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Farmers' perceptions of the challenges facing the biomass market in Poland; a case study from South and Central Poland

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ABSTRACT

Farmers' perceptions and values are a fundamental part of a polycentric approach aimed at improving the financial feasibility of biomass-based enterprises. In this survey-based study, 210 farmers from central (Toruń province) and southern (Upper Silesia region) Poland completed a self-instructed questionnaire dealing with their perceptions of the challenges currently facing the biomass market and their willingness to change from traditional farming to feedstock production for energy generation. The results indicate that only 12% of the farmers are willing to switch to biocrop cultivation. Moreover, selected socio-economic and demographic variables (gender, age) had an impact on their willingness to adopt energy crops. All the presented challenges appeared to be of high relevance to the farmers who participated in this study. However, farmers from Toruń province attributed substantial relevance to the social transformation in the agriculture sector, and to the lack of seasonal workers. In the Upper Silesia region, the lack of a well-established biomass market was of greatest relevance. A cross-tabulation method revealed statistical differences between the perceived value of farming and the farmers' perceptions toward the challenges facing the biomass market. These findings are insightful for policies that aim to address the shortcomings in current biomass market development in Poland.

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Introduction

Biomass-based biofuels have been positioned in the vanguard of solutions to address contemporary yet highly pressing challenges, such as the sustainability of the transport sector, political concerns over energy security, and the European Union (EU)'s stringent targets to cut carbon emissions in the battle against climate change. Moreover, technological achievements in bioenergy technologies (thermal-mechanical, biochemical), set-aside land availability, multiple biomass sources, and changes in energy markets position biofuels as a unique renewable energy source as they are available in different chemical forms (gaseous, liquid and solid wastes) [1,2]. Currently, four generations of biofuels have been developed (i.e. 1st carbohydrates, 2nd cellulosic, 3rd biodigesters, and 4th non-traditional) depending on the source of the raw materials [2]. Biomass from traditional sources, such as agricultural residues, remains a competitive resource, and from a political and environmental point of view the least contentious resource. Improvement in agricultural practices (e.g. better crop varieties, soil management, weed control, education of farmers, advanced machinery) and the possibility to process residues into energy-dense feedstocks (pellets and briquettes) have made this source an attractive, economic option for energy generation. According to the World Bioenergy Association (WBA), the potential of agricultural residues for energy ranges from 13.1 to 122 EJ [3]. It is also estimated that EU countries can sustainably utilize 1 billion dry tonnes of lignocellulosic biomass by 2030 [4]. In the USA, the annual biomass potential has been estimated at 1 billion tonnes, to which corn stover contributes significantly [5].

In Poland, many studies have estimated the biomass potential from agriculture, forest, energy plantations, and municipal waste. Iglinski et al. [6] estimated that Poland produces approximately 23 million tonnes of biomass waste per year and that 1.5 kg of straw can substitute for 1 kg of coal. Other studies have calculated the technically recoverable potential of straw at 6.7 million tonnes, which is expected to increase to 8.63 million tonnes by 2020 [7,8]. Differences in estimating quantities of biomass may have resulted from the unit of mass used and other sources do not specify exactly whether it is dry or wet biomass. Like many other European states, Poland has positioned bioeconomy and bioenergy objectives and targets in its regulatory frameworks, legislations and policies. For example, *Polish Energy Policy Until 2030* (*EPP 2030*), the *National Renewable Energy Action Plan 2010*, and the most recent *Renewable Energy Sources Act 2015* are major policies aimed at increasing the share of renewable energy up to 15% of

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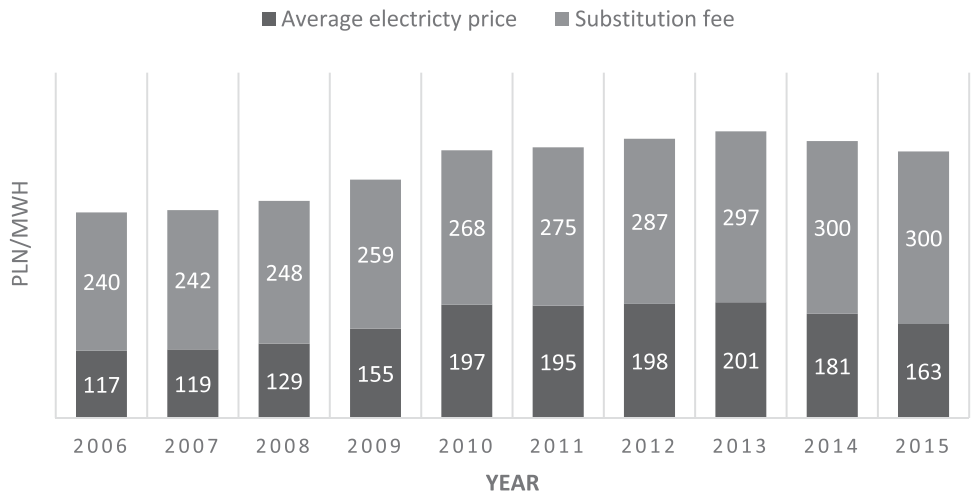

Figure 1. Average electricity prices and substitution fees (PLN/MWH) in Poland between 2006 and 2015 under the quota obligation system. Electricity price + substitution fees = income for electricity producers. (PLN = Polish zloty, 1 euro =4.34 Zloty as of 9 November 2016).

gross final energy consumption by 2020 (from 7.2% in 2005). Moreover, 10% of the energy used in transport must come from biofuels or other renewable energy sources by 2020 [9]. Given the importance of biomass (energy crops, firewood, biogas, and waste from agriculture, industry and forestry) the *EPP 2030* policy has stipulated a doubling of electricity produced from highly efficient co-generation by 2020. To implement this ambitious target, the government has adopted the *Programme for the Development of Co-generation in Poland to 2030*. This programme aims at identifying the combined heat and power (CHP) potential and the development of new mechanisms to support CHP [10].

In accordance with the EU CHP Directive, the Polish government has obliged energy suppliers to ensure that a certain share of electricity sales comes from co-generation (at least 13.7% in 2005 and 16% in 2010). In doing so, electricity suppliers must either submit the requested number of certificates of CHP origin (also known as green certificates) to the Energy Regulatory Office or pay a substitution fee equivalent to about €68/MWh. However, suppliers can acquire the certificates of origin by generating their own CHP power or buying tradable certificates from the market (Figure 1). In addition, energy suppliers have an obligation to purchase energy from CHP at an amount that does not exceed the demand of consumers connected to the network [10]. Companies or suppliers who fail to meet the requirements are subjected to penalties. Previously, the penalty was calculated by multiplying the substitution fee by a factor of 1.3, which is approximately €100/MWh. Currently, the Energy Regulatory Office may impose a fine of up to 15% of the energy producer's previous year's income. This support mechanism has led to a resurgence in the co-firing industry for a number of reasons. Firstly, a complete shift to biomass would require the collection of biomass from vast areas, which is a major logistical challenge. Secondly, co-firing of biomass entails a lower risk of corrosion and ash deposition problems than does the combustion of biomass alone. Finally, pulverized coal-fired boilers, which dominate the market in Poland in terms of installed capacity, are inflexible compared to grate and circular fluidized bed boilers, which are able to combust a relatively wide range of fuels in terms of particle size, composition, and moisture content [11,12]. Co-firing power plants provide extra income in various ways: the sale of electricity at a guaranteed price equivalent to the average price from the previous year €35/MWh; and the sale of 'certificates of origin' bilaterally at an approximate price of €25/MWh or on the spot market at a price of about €50/MWh. Other support mechanisms include an exemption from the excise tax of €5.2/MWh that is levied on electricity production. The EU emission trading scheme is another policy instrument that has promoted co-firing. The scheme is relevant for boilers with a thermal output of 20 MW or more. These plants are allocated a certain amount of tradable emission allowances (EAs) and the price of EAs varies according to the price of carbon dioxide (CO_2) per tonne; however, at €16/tonne CO_2 biomass provides €1.5/GJ [11,13]. As a result of the quota obligations and green certificate support mechanism, the share of biomass in total renewable electricity installed capacities has increased substantially (Figure 2). Moreover, the share of processed biomass (pellets) used in the co-firing process and in power plants with dedicated biomass has also increased since 2004 (Figure 3). In 2012, the biomass market in Poland collapsed due mainly to a glut of tradable green certificates (12–15 TWh), low prices (€25/MWh down from €75/MWh), and increased biomass imports from the surrounding countries and also from developing countries, which eventually led to low demand and low biomass prices. These shortcomings in the biomass market, accompanied by the low price of fossil fuels, have negatively affected all bioenergy pathways and the farmers who are either directly or indirectly involved in the biomass supply chain. For instance, as heat and electricity from fossil fuels (coal and natural gas) have become more competitive, the demand for agro-pellets from power plants has drastically plummeted and pellet production became only marginally profitable [14].

Farmers (biomass producers) have suffered the most from the consequences of market collapse. For instance, due to the low demand for biomass from power plants, biomass prices substantially plummeted and contracts with farmers have been either frozen or in some cases broken. This has also resulted in delayed payment to farmers struggling to make repayments on their loans. Overall, many biomass-related operations have become idle or have closed down, with personnel laid off [14]. In their recent study, Zyadin et al. [15] investigated farmers' willingness to supply surplus biomass for energy generation in southern

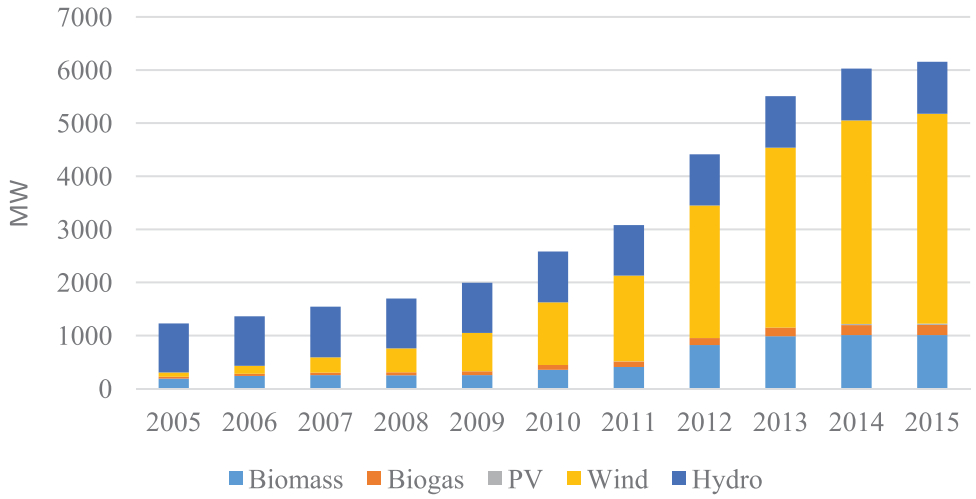

Figure 2. Renewable electricity installed capacities (MW) in Poland between 2005 and 2015. PV; Photovoltaics

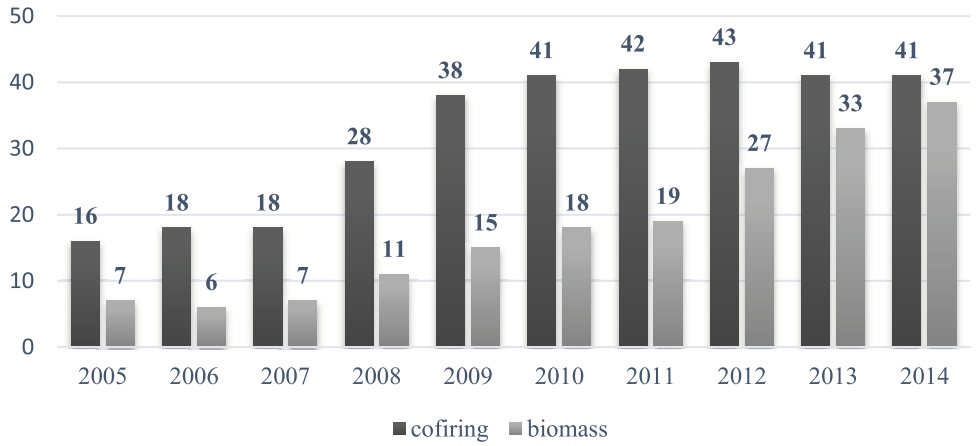

Figure 3. The number of dedicated biomass power plants and power plants with cofiring technology.

and central Poland. The study found that the majority of the study participants currently utilized the biomass for animal feeding, animal bedding, or incorporation into the soil. The share of biomass that could be sold on the market was indicated to be around 10%. Therefore, the participants appeared unwilling to collect, store and transport biomass with their own vehicles to an energy production facility (power plant). Farming was perceived by 50% of the participants as their only source of income, although 75% perceived/considered farming as a cultural heritage. The authors argued that these findings may have stemmed from the weak, imbalanced and perplexing biomass market situation marked by low demand and low biomass prices.

In an attempt to ameliorate the shortcomings of the biomass market, the Polish government introduced a new support mechanism for renewable energy based on an auctioning system and cut the support for green certificates by 50%. The implications of such a policy on the biomass market and the prospects for bioenergy development in Poland are not yet fully understood, especially as the legislatory act is subject to fierce debate from multiple stakeholders. Finding policy solutions and incentive mechanisms to calibrate the current biomass market would require a polycentric approach where different stakeholders' opinions and viewpoints are channelled, prioritized, and transparently disseminated to policymakers to allow inclusive and supportive policies to be crafted. Therefore, it is essential to investigate the farmers' perceptions and opinions toward the challenges facing biomass/bioenergy development. To our knowledge, this study is the first to address these issues in Poland, particularly in the current uncertain biomass market environment. The findings of this study will assist policymakers in the design of new policies that aim to encourage biomass utilization in energy generation. Challenges such as an ageing population and the migration of young people from rural areas to cities, the import of biomass from Asia and neighbouring countries, coal availability and its widespread utilization, the logistical costs of biomass transportation, and public policies and support were identified and presented to Polish farmers for investigation.

Survey data

A survey tool/questionnaire was developed for farmers in Southern (Upper Silesia region) and Central Poland (Toruń province) (Figure 4). The two regions are characterized differently in terms of coal deposits, agricultural practices, and scale of renewable energy development. For example, Upper Silesia was selected as it accommodates the Upper Silesian coal basin, one of the three largest coal and ignite deposits in the country (the Lower Silesian coal basin and the Lublin coal basin are the other two) [16]. The Upper Silesia region is also home to many large coal-based power plants, experiences problems with air pollution in some cities, such as Katowice, and is a region with over 30% forest

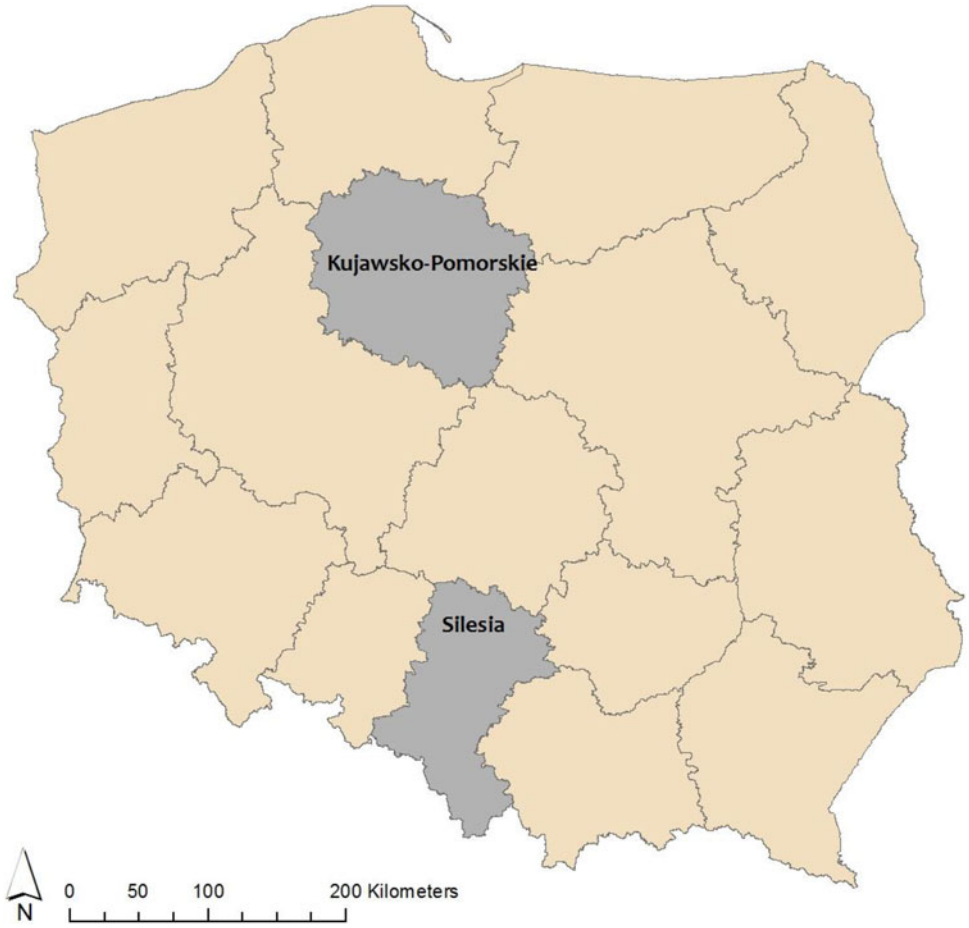

Figure 4. Map of the provinces in Poland with the two study provinces highlighted in gray.

cover. Toruń province and the surrounding provinces are reputed to be the home of renewable energy development in Poland, especially wind energy and energy crop plantations such as *Miscanthus* [17,18].

The designed survey study had three main sections. The first section was dedicated to identifying socio-economic and demographic variables such as gender, age, own/rent land, land size, and type of land. The farmers were also asked about the type of agriculture crops they plant (wheat, barley, corn, triticale, rye, etc.), type of fertilizers they use, and type of machinery they own. Another subsection was devoted to identifying the type of energy sources used at home (natural gas, coal, electricity, etc.). A key element of this section was to identify and quantify the existing uses of agricultural residues at the farm (e.g. cooking, animal bedding and feed, or incorporated with soil), and how quantities of residues are being sold out. The objective here was to estimate the amount of surplus biomass that could be used for energy generation after deducting the existing uses at the household level. The results of this section are published in Zyadin et al. [19]. The second section of the questionnaire was devoted to investigating farmers' willingness to supply surplus biomass for energy generation and under which types of selling contracts. Lending support to this approach, several studies investigating farmers' willingness to switch to energy crop cultivation and from the UK and USA were adopted for a case study in south and central Poland [15]. Whether farming is considered a source of income or cultural heritage, and the availability of agricultural machinery were independent variables selected for use in this study [15].

The third section of the questionnaire was devoted to investigating farmers' perceptions toward a list of selected challenges currently facing the biomass market in Poland. These factors were selected from the relevant studies in Poland, roundtable discussions, and feedback from Polish experts. Therefore, eight challenge-related statements were formulated, introduced to farmers and cross-tabulated with a number of socio-economic variables, such as gender, age (young vs old), place of residence (central vs. south), the perceived value of farming (income source vs cultural heritage), land ownership (owned or leased), size of the land (small, medium, large), and type of energy source used for space heating. The objective was to reveal key obstacles to competitive biomass markets and suggest a set of policy recommendations to policymakers in Poland for overcoming these challenges.

Data collection was conducted between July and October 2015. The data collection procedure coincided with the harvesting season of grain crops. As a result, some farmers refused to participate, whereas others appeared reluctant to participate but proposed some other time to fill in the questionnaire. The authors put substantial time, effort, and resources into finding farmers in both regions; however, due to the project timetable and deadlines the authors had to stop interviewing farmers by October 2015. Through the data collection period, several methods were used to collect a sufficient number of filled-in questionnaires. In central Poland, surveys were posted to the farmers' address with a return envelope, and by approaching farmers when they deliver their biomass truck loads to the pellet production factories. In the south,

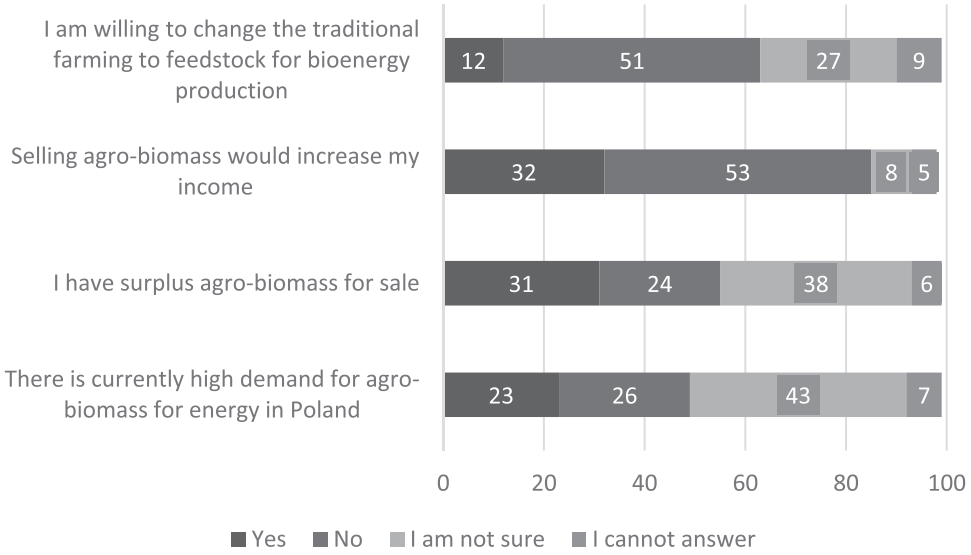

Figure 5. Response frequencies of farmers' perceptions toward the biomass market and their willingness to adopt biocrops.

farmers' addresses were obtained from magazines and online biomass auctions and they were later contacted to arrange an appointment. As per phone calls, field excursions were organized to interview the farmers. These methods may be associated with a degree of bias as the sampling procedure was not fully random and in some cases was conducted using the snowball effect (meaning a selected farmer identified fellow farmers from his social circle). In an attempt to overcome possible bias, the authors exclusively selected farmers who sell their biomass, and data from secondary sources and a national database were used to crosscheck biomass figures calculated in the aforementioned studies. For more details on the study's sampling methods, please refer to Zyadin et al. [15] and Zyadin et al. [19]. Data coding and analysis were performed using IBM SPSS Version 21 (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). Non-parametric tests such as Chi-square through the cross-tabulation method, and Mann–Whitney tests were selected and used for this data set. An electronic copy of the full questionnaire can be requested from the corresponding author via email.

Results

Bio-demographics and socio-economic characteristics

In total, 210 farmers participated in this survey study, 110 of whom were from Toruń province and 100 from Upper Silesia. The descriptive statistics showed that 62% and 74% of the participants from Toruń and Upper Silesia, respectively, were male. In regard to age, 67% of the participants from Toruń were young to middle age (less than 50 years old) and the remainder were over 50 years. In Upper Silesia, 58% of the participants were less than 50 years old, 36% were over 50 years old, and the remaining 6% did not answer the question. The results also indicate that 56% and 94% of the farmers in Toruń and Upper Silesia, respectively, own their land, with the remainder in both locations leasing the land. In regard to land size, 60% of the participants in Toruń cultivate up to 20 hectares of land and 40% cultivate larger land areas, compared to 68% and 32%, respectively, in the Upper Silesia region. The main crops planted by the farmers in both locations were wheat, barley, rye, and corn. In addition to biomass, the majority of the farmers also used coal as an energy source for space heating and firewood for cooking. For more detailed information see [15].

Farmers' perceptions toward bioenergy in Poland: market related

The farmers were asked to respond to four statements related to the biomass market in Poland (Figure 5). Only 23% of the farmers indicated that '*there is currently a high demand for biomass*' and almost 70% either said no or were not sure. Although 31% reported having '*surplus biomass for sale*', 62% were not sure or answered no. A similar share of surplus biomass available for the market was also reported in India [20,21] and the USA [22]. Approximately one-third of the farmers in this study reported that '*selling biomass would increase my income*'. The aforementioned findings might reflect the current biomass market: low demand and low biomass prices accompanied by increased biomass imports. Low biomass prices probably do not offer a sufficient profit margin and as such the farmers retained the biomass for animal feed and bedding [15]. As a result, farmers increased the use of biomass at the household level for purposes such as animal feed and bedding and incorporated excess residues in the soil by ploughing [15].

The degree of farmers' willingness to switch to biocrop cultivation has also been investigated in the UK, Australia, and the USA [23–27]. In this study, 12% of the farmers showed an interest to '*change the traditional farming into feedstock for bioenergy*' whereas 78% were unsure and/or did not know. In the USA, almost 30% of 3244 Tennessee farmers stated that they would be interested in growing switchgrass and about 24% were not interested [24]. The interest in growing biocrops was found to be higher (39%) among farmers with a prior knowledge of switchgrass production for energy [24]. In Cumbria, UK, farmers appeared reluctant to change from traditional farming to producing feedstock for bioenergy, and older farmers were likely to be most resistant to change [25]. For Australian farmers, farming was considered to be not only an economic goal but also the maintenance of a lifestyle [23]. According to Caldas et al. [26] and Sherrington and Moran [27], the

Table 1. Farmers' perceptions toward challenges in biomass market development: Central Poland (N = 110).

Item no.	Statement	Highly relevant (%)	Relevant (%)	Irrelevant (%)	Highly irrelevant (%)	I don't know (%)
1	Lack of well-established biomass market	**29**	40	7	0	21
2	Lack of government support in bioenergy (policy, subsidy)	26	46	4	0	22
3	Low market price for biomass	25	40	7	0	25
4	Import of biomass from other countries	22	33	7	2	**33**
5	Availability and heavy use of coal	13	50	15	2	17
6	Logistical costs of collection and transport of biomass to its destination	26	47	7	2	17
7	Lack of seasonal workers	**37**	33	14	2	12
8	Transformation in agriculture (migration of young people to big cities or less interest in farming)	**47**	32	6	1	13

propensity to adopt new technology, such as energy crops (biocrops) by farmers is often a complex and intertwined relationship between biophysical, operational and financial characteristics, socio-economic, demographic and regulatory factors. Caldas et al. [26] suggest that biophysical factors, such as higher erosion risk, higher variability of drought conditions, and low levels of rainfall generally reduced the farmers' propensity or willingness to grow dedicated bioenergy crops in Kansas, USA, for example. On the other hand, when the depth to the water table is deeper and available water content is higher, farmers in eastern Kansas were more willing to harvest crop residues and grow an annual bioenergy crop [26]. The use of no-tillage practices among Kansas farmers has had a negative impact on the willingness to grow biocrops [26] and a willingness to try environmentally friendly technologies was positively associated with the adoption of switchgrass among Tennessee farmers [24]. Farm operational characteristics, such as farm size, type of land ownership and share-crop agreement, purpose of farming (livestock vs crops), and whether the farm was located close to coal-fired power plants had an impact on farmers' willingness to adopt biocrop cultivation, either positively or negatively [26]. Financial characteristics, such as market prices, net farm income, off-farm income sources, higher debt percentage, availability of establishment grants, confidence in procurement contracts, and, most importantly, the perceived level and security of the financial return, were important factors [24–29]. In the context of socio-economics and demography, factors such as gender, age, educational level, and years of experience are posited as having an influence on the willingness to adopt energy crops. A young male farmer with a college degree has a higher propensity to adopt energy crops [26]. That 12% of farmers in Poland are willing to change to biocrops is encouraging, especially under the current tough market conditions. There are approximately 3 million hectares (Mha) of land that can be utilized for energy crops in Poland [30]. Faber [31] proposed a slightly smaller technical area of 2.18 Mha for energy crops and economically justified 0.64 Mha.

The willingness to change from traditional farming practices to feedstock for energy generation was cross-tabulated with a number of independent variables, and the results of the chi-square test showed a statistically significant difference for only income source vs cultural heritage. In this regard, 18% of the farmers who do not consider farming a source of income are more willing to cultivate feedstock for energy generation compared to 7% of the farmers who consider farming as their only source of income (p = .04). This finding may be associated with the aforementioned financial characteristics such as off-farm income. A noteworthy finding is that 82 out of 160 (51%) farmers who consider farming a cultural heritage were unwilling to change their traditional farming practices to cultivate energy crops. Similar findings have been reported for UK and Australian farmers [23,25]. Notably, 59% of the female participants in this study were reluctant to change from traditional farming compared to 48% of male farmers. Furthermore, 60% of the older farmers also appeared unwilling to change compared to 46% of the young participants. In the context of land ownership, the farmers who own their land and have a land size over 20 hectares appeared unwilling to change their farming practices (53%) compared to 39% of the farmers who leased their land and had smaller land sizes. These findings correspond to findings from a study with farmers in Kansas, USA [26].

Farmers' perceptions toward challenges facing bioenergy development in Poland

This part of the study sought to examine farmers' perceptions of the challenges facing bioenergy development in the two selected provinces. The challenges were selected based on an examination of the biomass market in Poland, and a review of related publications, such as Iglinski et al. [6] and the BioTeam Project [14]. Therefore, eight challenges facing bioenergy in Poland were presented to the farmers. Summaries of the frequencies are presented in Table 1 for central Poland (Toruń province) and Table 2 for southern Poland (Upper Silesia).

The results from Toruń province clearly indicate that all presented challenges are *highly relevant* and/or *relevant* for the biomass market. The challenge that was perceived to be of most concern was the 'transformation in agriculture', with young people leaving rural areas for better life opportunities in the cities. Here, 79% of the farmers expressed their concerns but 70% also indicated that the 'lack of seasonal workers' as the second most challenging issue. Migration of young people to the larger cities results in a smaller workforce for farming and fewer seasonal workers during the harvesting season. The third most important challenge was the 'lack of well-established biomass market' with 69% of the farmers indicating it to be *highly relevant* or *relevant*. This is predictable since the biomass market has collapsed, with negative consequences for farming and biomass markets alike. Although 55% considered it to be still important, 33% of the farmers were unaware that biomass is currently imported. This may be due to a lack of information on this topic or because the farmers cannot establish a link between imported biomass and local

Table 2. Farmers' perceptions toward challenges to biomass market development: South Poland (N = 100).

No.	Statement	Highly relevant (%)	Relevant (%)	Irrelevant (%)	Highly Irrelevant (%)	I don't know (%)	NR (%)
1	Lack of well-established biomass market.	41	32	0	0	23	4
2	Lack of government support for bioenergy (policy, subsidy).	27	41	2	0	21	9
3	Low market price for biomass.	27	33	0	0	32	8
4	Import of biomass from other countries.	20	13	4	0	51	12
5	Availability and heavy use of coal.	26	46	0	0	15	13
6	Logistical costs of collecting and transporting biomass to its destination.	20	43	2	0	22	13
7	Lack of seasonal workers.	16	14	21	1	13	35
8	Transformation in agriculture (young generation migrating to big cities or less interest in farming).	13	37	18	0	15	17

NR: No Response

Table 3. Statistical significance of selected socio-economic and demographic variables on farmers' perceptions toward the relevance of challenges to the biomass market and biomass development (N = 210).

	Location		Gender		Age		Statistics (chi-square)		
Item	Toruń (%)	Upper Silesia (%)	Male (%)	Female (%)	Young[b] (%)	Old[c] (%)	Location	Gender	Age
1	69[a]	73	71	71	74	69	.024	NS	NS
2	72	68	73	62	73	67	NS[d]	NS	NS
3	65	60	67	47	67	60	.008	.025	NS
4	55	33	46	38	54	40	.000	NS	NS
5	63	72	66	71	70	68	.000	NS	NS
6	73	63	70	62	76	64	.004	NS	NS
7	70	30	47	57	62	43	.000	NS	.042
8	80	50	61	72	71	61	.000	NS	NS

[a]Percentage of relevance, rounded; [b]young: less than 40 years old; [c]old: more than 40 years old; [d]NS: not significant, $> .05$.

demand for biomass. Low biomass prices and the costs of collection and transportation of biomass were also important considerations from the farmers' point of view.

For the farmers from the Upper Silesia region who participated in this study, the 'lack of well-established biomass market' was perceived as the most challenging factor by 73% of the participants. Moreover, 72% of the farmers perceived the 'availability and heavy use of coal' as the second most challenging factor to the biomass market in their region, followed by 68% who referred to the 'lack of government support for bioenergy' as a challenging factor. Over 50% of the participants did not know whether biomass is currently imported, while the remainder stated it to be a *highly relevant* and *relevant* factor. Furthermore, 32% could not establish a logical link between low biomass prices and the import of biomass. Only 50% of the participants in Upper Silesia considered migration to bigger cities as *highly relevant* and *relevant*, compared to 79% of the participants in Toruń (central region).

The significance of selected socio-economic and demographic variables on farmers' perceptions of biomass market development in Poland

The same independent variables were employed in the cross-tabulation method to reveal any statistical difference in the willingness to change from traditional farming to energy crop production. Table 2 shows the results of the cross-tabulation method for selected socio-economic and demographic variables.

The location variable (Toruń vs Upper Silesia) had the highest statistical difference among the presented challenges, with the exception of item 2 (*lack of government support for bioenergy*) (Table 2). For the Upper Silesia province, item 1 (*lack of well-established biomass market*) and item 5 (*availability and heavy use of coal*) were of slightly greater relevance in comparison to Toruń province and showed a clear statistical significance. Moreover, clear statistical significance was found for items 4, 7, and 8 and they were of far greater relevance for Toruń province in comparison to the Upper Silesia province. For farmers in Toruń province, '*import of biomass*', '*lack of seasonal workers*', and '*social transformation in the agriculture sector*' were the most important challenges. It is noteworthy to mention that while Upper Silesia accommodates both the highest number and one of the largest coal-fired power plants in the country, this juxtaposition to power plants did not have a positive impact on biomass business in the region as suggested by Caldas et al. [25]. In contrast, Toruń and the surrounding provinces accommodate many agro biomass-based pellet production facilities, and biomass imports and the lack of seasonal workers may have had a negative impact on biomass business and the associated biomass supply chain.

While not statistically significant, female farmers indicated a higher relevance for items 5, 7 and 8 in comparison to male farmers (Table 3). Although the remainder of the challenges were of higher relevance to the male farmers, item 3 (*low market price for biomass*), however, showed a statistically significant difference (p = .025) with 67% of the male farmers indicating a greater relevance in comparison to 47% of the female farmers (Table 3). The study argues that since male farmers are directly involved in the sale of biomass, the price of biomass clearly appeared to be more important to them. Age and educational level are important socio-economic factors and have been reported to have an impact on the propensity to adopt energy crops. (The farmers' perceptions toward bioenergy in Poland: Market related). In this study all the challenges presented to the participants appeared to be more relevant to the young farmers in comparison to the older ones. Of particular importance is the statistical significance of item 7 (*lack of seasonal workers*) (Table 3). Younger farmers may

Table 4. Statistical significance of the perceived value of farming on farmers' perceptions toward the relevance of challenges to the biomass market and biomass development.

	Income[a]		Heritage[b]		Adopt[c] biocrops		Statistics (chi-square)		
	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Income	Heritage	Adopt biocrops
1	67	77	73	78	80	70	NS	NS[a]	NS
2	71	71	71	72	76	71	NS	NS	.025
3	62	65	63	67	68	62	NS	NS	NS
4	40	50	45	47	68	39	NS	NS	NS
5	64	73	71	61	84	63	NS	NS	NS
6	64	75	70	69	72	63	NS	NS	NS
7	50	53	58	25	52	47	NS	.000	NS
8	58	75	72	39	76	62	.009	.000	NS

[a]Whether farming is the only source of income.
[b]Whether farming is a cultural heritage.
[c]Whether willing to adopt biocrop planting.
NS: not significant.

have engaged previously in the biomass selling process and realized that seasonal workers are not available at the time of collection and transportation of the biomass. For young farmers all the financial components are critical for engagement in biomass-based business in contrast to the older generations who might still consider farming symbolic, a lifestyle choice, and who value the sense of place, lineage, and autonomy [25].

The significance of selected farm characteristics on farmers' perceptions of biomass market development in Poland

It was difficult to statistically assess the differences between those who own and those who lease their land simply because the majority of the farmers in this study own their land. With no notable statistical differences, farm type (agriculture vs. forest and other types) had no influence on farmers' perceptions. However, farmers who mainly own agricultural land appeared slightly more concerned in regard to biomass market development compared to those who own forest and other types of lands, such as grassland.

The relevance of the perceived value of farming (source of income vs cultural heritage) and willingness to adopt biocrops on farmers' perception of the challenges facing the biomass market

The perception of traditional farming may vary between farmers who seek profit maximization and farmers who only consider profit sufficiency. Therefore, willingness to adopt biocrops may also vary [25]. In this study, farmers were asked whether farming is their only source of income, whether they view it as a cultural heritage, and whether they are willing to change from traditional farming to feedstock for energy production. These variables were cross-tabulated with the presented challenges to biomass market and development. The results are presented in Table 4 along with the chi-square test.

In theory, farmers with a 'profit sufficiency' attitude may attribute less relevance to the challenges since they may appear reluctant to change their current farming practices. In contrast, it can be argued that farmers with a 'profit maximization' attitude tend to have a higher tendency and willingness to engage in energy plantation and thus attribute a higher relevance to regional and national challenges to biomass market development. In this study, farmers who indicated that farming was *not* their only source of income attributed a higher relevance to the presented challenges, with a clear statistical difference found for item 8 (*social transformation in agriculture sector*; $p = .009$). Here, 75% of the farmers who indicated that farming was not their only source of income placed a higher relevance on social transformation in the agriculture sector in comparison to 58% of the farmers who indicated that farming was the only source of their income. Farmers with a business-oriented mentality perceived that the future of this vital sector was in danger as young people continue to migrate from rural areas, which in turn makes the succession process (i.e. handing over the farm/business to younger generations) more difficult. Interestingly, farmers who considered farming a cultural heritage were found to attribute a higher relevance to item 7 (*lack of seasonal workers*) and item 8 (*social transformation in agriculture sector*) with clear statistical differences ($p = .0001$) for both items. These findings highlight the importance of social challenges to biomass market development even for those with no business orientation. Unsurprisingly, farmers with a higher willingness to adopt biocrops attributed a higher relevance to all of the presented challenges (Table 4). Moreover, instability and insecurity of the financial return from energy plantations would provoke a sense of uncertainty and fear among farmers with or without previous experience in biocrop cultivation [24–29].

Conclusion and recommendations

The farmers who participated in this survey-based study appeared reluctant to change their traditional farming practices to feedstock production for energy generation. Of particular interest were the female farmers, older farmers, farmers with large land holdings, and those who consider farming symbolic and a cultural heritage. They attributed significant relevance to the presented challenges to biomass market development in both regions (Toruń and Upper Silesia provinces). Lack of seasonal workers and social transformation appeared to be of high relevance for the farmers who consider farming as a cultural heritage. On the basis of the results presented in this study, the authors highly recommend a review of the current biomass-related policies and the development of new policies to encourage re-engagement with farmers in the biomass supply chain by boosting the supply of biomass from their agriculture land and/or the adoption of energy crops for

energy generation. Financial support in the form of establishment grants for energy plantations, optimal contracting between power plants and farmers, and a cessation of biomass imports are examples of some policies that might amend the current shortcomings in the biomass market. In some cases, elevating farmers' knowledge of energy crops and cultivation methods by conducting capacity-building programmes is essential. The government should also carefully examine the social challenges related to farming, such as the migration of young people from rural areas to the cities, and endeavour to find short- and long-term solutions. The promotion of farm succession planning by devolving lands from the older to the younger farmers through financial supports and training programmes is essential for young farmers to continue farming and/or engage in new farming practices such as biocrop cultivation.

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