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Potential, spatial distribution and economic performance of regional biomass chains: The North of the Netherlands as example

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ABSTRACT

This work assesses the viability of regional biomass chains by comparing the economic performance of potential bioenergy crops with the performance of current agricultural land uses. The biomass chains assessed are ethanol production from Miscanthus and from sugar beet in the North of the Netherlands. The competitiveness of bioenergy crops is assessed by comparing the Net Present Value (NPV) of perennial crops, current rotations, and rotation schemes which include additional years of sugar beet. The current land use and soil suitability for present and bioenergy crops are mapped using a geographical information system (GIS) and the spatial distribution of economic profitability is used to indicate where land use change is most likely to occur. Bioethanol production costs are then compared with petrol costs. The productions costs comprise costs associated with cultivation, harvest, transport and conversion to ethanol. The NPVs and cost of feedstock production are calculated for seven soil suitability classes. The results show that bioenergy crops are not competitive with current cropping systems on soils classed as "suitable". On less suitable soils, the return on intensively managed crops is low and perennial crops achieve better NPVs than common rotations. Our results showed that minimum feedstock production costs are 5.4 €/GJ for Miscanthus and 9.7 €/GJ for sugar beet depending on soil suitability. Ethanol from Miscanthus (24 €/GJ) is a better option than ethanol from sugar beet (27 €/GJ) in terms of costs. The cost of bioethanol production from domestically cultivated crops is not competitive with petrol (12.34 €/GJ) production under current circumstances. We propose that the method demonstrated in this study, provides a generic approach for identifying viable locations for bioenergy crop production based on soil properties and current land use.

1. Introduction

Energy from biomass, including biofuels like ethanol, can play a major role in local, national and global energy supplies depending on land availability, costs, and supply. However, in both scientific and political arenas, it is seen that such bioenergy chains need to evolve in a way that is compatible with sustainable development.

In recent years, several studies (e.g. Hoogwijk et al., 2005; Smeets and Faaij, 2007; Dornburg et al., 2008) have assessed the world bioenergy potential and the contribution to the world energy demand. Other studies have focused on bioenergy potential and related costs at a European level (e.g. EEA, 2006; van Dam et al., 2007; de Wit and Faaij, 2010; Fischer et al., 2010a,b) or national level (e.g. van den Broek et al., 2001; e.g. Batidzirai et al., 2006; Styles and Jones, 2007). However, few studies describe the spatial variation of bioenergy production potential and the cost of bioenergy supply within a region. Since the physical environment is spatially heterogeneous, location is a key factor for the economic viability and environmental performance of bioenergy production. Because economic benefit is a major incentive for adoption, this paper focuses on the competitive advantage of bioenergy crops in relation to conventional land use in order to increase understanding of where, and on which types of soils, such land use changes might occur.

Ethanol production from Miscanthus (*Miscanthus* × *Giganteus*) and sugar beet (*Beta vulgaris* L.) in the North of the Netherlands is selected for our case study. This region is important as a test case, because of the high pressure on land for various uses

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including intensive agriculture. This enables an extensive analysis of the economic viability of regional biomass chains. Sugar beet and Miscanthus are selected because of their high potential yields and because they represent a typical first and second generation bioenergy chain. These are compared with current land use to determine their relative economic viability.

In Section 2, we elaborate on the design of the bioenergy chains, the characteristics of the region and the potential land availability in the region. In Section 3, the methods applied to asses the competitiveness of new bioenergy crops compared to current land use and the methods to calculate the cost of feedstock and ethanol production are discussed. The approach to determine the soil suitability and the effect on the spatial variation of economic performance of potential and current land use is described in section 3.3. In Section 4 the results of the assessment are presented and the spatial variation is depicted in maps of the region. A sensitivity analysis shows the level of robustness of the results. In Section 5, the applied method, the data used and the results are discussed, and in Section 6, conclusions are drawn.

2. Case study description

2.1. Study region

The Northern region of the Netherlands (Groningen, Friesland and Drenthe) was selected as the area for our research for several reasons. Firstly, the Dutch government has provided clear targets for substitution of fossil fuel and green house gas emission reduction (Menkveld, 2007; Ministerie van VROM, 2007; Ministerie van Economische zaken, 2008). Secondly, the pressure on land is relatively high due to a high population density, diverse land uses and an intensive agricultural sector, resulting in intense competition between different land uses. Thirdly, access to sea transport through the Eemshaven ports facilitates the possible transport of biomass feedstock and intermediate- or end-products to and from the rest of the world. Fourthly, this is a highly productive agricultural area with fertile soils, favourable climatic conditions, and advanced agricultural management (Romkes and Oenema, 2004) with a farming population that is interested in alternative economic activities for the agricultural sector. Finally, several regional stakeholders have also articulated on the need for sustainable development in the region (Costa Due, 2009; Energy Valley, 2009).

The region has a mild maritime climate with average temperatures of 16 °C during summer and 3 °C during winter (KNMI, 2002). The most common soil types in the Northern region of the Netherlands are sand, clay, sandy clay and peat, and soils are generally fertile. Precipitation is relatively high as are ground water levels. The climate and soils are suitable for a wide range of crops (Christian et al., 2001).

Land use in the region (1.1 Mha) is dominated by agricultural activities: 68% of the total area is agricultural land of which 41% is used for agricultural crops and 57% for pastures. On parts of the pasture areas, silage maize is continuously cultivated by intensive cattle breeders. Cereals, potatoes, sugar beet and silage maize are the most dominant crops cultivated in rotation. Two common rotations schemes for sandy soils and two rotations schemes for clay soils are selected to represent current land use of arable land in the region and are depicted in Table 1.

Due to intensive livestock production, the Netherlands faces a manure surplus. Because of the costs of managing this surplus, the application of manure on agricultural land has negative costs. Therefore, application rates are high in pasture areas with intensive cattle breeding.

Transport infrastructure in the region is well developed. Whilst waterways and railways are available, road transport is the most convenient way of transporting agricultural goods within the region due to the relatively short distances and the flexibility that multiple production sites require (Hamelinck et al., 2005b). Rail and waterways and the Northern ports, connect this region to the rest of Europe and beyond.

Table 1
Two typical rotation schemes for sandy soils and two typical rotation schemes for clay soils for Northern region of the Netherlands derived from (LEI CBS, 2007; van der Voort et al., 2008) expressed as share of individual crop in each of the rotations.

Share of crop in rotation	Clay rotation		Sand rotation	
	I	II	I	II
Winter wheat	0.57	0.20		0.05
Summer barley		0.10	0.28	0.25
Winter barley	0.20		0.06	
Seed potato		0.15	0.03	0.05
Industrial potato		0.15	0.30	0.45
Sugar beet	0.14	0.10	0.20	0.20
Maize		0.25	0.04	
Other			0.06	
Fallow	0.09	0.05	0.04	
Total	1.00	1.00	1.00	1.00

2.2. Biomass potential in the region

The introduction of bioenergy crops to large areas of land would create competition with the food and feed crops already being grown in the region. Thus, in order to define a limit to the arable land available for bioenergy production, information provided by the EU Refuel project is used (de Wit and Faaij, 2010). One of the objectives of the Refuel project was to map the potential production and costs of biomass crops in the EU for different time frames and for several land use scenarios. The method used in this study, is comparable with the approaches used by Smeets et al. (2007) and van Dam et al. (2007). In the Refuel approach, projections are used to describe the future dynamics of population growth, food intake per capita, agricultural production intensity, livestock intensity and land requirements for the growth of cities, villages and infrastructure (Fischer et al., 2010a,b). The land available for biomass production is calculated by subtracting the land needed for other land use functions (including nature) from the total available land, assuming the self-sufficiency in food production in the region remains constant. In the Refuel study it is assumed that typical agricultural crops are only produced on arable land, while for herbaceous crops like Miscanthus it is assumed that pasture could also become available.

The base case scenario of the Refuel assessment is derived from the CAP (Common Agricultural Policy) of the EU. In addition, a more optimistic (high land availability) and a more pessimistic (low land availability) variant have been developed. In Table 2, the amount of agricultural land that according to the Refuel results could become available for biomass production in the North of the Netherlands in 2015 and 2030 is depicted. The Refuel projections of land availability for biomass production in the North of the Netherlands are somewhat higher but in the

Table 2
Share of land that could become available for biomass production in North of the Netherlands according to three Refuel scenarios.

Type of land	Availability in % of land					
	Low		Medium		High	
	2015	2030	2015	2030	2015	2030
Arable	1.9	6.1	2.7	7.4	4.3	10.2
Pastures	0.5	8.6	0.5	8.6	0.5	8.6