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ENERGY CROP PRODUCTION COSTS IN THE EU

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ABSTRACT: The objective of this study was to calculate indicative ranges of production costs and assess the main sources of cost for a number of energy crops, both annual and perennial, on a regional level in Europe. The production costs were calculated in terms of the economic compensation required by the farmer in order to grow the crop, and therefore include not only the cost of cultivation, but also the costs of land and risk, which are often omitted in production cost calculations. The cost of land was calculated as the opportunity cost based on the production of cereals. Thus, higher food prices lead to higher land costs, which in turn lead to higher energy crop production costs. The analysis was performed for three cases with different assumptions concerning yields and production cost reductions resulting from scale (total cultivation area in the region), and learning effects. The calculated energy crop production costs were found to be consistently lowest for short-rotation coppice (SRC) crops and highest for annual straw crops. The production costs of SRC crops were calculated to be about 4-5 € GJ^{-1} under present conditions and 3-4 € GJ^{-1} under improved future conditions. The production costs for perennial grasses were calculated to be about 6-7 € GJ^{-1} and 5-6 € GJ^{-1} under present and improved future conditions, respectively. The production costs for annual straw crops were estimated to be 6-8 € GJ^{-1} under present conditions with small potential for cost reductions in the future.

Keywords: biomass production, energy crops, production cost

1 Introduction

Prompted by increasing concerns over climate change and energy security, the EU has declared a commitment to increase the use of renewable energy sources (RES). In March 2007 the European Council endorsed two binding targets for 2020: i) to increase the proportion of RES in the EU's final energy consumption to at least 20%, and ii) to increase the proportion of biofuels in the road transportation sector to least 10% in each member state [1]. A Framework Directive on renewables is now being negotiated. This directive will contain national targets concerning the proportion of RES in final energy consumption, and will oblige member states to implement interim sectoral targets for the electricity, heating/cooling and the biofuel sectors. Biomass can contribute to the energy supply in all three sectors and can thus play a key role in meeting the RES targets. In 2005 RES accounted for 4.5% (1059 PJ) of the gross inland energy consumption in the EU27, 68% of which was biomass [2].

Various assessments of the potential biomass supply show that the greatest opportunities for biomass production in Europe, and elsewhere, lie in energy crop production on agricultural

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land [3 ,4]. So far, energy crops make a fairly small contribution to the biomass supply, and production is totally dominated by annual crops for the production of transportation fuels. In 2005 the energy crop cultivation area in the EU25 amounted to about 2.5 Mha, 80-85% of which was rapeseed cultivation for the production of biodiesel [5]. On the remaining fraction mainly wheat, sugar beet and sunflower seeds were grown and, to a very limited extent, perennial energy crops, such as short-rotation coppice (SRC) crops and perennial grasses. If biomass is to make a substantial contribution to the future energy supply, it is important that dedicated, preferably perennial, energy crops achieve a more important role, since in general they show better environmental performance than traditional, annual crops. On the whole, perennial energy crops are associated with higher biomass yields, better net energy balance and less environmental impact [6, 7].

Whether or not perennial energy crops will be adopted by farmers largely depends on the economics of these crops. Understanding the character and significance of different sources of cost in energy crop production is therefore important when addressing future strategies for bioenergy. This paper presents an economic analysis of the production costs of a number of energy crops, both annual and perennial, on a regional level in Europe. Energy crop production costs in Europe have been analysed previously in some European-wide studies, e.g. [8, 9], as well as in a number of national studies. It is in general difficult to compare the results from different studies due to the use of different methods, assumptions and delimitations. In this study the energy crop production cost describes the economic compensation required by the farmer in order to grow the crop. For that reason, our cost estimates include the cost of overheads, brokerage, land and risk, four items that are often omitted in cost assessments. The cost of land was estimated in terms of the opportunity cost, for which we used the net gross margin of cereal crop cultivation, the main activity on arable land in Europe. The objectives of this study were to calculate indicative ranges of production costs for these crops and to identify and analyse the structure of production costs. The analysis was performed for three cases that represent different stages of energy crop development in terms of yield, cultivation area, knowledge and cultivation technology. Due to uncertainties concerning commercial yields for many energy crops and the costs of various production inputs, the aim was not to produce exact numbers, but to explore cost structures and relative costs.

This study was conducted within the integrated project Renewable Fuels for Advanced Powertrains (RENEW) (2004-2007). One task of this project was to calculate the total cost of producing biomass-to-liquid fuels, which motivated the present study on biomass production costs [10].

2 Scope and case descriptions

The geographical scope of this study is Europe, which was divided into six regions: Northern[2], Western[3], Southern[4] and Eastern[5] Europe, the Alps[6] and the UK & Ireland. Nine energy crops

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[2] Sweden, Denmark and Finland

[3] Belgium, the Netherlands, Germany and France

[4] Greece, Italy, Portugal and Spain

[5] Estonia, Latvia, Lithuania, Poland, the Czech Republic, Slovakia, Hungary and Slovenia

[6] Austria and Switzerland

were identified based on the climate conditions in these regions These crops are listed in Table 1, which also indicates the crop type, lifespan (those used in our calculations) and our qualitative assessment of their stage of development. Crops usually go through different stages of development in terms of plant breeding, availability of special machines for managing and harvesting the crop, and the organisation and existence of crop markets. We consider SRC crops to be the least developed and annual straw crops to be the most developed. Annual straw crops are grown as dedicated energy crops, and it was thus assumed that the whole crop is used for energy. The stage of development of the crop affects the potential for future cost reductions in growing of the crop. We therefore analysed the production costs not only under present conditions, but also under possible future conditions, including an increase in cultivation area and greater experience of growing the crop.

Table 1: The energy crops included in this study, their characteristics and our expert assessment of their level of development.

Crop	**Crop type**	**Lifespan (years)**	**Level of development**
Willow	SRC crop	22	Low
Poplar	SRC crop	22	Low
Eucalyptus	SRC crop	22	Low
Miscanthus	Perennial grass	21	Low
Reed canary grass (RCG)	Perennial grass	10	Medium
Switch grass	Perennial grass	10	Medium
Hemp	Annual straw crop	1	Medium
Triticale (whole crop)	Annual straw crop	1	High
Sorghum (whole crop)	Annual straw crop	1	High

The economic analysis of each crop was carried out for three cases, which are summarised in Table 2. Case 1 reflects present conditions, assuming the yields and cultivation technologies of 2005 and a small total cultivation area of the crop, about 10 000 ha in each country or region, depending on the area of agricultural land. The total cultivation area is quantified only for the purpose of indicating that it is small, but larger than that used for pioneer cultivation, for which costs are normally higher [11]. Cases 2 and 3 were designed in order to reflect how energy crop production costs could be reduced as a result of: i) an increase in the total cultivation area (large-scale cultivation) of the crop, ii) crop refinement and iii) accumulated experience of growing the crop. Case 2 assumes large-scale cultivation of the crop (at least 100 000 ha of the crop in each country or region) in combination with the yields and cultivation technologies of 2005, assuming cost reductions from large-scale cultivation. Case 3 assumes 15 years of plant breeding and 15 years' accumulated experience of growing the crop on a large scale. Hence, Case 3 describes the yield and cultivation technologies that could be the state of the art in 2020, assuming that rapid expansion of crop cultivation area had started in 2005. Despite the future outlook considered in Case 3, the cost levels are realised in 2005. Large-scale cultivation methods at farm level are assumed in all three cases.

Table 2: Description of the energy crop cultivation conditions in the three cases for which the economic analyses were carried out.

Case description	**Level of knowledge, cultivation technology and yields (year)**	**Cultivation area per region/country (ha)**
1. Current cultivation conditions	2005	~ 10 000
2. Current cultivation conditions, large scale	2005	>100 000
3. Established cultivation, large scale	2020[a]	>100 000

[a]That which can be achieved by 2020, assuming 15 years of crop refinement and experience of growing the crop. The cost levels are realised in 2005.

3 Method and input data

In this paper the energy crop production cost is expressed in terms of the economic compensation needed by the farmer to grow that energy crop. We distinguish between three main components of the production cost:

- the cost of cultivation
- the cost of land
- the cost of risk

The methods used to calculate or estimate these costs are described below.

3.1 The cost of cultivation

The cost of cultivation includes all costs associated with growing the energy crop. The main costs are those of establishment, fertilisation, harvesting, field and road transport, weed control, brokerage, overheads and wind-up (when terminating cultivation). Many of these cost items include both labour and machinery costs; the latter refer to contractors' costs. We assume that all crops are fertilized and transported 30 km to a collection point after harvesting. In order to produce comparable cost estimates for different crops grown in different regions, we employed a method that consists of two types of calculations:

1) Base-case calculations
2) Regional calculations

The base-case calculations were carried out as the first step in the economic analysis of each crop in order to ensure that the calculations for the different regions were performed in a consistent way. The base-case calculations were made using prices in Northern Europe. Regional calculations were then made, in which the yield and cost levels of the different regions were taken into account. Figure 1 illustrates the calculation steps carried out for each crop, together with the inputs and outputs of the calculations.

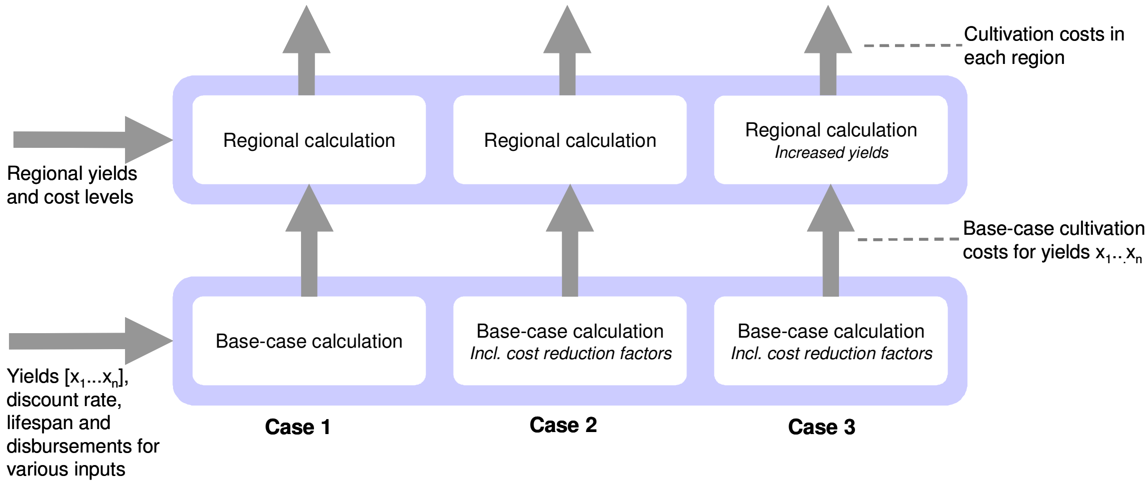

Figure 1: Schematic showing the different types of calculations made for each crop, together with the inputs and outputs of the calculations.

3.1.1 Base-case calculation

Three base-case calculations were performed for each crop, in which the cost of cultivation was calculated for a series of yields. The calculations were carried out using a model developed by Rosenqvist [12]. This model combines the present value method and the annuity method, thus making it possible to compare the economics, including production costs, for perennial and annual crops. The model employs a total-step calculation method, in which all disbursements over the estimated lifespan of the plantation are discounted. The annual cost of cultivation for a crop was calculated by multiplying all disbursements by their present value factor and the annuity factor of the discount rate (according to the equation below).

$$\text{Annual cultivation cost} = \frac{r}{1-(1+r)^{-n}} \sum_{T_{t-0}} (1+r)^{-t} \cdot A_t$$

n=the length of the calculation period (lifespan) in years
r=discount rate (6%)
t= time (year) at which a disbursement (or revenue) is made (or received)
T=time period during which the disbursements (or revenues) are made (or received)
At=size of payment

All the base-case calculations were performed with a discount rate of 6%. The disbursements in Case 1 are based on input prices in 2005 in Northern Europe, regardless of whether the crop can be grown in this region or not. The disbursements in Cases 2 and 3 were calculated by multiplying each Case 1 disbursement by a factor of (1-cost reduction factor).The cost reduction factors vary between inputs from 0 to 0.5, and were motivated by the different stages of development of the crops, and reflect potential cost reductions from large-scale cultivation and the experience of growing this crop. Large-scale cultivation of the crop is likely to increase competition between the companies involved in activities related to (perennial) energy crops, decrease the distance between fields containing these crops, and decrease the costs of organisation, advisory services and brokerage. The fixed costs for special machines, such as a harvester dedicated to SRC crops, are also likely to decrease per hectare due to increased utilization of the machines and increased competition between different contractors. In addition, the costs of special machines are likely to decrease to the level of those in traditional agriculture due to a shift from single, custom-made machines to longer production series. Over time, machinery development and increased experience of growing the crop on a large scale can be expected to reduce costs even further.

The reduction factors are greatest for inputs specific to SRC crops and smallest for those specific to annual straw crops. The largest cost reduction factors in SRC crop cultivation were assumed for planting and harvest, being 0.25[7] for each of these operations in Case 2, and 0.5 in Case 3. For perennial grasses, the largest cost reduction factors were assumed for the planting material and planting of miscanthus, being 0.25 in Case 2 and 0.5 in Case 3. For the annual straw crops, the largest cost reduction factor was assumed for brokerage, being 0.15 and 0.25 in Cases 2 and 3, respectively. The cost reduction factor for, e.g., fertilizers was assumed to be zero for all crops.

3.1.2 Regional calculations

In the regional calculations, energy crop cultivation costs in the different regions were calculated by taking regional differences in yield and cost levels into account. Calculations were only made for the regions in which the crop can be grown. For each crop and region, the cost of cultivation was established by multiplying the base-case cost for the yield of the region by the cost level of that region. Typical yields for the different energy crops and regions were estimated by project partners, and are presented in Table 3. These yields reflect what can be achieved today (2005) in commercial cultivation, assuming the crops are well managed (fertilized, but not irrigated). Hence, these yields are lower than those that can be obtained in optimized field trials. The estimated yields are consistently higher in the UK & Ireland due to mild climatic conditions and higher precipitation, and lower in Northern and Southern Europe due to colder climate and lower precipitation, respectively. The estimated yields for 2005 were applied in Cases 1 and 2, while higher yields were assumed in Case 3. The right-hand column in Table 3 gives our estimates of the increase in yield for energy crops relative to cereal crops assuming 15 years of crop breeding and accumulated experience of growing the crop. Crop breeding was assumed to lead to greater increases in yield for the least developed crops.

[7] 0.25 equals a cost reduction of 25%.

Table 3: Estimated yields of non-irrigated crops (9 energy crops and 2 competing cereal crops) when grown on soil of average quality in different regions. The right-hand column shows our estimates of the increase in yield for energy crops relative to cereal crops, assuming 15 years of plant breeding and cultivation experience. The yields are given in tonnes of dry matter per hectare per year (t_{DM} ha^{-1} y^{-1}), except for wheat and barley for which it is given in t ha^{-1} y^{-1}.

	Annual yields for 2005						Relative increase in yield by 2020
Crop	**N. Eur.**	**UK & Irel.**	**W. Eur.**	**The Alps**	**S. Eur.**	**E. Eur.**	**(%)**
Willow	9	13	10	10	-	9	+40
Poplar	9	13	10	10	-	9	+25
Eucalyptus	-	-	-	-	12	-	+25
Miscanthus	10	18	16	11	-	11	+60
Reed Canary Grass RCG	7.5	-	-	-	-	7.5	+40
Switch grass		-	-	-	13	-	+40
Hemp	10	-	11	10	-	10	+25
Triticale (whole crop)	11	-	12	11	8.0	9	+5
Sorghum (whole crop)	-	-	10	-	-	-	+5
Barley (wet)	4.2	8.1	5.5	6.4	2.0	4.2	-
Winter wheat (wet)	6.2	10.2	7.9	6.0	2.0	5.5	-

The cost level in each region was calculated based on regional prices of a number of key inputs that functioned as cost indicators. The prices of these inputs were collected by project partners and included the prices of, e.g., farm labour and fertilizers (Table 4). In the cost level assessments, the inputs were given the same weight as in the cost distribution of willow production in Northern Europe. The cost levels in the different regions were calculated in relation to that in Northern Europe (the cost level of which was used in the base-case calculations). This approach, in which the collection of regional data was limited to a small number of clearly specified inputs, was chosen in order to make the calculations more consistent, and to reduce the workload for project partners. The results of the cost level assessments are given at the bottom of Table 4. The cost level is highest in Northern Europe and somewhat lower in the UK & Ireland, the Alps and Western and Southern Europe, and lowest in Eastern Europe. For Case 3 the regional calculations were based on both non-equalized cost levels (using the results from the cost level assessments) and equalized cost levels (assuming convergence of cost levels to that in Northern Europe).

Table 4: Regional prices of different inputs used in the cost level assessments in Cases 2 and 3. The third column gives the relative weights of the different inputs. The bottom line shows the calculated cost level for each region.

	Unit	**% of**	**Price (€/unit)**					
Cost indicator		**cost level**	**N. Eur.**	**UK & Irel.**	**W. Eur.**	**The Alps**	**S. Eur.**	**E. Eur.**
Fertilizer (N)	1 kg	12.9	0.88	0.71	0.82	0.80	0.63	0.46
Fertilizer (P)	1 kg	1.7	1.21	0.71	1.33	1,29	0.67	0.55
Fertilizer (K)	1 kg	2.1	0.44	0.36	0.36	0.39	0.67	0.3
Glyphosate (Roundup)	1 l	0.7	5.05	5.60	4.45	4.50	4.00	6.40
Farm labour	1 h	21.7	18.13	16.00	17.00	18.40	8.00	3.80
Ploughing	1 ha	20.3	91.21	74.13	90.60	54.65	90.00	38.00
Spraying	1 ha	20.3	14.29	17.30	13.18	19.29	14.00	6.50
Fertilizer spreading	1 ha	20.3	15.38	14.83	10.43	6.43	15.00	7.00
Cost level		100	100	93.7	89.2	86.2	83.2	41.3

3.2 The cost of land

It is difficult to estimate the general cost of land, as it may be defined as a tenancy cost, the interest rate on loans taken out to purchase the land or the opportunity cost. The first two alternatives are not compatible with the economic model in this study since they relate to the price of a limited area of agricultural land. The farmer who rents or buys land, after having placed the highest bid, generally already has access to some land. The cost of this additional land is therefore not the average cost of land but the marginal cost. Other arguments for not using price-related costs are that the price of land is greatly influenced by current agricultural policies and includes non-monetary values of land such as the proximity to cities and opportunities for hunting.

In this study, the cost of land used for energy crop cultivation was expressed as the opportunity cost, i.e. the profitability of alternative land uses. Among the alternatives, we chose cereal crop cultivation, which is the most common form of arable farming. Hence, the cost of land was assumed to correspond to the net gross margin of cereal crop cultivation. The cost was calculated as a cost range, where the lower and upper limits describe the net gross margin of cereal crop cultivation in the long- and short-term perspectives, respectively. The net gross margins of cereal crop cultivation include revenues from crop sales and costs that were calculated in the same way as the cost of cultivation for the different energy crops (described in Section 3.1). The prices of winter wheat and spring barley were assumed to be 100 € t^{-1} and 90 € t^{-1}, respectively throughout the whole of the EU. The short-term calculations were based on the net gross margin of winter wheat and only included 50% of the cost of farm labour, machinery and overheads. The rationale for not including all costs is that cereal crop farmers generally have resources tied up in this activity and that these resources can not easily be shifted to energy crop production. The cost of land presented in this paper is consequently higher in the short-term perspective. The long-term calculations were based on the net gross margin of a mixture of cereal crops (50% spring barley and 50% winter wheat) and included all costs at farm level (similar to the energy crop calculations), thus leading to a lower land cost. In cases where the net gross margin of cereal cultivation was estimated to be negative, the cost of land was set to zero. In this case, letting the land lie fallow is a better alternative form of land use than cereal cultivation.

3.3 The cost of risk

The cost of risk is the economic compensation, i.e. risk premium, that an individual or company requires in order to undertake an investment that is associated with an additional risk – real or perceived. In this study, the risk premium describes the economic compensation that the farmer requires in order to shift production from a cereal crop to an energy crop. The size of the risk premium varies between farmers and depends on the crop. In general, farmers require a higher risk premium for growing less developed, perennial energy crops than for growing traditional, annual crops. A higher risk premium is generally ascribed to perennial energy crops due to the limited knowledge and experience of growing these crops, necessary changes at farm level (not being able to use existing machinery) and the low flexibility in land use that these crops entail. Land-use flexibility is related to the lifespan of the crop and the cost of establishment and wind-up. High land-use flexibility is an advantage since it enables the farmer to choose a crop based on current prices on the market. Due to higher costs of establishment and wind-up, the risk premium should in general be higher for SRC crops than for perennial grasses. Table 1 gives our estimates of the cost of risk for different crop types.

These values are "guesstimates" since the empirical basis for quantifying these costs is rather weak and not comprehensive. It should also be noted that the size of the risk premium can be influenced by several factors such as: i) information campaigns, ii) agricultural subsidies and iii) the nature of the contract between the farmer and the buyer of the biomass. The cost of risk for a crop, expressed per unit energy content (€ GJ^{-1}), was assumed to be the same in the different regions, but to differ between the three cases. The cost of risk is highest for Case 1 and lowest for Case 3 since large-scale cultivation of the crop and accumulated experience of growing it are assumed to reduce the cost of risk. Among the perennial grasses the cost of risk is highest for miscanthus.

4 Key findings

4.1 Crop comparison

Our results show that the production costs differ greatly between the three types of energy crops, i.e. the SRC crops, perennial grasses and annual straw crops. Figure 2 shows the calculated energy crop production costs for three crops, i.e. the most promising crop for each crop type, in each region. The results for Case 3 are shown in two diagrams, one based on non-equalized cost levels, as in Cases 1 and 2, and one based on equalized cost levels.

The SRC crops, i.e. willow and eucalyptus, were found to have the lowest production costs in all three cases. The cost range is about 4-5 € GJ^{-1} under present conditions (Case 1) and about 3-4 € GJ^{-1} assuming 15 years of experience of large-scale energy crop cultivation (Case 3). The production costs of these crops are relatively low due to the low annualized costs of harvesting (which takes place every three or four years) and of establishment (which is required only once during the 22-year lifespan of the plantation) (exemplified by willow in Figure 3). In addition, the cost of handling wood chips from SRC crops is low due to their relatively high density and little need for storage.

The production costs of perennial grasses, i.e. miscanthus, RCG and switch grass, were calculated to be about 6-7 € GJ^{-1} under present conditions and 5-6 € GJ^{-1}, assuming accumulated experience of large-scale energy crop cultivation (Case 3). These crops have low establishment costs, but relatively high handling costs, including storage (exemplified by RCG in Figure 3).

The annual straw crops, which include triticale, hemp and sorghum, were found to have the highest production costs and to have small potential for future cost reductions. The production costs were calculated to be about 6-8 € GJ^{-1} under present conditions assuming that the whole crop (kernel and straw) is used for energy. The production costs of the crops in this group are high due to the need for annual establishment and harvest, and due to high costs for storage and handling of the crop.

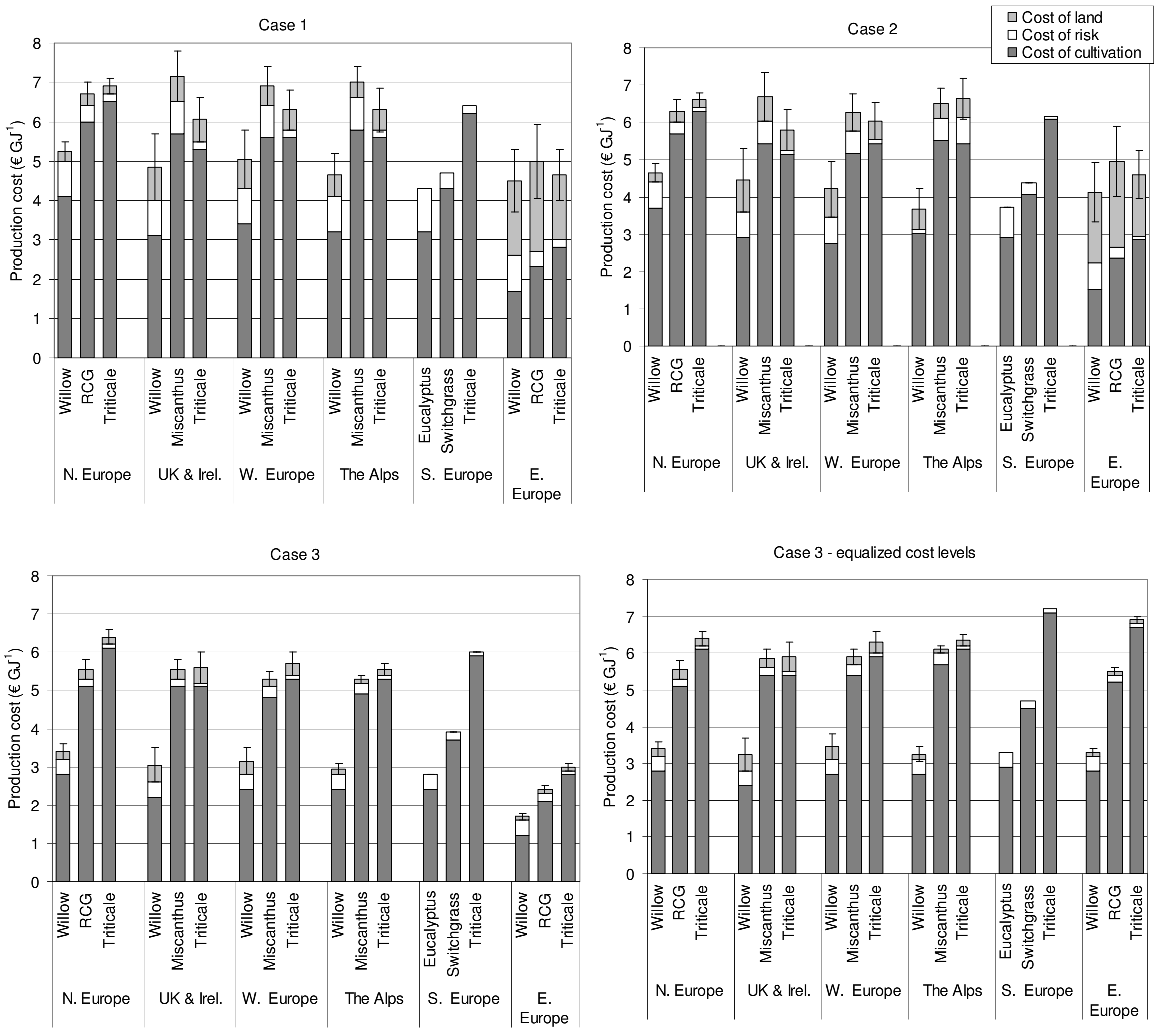

Figure 2: Energy crop production costs for the three most promising energy crops in each region for the three cases studied. Results for Case 3 are shown for both non-equalized and equalized cost levels. The error bars show the minimum and maximum costs of land.

4.2 Regional comparison

The calculated energy crop production costs are somewhat higher in Northern Europe and somewhat lower in Eastern Europe (Figure 2). The regional differences in total energy crop production costs are, however, rather modest, as a result of our method of estimating the cost of land as the opportunity cost based on cereal crop cultivation. The regions with low energy crop cultivation costs in general also have high net gross margins in cereal crop cultivation and thus high costs of land. The results will be similar when comparing energy crop production costs on agricultural land of different quality. The cost of land was set to zero in Southern Europe as a result of the calculated negative gross margins in cereal crop production in this region caused by low cereal crop yields. A different reference should perhaps have been chosen for this region, but this was not done in this study.

4.3 Case comparison

The energy crop production costs are highest for Case 1 and lowest for Case 3. The main factors that influence the production costs for a certain crop are yield, machinery development and experience of growing the crop. The potential for future cost reductions is greatest in the production of SRC crops and somewhat lower in the production of perennial grasses, due to the difficulty in achieving further cost reductions in the handling of bales. Assuming convergence of cost levels in Europe, the potential for cost reductions in Eastern Europe is relatively modest since the gains in overall productivity are offset by an increase in cost level (bottom right diagram in Figure 2).

The potential for cost reductions differs between the cost items depending on the opportunities for technical development and whether the cost is related to the yield, thus changing the relative importance of the different cost items in the three cases. For example, if the yield increases, the cost of administration etc. will decrease per GJ biomass, while this is not the case for transportation costs. There is in general limited potential for cost reductions in transportation and fertilisation, which makes the relative weights of these costs greater in Cases 2 and 3 than in Case 1 (Figure 3).

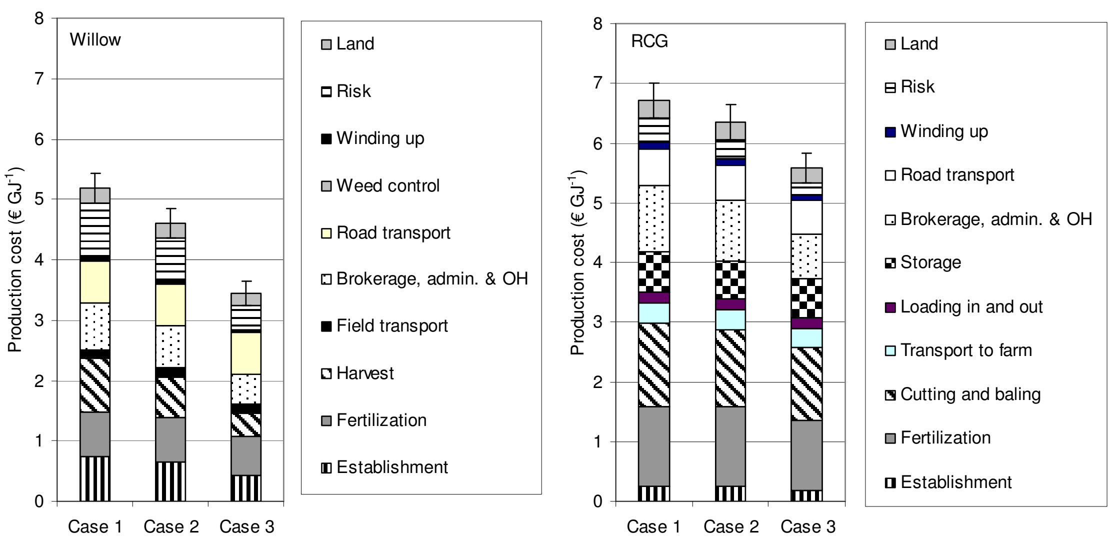

Figure 3: Breakdown of the production costs of an SRC crop and a perennial grass for the three cases exemplified by willow (left diagram) and RCG (right diagram) cultivation in Northern Europe. The error bars show the minimum and maximum costs of land.

5 Discussion of the economics of energy crops

In order for (perennial) energy crops to be adopted by farmers, the economics of these crops must be at least as good as those for traditional crops such as cereals. The relative viability of cereals and energy crops depends not only on their production costs, but also on the prices of biomass and of cereals (which was accounted for in the cost of land) and agricultural policy. In this section, the prices of biomass and cereals, agricultural policy, and the cost of risk and multi-functional energy crop plantations are discussed.

5.1 The price of cereals

The price of cereals has a considerable impact on the relative viability of cereals and energy crops. In our estimates of the cost of land, the prices of winter wheat and barley were assumed to be 100 € t^{-1} and 90 € t^{-1}, respectively. These prices are in line with cereal prices in 2005, the year the calculated costs refer to. However, since June 2007 the price of cereals, wheat in particular, has been volatile and, on the whole, increased markedly [13]. As a result, the profitability of cereal production has increased considerably, which leads to higher energy crop production costs when estimating the cost of land in terms of the net gross margin of cereal production. Figure 4 shows the willow production cost in Northern Europe as a function of the wheat price. If the wheat price doubles to 200 € t^{-1}, the cost of land will increase by 5.7 € GJ^{-1} biomass, assuming maintained input costs. An increase in wheat prices is likely to increase the price of certain inputs in the short term. In addition to the effect on the cost of land, higher cereal prices are also likely to increase the risk premium ascribed to the growing of perennial energy crops since the farmer risks missing out on future high economic returns from cereal crop production.

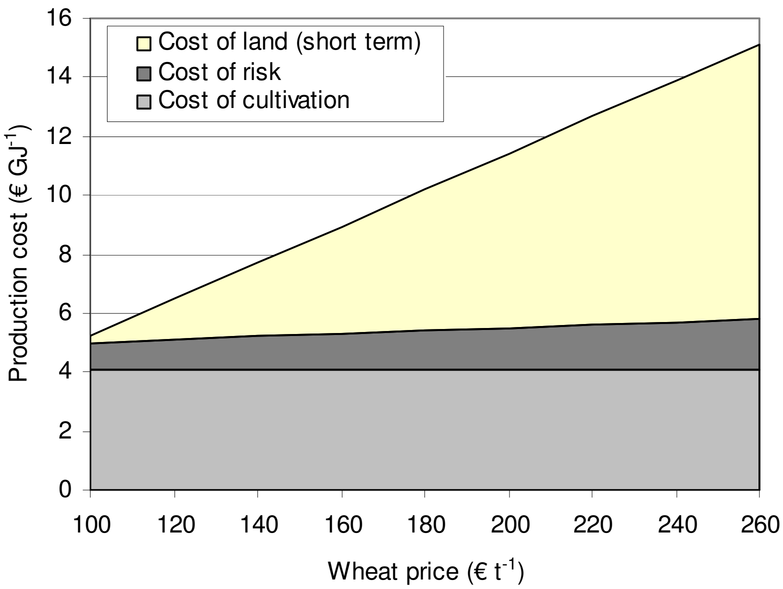

Figure 4: The willow production cost in Northern Europe as a function of the wheat price. The production cost was estimated using the model described in this study.

The dramatic increase in the price of cereals since June 2007 is partly due to incentives to increase the production and use of bioenergy, more specifically the ethanol programme in the USA. Due to generous subsidies, the US production of ethanol and its feedstock maize has increased considerably over the past few years. This development has affected the prices of other crops on the world markets since the US maize production has expanded, partly at the expense of other crops, and because of the reduced US export of maize [14]. Other factors contributing to high cereal prices are increased global demand for cereals and the lower than expected global production of cereals in 2006/2007 caused by droughts, mainly in Australia and Eastern Europe [13].

5.2 Agricultural policies

The Common Agricultural Policy (CAP) has a major impact on farm-level economics in the EU. By and large, the past few CAP reforms have made energy crops more attractive to farmers. Examples of such reforms include the set-aside scheme and the shift from production-based subsidies to area-based subsidies. The set-aside scheme introduced in 1992 encourages energy crop production since only non-food crops are eligible for support when grown on set-aside land. Interest in growing perennial crops, which require long-term commitment of the land, has, however, been dampened by the volatility of the set-aside rate [15]. The EU decision in September 2007 to reduce the set-aside rate from 10 to 0% for the autumn of 2007 and the spring of 2008 is a case in point. This decision was prompted by the current high cereal prices and low stocks. As a result of the current high wheat price and the reduction of the set-aside rate, the area used to grow wheat in the EU is expected to increase by 6% between 2007 and 2008 [13].

In the CAP reform of 2000, energy crops became eligible for the same area-based subsidy as cereals, irrespective of whether they were grown on set-aside land or on regular arable land. The CAP reform of 2003 introduced an energy crop subsidy of 45 € ha^{-1} y^{-1} to farmers who grew energy crops on land that is not part of the mandatory set-aside land and who had a contract with a buyer [16]. This subsidy was first guaranteed for a maximum area of 1.5 million hectares, which was later increased to 2.0 million hectares. If the cultivation area exceeds this amount the subsidy (per hectare) is reduced. The 12 newest EU member states have also been able to benefit from this subsidy since 1st January 2007. This subsidy corresponds to an income of about 0.3 € GJ^{-1} for willow, assuming a yield of 9 t ha^{-1} y^{-1}.

5.3 The price of biomass

The price of biomass is determined mainly by market energy prices (including effects from energy and environmental policies), in particular those of fossil fuels. The price of unrefined biomass such as wood chips is about 4-5 € GJ^{-1} in Europe. So far, biomass from SRC crops and perennial grasses are only used in heat and electricity production. The production of transportation fuels from these lignocellulosic biomass feedstocks requires the use of so-called second generation technologies, which have not yet been commercialised. Hence, the increasing demand for biofuels in the transportation sector has so far not stimulated the production of perennial energy crops.

5.4 Reducing the cost of risk

There are a number of factors that contribute to the relatively high cost of risk that farmers ascribe to perennial energy crops. Some of these factors may be addressed, thus making these crops more attractive to farmers. For example, few farmers will introduce a production system they have no knowledge about. Information and advice will improve their knowledge about these crops and can reduce the farmer's perception of risk.

The uncertainty of future biomass prices is an important component of the cost of risk that farmers ascribe to perennial energy crops. The market for solid biofuels/biomass is not as well developed as the market for food and feed. With a larger market for solid biofuels, and more reliable channels to sell these biofuels, income will be less uncertain. One way to make incomes from biomass less uncertain is to use contracts that distribute risks. Helby et al. [15] suggested ways to develop contracts between buyers of biomass/solid biofuels who take most of the fuel price risk (changes in relative fuel prices), and the producers of biomass, who can take most of the cultivation risk (changes in relative profitability of crops). Such contracts may be equally attractive to the buyer and the farmer if there is a significant increase in the demand for bioenergy. This is particularly the case for buyers who use biomass in conversion processes that are sensitive to the quality and composition of the biomass. Examples of such facilities include various types of bio-refineries.

An establishment subsidy can play an important role in reducing the financial risk associated with the growing of perennial crops by improving liquidity during the first few years of cultivation. EU member states are entitled to grant a national establishment subsidy for perennial energy crops of up to 50% of the establishment cost. In Sweden, willow growers have been entitled to an establishment subsidy since the early 1990s, and this now amounts to about 560 € ha^{-1} (5,000 SEK ha^{-1}). This subsidy increases income by about 0.39 € GJ^{-1} biomass.

5.5 Multi-functional energy crop plantations

In addition to the potential for cost reduction associated with crop refinement and the increase in experience and cultivation area of the crop, niche areas provide an opportunity to capitalise on environmental benefits in addition to energy production. Energy crop plantations that produce additional environmental benefits are commonly denoted multi-functional energy crop plantations. They can be divided into two categories: those designed for dedicated environmental services (e.g., vegetation filters for waste water and sewage sludge treatment, and shelter belts against soil erosion), and those generating more general benefits (e.g., soil carbon accumulation, increased soil fertility, cadmium removal and increased hunting potential). Rosenqvist and Dawson [11] and Börjesson and Berndes [17] have shown that vegetation filters employing willow can be a cost-effective way to treat waste water. A similar conclusion was reached by Rosenqvist and Ness [18] concerning the treatment of leachate water. The cost of waste water treatment is lower, and the farmer benefits from a higher yield and lower cost of fertilizers. The yield increase is caused by both the fertilizing effect and the secured water supply. Lindroth and Båth [19] have shown that water availability is often a factor limiting willow crop growth, thus making waste water irrigation particularly interesting in relatively dry areas. The financial value of multi-functional plantations is normally highest for those designed for such dedicated environmental services. The greatest potentials are found in farm land areas surrounding towns and cities. However, using multi-functional energy plantations as a prime mover for energy crops requires that the value of the environmental service be monetized and transferred to the energy crop producer.

6 Conclusions

This paper presents a method of calculating comparable energy crop production costs for different crops and regions, and the results of applying this method to energy crop production in Europe. The production costs presented in this paper refer to the economic compensation required by the farmer to grow the crop, thus also including the costs of land and of risk, which are usually omitted in cost assessments. The energy crop production costs calculated in this study are consistently lowest for SRC crops and highest for annual straw crops. The production costs of the SRC crops were calculated to be about 4-5 € GJ^{-1} under present (2005) conditions (Case 1) and 3-4 € GJ^{-1} under future conditions that include 15 years of crop breeding and experience of growing the crop on a large scale (Case 3). The production costs for perennial grasses were calculated to be about 6-7 € GJ^{-1} under present conditions (Case 1). These costs could be reduced to 5-6 € GJ^{-1} (Case 3). The production costs for annual straw crops were calculated to be 6-8 € GJ^{-1} under present conditions, with small potential for cost reductions. Hence, production costs are lowest for the energy crops that are associated with the highest costs of risk and the largest changes at farm level in terms of workload and machinery. Measures for reducing the cost of risk that farmers ascribe to the cultivation of energy crops will therefore be important for the adoption of these crops. Our analysis demonstrates the importance of including the cost of land, which was calculated here as the opportunity cost based on growing wheat. Regional differences in energy crop production costs are relatively modest as a result of calculating the cost of land as the opportunity cost. High profitability for conventional food crops is reflected in high land and production costs for energy crops. For example, a doubling of wheat prices may roughly double the energy crop production cost. Correspondingly, high profitability for energy crops will lead to high land and production costs for food crops.

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