SIMULATION OF THE ENERGY PERFORMANCE OF MAIZE PRODUCTION INTEGRATED TO PIG FARMING

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ABSTRACT: The study evaluated the energy performance of pig farming integrated with maize production in mechanized no-tillage system. In this proposed conception of integration, the swine excrement is used as fertilizers in the maize crop. The system was designed involving the activities associated to the pig management and maize production (soil management, cultivation and harvest). A one-year period of analysis was considered, enabling the production of three batches of pigs and two crops of maize. To evaluate the energy performance, three indicators were created: energy efficiency, use of non-renewable resources efficiency and cost of non-renewable energy to produce protein. The energy inputs are composed by the inputs and infrastructure used by the breeding of pigs and maize production, as well as the solar energy incident on the agroecosystem. The energy outputs are represented by the products (finished pigs and maize). The results obtained in the simulation indicates that the integration improves the energy performance of pig farms, with an increase in the energy efficiency (186%) as well as in the use of the non-renewable energy resources efficiency (352%), while reducing the cost of non-renewable energy to produce protein (-58%).

KEYWORDS: pig farming, integrated agroecosystems, energy analysis.

SIMULAÇÃO DO DESEMPENHO ENERGÉTICO DA PRODUÇÃO DE MILHO INTEGRADA À SUINOCULTURA

RESUMO: Foi avaliado o desempenho energético da suinocultura integrada à produção de milho em grão em sistema de plantio direto mecanizado. Nesta concepção de integração proposta, os dejetos suínos são utilizados como fertilizantes na produção de milho. O sistema foi delimitado envolvendo as atividades associadas ao manejo dos suínos e de produção do milho (manejo do solo, cultivo e colheita). O período de análise considerado foi de um ano, o que possibilita a produção de três lotes de suínos e duas safras de milho. Para avaliar o desempenho energético, foram criados três indicadores: eficiência energética, eficiência de uso de fontes não renováveis e o custo de energia não renovável para a produção de proteína. As entradas energéticas são compostas pelos insumos e pela infraestrutura, utilizados na criação dos suínos e na produção de milho, e pela radiação solar incidente no agrossistema. Já as saídas são representadas pelos seus produtos (suínos terminados e o milho). Os resultados obtidos nas simulações apontam que a integração melhora o desempenho energético das granjas suinícolas, aumentando a eficiência energética (186%) e a eficiência não renovável (352%), além de reduzir o custo de energia não renovável para a produção de proteína (-58%).

PALAVRAS-CHAVE: suinocultura, agrossistemas integrados, análise energética.

INTRODUCTION

As mentioned in CERVI et al. (2010), the expansion of pig farming has resulted in a significant increase in the volume of produced waste, increasing the risks of environmental contamination. The swine excrement show great pollution potential. Thus, this residue must be handled properly, or may cause serious impacts to the ecosystem. In the definition of KUMAREZAN et al. (2009), residue is an energy resource disposed in an inappropriate location; however, this could become an input for other producing processes, if handled correctly. So, the integration of pig farming with other agricultural activities may reduce the risk of environmental contamination, and increase the supply of products in the property.

Several ideas of integration have been proposed, highlighting the association of pig farming and maize production (DAUDÉN & QUÍLEZ, 2004), fish (TOMAZELLI JR. et al., 2007), sugar cane (LEITE et al., 2009) and pasture (DRUMOND et al., 2006). In addition to these concepts, it has been proposed the use of swine excrement for biogas production (CERVI et al., 2010). Among these concepts above, the integration of pig farming with the grain maize production is predominant (KUNZ et al., 2009). In the integrated pig farming/agriculture system, as this productive concept is called in this study, the waste is collected and stored in dunghills for stabilization, and then distributed in the soil to supply the nutrient requirements for culture.

The energy analysis is an instrument that aids in the evaluation of the efficiency profits obtained with the reuse of pig production residues as productive inputs in the maize cultivation. With the integration of the two agricultural activities, the energy performance tends to increase when compared to non-integrated system. SOUZA et al. (2009) justifies the use of energy analysis in agricultural systems for their applicability in identifying processes with lower efficiency. Additionally, the authors discuss that the evaluation of energy flows in agricultural systems as well as the evaluation of its energy performance, is an important instrument to evaluate the sustainability of the agroecosystems.

Therefore, this study aimed to simulate the energy performance of the production of three batches of 500 pigs integrated to the production of grain maize in no-tillage system in two crops in a year. With these results it was possible to evaluate the influence of the integration of productive activities in the energy performance of the agroecosystems.

MATERIAL AND METHODS

The object of analysis encompassed the management activities of pigs (called pig farming stage) and the processes that formed the maize production (fertilization of soils with swine excrement, soil preparation, cultivation and maize harvest) called agriculture stage. The integration of activities occurs by the use of excrements produced by pigs as organic fertilizer in maize production. One-year period of analysis was considered, which would allow the production of three batches of pigs and two crops of maize (main crop and off-season). The results obtained by the simulation of the pig farming/agriculture integrated system were compared with the energy performance of an equivalent system, where the activity of pig farming is developed without integration with agriculture.

The energy inputs of the integrated system were associated with the inputs (direct energy), directly expenses in breeding of animals and production of maize, and energy depreciated by the use of infrastructure (indirect energy). The direct energy was evaluated by the product of the physical demands for the agroecosystem by its energetic coefficient. To calculate the indirect energy, we used the method of energy depreciation, which considered using time and equipment useful life (SOUZA et al., 2009; ANGONESE et al., 2006).

In the energetic evaluation of the agroecosystems were assessed commercial energy flows (inputs and infrastructure) and non-commercial energy flows (solar radiation). The energy flows were classified in two forms: renewable and non-renewable. The renewable resources included the

products originated from the photosynthetic process, such as vegetal products, propagating material, work force, and solar radiation. The non-renewable energy resources included the fossil inputs and/or mineral, such as chemical fertilizers, diesel oil, mineral supplements, pesticides and energy depreciated by use of productive infrastructure. This classification was useful to evaluate the dependence of agroecosystems on non-renewable resources, which availability is finite. A system highly dependent on non-renewable resources tend to have their sustainability compromised (FURLANETO et al., 2009; LAMMERS et al., 2010).

There are several indicators available in the literature, each one constructed in order to facilitate the analysis within the scope proposed by each author (CAMPOS et al., 2003; FURLANETO et al., 2009; SOUZA et al., 2009). The indicators considered in this study were energy efficiency (eq.(1)), non-renewable efficiency (eq.(2)) and the cost of non-renewable protein (eq.(3)):

$$\eta = \frac{\sum \text{energy inputs (MJ)}}{\sum \text{energy outputs (MJ)}} \tag{1}$$

$$\eta_{NR} = \frac{\sum \text{energy inputs (MJ)}}{\sum \text{non-renewable energy inputs (MJ)}} \tag{2}$$

$$C_{Pr.} = \frac{\sum \text{non} - \text{renewable energy inputs (MJ)}}{\sum \text{produced protein (kg)}} \tag{3}$$

The pig farming stage was shaped having as parameter the technical requirements for the production of a batch of 500 pigs on a unity of growth and termination (UGT). In a year of production can be produced three batches, with average animal[-1] weight[1] of 75 kg. The average mortality was estimated at 10%. The production system, that involves management techniques, demand for inputs and infrastructure, was characterized based on the technological pattern of pig farming in southern region of Brazil.

In this study it was considered that the animals were fed with a commercial ration containing 17% crude protein, whose main components were maize (78%), soybean meal and wheat (19%) and vitamin and mineral supplements (5%). Regarding the classification of the energy associated with the ration, it was estimated that 33.0% would be of non-renewable origin and that 67% would be renewable (PERIN, 2010). The inputs used in pig farming stage are presented in Table 1.

TABLE 1. Quantities and energetic coefficients of inputs used in a year of pig farming (three batches).

Item	Quantity	Energetic Coefficient
Ration	414.33 t	18.00 MJ kg[-1 (i)]
Suckling pigs	30.00 t	9.21 MJ kg[-1 (ii)]
Eletric energy	1.85 MW h	3.60 MJ kWh[-1 (iii)]
Work force (man-hour)	2,257.00 h	0.47 MJ h[-1 (iv)]

(i) PERIN (2010); (ii) ANGONESE et al. (2006); (iii) BEN (2009); (iv) SANTOS & LUCAS JR. (2004).

The average daily production of waste for finishing pigs was estimated at 10.5 L animal[-1] (PERIN, 2010). This estimative took into account, in addition to the feces and urine of the animals, the wasted water in animal drinking places and in the washing of the pigsty. The management in the water level system is the most used technique in UGT farms. This water level is formed by the construction of a small salience on the floor, next to the waste outlet piping (DAGA et al. 2007).

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[1] The batch of pigs enters in the productive system with an average animal weight of 30kg and is delivered with an average animal weight of 130 kg.

The physicochemical characterization of swine excrement was estimated using the data supplied by ASAE (2005) (Table 2). The use of these parameters is based on the hypothesis that, in pig farming industry, with controlled handling and feeding, there is little variance in the composition of the excrements. What differs significantly is the concentration of these elements in the excrements, due to its dilution.

TABLE 2. Characterization of excrements produced by pigs in terms of total solids and NPK Macronutrients.

Item[2]	Daily Production by ton of meal
Total solid	11.00 kg
Total nitrogen	0.52 kg
P_2O_5	0.41 kg
K_2O	0.35 kg

Source: Adapted from ASAE (2005).

The waste is collected and stored in dunghills for posterior agricultural use. The dunghill is sized considering the daily production of waste, ensuring minimum storage time of 120 days. The energy associated with the use of the dunghill is calculated based on the items that compose its structure (plastic blanket and PVC pipes). The energetic coefficient of the blanket is 130MJ kg^{-1} and of the PVC is 120 MJ kg^{-1} (ANGONESE et al., 2006). Calculating the depreciated energy it was considered the usage time of 1 year, with a lifetime of 20 years (SOUZA et al., 2009). Table 3 shows the other items that make up the pig infrastructure.

TABLE 3. Infrastructure of the pig farming stage: quantities and energetic coefficients.

Item	Quantity	Material	Energetic Coefficient
Pigsty	676.20 m^2	Mixed	956.03 MJ m^{-2} [(i)]
Silo for ration (16 t)	9.00 t	Steel	62.78 MJ kg^{-1} [(i)]
Transport cart	20.00 kg	Steel	62.78 MJ kg^{-1} [(i)]
Composter	20.00 m^2	Masonry	1,208.17 MJ m^{-2} [(ii)]
Water tank (15 m)	226.00 kg	Plastic	130.00 MJ kg^{-1} [(i)]

(i) ANGONESE et al. (2006); (ii) CAMPOS et al. (2003).

The energy outputs of the pig farming stage are represented by the finishing pigs whose energetic coefficient is 9.21 MJ kg^{-1} (ANGONESE et al., 2006). The protein production was estimated at 10.4 kg per each 100 kg of live pigs (PERIN, 2010).

The excrements produced by the animals are used as organic fertilizers, replacing the use of chemical fertilizer, based on Nitrogen, Phosphorus and Potassium in maize production. The agriculture stage was modeled following the technical script recommended by Embrapa Maize and Sorghum (CRUZ, 2009) for the production of grain maize under mechanized no-tillage. In this script were added the operational requirements for application of the excrements as a biofertilizer.

Table 4 presents the description of the main activities involved, equipment used and fuel demand. It was considered the production of two annual crops. Using the technical script above mentioned, we estimated a productivity of 7 t ha^{-1} for the first crop (main crop) and 3 t ha^{-1} for the second crop (off-season), which totalized an annual production of 10 t ha^{-1}.

[2] The production of the P_2O_5 and K_2O compounds is obtained by the mass coefficient of the P and K elemental forms by the 2.29 and 1.20 factors, respectively.

TABLE 4. Recommended technical procedures for maize production in one hectare of mechanized no-tillage, fertilized with swine excrement.

Activity	Equipment	Spent time	Fuel [ii]
Herbicide application	Tractor 85 cv + Pulverizer	0.75 h ha^{-1} [i]	1.00 L h^{-1}
Calcareous distribution	Tractor 85 cv + Distributor	0.13 h ha^{-1} [i]	1.00 L h^{-1}
Mechanized tillage	Tractor 85 cv + Planter	1.60 h ha^{-1} [i]	4.50 L h^{-1}
Insecticide application	Tractor 85 cv + Pulverizer	0.90 h ha^{-1} [i]	1.00 L h^{-1}
Mechanized harvest	Harvester 160 cv	1.45 h ha^{-1} [i]	10.00 L h^{-1}
Intern transport	Tractor 85 cv + transport wagon	1.20 h ha^{-1} [i]	1.00 L h^{-1}
Fertilization with excrements	Tractor/distributor Set	5.21 h ha^{-1} [iii]	1.00 L h^{-1}

(i) Adapted from CRUZ (2009); (ii) Adapted from JOHN DEERE (2010); (iii) PERIN (2010).

The volume of biofertilizers that should be applied in the soil depends on the nutrients extracted by the maize and the concentration of these elements in swine manure. Regarding the extraction of nutrients, this is influenced by the culture productivity, soil characteristics, among other parameters. In the balancing of the fertilization of maize were considered only the NPK (Nitrogen, Phosphorus and Potassium) macronutrients. These elements are the most abundant in swine manure and also those with higher demand for maize. To a productivity of 10t/year we estimated that are extracted on average 238.57 t of Nitrogen, 107.96 t of Phosphorus (P_2O_5), and 193.71 t of Potassium (K_2O) per hectare of cultivation (COELHO & FRANÇA, 1995).

When the fertilization is performed by organic fertilizer, differences occur between the amounts of nutrients available and the required by the plants. Some nutrients are not readily available, while for others the ability of absorption by the plants is low. SEGANFREDO (1999) recommends defining the nutrient to be supplied entirely by the organic source (nutrient base) and supply the other elements with balanced chemical fertilizer. Among the NPK macronutrients, according to COELHO & FRANÇA (1995), the phosphorus is the element with lower extraction by the maize. Thus, in this study it was adopted the criterion of phosphorus as a basis element to estimate the volume of waste to be applied and the demanded cultivation area. In this case, there will be deficiencies in the supply of nitrogen and potassium (K_2O), which must be supplied by chemical fertilizer. The energetic coefficient of these elements, presented in ANGONESE et al. (2006), is 73 kg and 9 MJ kg^{-1}, respectively. The demand for fuel was estimated using the Table 4. The energetic coefficient of diesel oil is 35.52 MJ L^{-1} (BEN, 2009). The other inputs required in this stage are presented in Table 5.

TABLE 5. Inputs used to produce one hectare of maize at two annual crops: quantities and energetic coefficient.

Item	Quantity	Energetic Coefficient
Herbicide	8.30 L ha^{-1} [i]	288.00 MJ kg^{-1} [ii]3
Insecticides	1.92 L ha^{-1} [i]	237.00 MJ kg^{-1} [ii]
Maize seeds	40.00 kg ha^{-1} [i]	33.21 MJ kg^{-1} [iii]
Calcareous	1.10 t ha^{-1} [i]	0.20 MJ kg^{-1} [iv]
Work force (man-hour)	17.23 h ha^{-1} [i]	0.47 MJ h^{-1} [v]

(i) Adapted from CRUZ (2009); (ii) HÜLSBERGEN et al. (2001); (iii) ALMEIDA et al. (2010); (iv) SALLA et al. (2010); (v) SANTOS & LUCAS JR. (2004).

In Table 6 are presented the mass and the energetic coefficient of agricultural equipment described in Table 4. To calculate the energy depreciated by the use of this equipment, it was considered a lifetime of 10,000 h, following the procedures adopted by SOUZA et al. (2009).

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[3] In the conversion of the volume liter unity to kg of herbicide and insecticide, is adopted the 1 kg L^{-1} density.

The energy output of the agriculture stage is represented by the production of grain maize, whose energetic coefficient is 16.5 MJ kg^{-1} (SANTOS & SIMON, 2010). The considered protein concentration in the maize was 79.3 kg per ton of grains (PERIN, 2010).

TABLE 6. Equipment used for execution of technical scripts of agricultural stage (Table 5) and its corresponding energetic coefficients.

Item	Mass	Energetic Coefficient
Tractor 85 cv traction	4.90t [i]	69.83 MJ kg^{-1} [iv]
Harvester 180 cv - platform 4m	9.10t [i]	69.83 MJ kg^{-1} [iv]
Pulverizer bar 2,000l	7.90t [i]	83.71 MJ kg^{-1} [iv]
Planter 7 lines	2.90t [i]	83.71 MJ kg^{-1} [iv]
Transport wagon	2.00t [ii]	83.71 MJ kg^{-1} [iv]
Distributor of corrective 1.2m^3	1.10t [ii]	83.71 MJ kg^{-1} [iv]
Distributor of liquid fertilizer	1.30t [iii]	57.20 MJ kg^{-1} [iii]

(i) JOHN DEERE (2010); (ii) MARCHESAN (2010); (iii) SOUZA et al. (2009); (iv) CAMPOS et al. (2005).

Regarding the contribution of solar radiation, this was computed by the product of the index of average solar irradiation in the southern region of Brazil and the demand of area in the agroecosystems. According to the Solarimetric Atlas of Brazil (TIBA, 2003), the average annual solar irradiation in the southern region is 15 MJ m^{-2} (average irradiation between January and December). The demand of area in pig farming stage was estimated at 0.2 ha (PERIN, 2010). In agriculture stage, the demand of area depends on the balance of the maize nutrients.

RESULTS AND DISCUSSION

The production of live pigs for this period was estimated at 101.25 t (live weight), which represents an animal protein production of 18.25 t. The energetic equivalent of this production was estimated at 1.62 TJ. This sum is for the delivery of three batches of 500 pigs per year, average mass of 130 kg, with 10% of mortality.

The daily production of swine manure was estimated at 5.25 m^3. Considering a productive year of 330 days, it was obtained an annual production of 1732.5 m^3. To store this volume of waste it would require a dunghill with 630 m^3. The materials used in the construction of this dunghill would be 392.5 kg of plastic blanket (513.7 m^2 of blanket with 0.8mm thick) and 30 kg of PVC pipes (AVISERRA, 2010).

The energy inputs of pig farming stage (Table 7) totalized 7.83 TJ year^{-1}, being the ration (renewable and non-renewable fraction) the item with the largest representation in expenditures of the agroecosystem (95.26%). Regarding the participation of non-renewable sources in the energetic consumption, this was estimated at 31.4% (2.52 TJ).

The pig farming is a deficient activity from the energetic point of view, importing much of its energetic demand. The energetic efficiency of pig farming production stage was 0.21, while the non-renewable efficiency was evaluated at 0.64. However, the non-renewable cost of the protein production was estimated in 137.96 MJ kg^{-1}.

TABLE 7. Energy inputs used for pig farming stage in a year of production.

Item	Consumed/Depreciated Quantities	Energetic Equivalent
Renewable Inputs		
Solar radiation	2,000.00 m^2	30.00 GJ
Ration - renewable fraction	277.60 t	4,996.82 GJ
Suckling pigs	30.00 t	276.30 GJ
Electric energy	1.85 MWh	6.65 GJ
Work force (man-hour)	2,257.00 h	1.06 GJ
Non-renewable Inputs		
Ration - non-renewable fraction	136.73 t	2,461.12 GJ
Pigsty	30.43 m^2	29.09 GJ
Silo for ration (16 t)	405.00 t	25.43 GJ
Plastic blanket	17.66 kg	2.30 GJ
Water tank (15 m)	10.17 kg	1.32 GJ
Composter	0.90 m^2	1.09 GJ
PVC piping	1.35 kg	0.16 GJ
Transport wagon	0.90 kg	0.06 GJ

In the agriculture stage, the energy inputs and outputs depend on the area of cultivation. Using the criterion of phosphorus base (concentration of 2.95 kg m^{-3}), it was estimated that it would take 47.25 ha, for the application of the waste. Table 8 shows the balance of NPK macronutrients for the agriculture stage, based on the total production of these elements by the pigs in the three batches and the amount extracted by the maize in the two annual crops (10 t ha^{-1}). As the use of agricultural equipment and implements, these are presented in Table 9.

TABLE 8. NPK macronutrients balance of maize in a cultivation area of 47.25 ha in one year of production.

Nutrient	Provided by Swine Excrement	Nutrients Extracted by the Maize	Supplied by Chemical Fertilizer
Nitrogen	6,435.00kg	11,272.50 kg	4,837.50 kg
Phosphorus (P$_2$O$_5$)	5,100.98kg	5,100.98 kg	---
Potassium (K$_2$O)	4,306.50kg	9,153.00 kg	4,846.50 kg

TABLE 9. Energy associated to the depreciation of the equipment that composes the infrastructure of agriculture stage for a year of production in 47.25 ha area of cultivation.

Equipment	Time of Use	Depreciated Mass	Depreciated Energy
Tractor 85 cv	462.25 h	203.85 kg	14,235.00 MJ
Harvester 180 cv	68.51 h	56.11 kg	3,918.28 MJ
Pulverizer bar 2,000 L	77.96 h	55.43 kg	4,640.16 MJ
Wagon	56.70 h	10.21 kg	854.34 MJ
Distributor of corrective 1.2 m^3	5.91 h	0.58 kg	48.95 MJ
Planter 7 lines	75.60 h	19.73 kg	1,651.73 MJ
Distributor of liquid fertilizer	246.08 h	28.79 kg	1,646.87 MJ

Using the criterion of phosphorus base, the use of pig excrement to fertilize the maize planting provided 57% of the demand for nitrogen, 47% for potassium and 100% for phosphorus. Still, in the composition of the energetic matrix of the maize system, the fertilization remained the item with the largest representation in the non-renewable expenditures, with 52.9%. The nitrogen was responsible for 47.7% of the non-renewable energy inputs. This is due to the characteristics of

the maize, which requires large amounts of nitrogen and potassium for its cultivation. If the criterion applied was the nitrogen, there would be no spending on fertilizers. However, the phosphorus would be in excess in the system, with the possibility to contaminate the local ecosystem. Table 10 shows the relation of energy inputs of the agriculture stage for a production year.

TABLE 10. Energy inputs used at agriculture stage in one year of production, with 47.25 ha of planting area.

Item	Consumed/Depreciated Quantities	Energetic Equivalent
Renewable Inputs		
Solar radiation	472,500.00 m^2	7,087,500.00 MJ
Work force (man-hour)	1,059.96 h	62,766.90 MJ
Seeds	1,890.00 kg	498.18 MJ
Non-renewable Inputs		
Herbicide	784.35 kg	225,892.80 MJ
Insecticide	181.44 kg	43,001.28 MJ
Nitrogen	4,837.50 kg	353,137.50 MJ
Potassium	4,306.50 kg	38,758.50 MJ
Fuel	1,415.00 L	50,260.77 MJ
Calcareous	51.98 t	8.84 MJ
Equipments depreciation	---	29,602.86 MJ

The energy inputs of the agriculture stage totalized 7.9TJ, while the outputs were estimated at 7.8 TJ (on production of 472.5t of grain maize). Thus, the energetic efficiency of agriculture stage was 0.99. The efficiency of use of non-renewable energy was estimated at 10.53.

Regarding the protein production, this was estimated to be 37.33 t year^{-1}. Having as base a demand for non-renewable inputs of 740.66 GJ, it is obtained a non-renewable energetic cost of 13.33 MJ kg^{-1} to produce maize protein in integrated systems.

Table 11 shows the energetic matrix consolidated to the integrated system for a one-year production. In the integrated system, the energetic efficiency of the integrated system was evaluated in 0.6. The non-renewable efficiency was estimated at 2.89. The non-renewable cost of protein production was estimated to be 58.63 MJ kg^{-1}. Comparing the obtained results of the integrated system with the evaluated data for non-integrated pig farming, it is clear that the integration has greatly improved the energy performance of pig farms. With the integration, the energetic efficiency increased 186% non-renewable efficiency 352%. The cost of non-renewable energy for protein production was reduced 58%.

The results obtained in the simulations show the strong participation of two components: the pig ration (47.4%) and solar radiation (45.3%). The strong participation of the ration is because of the characteristics of the pig culture. The animals are confined. Thus, all the metabolic energy that the animal needs must be provided by rations. This fact justifies the strong participation of the ration in the energetic total expenditures integrated system. In non-confined creations, part of this energy could be supplied by non-commercial energetic sources. However, the contribution of solar radiation in the total expenditure of energy is due to a high demand for area by the system (47.45 ha). Although solar radiation is not a commercial input, its computation in total expenditure highlights the importance of the energetic matrix of the integrated system.

TABLE 11. Energetic matrix from integration between pig farming and maize cultivation for one year production.

Item	Energy	Participation
Energetics Inputs		
Pig Farming Stage	7,828.94 GJ	49.8%
Renewable	5,310.83 GJ	67.8%
Non-renewable	2,518.10 GJ	32.2%
Agriculture Stage	7,891.43 GJ	50.2%
Renewable	7,150.77 GJ	90.6%
Non-renewable	740.66 GJ	9.4%
Integrated System	15,720.36 GJ	100.0%
Renewable	12,461.60 GJ	79.3%
Non-renewable	3,258.77 GJ	20.7%
Energetics Outputs		
Pig Farming Stage	7,796.25 GJ	17.2%
Agriculture Stage	1,616.36 GJ	82.8%
Integrated System	9,412.61 GJ	100.0%

The annual maize production was estimated at 472.5 t. In the composition of the ration of pigs, this product represents 79% of the inputs used. Considering an annual consumption of ration in the order of 414 t, it was estimated that the demand for maize would be of 327 t year^{-1}. Thus, under normal conditions of crop, the integrated system would be self-sufficient in maize, getting to produce a surplus of 145 t year^{-1}. This surplus could be sold or used in other production processes of the property.

The consumption of protein in pig farming production was 58.00 t year^{-1}. The production was 55.72 t year^{-1}, being 34% of animal protein and 66% of vegetable origin. Thus, it was estimated that the integrated system would recycle 96% of the protein invested in the productive stage in the form of ration. However, we must consider that these results consider a full season without breaks of productivity. Any eventual environmental bad weather and/or deficient management of the system could compromise the results.

Furthermore, the ability of the cultures to recycle applied nutrients is fundamental to properly estimate the volume of waste to be applied. When the agricultural use is the only destination of these wastes, the availability of agricultural area becomes a limiting criterion of the number of animals that can be created on the property. Thus, a plan for the batch of pigs must be done to be appropriate to the agrarian reality of the pig farms.

The total area demanded by this integrated pig farming/agriculture system proposed was 47.45 ha. The pig producers who do not have this agricultural area on their properties should reduce the size of the batch of pigs or hire the remaining area with third parties. However, should be assessed the feasibility of exporting waste. The high dilution, common in most properties, makes this practice not viable.

The effectiveness of the integration in the energetic performance of the agroecosystems depends on the fulfillment of production criteria recommended in the technical scripts presented. Otherwise, may reduce the energetic performance, and make impracticable the application of this conception of production. In addition, there are restrictions on the implantation of integrated systems related to the fulfillment of the criteria of technical feasibility (availability of technology, water and farming areas) economic (market for generated products), licensing activities and management and operation of the systems.

CONCLUSIONS

The simulation of the energetic performance of the integrated system of maize production with pig farming proved to be efficient, increasing the energetic performance and reducing the environmental impacts of the agroecosystems. The swine manure could supply 57% of the demand for nitrogen, 47% for potassium and 100% of the phosphorus needs. Comparing the pig farming stage not integrated with the integrated system, it was found that the energetic efficiency increased by 186% and the non-renewable efficiency by 352%. Moreover the cost of non-renewable energy for protein production was reduced by 58%. Furthermore, with the integration, 96% of the protein invested in the agroecosystem in the form of ration could be recovered in the form of vegetable (grain maize) and animal (meat). It is noteworthy, however, the need to accordingly plan the size of the pig batch to be suitable for the availability of the agricultural area in the property.

ACKNOLEGMENTS

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