Socio-economic and environmental aspects related to development of agro-energetic chain: the case of the Tuscany region

SOCIO-ECONOMIC AND ENVIRONMENTAL ASPECTS RELATED TO DEVELOPMENT OF AGRO-ENERGETIC CHAIN: THE CASE OF THE TUSCANY REGION

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ABSTRACT: This work aims at highlighting relevant aspects concerning the impact of agro-energetic short chain, based on vegetable oil, in the Tuscany context (Italy), according to socio-economic and environmental point of view. The methodology here proposed defines the main parameters of investments' financial efficiency regarding the use of pure vegetable oil as a transport fuel (in agricultural tractors or cars) or for the production of heat and electric energy, in order to point out the economic, fiscal and managerial aspects of the chain. To take into account the characteristics of territorial suitability for the cultivation of oil crops, such as, for instance, the environmental specificities, a "Vocation map" has been created. The methodology to develop this map, is based on Geographical Multiple Criteria Evaluation (GMCE) approach, that combines the classical methodology of Multiple Criteria Evaluation (MCE) and Geographical Information System (GIS). In this part not only environmental parameters but also economical ones have been integrated. Finally the examination of suitable areas highlights the possible impacts and contrast with actual rural market and arable land use.
Keywords: environmental limitations, geographical information system (GIS), land use, logistic, socio-economic impact, vegetable oil.

1 INTRODUCTION

In order to cope with the rising interest on renewable energies and in particular bioenergy, it is necessary to carry out an accurate setting of the interventions and investments in the sector, in order to avoid impoverishment phenomena of the environmental resources and improvement of the financial ones [1].

Thus, this work aim at analysing the environmental, logistic and economic issues of the production of vegetable oil for energetic use, in the Tuscany context.

The technological development actually reached in the agro-energetic sector allows to direct the products, such as bio-fuels, towards different typologies of energetic production, as power, heat, electricity or transport.

The final aim of the work is to integrate and summarize the elaborated information into an analysis, which highlights the strengths and weaknesses of the internal environment (for instance as a function of the farm characteristics or of the farming of the examined area) and the opportunities and threats generated by the exterior environment (evolution of the norms, of the market, etc.).

2 DESCRIPTION OF THE METHODOLOGY

2.1 Area under study

Tuscany (Fig. 1) has a strong variability in agricultural use, both in terms of cultivated crops and geomorphological conditions.

The most important cultivation, in terms of sown area, are arable crops, practiced by 67.9% of the farms [2].

During the last decade the agricultural system of the region significantly changes. Numerous countryside zones were urbanized due to the effect of industrialization and to expansion of house. Some traditional cultivated plants were substituted by the new ones: olive groves to vineyards.

The most important agricultural products in Tuscany are flowers, wine grape and oil. Less important are cultivation of maize, vegetables and fruits.

Breeding (sheep) and fishing is in line with average Italian rate in these sectors.

Figure 1: Area under study

2.2 Crops account approach: analysis of short agro-energetic chain

The main suitable areas for sunflower seed production in the whole Italy territory are represented by the central ones; therefore a structured sunflower chain already exists in Tuscany. In fact this study analyzes the implementation of short agro-energetic chains based on this oil crop in the Tuscany territory.

At the present time, in the examined region, almost the total amount of the production of sunflower seeds is for food uses (food oil), while the by-product, mainly flour, is used in the feed sector.

The oil extraction for majority of the Tuscan seeds is done in an industrial plant located in the Castelfiorentino County in the province of Florence. In the same place also cleaning and dehydration take place.

Our hypothesis on the chain, regarding the production of sunflower oil for energetic use, do differ from the present one, considering the possibility of realizing decentralised pressing plants in each farms or, more realistically, at a consortium level. Industrial plant will in fact limit the benefits on the territory at local scale, for instance for the single farmers involved in the productive process.

The considered agro-energetic chain is assumed to be structured as follows:

- Production of the seed (field phase)
- Switching phase in the Province Agricultural Consortiums and transportation to the extraction plant
- Dehydration and storage of the seed
- Pressing of the seed and filtering of the sunflower oil
- Use of the oil for energetic production

For each step of the productive process a processing cost is associated.

2.2.1 Description of the field phase

The first part of the work analyses sunflower cultivation.

In order to determine the costs related to this phase, a set of variables have been defined, on the basis of the farm and territorial characteristics of the Tuscany context.

The cultivation account will consequently be elaborated through the analysis of the processing process with the matrixes of the technique (1) and the productive yields of sunflower [3].

In the Tuscany territory, the most frequent typology of cultivation interventions for sunflower can be summarized as follows:

- Ploughing
- Harrowing
- Hydraulic enhancement
- Fertilization
- Pre-planting enhancement
- Planting
- Harvesting (2)

The definition of the matrixes of the techniques meant also the selection of the most suitable equipments for each of the productive processes, of the working time and of the quantity of the phytosanitary products needed.

The costs for each working phase have been, in synthesis, calculated as the product between the working times (h/ha) and the cost per hour of the working phase (€/h) [4].

The second considered characteristic is the farm size; as a function of this aspect, in fact, the typology of machinery used can change for the different working phase, both for the size and for the technical characteristics of the machinery itself, thus the starting investment for the purchase of the equipment varies. This means, considering the same cultivated agricultural area, a variation in the working times and in the cost of the whole productive process. Based on Agricultural Census 2000, three farm sizes for the Tuscan region, have been defined: small sized farms (30 ha), medium sized farms (150 ha) and large sized farms (300 ha), and for each of them the used machineries, the matrixes of the techniques and the production costs have been calculated (3).

As regard to crop yield this parameter depends on numerous environmental and technical variables. In the Tuscany context, the climatic, pedological, morphological characteristics are very variable; moreover, considering the erratic yearly meteorological trends, typical of the Mediterranean climate, and also the different cultivation techniques used in the examined territory, it is possible to deduce how the definition of an exact average yield for this typology of cultivation is an hard work.

Thus, the analysis of the costs considered a range of yields for the sunflower seed for area unit to be correlated to the farm sizes (Fig. 2). The average productivity of the cultivation has been defined through the elaboration of the data published in the *IXth Report on Economic and rural policy in Tuscany*, which defines the average production yield of sunflower, at Province level, for the three year period 2004-2006.

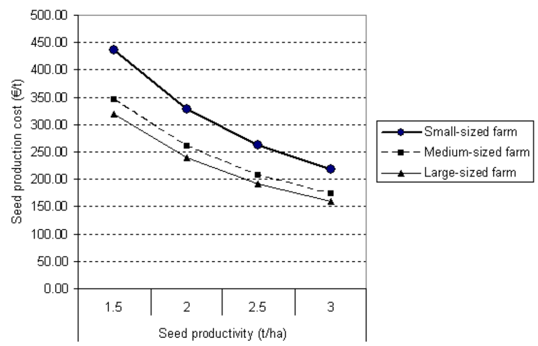

Figure 2: Sunflower seed production's cost depending on productivity and farm size

2.2.2 Switching in the province agricultural consortiums (CAP) and transportation to the extraction plant

The Tuscan sunflower chain for food purposes considers at the present moment, as said before, the transfer of almost the total production to an unique pressing plant, located in the Province of Florence.

The localization of the farms in the regional territory does not allow a direct transportation from the farm to the above mentioned plant. The transportation usually starts, in particular for the most distant areas, from switching centres located mainly in proximity of the secondment of the Province Agricultural Consortiums; here the seed is directly brought by the farmer and after it is transported to the final destination by tractor or trucks.

This simple switching phase counts an average cost of about 15 €/t (4). The switching cost has been recorded, with a conservative consideration, in the economic analysis; but if we look for the optimization of the logistic, that phase must be considered superfluous.

The analysis of the transportation cost of the sunflower seeds from the field to the extraction plant considers the opportunity of using both a tractor trailer or a truck; the convenience of a means in respect to the other depends on the distance to be covered.

2.2.3 Dehydration and storage of the sunflower seed

The sizing of the agro-energetic chain at farm or at small size agricultural cooperative level makes necessary the establishment of small size pressing plants that, as previously said, could maximize the local benefits. The investments in this type of technologies is made convenient if the machineries work for a considerable amount of hours per year (3-4000 hours/year), thus a large quantity of seed is needed.

The rooms with the equipments for the necessary dehydration and storage operations should be next to the pressing and filtering plant, in order to optimize the logistics of the chain and facilitate the organization of the different phases of the work. The alternative (here considered for the economic analysis) considers the handing over of the seed to agricultural cooperatives which carry out these operations.

2.2.4 Pressing of the sunflower seed and filtering of the oil

The plant studied for the definition of the costs is a very small (120 kg/h). The mechanical cold extraction achieves a yield of a 33% (weight/weight); the remaining 67% (by-product) of the processed is cake, until today exclusively used for animal feeding. A working of 4000 hours per year has been considered.

As said, the main use of the cake a "residual" is as feed for the animal production.

A further use of the by-product of the pressing can be the one regarding the production at the farm of heat energy for multi-fuel boilers. Finally, interesting and quite innovative, it is the use of the cake as organic fertilizer (for the sunflower cake) or as soil improver, able to improve the physical characteristics of the soil, especially the physical-chemical characteristics of the product deriving from the *brassicacea* [5].

According to the several use possible for the cake, as mentioned above, a market analysis on price of vegetable oil co-product has been developed. This research highlighted that the value obtained for this product is linked to the price of oil crops seed; therefore it was possible to select a possible range of revenues from cake selling approximately from 100 to 250 €/t.

2.3 Financial indicators and long term approach

The economic analysis, regarding the above mentioned uses of PVO, has been conducted on the basis of different bio-fuel taxation and/or tax exemption scenarios, besides considering the market characteristics (price of the raw material and of the productive factors), the farm characteristics (farm size, field techniques adopted and available technical means) and the possible selling opportunities for the by-product obtained by the pressing (cake). The work considers three different scenarios:

- Scenario 1: the administrator of the plant pays the farmer the cost for the production of the sunflower seed (field phase) and uses the oil for internal uses of the farm (fuel for tractors, greenhouse and/or rooms heating, production of electricity);
- Scenario 2: the administrator of the pressing plant buys the seed from the farmer at the market price, selling the oil obtained in the fuel market (as the equivalent of the diesel fuel for cars);
- Scenario 3: purchase of the seed at the market price and use of the oil for the production of electricity.

The financial analysis of the investments was done through the calculation of usual economic efficiency indexes, deriving from the application of the long term approach. This technique, which considers the financial analysis of an investment divided on a more or less long period (in this case ten years), implies the calculation of the following efficiency indexes, described later:

- Break Even Point (BEP)
- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Pay-Back Period (PBP)

2.3.1 Break Even Point (BEP)

The convenience in the use of vegetable oil for energetic purpose has been determined through the comparison between the price of the equivalent fuel (diesel fuel used as fuel or for the production of heating and electric energy), including VAT and excise duty, and the value of the *Break Even Point* that the PVO can have for the different scenarios. The price of BEP represents, in practice, the minimum figure to which the vegetable oil can be sold to have, in any case, a return in the initial investment (5) in the considered period; if the price of BEP for the oil is grater of the one of the equivalent fossil fuel, the use of the first for energetic use is not economically convenient. The price of BEP of the PVO has been determined as the selling value which makes the Net Present Value (NPV) equal to zero.

2.3.2 Net Present Value (NPV)

For the entire period of the assessment of the investment it is has been detailed the cash flow. It describes, for each single year, the costs supported for the implementation and the management of the plant and the revenues; these variables derive from the selling of the vegetable oil and of the cake (and eventually electric energy, depending on the scenario considered) and they allow the calculation of the Net Present Value (NPV) of the investment.

From the analytic point of view, NPV is represented by the summation of the differences between the annual revenues and costs, actualised with the following formula:

$$NPV = \sum_{i=0}^{n} (b_i - c_i) \Big/ (1+r)^n$$

with:

n duration of the investment, b_i annual total benefit (revenues), c_i annual total costs, r interest rate or discount rate (in the following analysis a rate of 5% has been adopted).

2.3.3 Internal Rate of Return (IRR)

The Internal Rate of Return is based on an opposite logic with respect to NPV. In this case, in fact, given a series of expected discounted cash flows, their sum is set equal to zero and IRR represents the discounted rate that solves the expression. Thus, IRR is the rate that puts equal to zero the formula of NPV.

2.3.4 Pay-Back Period (PBP)

The risk linked to the initial investment, in our case represented in purchasing of machinery for production of energy from biomass, is well-defined by the Pay-back Period (PBP). PBP is, in fact, the number of years that make net cash flow equal to initial investment.

Therefore Pay-back period represents also the time in that Net Present Value is equal to zero, in formula:

$$\sum_{i=0}^{x} b_i /(1 + r)^i - \sum_{i=0}^{x} c_i /(1 + r)^i = 0$$

whit:
x: years needed to make NPV equal to zero (period of Pay-back), b_i annual revenues, c_i annual costs, r interest rate.

This index doesn't consider the initial amount of money needed to start the investment and cash flows following the PBP year, but it is easy to calculate, elucidative and intuitive for entrepreneur.

The calculation of the previous financial indexes (NPV, IRR, PBP) was obtained, for each scenario, referring to the farm sizes, to the selling price of the oil seed and to the revenue deriving from the cake (referred to a medium value of 175 €/t). The selling price of the vegetable oil used for the calculation of these value is defined as the one that covers all the production costs (Break Even Point) and that is lower than the price of equivalent fossil fuel. The BEP, instead, has been calculated in a range of value concerning cake price, farm typologies and/or sunflower seed price, also depending on scenario.

3 DEFINITION OF POSSIBLE SCENARIOS IN TUSCANY

3.1 The Vocational map for the cultivation of sunflower

The definition of areas potentially appropriate for the cultivation of oil plants can be implemented on a local scale and can be considered the starting point for the analysis.

The "Vocational map" has been developed considering climatic, morphological, lithological and land use characteristics [6], implemented with cartographies concerning the average farm size for each territorial area considered.

The aggregation of the data, in order to create the "Vocation Map", was done through the development of a technique which uses the multiple criteria evaluation (MCE).

The term MCE considers a quite large set techniques which are used to define supporting methods for the decisions, when there are numerous criteria for the analysis, each of them characterized by its own unit of measurement. The main advantage of the multi-criteria analysis in respect to the other evaluation techniques is in fact the freedom in the collection and in the fixing of the elements which contribute the decision with the most appropriate examining method.

The typology of considered analysis is based on specific technique called Geographical Multiple Criteria Evaluation (GMCE), that combines the classic methodology of Multiple Criteria Evaluation (MCE) and Geographical Informative System (GIS) [7].

For its development, the model worked out considers:

- criteria: factors represented by layers that increases or decreases the suitability of a particular area to be used for a specific purpose (in our case the sunflower cultivation);
- obligations: factors that must be absolutely respected and that limit considered options (from point of view of spatial location). These are boolean factors (value 0 or 1).
- decisions: the final classification of results (in our case the definition of vocation classes for sunflower cultivation).

The evaluation is based on raster map with a resolution of each pixel equal to 75 x 75 m.

The GMCE approach considers the Weighted Linear combination; in this method the total value of each pixel derives from the average of the score of each criteria multiplied for the value of obligations, according to the following formula:

$$pixel\_value = (\sum_{i=1}^{n} x_i / n) * P_j$$

with n number of criteria, x value of each pixel for the criteria i, and P value (0 or 1) of obligation j for relative pixel.

Every criteria and obligations have different unit of measures, so they must be normalized in a real range from 0 to 1 to be compared.

An articulated procedure of normalization is the one based on the *"fuzzy group theory"* [8].

In the standardization through the principles of the fuzzy logic, specific "belonging functions" are adopted and they are defined between 0 - 1. For their interpreting simplicity, the most used function are the linear ones, which are showed, in their general form, in figure 3. In these functions the checking points a, b, c and d represent the condition for which the value is completely not satisfied in relation with the examined criterion i (when 0) or the limit of absolute suitability of value i (when 1).

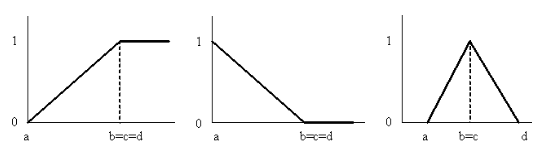

Figure 3: Linear normalization functions. (From left to right: linear increasing, linear decreasing, symmetric)

3.1.1 Criteria

<u>Climatic parameters</u>

The climatic parameters considered vary as a function of the growing phase of sunflower and derive from the data collected in the period 1990 – 2007 from the monitoring network of ARSIA (Regional Agency for Development and Innovation in the Agro-forestry sector), which counts 130 stations spread in an homogeneous way in the regional territory.

Average temperature for the sprouting period.

The sprouting period of sunflower seed depends, obviously, by the seeding moment and it is included, generally in the Tuscan area, between March and April. The optimal values of average monthly temperature vary for this phase between a minimum of 4°C and an optimum of 15°C. Thus, the normalization of this index in the range 0 – 1 considers the application of a function represented as follows (Fig. 4):

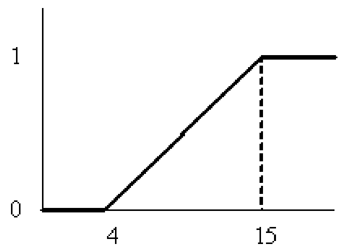

Figure 4: Normalization of average temperature for the sprouting period (value in °C)

Average temperature for the ripening period.

Generally, the sunflower ripening period ends in August; for this reason the average temperature that has been considered is the one among the months May and August.

The optimal values for this parameter range from a minimum of 15° C and a maximum of 30° C, with optimal figure among 18 and 22°C (Fig.5).

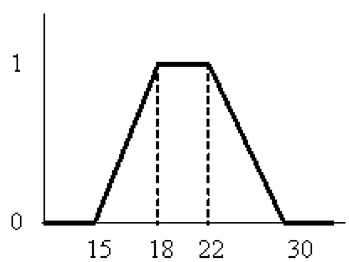

Figure 5: Normalization of average temperature for the ripening period (value in °C)

Cumulate precipitation

Data from literature suggest optimal value for the cumulated precipitation in the development period for the oil plant (March-August) is equal to 600 mm of rain, being in not irrigated areas. The minimum quantity of water for the growth of sunflower during the analysed period has instead been set at 160 mm (Fig. 6).

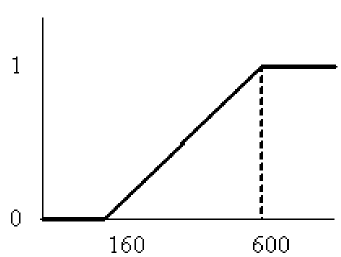

Figure 6: Normalization of cumulated precipitation (value in mm of rain)

Morphological parameters

The morphological parameters derives from GIS elaborations of the Digital Terrain Model (DTM) raster of Tuscany, with a single pixel resolution of 75 x 75 m. From the analysis the followings cartographies have been derived.

Exposure

The territorial vocation for the development of sunflower has been considered optimal if the referring site possesses an East and West exposure, or if it is in plain areas, with decreasing values until a North exposure. This parameter is correlated to the quantity of light received during the crop growing period; thanks, in fact, to the marked heliophilia of sunflower, a greater quantity of received light allows a better development of the crop (obviously considering in the appropriate way the correlation with the other parameters which influence the water balance, such as temperature, precipitations and lithology). The normalized function has a symmetric shape, with values expressed in degrees respect to North (Fig. 7).

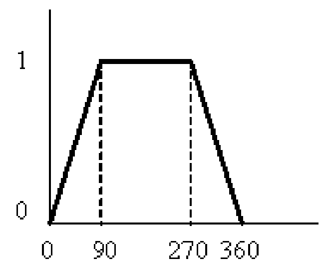

Figure 7: Normalization of exposure (value in degrees respect to North)

Altitude

In general, in Tuscany, the cultivation of sunflower is not carried out above 600 m a.s.l. For this reason a further parameter which integrates the climatic indexes is represented by altitude, through a linear decreasing function, described as follows (Fig. 8):

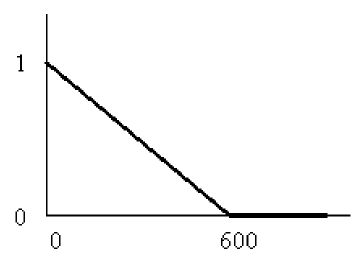

Figure 8: Normalization of altitude (value in m a.s.l.)

Slope

Slope represents a morphological index that defines the facility with which an area can be mechanized also with heavy vehicles, necessary during some phases of the sunflower cultivation, such as the combine harvesters for the final harvest. For this reason, we thought to be correct to assign the value 0 to the pixels with a slope grater than 20% (Fig. 9).

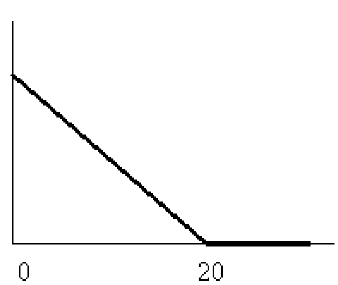

Figure 9: Normalization of slope (value in %)

Lithological parameters

Lithology

Sunflower it is not a demanding crop as for the soil typology; however, it can suffer in soils with a scarce capacity of keeping the humidity and particularly incoherent.

The following values of vocation has been given (6):

- 0: sandy shores and recent and present coastal dunes;
- 0,5: deposit of waterway – lacustrine or sea origin sand interbedded with clay, gravel and other materials; sandstone scarcely cemented such as "*panchina*", old dunes, "*molasses"*;
- 1: all the other soils.

Farm parameters

Average farm size

As already said, in the case agro-energetic chains, the size of the farms involved in the process become an important parameter for the economic efficiency of the system.

Therefore, a further analysis considered the introduction of the "average farm size" variable; this last one is a parameter that can influence the real economic performance of the investments and it is linked with the field phase, that is the production cost of the sunflower seed. Farms of medium-large size can guarantee a greater use of the technical means on a yearly base, with greater capability of amortization of the machineries; these aspects influence the final price of the raw material.

For this reason, the average arable crop farm size for each single County has been introduced afterwards. This parameter derives from the elaboration of the data from the Vth Agricultural Census. The limit value for the dimension *optimum* (equal to 6 ha in the modelling of figure 10) derives from the fact that the indicator considers the "Ordinary value" representing the conditions in which the entrepreneur (farmer) has (in the long period) profit equal to zero (see Romano, 2008 [7]), that is in the case of farmer of medium capabilities (compared to the whole region). Therefore the "ordinary farm" is the one that has revenues equal to production costs so it is conduced by a farmer of medium capabilities.

In this case the ordinary conditions are considered as a function of farm size and in particular the distribution of regional farm size (arranged as gaussian function) suggest that the medium value is equal to 6 ha.

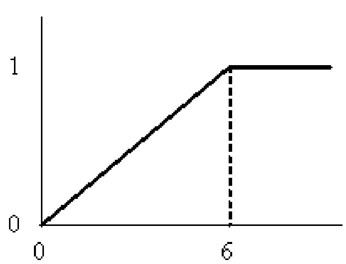

Figure 10: Normalization of average farm size (value in ha)

3.1.2 Obbligation

Land use

The parameter used as a bond is represented by land use deriving from the cartography of Corine Land Cover (CLC) 2000 (III° level of detail). All the soils classified as arable crops in non irrigated area, with slope lower than 20% and a proper level of precipitation and other climatic parameters, have been considered as appropriate for the cultivation of sunflower.

3.1.3 Decision

The aggregation of the above mentioned data has been done with a GIS software by using a model synthesised by formula in paragraph 3.1. Afterwards a classification of areas in suitability range of value has been carried out, as explained in paragraph 4.1.

3.2 The specialization of the vocated territories: possible impacts deriving from the implementation of agro-energetic chains in Tuscany

The analysis of the impact between the sunflower used for energetic purposes and the other regional cultivation considered the variations which took place in the primary sector in the last years and their possible evolution, also bearing in mind the new changes in action in the Communitarian Agricultural Policy. For instance, the introduction of the decoupling started in 2005 led the farmers to the perception that they could release from the production of specific cultivations, increasing the dynamism and the degree of freedom in the use of the agricultural areas, which are strongly connected to cyclical and market factors. The analysis of these aspects is essential, in particular considering recent regional data [9], which highlight how the gross agricultural production of Tuscany is equal to the 95% of the whole primary sector, representing the 5,4% of the total of the nation, value that clearly defines the relevance of the sector at regional level.

The definition of appropriate areas for the cultivation of sunflower and, more specifically, to the creation of an agro-energetic chain based on pure vegetable oil, it is not sufficient for the determination of the possible impacts (positive or negative ones) that this new market can generate on a local and regional level.

The next phase will be in fact linked to the study of the present productive characteristics of the single vocated territory and with the importance that some particular and specific cultivations can have for the entire regional primary sector.

In order to define the weight that a particular cultivation has at county level has been defined a Specialization Index. In particular, on the basis of the data deriving from the Vth Agricultural Census, a series of maps have been developed. They highlight the specialization of a County in relation to the production of a particular cultivation. The cultivations considered are the same that are listed in the legenda CLC IIIrd level in the code 211, used for the previous analysis, that are:

- Cereals
- Legumes
- Flowers and ornamental plants
- Nurseries
- Vegetable plants
- Oil seeds
- Forage crops
- Potatoes
- Seeds
- Sugar beet
- Set aside areas

The Specialization Index (SI) is a particular value that is useful for detecting Developing Local Systems and

Industrial Districts, which are important for a particular production for the agricultural, industrial or services sectors. If the Index has a value grater than **2** it means that in the examined area there exists a high specialization for the considered sector, thus a solid Developing Local System.

In this specific case, the Specialization Index is calculated as follows:

SI = A / B
where:
A = (Area of the crop cultivation for County / Total arable crop area of the County)
B = (Regional area of the crop cultivation / Total regional arable crop area)

4 RESULTS

4.1 The potential diffusion of the sunflower surfaces

The aggregation of the data above described, led to the creation of a "Vocation map" that considers the climatic, morphological, lithological and land use parameters combined to average arable crop farm size for single County.

The result represent the areas inside the Tuscan territory with a different vocation index for the cultivation of sunflower; in fact, on a total of 516.210 ha of non irrigated arable crops, on the basis of the classification, *range* of territorial appropriateness to the cultivation of sunflower, are:

- areas without vocation (suitability degree equal to 0): 174 ha
- areas with a low vocation (suitability degree from 0,01 to 0,25): 0 ha
- areas with a medium vocation (suitability degree from 0,26 to 0,5): 1.179 ha
- areas with a high vocation (suitability degree from 0,51 to 0,75): 257.197 ha
- areas with a very high vocation (suitability degree from 0,76 to 1): 257.660 ha

Subdividing the results at a Provincial level, as it is showed in table I, it is possible to highlight that the greater territorial aptitude for the cultivation of the oil seed-sunflower (areas with a *very high* vocation) is localized in the Provinces of Grosseto and Pisa, and a large area also in the Provinces of Livorno, Florence, Siena, Arezzo and Pistoia; this spread of vocated areas shows again the aptitude of Tuscany for the cultivation of sunflower, if we exclude the mountain areas (Apennines and Monte Amiata), the Province of Massa Carrara and a large percentage of the interior areas.

Table I: Very high vocation areas subdivided by Province

Province	Surface (ha)
Arezzo	8.761
Firenze	20.405
Grosseto	95.176
Livorno	27.289
Lucca	3.807
Massa Carrara	191
Pisa	52.608
Pistoia	9.130
Prato	4.401
Siena	35.692
Total	**257.660**

By detracting the areas that fall in a specific Productive District for a particular cultivation (that are characterized by a SI > 2 for this cultivation, i.e. cereals, flowers, legumes etc.) to the highly vocated ones for the production of the oil plant, it was possible to define the zones in which the implementation of agro-energetic chains could have a success.

The result is highlighted in figure 11.

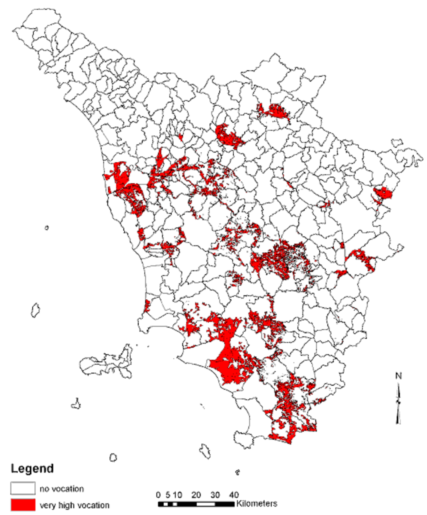

Figure 11: Vocated areas for sunflower and with low impact on actual cultivated crops

In conclusion, sub-dividing the data obtained for Province, it is possible to explain how the territories in which the cultivation of sunflower could spread in a profitable way are dislocated, as it is showed in table II.

Table II: Provincial dislocation of the surface which have greater chances of diffusion for the cultivation of sunflower

Province	Surface (ha)
Arezzo	7.894
Firenze	15.093
Grosseto	69.143
Livorno	5.297
Lucca	0
Massa Carrara	0
Pisa	25.664
Pistoia	421
Prato	4.026
Siena	22.306
Total	**149.844**

As it comes out from table II, the Province with the greater usable surface for the cultivation of sunflower is Grosseto, which is followed by distance by Pisa, Siena and Florence.

Limited are, at last, in respect to the total of the region, the territories which are adequate in the Provinces of Pistoia, Prato, Livorno and Arezzo, with a non vocation at all for Massa and Lucca.

If we make the hypothesis of the creation of agro-energetic chains at provincial level, we could imagine the maximum attainable dimension for the pressing plants, as a function of the different technical and agronomic characteristics; for instance, a productive structure of

PVO, with a press of big dimensions (for example with a capacity of 1000 Kg/h), working for 4000 h/year, will need about 4000 tons of seed per year. With a prudential yield per hectare of 1,5 t/ha and a quadrennial rotation of the agricultural surfaces, it is possible to imagine, with a good degree of approximation, the need of an extension of arable crops of about 3.300 ha, which is present in the majority of the Tuscan provinces (Table II)

However it is necessary to point out that, as defined on the new Energetic Regional Plan (PIER) for the period 2007-2010, according to the complementary rule of agro-energetic crops in the agricultural regional sector, approximately only a 15% of total arable land can be cultivated for this purpose. This value is equivalent to about 77.000 hectares and it means that only few province can implement large-sized agro-energetic chain based on PVO, in particular the province of Grosseto.

4.2 Financial analysis

The analysis of the costs linked to each compartment of the agro-energetic chain pointed out that the higher incidence for the entire productive sector is due to the field phase, that, by itself, can reach a weight up to the 70% of the total cost for the production of oil and cake; this phase is followed by the dehydration and storage phase and by the pressing and the filtering ones, which reach values of about 10% each.

The effective economic assessment regarding the use of vegetable oil for energetic use has been conducted considering three different possible scenarios, several of which strictly dependent on the role of the farmers within the productive process. However, it must be considered that the optimization of the agro-energetic VO chain, can be reached only trough an implementation of consortium, founded by the owner of pressing and filtering plant, the farmers and, eventually, the transporters. The rules pinned down from these local stakeholders must be very well defined, considering prices and actions of labour and products in each step of the process, to warrant the supply of raw material, possible opportunities or risks for the entire short chain and, consequently, the feasibility of production in economic terms. Furthermore, a consortium can involve the possibility of additional form of incentive and tax break, i.e. in terms of purchase of engine or agricultural tractors or to sell energy or bio-fuel.

4.2.1 Results of the simulation for agricultural transports and energy generation in farm

In the first hypothesis of the chain, the farmers can hold an active role for the energetic production from biomass. In fact, in this case the creation of consortium among the different involved persons is possible, thus allowing the direct selling of the oil to the seed producer.

The economic assessment did take into account different typologies in the use of the oil as a fuel and two different tax systems.

Figure 12 refers to the selling of the oil to the farmer, considering the payment of a subsidized excise duty, because dealing with farm uses (as it happens at the present time for the purchase of the so called diesel fuel for agricultural purposes to be used as fuel for tractors or for greenhouse heating).

In the case of utilization of bio-fuels for the production of electric energy, on the basis of what it is stated in the Italian d.lgs. of February 2nd, 2007 n. 26, the excise duty is not due; for this reason it has been defined a variation to the first scenario which highlights the convenience margins of the selling of the oil for energetic use for the farmers, in the hypothesis in which this regulation is going to be broaden to the use of PVO in tractor or for greenhouse heating (Fig. 13).

The two possibilities above described, considering as the key parameter the cost of production of the sunflower seed, are mainly based on two variables: the yield per hectare of the oil plant and the farm size, as they have been defined in paragraph 2.2.1.

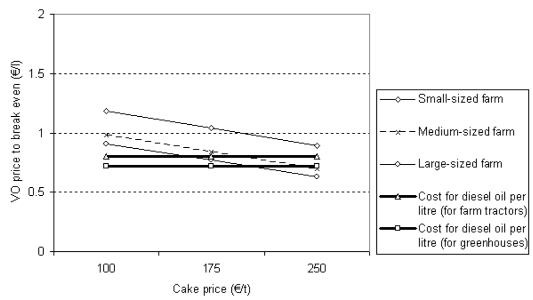

Figure 12: VO price to break even: selling of VO to farmer for tractors or greenhouses heating (with excise duty).

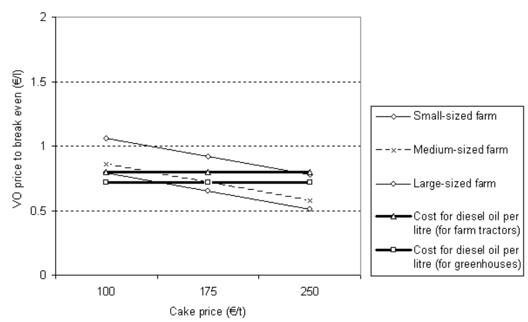

Figure 13: VO price to break even: selling of VO to farmer for tractor or energy production (heat or electricity) (without excise duty).

Financial indexes for scenario 1 (*selling with excise duty*):

Large sized farm (Selling price of PVO = 0,80 €/l; cake price = 175 €/t):

NPV= 44.765 €

PBP= 6 years

IRR= 15%

Financial indexes for scenario 1 (*selling without excise duty*):

Medium sized farm (Selling price of PVO = 0.75 €/l; cake price = 175 €/t)

NPV= 37.808 €

PBP= 7 years

IRR= 14%

Large sized farm (Selling price of PVO = 0.70 €/l; cake price = 175 €/t)

NPV= 137.829 €

PBP= 4 years

IRR= 33%

Comparing figures 12 and 13, it is possible to point out, thanks to the fact that the production costs of the seed are relatively low, that the selling of the sunflower oil to be used for energetic purposes is particularly convenient for large sized farms.

Under the hypothesis of an excise duty in force, even if reduced for the agricultural use, it comes out that the selling to small sized farms does have very tight convenience margins, while in the case of medium sized farms, in order to make the bio-fuel competitive in respect with the other fossil fuels, the by-product has to be sold respectively to a price of at least 220 €/t if the oil is used for greenhouse heating and of 190 €/t if used as agricultural tractor fuel.

By removing the excise duty, the price of Break Even of the bio-fuel reduces of about a medium value of 15%, thus allowing a consequent reduction of the previous selling prices of the cake to about 175 and 130 €/t. The bio-fuel duty-free increases, in this scenario, its selling chances also towards small sized farms, but only with a cake price equal to 250 €/t.

4.2.2 Results of the simulation for PVO on fuel market

In the second hypothesis of scenario, as for the following one, the farmer keeps unchanged its typology of production and processing, selling to the administrator of the pressing plant the seed, in relation to the price determined by the market.

Under this hypothesis, the oil is sold in the fuel market; thus, on the final price will bear the entire excise duty (actually equal to 0,56 €/l) and the VAT at 20%, being the purchaser the final user (Fig. 14).

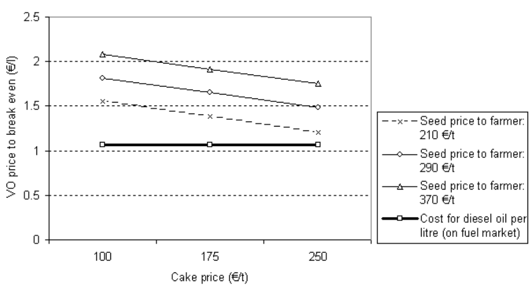

Figure 14: VO price to Break Even: selling of VO on fuel market (without excise duty reduction)

The alternative is selling the PVO for an equivalent use, but with a reduction of the excise duty equal to a 20% of the today's value, as it actually happens for bio-diesel (Fig. 15).

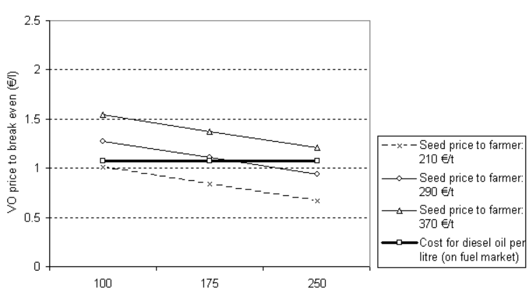

Figure 15: VO price to Break Even: selling of VO on fuel market (with excise duty reduction)

Financial indexes for scenario 2 (*selling with excise duty reduction*) (seed price: 250 €/t; selling price of PVO = 1,00 €/l):

NPV= 30.055 €
PBP= 7 years
IRR= 12%

Financial indexes for scenario 2 (*selling with excise duty reduction*) (seed price: 210 €/t; selling price of PVO = 1,00 €/l)

NPV= 178.314 €
PBP= 3 years
IRR= 40%

Figure 14 highlights in a clear way how the selling of the vegetable oil on the fuel market does not reaches, considering the present prices for the raw material, margins of economic convenience. The reduction of the excise duty (which in this scenario has a relevant weight on the final price of the fuel) makes however competitive the use of sunflower oil on the market of bio-fuels, in the case in which the price of the sunflower seed decreases approximately below 260 €/t (with a cake price of about 175 €/t) (Fig. 15).

4.2.3 Results of the simulation for electricity generation

The analysis of the economic convenience in the production of electric energy from pure sunflower oil has been taken into account considering the following hypothesis:

- production of PVO for the selling in the market of electric energy (not in farm) (7) and calculation of related price to Break Even, as it shown in figure 16;
- definition of the net annual income derived from the selling of electric (and thermal) energy, with the functioning of three different typologies of bio-fuel engines, with different powers (DACHS of 5 kW_{el}, MGT of 30 kW_{el} and DEUTZ of 50 kW_{el}) (Fig. 17). The costs and revenues for the production of electric energy for each machinery have been determined on the basis of the analysis developed in the Life VOICE project.

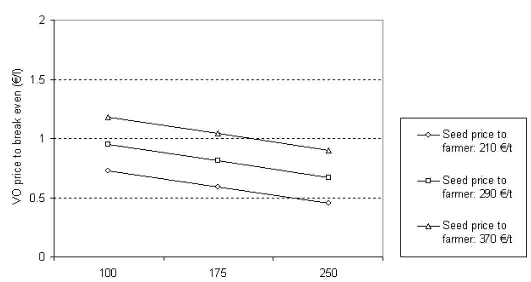

Figure 16: VO price to Break Even: selling of VO for electricity production (not in farm)

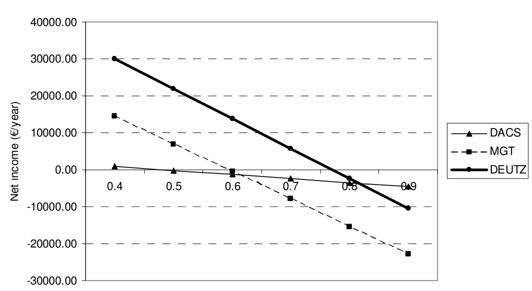

Figure 17: Net income from electric energy and heat production

Financial indexes (*selling of PVO for electric energy production*) (seed price: 250 €/t (incentive for electric energy production: 220 €/MWh (8)); selling price of PVO = 0,75 €/l)

NPV= 65.509 €
PBP= 5 years
IRR= 20 %

The analysis of the figures 16 and 17 highlights how, under the present market price for sunflower seed, the production of electric energy can be convenient only with the utilization of machineries with a medium-high power (particularly, in this case, the 50 kW_{el} of DEUTZ).

Figure 16, in fact, points out that the minimum selling price for the oil, for the considered typology of investment and of utilization, is approximately of 0,70 €/l (with a purchase cost of the seed of 250 €/t and a selling price of the cake equal to 175 €/t); introducing this value in figure 17, it is possible to see how the use of engines of 5 and 30 kW_{el} turns into negative income, so this isn't convenient.

4.3 Discussion

The results that come out during the work allow at the moment to analyse the main strengths and weaknesses, as well as the opportunities and threats deriving from the implementation of agro-energetic chains in the area of Tuscany.

Strengths

The territory of Region Tuscany resulted to be highly vocated for the creation of agro-energetic chains, both regarding the environmental characteristics and the technical (farm typology) and historical-cultural aspects.

In addition suitable surfaces for the implementation of the examined chain models are appropriate for the installation of small and also medium size plants, which could allow a greater economic performance of the investments, even maintaining benefits at a local scale (for instance with productive systems referred to the provincial context).

In the first scenario the farmer can play an active role inside the chain, not only as a producer, but also as a final user of the pure vegetable oil, for instance by using it in tractors or for the production of heat and/or electric energy. Furthermore the greater involvement of the farmers improves the organizational and managerial possibilities for the production of PVO, thanks to the need of planning the annual cultivations and the estimation of oil needed yearly for the use in the farm.

Weaknesses

The Consortium organization at the agricultural level are not very important in the Tuscan context; this can lead, at least at the beginning, to a more difficult organisation of the agro-energetic chain, regarding the managerial, information and development opportunities.

The lack of sure market areas for the by-product (seed cake) puts into risk the whole economic stability of the chain, counting it for a very important percentage of the total earnings. It seems therefore necessary to set precautionary agreements with the possible final purchasers (usually seed cake is destined for animal feeding), considering the need of minimizing the transporting distances from the pressing plant to the user, both for economic and environmental reasons (reduction of CO_2 emissions deriving from the road transport).

Opportunities

The total exemption from the excise duty on bio-fuel used for the internal use of the farm can increase the economic margins and consequently the possibilities of use also in small size farms.

Funding at regional, national and European level are numerous and they regard the purchase of machineries for the production of energy from renewable resources, funding deriving from various regulations (Rural Development Plans, Financial Laws, etc.), which the farmer can use too.

The transfer of tax exemption schemes at the moment in force for bio-diesel to the market of pure vegetable oil (see reduction of excise duty to 20% of the present value) can make more gainful this use, also in case of a certain degree of fluctuation of the market price of the oil seed.

Threats

The non application of implementation regulations of the norms and bureaucratic complications can delay the entry into force of incentive arrangements or tax exemption, with the consequent giving up of the investments by the farmers.

An inadequate evaluation of the relationship between demand and offer of vegetable oil leads to a non correct dimensioning of the energetic chain with consequent possibilities of overestimation of the suitable surfaces for the cultivation of energetic crops and consequent import from other areas (national or international) of vegetable oil. These two aspects above mentioned mean, not only a decrease of the environmental and socio-economic benefits at the local level, but also a greater pressure on the external resources, because the fuel can potentially come from areas not managed with sustainability criteria.

5 CONCLUSION

The development of short agro-energetic chains based on the use of pure vegetable oil can have a interesting convenience if realized with models implemented at a local scale. In this case with the term *convenience* it is not only meant a certain degree of profit on the economic point of view, but also the sustainability in environmental and social terms.

The analysis of territorial vocation implemented for Tuscany and developed with a GIS methodology defined a good degree of territorial suitability for the cultivation of oil plants to be used for energetic purposes, both in qualitative (vocation degree) and quantitative (size of the not irrigated arable crops surfaces suitable to the cultivation) terms.

The possibility of including in the models also the degree of specialization of the regional counties for other typologies of crops allowed the integration of the territorial suitability evaluation, excluding from the highly vocated surfaces the ones in which the development of agro-energetic chains could negatively affect the cultural systems already established in Tuscany and that generate quality productions.

The analysis highlighted, as the better way for the implementation of an agro-energetic chain in Tuscany, both the one linked to the creation of consortiums in which the farmers do not play only the role of seed producers, and the one in which the farmers are also the final users of the vegetable oil to be used in farm tractors or for the production of heating and electric energy.

The economic analysis defines several aspects on which it is possible to intervene in order to optimize the agro-energetic chain.

Starting from the production of the raw material it is important to define that the final price of pure vegetable oil is mainly influenced by field phase processes.

Another aspect on which it is necessary to intervene is the logistic optimization of the chain. A short chain can favour the elimination of intermediaries such as the one for the sorting to the different Provincial Agricultural Consortiums, or for the storage and dehydration of the seed. In this sense, it seems necessary to realize appropriate infrastructures next to the pressing seed plant.

From fiscal point of view, the presence of excessive taxations (i.e. partial or total excise duty) and the lack of legislative instruments or bureaucratic complications that slacken the coming into force of incentive or no-taxation interventions for the agro-energetic sector, were pointed out.

An interesting tax exemption instrument can be the one of the partial or total exemption of the excise duty on sunflower oil.

The financial analysis of the first scenario pointed out how the elimination of the same duty, as it happens for the production of electric energy, can increase the convenience margins widening the use also to the medium-small farms and not only to the large ones.

The selling of the vegetable oil on the fuel market (extra-farm) it is not, instead, convenient at the present time; the most important influence is related to the high costs of the raw material and to the presence of an high value of excise duty.

The in force incentives, linked to the purchase of technologies for the bio-energetic production, can favour the investments in this sector; it is, however, necessary to correctly assess all the typologies of incentives, defining the effective convenience margin in the substitution of the fossil fuels, in order to avoid erroneous economic plans due to market distortions.

6 NOTES

(1) They are tables that, for each agronomic intervention, define the corresponding quantities of the different productive factors.

(2) The harvesting phase generally is not done by the farms with their own technical means (because of the high investment for the purchase of the suitable machinery for this process); for this reason it has been considered the cost of the outsourcing for combine harvest (source: data for Tuscany from APIMA - Associazione Imprese di Meccanizzazione Agricola – 2007, re-elaborated).

(3) The sizes considered do refer to the arable crop area for each farm and they represent merely an indication. It comes out, in fact, an high number of farms with an area lower than 30 hectares, but, until that threshold, the variability in the characteristics of the machineries, of the productive processes and, consequently, of the processing costs is not significant.

(4) Data directly given by the Agricultural Consortiums of the Provinces of Florence, Pisa, Livorno and Siena.

(5) In this case, the initial investment is represented by the purchase of the machineries for the pressing and filtering plant and for the energetic production.

(6) The database derives from an elaboration on the Tuscan Lithological Map scale 1:250.000.

(7) The difference between this scenario and the hypothesis of selling of PVO to farmer for the internal electric energy production (in farm), consists in the cost of raw material: in fact in the first scenario the owner of the press-filtering plant purchases sunflower seed at the production cost, instead of this one in which the price is equal to the value in seed market.

(8) In force to the decree December 18, 2008 "*Incentive to electric energy production from biomass"*, applying article 2 of Italian Financial Law 2008, has been modified the 30 c€/kWh_{el} incentive, decreasing it to a value of 22 c€/kW_{el}.

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