ECONOMIC VIABILITY OF REGIONAL BIOMASS CHAINS

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ABSTRACT: The objective of this work is to assess the viability of regional biomass chains by comparing the economic performance of potential bioenergy cropping systems with the performance of current agricultural land uses and by comparing bioethanol production costs with petrol costs. Economic viability of biomass chains is spatial variable due to the spatial heterogeneity of the physical context. This is mapped using GIS (geographic information system). Ethanol production from Miscanthus and sugar beet in the North of the Netherlands is used as a case study to demonstrate this methodology. The results show that areas where energy crops can compete with current land use and where feedstock production costs are relatively low are the most promising locations for bioenergy crops. At these locations soils are less suitable for conventional crop rotations yet suitable for perennial energy crops.

The cost of bioethanol production from domestically cultivated crops is not competitive with petrol at current oil prices levels. Bioethanol could become competitive when (increased) support for energy crops is provided for, conversion technologies improve and/or ethanol receives a (partial) excise exemption.

Keywords: Land use, Economical aspects, Geographical Information System (GIS), bioethanol, Miscanthus, Sugar beet

1 INTRODUCTION

In recent years, several studies have assessed the bioenergy potential and costs at a global level e.g.[1-3], European level e.g.[4-6], or at a national level e.g. [7-9] . However, a limited number of studies are available about the potential and costs of biomass production and bioenergy supplies at a local or regional level. Because economic benefit is a major incentive for adoption, this paper focuses on the competitive advantage of bioenergy crops compared to current agricultural land use and the competitiveness of production costs of biofuels compared to conventional fuels. This contributes to an increase in the understanding of where and on which types of soils land use changes might occur when promoting biofuel use. In this study we focus on ethanol production from Miscanthus and sugar beet in the North of the Netherlands.

Section 2 will elaborate on the selected region and the bioenergy chains. In section 3, the methods applied and the data used to asses the economic viability will be discussed. The results of the assessment are presented in section 4. In section 5, the applied method, the data used and the results are discussed and in the final section conclusions are drawn.

2 CASE

In this study the production of bioethanol from sugar beet and Miscanthus cultivated in the Northern region of the Netherlands (the province of Groningen, Friesland and Drenthe) is investigated.

Land use in this region is dominated by agricultural activities. Main part (68%) of the total area is agricultural land of which 41% is used for agricultural crops and 57% for pastures. Cereals, potatoes, sugar beet and maize are the most dominant crops cultivated in rotation. Two common rotation schemes for sandy soils and two rotation schemes for clay soils are selected to represent current land use of arable land in the region.

2.1 Biomass potentials in the selected region

In order to set a range for the potential available arable land for bioenergy production, information provided by the Refuel study about bioenergy potentials in Europe is used [5]. The base case scenario of the Refuel assessment is derived from the Common Agricultural Policy (CAP) of the EU. In addition, Refuel developed a more optimistic and a more pessimistic variant. For the near future (2015), a land availability for bioenergy crop production of 2.9 to 4.3 % of arable land and 0.5% of pastures is projected by the Refuel study for the North of the Netherlands.

2.2 Bioenergy chains

Sugar beet is a crop which requires good quality soils and high inputs of fertilizers and pesticides. It is grown in rotation with cereals and potatoes. In our study, it is assumed that sugar beet for ethanol production is cultivated on land that is currently in use as arable land (hence pastures are excluded for this crop). After harvest, it is assumed sugar beet is transported by truck to an ethanol plant close to the current sugar plant. The conversion plant is assumed to have a scale appropriate for the expected supply of sugar beets in the region. In the ethanol plant, sugar beets are shredded to cossettes and diffused in water in order to produce raw sugar beet juice and pulp. Pulp is further processed for animal feed and put on the market as co-product. The raw juice is pasteurized, fermented and distilled in order to produce ethanol.

Miscanthus is a perennial crop with a lifetime of 20 years, which does not require high fertilizer and pesticide input or optimal soil conditions [10-15]. Following the Refuel study, it is assumed that Miscanthus can be cultivated on agricultural land currently in use as arable land or pastures. Miscanthus is chipped and transported to a lignocellulose ethanol plant by truck. It is assumed that Miscanthus is processed in an ethanol plant located closely to the harbour. Feedstock supply of the plant is derived form a combination of domestically cultivated Miscanthus and lignocellulose from international supply chains. After physical size reduction, the cellulose is broken down to free glucose molecules by means of enzymatic hydrolysis (Hamelinck, 2004). In the fermentation step, the free sugars are converted to ethanol.

3 METHOD AND INPUT DATA

3.1 NPV calculations for crop production

In order to compare both annual and perennial crops, all costs and benefits related to the cultivation of conventional and energy crops are discounted to the net present value (NPV). The NPV of rotation schemes is calculated by multiplying the NPV of the individual crops by their proportion in the rotation scheme.

The costs and revenues of crop production depend on soil and climate conditions, economic environment and farm management system applied. All these parameters are regionally specific.

The costs related to crop production generally include four main categories of expenses:

- land costs
- field operation costs (contractor, machinery, labour and diesel cost)
- input costs (seeds, fertilizers and pesticides)
- fixed costs (insurance, soil sample assessment etc).

The benefits related to crop production are the revenues from:

- selling the main product
- selling the co-product

In this study, (European) subsidies for crop production are excluded. Data on field operations and inputs are based on [16, 17] for annual crops, on [18-20] for pastures; and on [10, 13, 21-24] for Miscanthus. It is assumed that nutrient requirements are met by fertilizer (N, P_2O_5, K_2O) application and that no lime or magnesium is needed.

3.2 Cost of ethanol

In order to calculate the ethanol production costs, all costs and benefits during all stages of the supply chain need to be taken into account. The calculation method has been demonstrated by e.g. v.d. Broek et al [25].

All costs related to biomass transport (including costs of labour, fuel and depreciation of machinery) are incorporated as well as the costs and revenues for ethanol production (investment costs, O&M costs, costs energy and other inputs needed for the process and benefits related to the production of co-products).

3.3 NPV and costs of feedstock differentiated for soil suitability

Crop yields vary within the region due to different soil qualities. Therefore, the NPV of crops and the costs of feedstock are differentiated for different soil quality classes. To map the soil suitability and the related yield for the different crops, the most recent HELP (*Her-EvaluatieLandinrichtingsProject*) system, developed by Brouwer et al [26, 27], was used. In this method, yield levels are determined by a combination of soil characteristics and water table levels. Seven soil suitability classes from very marginally suitable to very suitable were distinguished. Separate yield reduction tables based on water and drought damage were developed for the most common arable crops and linked to the map of the area (at a grid level of 25mx25m) using GIS (Geographical Information System) [26].

The NPV values of the crops for each soil suitability class are linked to the crop specific soil suitability maps. For the NPV of rotations, the individual map layers of the crops are combined in a spatial weighted summation for a final NPV map (in which weights represent the share of the individual crop in the rotation). In addition to the NPV, the costs of feedstock production of Miscanthus and Sugar beet are calculated for every soil suitability class and linked to GIS maps.

4 RESULTS

4.1 Competitiveness

The Net present value of perennial crops, typical rotations for the North of the Netherlands, and rotations including an increased share of sugar beet are calculated for different soil suitability classes. The results show that all NPVs decline for less suitable soils. The economic performance of intensively managed crops declines more rapidly than the performance of less intensively managed crops on less suitable soils.

Since soil suitability characteristics are not equal for every crop and perennial crops are more tolerant to water and drought stress, some production sites could be suitable for perennial crops but less suitable for rotation crops. For the whole agricultural area, the NPV of current land use has been compared to the NPV of potential land use of Miscanthus.

The locations where the NPV of Miscanthus is higher than current land use are mostly areas currently in use for pastures and often too wet for arable crops. The zones in which current land use is most profitable are areas of fertile soils and are well suitable for profitable crop cultivation like potatoes and sugar beet. At these locations, it is very unlikely farmers are willing to switch to energy cropping systems from an economic point of view.

Since additional share of sugar beet for ethanol production is not competitive with current rotation schemes and sugar beet has high soil suitability requirements, there are no locations at which sugar beet for ethanol production could compete with current arable land use.

4.2 Cost of biomass

The cost of feedstock production has been calculated for 7 soil suitability classes. Comparing the results of the NPV with the results of the feedstock production costs shows that for some locations where Miscanthus performs better than current land use, production costs are very high. However, most areas where Miscanthus has a better NPV than current land use have relatively low production costs. These are the most promising locations for Miscanthus production. Nevertheless, these production costs are most probably above the costs of biomass imported from abroad [28]. The feedstock production costs for sugar beet are higher than for Miscanthus. The spatial variation in feedstock production costs is higher for sugar beet than for Miscanthus, since sugar beet is more sensitive for soil conditions.

4.3 Costs of ethanol

The ethanol production costs from sugar beet and Miscanthus [€/GJ] are calculated based on the least cost feedstock produced on very suitable soils. For comparison, the present costs of petrol have been calculated as well. The difference between cost of bioethanol and petrol is significant (>182%, assuming a price level of 62 US$/barrel). The contribution of capital and O&M cost are relatively large for ethanol production from lignocellulosic crops. The share of transport costs for ethanol from sugar beet is substantial due to the high moisture content of sugar beet.

If all competitive areas are dedicated to Miscanthus for ethanol, 25 PJ ethanol could be produced annually. However, the Refuel study indicated that only a minor share could be used for bioenergy crops. This results in an annual production of 1 PJ ethanol at a cost of 22.5 to 24.0 €/GJ. This is equivalent to 0.7 % of the total gasoline use in the Netherlands of 142 PJ in 2006 (CBS, 2008).

4.4 Sensitivity analysis

The NPV of Miscanthus and sugar beet is very sensitive for changes in yield levels and market prices. The NPV of sugar beet is more sensitive for changes in labour and energy prices than Miscanthus because of the relative intensive management that is applied in sugar beet cultivation. The cost of biomass is quite sensitive to changes in yield, especially for yield decreases. The cost of Miscanthus production is sensitive for changes in the discount rate unlike the cost of sugar beet. This is due to the uneven distribution of costs and benefits of Miscanthus in time. The impact of higher energy prices is different for the cost of ethanol production from Miscanthus and from sugar beet. When energy costs increase, cost of ethanol production from sugar beet increase due to higher feedstock and transport cost. Although, these costs increase for Miscanthus as well, this is by far compensated by an increase of value of the electricity generated when Miscanthus is converted to ethanol. Therefore, for ethanol from lignocellulose the net effect is a decrease in ethanol production costs when energy prices increase.

5 DISCUSSION

Although, the economic performance is assumed to be a main driver for the adoption of other agricultural systems by farmers, physical or more personal drivers affect land use change as well . Also, economic factors that are very specific for the individual farmer are not included in this study. Therefore, the NPV does not necessarily represent the farmers' perspective.

Every farmer has it's own individual practices. This is especially true for the use and management of pastures. In addition, benefits and subsidies from cattle breeding and local enforced subsidies are not taken into account. Therefore, assuming general practices for pastures is a theoretical assessment.

A very significant assumption in this study is that management is not altered for different soil suitability classes. Main reasoning here is that poorer soil qualities could require both higher and lower input rates (see section 3.3), since no general trend could be distinguished.

Since in our assessment a level playing field (in terms of subsidies) is assumed, the maps do not represent the actual situation but give an indication of which areas could become the most promising ones for energy crop production.

In this study, the feedstock costs are expressed in €/GJ_{LHV}. However, biomass products can be valued for other characteristics than their heating value (namely: nutrition-value or potential substitution for precious products like rare pharmaceuticals).

6 CONCLUSIONS

In this paper, the potential and economic viability of bioethanol chains in the Northern region of the Netherlands differentiated for different soil suitability classes has been assessed. In the assessment we explored which areas are most favourable for bioenergy crops that can be used for ethanol production.

The results of the NPV calculations show that an increased share of sugar beet for ethanol production can not compete with current cropping systems under current conditions and commodity prices. Miscanthus could compete with current land use in areas where soils are suitable for Miscanthus and suitable for intensive-managed annual crops. However, competitiveness is only achieved when a level playing field is established (in terms of subsidies). Ethanol production of Miscanthus appeared to be the least cost option, but is still far more expensive than gasoline (at an oil price level of 62$/barrel) or ethanol produced from feedstock imported from abroad. Therefore, there are no economic incentives to produce sugar beet or Miscanthus for ethanol production in the North of the Netherlands under current conditions.

Taken the land availability of the Refuel study into account, the contribution of ethanol from domestic cultivated feedstock would be less than 1% of the gasoline use in the Dutch transport sector. This indicates a marginal potential for biofuel chains in this particular region, but it could contribute to meet the blending targets of the Netherlands in the near future.

The assessment can be extended by investigating the economic performance of pastures and new bioenergy crops. In addition, a more in depth assessment regarding the relation between management, soil suitability and yield levels is needed to comprehend the individual and location specific management choices.

This study provides a methodology to assess the economic viability of regional biomass chains by analysing the competitiveness of bioenergy crops compared to conventional agricultural land use and the spatial specific feedstock production costs taken into account region specific parameters like yield levels, commodity prices and chain design. This methodology is also applicable to other regions and it could be applied to higher scale levels (higher grid levels of administrative units).

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