Economic Analysis of Perennial Energy Crop Production in Greece under the light of the new CAP

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Abstract

Rising trends and volatility of fossil fuel prices and an E.U. directive that promotes bio-energy on the 2010 horizon as well as a CO2 reduction policy increase momentum for biomass in Europe as a renewable energy source. Raw material cost is an important part of bio-energy products, thus a valuable item of information for entrepreneurs. For this reason there is a need for studies assessing biomass costs in Southern Europe, especially after the last CAP reform (from the 2005-06 cultivation period) that represents a fundamental shift in policy. In this paper, dedicated biomass cost for conversion in power plants at the farm gate is estimated in Central Greece, taking into account agricultural policy changes. A harvesting service provided by a cost-minimizing company is incorporated into an arable agricultural programming model. Using an analytical technique which attempts to simulate the crop enterprise planning process at the farm level we present estimates of the regional supply of biomass to energy under the current and the new CAP based on spatial and expert information. Results confirm up to a 50% biomass cost decrease if the new CAP is fully applied to perennial energy crops.

Résumé

La hausse des prix, la volatilité des carburants fossiles ainsi que la directive de l'U.E. sur les bio-énergies à l'horizon 2010 et la politique de réduction des émissions de CO2 contribuent au développement de la biomasse énergétique en Europe. Le coût de la matière première, étant une partie considérable du coût de revient des produits bio-énergétiques, constitue une information valable pour les entrepreneurs. Des études spécialisées sont nécessaires en particulier après la réforme de la PAC qui constitue un tournant important en matière de politique agricole en Europe. Ce travail estime le coût de la biomasse issue des cultures pérennes en Grèce Centrale sous l'influence du changement de la PAC. Le coût de la récolte (service fourni par des entrepreneurs privés) est incorporé au modèle de programmation mathématique de l'agriculture régionale. La technique d'optimisation permet de simuler le processus de décision au niveau des exploitations et capte l'hétérogénéité régionale par des avis d'expert et de l'information spatiale. Les estimations des courbes d'offre régionale de biomasse énergétique sont présentées selon différents scénarios de politique. L'application du nouveau régime de la PAC permet de réduire de moitié le coût de la biomasse énergétique.

1. Introduction

Energy crops are cultivated in Europe to a large extent as a consequence of the revised Common Agricultural Policy in 1992, known as MacSharry reform. Under this reform set-aside was part of a compensation mechanism for price reductions agreed for subsequent periods (1993-94, etc.). In order to qualify for the compensatory payments, farmers should set aside a considerable fixed proportion of their land (decided annually by the Council of Ministers of Agriculture, varied within the range 5-15% during the decade following the reform). The provision that non-food crops were allowed to be cultivated on the land set-aside contributed to launch national bio-energy development programmes based on tax credits for bio-fuels. Thus, farmers introduced energy crops in the land use pattern by taking prices lower than those applied to respective food crops, therefore assuring the viability of bio-energy industry. For instance, in 1998 bio-diesel units in France could buy rapeseed raw material at 130 €/t when rapeseed for food was 160 €/t. However, due to the fact that 'small producers' (i.e. those who produce less than 92 tons of cereals a year) have been exempt from the set-aside obligation, energy crop production has not been undertaken in Greece where the quasi-totality of cereal farm production do not reach the aforementioned quantity. Current CAP reform decided in 2003 (Council Regulation (EC) 1782/2003) decouples subsidies from production thus restoring competition (EU, 2003 [1]). First estimates of CAP impact show that decoupling results in higher opportunity costs of energy crops previously cultivated in set-aside land (Tréguer et al., 2005). However, for Greek conditions the decoupled payments may result in lower opportunity cost for alternative crops as heavily subsidized crops such as cotton, tobacco etc. are hereafter only partially supported or not supported at all.

The European Commission's White Paper on Energy strategy suggests the increase of renewable energy sources contribution to 12% of the EU gross inland primary energy consumption by the year 2010 (EU, 1997). Biomass contribution accounted for about 3% of total inland energy consumption (EU15) in 1997, which equals to 44.8 Mtoe (Million tons of oil equivalent). The White Paper bioenergy objective on the 2010 horizon is set up to 90 Mtoe (equal to 8.5% of projected total energy consumption), of which energy crops account for 45 Mtoe. In this respect, energy from biomass is regarded as a significant potential contributor towards the reduction of fossil fuel usage.

On the other hand, environmental global issues have become of such prime importance that the European Union

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strives to comply with its international commitments promoting alternative energy sources to that of fossil fuels. Thus, the European Commission published the Green Paper on the European strategy of energy supply security (Green Paper, 26.6.2002 COM (2002) 321 final) that is later detailed in several directives and policy measures such as:

- directive 2003/30 on promotion of liquid bio-fuels for transport (EU, 2003 [2])
- directive 2001/77 on promotion of electricity generated by renewable energy sources (EU, 2001).

The European Union Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources (EU, 2001) demands, for every member state, 12% of the national energy consumption and 22.1% of the electricity consumption to be produced from renewable energy sources by 2010.

- directive 2003/87 on trading system of greenhouse gases rights (EU, 2003 [3])

Within the context of greenhouse emission, trade rights to emit have been fixed for Greece and specified for each major polluter. For instance the Greek Public Power Corporation (DEH) has been allocated the right to emit about 33 million tonnes of $CO_{2\ equiv}$ per year. A penalty payment of 40 €/t is fixed for the excess quantity from the 2005 period. Given that DEH actually emits about 40 million tonnes of $CO_{2\ equiv}$ (including all productive units generating electricity) one can calculate the price of interest of the Utility to buy electricity from Independent Producers. Recent estimates report that the utility would buy lignite at 38 € t^{-1} instead of 9 € t^{-1} today (Koutsouvelis, 2005).

- special subsidy of 45 €/ha for energy crops (Council Regulation (EC) 1782/2003)

The above provision has been added in the decoupled payment scheme of the new CAP, as an exception to support energy dedicated crops.

All the above raise interest in electricity generation from solid biomass. In this paper biomass for electricity produced by perennial energy crops is studied, in order to determine the opportunity cost, in other words to estimate the bioelectricity raw material supply curve. The analysis is spatially dependent, assisted by Geographical Information Systems (G.I.S.) focusing on Thessaly, situated in Central Greece. Thessaly plain is undoubtedly the most dynamic agricultural region of the country in terms of investments in agricultural equipment undertaken the last twenty years. The most important crops are cotton and durum wheat. Both cotton - which has practically been cultivated as mono-culture in irrigated land - and durum wheat are subject to co-responsibility payments in the context of the EU Common Agricultural Policy (CAP)[1]. Indeed, a member State exceeding its aggregate production quota foregoes a reduction in the intervention price. This mechanism, however, has failed to restrain Greek cotton production. In recent years, Greek cotton production has overwhelmed the Common Agricultural Policy maximum guaranteed quantities and triggered co-responsibility penalties, resulting in lower price subsidies for cotton farmers.

This fact - combined with an increased exposure to risk because of the expansion of cotton mono-culture - has raised farmers' discontent and pushed them into seeking alternative crops. Specifying the new CAP regime, the Greek government applied total decoupling to durum wheat and 65% decoupling to cotton. In this context, first estimates show a 10-20 % decrease in gross margins for arable farms in Thessaly that can only indirectly return to the farmers through the second Pillar, that is in development initiative funding. Among other alternatives, such as support to the livestock industry and the cultivation of feed crops, the planting of energy crops in support of bio-energy regional projects to generate electricity merits further study.

For this purpose the analytical framework of linear programming models is used in this paper in order to simulate the crop-planning process at the farm level focusing on substitutions of wheat and cotton by four perennial energy crops cultivated in experimental scale in Central Greece: Arundo donax L. (Giant Reed), Miscanthus x giganteus, Panicum virgatum L. (Switchgrass) and Cynara cardunculus L. (Cardoon). The fact that no real market for multi-annual energy crop cultivation exists creates no available parameters representing rents paid by the farmers for harvesting and baling. In order to overcome this difficulty an integer programming component is incorporated into the agricultural sector model that simulates the private company cost-minimising behaviour and determines the optimal number of machinery for harvesting and baling. This allows the estimation of energy supply from arable agriculture at the farm gate, consequently an assessment of the impact of the recently revised CAP to the opportunity cost of energy crops and the suggestion of efficient policy instruments specifically designed to encourage energy crop development.

2. Methodology

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. Although it is important that this cost be estimated correctly, three principal difficulties are faced (Sourie, 2002).

Firstly, the scattering of the resource. As mentioned, ac-

[1] Since 1987 the EU has replaced this policy regime with an intervention mechanism consisting of: (i) an intervention price, (ii) an aggregate production quota, called maximum quantity guaranteed (MQG) which is set at the country-level, and (iii) a reduction in the intervention price, called the co-responsibility levy, which is applied to all cotton farmers when the actual cotton production of the country exceeds the pre-determined maximum quantity guaranteed. As a result of the initial favorable CAP measures, cotton cultivation gradually became the primary farm activity (and source of income).

cording to the EU White Paper on RES (COM(97)599 final) targets 8.5% of the EU15 inland fuel consumption in 2010 to be produced by biomass. According to the energy balance of Greece, 2003 (Ministry of development), the total fuel consumption was 30.7 Mtoe (Million Tonnes of Oil Equivalent). In order Greece to reach such a target (using crop residues and energy crops), it means that in 2010 about 1.3 Mtoe energy should be produced by energy crops. Knowing that 1 toe equals to 10,000 kcal and the average energy content of biomass is about 3,600 kcal per tonne DM we conclude that about 325 thousand hectares cultivated with energy crops are needed (assuming that the average yield is about 11 tonnes DM per hectare). The average farm size being about 5 ha, more than 130,000 producers should be involved in the activity assuming that no farmer will cultivate more that 50% of land with energy crops. In this heterogeneous context, average cost is not a suitable concept.

Secondly, the competition existing between agricultural activities and non-food crops at the farm level. In order to satisfy agronomic constraints when introducing non-food crops, food rotation may be altered. This competition imposes a minimum level of profitability for non-food crops. We cannot consider the food activities and the non-food activities as independent so this implies that the full cost valuation method results, which do not take into account endogenous dependences between crops, may be a misleading indicator to predict farmers' decisions regarding energy crop cultivation.

Finally, the dependence of raw material costs on agricultural policy measures. The changes in agricultural policy, for example, a modification of the obligatory set-aside land rate or of the levels of direct subsidies to crops, affect the opportunity costs.

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. Thanks to supply models, it is possible to correctly estimate these costs by taking into account heterogeneity and finally to aggregate them in order to obtain raw material supply for industry.

This approach also leads to an estimate of the agricultural producers' surplus, which is an item of the cost-benefit balance of bio fuels. It is postulated that the farmers choose among food crops X_c and non-food crops X_d so as to maximize the agricultural income of their farm.

Thus, each producer f maximizes gross margin (g). Variables X take their values in a limited feasible area defined by a system of institutional, technical and agronomic constraints. The opportunity cost is obtained in the following way: Firstly, transforming the coefficients of the non-food cultures in the objective function, by removing the sales component, (thus there remain variable expenses C_d + subsidies S_d):

$$\max \sum_{f\in F}\sum_{c\in C} g_{c,f} x_{c,f} + \sum_{f\in F}\sum_{d\in D} \left(S_d - C_{d,f}\right) x_{d,f} \qquad (1)$$

At the optimum of (1) under constraints, surfaces cultivated by energy crops will be zero. Now consider a production of a minimal quantity q of a crop X_d by setting down the constraint $y_d\, x_d > q$, where y_d represents the yield of the energy crop *d*. The objective function will decrease and the model will automatically calculate a result which is interpreted as the cost of the last unit produced to reach the imposed quantity *q*. It is the opportunity cost estimate. This result is an output of any optimization model under constraints, known as its shadow price equal to the constraint dual value. The opportunity cost will vary according to the produced quantities q, within each farm but also across farms when the constraint applies to all farms (Q_d non-negative quantities of non-food resources):

$$\sum_{f\in F} y_{d,f}\, x_{d,f} \geq \overline{Q}_d \qquad \forall d \in D \qquad (2)$$

Thus, the energy crop supply takes into account competition with other non-food as well as food crops in a large number of farms. These results underline the interdependence between arable crops as well as cross-price dependencies. The national model is a set of individual farm models, suitably weighted to obtain a representative image of the farms able to produce non-food cultures. The dual values of the binding constraint (2) give the minimal prices P_d that the industry must pay the producers in order to obtain the demanded quantity Q_d. Non-food crop production is distributed in an optimal way among the various farms f, so that reduction in the objective function value, i.e. the total cost of production, becomes minimum. By increasing the quantity Q_d, one obtains the corresponding P_d. The relation $P_d=J_d(q_d)$ is a (inverse) supply curve of the resource *d*.

If the optimal distribution of production is not satisfactory when taking into consideration the equity criterion or other political criteria, the model could be modified by imposing rules of sharing out non-food crop production among farms. Consequently, the opportunity cost will be higher, as the solution of the modified model shows. 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 crop *d*, there exists a family of supply curves.

2.1. The Model specification

The general formulation of the model maximising total gross margin under cultivation, harvesting and baling constraints is as follows:

Indices

i crop {Wheat, Cotton, Arundo, Miscanthus, Switchgrass, Cardoon}

g energy crop {Arundo, Miscanthus, Switchgrass, Cardoon}

j farm (land units in the map) {landunit1, .., landunit416}

m machinery for harvesting and baling energy crops where {Sillage, Lorry10, Tractor65, Tractor90, Tractor100, Cutter, Windrower, DrumMower, Baler}

t tractors' subset of machinery that require an operator {Sillage, Lorry10, Tractor65, Tractor90, Tractor100}

l categories of the techno-economic data of machinery {PURCHCOST, ECONLIFE, MAINTENANCE, INSURANCE, ANNDEPR, ANNDEPRINTER, ANNINTEREST, ANNCSC}

n months {Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec}

r categories of labour {Operator, Unskilled}

p Common Agricultural Policy (CAP) scenario {CAP 2002, Reformed CAP (1st scenario), Reformed CAP (2nd scenario)}

Where the decision variable $A_{c,f}$ is the cultivated area in hectares of crop c and land unit f and $Y_{c,f}$ is the respective yield vector in tonnes ha^{-1}. The parameter P_c is the price of each crop in € t^{-1} (assumed zero for energy crops), while $PS_{c,f,p}$ and $S_{c,f,p}$ represent the subsidisation over price (price subsidy only applies for "cotton" and for "CAP 2002" scenario) and over area respectively based on the agricultural policy context p. $PC_{c,f}$ is the crop's cost of production parameter in € ha^{-1}, where land rent, overheads and harvesting and baling cost of energy crops are not included.

The integer variable MN_m is the number of every machine m while the CSC_m parameter is the annual capital service cost of every machine, in €, that includes annual depreciation, interest, maintenance and insurance, while diesel price DP was considered as constant. The annual CSC_m calculated as

$$CSC_m = \frac{d}{1-(1+d)^{-EL_m}} \cdot PV_m + MNT_m + INS_m$$

where d is the discount rate, PV_m is the purchase value of the machine, EL_m is its economic life and MNT_m and INS_m are the annual maintenance and insurance.

$HE_{m,c}$ and $BE_{m,c}$ is the parameter of harvesting and baling efficiency of each machine for every crop in hrs ha^{-1}, while $HC_{m,c}$ and $BC_{m,c}$ is the fuel consumption, in l hr^{-1} of machines for harvesting and baling respectively. The constant R is the wage rate, while the index tr represents the subset of machines that need human operator.

ASf is the parameter of the useful agricultural surface of each land unit, in hectares, while the constant D is the demand of biomass in tonnes. The index ec covers the subset of energy crops that produce biomass. $MO_{c,n,m,f}$ is the variable of monthly operation (in hours) of each machine for harvesting or baling, where $HP_{n,c}$ is the harvesting period of each energy crop ,in months, that is the available period for harvesting based on crops characteristics,

$$MH_c = \sum_n HP_{n,c}$$

is the total of harvesting months. The parameter AV_n is the amount of available hours per month for cultivation activities, based on regional climatic conditions.

The objective function of the model (eq. 3) represents the total profit of the "arable farming activity" at the regional level as the total revenue minus the total cost of production. The total revenue includes sales and subsidies while the total cost consists of the production cost, machinery cost for harvesting and baling, fuel cost for harvesting and baling, and labour cost for harvesting and baling.

$$Max \begin{cases} \sum_{c,f} \left(Y_{c,f} \cdot \left(P_c + PS_{c,f,p}\right) + S_{c,f,p} - PC_{c,f}\right) \cdot A_{c,f} \\ -\sum_m \left(MN_m \cdot CSC_m\right) - \sum_{c,m,f} \left(DP \cdot A_{c,f} \cdot \left(HE_{m,c} \cdot HC_{m,c} + BE_{m,c} \cdot BC_{m,c}\right)\right), \forall\ p \\ -\sum_{c,f,tr} \left(R \cdot A_{c,f} \cdot \left(HE_{m,c} + BE_{m,c}\right)\right) \end{cases} \quad (3)$$

Subject to constraints:

The first constraint (eq. 4) is a resource restriction of the cultivated area of each land unit-farm to be lower than the useful arable surface. Next equation (eq. 5) is a constraint for the minimum produced quantity of biomass (corresponding to the equation 2 in the methodology section). The shadow price of this constraint is considered as the marginal cost or the opportunity price of biomass as explained in the previous section.

$$\sum_c A_{c,f} \le AS_f\ , \ \forall\ f \text{ and } p \quad (4)$$

$$\sum_{ec,f} A_{ec,f} \cdot Y_{ec,f} \ge D\ , \ \forall\ p \quad (5)$$

Balance equations follow, that calculate the monthly operating hours of every machine based on the cultivated area of each crop (eq. 6) and estimate the number of machinery required based on the monthly operation of each one and the available hours per month (eq. 7).

$$MO_{c,n,m,f} = \frac{1}{MH_c} \cdot \left(HP_{n,c} \cdot A_{c,f} \cdot \left(HE_{m,c} + BE_{m,c}\right)\right), \forall\ c, n, m, f \text{ and } p \quad (6)$$

$$AV_n \cdot MN_m \ge \sum_{c,f} MO_{c,n,m,f}\ , \ \forall\ m, n \text{ and } p \quad (7)$$

Finally, we have the nonnegative condition for the variables, while the variable of machinery number is integer (eqs. 8-9).

$$A_{f,c}, MO_{c,n,m,f} \ge 0\ , \ \forall\ c, f, n, m \text{ and } p \quad (8)$$

$$MN_m \in N\ , \ \forall\ m \text{ and } p \quad (9)$$

3. The Case study

The main idea of this work was to identify how the reform of the Common Agricultural Policy (CAP) for the period of 2006 to 2013 will affect energy crop production in Greece. For this reason, two main scenarios were analysed with the model. The first scenario was based on 2002 data of prices and subsidisation of cotton and wheat and is called the "CAP 2002" scenario. The second scenario was based on the Council Regulation (EC) 1782/2003 (EU, 2003) and is called the "Reformed CAP" scenario. According to the adoption of the above regulation by the Greek law, it is not defined yet whether perennial energy crops will receive the decoupled subsidy or they will only receive the energy crops subsidy of 45 € ha^{-1}. For this reason, in the context of the reformed CAP scenario, two sub-scenarios were analysed. The first was based on the assumption that perennial energy crops receive the decoupled subsidy in addition to the energy crops subsidy of 45 € ha^{-1}. For the second it was assumed that those crops receive only the energy crops subsidy. We should note that besides subsidies, all the other data such as prices, production cost, yield, etc. are common for all the scenarios.

The analysis focuses on Thessaly region, Central Greece. The total agricultural area of Thessaly is about 497 thousand hectares, and 80% of this area (400 thousand hectares) is occupied by arable crops. Two important crops in this region are cotton and durum wheat. Based on 2000 data (NSSG, 2000), the total harvested area of cotton was 160 thousand hectares and about 125 thousand hectares of durum wheat. For this analysis, 416 land units[2] - farms - in a sub-region in Thessaly were studied[3]. There were two basic types of land units, irrigated and non-irrigated. In order to estimate the subsidy that each land unit was receiving before and also after the reformulation of CAP, we have made the assumption that irrigated land units were cultivated with cotton during the period 2000-2002, while non-irrigated land units were cultivated with durum wheat.

3.1. CAP 2002 scenario - subsidies

According to Agenda 2000 the deficiency payments for cotton were coupled to production of every farm, while the subsidization of cereals was on the cultivated area.

The subsidy of cotton for the year 2002 was about 557 € T^{-1} (data source: Ministry of Agriculture Development and Food of Greece, and OPEKEPE[4]). This value was multiplied by the cotton yield of every land unit (primary data) in order to estimate the subsidy per hectare of each land unit for this period.

Based also on data from the Ministry of Agriculture Development and Food of Greece, the main subsidy of cereals for 2002 was 155.6 € ha^{-1}, while the additional subsidy of durum wheat was 344.5 € ha^{-1}. The deduction coefficient of the co-responsibility payment for Larissa region was for the same period 11%. This coefficient has been calculated every year for each region according to the total produced quantity of the specific region. When the total production of the region was higher than its upper limit of the supported quantity, then the deduction coefficient resulted to be lower that 1 (100%). So the subsidy of durum wheat for 2002 for Larissa region was calculated as follows: 155.6 + (344.5 x 0.8874) = 461 € ha^{-1}.

3.2. The Reformed CAP scenario - subsidies

According to the reformed CAP, every farmer will receive a decoupled subsidy, for the period 2006-2013, which will be independent of what the farmer produces and will be a percentage of the average subsidisation that they were receiving during the period 2000-2002. Energy crops production will be subsidised by an extra amount of 45 euro per hectare. For this analysis we have made the assumption that each land unit had a specific history of what the farmers were cultivating in the past. We have assumed that all irrigated land units were producing cotton; while non-irrigated units were producing durum wheat.

Subsidisation of cotton farms: In this case there will be a decoupled subsidy which is 65% of the total subsidy and is 966 € ha^{-1}. The non-decoupled subsidy will be the balance of 35% (546.5 € ha^{-1}.) and the farmers will receive this part of the subsidy only if they produce cotton again. There is no "quality deduction" or co-responsibility levy. Those figures were based on OPEKEPE data (M.Korasidis, pers. comm. 2005).

Subsidisation of durum wheat farms: Based on the Agenda 2000 subsidisation, the main subsidy for cereals for 2000 was 143.18 € ha^{-1}., and 155.61 € ha^{-1}. for 2001 and 2002. The additional subsidy of durum wheat for the same period was 285 € ha^{-1}. per year. There was a deduction coefficient on the additional subsidy, for every year, as described previously. The quality deduction of 10% affects the additional payment, after its reduction by the deduction coefficient. We have assumed that the quality deduction will be returned to the farmers who cultivate durum wheat. Finally, the deduction because of the max guaranteed excess quantity, also affects the additional payment after the deduction of the first coefficient. This reduction is due to the excess of our country of the maximum guaranteed value for the specific period and it ranges from 5% to 10%. For our analysis we have assumed that this percentage will be 10%.

According to the above data and assumptions, the farmer will receive as decoupled subsidy the amount of 387.48 € ha^{-1}. if he/she cultivates d. wheat or 361.23 € ha^{-1}. if he/she cultivates any other crop.

Based on the above information and assumptions we have

[2] Elementary units are land-units as defined by the GIS (Geographical Information System). These land units aggregate homogeneous land pieces (pixels) that belong to the same class. Adjacent pixels of the same class form a land unit (LU, in total 12,395 land units). Through the databases created, information regarding agricultural land was processed to distinguish land classes: land units with similar soil type, slope, and current land use were gathered in the same class. 1,090 classes are considered in this case study (416 classes with arable crops). After obtaining this information, expert knowledge was used to estimate yields of all conventional and energy crops examined for each class (Varela et al., 2001).

[3] The region of study is a flat and hilly area, a part of the Thessaly plain, located in central Greece with an average farm size larger than that for the entire plain. The Spot XS image used focuses on an area about 45,000 ha in size extended around Farsala. Based on the satellite image, additional maps (road infrastructure, electrical network, population concentration, district boundaries) were geo-referenced and digitized (Rozakis et al., 2001).

[4] O.P.E.K.E.P.E.: Payment and Control Agency for Guidance And Guarantee Community Aid - Greece

the following analytical cases:

- *Durum wheat cultivated on irrigated land*: The land unit will receive just the decoupled subsidy of the cotton (966 € ha^{-1}.).

- *Durum wheat cultivated on non-irrigated land*: The subsidy will be 387.48 € ha^{-1}., as described above.

- *Cotton cultivated on irrigated land*: The farmer will receive the total amount of cotton subsidisation (100%) that is 1512.50 € ha^{-1}..

- *Cotton cultivated on non-irrigated land*: This is a case unlikely to happen according to our assumptions. Nevertheless, if a farmer decides to do so, the subsidy will be 361.23 € ha^{-1}..

- *Energy crops cultivated on irrigated land*: according to our basic assumptions, all four perennial crops could be cultivated under irrigated conditions. In that case, the farmer will receive the amount of 1011 € ha^{-1}., which consists of the decoupled subsidy of cotton (966 € ha^{-1}.) plus the subsidy of energy crops (45 € ha^{-1}.).

- *Energy crops cultivated on non-irrigated land*: This case could stand only for Cardoon, since we have assumed that the other three crops have negligible productivity under non-irrigated conditions. In that case, although the yield will be zero, the farmer may receive the subsidisation of durum wheat (361.23 € ha^{-1}.) plus the subsidy of energy crops (45 € ha^{-1}.), 406.23 € ha^{-1}. in total.

We should note that the estimation of the above amounts of subsidisation energy crops production were based on the assumption that perennial energy grasses could receive not only the amount of 45 € ha^{-1}. but also the decoupled subsidy. Nevertheless, it has not been confirmed yet that perennial energy grasses will also receive the decoupled subsidy. For this reason, we have analysed the second sub-scenario based on the reformed CAP, where energy crops under consideration receive as subsidy an amount of only 45 € ha^{-1}.. This analysis will give us the opportunity to record basic guidelines on the actions that Greece should take on this issue.

3.3. Prices

According to the Ministry of Agriculture Development and Food of Greece, and OPEKEPE data, for 2002, the price of cotton (subsidies not included) was about 275 € t^{-1}, while the respective price of durum wheat for the same period was 150 €t^{-1}. Those figures are the most recent available data in Greece and they were used for both scenarios.

3.4. Yields

Specific data for the land units in Central Greece, on the Thessaly plain, were taken from the EU Altener project "MULTISEES - A Multiple Criteria Decision Tool for the Integration of Energy Crops into the Southern Europe Energy System" (Varela et al., 2001). The data that were used for this analysis were the available surface and the yields of cotton, wheat, cardoon and Miscanthus of each land unit. Yields data for each land unit of cotton and wheat were estimated using expert knowledge, combined with growth model information assisted by GIS. In Central Greece, cotton is only cultivated on irrigated land. Thus for modelling purposes, cotton yield on non irrigated land is considered as zero. On the other hand, durum wheat can be cultivated under irrigated or non irrigated conditions but its yield under irrigation is higher (Table 1).

Energy crops yield data were based on estimations for crops productivity under real conditions. For this analysis, Cardoon and Miscanthus yield data of the Multisees project for the Thessaly region were used as primary data. Those data have been calculated using expert knowledge based on the characteristics of every land unit. In order to use up-to-date estimations of all energy crops yields, we have made adjustments on those data. Those adjustments were based on estimated average yields data of "Bioenergy chains" project[5]. From the four energy crops under consideration, cardoon is the only one that can be cultivated under irrigated and dry conditions, having higher yields with irrigation. The productivity of the rest is considered as zero when cultivated on dry land.

3.5. Cost of production

For this work, we have made the assumption that the cost of production of all crops remains constant between similar land units (e.g. irrigated). Total cost of production of all crops (conventional and energy) includes the cost of all cultivation activities, which is the sum of labour, machinery and raw materials cost, but not the cost of land and overheads. The variable costs for each crop are derived from an accounting model (BEE[6]) that enables the breakdown of the

Tab. 1. *Yield distribution in the study area*

	wheat		cotton	cardoon		miscanthus	arundo	switchgrass
Land type	non-irrig	irrigated	irrigated	non-irrig	irrigated	irrigated	irrigated	irrigated
mean	3.41	3.67	3.33	10.85	15.46	9.16	11.38	9.86
stDev	0.71	0.71	0.40	2.33	3.00	0.63	0.79	0.69

[5] Technical data of energy crops cultivation activities and crop yields in Greece were taken from the EU research project entitled "Bioenergy chains from perennial crops in South Europe" (Project No: NNE5-2001-00081). More specifically, Arundo and Miscanthus technical data were taken from AUA data and from personal communication with the Centre for Renewable Energy Sources (CRES) in Greece. Technical data of Switchgrass cultivation were taken from the data that were recorded for the Bioenergy Chains project by the University of Bologna (UNIBO), while the respective data for cardoon cultivation were taken from personal communication with the Polytechnic University of Madrid (UPM). Those data were analysed to calculate the production cost of the energy crops. For this purpose, only primary technical data for perennial crops production were used from "Bioenergy Chains" project. This information was combined with technical and economic data from previous experience of the Laboratory of Agribusiness management of the AUA and ongoing research (Psarou, 2005) in order to provide cost estimation for Thessaly.

[6] Bee software available by the Agribusiness Lab, Dept. of Agricultural Economics and Rural Development, Agricultural University of Athens, URL: http://www.bee.aua.gr

costs of multi-annual crops in order to make them comparable to those of annual cropping systems (Soldatos, 2002).

Land rent and overheads were not included because the model considers all crops as competitive for the same farm. In the Thessaly region, the cost of water for irrigated farms is a flat fee. For this reason we have assumed that the cost of water (not the cost of irrigation as an operation) is included in the land rent and we have excluded this cost item from the cost of production.

All irrigated crops, either energy or conventional, can only be cultivated on irrigated land. In non irrigated land units, those crops have zero cost and yield. This prevents the model from choosing an irrigated crop to be cultivated on a non-irrigated land unit. On the other hand, non-irrigated crops, such as Cardoon and D. Wheat, can be cultivated either on irrigated or non-irrigated land. The cost of production and the yields under non-irrigated conditions are lower.

Cost of Cotton and Durum Wheat: The cost of conventional crops production was calculated with the BEE Model, using technical and economic data for the Thessaly region (Psarou M., 2005). Irrigated durum wheat is charged with the additional cost of irrigation as an operation.

Cost of energy crop production: The production cost per hectare of energy crops was calculated using the BEE Model. This cost includes the cost of all agricultural operation but not the cost of land, overheads and harvesting and baling. It is the annual equivalent cost of production (cost of establishment is included) and represents an estimation of the average production cost in Central Greece. All energy crops except Cardoon were considered as irrigated crops and the cost of irrigation was included in the total production cost. Irrigated and non-irrigated cardoon cultivations have similar production activities, while the former is charged with the cost of establishment and annual irrigation activities. Tables 2 and 3 present the cost of production of all crops.

Tab. 2. *Cost of conventional crops production in Thessaly region*

	Cotton (Irrigated)	D. Wheat (Non Irrigated)	D. Wheat (Irrigated)
			euro ha^{-1}
Labour	133.20	82.64	146.64
Equipment	322.21	147.99	246.21
Raw Materials	415.75	265.30	265.30
Total	***871.16***	***495.93***	***658.15***

Tab. 3. *Annual equivalent cost of perennial energy crops production in Thessaly region*

	Arundo (Irrigated)	Miscanthus (Irrigated)	Switchgrass (Irrigated)	Cardoon (Non Irrigated)	Cardoon (Irrigated)
					euro ha^{-1}
Labour	92.99	141.96	85.37	43.58	81.89
Equipment	88.00	122.63	90.87	37.68	80.39
Raw Materials	293.15	215.03	73.88	162.25	162.25
Total (€/ha)	*474.14*	*479.62*	*250.12*	*243.51*	*324.53*

3.6. Harvesting and baling of energy crops: activity analysis

For this analysis we have made the assumption that although the production of crops is performed by individual farmers who maximize their profit using crop rotation (combination of crops), harvesting and baling of energy crops is performed by an individual enterprise. This assumption was made based on the fact that harvesting and baling mechanical equipment is specialized and expensive. The enterprise owns a fleet of equipment and provides harvesting services for the whole area.

Arundo is harvested in chips, using a silage harvester and a lorry, while the other three crops are harvested in bales. The mechanical equipment for harvesting and baling consists in various types of tractors, cutter, windrower and a baler.

All economic and technical data of those operations were based on the “Bioenergy Chains” project data. Using machinery purchase cost, economic life, annual maintenance and insurance, the annual Capital Service Cost (CSC) of every machine was calculated. The annual CSC includes the cost of depreciation and interest plus the cost of maintenance and insurance. Harvesting and baling efficiency in hours per hectare and fuel consumption of every machine in each crop were considered.

The total cost of harvesting and baling was calculated as the annual CSC of machinery needed plus fuel cost. Fuel cost was calculated as the cost of diesel (€ lit^{-1}) multiplied by the efficiency of the operation (hrs ha^{-1}), the fuel consumption (lit hr^{-1}) and the total cultivated area of the crop for every land unit.

3.7. Number of machines

The private company needs to determine the optimal number of machines required for harvesting and baling minimizing costs. Each crop has a specific period, in months, when it can be harvested. In order to maximize machinery usage and to minimize harvesting cost, we assume that the whole available period for each crop is used. According to the needs (machine hours) of every month and the availability (based on climatic and social regional conditions), the model estimates the maximum integer number of machines required according to the “optimal” crop mix.

3.8. Energy Content

To estimate the total energy from biomass, we have used the average Gross Calorific Value of the crops that resulted from Bioenergy Chains project experimental fields in Central Greece. According to those data the average energy content of the four energy crops is as follows:

- Arundo: 18.55 GJ t^{-1} DM,
- Miscanthus 18.93 GJ t^{1} DM,
- Switchgrass 18.52 GJ t^{-1} DM and
- Cardoon 16.94 GJ t^{-1} DM.

This analysis gives us the opportunity not only to estimate the supply curve of biomass but also the supply curve of energy. We can also determine the minimum demand either for biomass or energy units.

3.9. Other data

There are also other constant data that are important for the analysis. Those data are: the amount of *Monthly available hours* for agricultural operations of Thessaly region estimated based on the climatic conditions and social parameters of the region.

Cultivated land is usually less than occupied land (i.e. total land), because part of the land may not be able to be planted because of the existence of buildings and constructions, roads, paths, rocks, irrigation canals, lakes, etc. The percentage of cultivated land to occupied land is a user supplied *cultivation coefficient* (e.g. 90% to 95%), which adjusts occupied land size to cultivated land (Eidman et al., 2000). In our analysis the cultivation coefficient affects only the cost of land so we have set it to zero, as mentioned before. Nevertheless, although this percentage does not affect our results, we have set it to 95% for future use. The *discount rate* was determined as 10%. The *diesel price* for agricultural use that was used in this analysis is 0.6 €/l, based on 2004 data.

4. Results

The regional model was run under the quantity constraint to produce biomass demanded by the conversion plant. Biomass production and harvesting cost curves are generated separately for each energy crop considered (graphs in figures 1 and 2). As there is no experience of energy crop cultivation in the area, it is assumed that farmers would hesitate to offer their total available area for energy crops cultivation. The maximum percentage of each land unit dedicated to biomass production was set at up to 50%.

Fig. 1. *Harvesting and baling costs*

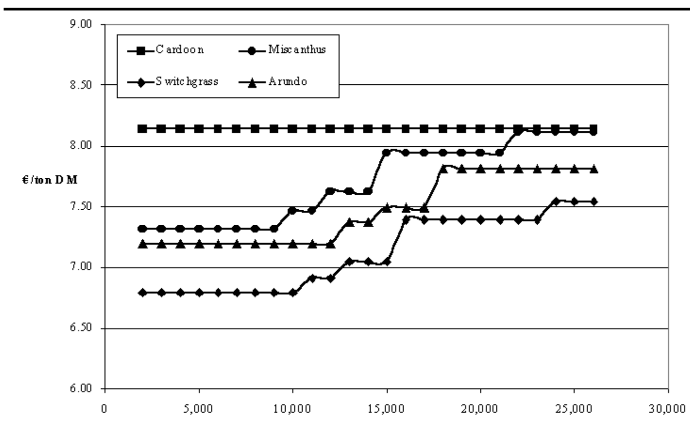


Fig. 2. *Marginal biomass costs for perennial crops*

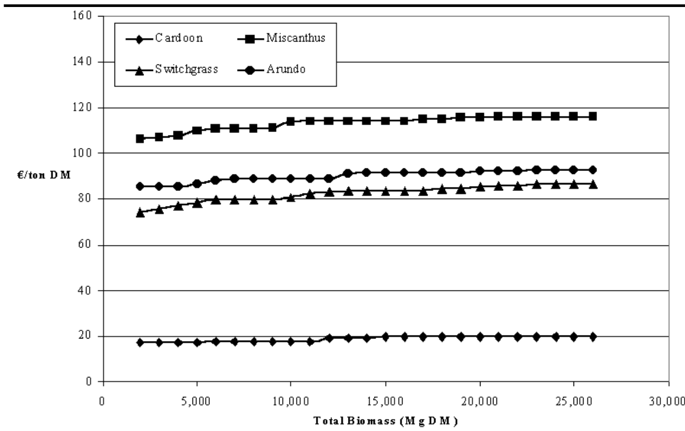
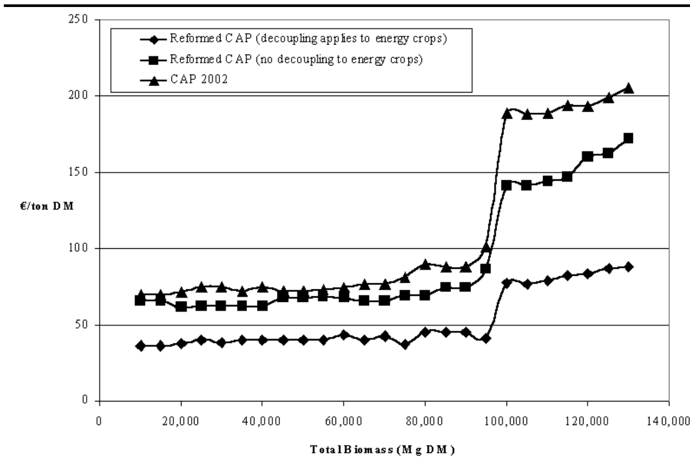


Fig. 3. *Marginal Biomass Cost (including harvesting) in € t-1 DM*



When all four perennial crops are allowed to be cultivated, the least cost crop combination is revealed at the optimal regional crop mix for a fixed biomass quantity demanded. Parametric solution of the constrained model gives, after a number of iterations, supply curves generated for different sets of assumptions.

Figure 3 presents the total marginal cost of biomass production for the three scenarios. The cost of harvesting is included. According to the "CAP 2002" scenario, the marginal price of biomass ranges between 70 and 101 € t^{-1} DM for the supply of 10 to 95 kt (cardoon is supplied cultivated in dry land) and raises to over 200 € t^{-1} DM for higher production. This increase is due to the use of "expensive" cotton land for energy crop cultivation (switchgrass) over 95 kt.

In the "Reformed CAP (1st scenario)", where it was assumed that perennial energy crops do receive the decoupled subsidy, the marginal value of biomass is dramatically decreased. The marginal value ranges between 36 and 45 € t^{-1} DM for the production of 10 to 95 kt. If there is higher demand, the marginal price raises to about 90 € t^{-1} DM.

The "Reformed CAP (2nd scenario)" assumes that perennial energy crops do not receive the decoupled subsidy. The estimated marginal price of biomass is lower than the scenario before the CAP reform but it is much higher than the previous scenario. It is obvious that in this case, the reformation of CAP has no significant effect on biomass supply.

5. Conclusions

Supply of biomass for energy purposes from perennial crops has been studied in the region of Farsala in Thessaly, Central Greece. Production and harvesting cost has been assessed assuming that profit maximising firms decide their cultivation plan rationally among food and non-food crops, taking into account current land use and agricultural policy scenarios. Exploiting G.I.S. information land rent incorporated in biomass costs is no longer an average figure but reflects land heterogeneity and alternative land uses specific to each individual land unit. Parametric optimisation of a mathematical programming model is performed for the generation of biomass to energy supply curves, following a regional approach for the set-up of new activities to farming systems. Results show that the impact of the latest CAP reform on the competitiveness of perennial energy crops in Greece is important. In case of full decoupling subsidy to perennial energy crops solid biomass to energy cost drops by 50% compared with previous CAP regime. More specifically we could point out:

- Preference for non-irrigated perennial energy crops (among four perennial crops examined cardoon proves to be the less expensive thus providing biomass quantities up to 95kt).
- Results of this exercise show that the monoculture of cardoon is sufficient to provide enough biomass for a medium plant size. Nevertheless, if we take into account more technical and economic factors such as different harvesting period of crops combined with storage cost, we expect as a result the combination of more than one crop in a specific region.
- If decoupled payment is not allocated to perennial energy crops, solid biomass production would be practically as costly as under the previous CAP.
- In the Thessaly region, the opportunity cost of irrigated land is much higher than the cost of dry land, because of the cultivation of demanding industrial crops such as cotton. In other Greek regions, for example in Northern Greece, where the opportunity cost of land does not differ so much between irrigated and dry land, selection among energy crops could be different. Thus, the Thessaly region may not be the most appropriate area to introduce energy crops in Greece.

Preliminary results are presented in this paper; feasibility studies of heat and electricity generation from perennial crops requires further scrutiny. Pilot projects are necessary in order to test large scale cultivation as well as to verify technical feasibility along the entire chain.

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