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Suitability of biomass from riparian areas of the Noteć River Valley for renewable energy production

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Abstract

In the Wielkopolskie region (western-central Poland), the largest protected area under the Natura 2000 network is located along the Noteć River Valley. The problem of these riparian areas is lack of utilisation and abandonment of grass communities. The production of storable biofuel from harvested biomass using the IFBB (Integrated generation of solid Fuel and Biogas from Biomass) technology of such communities should be a suitable strategy for conservation and maintenance of semi-natural grassland in this region. Analysis of natural conditions and harvesting tests showed that the middle and lower parts of the Noteć River Valley – an area of 770–790 km^2 covering the 180 km-long and 2–13 km-wide floodplain – are the most appropriate areas for the implementation of the IFBB technology. The dominant species were *Phalaris arundinacea*, *Carex acutiformis* and *Carex gracilis*. The briquettes from this biomass after IFBB processing had a high heating value (on average 17.54 MJ/kg) and high level of combustion. The concentration of nitrogen in the biomass was very low, on average 1.23% in DM. The biomass after IFBB processing had a low level of ash in comparison to typical grassland used for forage purposes. The average yield of harvested grass communities was ca. 5 t DM/ha. A plant in Osów village was proposed for applying the IFBB technology in the Noteć River Valley. This was considered profitable with an Internal Rate of Return of 11.05%. Economies of scale apply since, with an IFBB plant of that size, investment costs disproportionately decrease relative to the large amount of output (grass briquettes, power). Cash flow calculations show a positive result from Year 1. With an annuity of 68.814 €/annum, the entrepreneurial risk of investing in a new technology such as IFBB might not be covered entirely. However, potentially reducing investment costs – e.g. by making use of regional investment subsidy programmes for investments in new renewable energy technologies – should make this investment attractive.

Introduction

Floodplain grass communities are frequently characterised as high-nature-value areas and, furthermore, fulfil various ecological services (Verhoeven & Setter 2010). Considering flood protection, they play an important role as riparian areas to reduce the risk of flooding by increasing the infiltration capacity. In addition, the year-round plant cover minimises soil erosion and loss of nutrients. However, the management of these grass- and/or rangeland sites is comparatively challenging due to particular soil conditions and, in many cases, the low nutritive value of the vegetation. Hence, these areas are becoming increasingly abandoned in many European regions. Many farmers

managing these grass communities are looking to diversify their activities. Therefore, agri-environmental programmes have been established that are focused on protection of endangered bird species, habitats and natural sites. Farmers receive financial support for fulfilment of special management of these grass communities. One of the main conditions is late harvest time – typically in the middle of July or beginning of August. Because the harvested biomass can be used for bioenergy purposes, we evaluated the quantity and quality of the biomass from selected grass communities.

The aim of the study was to analyse the suitability of biomass from riparian areas of Noteć River Valley for renewable energy production in the form of storable biofuel using the IFBB technology.

Methods

The study was carried out in the years 2014–2016. We focused on the Noteć River Valley (Wielkopolska region, western-central Poland), where the largest riparian grass- and/or rangeland sites are located. This area contains high-nature-value riparian semi-natural grasslands and rangelands that are included in the European network Natura 2000 as areas of special bird and habitat protection. The area is a second largest peatland in Poland. It is a part of one of the most important ecological corridors between the Odra and Vistula Rivers and a refuge for wild birds at a European scale. For possible use of those areas towards their conservation and maintenance, we analysed the suitability of biomass for renewable energy production using the IFBB (Integrated generation of solid Fuel and Biogas from Biomass) technology (Wachendorf et al. 2009, Blumenstein et al. 2012). Preliminary analysis of natural conditions and harvesting tests showed that the best potential for the IFBB technology was in the middle and lower parts of the Noteć River Valley from Nakło nad Notecią town in the east to Santok village in the west, an area of 770–790 km^2 covering the 180 km-long and 2–13 km-wide floodplain. The botanical composition using the phytosociological method and the yield (quadrat frame method) of harvested biomass from 20 grass communities located in the valley were estimated and samples of biomass for chemical analyses were collected. In the samples, the crude protein (XP), NDF, ADF and ash (XA) using commonly accepted methods were determined. The economic calculations were based on the annuity method according to the guidelines for economy calculation systems for capital goods and plants (VDI 2002). The annuity displays the average yearly net operating result as calculated over the life span of 20 years. If the annuity is > 0, the investment is profitable. The Internal Rate of Return (IRR) is a key profitability measure. If the IRR exceeds the target rate, the investment is profitable.

Results

A majority of the vegetation was classified as *Arrhenatherion*, *Calthion* and *Filipendulion* as well as *Phragmition* and *Magnocaricion* alliances. The dominant species in the sward of the grass communities were *Phalaris arundinacea*, *Carex acutiformis* and *Carex gracilis*. The average yield of harvested grass communities was ca. 5 t DM/ha with huge deviation depending on site and type of plant vegetation. Therefore, the technical production potential for the IFBB technology was estimated to be on the level of 316.5 thousand tons.

In Table 1, the results (average values) of chemical composition of biomass after ensiling and after hydrothermal conditioning from raw materials harvested in the Noteć River Valley are presented. It turned out that the biomass after IFBB processing (press cake) had a low level of ash in comparison to typical grassland used for forage purposes. In particular, the most detrimental minerals Cl, K, N and S were leached into the press fluid resulting in concentrations in the press cake, which were for K and S close to wood from beech including bark. The concentration of nitrogen in the biomass was very low, on average 1.23% in DM. In general, the analysed biomass is a promising substrate for solid fuel (briquette or pellet) produced in the IFBB technology. The briquettes from this biomass after IFBB processing had a high heating value (on average 17.54 MJ/kg) and high level of combustion.

Table 1. Chemical composition of biomass before (silage) and after (press cake) hydrothermal conditioning from raw materials harvested in the Noteć River Valley

Parameter	Biomass silage	Press cake from IFBB	Difference (%)
Dry matter (%)	39.5	31.7	-20
Ash (g/kg DM)	72.2	35.4	-51
N (g/kg DM)	12.3	7.0	-43
Cl (g/kg DM)	6.1	0.8	-87
S (g/kg DM)	2.8	0.9	-68
K (g/kg DM)	8.2	1.1	-87
Ca (g/kg DM)	11.7	4.1	-65
Mg (g/kg DM)	2.4	0.5	-79
P (g/kg DM)	1.8	0.4	-78
Na (g/kg DM)	0.8	0.4	-50

A plant in Osów village (52°49′04″N 15°48′03″E) in the Drezdenko Commune was proposed by the research team for applying the IFBB technology in Noteć River Valley. Assuming that the average distance between the harvesting site and the potential plant location is 15 km, more than 1000 ha of extensive grassland and rangeland are available for bioenergy production. The average size of a riparian grass community plot is 100 ha per single site. Harvesting in many cases takes place after 1 August, due to agri-environmental schemes, mainly 'Protection of endangered bird species and natural habitats in Natura 2000 areas'. For this reason, harvesting is done once a year. There are possibilities to deliver biomass from Noteć River Valley located further away from the biogas plant by river transport, which could create an additional advantage concerning sustainability of a locally feasible processing mode.

After many analyses and much research, the best solution suitable for Noteć River Valley was identified as the IFBB technology as an add-on option (conventional biogas plant with IFBB module). The two main products of the IFBB technology are solid fuel (briquette or pellet) and electricity from biogas. Electricity from cogenerated biogas combustion is used to provide energy for the installation. Surpluses of electric energy could be sold through the Polish Power Grid Company, manager of the public grid network. Solid fuel could be offered in retail locally, but the main target market should be the wholesale one for large combined heat and power (CHP) operators.

Considering an average yield of 5 t DM/ha and an extensive grassland and rangeland area of 1000 ha, a total of 5000 t DM biomass are provided (or approximately 16,100 t FM, respectively), available for energy generation with the IFBB process. Based on the substrate available, a total of 4686 t (85% dry matter) of grass briquettes for heating purposes are produced per year. All of these can be sold, since the internal heat demand of 4,882,835 kWh_{therm} per annum is more than covered by the adjacent biogas plant, which provides approximately 6.3 Mio. kWh_{therm} per annum. In addition, about 1.35 Mio. kWh_{el} per annum electricity are generated from the IFBB press fluids by the CHP of the biogas plant. The proposed IFBB add-on plant in Osów can be considered profitable under the given circumstances. The IRR of 11.05% is close to being considered appropriate regarding the volume of investment. Here, economies of scale apply since, with an IFBB plant of that size, investment costs disproportionately decrease related to the large amount of output (grass briquettes, power). Cash flow calculations show a positive result from Year 1 on. With an annuity of 68,814 €/annum, the entrepreneurial risk of investing in a new technology such as IFBB might not be covered entirely. However, potentially reducing investment costs – e.g. by making use of regional investment subsidy programmes for investments in new renewable energy technologies – should make this investment attractive.

Discussion

Riparian areas of Noteć River Valley in western Poland are high-nature-value areas, mainly in terms of biodiversity. The semi-natural grasslands and rangelands are mostly covered by Natura 2000 network and included in agri-environmental schemes. In a previous study, we already indicated that, because of late cutting, the harvested biomass is fibre-rich and can be used for bioenergy production (Goliński & Goliński 2013). The study of Wachendorf et al. (2009) and other authors shows that the IFBB technology helps to improve the process of bioenergy conversion from riparian grassland biomass.

Biomass obtained from riparian areas of Noteć River Valley is a potential feedstock for renewable energy production. As reported by Hensgen et al. (2012), technical and environmental limitations exist in using this biomass for combustion, due to the presence of harmful elements. Converting biomass using the IFBB technology produces a press cake with lower concentrations of harmful elements and a press fluid usable for biogas generation. The concentration of harmful elements such as N, S, Cl and K in the solid fuel was significantly reduced compared to the original biomass silage. Comparatively high heating value (on average 17.54 MJ/kg) of received briquettes indicates a high performance of this material for combustion. This result was similar to the findings presented by Blumenstein et al. (2012) and Bühle et al. (2014).

The proposed IFBB add-on plant in Osów, Poland, can be considered profitable with an IRR of 11.05% under the given circumstances considered in the investment plan. Economies of scale apply, since with an IFBB plant of that size, investment costs disproportionately decrease relative to the large amount of output (grass briquettes, power). Cash flow calculations show a positive result from Year 1. It can be concluded that the production of storable biofuel from biomass harvested from riparian areas of Noteć River Valley using the IFBB technology should be a suitable strategy for conservation and maintenance of semi-natural grassland and/or rangeland in this region and other central European floodplains.

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