BIOENERGY FARM PROJECT: ECONOMIC AND ENERGY ANALYSIS OF BIOMASS BY WEB APPLICATION

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ABSTRACT

Agriculture faces new and rapidly changes: increasing cost of technical means for production, new machinery and new crops (e.g. biomass crops), new low-input techniques, EU policies and contribution. On the other hand new information is requested by the market or by public agencies: energy balance and life cycle analysis of crop cultivation, labor budget, etc. This situation challenges the farmers, which need standard data and procedures in order to compare the cultivation systems, and to make all the requested assessment. The aim of the research is contributing to knowledge which can be exploited in designing and evaluating biomass production system, within a standardized system approach. An IEE project, named Bioenergy Farm (IEE Contract N°: IEE/09/637 SI2.558213), has been financed with this aim. The proposed WEB application, developed with ASP.NET® technology with a SQL server database within the frame of the IEE Project Bioenergy Farm allow the user, in anonymous way, to compute its own crop cultivation costs, including the use of machinery, manpower, and production factors in order to compare different biomass production systems. In this way a single farmer or a consultant could compare crop performance in different situation, farmer performance from one year to the next and so on. The application represents a step toward the standardization of data and calculation procedures for working time, energy balance and operation costs assessment. The comparison can be carried out among farmers in different EU states. The interface to the application is provided in English, Italian, Polish, German, Nederland, Estonian and French languages. The data provided are general (to allow comparison of scenarios between biomass production processes within the EU) but there is also a local dataset that allows the user to do calculation with country specific data (e.g. yield range, fuel cost, energy coefficients and so on). The application also allows detailing the type of field where the cultivation takes place (different yield, irrigation type, field shapes and distances). In this way the user could compute average or field specific performance of its farming activities. The short rotation forestry and the forestry activities are integrated into the web application as well.

Keywords: Agroenergy farm, sustainability, energy balance, biomass production.
1 INTRODUCTION

In order to assess the feasibility of a biomass supply chain, it is important to consider the biomass availability and logistic costs.

The logistic costs consider the distance for transporting the biomass and the energy/volume ratio of the product. In the short supply chain, agricultural equipment is often used for harvesting and transporting biomass. When farmers perform these activities involving the biomass supply independently, these costs are often not computed. However, farm managers, consultants, and others who manage machinery use equipment capacity information for estimating costs and selecting adequate machinery for completing field operations within the time available. As new technology and information become available, a periodic study of on-farm activities is required in order to maintain current and useful information (Harrigan 2003).

Also, the technical coefficients related to biomass energy content are far out of reach for farmers or people who want to start business in the field of biomass energy production. Data is included in publications which those who are outside the academic and research domain will not have easy access to. Hence, there is need for a standardized tool for assessing feasibility study - this includes the use of common input data and evaluation procedures in order to ensure uniformity, which in turn is a guarantee of the quality of the assessment (Boehmel, Lewandowski et al. 2008).

The use of the web presents many advantages toward the standardization of coefficients and procedures while providing low cost service for the farmers (Berruto and Busato 2006; Berruto, Busato et al. 2008; Berruto and Busato 2010).

The aim of this research is to contribute towards the dissemination of knowledge and information which can be exploited by designing and evaluating biomass supply chains within a standardized system approach. The implementation of a web application that allows for the computation of technical, economic and energetic indexes relative to biomass supply chains is a step toward this objective. An IEE project, named Bioenergy Farm (IEE Contract N°: IEE/09/637 SI2.558213), has been financed to achieve this goal.

2 WEB APPLICATION FOR THE ASSESSMENT OF BIOMASS PRODUCTION AND LOGISTICS

The Multilanguage web application (www.bioresource4energy.eu, available through www.bioenergyfarm.eu), developed with asp.net® and MVC technology by the authors at DEIAFA - University of Turin, Italy, allows the user to compare biomass supply chains under economic and energetic aspects, for a single biomass crop.

The idea behind this tool is to provide a simple way to compute biomass costs and energetic balance without needing to insert the entire farm business plan. All the coefficients relative to tractor and machinery use are already included in the database (e.g. maintenance, fuel consumption, machinery lifetime, machinery depreciation rate, etc.). The energetic coefficients for both technical means (fertilizers, chemical, seed, etc.) and biomass are also provided by the system (Berruto and Busato 2008).

The web application is made up of forms in which users may insert their data, and output procedures to visualize the results. The interface is provided in seven languages (Italian, Nederland, Estonian, English, German, Polish, and French) and access to the
database is completely anonymous. Some data is common for the entire farm (general parameters, technical means, tractors and equipment), while others are specific for each crop (operations, use of technical means, extra costs and revenues).

2.1 User management and help content

Questo In order to manage their own data, the users need to register. The information provided is limited to username, password, email and language interface for the application. There is no check on the data inserted into the profile. In this way the anonymous insertion of data is guaranteed.

2.2 General farm data

In this form the user has to insert some info about the farm, the interest rate, the fuel price and the currency used. The currency is selected on the farm general data, in order to allow a consultant to manage different farms around the world, and thus using different currencies. In the report both the user currency and the EURO are displayed for comparison. These parameters will be used consistently through the evaluation of different crops and operations within the same farm.

2.3 Fieldgroup definition

Farm fields are characterized by different shapes, sizes, and distance from the farm or from the biomass conversion plant.

In order to allow the user to define with a great level of detail his farm, the operations are computed on a crop cultivated on a single fieldgroup. The fieldgroup represent, with a low level of detail, the average farm field, distance, etc. or, at high level of detail, the single field plot with his distances, field size, and irrigation method used.

It is also possible to insert some remarks/comments that describe the fieldgroup. In this way it is up to the user implement a detailed or summary analysis of his cropping system.

Figure 1: Fieldgroup characteristics
The distance presented in Fig. 1 represents the fieldgroup distance from the farm. The traveling speed here defines the transfer speed for field operations, while the speed for logistic operation will be requested into the form related to logistic operations.

2.4 Crop definition

Each crop has to be inserted along with the definition of the area cultivated within the farm since this data is used as reference for all the calculations. This application deals with annual and perennial crops, including forestry. To specify a multi-year crop, the user should specify in the form fieldgroup x crop to which year is referred the cultivation, and at which distance is located the biomass conversion plant (see Fig. 2). While adding logistic operations, the user could choose among farm distance or plant distance to compute the logistic operation working times and costs.

![Figure 2: fieldgroupxcrop characteristics.](image)

The rotation year allows great detail in year-by-year economic and energetic evaluations. In the case of multi-year crops, a multi-year economic and energetic balance is done by using a special result page where the results are presented not per crop but per crop cultivated on a single fieldgroup.

2.5 Tractors and equipment insertion

The tractors and equipment owned by the farm must be inserted prior to defining the field and logistic operations. For the equipment, the user has to insert some main characteristics necessary to compute the operations, like working width, purchase value, and hours spent doing other operations.

The required data for a single machine are the description, the year of purchase, the cost of the new machinery, and the manpower. The hopper capacity (up to 4 hoppers available) is required just for the machine type that is used to spread fertilizers or other productive means (e.g. herbicides, etc.).

2.6 Field and logistic operations data

For field operations the user has to insert the working width, working speed, as well as the tractor and the equipment used. Here the total crop area as specified in the general farm data if used as default. If this is not the case, users should provide the area in which operations are carried out. The number of people involved into the operation and the labor coefficient allows to compute accurately the manpower cost and working time.
Figure 3: Data required for field operation definition

For operations that include the distribution of fertilizers, the Resources tab is also active and the user can define the amount distributed (e.g., mineral fertilizer per ha and so on). Similarly, for the logistic operation, there are some data to be inserted (Fig 4).

Figure 4: Logistic operations form

The logistic parameters to be specified are the following: total amount carried by the operation (e.g., total corn silos used at the farm), quantity carried per cycle, and the working times for tractors and other equipment. The working times refer specifically to the quantity carried by each cycle: loading and unloading time in the field, loading and unloading time at the farm and transport time, based on transport speed.

Estimating the logistic operation working times and costs is a complex task because this process involves the participation by a system of machines.
Recent advances in computational tools have made it possible to build simulation models for the analysis of complex supply systems in a more detailed way (Busato, Berruto et al. 2005; Sokhansanj, Amit et al. 2006; Busato and Berruto 2007; Busato and Berruto 2008). The results of the simulation (working times) could be used as input in the logistic operation form.

2.7 Extra-farm factors and gross income data

Other costs such as land rent, water irrigation, taxes and services (harvesting, drying operation, accounting, etc.) refer to the entire field group x crop area and must be inserted separately for each crop. Finally, farm revenue is calculated by inserting the total quantity sold for each product separately (e.g. grain and straw from wheat). It is also possible to specify cultivation subsidies (e.g. EU contribution, national and regional contributions, and so on).

2.8 Partial insertion of parameters on a single crop

The insertion of data may also be partial if the user is only interested in partial results. For example, if the user only wants to assess machinery costs, only general data, tractors, machinery, field and logistic operations may be inserted. In this case the gross margin and the output input ratio could not be computed.

2.9 Equipment working times and mechanical operation costs

The variation of mechanical operations costs is greatly dependent on farm size, field size, distance from the farm, and other factors such as yield and timeliness. The summation of the working times for field and logistic operations gives an exact figure for machinery and tractor use per year. This number allows users both to determine the duration of the tractors and equipment and to compute detailed fixed and operation costs (Piccarolo 1989).

The introduction of a new crop or the use of new equipment involves the recalculation of the unitary cost of all the operations that have some link with the machine and tractor that carry the operation

2.10 Energy coefficients

The authors have considered both direct and indirect consumption for the energy balance.

The energy coefficients - machinery, fertilizers, and chemicals - have been taken from different sources (Nagy 1999; Pimentel, Pimentel et al. 1999). Coefficients were then inserted into the database, allowing the application to calculate all the inputs and outputs for each crop, without requesting the manual insertion of these parameters by the user.

However, the user may provide or change parameters for products or equipment not already included in the database. The standardization of these coefficients is a key point that will allow different users to compare their results with those of other biomass supply chains already in the database.

The energy expense for tractors and other equipment is calculated as a function of their usable machine lifetime and yearly use of the equipment (Berruto and Busato 2006).
2.11 Economic and energetic indexes

The results are given for each crop.

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount (€/ha)</th>
<th>Amount (£/ha)</th>
<th>Energy amount (MJ/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeding</td>
<td>5.28</td>
<td>5.26</td>
<td>825.3</td>
</tr>
<tr>
<td>Fertilizing</td>
<td>6.29</td>
<td>6.13</td>
<td>450.9</td>
</tr>
<tr>
<td>Harvesting</td>
<td>20.63</td>
<td>21.12</td>
<td>786.0</td>
</tr>
<tr>
<td>Handling and Transport</td>
<td>17.52</td>
<td>17.53</td>
<td>422.0</td>
</tr>
<tr>
<td>Driving</td>
<td>10.87</td>
<td>11.02</td>
<td>165.0</td>
</tr>
<tr>
<td>Maintenance</td>
<td>15.23</td>
<td>15.60</td>
<td>145.0</td>
</tr>
<tr>
<td>Productivity</td>
<td>5.98</td>
<td>5.68</td>
<td>115.6</td>
</tr>
<tr>
<td>Profitability</td>
<td>6.11</td>
<td>5.90</td>
<td>96.4</td>
</tr>
</tbody>
</table>

**Fig. 5:** Economic and energetic balance for crop production.

The outputs for the mechanical operation are shown in detail:
- working times for tractors and equipment;
- hours of use of the machine (h.year⁻¹);
- hourly cost (€.hour⁻¹) for tractors and equipment, visible in tractors and equipment form;
- unitary cost for the operation (user defined currency and €.ha⁻¹);
- unitary energy consumption (MJ.ha⁻¹).

The energy consumptions are then divided into categories and added in order to compute the total energy inputs.

An example of the crop cultivation result can be seen in Fig. 5. It refers to a corn silo crop cultivated in a 50 ha area. The outputs related to the crop are presented in the following categories:
- cost of equipment use and field/logistic operations;
- cost of use of fertilizers, herbicides, etc.;
- other costs including extra-farm costs (e.g. contractors, irrigation costs, land leasing and so on);
- product sales (corn grain, wheat, straw, etc.);
- energy balance for each crop;
- total gross income and net income for the crop;
Conclusion

The web-based application, developed with asp.net® and MVC technology, allows the user to compare different farming systems and machinery performances, under technical, economic and energetic point of view.

The use of the web to run the application has the following advantages:
- standardization of the results obtained through the same method of calculation and with the same energy coefficients;
- comparison of studies carried in different condition and location, made possible because of the same energetic coefficients;
- free availability of standard data on biomass characteristics (Low Heating Value, moisture content, density, etc.) for non-expert users;
- no need for installation and distribution costs for the software and the updates since the application resides only in one server;
- possibility to make scenarios in order to compare different techniques and biomass in term of energy balance and net return for the enterprise;
- availability of a lot of samples already into the web, made by the authors;
- possibility to compare in anonymous way farms and crops within different EU countries and the world.

The ability to compute the logistic costs and energetic balance of crops is both a unique feature of the web tool as well as a knowledge base for further development of the application.

The tool also allows managing short rotation forestry crops and forestry crops. All the farm activities related to these crops are inserted in the same application, so the user could see the impact of different scenarios and biomass crops on his farm profitability.

The application is offered in seven languages: Italian, English, French, Estonian, German, Polish and Nederland; however the multi-lingual project has been developed to easily implement other languages. In order to provide comparison of the results the calculation are computed both in EURO and in the currency chosen by the user. In this way will be easy to compare the economic results from users all over the world and consultants could also compare crop results and farm results from different countries.

References


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