Evaluation of Crop System Considering Both Economic and Energy Aspects with Web Application: The Use of Slurry Digestate as a Fertilizer Vs. the Traditional Mineral Fertilization

Berruto R.[1], Busato P.[1]
[1]*University of Torino, DEIAFA*
Via L. Da Vinci, 44 – 10095 Grugliasco, ITALY.
Tel 0039 0116708596, Fax 011 2368596, remigio.berruto@unito.it

Abstract

The experimentation was carried out during three years (2007-2009). The use of machinery and all other technical means was recorded and loaded into a web application made by the authors (www.biomass4energy.eu). The application compute the costs based on real machinery use and fit very well the needs of all kinds of farms and sizes. Both economic and energy balance for a single crop are presented. For the analysis the slurry was computed just the cost of the distribution and no-value (both energetic and economic) was given to the fertilizer. Were considered two farms of 30 ha each. The distribution of slurry was considered ad 1,5 km distance.

The results showed important economic convenience to use the digestate from biogas plants even if this fertilizer should be balanced with mineral fertilizers.

The most important result was the energetic balance: the crop treated with slurry yield Input/output ratio on average of 13,1, while the conventional crops reached 7,04. The net energy value was 175 GJ/ha vs. 140 GJ/ha for the slurry treated plots vs. the conventional treatment.

The web application allow a fair comparison of traditional and biomass crops and it is useful to assess not just the traditional crops but also the biomass crops, considering both economic and energetic aspects.

Keywords: economic balance, energy balance, crop comparison, slurry digestate

Introduction

The spreading of biogas plants in piedmont region lead to experimentation of the use of digestate from biogas plants on cereal crops that represent the majority of the land cultivated in the North-West of Italy.

Producing and selling energy with biogas plant is a brand new scenario for farmers, where often the lack of reliable and complete information are not enough to carry out a correct economic and energetic analysis.

There is still a need of a standardized application to verify the viability of a crop system or purchase of machinery at farm level. The use of the web present many advantages toward the standardization of coefficients and procedures, providing low cost service for the farmers (Berruto and Busato, 2006).

The aim of the research is contributing to knowledge which can be exploited in designing and evaluating biomass supply chains involves particular crop systems, within a standardized system approach. The application compute the costs based on real machinery use and fit very well the needs of all kinds of farms and sizes. Both economic and energy balance for a single

crop are presented. This allow to compare the crops (e.g. cereals and biomass, corn and wheat, etc.) within the farm or groups of farmers.
The paper describes briefly the structure and the methodology used for the implementation of the WEB application and introduced a case study with two different cultivation scenarios, the use of slurry digestate as a fertilizer [BIOGAS] vs. the traditional mineral fertilization and adoption of rotation requested by PSR contribution scheme [PSR].

Methods

Implementation of the WEB application

The WEB application is made with the language Active Server Pages (ASP), connected to a database built with Microsoft® Access®. The multilingual (Italian and English) application could be accessed at: http://www.biomass4energy.eu.
The application consists of forms for data insertion and form for the presentation of the results. The access to the database is guaranteed in anonymous way (Berruto & Busato, 2006). The first phase concern the insertion of the following data: description of the farm; cultivated crops and their surface; tractors and equipments own by the farm; productive means prices (fertilizers, herbicides, pesticides, etc.).
During the second phase the user inserts the field operations. The logistic operations, such the transport of fertilizers and manure to the field, are considered separately from the traditional field work.
In the third phase the user could insert the sale of produce and other revenues, including the EU contribution and the cost for services paid by the farm (e.g. drying, grain harvesting, and irrigation expenses not related to agricultural equipment).
The database provide a list of machinery and tractors with all the coefficients needed for working time calculation which are the basics for the economic and energetic evaluation of machinery field work. Some of them were taken from agricultural mechanization books (Bodria et al., 2006; Hunt, 2001), while other come out of farm survey.
The application considered both direct (gas-oil) and indirect (chemicals, tractors and agricultural equipment) consumptions. The energy coefficients have been taken from different sources (Boehmel et al., 2008; Kitani et al., 1999; Nagy, 1999; Pimentel et al., 1999) and inserted in the database, so the user could compute the energy balance without the insertion of such coefficients.

Model Results

The results are showed both for single operation and for the crop.
The module with the results for the operation shows in detail: Working times for tractors and equipment (CIOSTA classification); Fuel consumption; Hourly cost for tractors and equipment; Unitary cost for the operation (€/ha); Unitary direct and indirect energy consumptions (MJ/ha).
For the crop, the application provides the following grouped results for both economic and energetic analysis: machinery cost; resource cost; extra-farm costs; total revenues; net income for the crop.

Case Study

Parameters and hypothesis for economic and energetic analysis

Two cropping systems were compared: BIOGAS and PSR, as described in the objective of the paper. For the two cropping systems compared was considered a farm area of 30 ha, with a four-year rotation crop. The technical-economic and energy calculations on a single crop are therefore reported to 7.5 ha. The field size was 2 ha (200x100 m) while the field distance was of 1,5 km.

We assume the operations were carried out with mechanical equipment owned by the farmer except for the harvest and drying of the product, carried out by contractors. The logistics operations were not considered in this analysis.

For both equipment and the inputs (herbicides, pesticides, fertilizers), were used as reference the prices of 2009. The prices of tractors and equipment were assumed as for a new purchase. The fuel has an average price of 0.62 € / kg in 2009.

The wheat straw was counted as sold on the ground, without baling operation, very expensive on small areas (7.5 ha). For the biogas slurry were calculated only the distribution costs and energy consumption for that operation.

For all crops was assumed the surface irrigation, with one intervention on sunflower, two on sorghum and three on corn (grain and silo). The cost of each operation was set at 80 €/ha (Berruto et al., 2009).

The times of use per year were calculated on the basis of the actual operations performed by a single machine or tractor.

The coefficients used in energy balance, converted into megajoules (MJ), were derived from the literature (1 tonne of oil equivalent = 41,868 MJ, according to International Energy Agency). The energy yield of sorghum and maize for silo was calculated using the energy contained in the methane produced before its conversion into electricity. The costs of labor and the rent of the land were not calculated and therefore form part of gross profits.

Results

The BIOGAS cropping system

<u>Technical and economic aspects</u>

At current market prices, biomass production allows higher incomes than cereals and oilseeds. This is particularly evident for sorghum characterized by increased production, lower cost of cultivation and higher MC than maize (26% DM versus 32% DM for corn silo), with no corresponding reduction in the price of the sale product . The gross margins were positive for all crops, because of less cost of fertilizers. Without PAC and PSR contribution, just the biomass crops present positive figures (Table 1).

<u>Energetic aspects</u>

All crops showed an output / input ratio exceeding 10. This is mainly due to lack of use of chemical fertilizers. The major energy inputs are associated with the consumption of diesel and corn herbicides. The balance of net energy per hectare of maize and sorghum biomass was respectively 4.88 and 5.28 toe/ha (Table 2).

Table 1. Economic balance for the BIOGAS cropping system.
All item are expressed in €/ha

Parameters	Wheat		Sorghum		Corn grain		Corn silo	
	Costs	Revenues	Costs	Revenues	Costs	Revenues	Costs	Revenues
Operation (equipment) cost	-415,42		-448,16		-508,12		-509,19	
Technical means	-150,62		-23,77		-454,85		-453,52	
Services	-359,73		-582,00		-608,93		-662,00	
Total	-925,77		-1053,93		-1571,90		-1624,71	
PAC contribution		292,53		292,53		292,53		292,53
PSR contribution								
Product sale		836,53		2452,48		1338,13		1800,40
Total revenues		1129,06		2745,01		1630,66		2092,93
Gross profit with contribution		203,29		1691,08		58,76		468,22
Gross profit without contribution		-89,24		1398,55		-233,77		175,69

Table 2. Energetic balance for the BIOGAS cropping system. All item are expressed in MJ/ ha

Parameters	Wheat		Sorghum		Corn grain		Corn silo	
	Input	Output	Input	Output	Input	Output	Input	Output
Fuel	-4.973		-5.767		-5.655		-5.871	
Tractors	-1.417		-1.402		-1.601		-1.583	
Equipments	-863		-906		-1210		-974	
Fertilizers	0		0		0		0	
Herbicides	-369		-590		-2.360		-2.360	
Pesticides, etc.	0		0		0		0	
Seed	-3.233		-94		-419		-419	
Technical input (total)	-3.619		-697		-2.798		-2.801	
Service input (total)	-1.634		-3.794		-3.326		-4.186	
Energetic input (total)	-12.506		-12.566		-14.590		-15.415	
Energy output (total)		139.886		233.752		163.561		219.649
Net Energy (MJ/ha)		**127.377**		**221.184**		**148.972**		**204.237**
Net Energy (toe/ha)		3,04		5,28		3,56		4,88
Output / Input ratio		**11,18**		**18,6**		**11,21**		**14,25**

The PSR cropping system

Technical and economic aspects

Because of low production and high costs, corn (grain production) presented a profit per hectare lower than other crops. Among the costs, the irrigation is very expensive with 3 interventions (240 € / ha). The cultivation of sunflower and maize, in the absence of PAC contributions, result in a loss. The profitability of the sunflower is a valid alternative to corn grain in areas with water shortages. The good production of rapeseed has enabled gains comparable with wheat. These two winter crops, showed good production with less cost and so presents the best results (Table 3).

Table 3. Economic balance for the PSR cropping system.
All item are expressed in €/ha

Parameters	Rape seed		Wheat		Sunflower		Corn grain	
	Costs	Revenues	Costs	Revenues	Costs	Revenues	Costs	Revenues
Operation (equipment) cost	-396,82		-429,89		-372,36		-509,58	
Technical means	-224,02		-334,04		-283,71		-673,60	
Services	-367,60		-359,73		-447,60		-837,87	
Total cost	-988,44		-1123,66		-1103,67		-2021,05	
PAC contribution		292,53		292,53		292,53		292,53
PSR contribution		120,00		120,00		120,00		120,00
Product sale		1097,60		1247,74		947,20		1707,33
Total revenues		1510,13		1660,27		1359,73		2119,86
Gross profit with contribution		521,69		536,61		256,06		98,81
Gross profit without contribution		109,16		124,08		-156,47		-313,72

Table 4. Energetic balance for the PSR cropping system.
All item are expressed in MJ/ ha

Parameters	Rape seed		Wheat		Sunflower		Corn grain	
	Input	Output	Input	Output	Input	Output	Input	Output
Fuel	-6.209		-6.883		-4.466		-5.490	
Tractors	-1.258		-1.375		-1.372		-1.790	
Equipments	-845		-873		-674		-1.136	
Fertilizers	-8.331		-10.297		-6.374		-14.336	
Herbicides	-590		-369		-1.475		-2.360	
Pesticides, funcicides	0		0		0		0	
Seed	-101		-3.233		-48		-419	
Technical input (total)	-9.022		-13.900		-7.896		-17.115	
Service input (total)	-1.763		-1.634		-2.155		-11.541	
Energetic input (total)	-19.097		-24.665		-16.563		-37.072	
Energy output (total)		124.578		204.949		125.425		208.689
Net Energy (MJ/ha)		**105.486**		**180.291**		**108.868**		**171.621**
Net Energy (toe/ha)		2,52		4,31		2,60		4,10
Output / Input ratio		**6,53**		**8,31**		**7,58**		**5,63**

<u>Energetic aspects</u>
For the PSR cropping system was clear the impact of fertilizers and herbicides on summer crops. In particular, maize has requested an energy twice as oilseeds and 50% higher against the wheat. The oilseed crops yielded net energy per hectare respectively of 2.52 and 2.65 toe/ha for rapeseed and sunflower, about half of that produced from corn and sorghum for biomass in the BIOGAS cropping system (Table 4).

Conclusion

Comparison of the two cropping systems

The net energy expresses the efficiency with which the crop use the soil resource. The BIOGAS cropping system allowed to produce 4.38 toe/ha and is therefore the most interesting at the moment, in the presence of water availability. In contrast, in the absence of biogas plant nearby the PSR cropping system is ensuring good average profit per hectare with a production of net energy of 3.38 toe/ha (Table 5).

Biomass production for BIOGAS plant

BIOGAS cropping system enables the best returns in economic and energetic terms, as at present the price of biomass is high, and so are the yields. This is the only system that has a cost of production per dollar of value produced less than 1. The convenience of using such a path is linked to water availability and proximity of plots to a biogas plant, which would reduce transport distances of biomass and waste products, thereby reducing time, cost and energy consumption related to logistics operations.

Where to plant oilseed crops

In the absence of nearby plants involved in the use of biomass is well suggest the use of the PSR – traditional cropping system. In the case it is difficult to practice irrigation, the farmer should carefully evaluate the convenience to produce oilseeds as summer crop. In particular, the sunflower is favored by using less water and thus lower the incidence of irrigation on operating costs and energy consumption.

Table 5. Overall comparative indexes of the two cropping systems

Parametri	BIOGAS	PSR
Gross margin (€/ha)	605	353
Ratio (PAC+PSR)/ha	293	413
Ratio Gross margin/(PAC+PSR)	2,07	0,86
Production cost ratio €/€Plv	0,81	1,13
Revenues PLV/ha (€/ha)	1607	1250
Net Energy value (MJ/ha)	175.443	141.567
Net Energy value (toe/ha)	4,19	3,38
Rapporto Output/Input	13,81	7,01

Importance of irrigation on production costs

The irrigation technique accounts for a major technical and economic aspects and energy. The implementation costs of irrigation are different depending on the systems used, although in many cases the water is not paid. They vary from 100 to 200 €/ha for surface methods to 520 €/ha with sprinkler. The irrigation with pivot costs about 250 €/ha, slightly more than some surface methods. It is obvious that choosing one or another cropping system should take into account also these aspects. More detail on irrigation costs and influence on energy balance could be seen in a specific publication on this issue (Berruto et al., 2009).

Logistic considerations

The economic and energy balances must also consider the impact of logistics operations, which is specific to each farm and is a function of the field distance from the farm. In particular, crops with high biomass production per unit, such as the silo of sorghum and maize, have high energy and transport costs when the distance is increasing. Results of testing performed by DEIAFA (Source: Project "Optimization of logistics sites of collection and transportation of biomass and waste for the biogas plants - Piedmont Region), indicate that the cost of the operation varies from 22 €/ha at a distance of 1 km to 181 €/ha about 10 km, up to 386 €/ha for 20 km. Depending on the distance of plots from the plant the gross profit may be, therefore, subject to large variations. The same issue apply for the distribution of slurry to be used for cultivation. The convenience to their use, compared with the use of mineral fertilizers, is limited to a radius of 10 km.

Acknowledgements

Support for this research was provided by a Grant "La sostenibilità agronomica, economica, energetica ed ambientale dei sistemi colturali erbacei" financed by Regione Piemonte Council, Italy.

References

Berruto, R. & Busato, P. (2006). EnergyFarm: Web Application to Compare Crop Systems Under Technical, Economic and Energetic Aspects. In *4th World Congress on Computers in Agriculture and Natural Resources*, ed. J. X. F. S. Zazueta, S. Ninomiya, G. Schiefer, Vol. I, American Society of Agricultural and Biological Engineers. Orlando, Florida USA, pp. 481-487.

Berruto, R., Busato, P. & Piccarolo, P. (2009). Economic and Energetic Analysis of Crop Systems Management Techniques by Means of WEB Application. In *XXXIII CIOSTA-CIGR V Technology and management to ensure sustainable agriculture, agro-systems, forestry and safety*, ed. G. G. G. Zimbalatti, Vol. I. Reggio Calabria, Italy, pp. 1093-1097.

Bodria, L., Pellizzi, G. & Piccarolo, P. (2006). *Meccanica agraria, volume II: la meccanizzazione*. Edagricole, Bologna.

Boehmel, C., Lewandowski, I. & Claupein, W. (2008). Comparing annual and perennial energy cropping systems with different management intensities. *Agricultural Systems*, **96**(1/3), 224-236.

Hunt, D. (2001). Farm power and machinery management, Vol. I, IOWA University Press, pp. 77-93.

Kitani, O., Jungbluth, T., Peart, R. M. & Ramdani, A. (1999). Energetic analysis coefficients. In *CIGR Handbook of Agricultural Engineers*

Vol. V, pp. 13-39.

Nagy, C. (1999). Energy coefficient for agriculture inputs in Western Canada. *CAEEDAC report*.

Pimentel, D., Pimentel, M. & Karpenstein, M. (1999). Energy use in agriculture: an overview. In *CIGR E-journal,* Vol. 1, pp. pdf file.