Ex-post Evaluation of Geomembrane Biodigesters to Treat Organic Residuals in Mountain Ecosystems

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ABSTRACT

The economic and financial efficiency of two 10 m^3 geomembrane biodigesters to treat swine and cattle residuals was evaluated. The study took place at the Cooperative of Credits and Services (CCS) of the municipality of Cumanayagua, Cienfuegos, Cuba. Its aim was to apply a procedure to evaluate investment projects management, based on the logical framework approach. The indicators for evaluation and the indexes of component and management were determined in two moments within the life cycle of the biodigesters: preparation and evaluation. The biodigester for swine residues had +185% economic efficiency, totally corresponding to the results from physical and financial efficacy, along with 69% undervalued operational costs. On the other hand, the biodigester for cattle residues had -90%, -87% periodic efficiencies, along with decreased relative physical, financial and cost efficacies, as well as a reduction of operational costs to 37 and 67%, respectively. In general terms, the economic efficiency had the greatest difficulties during the first three years of the application, caused by unbalances between the planned income and the real expenses. To conclude, biodigesters ranged from low to moderate operation, according to the values preset for the research. Technology proved feasibility, but the economic and financial variables were monitored permanently.

KEY WORDS/: impact assessment, monitoring, management, anaerobic digestion, renewable energy, cattle raising, methane, biogas

INTRODUCTION

The study and evaluation of investment projects are some of the aspects that help allocate the few resources available, by providing useful information to choose the most suitable investment for application.

Evaluations have usually included the organizational, technical, economic, financial and administrative sides. Today, however, it is also important to add the extent to which a project has a social positive impact, trying to use the required natural resources excessively (United Nations, 1958 and 1972; Allen, 1972; ILPES, 1974; UNIDO, 1987; Sapag, 2001; Baca, 2001; Rosales, 2006 and Parodi, 2013).

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Investing is a plan ahead whose preparation, application, implementation and exploitation imply putting large amounts of resources into production or services to achieve economic and social benefits. Continuous assessment over the life cycles of investment projects is a key factor to provide adequate management of the process, particularly on the third phase.

Financial evaluation constitutes an organizational process aimed at directing on-going activities and assist managements in planning and future decision making. They determine the timeliness, efficacy and impact of all the activities in light of their goals, systematically and objectively. The goals of evaluation are varied; hence, information must be organized according to the objectives and the stages of the projects (González, 2000; Rosales, 2006; Medianero, 2010; Vázquez, 2014; and Mata, 2015).

Internationally, there are many different evaluation models and perspectives whose initial approaches were optimized and simplified by other more participatory models. The three current trends are cost-benefit analysis (CBA), cost-effectiveness (CEA) with an economic perspective; the logical framework approach (LFA); and participatory rural diagnostic (PRD) (González, 2000).

However, Ander - Egg (1994), González (2000) and Vázquez (2014), considered that models in economy are more complex when they are implemented in social development projects. The participatory models do not usually respond to international cooperation standards, and they hinder information regularization. The logical framework is more an obligation than an open flexible proposal demanding prior training for application. It is important, then, to combine other techniques and methods during the various phases of the cycle, regardless of the evaluation approach chosen.

Twenty-four economic guidelines of the new Cuban economic model explain the issue of investment as one that must be solved in the country (Communist Party of Cuba, 2011). Accordingly, the Council of Ministers issued Decree 327/2015, that regulates the essential elements adapted to the new updating of the economy, thus putting an end to the scattered legislation in that respect. The current decree cancels all the previous similar provisions that contradicted the new regulations.

The technical and methodological breaches that exist in Cuba are mainly given by the following grounds.

Decree No. 327/2015, title 5, chapter 2, sections 2 and 3, tackles the economic and technical feasibility study in the preparation phase, with very clear regulations in items k and l, for risk studies, using sensitivity analysis and balance point techniques. They facilitate observation of a variable at a time and do not rely on the occurrence probability, so their results must be used cautiously.

Another important element in chapter 4, section 1, is the presentation of the closing file and the final technical and economic evaluation, according to article 179. Section 3, article 186, tackles final or post-investment technical and economic investment, but lacks explanation of how to present the behavior evaluation report, both during operation and implementation of investment and the contents to be considered, limiting the integrated character of the process.

To align cost-effectiveness with social and environmental responsibility in Cuba, it is important to implement sustainable investments in all the economic sectors of society, in accordance with the present-day financial paradigm (performance-risk-sustainability). Agriculture has an essential component within the business portfolio in Cuba, now open to foreign investment.

The application of sustainable alternatives is vital when the treatment of wastes from intensive animal raising in fragile ecosystems has become a priority worldwide (IEA, 2013).

Fernández *et al*. (2014) considered that biodigester technology offers simple solutions to the issue of final deposition of cattle manure. It points to the need of investment implementation, with comprehensive supervision to guarantee adequate management both technical and economic.

Consequently, the limited ex post evaluation of investment in geomembrane biodigester projects to treat organic residues produced in mountain ecosystems is a scientific problem.

The previous led to the following hypothesis: Ex post evaluation of a project for installation of a geomembrane biodigester to treat organic residues will facilitate measurements of economic efficiency, efficacy, appropriateness, impact and sustainability of investment processes in productive mountain ecosystems.

The general objective was to perform ex post evaluation of geomembrane biodigesters to treat organic residues, and their comprehensive use in mountain productive ecosystems.

Accordingly, the object of study was the financial administration of investment projects. The field of action was evaluation of the cycle of investment projects.

MATERIALS AND METHODS

Non experimental research was done, including a population of 47 small farms from the Cooperative of Credits and Services (CCS), in or near mountains, plains, and the mid-east of the municipality of Cumanayagua, Cienfuegos. Intentional non-probable sampling was made (12 cases), since the information compiled was not enough, time was limited, and there was little financing for laboratory and geographical dispersion analyses of biodigesters, between 2013 and December 2015.

Two digesters were chosen in order to perform ex post evaluation of implementation (farmers 2 and 11), based on the behavior of the efficiency indicators defined. The results achieved showed their importance according to the areas analyzed (swine and cattle, respectively), with the application of the box diagram technique, using SPSS, 15.0 to support the selection.

The feasibility study included discount rates between 7 and 15%. The values were based and supported by Resolution 59/2012, of the Central Bank of Cuba (BCC, 2012), for the lower interval; and the Ministry of Economy and Planning (MEP, 2006) to justify the higher value.

The procedure comprised verification of the following steps: management report, identification and classification of the project, localization, result indicators, analysis of results and conclusions and recommendations, and the final report called the Final Ex post Report (graph 1.).

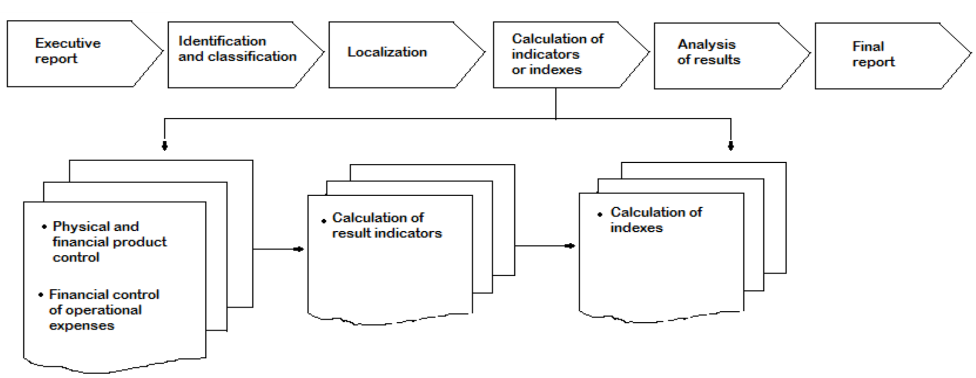

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Fig. 1. Ex post evaluation of investment project´s life cycle (Aguilar, 2009 and Mata, 2015).

The results were measured by calculating the management index, and it was important to create a separate index for each assessment criterion (pertinence, physical efficacy, economic efficiency, impact and sustainability). All the indicators are based on quantitative statistical data. The purpose was to achieve index between 0 and 1, to facilitate mutual comparability (Table 1).

Table 1. Assessment indicators*

Indicator	Explanation	Calculation formula
Cost (CI)	It helps determine the difference between total financing requested at the beginning of the project and expenses during project implementation. Work is also done on periodic operational expenses, being elements in the economic efficiency index or criterion.	$CI = \left[\frac{\text{Real}}{\text{Forseen}} \right] - 1$
Temporary completion (TIC)	It sets the difference between the deadline established initially for project implementation and the time actually used, as part of the economic efficiency index or criterion.	$TIC = \left[\frac{\text{Real time}}{\text{Estimated time}} \right] - 1$
Economic efficiency (EE)	It results from comparison between the current prior net value (ex ante CNV) and the current post net value (ex post CNV) of project implementation. Other indicators can also be applied, like TIR, IR, cash flow, etc., as part of the economic efficiency index or criterion.	$EE = \left[\frac{\text{CNV expost}}{\text{CNV exante}} \right] - 1$
Coverage (CovI)	It links the number of beneficiaries before and after the implementation of the project, and it belong to the impact and efficacy indexes or criteria.	$CovI = \sum_{i=0}^{n} \frac{Beneficiaries\ year\ i}{Beneficiaries\ year\ 0}$
Deficit (DI)	It compares the number of people who lack the service (deficit) to the total number of beneficiaries covered by the project. It shows the project´s contribution to reduce the deficit identified and it belongs to the impact and efficacy indexes and criteria.	$DI = \frac{\text{Deficit}}{\text{Number of beneficiaries wit}}$
Sustainability	It implies the financial and human resources needed for as long as the project lasts.	
Appropriateness	It determines the applicability or contribution of the project to the solution of problems emerged during formulation and if the operational results were useful.	

*Taken from Aguilar (2009), Sosa (2011), Díaz (2013), Santana (2014) and Mata (2015).

The criteria from Medianero (2010) and Mata (2015) were used for classification of project management: Poor, for index values below 0.3; Low, for index values within the 0.3 - 0.5 interval; Moderate, for index values within the 0.5 - 0.7 interval; High, for index values greater than or equal to 0.7.

RESULTS AND DISCUSSION

Application report and project identification

Mountains are commonly identified for their complex geography and high morphometric values, along with inappropriate agricultural practices, which lead to the emergence and development soil degradation processes, erosion and floods, that limit local farming motivation to forestry and coffee growing. The most widely observed damages to the topography are caused mostly by accelerated degrading exogenous processes, like stripping, erosion, gravitational processes, etc. They are locally fostered by human labor (deforestation, engineering works, heavy rains related to extreme weather conditions, etc. As mountains have an important environmental relevance in the province, it is important to implement actions directed to natural resource protection and reduction or mitigation of possible threats to the fragile ecosystems that form that important natural reservoir.

The purpose of this project is to improve management and use of organic wastes in productive systems, through biodigesters, to prevent pollution issues on farms with housed animals, along with soil improvements and increased agricultural production. This project classifies as strategic with technological innovation. The organizations in charge of application are the production cooperatives with the beneficiaries: The National Association of Small Farmers (ANAP), The Ministry of Science, Technology, and the Environment (CITMA), the Ministry of Economy and Planning in the province, the Ministry of Agriculture (MINAG), and Physical Planning.

Investment costs

The investment costs include three parts: equipment, materials, and inputs; training and administration costs. The total amount is $50 000.00 CUC and $16 000.00 CUP. In fact, the cost of investment was altered in each component, at a partial project implementation of 43%, and a value of $ 21 468.53 CUC, and 93 % in CUP, with an overall value of $ 14 966.50. The year 2010 was considered the beginning of planning, though case-study related activities actually started in May 2013, particularly with the construction of the reactors´ foundations, which lasted two months. Then the reactors began to work and biogas was generated 14 days later. There was a temporary prolongation of 36 months regarding the plan, mainly due to a halt between the moment of localization of biodigesters and the purchase of materials and other inputs which produced a temporary dilation in the other activities.

Operational costs

The operational costs on the Rancho Grande agroecological farm reached $ 4561.75 (69%), with very different behaviors observed in the components of periodic operational costs. The annual charge over depreciation costs were increased (130%), whereas maintenance costs were decreased (69%), in addition to idle work force. On La Almendra agroecological farm, total sub-costs climbed to $ 5824.84 (67 %). Furthermore, the periodic operational cost components had different behaviors: the annual charge for sub-costs was increased (220%) at the expense of increased net investment, whereas maintenance experimented no changes and the workforce was valued below actual costs (100%) due to the lack of contracts.

Efficiency indicators

The cash input data, the periodic cash flows and the current net value (CNV) are required for application of the efficiency indicator. Analysis of cost-effectiveness or the benefit-cost ratio and the internal return rate provided an extra possibility. The annual cash flows experimented average relative variations, with -67% on La Almendra agroecological farm, and +185% on Rancho Grande. These results corresponded to the behavior of physical and financial efficacy. CNV motility was significant on Rancho Grande, along with the internal rate of return (IRR), and the cost-effectiveness index, which remained positive all the time. When those indicators are below zero they express values below the expectations. The modular value revealed the variability of results, particularly IRR on La Almendra, with high negative variability (-90%). A similar behavior was observed in the other indicators (Table 2).

Table 2: Economic efficiency indicators from general cost-effectiveness variables on the studied farms, expressed for one unit*

Discount rate	EE (CNV)	EE (RI)	EE(IRR)
		Rancho Grande	
7%	1.53	0.08	
10%	1,60	0.09	0.51
12%	1.65	0.11	
15%	1.73	0.12	
		La Almendra	
7%	-3.53	-0.55	
10%	-7.69	-0.55	-0.90
12%	-17.05	-0.54	
15%	-47.22	-0.54	

* Self-made, based on the information collected in the field.

There are significant differences between economic efficiency and management of digesters installed on both farms. The ex post results on La Almendra were completely negative, especially caused by a significant increase in the investment costs over the plan (220%), and a relative decrease of annual cash flows (87%), which harms the general cost-effectiveness of the project. Rancho Grande had an ex post increase in investment costs (130%), linked to a simultaneous increase in cash flows (185%), thus improving the general cost-effectiveness.

Efficacy indicators

The indicators of physical and financial efficacy of the project showed positive and negative values, meaning that unplanned biogas production can have an infinite behavior. The temporary tomato production from either farm is positive at the expense of an increase in production; bean production on Rancho Grande was below the expectations. The financial efficacy was mainly measured by the sales income of three years of implementation, only positive on Rancho Grande (Tables 3 and 4).

Table 3: Physical efficacy indicators of the project on the farms studied*

Indicators	MU	Ex prior	Ex post	Absolute variation	Relative variation
		Rancho Grande			

Biogas production	m^3/day	0	1.76	1.76	∞
Beans	centals	30	25	-5	-17%
Tomato	cash	75	80	5	7%
		La Almendra			
Biogas production	m^3/day	0	2.7	2.7	∞
Tomato	cash/year	24	30	6	25%

* Self-made, based on the information collected in the field.

Table 4: Financial efficacy indicators of the project on the farms studied*

Indicators	**MU**	**Ex ante**	**Ex post**	**Absolute variation**	**Relative variation**
		Rancho Grande			
Sales income	Pesos/year	9351.31	10642	1290.69	14%
		La Almendra			
Sales income	Pesos/year	9351.31	5880	-3471.31	-37%

* Self-made, based on the information collected in the field.

- Project sustainability and appropriateness. During the implementation of the project, several sustainability issues caused by different factors, were observed.

1. Poor work force training.
2. Work force shortage.
3. Insufficient water supply.
4. Emission of greenhouse gases into the atmosphere
5. Gas leaks due to broken digesters.
6. No use of the residual network.
7. Deficiency in digester assembling.
8. Application of chemicals that affect the input mixture.
9. Morbidity or mortality of housed animals.

Disease and death of housed animals (risk 9) was identified as producing the highest effects on the project´s results. It implied the sacrifice of all the animals, so the potential project´s inputs were affected for a year, which will be needed to recover the previous levels naturally. The risk occurrence frequency was relatively low, but it had a considerable impact on the results, estimated in 1.10%.

Assessment indicators and indexes

For indicator selection, a survey (35 items) was suggested to determine the indexes that contributed to project management evaluation during the periods included. The survey provided 25 (five per criterion), from the results of statistical analysis: 1) Economic efficiency (investment costs, operational costs, cash flows, CNV and periodicity); 2) Physical and financial efficacy (unproduced methane, biogas production, temporary production, total volatile solids, periodicity, saving of resources, sales income); 3) Impact (unreleased methane, biogas production, number of biodigesters, efficiency of biodigesters, treated hectares); 4) Appropriateness (unreleased methane, biogas production, number of biodigesters, efficiency of biodigesters, treated hectares); and 5) Sustainability (risk-adjusted rate, cost-effectiveness/cost span, variance, typical deviation, variation coefficient of general cost-effectiveness).

The results showed that the highest deviations focused on real costs and income from the application. According to ex post evaluation, the project´s cost declined 55% in comparison to the values planned. Overall, considering the case studies, the operational costs decreased relatively (120%). Again, there was resource over-allotting in the ex ante evaluation. Contrary to the plan, the cash flows were positive (96%). The results of the main budgeting indicators showed a cost-effective project, based on the ex ante evaluation. However, the ex post evaluation showed the opposite, particularly on La Almendra. Project management on Rancho Grande moved from poor to high (17 %, 83 %), every index showed significant improvements. On the contrary, in La Almendra, it ranged from low to moderate (34 %, 66 %), with economic efficiency as the most depressed index, whereas the physical efficacy, appropriateness and impact improved considerably. However, financial efficacy and sustainability stayed unaltered, figures 1 and 2.

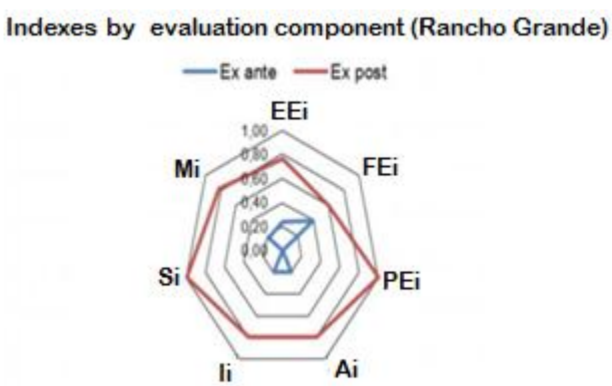

Figure 1. Indexes by evaluation criteria, Rancho Grande. Compiled with information collected through processing and standardization of indicators

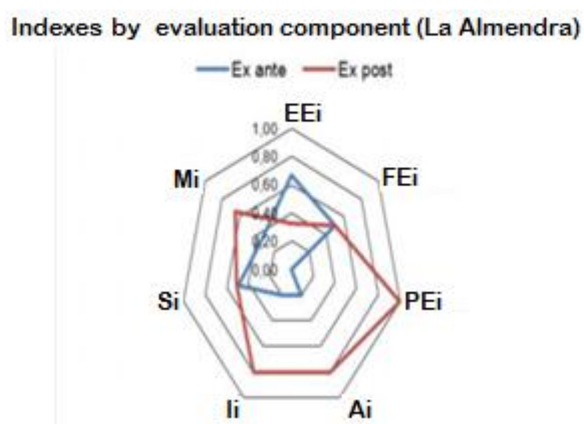

Figure 2. Indexes by evaluation criteria, La Almendra. Compiled with information collected through processing and standardization of indicators

Legend: EEi: economic efficiency index; FEi: financial efficiency index; PEi: Physical efficacy index; Ai: Appropriateness index; Ii: Impact index; Mi: Management index

Comparison of the results with other productive activities within the sector on a coffee farm (management index ranging between 36 % - 55 % (Sosa, 2011), and on a forestry farm in the mountains of Guamuhaya, over the same period (53 % - 67 %) (Abreus, 2014), concluded that project management behaved similarly during the cycle, regardless of the agricultural activity: it moved from low to moderate, and might get to high in some cases.

According to Mata (2015), based on assessment results from 28 investment projects (fifteen ex ante, four during, and nine ex post) in agriculture (68%) with implementation in varied crops (fruits, citrus, and grains); mountain agriculture (honey, fiber, coffee and timber); and livestock (swine, cattle, and others), the following results were achieved.

No changes were observed in localization, a strength of investments in agriculture.

Investment and operational costs underwent serious diversion (100%), showing planning deficiencies.

Absence of baseline evaluation to re-adjust budget, and follow up during the whole life cycle of investments.

Over-cost indicators that threaten evaluation.

The best results of the projects evaluated were achieved in cooperated production.

Evaluation component issues relied on efficiency (85% of cases), efficacy (60%), sustainability (40%), and appropriateness (30%), with effects on the management index.

Poor learning motivation to improve future applications.

Finally, the studied investment project was not an exception in the sector, in terms of economic efficiency (La Almendra) as a component of evaluation. However, it shows undeniable progress regarding the calculated indexes.

CONCLUSIONS

The diagnostic applied in the Guamuhaya mountains revealed economic, social and environmental issues in the area, which demanded new actions to protect natural resources and mitigate the threats to fragile ecosystems of an important natural reservoir like this.

Several factors were observed to reduce the efficiency of polyethylene tubular biodigesters on the farms studied. They had an effect on the quality of the main resulting products from the process of anaerobic digestion (biogas and boil).

As a result of the ex post assessment in the third phase of the investment cycle, the economic efficiency and efficacy were the main deficiencies, along with over confidence in indicators, which hindered management estimations, though technology played a key role.

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