4-CIAB
4th. IBEROAMERICAN CONGRESS ON BIOREFINERIES

WHEAT STRAW AS SUSTAINABLE FEEDSTOCK FOR A 2G BIOETHANOL PLANT IN BAVARIA

Ball, Ingo[1]*; Janssen, Rainer[1]; Rutz, Dominik[1]

[1] Unit Bioenergy & Bioeconomy, WIP Renewable Energies, 81369, Munich, Germany
* Corresponding author. *E-mail*: ingo.ball@wip-munich.de.

Keywords: Residual feedstock, bioethanol, sustainability environmental impact

Abstract

The production of 2G bioethanol needs to be economic viable and sustainable so that it is widely accepted and able to contribute to a more climate friendly fuel portfolio. In the South-East of Germany, in Bavaria, it was investigated whether regions can be found, in which more than 30,000 t_{dm}/y are available in a 50-km radius and the preconditions for a sustainable feedstock (a.o. soil carbon, climate change) are fulfilled. Investigated were the feedstocks wheat straw, rye straw, barley straw, oat straw, rapeseed straw, triticale straw and corn stover. It could be shown, that in the region Lower Bavaria, in a 50-km radius area around the city Landshut enough wheat straw (~ 121,000 t_{dm}/y) is available for the production of 2G bioethanol. Furthermore, it was found, that in Bavaria these amounts (i.e. the yields) can be also be provided when the local consequences of climate change are considered, as the negative impacts (i. e. heavy precipitation or heat waves) are presumably compensated by positive impacts (i. e. longer vegetation period, more CO_2 for plants growth). A first calculation of the environmental impact of the feedstock supply revealed that per supply ton of wheat straw 11.0 kg CO_{2eq} needs to be considered.

INTRODUCTION

Second generation biofuels from lignocellulosic biomasses were foreseen as attractive alternatives or complements to first generation biofuels. However, obtaining lignocellulosic biomass is not as favorable as initially thought. Most of the crop residues, except the straws that have a well-established use and market for animal littering and food, are currently left in the fields as a natural way of returning organic and mineral nutrients to the soil. A massive removal and exportation of the crop residues is not feasible in many

countries and areas where soil conditions already suffer from erosion and lack of organic and mineral nutrients due to climate conditions and intensive agricultural practices.
The purpose of this study was to evaluate the real available amounts of lignocellulosic biomasses starting from theoretical harvestable quantities and after the restrictions due to agronomic and technical constrains and current competitive uses. As transportation is making a high contribution to the supply cost and carbon foot print, the net available amounts were investigated in small catchment areas, limited to 50 km radius.

METHODOLOGY

The feedstock investigation started with the selection of suited feedstocks for the production of 2G bioethanol. In the EU funded project BABETHANOL, several feedstocks have been analysed, and for Germany, wheat straw, rye straw, barley straw, oat straw, rapeseed straw and corn stover were considered as suited feedstocks. In this study, also the potential of triticale was investigated as it is a hybrid of the suited feedstocks rye and wheat. The selection of the sustainable feedstock was carried out from theoretical to sustainable available potential (theoretical > technical > agronomic > non-competetive > sustainable available). To obtain reliable results, official data from the Bavarian State Office for Statistics and research results from agricultural experts, institutes and ministries were used.

RESULTS

From theoretical to sustainable potential

To calculate the theoretical potential, official statistics of the Bavarian State Office for Statistics were used. In order to receive one single value for each feedstock, data sets were elaborated that take into account average values of the past years. Each data set contains information about 3 years average of agricultural used lands, 10-year average of crop yields and straw rates for investigated crops. The formula used for the calculation can be expressed as following:

$$\underset{i=1}{\overset{n}{SY}} = \sum_{i=1}^{n}(CF_i * CF_i * FGS_i)$$

(SY = straw yield [t]; CF = cereal fields [ha]; CY = cereal yield [t/ha]; FGS = factor grain:straw-relation; i = cereals)

Starting from the theoretical potential, the share that is limited by technical restrictions and can be finally recovered with equipment is called technical potential. The restrictions can be technically like recovery rates but also legal or social limits (i.e. fodder production or composting). Thus, the technical biomass potential describes the “time and location related, primary from the technical perspective materially or energetically” usable amount of biomass (FNR, 2015). For the calculation of the technical potential, for all different straws but corn stover, it was assumed that 67 % of the theoretical potential can be recovered from the field (Schwarz, 2012). For corn stover, according to a recent study by Thurner et al. (2017), a technical potential of 49 % needs to be considered in Bavaria.

The agronomic potential considers the issues of soil erosion, soil biodiversity and soil organic matter. Soil erosion is an existing threat in Bavaria. To prevent the soils from erosion, it is recommended that conservation tillage is fostered. This measure includes all tillage techniques, that reduce losses of soil and water. Furthermore, after the cultivation, at least 30 % of the soil surface shall be covered with plant remains. It has already been proven, that conservation tillage is an effective cultivation technique when soil carbon matters need to be addressed (SMUL, 2017). Regarding the issues of soil biodiversity, results from the Global Soil Biodiversity Atlas, which was published in 2016 allow the conclusion that the soil biodiversity situation is not alarming, the soil biodiversity index for Bavaria ranges between medium and high (Orgiazzi, A., et al. (Eds.), 2016). For the issue of soil organic matter (in Germany mostly referred to as humus) and the sustainable supply of a residual feedstock, it is known that farmers can have an impact on the humus content development by the way they cultivate their lands. Carbon can be stored in the soils if farming methods like conservation tillage with cover crops and crop residue mulch, nutrient cycling including the use of compost are adapted (Lal, 2004). The Bavarian State Research Centre for Agriculture publishes recommendations for the farmers to secure the carbon storage on their fields. Regarding one value that considers the mentioned issues, the German IFEU (Institut für Energie- und Umweltforschung - Institute for Energy and Environmental Research) investigated the maximum amount of crop residues which can be taken from the fields without putting the soils at risk of nutrient degradation. According

to the IFEU, a maximum factor of 33 % of the total grain straw (i.e. the theoretical potential) can be taken from the fields if the soil quality shall be maintained.

The results for Bavaria are shown in Table I.

Table I: Bavaria - from theoretical to agronomic potential

Investigated feedstocks in Bavaria	Theoretical potential	Technical potential (in % of theoretical potential)	Agronomic potential (33% of theoretical potential)
	[t_{dm}/y]	[t_{dm}/y]	[t_{dm}/y]
Wheat straw	2,710,785	1,816,227 (67 %)	894.559
Rye straw	198.01	132,667 (67 %)	65.343
Barley straw	2,454,788	1,644,708 (67 %)	810.08
Oat straw	263.247	176,376 (67 %)	86.872
Rapeseed straw	1,781,221	1,193,418 (67 %)	587.803
Corn stover	929.337	455,375 (49 %)	306.681
Additionally investigated:			
Triticale straw	422.965	283,387 (67 %)	139.579

To obtain the sustainable potential, also the competitive uses where considered. It can be assumed that the competitive use (30 % of technical potential) which has started to decrease in the past years, will continue to decrease. In this study it is assumed that 30 % need to be subtracted from the agronomic straw potential.

The most potential region in Bavaria to find enough residual feedstock was identified in the region Lower-Bavaria for the feedstocks corn stover and wheat straw. In the investigated region, mainly the risk of erosion needs to be addressed by farmers, especially when growing corn on hilly slopes. That is the reason why wheat straw is considered to be the more sustainable feedstock in the region. The agronomic and the sustainable available potential around the district Landshut are shown in Figure 1. It can be seen, that in a 50-km radius around 121,000 t_{dm}/y of wheat straw would be sustainably available (considering a competitive use factor of 30 % of the residual potential).

A preliminary environmental impact assessment of the supply from field to gate was also carried out. It looked at the expected impacts related with the use of the crop residues, especially at the nutrition loss when taking the straws from the fields, the related CO_2-emissions and the climate change issue related to agriculture. It could be shown, that nutrition loss can be avoided by preventing soil erosion, and the nutrition loss that is related with the recovery can be compensated by applying compost on the field (for wheat straw for example: 11.42 t /ha of compost per 3 years).

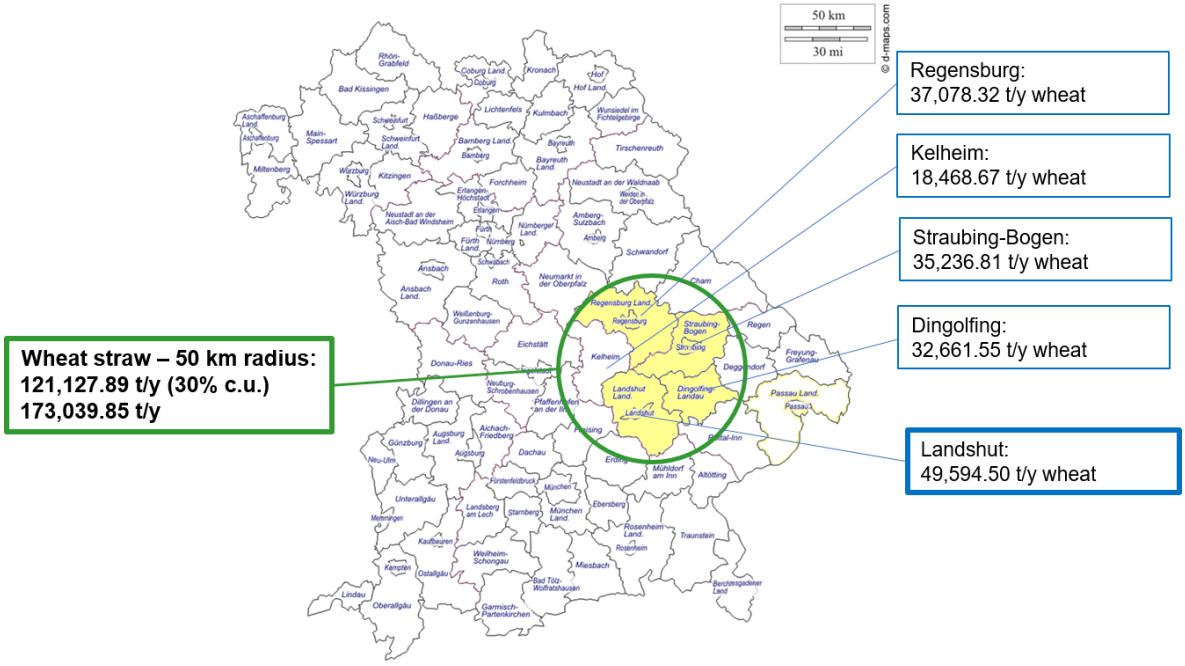

Figure 1: Bavaria - sustainable straw potential in Lower Bavaria

The expected CO_2-emissions related with the agricultural vehicles are 17.4 kg CO_{2eq} per supply ton of wheat straw (Ball, 2018). When simulating the use of agricultural vehicles that have proven their functionality with biofuels (regardless of the economic costs), then a CO_2-footprint reduction of 38 to 83 % can be achieved by using biodiesel, HVO or waste vegetable biodiesel, which would lead to a CO_2-footprint of 11.0 kg CO_{2eq} (RED, 2017). The expected environmental impact of the feedstock recovery related with climate change will probably not play a role in Lower Bavaria if the predicted scenario will develop (climate change related events are compensated by climate change related favorable conditions), and from 2030 on adapted crops will be available that might even lead to higher yields (Rauch, 2017).

CONCLUSIONS

It could be shown, that it is possible to find sustainable feedstock potentials of at least 30,000 t_{dm}/y of wheat straw in a 50-km radius zone near the city of Landshut. With amounts of 121,000 t_{dm}/y, the threshold of 30,000 t_{dm}/y is exceeded by far. The potential risks of soil erosion, biodiversity and climate change seem to be manageable in Bavaria, and the wheat straw feedstock can be provided sustainably also in the future. It needs to

be further investigated, whether the local farmers are willing to supply the feedstock and if then still the concept can be economical viable.

ACKNOWLEDGEMENTS

The research leading to these results has received funding from the European Commission in the Horizon 2020 Program (Project BABET-REAL5 No. 654365).

REFERENCES

Ball, I., 2018, Identification and selection of lignocellulosic biomass feedstock for a small-scale 2G bioethanol plant in Bavaria, 108 ff.

FNR, 2015, Biomasspotenzial von Rest- und Abfallstoffen. Schriftenreihe Nachwachsende Rohstoffe | Band 36. Gülzow-Prüzen. 5.

Lal, R., 2004, Soil carbon sequestration to mitigate climate change. Geoderma. Volume 123, Issues 1–2, November 2004, Pages 1-22.

Orgiazzi, A., et al. (Eds.), 2016, Global Soil Biodiversity Atlas. Pag. 91. European Commission, Publications Office of the European Union, Luxembourg. 176 pp.

Rauch, C., 2017, Mais trotzt Hitze, Kälte, Trockenheit. Münchner Merkur. Nr. 237, Wochenende, 14./15. Oktober 2017. J5.

RED, 2017, DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL. Pag. 52.

Schwarz, B., 2012, Potenziale und Wirtschaftlichkeit von Stroh als Substrat in Nassvergärungsanlagen. Energiepflanzentag in Trossin am 29.08.2012. [Online] Available: https://www.landwirtschaft.sachsen.de/landwirtschaft/download/05_Schwarz_Strohvergaerung_IKTS_TLL.pdf [25.10.2017].

SMUL (Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie), 2017, Konservierende Bodenbearbeitung. [Online] Available: https://www.landwirtschaft.sachsen.de/landwirtschaft/8120.htm [19.10.2017].

Thurner, S. et al., 2017, Verfahrenstechnik zum Einsatz von Körnermaisstroh in der Biogaserzeugung. In Schriftenreihe Landtechnische Jahrestagung 2017. 51.