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Economic potential of perennial energy crops in Poland

Antoni Faber [1]*, Rafał Pudełko [1], Robert Borek [1], Magdalena Borzecka-Walker [1], Alina Syp [1], Ewa Krasuska [2] and Panagioula Mathiou [3]

[1] Institute of Soil Science and Plant Cultivation , State Research Institute, 24-100 Puławy, Poland. [2] Automotive Industrial Institute, Warsaw, Poland. [3] Agricultural University, Athens, Greece.
**e-mail: faber@iung.pulawy.pl, antoni.faber@iung.pulawy.pl, asyp@iung.pulawy.pl*

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Abstract

Poland is committed to satisfy 15% of its energy needs from renewable sources by the year 2020. Biomass should make an important contribution to that, with perennial energy crops production potential of 1.59 million ha of arable land. However, the area of perennial plantations reached only 10,000 ha and started decreasing. Low competitiveness compared to traditional agriculture and high risk related to biomass production seems to be the main reason for that. On the basis of agricultural census data for 314 regions, biomass prices assuring the same profitability as traditional agricultural enterprises should carry out medians of 3.0-4.2 € GJ^{-1}. In practice, such prices are not attractive for farmers, therefore, risk premiums were calculated in order to enhance farmers to change from current production to biomass. Stochastic Efficiency with Respect to a Function (SERF) was applied to estimate risk premiums between 2.5 and 5.1 € GJ^{-1} dependent on the predominant type of production in a farm and the energy crop. The total median prices including risk premiums are in the range of 5.7-6.4 € GJ^{-1}. This is close to biomass price offered by the energy sector in Poland, which is currently at the level of 6 € GJ^{-1}. These prices in combination with areas suitable for energy crops were used to estimate economic potential of biomass, which amounted to 0.45 million ha of agricultural land. This accounts for 28% of technical biomass production potential with the capacity to produce 4.3 million t of biomass.

Key words: Perennial energy crop, price, risk premium, economic potential.

Introduction

The fulfilment of requirements of the EU directive 2009/28/EC will require among other renewable energy sources utilization of large amount of biomass [5]. Dedicated production of perennial energy crops on agricultural land is expected to be a crucial source of biomass for power and heat production as well as for 2nd generation liquid biofuels in most countries. The current area of perennial energy crop cultivated in the EU is estimated at 85 thousands ha and grows slowly with regard to the estimated land potential available for energy crops amounting to 13.2 million ha in the EU [1, 12].

Poland is obligated to satisfy 15% of energy consumption with renewable energy sources by 2010, and considered as one of the largest biomass producers in the EU. Different studies estimate the total potential of biomass production in Poland, depending on the assumptions and methodologies applied, at the level of 1.0 – 6.9 million ha of agricultural land [6, 8, 9, 14, 15]. The amount of land dedicated for perennial energy crops range from 0.9 to 2.2 million ha [8, 10, 14]. Despite of the large differences between estimations, there are expectations that Poland will be in a position not only to guarantee its own needs, but also to export biomass to the EU market [17, 19]. Additionally, it was presumed that Poland could supply considerable amounts of cheap biomass, because production costs of the woody crop were calculated on the level of 1.2-2.4 € GJ^{-1} which was below the respective costs estimated for Western Europe [4, 19]. However, the production costs are higher if the economic compensation required by the farmer in order to grow biomass is included. In this case, the calculations include not only the cost of cultivation, but also the costs of land and risk [7]. The production costs of woody short rotation crops (SRC) were calculated to be about 4–5 € GJ^{-1} and 6-7 € GJ^{-1} for perennial grasses under current conditions. The lower values are considered as typical for Eastern Europe and the higher values for Western Europe, respectively.

Risk issues related to perennial energy crops production in agriculture farms have been addressed only recently. Uncertainty about the key parameters, such as yield and market prices, make it difficult for the farmers to accurately estimate the revenues [3]. Moreover, long plantation lifespan and high establishment costs increase the economic risk accounted to this activity. In reference to that, it is hypothesised that in the situation of the immature biomass market the aversion of farmers to establish biomass plantations, is related to the significant risk of changing production profile from traditional enterprises to the new type of production. The objectives of this study are to estimate: (i) the biomass prices assuring the same profitability as traditional agriculture activities, (ii) the risk premium which farmer would need to be compensated with switching from current production to biomass crop production, and (iii) the probability distributions for biomass prices, including risk premiums. Finally, the area of cultivated land and the volume of biomass relevant to the price recently accepted by the energy sector is estimated, with the investigation of farm related factors affecting the biomass prices.

Materials and Methods

The analysis presented in this paper is based on the results of the national census data for 314 NUTS-4 regions from the 2002 year [2]. Data regarding an array of economic, social and agrarian factors was used as input. The agricultural market output and production costs were adjusted forward to 2007 using regression model projection from NUTS-2 data for 2007; thereby accounting for the most recent values. The biomass prices assuring the same profitability as the traditional agriculture enterprises are calculated from the formula:

$$P = [(Mo-Mc) + Cb] / Yb \quad (1)$$

where P is biomass price assuring the same profitability as the traditional agriculture PLN t^{-1}, Mo market output (PLN ha^{-1} agricultural land), Mc cost of production (PLN ha^{-1} agricultural land), Cb cost of biomass production PLN ha^{-1}, Yb biomass yield t ha^{-1} .

Energy crop yields were obtained from early modelling exercises for the most promising energy crops, which are willow (3-year cutting cycles on arable land and 7-year cutting cycles on green lands), Miscanthus and Virginia mallow. The yields were estimated at regional level grown in suitable soils for each crop and amounted to (median) 11.7, 7.0, 15.1 t and 11.4 t ha^{-1}, respectively. Yields within the regions vary at the range no higher than 1.0-1.3 t ha^{-1}. Annualised costs of energy crop production for the 18-year plantation lifespan were estimated at 1650, 500, 2664 and 2558 PLN ha^{-1}, respectively (399, 121, 643 and 618 € ha^{-1}). The estimated biomass prices were then recalculated to € ha^{-1} (1€ = 4.14 PLN) and € GJ^{-1} using biomass heating values (LHV = 18 MJ kg^{-1}).

The risk associated with energy crop production relative to conventional agricultural activities has been examined with the procedure Stochastic Efficiency with Respect to a Function (SERF) [16]. A range of gross margins from farms with leading production of cereals, mixed production, milk and pork were taken from 140 farm survey analysis from 2006-2008. Gross margins for biomass crops were assessed for randomly selected regions using yields, estimated prices from equation (1) and biomass production costs. A probability distribution of the gross margins from each enterprise was then calculated. This was stochastically simulated using the Microsoft Excel add-in SIMETAR. SERF was used to calculate a risk premium that would have to be paid to a farmer to be indifferent between two competing production directions. The risk premiums obtained for the normal risk averse group of farmers were recalculated to € GJ^{-1}. Next, leading production direction in each region was distinguished using a cluster analysis according to normalised Ward's method in Statgraphic software. Finally, total biomass prices for each region were calculated as a sum of estimated prices from equation (1) and risk premiums. The distributions of total prices were analysed. It was shown that prices came from the largest extreme value distribution with 95% confidence level. Critical values and cumulative probability (quantile plots) were accepted as good characteristics of biomass prices. Calculations were performed in Statgraphics.

Nowadays, power stations and CHP in Poland are inclined to accept price of biomass at the level of 6 €/GJ. Economic potential was calculated in regions, which can guarantee biomass production at this price level. The areas suitable for biomass crops and obtainable yields were used to calculate the production volumes. This was analysed and visualised using ArcGIS 9.3.

In order to better understand how the estimated economic potential depends on different farm-related factors additional statistical analyses were carried out. Biomass prices (Y) were investigated in relation to independent variables (X), such as farmers high school education (%), wheat, triticale and rye sown area (%), meadow and pasture area in agricultural land use (%), contribution of income from agriculture in house budget (%), farm area (ha), Animal Large Unit (number ha^{-1}) and farmers in age below 35 years old (%). The statistical analysis was carried out using principal component analysis with partial least square regression in SIMCA software. Scaled coefficients were used for interpreting the relative influence of the variables X on Y. For the same variables neural net regression was analysed in Statistica software. The best model with the logistic neurons activation was selected. The surface area plots for price and most important independent variables were shown.

Results

The biomass prices assuring the same profitability as traditional agriculture: Estimated prices did not have the normal distribution. Therefore, they are given as medians. Medians of farm gate-prices for willow on arable land and grassland, Miscanthus and Virginia were 3.1, 3.0, 3.3 and 4.2 € GJ^{-1}, respectively. The prices differ with regard to the predominant agricultural production type in NUTS-4 regions (Table 1). Though, the price differentiation was not large, the medians differed statistically significantly.

The obtained price values were higher than the production cost of woody crops estimated at 1.2-2.4 € GJ^{-1} for Eastern Europe on 2005 level costs [11, 13]. However, their values were nearer to production costs for Miscanthus (2.5-3.3 € GJ^{-1}) and SRC willow (2.1-3.2 € GJ^{-1}) estimated for Ireland for the 2006 cost levels [18].

The risk premium: The results for a normal risk averse producers group are presented below in Table 2. Enterprises with higher profitability are linked with bigger risk premiums. Switching from pork or milk production to energy crops is rather unlikely that it will occur. However, in Ireland dairy farms had significantly higher risk premiums, which would need to be paid to adopt willow (15.4 €) and

Table 1. Median farm gate prices in € GJ^{-1} of biomass estimated for the predominant agricultural enterprises in NUTS-4 regions.

Enterprises	Crop			
	Willow on arable land	Willow on grassland	Miscanthus	Virginia mallow
Cereals	3.2	3.2	3.4	4.3
Mixed	3.0	2.9	3.2	4.1
Milk	2.9	2.7	3.1	3.9
Pork	3.5	3.7	3.6	4.7
P-value for Chi-squared test	0.002	0.002	0.003	0.004

Table 2. Risk premiums necessary for a farmer to be indifferent between energy crops and their current enterprises in € GJ^{-1}.

Enterprises	Crop			
	Willow on arable land	Willow on grassland	Miscanthus	Virginia mallow
Cereals	3.7	4.3	3.7	4.7
Mixed	2.5	3.1	3.0	3.8
Milk	4.3	4.8	3.9	5.1
Pork	3.9	4.3	3.8	4.9

Miscanthus (11.4 €)[3]. Risk premiums for wheat estimated amounted to 3.4 € for willow and 1.7 € for Miscanthus under Irish farming conditions [3].

Biomass prices including risk premiums: The risk premiums should be added to biomass prices assuring the same profitability as the traditional agriculture to obtain optimal prices for farmers (Table 3). The median prices including risk premiums for the investigated crops were 5.9, 6.4, 5.7 and 6.2 € GJ^{-1}, respectively. These values were close to the estimates for the EU amounting to 4-5 € for SRC and 6-7 € for Miscanthus [7]. However, the analysis shows that it is not accurate for Poland, but the lower range values could be specific for Eastern Europe. In compliance with estimations carried out in Ireland, the replacement of the winter wheat with willow or Miscanthus will require price, taking into account the risk, at the level of 10.6 and 8.9 € GJ^{-1}, respectively. Table 3 presents the probabilities of prices less than or equal to a given price according to this distribution. The prices had the largest extreme value distributions with 95% confidence level (Fig. 1).

Table 3. Probabilities of total biomass price equal or lower than estimated values for NUTS-4 regions.

Total price € GJ^{1}	Crop			
	Willow on arable land	Willow on grassland	Miscanthus	Virginia mallow
5	0.14	0.13	0.14	0.05
6	0.54	0.38	0.62	0.38
7	0.82	0.63	0.89	0.72
8	0.94	0.80	0.97	0.90
9	0.98	0.90	0.99	0.96

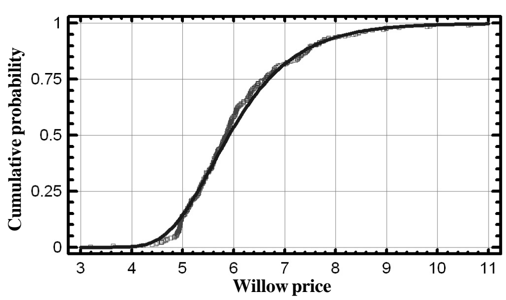

Figure 1. Cumulative probability (quantile plots) for willow biomass prices on arable land for 314 NUTS-4 regions (grey squares – data, black – distribution fitting).

The spatial economic potential of biomass: The spatial distribution of the prices at NUTS-4 regional level is presented in Fig. 2. It can be seen that the highest prices are found in regions situated in the Centre of Poland, where highly profitable intensive agriculture takes place.

In order to have a better view of the economic potential of biomass, cluster analysis was applied on the spatial distributions of production areas in hectares and total production potential in tonnes. It was decided to exclude production areas with biomass prices higher than 6.0 € GJ^{-1}, that offered currently by power plants, and is equal to the market price of forest wood chips in Poland. The results are displayed in Figs 3 and 4. The total acreage of 0.45 million ha was estimated as economic potential of biomass production (Fig. 3), which accounts for 28.2 % of technical biomass potential estimated on 1.59 million ha in Poland [14]. As can be seen, the majority of Polish regions (65%) display relatively low

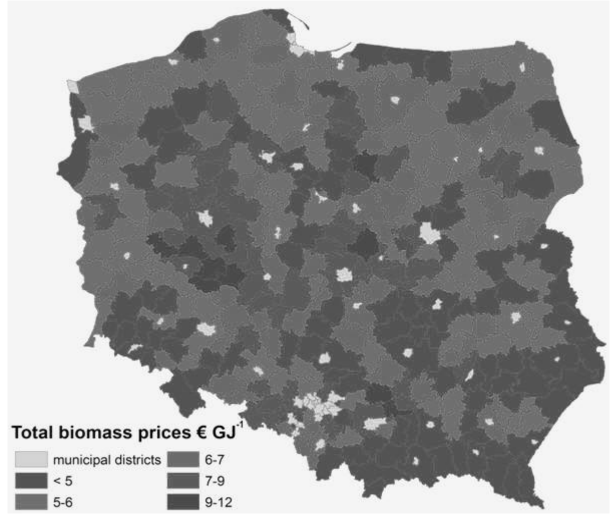

Figure 2. Biomass prices including risk premiums in NUTS-4 regions (averaged for four crops).

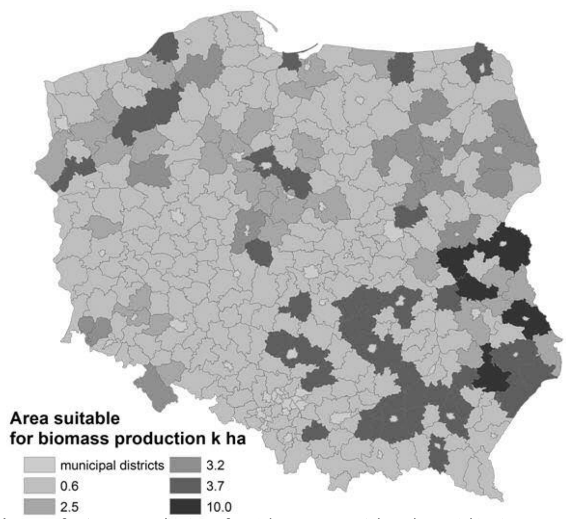

Figure 3. Areas suitable for biomass cultivation (kilo ha) at the price lower or equal 6 € GJ^{-1}.

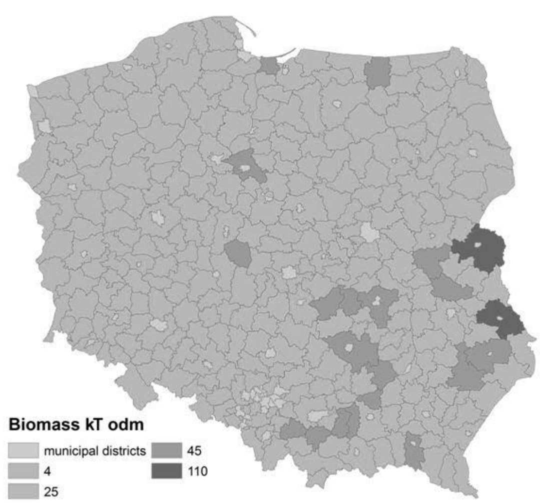

Figure 4. Economic potential of biomass (kilo tons of oven dry matter) at the price lower or equal 6 € GJ^{-1}.Farm-related factors influencing biomass prices.

economic biomass potential with an average of 4,000 t yr^{-1}, while 25,000 t yr^{-1} is the second best average for 29% of the area, situated mostly in blocks of adjacent regions (Fig. 4). The highest possible production of 110,000 t yr^{-1} is found in only two NUTS-4 regions, at the Eastern border of the country. The total economic potential corresponding to 4.2 million tons of dry matter was estimated for whole Poland.

Various factors influencing the estimated biomass prices were investigated in order to better understand the characteristics of farms and regions behind the economic biomass potential. The results of statistical analysis show that biomass prices grow mainly with the higher farmer's high school education (HSE), Animal Large Unit per hectare (ALU), the part of income from agriculture in household budget (income) and sowing area of triticale (Fig. 5).

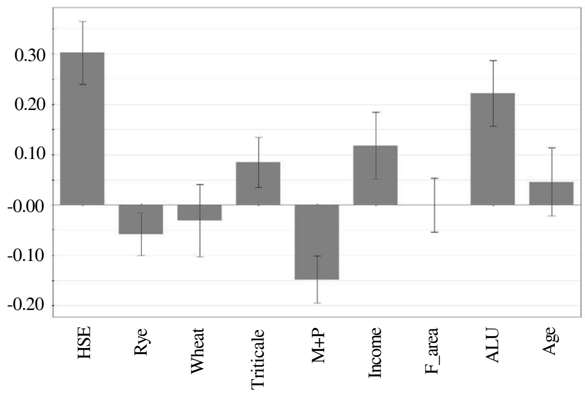

Figure 5. Relative influence of farm-related factors on willow biomass prices in NUTS-4 regions (explanation of symbols in the text of article).

Contrary to that, biomass prices decrease with higher sown areas of wheat or rye and growing contribution of meadows and pastures in agricultural land (M+P). The farm area did not affect the prices with regard to small variation of this factor between NUTS-4 regions. The neural net regression model for these variables explained 60 % variability of prices. The surface area plots for price and most important independent variables are shown in Figs 6 and 7. Biomass prices grow sharply not only with higher animal production, but also with better farmer education in regions and, to some extent, with higher agricultural income contribution to the household budgets. Contrarily, lower prices and higher economic biomass potential are connected with worse education and lower contribution of income from agriculture. These results suggest that for wider use of the economic biomass potential, education programs and encouragement for farmers to start more market oriented production are required.

Demand for biomass in Poland: According to the external estimations, roughly 6.7 or 4.0 million tons of biomass - in two scenarios - are required from Polish farmers in order to reach the renewable energy directive targets [11]. These numbers refer to the demand for biomass for co-firing with coal in power plants, CHP plants and district heating plants. It was presumed that domestic supply is set to overcome demand in both scenarios, however our results tend to differ. The first scenario assumes that 90% of existing boiler capacity will be in use in 2020 (210 boilers less than 40 years old), resulting to a biomass demand of 6.7 million t yr^{-1}. However, this exceeds with 2.5 million ton biomass estimations of this study. On the other hand, the second scenario (129 boilers

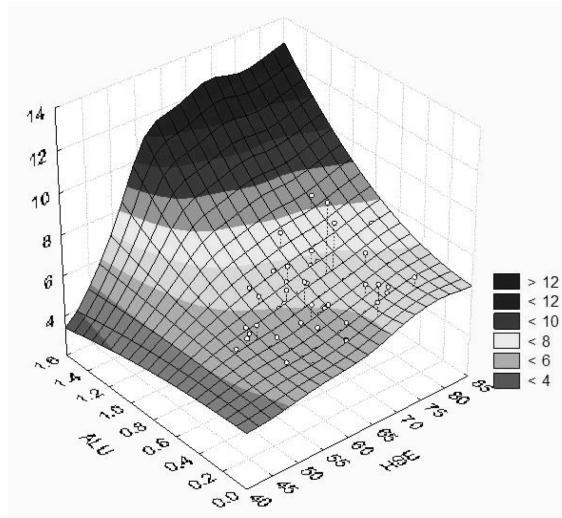

Figure 6. Relationship between total biomass prices (€ GJ^{-1}), HSE (%) and ALU (ha^{-1}).

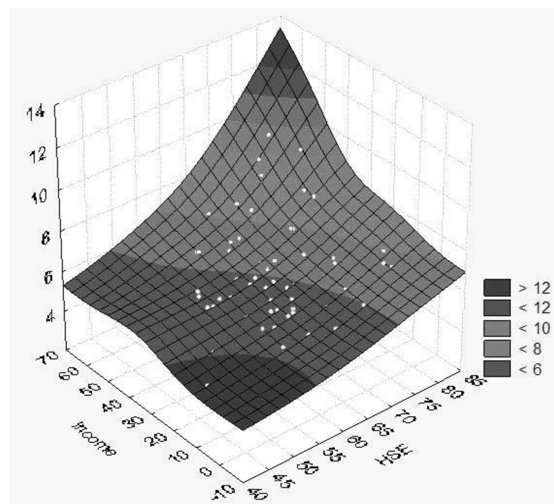

Figure 7. Relationship between total biomass prices (€ GJ^{-1}), HSE (%) and the part of income from agriculture in the household budget (%).

less than 30 years old) suggesting 4 million t yr^{-1} of biomass demand, which is in line with the economic potential estimated within our study, and also in close to the country estimate demand in 2020 perspectives [13]. This demand could meet our estimated economic biomass potential of 4.2 million ton.

Conclusions

The study shows that biomass prices should not only guarantee the same profitability as traditional agricultural enterprises, but also provide an additional premium to compensate the risk related with starting perennial energy crop plantations. The results indicate that the biomass price depends on the activity that would be replaced by biomass production as well as the type of energy crop. The average estimated biomass prices for Poland would not be lower than these estimated for Western Europe. At the price of 6 € GJ^{-1} it should be possible to satisfy the demand for biomass coming from power and heat generating plants in Poland, which is estimated at 4 million t yr^{-1} in 2020 perspectives. However, for the enlargement of the biomass, economic higher biomass prices would be required according to probabilities defined. The overall results suggest that it is hardly possible that Poland becomes an exporter of the cheap biomass to other European countries.

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