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# Agricultural raw materials cost and supply for bio-fuel production: methods and concepts

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**Abstract:** Due to an important spatial dispersion of raw materials in many farms and a 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 pose specific problems. Thanks to supply models, based on linear programming, it is possible to correctly estimate these costs, their diversity and finally to aggregate them in order to obtain raw material supply for industry. At the same time, one estimates the agricultural producers' surplus, one of the "macroeconomic" advantages of biofuels.

**Keywords**: Costs, linear programming, supply, surplus, biofuels, agricultural resources.

## Introduction

The raw material costs, defined at the farm level, form a significant part of the bio-fuels cost. Thus, in the French context, this share varies between 20 to 25% for wheat or sugar-beet and 60 to 65 % for rapeseed[1]. Although it is important that this cost be estimated correctly, three principal difficulties are faced:

**First**, *the scattering of the resource*. Currently, France, according to SIDO'S[2], counts has more than 50 000 of bio-fuel crop producers (wheat, beet, and rapeseed). Since farms have neither the same productivity nor the same economic efficiency, the production costs will be variable in space. In this context, average cost is not a suitable concept.

**Second**, *the competition existing between the agricultural activities and the non-food crops at the farm level*. In order to satisfy the agronomic constraints when introducing non-food crops, the 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 independent; this implies that the full cost valuation method results, that do not take into account endogenous dependences between crops, may be misleading 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. Thus, the set-aside land obligation that has been included in the revised CAP measures implemented since 1993 and the authorization to cultivate only non-food crops on land obligatorily set-aside, contributed to a decrease in the raw material (for bio-fuel) cost; if set-aside obligation disappears, an increase in the costs of crops grown on land set-aside, namely non-food crops, will immediately follow.

The microeconomic concepts of supply and opportunity cost, which are not independent, make possible a solution to these difficulties. These concepts could be elaborated in a satisfactory way

[1] JC Sourie, S Rozakis, Bio-fuel production system in France: an economic analysis, *Biomass & Bioenergy* 20(2001) 483-489.

[2] Cahiers de l'ONIOL, Jachère industrielle, Septembre 2000

by using mathematical programming models, called supply models, based on a representation of farming systems. This approach also leads to an estimate of the agricultural producers' surplus, which is an item of the cost-benefit balance of bio fuels.

## A simplified design of farming system economic model for the estimation of the opportunity cost of non-food resources

It is supposed that the farmer chooses among food crops $X_e$ ($x_{1,e}$ , $x_{2,e}$ $x_{i,e}$, … ,$x_{n,e}$) and non-food crops $Y_e$ ($y_{1,e}$ , $y_{2,e}$ $y_{j,e}$, …, $y_{m,e}$) so as to maximize the agricultural income of his farm. Thus, each producer e maximizes the following expression $fo_e$:

$$Max\ fo_e = \sum_i m_{i,e} x_{i,e} + \sum_j m_{j,e} y_{j,e} + b z_e - f_e$$

**m** gross margin of each activity in €/ha, **z** the CAP set aside land and its gross margin **b** and finally **f**$_e$, total fixed costs of the farm **e**.

Variables $X_e$ and $Y_e$ take their values in a limited area $D_e$ defined by a system of technical and agronomic constraints (feasible area). These constraints will not be described in detail; only the fallow constraint will be formalized because of the very significant role it plays on the cost of the non-food resources.

Let $\mathbf{K} \subset \mathbf{I}$ be the food crops that do not involve set aside obligation (for example, sugar-beet) and $S_e$ the surface of the farm **e**, then the fallow constraint at the rate of 10% is written:

$$\sum_j y_{j,e} + z_e \geq 0{,}1(S_e - \sum_{k \subset i} x_{k,e}) \qquad \textbf{(I)}$$

In other words, the surface of the non-food crops and land set-aside must at least be equal to 10% of the surface of the farm, minus the areas of the crops not subject to the set-aside obligation. This constraint implies competition between the non-food crops and fallow, which is the main determinant factor of the opportunity cost.

The model is made up by many other constraints, such as total surface constraint:

$$\sum_i x_{i,e} + \sum_j y_{j,e} + z_e \leq S_e$$

Then, various agronomic and technical constraints are added which can be summarized in the following way:

$$\sum_i a_{i,l,e} x_{i,e} + \sum_i a_{j,l,e} y_{j,e} + d_{l,e} z_e \leq R_{l,e} \quad \text{For any l}$$

where **a** and **d** are the technical coefficients and **R** the physical resources available to the farm **e**.

For $X_e$ , $Y_e$, $Z_e \in D_e$ , the maximization of **fo** leads to an optimal solution, **X* Y* Z***. (**Z***, the fallow area, can be possibly equal to zero if the non-food crops Y are profitable).

## Opportunity cost of the raw material

Within the framework of a price negotiation regarding the raw materials, it is traditional to calculate the cost value even if, in agriculture, this concept presents well known problems (firstly, because of the existence of non commercial factors such as agricultural family labour, agronomic value of heads of rotations, and secondly, because of estimates of certain factors without relationship with their economic value; for example, the land factor).

To carry out a public assessment of bio-fuel policy, which is the main purpose of this exercise, it will be more appropriate to refer to the opportunity cost (marginal) instead of the (average) cost value because of its rigorous determination and precise economic meaning. More precisely, the opportunity cost will give the minimal price which allows the introduction of a given quantity of non-food crop into a rotation without reducing the farm agricultural income.

The opportunity cost is obtained in the following way:

One transforms the coefficients of the non-food cultures in the objective function ***fo***, by removing the sales component, (thus there remain the variable expenses + the subsidies/ha); let **C j,e** be these new coefficients.

$$Max\ fo_e = \sum_i m_{i,e} x_{i,e} + \sum_j c_{j,e} y_{j,e} + bz_e - f_e \qquad \textbf{(II)}$$

At the optimum of ***fo***, surfaces cultivated by energy crops will be null, the fallow land occupying all the surface imposed by constraint **I**.

Let us suppose now a production of a minimal quantity ***q*** of a crop y by setting down the constraint ***yJ rJ >q***, where ***rJ***, yield of the energy crop ***j***.

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 **q**. It is the opportunity cost estimate. This result is an output of any optimization model under constraints, known as a dual value.

The opportunity cost will vary according to the produced quantities **q**, within each farm but also across farms.

Figure 1 gives an idea of the distribution of the opportunity costs of rapeseed (in €/ton) in France, for 2002, with the rate of obligatory set aside set at 10%.

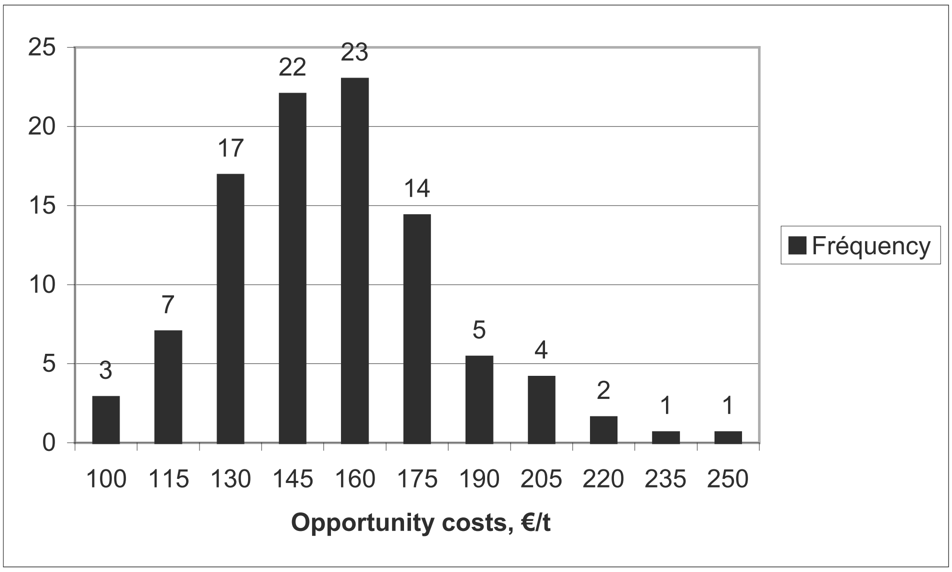


**Figure 1.** An example of a distribution curve for rapeseed

Significant variations can be noted: 10% of the producers have a cost lower than 115 €/t and 13% have a cost higher than 175 €, the average being located at around 156 €. This dispersion of the opportunity costs allows an optimization of raw materials cost by locating production in the most efficient farms; these latter coincide with those that generally have the highest rape-seed yields (Figure 2).

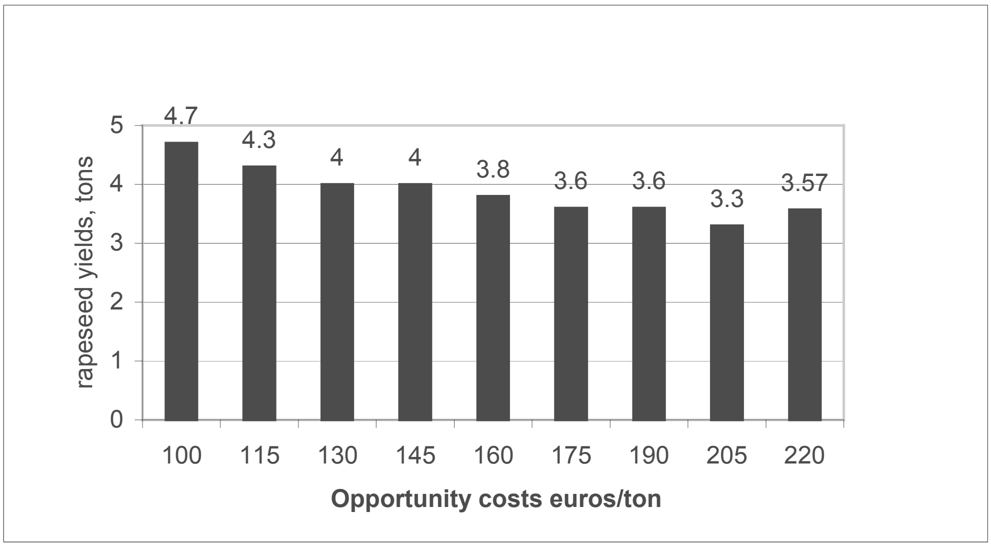


**Figure 2.** Opportunity costs of rapeseed against yields

## From the farm model to the national model, supply curves of non-food productions.

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.

Let E ($\mathbf{e_1}$, $\mathbf{e_2}$, ....$\mathbf{e_k}$, ....., $\mathbf{e_p}$) be the set of farms and **W** ($\mathbf{w_1}$, $\mathbf{w_2}$, $\mathbf{w_k}$, , $\mathbf{w_p}$) respective weights.

The national model can be written as follows:

$$MaxFO = \sum_e fo_e$$

subject to: $\boldsymbol{X_e}$, $\boldsymbol{Y_e}$, $\boldsymbol{Z_e} \in \boldsymbol{W_e}\,\boldsymbol{D_e}$ for any **e**

$$\sum_e y_{j,e} r_{j,e} \geq \overline{Q}_j \text{ for j non food crops} \qquad \textbf{(III)}$$

**j** supply constraints, as common constraints to the e individual farm models

$\overline{Q_j}$ Quantities of non-food resources.

By taking again the same formulation of $\mathbf{fo_e}$ as in **(II)**, the dual values of the saturated constraints **(III)** give the minimal prices **P*j** in which the industry must pay the resources in order to obtain the demanded quantity $\overline{Q_j}$. Non-food crop production is distributed in an optimal way among the various farms e, so that reduction in the function fo, i.e. the total cost of production, becomes minimum. If the optimal distribution of the 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 might show.

By increasing the quantity ***Qj***, one obtains corresponding ***P*J***, The relation ***P*J = OJ (QJ)*** is a supply curve of the resource j. Each modification of the parameters of the model (for example, modification of the rate of obligatory set-aside or of the quantity of bio-fuel to be produced[3]) gives rise to a new supply curve. For each non-food crop j, there exists a family of supply curves.

In practice, these curves are obtained by questioning the model OSCAR, a partial equilibrium model "supply and demand of bio-fuels" developed in INRA Grignon[4]. The quantity of ester is parameterised between 0 and 500 000 tons; for two set-aside land rates, two supply curves are obtained. A decrease in these rates involves an increase in the opportunity cost because additional producers that are less efficient enter the market to satisfy the bio-fuel demand (Figure 3).

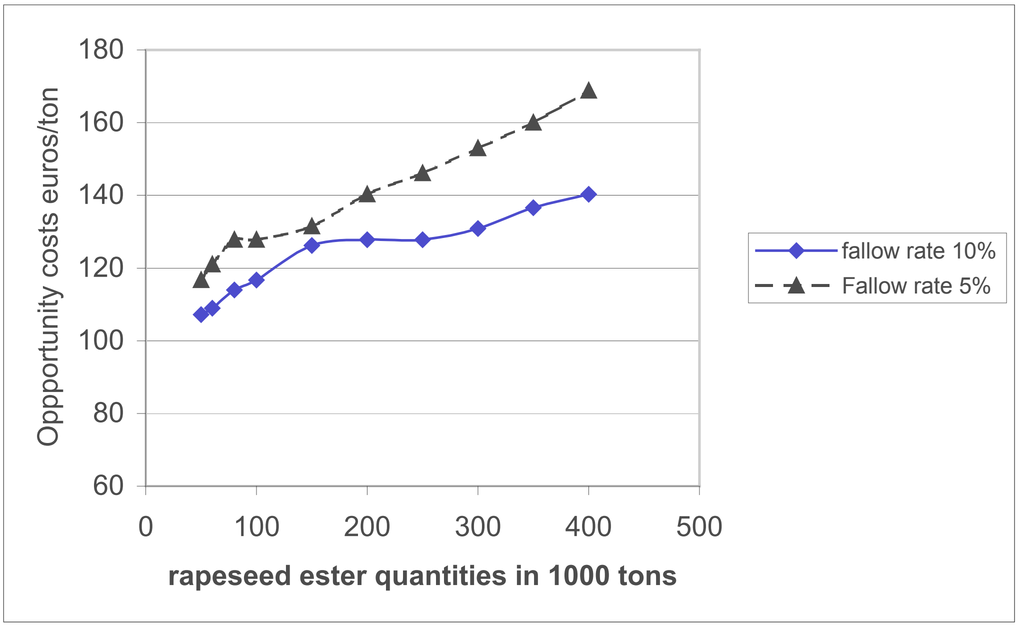


**Figure 3.** Rapeseed supply curves, in €/t

## The farmers' surplus S

Farmers' surplus measures the increase in producers' income, if the production $Q_J$ of renewable (biomass-to-energy) resource is bought at the price $P^*_J$ .This increase is expressed in the following way:

Let $fo^0$ be the optimal objective function when $Q_J$ are fixed at zero (no production of non-food crops), let fo* be the optimal objective function when $Q_J$ are fixed at the levels $\overline{Q_j}$

Then $S = P^*_J\ \overline{Q_j}$ - $(fo^0 - fo^*)$, the sales inflow brought by the production of non-food resources minus the minimal cost of production.

If the price of rapeseed is the same one for all producers and just equal to the opportunity cost given by supply curves, each producer benefits from an increase in agricultural income (except the less efficient producer whose cost equals the market price).

[3] The rapeseed supply depends not only on bio-diesel but also on the ethanol supply because sugar-beets or corn are in competition with rape-seed in a large number of farms. These results underline once more the interdependence between agricultural crops as well as cross-price dependencies.

[4] JC Sourie, S. Rozakis, ibid.

The higher the economic effectiveness of the farm, the more significant the increase in income. The sum of these increases constitutes the producers' surplus. Figure 4 gives the average surplus per m$^3$ of ester, i.e. the total surplus divided by the volume of ester (assumption 5% of set-aside).

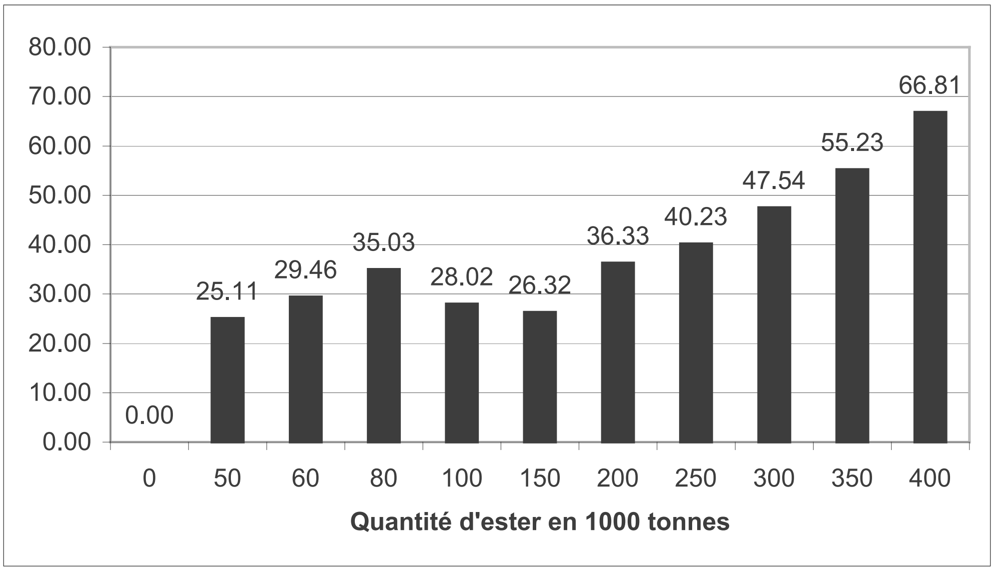


**Figure 4.** Farmers' surplus , € per m$^3$ of rapeseed ester

This surplus, whose order of magnitude exceeds the monetary value of avoiding "greenhouse effects", should not be overlooked as an advantage when effectuating a public assessment of bio-fuel policy.

## Conclusions

This analysis underlines different factors that determine the agricultural raw material cost used for the production of bio-fuels. Certain factors are endogenous to the farms such as crop yields; other factors are exogenous such as agricultural policy decisions, in particular those that relate to the rate of land set-aside. Climatic risks are also a source of cost variation.

In addition to cost variation factors that are farm specific, spatial variability exists, which is the result of differences in economic efficiency among farms. *The concepts of agricultural supply and opportunity cost* resulting from the microeconomic theory, which find an application within the framework of mathematical programming models, allow for modelling of the agricultural complexity with very interesting results.

Obtained directly from the evaluation of the agricultural supply, *the surplus* measures the farmers' profits and should be considered as an advantage of bio-fuels in public economy analyses.

The models that have just been described constitute a basis from which a partial equilibrium model has been elaborated[5]. This model allows comparisons of the various bio-fuel chains and a confrontation between the economic points of view of the private and public actors.

[5] S Rozakis, JC Sourie, D Vanderpooten Integrated micro-economic modelling and multi-criteria methodology to support public decision-making : the case of liquid bio-fuels in France. *Biomass & Bioenergy* 20(2001) 385-398.