,99	2,56	2,94	2,30
Simpson's diversity (Dsp)	0,18	0,10	0,18	0,21	0,18

most outstanding farm, because although it showed lower number of species, they and their individuals had better distribution in the agroecosystem; and, in turn, it showed a similar performance to that of the farm Uso Colectivo in the indicator equitability (0,82 and 0,84, respectively), but the diversity value (H') was higher and closer to the maximum diversity that can be reached by the system. In addition, it is valid to state that as the Shannon-Wiener index is closer to Hmax, the higher diversity will be (Sonia Jardines, personal communication).

Orihuela *et al*. (2007) state that the most accurate values for index H' are between 1,5 and 3,5 and they almost never exceed 4,5. This performance supports the productive results obtained, even when the farm Las Delicias showed 34 % of unproductive lands. In Uso Colectivo the lowest values of species richness and biodiversity were obtained; which was related to the fact that this farm recently started the transition towards the diversified and sustainable production model, because it had been previously dedicated to sugarcane monocrop and natural pastures for cattle production, during more than ten years.

The agrobiodiversity in all the farms turned out to be balanced, for which no species with protagonist role was observed in the obtained productions. This is corroborated, first, because a balance was appreciated in the list of species and their productions, and, second, due to the values reached by the equitability index. As this index approaches one, the distribution of species abundance will be better. If this aspect is taken into consideration, it is possible to infer that the productions were distributed more or less equitably in the species.

The proportional abundance, according to Simpson's index, showed a relatively low value, which indicates high diversity, because as such index decreases, diversity is richer (Sonia Jardines, personal communication). Hence a well-structured diversity ensures a more efficient use of the soil and its better conservation, adequate regulation of weeds and pests in general, optimum utilization of solar energy and higher organic matter production. These criteria are in agreement with those expressed by Altieri (1999), who sustains that higher biodiversity decisively contributes to reduce risk in these agroecosystems and increase productivity. In this sense, higher efficiency in the use of the available genetic resources positively influences productivity, which allows the sustainable intensification of agroecosystems.

The agroecological practices developed in the farms, besides favoring the biodiversity of productions, contribute to achieve the sustainable management of resources, and stimulate the use of the available richness in the farm and other organic inputs which help minimize the environmental impact and reduce the energy costs of production.

Taking into consideration the practices indicated by the ANAP (2003), it could be observed that a large number of them are executed in the farms under study in this research. As it is appreciated in table 3, not all the farms did equal number of agroecological practices, especially those related to compost elaboration and pest integrated management, which in all the farms was done with chemical products. The farm Uso Colectivo did the lowest number of practices, which can be associated to the achievement of limited productive results; however, an increase in the ones that were done in the farms guaranteed an increase of productivity, especially in the farm Fortuna which had the best results.

The energy analysis allowed to notice that those farms where the productive area was better utilized,

Table 3. Agroecological practices developed in the farms

Agroecological practices	La Primavera	Las Delicias	Fortuna	Riera	Uso Colectivo
Crop rotation	x		x	x	x
Association of crops	x	x	x	x	
Intercropping	x	x	x	x	
Organic fertilization	x		x		
Living barriers	x	x	x	x	x
Diversification of species, varieties and plant cultivars	x	x	x	x	
Rearing of small animals	x		x	x	x
Animal draught	x	x	x	x	
Recycling of harvest wastes			x		x

the use of agroecological practices was increased and also had higher productive diversity, achieved a more efficient use of energy (table 4). This has remarkable incidence on a higher social welfare for the farmers and their families, by guaranteeing the consumption of healthy foodstuffs throughout the year and higher economic incomes, aspects that allow the improvement of their quality of life.

Studies conducted in Cuba during the last years (Vera, 2011; Monzote *et al*., 2012; Rodríguez, 2013) indicate that with higher agrodiversity –regarding crops, animal husbandry and tree species, as part of integrated and multifunctional agricultural systems– in agroecological systems with high animal husbandry-agriculture integration and recycling levels, higher productivity and efficiency is reached.

The energy balance was positive for all the studied farms, although in La Primavera and Uso Colectivo the energy efficiency was low and the capacity to produce food (persons hectare^{-1}) was very low. These results are related to the low analyzed values, regarding land utilization and lack of agroecological practices in the management of productions, for the farm Uso Colectivo.

The farm Fortuna had high productivity, which has incidence on the capacity to produce food for a higher quantity of people. The obtained productions allow to feed approximately 20 persons ha^{-1} year^{-1} due to the energy contributions and 15 for the protein contributions, results that can be higher, as proven by Casimiro (2016) when obtaining values of 29,23 and 29,62, respectively, in the farm Del Medio in Taguasco, Sancti Spiritus province.

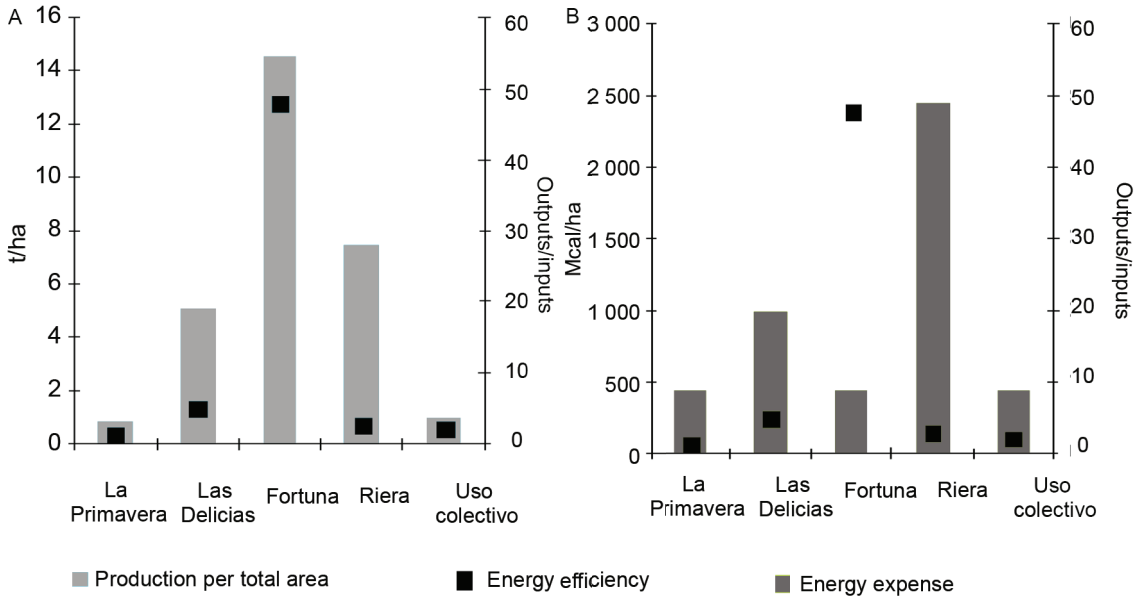
It should be considered that the indicator diversity of production did not influence considerably the results shown in table 4, because it turned out to be very similar in all the agroecosystems; but the utilization of the area, productivity and external inputs included in the productions did influence remarkably (figs. 2A and B). The sustainable management of the proper resources in the farm, with the possible minimization of the use of external inputs –especially those that show high energy cost–, contributes to a positive energy balance and favors the increase of the energy efficiency of the systems.

The study of the indicators in the energy balance indicates the productive potential of the systems, because with higher utilization of the farm's own resources and with the implementation of sustainable practices, higher efficiency values are reached and less productive and energy costs are incurred; this is shown in the relation that was established between the values of the indicator energy cost of the protein and energy efficiency (fig. 3).

Most of the evaluated farms used considerable amounts of external inputs (fertilizers, pesticides, fuels and others) and wasted animal husbandry and harvest residues, which can be composted and applied as organic fertilizer, which is more economical and healthy. In that sense, Abreu (2011) and Vizcón *et al*. (2016) refer that a change in the productive systems focused on the sustainable management of the farm's own resources, with adequate recycling and utilization of the produced nutrients, can contribute to increase the energy efficiency, by generating lower environmental damage and better conservation of the associated natural ecosystem.

Table 4. Energy and productive efficiency of the farms

Indicator	La Primavera	Las Delicias	Fortuna	Riera	Uso Colectivo
Area of the farm (ha)	26,84	13,42	12,56	10,37	13,42
Total production (t ha^{-1})	0,85	5,11	14,50	7,48	0,96
Energy production (Mcal ha^{-1})	543,76	4 932,17	20 819	6 764,64	936,98
Protein production (kg ha^{-1})	15,86	82,25	224,27	111,57	19,34
Energy expense (Mcal ha^{-1})	435,21	989,93	435,64	2 447,44	441,46
Energy cost of the protein (Mcal kg^{-1})	27,44	12,04	1,94	21,94	22,83
People fed by the system from the energy point of view (persons ha^{-1})	0,53	4,83	20,37	6,62	0,92
People fed by the system from the protein point of view (persons ha^{-1})	1,25	5,38	14,76	7,82	1,27
Energy efficiency (outputs/inputs)	1,25	4,98	47,79	2,76	2,12



Figures 2A and B. Relation among energy efficiency, production per total area and energy expense of the farms.

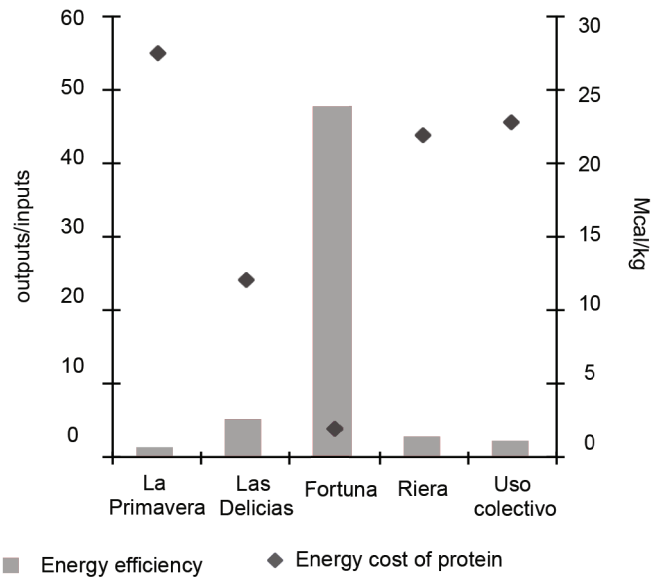


Figure 3. Energy cost of the protein production and energy efficiency in the farms

Conclusions

With the agroecological diagnosis the main components in the agroecosystems and how they contributed, in an integrated way, to sustainable food and energy production, could be identified. The utilization of the area, agrobiodiversity and implementation of agroecological practices influenced positively the farm productivity and sustainability, which in turn allowed to perceive that they were in a transition process towards an agroecological production model. In the farm Fortuna the highest productive results were reached, while in La Primavera and Uso Colectivo the energy efficiency and food production capacity were low; meanwhile in Las Delicias and Riera all the above-mentioned indicators had a favorable performance.

It could also be observed that the adequate management of the indicators utilization of the area, productivity and external inputs used allowed to increase the energy efficiency and reduce the energy cost of production in the farm La Fortuna. In this case, the diversity of production did not considerably influence the energy balance.

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