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Technological and Economic Viability of an Integrated Guava-Leguminosae Production System in the Conditions of Ciego de Ávila Province, Cuba

Technological and Economic Viability of an Integrated Guava-Leguminosae Production System in the Conditions of Ciego de Ávila

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ABSTRACT

Background: Several different plant species with a forage potential for ruminant nutrition can be found in fruit ecosystems. Their relevance is that a these plants produce a wide variety of foods containing high amounts of secondary metabolites. The aim of this research was to characterize the technological and economic viability of growing-fattening sheep integrated to a guava tree-leguminosae (*Teramnus labialis)* system.

Methods: A four-month study was conducted in 1.2 ha of guava under a irrigation by sprinkling, with a predominance of *T. labialis*. A total of 18 growing-fattening Pelibuey sheep were integrated to the area, with rotational grazing in three enclosures. All the phytotechnical and zootechnical work done to the polycrop and the animals was monitored, including the time used by laborers in different tasks. Salary and energy were calculated as well. Sheep weight increase and guava fruit yields (t. ha^{-1}) were determined, along with income, expenses, and profits of the system.

Results: Irrigation and animal grazing were the most time-consuming activities. The total income was over $10 000.00 per integrated hectare; however, the total profits per hectare were negative ($ -1 627 CUP), due to low guava yields during the season, and the costs of salaries and electric power from irrigation, which were partly mitigated with zootechnical profits of $ 1 925.00 generated by sheep production.

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Conclusions: The presence of animals in the integrated crop-livestock system contributes to the diversification of productions and repay production costs, especially under low crop yield conditions due to environmental or physiological causes.

Key words: agriculture, agroecology, animal nutrition, livestock raising (Source: *DeCS)*

INTRODUCTION

Guava (*Psidium guajava* L.) is one of the most commonly known and desired fruits worldwide. The global production of guava is estimated in approximately 1.2 million tons (Yam Tzec, Villaseñor, Romantchik, Escobar, and Peña, 2010). This fruit is commercially cultivated in quite a few tropical countries, India is the largest producer, followed by Pakistan, Mexico, and Brazil. Other important producers are Egypt, Thailand, Colombia, Indonesia, Venezuela, Sudan, Bangladesh, Cuba, Viet Nam, Malaysia Puerto Rico, Australia, And the United States (Singh, 2011, cited by Parra-Coronado, 2014).

The recommended technology for guava trees in Cuba, particularly, cultivar E.E.A 18-40 (Cuban Red Dwarf) is based on monocropping, using intensive techniques that include propagation by grafting or scions, combined propagation through chemical or organic fertilizers, application of irrigation standards or intervals according to the type of soil, climatic conditions, developmental stage and accessible technology, pest control through integrated methods, and weed control through manual, mechanical, and chemical methods (IIFT, 2009; IIFT- ACPA, 2011).

Despite the increase in guava production areas, and its perspectives, several factors are affecting yields, including pests (Rodríguez, Sisne, Izquierdo, and Nápoles, 2016). Besides, phytotechnical malpractice is said to have caused high weed infestation, as a result of inefficient control strategies that raise production costs significantly (Gómez, Carmona, Echevarría, and Rosso, 2003).

Herbaceous leguminosae have demonstrated that in polycropping conditions with guava trees Navia, 2005; Negrín, 2007; Fontes *et al.*, 2018), they create soil coverage layer that reduces the presence of weeds in plantations, apart from contributing with organic matter and nitrogen to the soil. One of these leguminosae is *Teramnus labialis (L.f.)* Spreng, which is also one of the favorite foods of ovine; the consumption of this plant along with others found in the ecosystem contributes with nutrients, allowing for daily weight gains of over 100 g per animal when grazing in integrated systems including citrus (Mazorra, 2006).

In addition to this leguminosae, several other plant species can be found in fruit tree ecosystems with the forage potential to feed ruminants (Mazorra *et al*., 2013), which is important, since in order to meet their need of protein and energy (Provenza, 2018), the animals must consume a high variety of plants containing different secondary metabolites, which are detoxified by different means in the liver and intestine, cutting down methane production, and improving ruminal ecology (Lakhani and Lakhani, 2018).

In contrast to monocropping, integrated production systems in agriculture keep interrelations between crops and livestock, in such a way that the subproducts or residues from a productive system become the inputs of the other, helping reduce costs and improve productions and generate income (Kumar, 2016).

Several papers (LEAP, 2014; Neivo, Agiova, Giolo, and Tadeu, 2014; Nicholls, Altieri, and Vazquez, 2016) also support the said advantages of integrated crop-livestock systems over mono-cropping, highlighting on greater soil fertility from stools and urine, weed growth control under trees, higher income for the farmer, and a reduction of risks of fire, which help improve natural resource use, reduce erosion, improve micro-climatic conditions, provide biodiversity, mitigate the production of greenhouse gases, and strengthen beneficial biological interactions and the synergy of components, stimulating ecological processes and services.

It has been demonstrated that in Cuba, the establishment of a guava-leguminous polycropping does not differ much from the traditional method to cultivate guava trees, in terms of phyto techniques and production costs, which makes it sustainable (Mazorra *et al*., 2016), and additionally, the leaves from the guava trees, unlike other fruit trees, are not eaten by sheep (Mazorra, Borroto, and Blanco, 2007).

The current fact is that guava has not been used in Cuba as part of multicropping with soil covering crops integrated with sheep. On the contrary, the fruit continues to be produced as a monocrop, with inefficient use of land, water, and energy, based on an intensive technological package that relies on the utilization of chemicals and machinery to control weeds (Espinosa, 2012).

One of the most important causes of this behavior, according to the author, was limited information about the costs, and phytotechnical and zootechnical labors required to achieve integrated guava tree-leguminosae *T. labialis*-sheep management. Hence, the aim of this paper is to evaluate the technological and economic viability of this integrated system.

MATERIALS AND METHODS

The research was done at Dr. Juan Tomás Roig Experimentat Station from the Bioplants Center, Máximo Gómez Báez University, for four months (November-March), in a 1.2 ha field of guava (Psidium guajava L.), cultivar Cuban Red Dwarf EEA 18–40, under semi-stationary irrigation with low trajectory angle sprinklers, in a 4 x 2 m frame, polycropping technique with leguminosae *T. labialis* coverage. The establishment stage of the area diversified is described by Mazorra *et al*. (2016).

At the beginning of the experiment, the guava trees were approximately 1.5 years old, with a mean height of 144 cm, and trunk diameter of 4.1 cm, whereas the leguminosae extended over 72% of the area, with an average height of 13.5 cm, under the permissible limit (20-30 cm) recommended for fruit trees, by the Advisory Committee of Citrus Ciego Company, cited by Fontes (2007).

Two months before the experiment, three enclosures were built in the diversified area with guava, with a fence consisting of 4 barb wire lines and sickle bush poles (*Dichrostachys cinerea* (L.) Wight & Arn.), placed every two meters. Table 1 indicates the investment costs of this operation.

Table 1. Investment in permanent fencing of a diversified hectare, divided into three enclosures, using four barb wire lines

Product	Measure unit	Quantity	Unitary price ($)	Expense ($)
Barb wire	Roll	7	650.00	4 550.00
Pole	u	450	1.50	675.00
Corner posts	u	30	5.00	150.00
Staples	kg	4	20.00	80.00
Labor	m[1]	700	1.00	700.00
Total				**6 155.00**

[1] fencing material

A number of 18 commercial male Pelibuey sheep were bought from the Small Livestock Company (EGAME). The animals weighed an average of 20 kg, and were between 6 and 7 months old, from herds that perform transhumant grazing on native grass. The animals underwent a 30 day pre-experimental period, through which they were treated for parasites, while grazing on native graminaceae, genus Dichanthium, mixed with naturalized leguminosae *Macroptilium atropurpureum* (DC.). Urb.

During the experimental stage (December to March), the animals were split into three groups, and performed continuous grazing in every diversified guava enclosure between 9:00 am and 12:00 m, and 2:00 pm and 4:00 pm. The rest of the time, the animals lodged in the roofed housing, with free access to water.

Determinations

All the phytotechnical and zootechnical labor done to the polycrop and the animals, respectively were monitored, and the workers and directors were interviewed. The time spent on phytotechnical and zootechnical labors was measured, and the cost of salary was calculated from the time spent on each labor and the coefficient of the salary paid to workers. The cost of power used for irrigation was also included.

The sheep were weighed while fasting, at the beginning and the end of the experiment, using a PESOLA scale to determine weight gain. Besides, all the investment done to integrate the ovines to the polycrop area, in terms of fencing, and animal purchasing and sale from and to EGAME, was monitored.

Main monitored activities

1. Irrigation of diversified area.
2. Guava fruit tree trimming.
3. Pest and disease control.
4. Weed control.
5. Zootechnical management of sheep.
6. Investment in fencing and animal purchase.

The guava fruit yields (t. ha^{-1}) were determined by counting all the fruit harvested at random from 24 trees, at both ends of the plantation as well as in the middle (six trees per enclosure); the weight of ten fruits per tree was also measured. The harvest was done when the fruits changed color, from green to yellow, according to Yam Tzec *et al*. (2010) and Parra-Coronado (2014).

The profits were calculated by determining the income, and production and investment expenses in Cuban Pesos (CUP). All the analyses were performed in a hectare of the diversified fruit tree plantation, using Microsoft Excel.

RESULTS AND DISCUSSION

Irrigation and animal grazing consumed most labor during the three evaluation months of the integrated ovine-polycrop (guava-leguminosae) hectare (Table 2). In this study, the ovine shepherd was excluded from the phytotechnical labor to the guava-leguminosae association; however, fencing the diversified area allows a person to do various productive labors: the worker who takes care of the confined animals might include phytotechnical activities as well (harvest, trimming, irrigation, weed control, etc.), thus contributing to a reduction of labor costs.

Table 2. Time spent on different labors within a diversified hectare during the months of production

Labor	Total hours in 1 ha	Total %
Clearing the guava tree shade area	217	14
Fruiting tree trimming	231	15
Irrigation	578	38
Ovine grazing	496	32
Antiparasitic treatment	10	1
Total	**1 532**	**100**

The system consumed 5 133 kW of electricity, which was associated to irrigation of the plantation. During the three months of the study, precipitations were below 90 mm (measured with the rain gauge at the Experimental Station), which led to increased irrigation standard and frequency, raising the cost of power consumed.

In order for this cultivar to produce its true production potential, it must keep uniform moisture throughout the productive cycle (IIFT, 2009). However, water shortage was increasingly higher, which demanded more efficient use and effective management (Fornaris, Hernández, and López, 2011). Integrated polycrop-livestock systems are alternatives allowing efficient use of water, especially when irrigation by sprinkling is used (Mazorra *et al.*, 2016).

Production costs

The irrigation standard and frequency, which are necessarily used during the three months of the dry season, accounted for about 80% of the system's costs (Table 3), a phytotechnical activity done to intensive guava tree production in Cuba.

Table 3. Three-month costs in the integrated system hectare

Item	Cost	
	($)	%
Clearing the guava tree shade area	412	5.1
Fruiting tree trimming	439	5.5
Irrigation	6 231	77.5
Ovine grazing	942	11.7
Antiparasitic medication	19	0.2
Total	**8 043**	**100.0**

Both the power and labor used to carry the low-angle irrigation by sprinkling, were the main reasons leading to the economic of this integrated system (77.5% of total expenses).

Irrigation is one of the most important phytotechnical activities of guava (IIFT, 2009), regardless of the production system implemented. In that sense, Mazorra *et al*. (2016) demonstrated that the guava-leguminosae polycrop system differs from the traditional system currently used to cultivate guava trees in Cuba in terms of phytotechnical labor and costs.

Investment costs of ovine purchases

Upon finishing the permanent fencing of guava areas, growing-fattening sheep were bought for integration to the system (Table 4). This activity represented a cost of $ 3 900.00 (Table 4).

Table 4. Investment costs of ovine purchase per diversified hectare

Quantity	Weight (kg)	Unitary cost ($/kg)	Cost ($)
15	20	13	3 900

Income

In three months of using the integrated system, the total income surpassed $ 10 500.00 per integrated hectare (Tables 5 and 6), of which 57% corresponds to livestock, due to high increases in mean weight gains in the system (13.4 kg per animal in 103 days), with no supplementation, which was corroborated by Mazorra (2006), by integrating ovines to citrus plantations (*Citrus sinensis*) with *T. labialis* soil coverage.

Table 5. Income from guava fruit collection in 1 ha for three months

Number of trees per ha	Fruits per tree	Fruits per ha	Average fruit weight (kg)	Yield per ha (t)	Unitary price ($/t)	Income ($)
1 250	12	15 000	0.27	3.6	1 109.00	4 491.45

Table 6. Income from the sale of ovines with a mean daily gain of 120 g/a/d, in 103 fattening days.

Quantity	Final weight (kg)	Unitary cost ($/kg)	Income ($)
15	33.4	12	6 012.00

The income behavior is relative, and it depends on tree and animal production, and the price of meat and guavas.

The integration of growing ovines (fattening on fruit trees) requires initial investment costs in relation to fencing of about six thousand pesos per hectare (Table 1), and the construction of facilities, which were not considered in this study. The depreciation rates varied 10-12% annually (Apollin and Eberhart, 1999), and the expenses caused by the purchase of growing-fattening animals (Table 5) were around 67% of the income produced by the animal component (Table 7).

Table 7. Income from the sale of ovines with a mean daily gain of 120 g/a/d, in 103 fattening days

Quantity	Final weight (kg)	Unitary cost ($/kg)	Income ($)
15	33.4	12	6 012.00

The farmer could minimize investment costs if no purchase of ovines from EGAME were needed. In that sense, having a breeding herd of their own under continuous reproduction could cut down costs. This variant would facilitate weaning and integration to the diversified system of entire male sheep, and even growing females born in the herd, for which males could be castrated, which, according to Perón (n/a), facilitates herd management.

It is also important to know that income from fruit sales depend on the season and the age of guava trees. The dwarf cultivars are productive throughout the year, though in Cuba, there are two defined seasons of production: March-April and July-October (IIFT, 2009), which explains the low production of fruits during the experimental period.

Profits

According to Pérez Infante (2010), the economic activity is the key and determining factor in agricultural exploitations: If profits are not generated, but losses, and there is no way of reverting that scenario, the business should be shut, accepting failure.

Table 8 shows that in three months, the integrated system failed to generate profit (the numerical value per diversified hectare was negative), which was caused by the negative ratio between income and costs in the guava-leguminosae polycrop system, the former was 63% of the latter.

Table 8. Profits generated in the hectare of diversified system during the three months of exploitation

Item	Income ($)	Cost ($)	Profits
Phytotechnical activities	-	7 082.00	
Zootechnical activities	-	4 861.00	
Fruit sales	4 491.45	-	
Ovine sales	6 012.00	-	
Total	**10 503.45**	**11 943.00**	**-1 439.55**

This paper also shows that the animal component can somewhat mitigate this economic unbalance, with profits of $ 1 151.00 CUP per ha. Other authors (LEAP, 2015; Nicholls, Altieri, and Vazquez, 2016) noted that the practice of integrating animals and crops strengthens the beneficial biological interactions and the synergy between components of the system, stimulating processes and services that generate economic and ecological interactions which are significant and positive.

The profits are numerically related, in a direct proportion, to the size of the production areas: the more animals in the system, the higher the profits, though there are zootechnical and economic parameters to be considered when deciding on the optimum size of the herds (Corzo, García, Silva, and Pérez, 2004).

Moreover, Negrín (2007), demonstrated that 1 ha of guava a polycrop system with leguminosae *Neonotonia wightii* (Wight & Arn) Lackey o *Lablab purpureus* (L.) Sweet, yields 34-40 t of fruit, without significant differences from the natural soil coverage and the bare soil, though the instruction manual (IIFT, 2009) indicate that the Red Dwarf Guava variety from Cuba, can produce more than 70 t/ha^{-1}.

Based on the results of this research, and the findings of Negrín (2007), in 13.42 ha of diversified guava, with yields of 40 t/ha^{-1} a year, around 537 t of guavas can be harvested, with an income of

$ 595 000 CUP, and about 400 sheep could be fattened annually in two cycles, with a production of $ 13.42 t of meat and $ 161 thousand CUP. Therefore, the sum of the income from both components (animals and fruits) would reach approximately 756 000 CUP every 13.42 ha, every year.

According to official documents of the Republic of Cuba (CITMA, 2017), climatic change is worsening, and will deteriorate the environmental problems accumulated in the country, such as soil degradation, affectation of vegetable coverage, pollution, loss of biological diversity, and water shortage, becoming a pivotal factor of sustainable development.

In that environmental context, agroforestry practice based on the integration of sheep to guava trees in association with herbaceous leguminosae, may become of special interest for national farmers in that it will enable diversification of productions, and better use of soil, water, and energy, among other benefits.

The guava-leguminosae-ovine system is in keeping with the concepts stated by Murgueitio *et al*. (2015), on livestock raising adapted to climatic change. It refers to the implementation of agroecological principles that can increase efficiency of several essential biophysical processes, like photosynthesis, nitrogen fixation, and the recycling of nutrients, in order to increase production, biomass quality, and to raise the contents of organic matter in the soil.

In Nigeria (Adewuyi and Olofin, 2018), demonstrated that the environment can be protected, conflicts between shepherds and farmers mitigated, soil degradation minimized, the vegetable layer can be improved, water use optimized, productions diversified, and higher income can be generated, through the application of agroforestry systems that comprise trees, crops, and animals.

Furthermore, the findings of reviews made by Cruz, Bastiani, Barrella, Garcia, and Théa (2015), in Brazil remarked on the need for integration of sheep to fruit cultivation as an alternative to achieve diversification of farmer activities, since fruit tree spacing promotes spontaneous growth of vegetation with high forage value for sheep. Those authors found 13 different species of plants from six botanical families among guava trees, none of which is toxic for the small ruminants.

In Cuba, studies conducted in integrated forest farms (Calzadilla and Jiménez, 2017), concluded that integrated management based on the introduction of agroforesting and forestgrazing techniques, along with other agroecological practices can contribute to economic sustainability and food safety of farm families.

Based on international studies, Almagro *et al.* (2017) stressed that climatic change affects men and women differently in rural areas, being the latter the most vulnerable group. In addition to it, the folk tradition says women have special attitudes to rear animals, and are even more patient than men for grazing. The integration of ovines to areas with guava and other fruit trees may become a new source of employment for women, which would help minimize the gender inequalities existing on the two locations.

CONCLUSIONS

The findings of this research corroborate that integrated polycrop-livestock system contributes to the diversification of productions, and repay production costs, especially under low crop yields, caused by environmental or physiological causes.

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Conception and design of research: CA, OF, data analysis and interpretation: JM, AG, redaction of the manuscript: YA, FS.

CONFLICT OF INTERESTS

The authors declare no conflict of interests.