A Web-based Spatial DSS for estimating biomass-to-energy supply in Thessaly[#]

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ABSTRACT

Biomass-to-energy projects have become attractive these days because of recent European policy measures that attempt to address acute environmental, agricultural and energy challenges accumulated during the last 30 years. Bio-energy issues constitute spatially dependent problems by definition due to the state-of-the-art technology and the bulky nature of biomass. Moreover, biomass profitability is linked to the structure and perspectives of the arable cropping systems since these are able to supply considerable quantities in the short and medium term required to fulfil the ambitious targets aimed at by policy makers. Therefore, appropriate tools are necessary to enable a comprehensive analysis and support decisions of policy makers, industry, researchers and farmers. Spatial Decision Support Systems that have been developed to support bio-energy decisions are used as a basis enhanced by a web-based interface, in this exercise resulting in a Web-SDSS. This tool is implemented in Thessaly, the most significant arable cropping region in Greece, in order to evaluate selected energy crop supply. The methodology and architecture of this tool are detailed in this paper, followed by an illustrative description of its operational version implemented in ex-tobacco producing areas.

Keywords: Web-based SDSS, Mathematical Programming, Agriculture, Energy crops, Thessaly

INTRODUCTION

Rising trends and volatility of fossil fuel prices coupled with a reduction policy for greenhouse gases created momentum for **biomass** in Europe as a **renewable energy source**. Various directives have been decreed and an ambitious bio-energy policy has been implemented since 2004. Moreover, the **Common Agricultural Policy** (C.A.P.) 2003 reform that **decoupled payments**, eliminating crop earmarked subsidies, has decreased opportunity costs for alternative crops. Particularly in Greece where the 1992 MacSharry[i] reform set-aside land was not applicable, it is the first time when energy crops seem to have become competitive against staple crops such as cotton and tobacco. Raw material cost is an important part of bio-energy products reaching more than 50% of the total cost thus a decrease in energy crops opportunity cost significantly affects the competitiveness

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of bio-energy. This hypothesis is confirmed in Thessaly by Lychnaras and Rozakis (2006) who have estimated regional supply of biomass for perennial plantations using analytical techniques such as **mathematical programming** (MP) and farm statistics (European Farm Accounting Data Network). Lacking spatial information, their results had limited value for decision makers regarding site-dependent bio-energy projects. As a matter of fact, with the exception of sunflower for biodiesel comprising a few hundred contracts, no bio-energy chain is operating in Thessaly. Therefore, it is very important for potential investors to have available information on raw materials cost.

For this purpose, a SDSS decision-making tool that contains optimisation models fed by technical, economic, and cartographic information has been built to provide stakeholders with region specific biomass-to-energy supply information. Energy to biomass raw material cost is provided in **supply curve** form incorporating physical land suitability for crops (survey and spatial information), farm structure (survey) and policy scenarios (new CAP specification in the model). Therefore, it is suitable for assisting in the evaluation of biomass-to-energy penetration into existing agricultural systems. Optimisation software (GAMS) is embedded in a **GIS** environment allowing for an interactive process in real time. A web-based interface built in open source software makes the **SDSS** tool available for collaborative decision-making.

A case-study explores potential supply of selected energy crops by arable farms in the Karditsa area, exploiting survey and spatial data. Numerous farms, geographically dispersed, decide maximizing gross margin, whether or not to introduce energy crops, namely sunflower, cynara and sorghum in their crop mix using crop suitability maps. **Mathematical programming** models of 70 representative farms are articulated and parametric optimization is used to generate supply curves for the energy crops at the regional level. The tool operates on the Internet[ii] where the user can have full access to the data-set, enter selected parameters into the model, and enables spatial visualisation and exploration of the results, enhancing interactivity in the decision process. The architecture and the task organisation among optimisation, simulation and software are illustrated in this paper and preliminary results are discussed.

FROM CLASSIC GIS TO WEB-SDSS: OVERVIEW AND APPLICATIONS RELATED TO AGRICULTURE

Evolution and state-of-the-art

Geographic Information Systems (GIS) have been applied to map biomass potential in forestry, industrial, agricultural or livestock residues and also have been used extensively since the eighties in numerous bio-energy studies. For example, a system model for estimating short rotation woody biomass production, harvesting and transport costs was developed and applied to a Hawaiian island, with GIS interfaced with the model to present results in cartographic form (Liu, 1992). More ambitious works have attempted to assist bio-energy policy at the national level by providing policy makers with quantitative economic and environmental information on the potential supply of energy crops in the UK (Cole et al., 1996), and the US (Graham et al., 2000).

While GIS can capture geographic variation which affects biomass cost and supply, they are effectively limited to deterministic analyses in spatial search. They can become a valuable tool when complemented by optimisation models or by Decision Support Systems (DSS), as they can exploit spatial data and also efficiently avail the model output. Limitations of decision models lying in their inability to exploit spatial data can be overcome when articulated in a GIS environment. The graphical representation of results can contribute by visualising the work of the decision maker and thus facilitate dialogue and debate. The integration of spatial and analytical models has brought about a new type of DSS known as **Spatial DSS** (SDSS). SDSS as defined by Sugumaran & Sugumaran (2005) are "flexibly integrated systems built on a GIS platform to deal with spatial data and manipulations, along with an analysis module ... they support 'what if' analysis ... and help the user in understanding the results". Although highly appealing, SDSS based on traditional GIS require sophisticated hardware and capital intensive resources, and these limitations hindered their adoption. With the development of the internet, Web-based SDSS have been developed, adding Internet interface programs to the computational models and geographic databases of the SDSS, in order to provide geographic information and decision support through the Web.

Web-SDSS may apply either client-side or server-side processing. The former approach identifies to a "thick" client in which GIS is downloaded on the end user computer and only the geographic data are retrieved through the web. It is certainly less resource-demanding than stand-alone SDSS based on traditional GIS, while offering standard menus and control buttons, and allows the developer diffusing applications while maintaining control over the data. On the other hand, under the server-side processing approach the end user operates their machine as a simple browser, having access to decision models and data provided by the remote server, then proceeds to tasks such as map display, queries to spatial or non-spatial databases, model execution and development of reports.

The progress in **Web-based decision support** technologies has been recently described by Bhargava et al. (2007) in a special issue of the Decision Support Systems journal, and distinguishes between model-driven and data-driven DSS to provide an impressive list of systems for decision support using the web as a medium (stand-alone commercial applications) or as a computer (web-DSS or web-SDSS). Most applications concern business decision support, some deal with environmental issues involving also multi-criteria models[iii], but only a few are related to agriculture. A tool for Decision Analysis specialises in cow culling choices via the Internet (thin client or server based) and a region specific (Iowa, US) SDSS called Agri-FACT, assisting the farmer to decide among cropping systems using agronomic research, are briefly presented below. Another two related applications are not further analysed: The first supports decision on the distribution of area of two agricultural zones among production technologies taking into account environmental considerations is developed by Lotov (1998). It is a stylized model illustrated by a cartographic picture –thus, there is no GIS behind it- aiming at diffusing The concept of decision maps. The decision process consists in graphically displaying trade-offs in cases of three or more objectives by exploiting altitudinal map techniques. The second one concerns a model-driven DSS developed by Grazing Systems Ltd. classified by Bhargava et al. (2007) in the optimization tools category, that offers decision support services in the agricultural sector, is not currently available in the web.

An interactive Decision Support System currently available on the web provides recommended culling decisions generated by a model (Cow Culling DSS, 2009). The model considers biological factors, market factors, costs of production, management alternatives, joint consideration of biological and market factors, the value of pregnancy testing and management of herd composition. It can be used as an extension instrument whose purpose is to provide ranchers with pertinent information on cow culling decisions.

Agri-FACTs is a web based GIS application that was developed as a coarse level decision support for farmers within the central Great Plains region in the U.S. to analyze alternative cropping systems for their farms (Vernon, 1999). It integrates agro-ecozone modeling with cropping systems research and is made available to the farmer with ArcView IMS and an easy to use graphical user interface, so identifies to "thick" client approach. Agro-ecological factors such as soil quality and weather related risks affect the suitability of a particular field for alternative cropping practices. This type of research information is typically unavailable to a farmer, but may greatly assist them in decision making regarding implementing alternative cropping systems on their farms.

DECISION SUPPORT RELATED TO BIO-ENERGY

Technical choices and past work

Concerning the estimation of **biomass supply**, this represents a much more complex and burdensome problem than the ones mentioned in the previous paragraphs, necessitating sector model aggregating numerous decentralised decision-making units (farms) and drilling information from detailed land suitability maps of a large region. Furthermore, biomass transformation to energy may be included in the analysis when the system assists in decision regarding location and size of bio-energy generating plants. It is a typical multi-criteria multi-stakeholder problem. Coupling GIS software to the multi-farm models[iv] is undertaken, thus constructing a Spatial DDS. Attempting to classify GIS – optimisation models Laaribi (2000) points out three modes of physical integration:

a. First integration level: GIS and optimisation software are independent; optimisation analysis assisted by GIS but it is non-interactive and inconvenient in use.
b. Second integration level: GIS and optimisation software is still independent but only one interface is used, that of GIS software. Interactivity is enhanced but it is limited to pre-designed capacities (data export import concerns only certain categories, parameters to determine are predefined by the designer).
c. Complete integration: unique software able to perform not only spatial analysis and database management but also optimisation and optimisation analysis.

According to the above distinction the tool described in this paper identifies to the second integration level where a unique interface accommodates all operations.

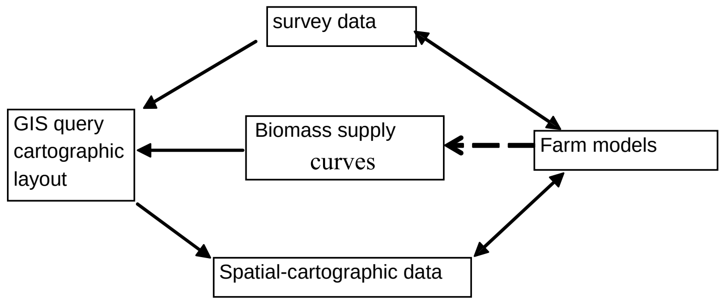

Figure 1. GIS – optimisation models integration and data flows

Relevant work undertaken by teams coordinated by the author started a decade ago in the context of the European research projects (Saez et al., 2004) within the framework of ALTENER programme (EU program to fund research and pilot applications of Renewable Energy Sources) evolving from a static SDSS on bio-energy **multi-criteria decision-making** (Rozakis et al., 2001), via a thick client ARC-IMS web-SDSS (Rozakis et al., 2002) to the web-SDSS using open GIS implemented for a site-selection bio-electricity problem in Farsala, Thessaly (Boretos & Rozakis, 2006) and the **thin client** current system. Thus, the thin client server-sided approach used by the current application is considered more appropriate to bio-energy related decision support systems, better responding to challenges pointed out in Web-SDSS literature. These can be grouped in technical, economic and social & behavioural, more concretely concerning system performance, technical integration, interoperability, security and privacy as well as quality of service.

SDDS Architecture and interface design

The basic series of steps of the proposed Web GIS/DSS is as follows:

- the user creates an input form and submits it to the web server
- the Web server passes the arguments to an external program or script that executes the DSS model.
- The external process runs the DSS and passes the results and control to the Map server.
- The Map server modifies spatial attributes and features based on the model's results, and runs any additional spatial analysis requested.
- The Map server creates the necessary map and translates it to a bitmapped file, usually a GIF or a JPEG file and passes it back to the web server.
- The Web server returns the image and results back to the user's browser using HTML.

Thus the logic of the tool is: to use the cartographic and statistical information then exploit economic data and crop productivity maps maximising farm gross margins to estimate biomass supply. The interface that illustrates spatial features of the optimal solution is presented in figure 2, with the optimisation model command menu in the left and the GIS explorer of available layers and query tables in the right.

Operations available in the screen are:

Scenario selection and model command section: The user can build the scenario to be tested selecting values of input parameters of the mathematical programming model and execute it. Then an optimal solution can be visualized in tabular, graphical forms. Results with a spatial dimension are incorporated in the spatial database.

Map visualization screen: In the middle of the screen selected layers and maps of the region can be retrieved.

Geographical Information Access section: The user may explore the map layers and perform spatial and attribute queries. Basic functionalities of GIS are made available in this section, in order to facilitate exploration of the region of interest and visualization of optimization model spatial output.

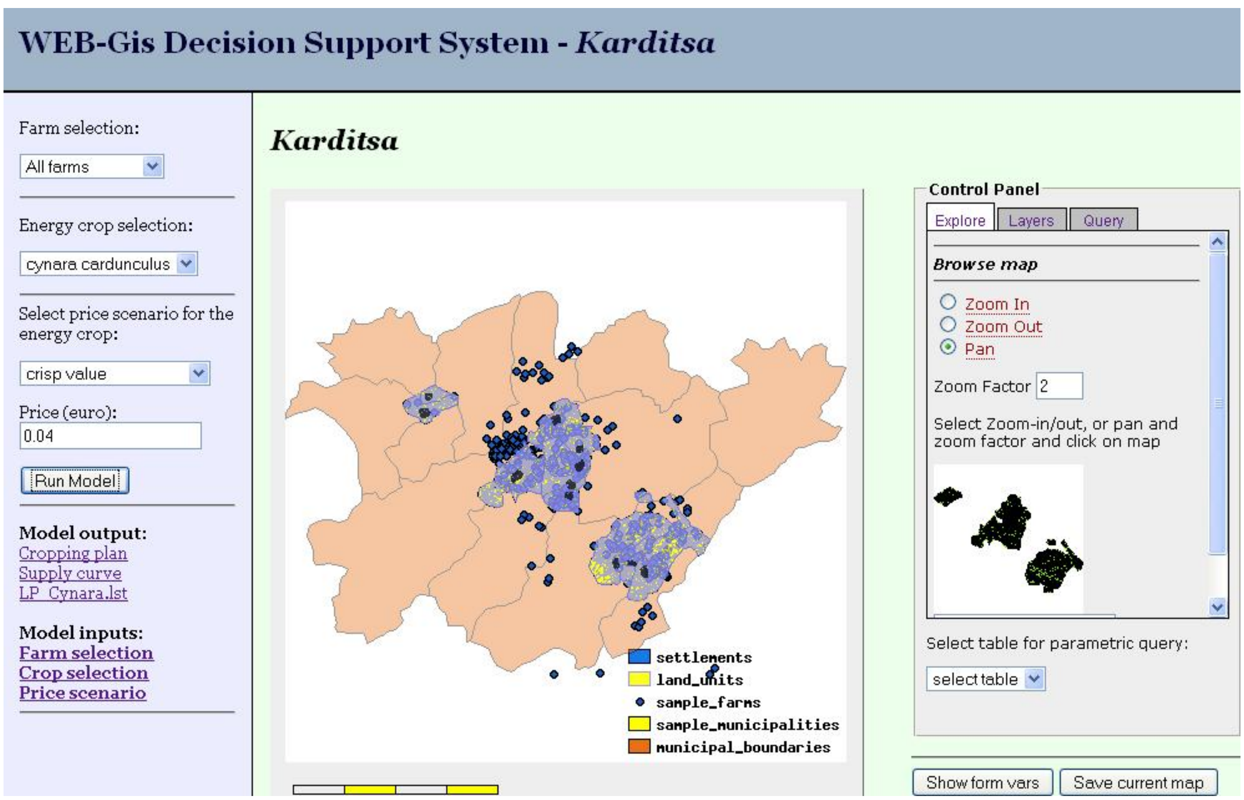

Figure 2. Spatial Decision Support System host page, Karditsa prefecture in Thessaly.

Basic technical specifications draw from Boretos and Rozakis (2006) [v]. The results of the client approach followed are impressive. User interface response is very fast, or at least indicative of a typical "web experience”. While the interface is not as rich, (nor as confusing), as the thick client interface, the most common operations are available, including zoom and pan features as well as parametric queries. Additionally, when input data is submitted for running a model, a very clear indication is given to the user as to processing times expected, as well as the model’s progress. When bugs were reported, most were easily reproduced and corrected on the server side. Since a scripting approach was used for the logic, changes were made “on the fly”, on a running, production system (Ousterhout,1997).

While the current bio-energy project thin-client approach produced acceptable results, and fulfilled its scope, several desirable features were identified and have been improved in the current version:

- The current geographic data sets are Arc-View shapefiles, which by nature, contains a DBF for attribute storage. DBF is difficult to manage in a multi-user environment as is the case on the Internet. It would be more appropriate to store features and attribute data in a spatially enabled database, such as ESRI SDE (SDE), or Postgre (PG-SQL), resulting in simplified user session management and customized “data views”.
- Economic and sector models are resource intensive, and as such tend to load the single server machine which was used for all web requests, model and geo-spatial processing. A layered, “Service Oriented” approach, can now be implemented on multiple machines to re-gain acceptable performance under load. Cross-platform distributed computing can be realized, based on XML/RPC, a remote procedure protocol using XML for the encoding and HTTP as the transport (XML/RPC).

OPTIMISATION MODULE: DESCRIPTION AND METHODOLOGY

Modelling regional agriculture: a bottom-up approach

Past experience shows that the raw material cost, defined at the farm level, forms a significant part of the bio-fuel cost. Due to an important spatial dispersion of bio-fuel raw material in many productive units (farms) and competition between agricultural activities for the use of production factors (land in particular), strongly dependent on the CAP, the cost estimates of these raw materials raise specific problems (Sourie, 2002). Although it is important that this cost be estimated correctly, three key difficulties are faced:

- scattering of the resource.
- competition existing between agricultural activities and non-food crops at the farm level.
- dependence of raw material costs on agricultural policy measures.

The microeconomic concepts of supply curve and **opportunity cost** make possible a solution to these difficulties. These concepts could be elaborated in a satisfactory way by using mathematical programming models, called supply models, based on a representation of farming systems, thus sector models.

Mathematical modelling provides a tool to evaluate simultaneous policy interventions in a system, such as arable agriculture, taking into account interrelationships such as resource and agronomic constraints, as well as synergies and competition among activities. Optimisation models maximising consumer and producer surplus selecting among feasible activity plans have been extensively used in agricultural sector modelling (Hazell and Norton, 1986). They allow for a techno-economic representation of the sector containing a priori information on technology, fixed production factors, resource and agronomic constraints, production quotas and set aside regulations, along with explicit expression of physical linkages between activities. The choice of mathematical programming methods is motivated by the importance of technical possibilities of substitution between activities and the importance of CAP measures for the different activity levels in the cropping plan.

Assuming rational economic behaviour, optimisation results in efficient allocation of production. When the base year optimal crop mix approaches the actual one, then the model can be expected to forecast future changes given specific policy parameters and to reveal impacts of different agricultural policy scenarios on production volume, resource allocation and farm income, eventually evaluating policy efficiency. Moreover, optimisation analysis is theoretically appealing as it generates shadow prices for explicit capacity, policy constraints providing valuable information to policy makers, as well as demand constraints whose dual values are used to determine supply response curves.

However, in most cases, it is difficult to replicate actual base year data, due to disadvantages inherent to the LP. Those usually mentioned in the literature as cited by Lehtonen (2001) are : a) normative optimisation behaviour due to strict neoclassical assumptions, b) aggregation problems, c) ad hoc calibration and validation procedure, d) discontinuous response to changing endogenous conditions, and e) tendency to strong specialisation. In order to mitigate the above deficiencies, the sector supply model developed in this exercise is sufficiently detailed to reflect the diversity of arable agriculture in the region of interest, articulating numerous farm sub-models in a block angular form, having neither the same productivity nor the same economic efficiency, so that the production costs are variable in space.

Thus, it is possible to correctly estimate biomass production costs by taking into account heterogeneity and finally to aggregate them in order to obtain raw material supply for industry. Different values of the parameters in the model (for example, the rate of obligatory set-aside or of the quantity of bio-fuel to be produced) give rise to a new supply curve. Thus, for each non-food or energy crop, there exists a family of supply curves.

Model specification

An individual farm (f) is supposed to choose a cropping plan (x^f) and input use among technically feasible activity plans $A^f x^f \leq b^f$ so as to maximise gross margin gm^f. The optimisation problem for the farmer f appears as:

$$
\begin{cases}
\max_{x^f} gm^f\left(x^f,\theta^f,\kappa\right) \equiv g^f\left(\theta^f,\kappa\right)x^f \equiv \sum_c \left(\left(p_c^f+s_c\right)y_c^f + sub_c - v_c^f\right)x_c^f \\
s.t.\_\_ A^f\left(\theta^f,\kappa\right)x^f \le b^f\left(\theta^f,\kappa\right)\_\_\_ A\in\Re^{m\times n}\ \_(I) \\
x^f \ge 0 \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ x\in\Re^n\ \_\_(II)
\end{cases}
\qquad (1)
$$

The sector model contains f farm problems such as the one specified above. The basic farm problem is linear with respect to x^f, the primal n × 1-vector of the n cropping activities. The m × n-matrix A^f and the m × 1-vector b^f represent respectively the technical coefficients and the capacities of the m constraints on production. The vector of parameters θ^f characterizes the f^{th} representative farm (y_c^f yields for crop c, v_c^f variable costs, p_c^f prices dependent on quality, s_c subsidies linked to crop quantity). κ stands for the vector of general economic parameters (p prices not dependent on farm, sub_c subsidies specific to crop cultivated area). The constraints can be distinguished in resource, agronomic, demand and policy ones. The model enables a comparative static analysis, but does not allow for farm expansion, as it takes as given land resource endowments and land rent of the base year. Different sets of parameters are applied to denote the CAP 2000 and the current CAP.

The model specified above is a linear version of an Non-linear Programming (NLP) arable sector model previously applied to the cotton sector response to policy changes (Rozakis et al., 2008). Alternative variants of mathematical programming the agricultural sector may use multi-criteria methods (Amador et al., 1998), Positive Mathematical Programming (Howitt, 1995), risk modelling (Hardaker et al., 2003) or interval linear programming. (Kazakci et al., 2007). It should be noticed that an important advantage of the server-based Web-SDSS is that the optimization basic LP model can be improved, or even replaced by models following alternative methodologies without involving the end user of the tool.

CASE-STUDY IN THESSALY, GREECE

Spatial and non-spatial information

The purpose of the project being to evaluate the feasibility of ex-tobacco growing farms to switch to energy crop cultivation (Pilotec, 2009), cartographic work focuses on eleven municipalities of the **Karditsa prefecture** concentrating the bulk of tobacco production. Pilot cultivations of different energy crops are installed in the area (project team, Arable Agriculture lab, Dept of Agronomy, University of Thessaly) in order to estimate yields and production costs in average parcel scale and operate in local conditions. Pilot plantations comprise sunflower, cynara cardunculus, fiber and sweet sorghum. The area of interest on the relief of the region appears in map 1 below:

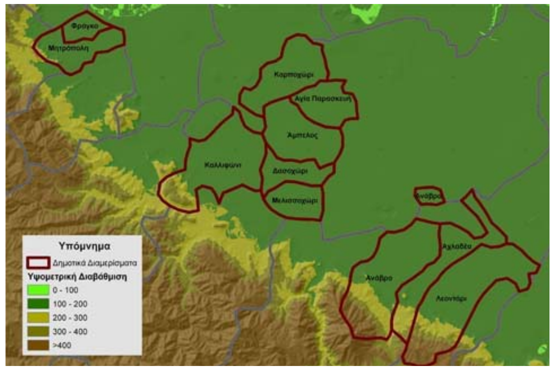

Figure 3. Tobacco growing municipalities in Karditsa relief.

The web application's map is composed of the following feature layers appearing in figure 2:

- Polygon layers of the administrative units of Municipalities ("Dimoi") and municipal tracks ("DD") and of the residential areas ("settlements").
- Point layer of the parcel centroids of the farms that participated in the project survey ("sample_farms"), provisioned by the Greek Payment and Control Agency For Guidance And Guarantee Community Aids (OPEKEPE)
- Polygon layer of land units partitioned on the calculated energy crops' yield per hectare. This layer was constructed only for ex-tobacco cultivated areas, as identified by satellite images and on-site survey. The calculation of the yields was based on the construction of probability digital map for each factor, including altitude, slope, PH, drainage and others (Perakis et al., 2009). The above factors are included on the attribute table of the layer.

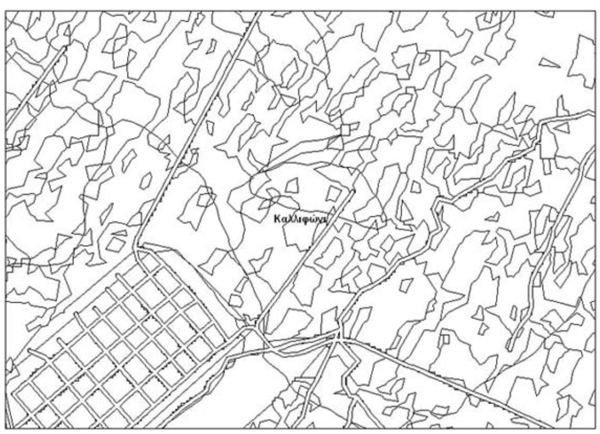

Figure 4. Detail of the final land unit map layer.

Using the query menu of the tool one can explore the attributes of the land units in relation to farms, for instance to obtain information on energy crop potential yield in each farm of the sample. For example, when selecting a farm parcel and activating the command "single join to other layer", the tool displays to the user the main features of the parcel and also which *land unit* this parcel belongs to and its principal characteristics.

Table 1: layer exploration through spatial query results

Layer: ***land_units***

OBJECTID	CYNARA (t/ha)	Land type	CULTIVATION	SLOPE CATEGORY	DETAILS
1029	28	Irrigated land	yes	0% - 3%	Details

Parcel ID 545 in Layer: ***sample_farms***

Surface (ha)	crop	ID	coordinates		parcel_code	Prefect_Code
3	Cotton	545	314760	4356390	4	41

The decision concerning the introduction of the energy crop in the rotation is made for each individual farm after taking into account the opportunity cost for each parcel. Using parametric optimisation one can estimate the opportunity cost derived by the dual value of the constraint imposed on the farmer to cultivate a certain area of the energy crop in question. Supply of energy biomass by area or group of farms is derived by aggregating individual farm supply curves.

The user can select which farm or group of farms to include in the analysis and which energy crop among those cultivated in pilot plants they wish to introduce in the cropping plan (rotation). Then they should fix a price at the farm level ("crisp value" in left side section in Figure 2) in order to observe the farmer's response with regard to the cultivation and supply of biomass-to-energy. This response will be the outcome of the farm model at the optimum since each farm model maximizes farm profit subject to relevant constraints.

Information on energy crop cultivation and yield is drilled from the pilot project results stored in a database embedded in the land suitability maps of the region. The current interface can test the farmers' response on only one energy crop at a time.

Alternatively the user can propose a price range triggering a loop of parametric optimization of the model, which determines quantity supplied at the optimal crop mix given farm-specific agronomic, economic and current policy parameters. In this case the result identifies to the well-known concept of supply curves that can be farm or cluster specific, or regional biomass supply if all farms are selected.

Once the input interface is filled (upper left section in Figure 5), optimization software is called to solve the model from the "run model" button. Results are given in four output files available to the remote user as appearing in the lower left section in figure 5.

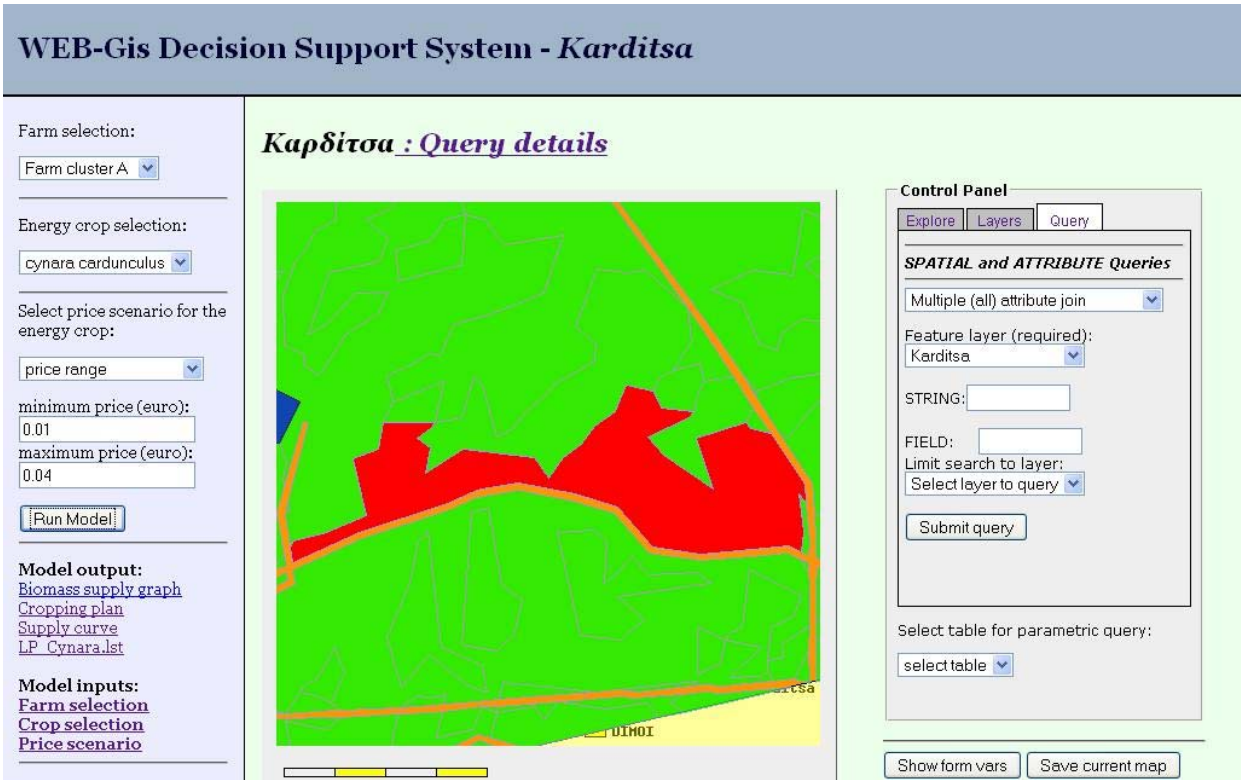

Figure 5. Farm geographical selection, farm model run, exploration of optimal solution

GAMS output file

This is a standard GAMS output text file returned by the software including the algebraic model code in GAMS language, the input data that the model developer had selected to display to the remote user making the model transparent, and visualizes the full extent model form as appears below :

```
LP_Cynara.lst
GAMS Rev 229  LNX-LX3 22.9.2 x86/Linux
03/29/09 18:42:58 Page 28
G e n e r a l   A l g e b r a i c   M o d e l i n g   S y s t e m
Equation Listing    SOLVE LP_Karditsa Using LP From line 561
---- eq_crop  =E=  Defining the vector of eligible activities
eq_crop(1,Alfalfa)..  - lg_x(1,Alfalfa) - nlg_x(1,Alfalfa) + x(1,Alfalfa) =E= 0 ;
(LHS = 0)
eq_crop(1,Cotton)..  - lg_x(1,Cotton) - nlg_x(1,Cotton) + x(1,Cotton) =E= 0 ; (LHS
= 0)
eq_crop(1,D_Wheat)..  - lg_x(1,D_Wheat) - nlg_x(1,D_Wheat) + x(1,D_Wheat) =E= 0 ;
(LHS = 0)
```

Figure 6. An excerpt of the GAMS output file (modelname.lst)

Furthermore it includes the full report of bugs and problems, if any, encountered during the solution process, consequently, informs the user on the solution status, and finally renders the full list of the results of the primal and dual models.

Cropping plan at the optimal solution

Table 2 shows the cropping plan displaying the optimal crop mix at different price levels of the energy crop. All crop cultivated surfaces in the farm or group of farms are calculated, including the energy crop. In this way the user can observe the evolution of conventional crop cultivating areas for increasing prices of the energy crop. In table 1 the farm in question cultivates durum wheat and alfalfa on 86 and 75 ha respectively. Maize, cotton, tomatoes and white beans are grown in the region but not in the particular farm (farm no1). When the price of cynara becomes 4.6 cents/kg, durum wheat is replaced by **cynara**, whereas when the cynara price raises to 8.2 c/kg part of the alfalfa is also replaced by cynara.

Table 2. Parametric optimization results : cropping plan versus energy crop price

scenario	Alfalfa	Cotton	D_Wheat	Maize	Tomatoes	White_Be	Cynara
scenario 1	cynara price =		0.01	euro/kg			
farm 1	75.1515	0	86.8482	0	0	0	0
scenario 2	cynara price =		0.028	euro/kg			
farm 1	75.1515	0	86.8484	0	0	0	0
scenario 3	cynara price =		0.046	euro/kg			
farm 1	75.1515	0	0	0	0	0	86.8484
scenario 4	cynara price =		0.064	euro/kg			
farm 1	75.1515	0	0	0	0	0	86.8484
scenario 5	cynara price =		0.082	euro/kg			
farm 1	28.7539	0	0	0	0	0	133.246

Supply curve – energy crop quantity vs. price graphical display

The columns denoting energy crop "price" and "quantity" at the optimum resulting from the parametric optimization are retrieved from the previous table to present a two-dimensional graphical visualization of the cynara supply curve. The user can have a clear idea on the capacity of the examined farms to provide biomass and the price-quantity elasticity over the range of proposed prices. In figure 6 one can observe the individual farm supply curve. Quantity-price relationships of all crops cultivated by the farm can be visualized simultaneously in order to give the evolution of the entire farm crop mix, if the output "cropping plan" text file is processed in a commercial spreadsheet.

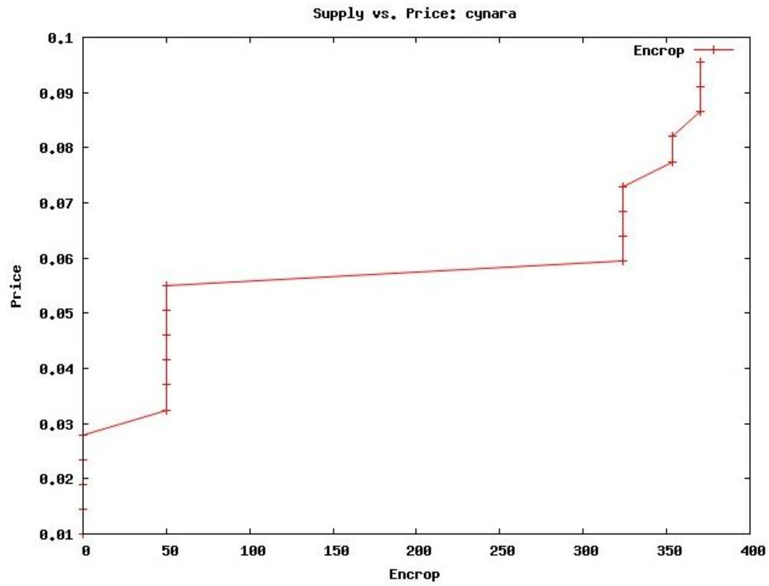

Figure 7. Cynara supply curve of the sample farm 1 in Karditsa region

The supply curve in the single farm graph (figure 7) presents abrupt changes due to the penny-switching nature of the LP model whereas it becomes smooth when a large number of farms supplies biomass as in figure 8. The estimated supply curve is much more useful when it is derived from a fair number of farms aggregating individual curves. Furthermore if supplied quantity is projected in the region of interest based on representative weights the resulting supply curve may be valuable for investors and the industry or cooperatives present in the biomass transformation to energy activities, who would be willing to pay to acquire such pieces of information.

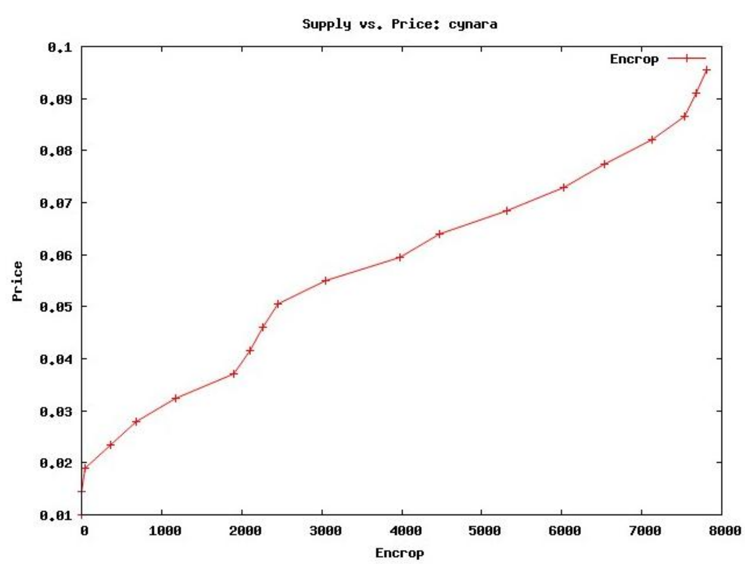

Figure 8. Cynara supply curve of survey farms in Karditsa region

It has to be noted that in the context of SDSS every point of the supply curve can be visualized in the map corresponding to a geographical snapshot of the focus area using Attribute queries from the interface (right side section in Figure 2). Once the model determines the optimal solution, the Land Unit attribute table is updated retrieving information from the model results regarding the energy crop produced quantities. Then the user could select Land Units that produce a positive quantity of the energy crop, obtaining information not only of the quantity produced at a given price level but also of the localization of this production in the region of study.

CONCLUSIONS

Decision-making in bio-energy is currently in high demand, especially in Greece, where the bio-fuel issue has been highlighted recently due to European strategy and promotion policies. Neither the government nor the industry and farmers were adequately prepared: the former imposed costly measures including tax exemptions and production quotas, the latter became involved in a risky business. Farmers and their cooperatives are in urgent need of alternative crops since the subsidies have been decoupled from production, thus causing them to behave differently from the past when policy makers indirectly dictated activity choices and production levels.

At the same time, research on bio-energy related fields and decision support systems being available and funding to ex-tobacco producers notwithstanding, a web-based SDSS has been proposed focusing on providing valid and documented estimations of biomass supply. In this paper, the above mentioned system is described, classified as thin-client processing, aiming at reaching potential bio-energy community stakeholders in Greece thus enhancing the dialogue and discussion on bio-fuel feasibility on sound bases.

Existing spatially dependent knowledge and agronomic information has been exploited and agricultural economics advances can be incorporated since optimisation models used are distinct within the DSS. At its present form the tool allows for geographic exploration and analysis of the farm sample, using sophisticated optimisation models and combining all of them so as to estimate biomass supply. Scenario building is incorporated in such a way as to facilitate sensitivity analysis concerning spatial and economic dimensions of the problem. Ensuring minimum performance and interoperability the tool has enhanced interdisciplinary team collaboration. End users comprise also agronomists and economists working in the field in the region of study and elsewhere, raising a large number of questions and revealing numerous deficiencies and rigidities especially related to transparency towards the background databases (geographic information and farm structure and operations) and the explanation of results. The more profane users are exposed to economic concepts such as the ubiquitous “supply curve”, the more they scrutinize background information and underlying assumptions. The web-based tool has proven an ideal context for this interaction obliging the development team to carry out constant improvement in order to keep up with the challenging bio-energy issue.

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XML/RPC, Remote Procedure Calling protocol. URL: http://www.xmlrpc.com/spec

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[i] The basic instruments of the CAP remained largely untouched during the first thirty years of its existence (1961-1992). The first major reform to the CAP occurred as a result of the MacSharry (EU Commissioner for Agriculture) propositions in 1992 and implemented in 1994. For the first time, MacSharry succeeded in reducing the level of support prices for a number of major commodities. The reason for his success was that he compensated farmers for the resulting loss of income by increasing direct payments. This has been the model for all subsequent CAP reforms (Bureau and Matthews, 2005).

[ii] The project site contains detailed information on project scope, project results, deliverables and publications. The tool operates online in http://aoatools.aua.gr/pilotec/webgis.php.

[iii] An excellent example that enhances public participation in local environmental decision making in the UK is analyzed in Kingston et al. (2000).

[iv] The models are written and executed in GAMS a software extensively applied by the academic community regularly maintained and updated with powerful optimisation solvers appropriate to LP, NLP and MINLP problems (Rosenthal, 2006).

[v] Initial efforts adopted fairly "thick" client approach was implemented as follows:

- connect to the central tool web site
- download a Java runtime (SUN Microsystems, 96) for their specific platform if not already installed
- download application specific applet containing application logic and mapping functionality

Issues encountered with the thick-client approach included:

- Substantial download times for both Java runtime (50 Mb) and the application applet (30Mb)
- Installation failures/version conflicts
- Unacceptable response time of the interface (client-side processing)
- Complexity of interface
- Minimal event notification (inform user that the system is processing)
- Browser incompatibilities
- Non reproducible bug reports (most processing was on the client side)

As a result of the above, a second approach was undertaken and implemented, based around "thin-client" technology. Working requirements were:

- User base only requires an HTML4.0 compliant Browser (Internet connected PCs generally have a suitable browser installed)
- No DHTML (different browsers (may) respond differently)
- No Javascript (as above)
- Server-side processing (scalability, reproducible bugs)

The modelling routines, as in the first phase, were programmed in GAMS, and were called via CGI scripts written in TCL.