ANALYSIS OF LOCAL AGRICULTURAL BIOMASS RESOURCES IN WARMIA AND MAZURY VOIVODSHIP

Stanislaw Bielski, Marek Marks
University of Warmia and Mazury in Olsztyn, Poland
stanislaw.bielski@uwm.edu.pl, marek.marks@uwm.edu.pl

Abstract. Our aim has been to review the potential of using straw for energy purposes in the province of Warmia and Mazury. The structure of sown crops and the number of livestock in the province were analysed, an estimate of the volume of straw produced was made, after which the amounts of straw used in animal production (feed and bedding) were distracted from the estimated quantity, and finally the organic substance balance in soil was calculated. The calculations substantiate the conclusion that on average there are about 258 811 Mg of straw left every year that could be used for energy generation. This amount of straw corresponds to 3 752 756 GJ of energy, which equals to the energy contained in 150 110 tons of coal.

Keywords: biomass, biofuel, straw, renewable energy.

Introduction

Poland's current energy policy has been defined in the document titled 'Poland's Energy Policy until 2030'. It was developed by the Ministry of Economy and adopted by the Council of Ministers in 2009. According to this policy, the major goal of the Polish energy policy is to enhance the country's energy safety, while adhering to the principle of sustainable development [1] .

It is envisaged that in 2020 at least 15 % of energy in final energy consumption will originate from renewable energy resources (RER). The state policy is also orientated towards the development of distributed energy generation, which utilises locally available resources. Biomass is a resource that seems to be a promising energy carrier. Agricultural biomass can be used for energy purposes in direct solid biofuel combustion processes (e.g. wood, straw), or converted to gas (e.g. agricultural biogas). However, when compared with other popular energy resources, biomass is more difficult to be utilised, mostly because it is not homogeneous and has a low energy content relative to its volume [2]. In Denmark, growing interest in straw as an energy source has led to a more detailed assessment of the availability of straw for bioenergy production [3]. Monforti et al. [4] have estimated total UK crop residues of 20.4 Mt dry matter production, of which 8.37 Mt were collectable and 4.2 Mt were available. Except heating use, straw is also used for biogas [5] and bioethanol production [6].

According to [7], there is much spare potential of agricultural production dedicated to energy purposes. It would be recommendable to strive towards using all the biomass, which exceeds the agricultural demand that has not been utilised yet, especially the worse quality one, in order to generate energy.

A growth in the bioenergy sector offers a great chance to create new jobs, especially in rural areas. Production and utilisation of renewable energy resources locally will help enhance the condition of the natural environment as well as the health of local populations. Moreover, small towns and villages will stand a chance to become independent from the power delivered from external sources [8]. The decreasing profitability of agricultural production forces us to seek for new solutions that will generate higher agricultural income [9].

Straw is typically defined as ripe or dry stalks of cereals, although the term can also refer to dry stems of legumes, flax or oilseed rape. Straw, counted as agricultural biomass, is a by-product of on-farm plant production. Utilisation of straw as raw material for power generation offers various benefits. Lewandowski and Ryms (2013) [10] claim that straw is the most important solid biofuel in Poland, second only slightly to wood.

When using straw for energy purposes, the distance of the collecting unit to the production area of the raw material should be taken into account, as transport costs may prove decisive in the success of the straw exploitation as a renewable energy source [11].

We should underline that despite straw yields are available, the use of straw for power generation is not a widespread practice. One of the major obstacles to using straw for energy purposes is its heterogeneous structure, which makes straw transport and storage difficult. Moreover, straw as raw

material for power generation has a very low energy content, and therefore it should first be processed into pellets, briquettes or bales.

Furthermore, for the technological potential of straw to be used in practice, it is necessary to generate energy from straw locally, so as to exclude additional transportation costs that would reduce cost-effectiveness.

The purpose of this study has been to identify the balance of agricultural biomass that could be dedicated to generating energy. While analysing data, our focus was on estimating the stock of straw from cereals and oilseed rape in the province of Warmia and Mazury.

Materials and methods

Complete information about the structure of sown crops and number of livestock in the province was collected so as to make calculations of the potential volume of straw biomass originating from agriculture. To this aim, the database of the Statistical Office in Olsztyn was searched. The structure of crops and the number of livestock presented in this paper are based on the latest information covering two-year periods (2015 and 2016).

The following formula was applied to calculate the yields of straw from individual crop plantations:

$$P = \sum_{i=1}^{n} a \cdot y \cdot w_{zs} \,, \tag{1}$$

where P – production of straw from basic cereals and oliseed rape;
a – area cropped with i-th crop species, ha;
y – yield of grain from i-th crop species, t·ha^{-1};
w_{zs} – straw to grain yield ratio.

The analysis included straw obtained from the cultivation of basic cereals (wheat, rye, barley, oat and triticale) and cereal mixes grown for grain as well as oilseed rape. The straw yield to grain yield ratios were adopted from the research by [12-14].

For correct estimates of the potential quantity of straw that can be dedicated to power generation, the straw yields harvested must be decreased by distracting the amounts of straw used in farming. First of all, straw should cover the demand of animal production (bedding and feed). If necessary, it ought to be used to keep the balance of soil organic matter (fertilisation by ploughing straw into soil). For our calculations, the following formula was used:

$$N = P - \left(Z_s + Z_p + Z_n\right), \tag{2}$$

where N – surplus of straw for alternative (energy generation) use;
P – production of straw from basic cereals and oilseed rape;
Z_s – demand for straw bedding;
Z_p – demand for straw as animal feed;
Z_n – demand for straw for incorporation into soil.

The demand for straw in animal production (feed and bedding) was derived from the following equations:

$$Z_s = \sum_{i=1}^{n} q_i \cdot s_i \,,\; Z_p = \sum_{i=1}^{n} q_i \cdot p_i \,, \tag{3}$$

where Z_s – demand for straw bedding;
Z_p – demand for straw as a feed;
q_i – livestock of i-th animal species and type;
s_i – standard demand for straw as bedding by the i-th species and type;
p_i – standard demand for straw as a feed by the i-th species and type of animals.

While calculating the amounts of straw needed to be incorporated into soil as organic matter, it was necessary to take into account the structure of sown crops, quality of soils and the organic matter balance. An increase or decrease in organic substance can be measured with the help of indices, which implicate its reproduction or degradation. Organic matter reproduction or degradation factors adopted

for the study were the ones ascribed to medium soils, as these are the most widespread type of soils in Warmia and Mazury.

Knowing the total area cropped by particular groups of plants and amounts of manure produced by farm animals, the latter calculated from the number of livestock and corresponding norms, the balance of organic substance was derived from the following formula:

$$S = \sum_{i=1}^{n} r_i \cdot w_{ri} + \sum_{i=1}^{n} q_i \cdot o_i \,, \tag{4}$$

where S – balance of organic matter;
r_i – area covered by a given group of crops;
w_{ri} – organic matter reproduction or degradation for a given group of crops;
q_i – number of livestock in physical individuals, according to species and age groups;
o_i – norms of manure production in tons per year by animal species.

In our calculations, the number of livestock in the province as well as the yearly norms for individual species and types of animals were adopted from the Abridged Norms for Agricultural Production [15].

Whenever the organic matter balance in soil is found to be negative, it is necessary to incorporate an adequate amount of straw into it, so as to keep a sustainable content of organic substance (assuming that 1 ton of dry matter of manure equals 1.54 tons of straw). The following formula served to calculate the balance of organic matter in soil [16]:

$$Z_n = w_s / o \cdot s \,, \tag{5}$$

where Z_n – demand for straw to be ploughed into soil;
w_s/o – coefficient 1.54 Mg of straw to equal the amount of straw to 1 Mg of manure dry matter;
s – organic matter balance.

Results and discussion

The volume of straw production depends on a number of factors, of which the most important ones are: the area cropped with agricultural plants, crop yields, crop species, fertilisation regimes, cultivars – especially ones with stiff or short stems, where the straw yield to grain yield ratio is lower. Average yields of crops in the province of Warmia and Mazury were computed from the data gathered by the Provincial Statistical Office in Olsztyn. Calculations of straw yields included ratios of the main and by-product yields (Table 1).

Table 1

Area and yield of crops providing straw and its potential in the province of Warmia and Mazury (average of 2015-2016)

Species	Crop aera, ha	Yields, dt·ha^{-1}	Coefficient	Straw potential, Mg·year^{-1}
Wheat	154 307	4.56	0.46	323 674
Barley	40 514	3.22	0.78	101 755
Rye	30 610	2.86	1.45	126 940
Triticale	83 045	3.84	1.13	360 349
Oat	21 863	2.90	1.05	66 573
Cereals mixtures	39 717	2.92	1.10	127 571
Rape	65 814	2.43	1.00	159 928
Total	370 056	-	-	1 266 790

The calculations of the straw potential quantities in the province of Warmia and Mazury took into account areas cropped with plants yielding straw, levels of yields obtained from these crops and ratios of the main to by-product yields. Considering the above, the amount of straw that can be harvested from the farmlands in the whole province is 1 266 790 Mg. In 2000 the province of Warmia and Mazury has produced 1 438 551 and in 2006 1 873 794 Mg of straw.

The amounts of straw needed for bedding depend on the number of livestock and the type of housing (housing management). The most popular solutions are: shallow litter, deep litter and litterless. The estimates suggest that about 80 % of farm animals in Poland are kept on shallow litter, around 15-20 % on deep litter and just 3 to 5 % stay in litterless barns. It was therefore assumed that 100 % of the housing facilities for farm animals in the province are the ones with shallow bedding. It was presumed that a higher consumption of straw in barns with deep bedding is offset by the savings made in beddingless buildings [17]. Table 2 shows the stocks of individual farm animal species in the analysed area and the annual demand for feed and bedding.

Table 2

Number of livestock in the province of Warmia and Mazury, average of 2015-2016 and demand of straw for agricultural purposes

Species	Animal number	Fodder demand, Mg	Bedding demand, Mg
Cattle	185 955	223 146	185 955
Pigs	32 880	0	16 440
Sheep	8 997	1 799	1 799
Horses	13 208	10 566	11 887
Poultry	6 899 000	0	137 980
Total	-	235 512	354 062

The final balance also included the demand for straw needed to be incorporated into soil in order to maintain a proper balance of organic substance in soil. The livestock kept on farms in the province of Warmia and Mazury produce 2 097 813 tonnes of dry matter of manure. This is not enough to cover the loss of organic matter in soil (-282 693 tonnes) (tab. 3). Our calculations show that the balance of organic matter in soils in the whole province is negative (-0.26 Mg d.m. of manure·ha^{-1}).

Table 3

Balance of soil organic matter

Specification	Area sowing, ha	Reproduction or degradation ratio of organic matter	Balance of organic matter, t
Basic cereals	370 056	-0.53	-196 130
Raps	65 814	-0.53	-34 881
Sugar beat	2 417	-1.40	-3 384
Potato	8 838	-1.40	-12 373
Legumes	31 980	0.35	11 193
Maize	40 970	-1.15	-47 118
Total	520 732	-	-282 693

The negative balance of organic matter means that 258 478 Mg of straw should be incorporated into soil by ploughing, so as to maintain a substainable balance of humus in soil. First of all, oilseed rape straw should be used for this purpose, as it is practically unused in animal rearing technologies or to other aims on farms. It can therefore be treated as either fertiliser or fuel. Oilseed rape straw is best to be used for fertilization, because of its higher content of nitrogen. By ploughing oilseed rape straw into soil, it may become unnecessary to apply an additional dose of nitrogen. Oilseed rape straw is more readily degraded in soil than cereal straw, it contains 2- to 3-fold more sulphur than the latter and it does not create a risk of transmission of fungal diseases of cereals. The demand for bedding straw in the province is 354 062 Mg, while the amounts of straw needed to make animal feeds are 235 512 Mg a year. These data suggest that 258 811Mg of straw remains each year in the whole province that could be used for alternative purposes, like power generation.

Conclusions

The theoretically available amounts of straw in the province of Warmia and Mazury equal 1 266 790 Mg per year. To estimate the potential quantity of straw that could be used for energy purposes in the whole province, the straw yield was decreased by distracting from it the amounts of straw used in agriculture – for bedding, feed and maintenance of the sustainable balance of organic substance in soil.

The calculations substantiate the claim that there is a surplus of straw in the province that exceeds the amounts of straw needed in farming. The annual average quantitity of straw left in the whole province for possible energy generation is around 258 811 Mg, and the market value of this amount of straw is 3 671 074 EUR. The overproduction of straw corresponds to an equivalent of energy of ca 3 752 756 GJ. Assuming that the calorific value of medium quality coal is 25 $MJ \cdot kg^{-1}$, the above amount of straw corresponds to 150 110 tons of coal. Should we assume that an average price of coal is 179 $EUR \cdot t^{-1}$, the monetary value of straw as a fuel substitute is around 26 970 158 EUR. If we could process surplus straw into pellets, its value would increase to 29 368 594 EUR (at a price of pelleted straw at 114 $EUR \cdot t^{-1}$, data from the website http://www.cenypaliw.eu/).

Fewer and fewer companies produce heat from straw. Farmers are increasingly aware of the high value of straw as organic fertiliser, especially on farms without livestock production. The farms where animals are reared use straw for bedding. Straw is also used as mushroom substrate.

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