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Research paper

Assessment of sustainable Grassland biomass potentials for energy supply in Northwest Europe

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ABSTRACT

Part of grasslands in Northwest Europe is no longer needed for animal husbandry and could be used to support the energy transition towards renewable energies. For assessing the possible contribution of the feedstock grass, a new improved model based on a Geographic Information System (GIS) has been developed and applied to the model regions in the United Kingdom, the Netherlands, Belgium, France, and Germany within the INTERREG project BioenNW – Delivering Local Bioenergy to Northwest Europe. The grassland-to-energy model links geospatial maps data with agricultural data which had been made available by European, national, and regional authorities. The spatially differentiated grass yields rely on an elevation and soil-based classification.

The so-called surplus grass is available for energy conversion after satisfying first existing fodder demands from animal husbandry, and secondly environmental sustainability criteria representing a weak sustainability (Basis) scenario and a strong sustainability (Restrict) scenario. The results show large potentials which vary strongly between the model regions. Local biomass potentials account for up to 1416 tonnes per square kilometre dry mass (t/km^2 dm) per year in the Basis scenario in South Netherlands, while the annual mean values for the regions vary between 100 t/km^2 dm in Île de France and 374 t/km^2 dm in the West Midlands region. Five out of seven regions show surplus grass in the Basis scenario; four regions even in the Restrict scenario. Thus, the model approach provides improved quality and consistency in biomass assessment at different scales and for different regions in the EU.

1. Introduction

The European energy supply needs to be transformed in the next decades as climate change issues are closely connected to carbon dioxide emissions from fossil energy consumption [1]. In the European Union (EU), the use of renewable energy sources is a key element in energy policy, reducing emissions from fossil fuel sources and the dependence on fuel imported from non-EU countries, and decoupling energy costs from oil prices. In 2014, the share of energy from renewable sources in gross final consumption of energy reached 15% in the EU, compared to 8% in 2004, the first year for which the data is available [2]. The most important renewable energy source in the EU-28 is biomass, contributing to almost two-thirds of the primary renewable energy supply in 2012 [2].

Despite this key role, the use of biomass derived from the agricultural sector for energy conversion is controversial, mainly due to the production of first generation biofuels from crops grown on agricultural land and competing with food and fodder production. Increasing bioenergy production from dedicated energy crops might strengthen land use competition and induce conflicts with regard to nature conservation [3,4]. Therefore, the EU has reshaped its biofuel policy stating that first generation biofuels should account for only up to seven percent of final energy consumption in transport by 2020 [5].

Grass from surplus grassland not needed any longer for animal

Abbreviations: GIS, Geographic Information System; NUTS, Nomenclature of Units for Territorial Statistics; NRW, North Rhine-Westphalia; GADM, Global Administrative Areas; EEA, European Environment Agency; EC, European Commission; CORINE, Coordination of Information on the Environment; EU, European Union; DST, decision support tool; UAA, utilised agricultural area; dm, dry mass; WML, West Midlands; UK, United Kingdom; ZN, Zuid-Nederland; WA, Wallonia; RLP, Rhineland-Palatinate; SLD, Saarland; LSU, Livestock Unit; SRTM, Shuttle Radar Topography Mission; DEM, Digital Elevation Model; ESD, European Soil Database; a.s.l., above sea level.

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husbandry does not compete with food production and thus could be used for energy production without ethical concerns or land use conflicts.

Grass is an excellent feedstock for anaerobic digestion and the resulting biogas can be used for thermal combustion [6], to generate heat and electricity [7], or can be upgraded to biomethane as a transport fuel [8]. Grassland derived biomass can also be used for direct combustion to produce heat and electricity. Grassland potentials can vary considerably because the area-specific yields are highly dependent on local conditions like climate, soil, elevation and slope as well as agronomic characteristics. For example: Higher elevations shorten the vegetation period and provide poorer soil conditions [9,10]. The spatial variation of grass yield values is often not accounted for in potential assessments. Against this background, it is the objective of this paper to present a GIS-based model to calculate spatially differentiated yields from surplus grassland considering environmental sustainability issues.

This methodology has been developed within the INTERREG project BioenNW – Delivering local Bioenergy to Northwest Europe. The model is applied to calculate grassland biomass potentials at the NUTS (Nomenclature des Unités territoriales statistiques) level 1, 2, and 3 for selected model regions in the United Kingdom (West Midlands), the Netherlands (South Netherlands), Belgium (Wallonia), France (Île-de-France), and Germany (North Rhine-Westphalia, Rhineland-Palatinate, and Saarland) considering two scenarios with different sustainability restrictions. This approach provides data for a decision support tool (DST) that allows for improved estimates of available biomass for meeting EU bioenergy policy targets [11,12].

2. State-of-the-Art

In 2010, the utilised agricultural area (UAA) in the EU-28 covered 176 million hectares. Around 34% or 59 million hectares are available for grazing of livestock (excluding common land) [13]. Grassland serves as forage area for cattle, sheep, goats and equines and is the basis for value creation in the livestock sector and contributes to meat and milk production [14]. Grassland also provides a broad range of services that are beneficial for man. In addition to the production of herbage for livestock, grassland plays a major role in, for example, the maintenance of biodiversity, carbon sequestration into soils, clean surface and ground water, and the provision of an attractive environment for recreation and leisure activities. However, grassland farming, the intensity of management and utilization, and the production of goods and environmental services at a given site are strongly affected by ecological and societal developments and the global markets for tradable goods. Respectively increasing competition on arable land, due to the promotion of energy crops, is seriously challenging the functioning and maintenance of grassland. Furthermore, many of the European grassland ecosystems face part afforestation or transformation, either natural or planned, or ploughing for growing energy crops [15,16]. The permanent grasslands covered over 57 million hectares in the EU-27 (2007) and temporary grasslands about 10 million hectares. Together, they made up about 39% of the European utilised agricultural area. The permanent grassland area has decreased continuously in most European countries over the last fifty years [16–18]. Between 1967 and 2007, about 7.1 million hectares of permanent grasslands were lost just in the EU-6 [17], which corresponds to 30% of 1967s levels. In the EU-9, 5.5 million hectares were lost between 1975 and 2007. This change in the grassland area has considerable impacts on ecosystem services, respectively on the maintenance of biodiversity because permanent grassland, meadows and in particular natural unfertilized grasslands are generally considered the most important from a landscape and nature conservation perspective [19], [20]. The trend to intensify, transform or abandon grassland management for economic reasons is still ongoing with major impacts on landscape and biodiversity.

2.1. Studies assessing the availability of grassland biomass

On the European level, studies assessing the availability of grassland biomass in excess of livestock requirements are rather missing. Prochnow et al. [21] indicate that the theoretical grassland potential for energy and materials in the EU-27 ranges between 9.2 and 14.9 million hectares. This is equal to 15% and 24% of the currently available permanent grassland in the EU-28. A few assessments exist on the national and regional level. Smyth et al. [22] reported that 10% of the grassland area in Ireland is not needed for the livestock sector and thus could be used to fuel approximately 1.05 million cars with compressed biomethane. McEniry et al. [23] conclude for Ireland – where approximately 92% of the 4.19 million hectares of land used for agriculture are grassland – that under current grassland management and production practices and present livestock numbers, there is an average annual grassland resource of ca. 1.7 megatonnes (Mt) dry mass (dm) available in excess of livestock requirements. Changes to current grassland management and production practises have the potential to significantly increase this resource to ca. 13.2 Mt dm/year. Permanent grasslands in Poland occupy an area of about 3.18 million hectares which corresponds to about 20% of the utilised agricultural area [19]. In the last ten years, permanent grasslands have decreased by nearly one million hectare. On average, only 67% of the meadows are used for fodder, while 9–16% are not mowed at all [19]. This finding is supported by Mikołajczak et al. [24] stating that approximately 20% of permanent grasslands have remained unused in the last ten years. This is mainly due to the declining profitability of animal production and a lack of demand for food products produced. They assume that approximately 2.3–3.4 Mt dm/year of biomass can be obtained for energy purposes from grasslands. In some regions of Germany, almost one-quarter of the grassland is not needed any longer for animal husbandry due to progress in breeding and production technology and to structural adjustments in agriculture [25]. The current and future increases in productivity may even amplify this trend.

The spatial distribution of available excess grassland can differ significantly not only between countries, but also on the regional and local level [25], [26]. Declining numbers of livestock, occur in areas with unfavourable natural conditions for cattle farming. In these areas, no competition with traditional agricultural commodities occurs if grassland biomass is used for energy purposes. Instead, potential supplementary income to farmers can be provided by providing feedstock for bioenergy production from grassland [25,27].

3. GIS-based model to estimate surplus grass potentials

The sustainable potential of grassland biomass is calculated with the GIS (Geographic Information System)-based model developed at KIT-ITAS within the BioenNW project. The model is developed using the programming language Python to drive the ArcGIS software for combining geospatial data on e.g. land cover and soil properties as well as statistical data. The general approach is described in Haase [28] and a detailed description of the model developed for the assessment of crop residues can be found in Haase et al. [29].

For this research, the specific characteristics for assessing grassland potentials are described. In a first step, the investigated model regions are tailored using the Global Administrative Areas (GADM) files (see Table 1), which show the region boundaries at the