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Sustainability Analysis on a Small Farm with Crop and Livestock Integration

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Increasing Sustainability on a Small Farm by Integrating Cattle Raising and Agronomy

ABSTRACT

A small farm affiliated to a credit-and-service cooperative collective venture in Camagüey, Cuba, was studied to determine its sustainability under a system integrating cattle raising and agronomy. Data from January 2009 to April 2010 were collected and the Logical Operation Schedule for Sustainability Evaluation (ECOFAS) by Funes-Monzote *et al*. (2002) was applied. Findings indicate an increase in incomes from sales compared to expenses. This evidence, therefore, shows that sustainability can be attained at short and median terms, but not at a long term, by implementing this system. Energy, nitrogen, and phosphorus balances confirm these results.

Key Words: *farm sustainability, cattle raising and agronomy integration*

INTRODUCTION

Sustainable agricultural practices may be implemented to feed population and protect the seas, forests, prairies, and other ecosystems. Biodiversity protection is decisive to achieve world food safety (FAO, 2008).

In initial works Monzote and Funes-Monzote (1997), Funes-Monzote and Monzote (1999), Monzote, Funes-Monzote, Martínez, Pereda, Serrano, Suarez *et. al.* (2001); then Blanco, Monzote, Ruiz and García-Soldevilla (2006) and Guevara *et al.* (2007), great progress was made. Today, however, the number of Cuban farms with sustainability assessment is very low.

The aim of the work was to analyze sustainability indicators in a productive entity, with a crop-livestock production integrated system.

MATERIALS AND METHODS

The study was conducted on La Victoria private farm, from the Credit and Services Cooperative (CCS) *Renato Guitart*, owned by Victor Mauri Rodríguez, in the municipality of Camagüey, epizootiological quadrant 7413615. To the north it is bordered by Carretera Central (Main Road); to the south, by the Prefabricated Parts Plant; to the east, by Tayabito MINAZ; and to the west, by Commandant *Rene Vallejo* Psychiatric Hospital.

The farm covers an area of 26.84 hectares, with minimum temperatures of 15.0-19.9°C, and maximum of 30.0-34.9°C; mean humidity is 84.6 %, and rainfall means of 1 200-1 400 mm . The farm is located on Inceptisol soils (US Agriculture Department, 1999). The total area is used for different purposes, fruit and wood trees, facilities and cattle grazing.

The cattle herd is made up of 36 bovines: 11 cows, 10 young cows, 3 female yearlings, 1 male yearling, three male calves, 7 female calves, and a bull. Other animal species are bred for human consumption (77 hens, 94 Guinea fowls, 23 turkeys, 2 pheasants and one pig.

Data from the farm´s economics, production and reproduction, reforestation, material resources and cooperative management structure were used. The information was collected from the farm´s owner and his family. Subsequent visits were paid to the farm to carry out evaluations and assessment.

Energy, nitrogen and phosphorous balances were performed. The energy balance was determined by inputs and the system outputs were determined. The criteria used was the input-output balance. Energy equivalence coefficients were used for crop and animal products; as well as products for human consumption, according to Funes-Monzote (2000), for multiplication by the kilograms produced that exit the system; the 6.25 nitrogen equivalence was applied for nitrogen-protein conversion.

The sustainability indicators determined were,

- Energy balance

- Nitrogen and phosphorous
- Economic efficiency
- Use of stalks
- Use of draft animal power
- Use of manure
- Soil worm culture

Plant depopulation, products and reforestation

To assess farm sustainability the results from a participative agro ecological diagnostic, were used. The working stages were arranged and adapted to the Logical Operating Scheme for Sustainability Assessment (ECOFAS), proposed by Funes-Monzote, Monzote and Lantiga (2002). For the study, string data relevant for productive, economic performance of the farm were used.

RESULTS AND DISCUSSION

The farm is a bio diversified system with the largest area for cattle, followed by fruit, facilities (family home, cattle corrals and soil worm culture). The smallest area is planted with sugar cane.

Area 1: Avocado *(Persea americana*) 2.49 ha producing for 36 years.

Area 2: Avocado, 1.24 ha producing for 18 years. Papaya (*Carica papaya*), coffee (*Coffea arabica*), coconut (*Coco nucifera*), guava (*Psidium guajava*), custard apple (*Annona reticulata*), mangoes (*Mangifera indica*), soursop (*Annona muricata*), red mamey (*Colocarpun sapota*), medlar (*Manilkana sapota*), bergamot (*Citrus bergamia Risso*), oranges (*Citrus sinensis*), tangerines (*Citrus nobilis*), peaches (*Prunus persica*) and cashew nuts (*Anacardiun occidentale*).

Area 3: Avocado, 3.71 ha, producing for 2 years, with guava (*Psidium guajava)* inserted for 6 years; and papaya (*Carica papaya*).

Area 4: Guava, 0.34 ha (200 plants), producing for 18 years, previously inserted with 998 papaya plants (*Carica papaya*), demolished 5 years after plantation.

Area 5: Sugar cane (*Sachaarum officinarum*).

The first visit took place 3 months after plantation of 0.61 ha, alternating with tomatoes (*Solanum lycopersicum*) and cucumber (*Cocumis sativus* L), harvested later on.

Area 6: Facilities, 4.16 ha: family homes (4), corral for cows (1), spaces for soil worm culture and dirt roads.

Area 7: Grazing area with 3 with three fields comprising 14.29 ha, where Texan *(Paspalum nonatum*) and Camagüeyan grass (*Bothriochloa pertusa)* are predominant.

In the first enclosure there are three water containers for animal consumption, a ceyba tree (*Ceiba pentandra*), two algarroba (*Caratonia siliqua*), a guasima (*Guazuma ulmifolia*), and 100 neem trees (*Azadirachta indica*). In the second enclosure there are two ponds, which were dry in the first visit; 2 ceyba trees and 100 neem trees. The third enclosure has a mango tree and 100 neem trees.

The main item sold is fruit, such as, avocado, papaya, produce and vegetables. Milk is sold to the Camagüey Dairy Plant. Due to lack of space, some cattle is sold. The remaining fruit is for the farm workers, and the workers and their families. Plants like pinnon (*Gliricidia sepion*) and mottled spurge (*Euphorbia lactea*), used for hedges; neem tree (*Azadirachta indica*); noni (*Morinda citrifolia*); ceyba (*Ceiba pentandra*); algarroba (*Caratonia siliqua*); guasima (*Guazuma ulmifolia*) and cedar (*Cedrus indica*), are well established.

Table 1 shows the variables for bovine production corresponding to the system. It shows that the area used by them poses a relatively high load, though it does not go over 2 UGM/ha, because availability in the rainy season is low. This may happen due to the reduced number of enclosures and the poor quality of the native pasture, which have a significant impact on bovine exploitation (Del Risco, 2007).

Valdés (2007) has claimed that the use of a relative and permissible high load is very satisfactory, considering the capacity and other features of the pasture lands. Minimum values of 10 and 6 kg of dry matter/100 kg of PV are required during the rainy and dry seasons, respectively.

Table 1 shows an analysis of productive aspects linked to indicators like birth rate and interval between deliveries, which might be improved. It is one indicator which requires full attention to prevent animal and milk losses. The birth rate per hectare was 0.37, way higher than reports by Guevara *et al.* (2005) (0.25 for dairies). Mortality has remained null in dairies for five years.

Annual milk production per hectare was over the reports by Loyola (2010), with values of 819.5 kg/ha in the rainy season and 685.3 kg/ha in the dry season. This study showed results of 862.3 kg/ha .

Table 2 shows crop production, especially papaya, followed by guava, as they can produce the whole year. Irrigation in the rainy season in minimal. Avocado, however, is not producing as much, since it was stricken by hurricane Ike in 2008.

Tomato and cucumber productions are more discrete, as they are alternate crops in small areas.

As sugar cane was developing, papaya yielding were 78 t/ha; guava, 22 t/ha; and avocado, 5 t/ha. Of the three fruit crops, only papaya kept high levels, according to IIFT (2009), which establishes yielding of 40 t/ha in the case of papaya; and 8-10 t/ha for avocado. It would be useful to review topics like population distribution depending on the vital space for each species, plantlet quality, soil moisture (according to plant requirements), trimming to shape and control plant size, location, application of integrated pest management, diseases, weeds and plant nutrient requirements.

Table 3 shows a set of economic variables. Most expenses are related to electricity; something that must be fixed, considering the world need to cut down on fossil fuels.

Sales on the farm are varied, but crop productivity is dependent on proper irrigation. However, the outcome was positive, sale income was higher that expenses.

Table 4 shows the energy balance on the farm; output was greater than input. Inputs included electricity, feed concentrates and fuel, which greatly increase expenses.

Hand weeding in the fruit tree areas; stalks used as animal feed; milking; fence repairs and others, are done by hand, which should be included in the energy balance analysis.

The number of people who can be fed per hectare is greater than the one reported by Guevara *et al.*, (2006) and Funes-Monzote (2000). Their analysis was positive considering the energy contribution of fruit, milk and crops in the system they studied. Those results are in agreement with the results of this study, where there was a great production diversity and the outcome was favorable.

Under current conditions, grazing cattle usually has multiple nitrogen and certain mineral deficiencies, because the pastures and forages often fail to provide such nutrients (Gutiérrez and Crespo 2003). Nutrient shortage is closely related to soil features.

Table 5 shows the nitrogen balance, with a negative result. Nitrogen lack is critical in agricultural systems, it can be solved by large-scale nitrogen-based fertilizers (Funes-Monzote, 2000). The farm should also increase legume culture in hedges.

Senra (2005) recommended that nutrient balance should be achieved in the case of nitrogen, especially by planting more legumes, mainly shrubs, both in protein stocks and linked to graminaceae. Shrub legumes provide nutrients, green fertilizing and shade from the sun.

In this particuar study, nitrogen inputs (mainly in concentrated feed) to the system, were limited. Nitrogen consumption, therefore, is restricted to suplies from small clusters of plants in certain enclosures. Simón *et al.* (2005) reported that pasture yieldings and animal productive behaviors are more stable when leucaena is present; paired to trees (legumes) in relation to the monoculture pastures. Humid tropical soils are short in phosphorous, which is vital for plant growth and development. Table 6 shows the phosphorous balance.

Grant *et al.* (2001) claimed that phosphorous balance plays a key role in energy transference, breathing and photosynthesis. Its deficiency may reduce cell growth, decrease flowering, fruiting, and the number and size of seeds. Phosphorous can also effect on carbohydrate use and root growth, mainly on the thin fibrous lateral roots.

Romero, Márquez and Falcón (2002) reported that studies on phosphorous balance are deficient, and producers often overlook the role nutrition plays in animal productive behavior.

Phosphorous concentration may range from 1 mg/l to over 20 mg/l, depending on the animal diet intake, and second, on its physiological activity.

Phosphorous output greater than input is negative. It tends to disappear in the mid and long terms, and actually, recovery possibilities are few. In common productive practice in small farms, producers cannot access sources of fertilizers, like phosphoric rocks and calcium diphosphate, only used for sugar cane and potato production. Consequently, it is an unsolved problem for small diversified producers.

Table 7 shows energy, nitrogen and economic efficiency indicators with a positive assessment. It is all related to the farm´s sustainability efficiency indicators, very efficiently accomplished.

The indicator phosphorous was negative, as inputs were lower than outputs. The only way it can be tackled is through nitrogen-based fertilization, but not all agricultural projects can access it. Outputs, however, also include crops for human consumption.

Animal drafting power is not used. Its use in tropical areas should not be regarded as technological obsolescence, but as a way to preserve soils. Ponce *et al.* (1996) proved that high soil compaction is produced by machinery, around 5-8 more than drafting animals pulling similar technology.

Social acceptability of the system is good, because it guarantees well-being and higher living standards.

Biodiversity is one of the most effecting factors on cattle farm sustainability in the municipality of Cotorro, province of Havana (Blanco *et al.*, 2006). It had already been acknowledge by the institutions that regulate organic production IFOAM (Funes-Monzote *et al.*, 2002).

It was also corroborated that the number of species was acceptable when compared to other studies (Perera, 2002), who reported values over 50 species on farms; and Monzote *et al.* (2001), identified more than 100 species of farms which applied crop-livestock integration.

Poor availability of pastures and low feed preservation in the dry season are clearly observed, along with inadequate grazing management. In contrast, the application of practices in favor of biodiversity (multi-culturing, bio pesticides, medicinal plants and reforestation) is remarkable. Moreover, natural resource preservation, minimal soil tilling, crop and animal alternate rotation, organic fertilizers from animals and plants are included. Altogether, these factors led to farm sustainability results, which corroborate the results in this study.

Other indicators like soil worm culture, number of products, energy balance, and use of stalks from trimming had a remarkable excellent assessment. Manure use as organic fertilizer is outstanding, considering the nutrient recycling possibilities it brings.

Other indicators should be approached more preventively, as they might compromise the farm in the long-term, such as: nitrogen and phosphorous balances, use of renewable energy and reforestation, a key element in integrated crop-livestock, were better than Guevara *et al.* (2006), as a greater number of agro ecological practices are applied.

CONCLUSIONS

Regardless of its great biodiversity, productivity, and cost-effectiveness, a biogas plant should be built on the farm, and the phosphorous and nitrogen balance should be improved.

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Table 1. Variables of animal production

Variable	Unit	Level	Variable	Unit	Level
Grazing area	(ha)	14.63	Annual milk production	kg	23145.0
Total number of bovines	(hd)	35	Annual milk production per ha	(kg/ha)	862.33
Load	UGM/ha	1.8	Births	(hd)	10
Enclosures	(hd)	3	Births/ha	(hd/ha)	0.37
Pasture availability	(MT/ha)	1.8	Birth rate	(%)	71.43
Sugar cane availability	(MT/ha)	2.7	IPP	(days)	397
Cows	(hd)	11	Adult deaths	(hd)	0
Reproductive cows	(hd)	1	Deaths of young animals	(hd)	0
Annual milk production per ha	(kg/ha)	862.33			

Table 2. Variable of plant production

Variables	Unit	Level
Fruit crop areas	(ha)	7.6
Produce and vegetables inserted with sugar cane	(ha)	0.61
Papaya production	(kg)	73 600
Guava production	(kg)	9 200
Avocado production	(kg)	1 860
Tomato production	(kg)	1 840
Cucumber production	(kg)	1 800
Total fruit species	u	15
Total wood species	u	8
Fruit production/year	kg/ha	3 154
Total high-valued hardwood species	u	2
Total fruit crop species marketed	u	3
Plant production	t/ha	6.59
Total production	t/ha	8.93

Table 3. Economic variables

Variable Expenses	Percent	Variable Sales	Percent
Salary Expenses	28.82	Cattle sales	9.82
Material expenses	27.62	Cucumber sales	1.26
Electricity expenses	37.72	Avocado sales	4.05
Concentrated feed expenses	8.11	Tomato sales	2.91
Fuel expenses	1.44	Papaya sales	58.83
Medication expenses	0.40	Guava sales	3.16
Veterinarian services expenses	0.28	Milk sales	19.92
Sales/expenses ratio		1.23	

Table 4. Energy balance

Source	Energy X ha (MJ)
Inputs	
Fuel	14.9
Home electricity consumption	61.2
Irrigation electricity consumption	592.5
Concentrated feed	2 442.4
Human labor	5.2
Total inputs	3 116.2
Outputs	
Beef	2 201.2
Milk	2 689.8
Papaya	7 217.9
Guava	872.7
Avocado	328.9
Tomato	59.2
Cucumber	43.4
Total outputs	13 413.1
People fed/ha according to energy sources	3.1
Energy balance (production/expenses)	4.30

Table 5. Nitrogen balance

Source	Nitrogen (kg/year)
Inputs	
Concentrated feed	92.8
Total inputs	92.8
Outputs	
Beef	102.1
Papaya	44.2
Guava	7.4
Avocado	2.5
Milk	83.6
Tomato	1.8
Cucumber	1.6
Total nitrogen produced	243.2
Total nitrogen produced by plants	57.45
Total nitrogen produced by animals	185.7
Total nitrogen produced by ha	9.1
Total people fed/ha in a year	3.30
Produced/incorporated nitrogen ratio	2.62
Balance (input/output difference)	-150.35

Table 6. Phosphorous balance

Source	Phosphorous (kg/year)
Inputs	
Concentrated feed	19.41
Total inputs	19.41
Outputs	
Milk	254.59
Beef	19.83
Tomato	5.51
Cucumber	1.78
Papaya	147.24
Guava	18.41
Avocado	5.58
Total outputs	452.94
Input/output balance	-433.53

Table 7. Sustainability indicators

Indicator	Result	Assessment
Energy balance	Positive	Excellent
Nitrogen balance	Negative	Bad
Phosphorous balance	Negative	Bad
Productive efficiency	Positive	Good
Economic efficiency	Positive	Good
Animal drafting power	Negative	Bad
Use of stalks from weeding	Positive	Excellent
Use of manure as organic fertilizer	Positive	Very good
Soil worm culture	Positive	Excellent
Reforestation	Positive	Average
Number of products	Positive	Excellent
Depopulation	Positive	Good
Use of renewable energy	Negative	Bad