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Article *in* Biofuels · September 2016

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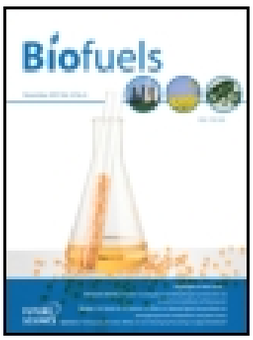

Biofuels

ISSN: 1759-7269 (Print) 1759-7277 (Online) Journal homepage: http://www.tandfonline.com/loi/tbfu20

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To cite this article: Anas Zyadin, Karthikeyan Natarajan, Bartłomiej Igliński, Anna Iglińska, Aleksandra Kaczmarek, Jakub Kajdanek, Ari Pappinen & Paavo Pelkonen (2016): Farmers' willingness to supply biomass for energy generation: evidence from South and Central Poland, Biofuels, DOI: 10.1080/17597269.2016.1225647

To link to this article: http://dx.doi.org/10.1080/17597269.2016.1225647

Published online: 14 Sep 2016.

BIOFUELS, 2016
http://dx.doi.org/10.1080/17597269.2016.1225647

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Farmers' willingness to supply biomass for energy generation: evidence from South and Central Poland

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ABSTRACT

The objective of this survey-based study was to investigate farmers' willingness to supply biomass for power generation in the south and in the centre of Poland. In total, 210 farmers participated in this study by filling in a self-instructed questionnaire. The results indicate that the majority of farmers (two-thirds) in both regions appeared unwilling to collect, store and transport biomass to the market or to the energy production facility. It is likely that an unstable biomass market marked by low demand and low prices has led to unwillingness by farmers to engage in bioenergy production in Poland. Increasing the role of biomass as a renewable energy resource and recovering the farmers' confidence in the market would require fixing the shortcomings in the biomass market and the provision of clear public policies that aim at long-term market stability.

ARTICLE HISTORY
Received 8 June 2016
Accepted 4 August 2016

KEYWORDS
Farmers; Poland; supply chain; Torun region; Upper Silesia; willingness to supply

Introduction

The use of biomass as a source of renewable energy has been justified for numerous environmental (curb fossil fuel greenhouse gas emissions – GHG), geopolitical (energy security), and socioeconomic (rural development) reasons [1]. The interest in utilizing biomass resources rests on the availability of relatively cheap and technically recoverable agricultural residues around the world (estimated as high as 122 EJ [2], the potential for use in coal-based power plants (co-firing) and/or biomass stand-alone boilers, and near-commercialization technologies that have made biomass materials an attractive renewable energy source that could contribute to the bioeconomy and to sustainable development [3].

Poland is a central European country on the Baltic Sea with total area of about 312,679 km^2 and a population of about 38.1 million, which accounts for nearly one-tenth of the population of the European Union (EU) [4]. Poland is the ninth largest country and the sixth largest economy in the EU [4]. A very distinctive feature of the country's domestic energy supply is the enormous deposits of hard coal and lignite found in three major basins: Upper Silesian, Lower Silesian and Lublin coal basins [5]. Overall, the country is heavily reliant on fossil fuels (domestic and imported), which account for 55% of the primary energy supply and about 90% of the electricity generation [4].

In Poland, the agricultural sector is strong, with a high agro-biomass potential estimated at 25 million tonnes per annum [6]. Straw from crops such as wheat, barley, ryegrass, triticale and oats remains the main biomass type from agricultural activities [6]. The high potential of straw biomass reveals the importance of the agricultural sector in contributing to renewable energy generation, and it highlights the pivotal role the farmers play in securing an affordable, reliable and sustainable biomass supply in order to maintain the financial feasibility of bioenergy production facilities (small or large scale) [7]. Biomass procurement and supply is often considered a logistical concern affecting the development of bioenergy in Poland [8], and its cost-effectiveness, therefore, will continue to be largely and critically dependent on the biomass producers' (farmers) willingness to supply biomass at competitive prices [1,7]. Farmers in Poland and elsewhere can also promote bioenergy production by willingly growing non-edible feedstock for energy generation from, for example, miscanthus, willow, and switchgrass [9–11].

Polish energy policies have encouraged the use of biomass in coal-based power plants in a process called co-firing under the quota obligation and 'green certificate' mechanism. However, biomass imports and the excessive use of biomass in the co-firing industry led, by the end of 2014, to a glut of green certificates in the market – about 12 TWh by the end of 2014. The low

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prices associated with green certificates have led to low demand and low biomass prices, which triggered the collapse of the biomass market in late 2012.

The objective of this survey-based study was to investigate the farmers' willingness to supply surplus biomass for power generation in Upper Silesia (south) and Torun (central) provinces in Poland. The study is inspired by and will add further evidence to studies conducted in the USA [1,7,9,11,12] and UK [10]. To our knowledge, no similar studies have been carried out in Poland. In addition to improving our understanding of the factors that may influence a farmer's ability and willingness to supply biomass to the market, it will also provide insights for policymakers to craft policies aimed at increasing the utilization of available biomass resources with a win–win approach.

Literature review

There are a number of socioeconomic, environmental, logistical, behavioral and market factors that influence farmers' ability and willingness to supply/grow biomass for energy production. Socio-economic factors, such as age, educational attainment, family and home size, and prior knowledge of biomass crops have been considered highly important in determining the availability of biomass for sale [9,10]. Other considerations include whether farmers have outstanding bank loans, and whether the farmers have other sources of income (off-farming income). For instance, younger farmers in the USA with higher levels of educational attainment and off-farm incomes are more willing to convert a higher share of farmland to switchgrass production [11] while, in contrast, older farmers with large areas of leased land are unwilling to supply biomass [1].

Profitability remains a core objective of farming, although farmers may appear satisfied with a certain level of income or 'profit sufficiency' that covers the production costs and provides a marginal profit. However, farmers who seek 'profit maximization' are more interested in selling higher quantities of biomass on the market and are more willing to switch to energy plantations on their farms [9,10]. Altman et al. [1] studied the degree to which biomass producers from mid Missouri and southern Illinois, USA, would respond to price incentives to supply their products, and found that producers would supply an additional 17–24% biomass production for a US$10 per ton increase in price and that supply for three types of biomass (stover, straw and hay) was elastic. Recent studies from the UK have shown that farmers have other objectives in farming, such as farming being considered a lifestyle with a sense of place and lineage; it provides autonomy and is an interesting outdoor activity [9,10].

Climatic and environmental factors may have a pronounced effect on the quantity and quality of produced biomass. Drought frequency, soil conditions, disease, tillage practices and cutting height are a number of studied factors. Hakala et al. [13] studied the influence of cutting height on 'harvestable biomass' availability in southwest Finland – the main cereal production area. Harvesting is usually done at a height of 10–25 cm, which means that approximately 30% of the straw biomass is left on the ground. Hakala et al. observed that as the cutting height increased (e.g. to 40 cm), the availability of biomass decreased and the organic matter content in the soil increased. When GHG emissions, soil fertility and carbon stock were considered, they recommended that the straw be harvested every second year with a lower cut (leading to higher straw volumes) [13].

Market related factors include, *inter alia*, market development and support policies, biomass imports and price elasticities. For farmers, the nature of biomass purchase contracts (fixed-price, annual, market-based) and the farmer's prior experience in selling biomass seem important factors [9,10]. In India, 97, 79 and 69% of farmers in Maharashtra, Madhya Pradesh and Tamil Nadu, respectively, expressed a preference for a binding contract with energy producers, without the involvement of middlemen [14]. In general, farmers with prior experience in selling biomass appeared more willing to engage in the biomass-to-energy supply chain [9]. The previous experience helped farmers make decisions on where, when and to whom to sell the biomass.

On supply-chain logistical issues, the availability of farm machines (such as harvester, baler, tractor and truck), availability of a storage place on the farm, transportation distance and costs are crucial factors that may influence the farmers' ability and willingness to sell their surplus biomass in the market [7,9,10]. Farmers with large land holdings may be able to supply more biomass but may not be willing to transport the large quantities of biomass [9,10,14]. Other psychological factors studied by Convery et al. [10] alluded to the importance of the 'follow the leader' mentality, where one farmer must first start the biomass business and then others will follow in a so called 'snowball' effect. Confidence is also crucial to the success of the biomass supply chain, and can be gained through contracts with a secured buyer, and a stable monthly income [15,16].

Survey data

The main methodological tool implemented in this study was a self-instructed survey tool designed for farmers in two contrasting regions in Poland (Figure 1). The tool was designed based on several similar studies and with an understanding of the current challenges facing the biomass market in Poland. In the central part of Poland, Kujawsko-Pomorskie Voivodeship (Torun) was selected for the study as the highest amount of renewable energy has been developed in

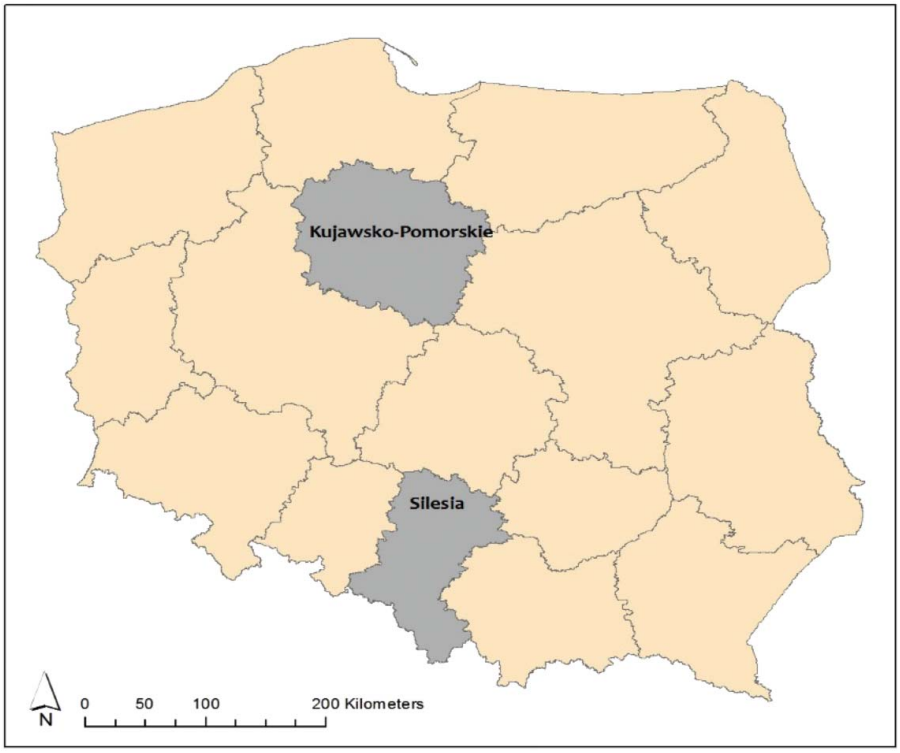

Figure 1. Locations of the survey study, Poland (grey area).

this region [6]. In the south of the country, Upper Silesia and the surrounding cities (Częstochowa, Łódź, Opole and Kraków) were selected as this region holds vast coal deposits, numerous coal-based power plants, and one of the highest rates of forest cover in the country. For the collection of data, stratified random sampling was used, and in some circumstances simple random sampling was employed due to time and resource constraints.

The first part of the questionnaire investigated size and type of land holding, agricultural activities and productivity, use of fertilizers, and the existing uses of biomass on farms. The aim was to calculate the biomass potentials and also to calculate the share of biomass used in farm activities, such as animal feed, bedding, ploughing, cooking, etc. The objective was to calculate the surplus biomass that can be used for energy production without jeopardizing the livelihoods of rural communities who rely on biomass for household use. Important considerations such as whether farming is the only source of income, whether it is considered a cultural heritage, and whether the farmer is willing to switch to energy plantations under ideal conditions were considered in the questionnaire. The farmers' understanding of the problems and challenges in the bioenergy sector in Poland were investigated through eight statements with a Likert scale that ranged from *highly relevant* to *relevant*, *irrelevant*, *highly irrelevant* and *I don't know*. Farmers' ability and willingness to engage in a new biomass supply chain for energy production was investigated through a further eight statements with optional answers *yes*, *no*, *I am not sure*, *I cannot answer*. Other socio-demographic factors, such as age, gender, and land ownership, were also included in the survey. A full version of the questionnaire is available from the corresponding author upon request. The data collection period extended from July to September 2015 during the peak harvesting season, which rendered data collection a difficult task in some locations, especially with busy farmers. Since a farmer database does not exist, the contact addresses of the farmers were obtained from various sources, such as online auctions, magazines and advertisement sites. An email-based approach proved unsuccessful. Other methods involved visiting the Agricultural Advisory offices in Kluczbork, Częstochowa, Łódź, Opole and Kraków, where a number of questionnaires were left and were picked up after a week or two. In Torun and the surrounding provinces, the survey research was conducted mainly in person by the authors Anna Igliński and Bartłomiej Igliński-Nicolaus of Copernicus University. If no persons were there to fill in the questionnaire, the questionnaire with an envelope and stamp were left in the mailbox. A number of questionnaires were collected from farmers by biomass processing companies, such as BioFuture in Lubień Kujawski and OpecBio in Grudziądz. Descriptive statistics were used to describe frequencies, and non-parametric tests such as Chi-square through the cross tabulation method were used to unveil statistical significance among the study variables. Data analysis was conducted with IBM SPSS statistics version 21.

Results and discussion

Socio-demographic

In total, 210 completed surveys were collected from both locations (110 from the central region, 100 from the southern region). In regard to *gender*, the results showed that males accounted for 62% of respondents in Torun province and for 74% in the Upper Silesia region. The respondents' *age* was categorized into five groups: under 30 years, 31–40 years, 41–50 years, over 50 years, and no response. The results showed that 34% of the respondents were less than 40 years of age and 60% were between 41 and 65 years of age in Torun compared to 29% and 65% in Upper Silesia, respectively. The *land ownership* variable showed that the majority (94%) of the respondents in Upper Silesia owned their land, compared to Torun province where 56% owned and 21% leased their land. About 12% of the respondents in Torun indicated that they owned and leased land simultaneously. Several *land types* were identified during the data refining process: agricultural, forest, grassland, energy plantation, and a mix of land holdings (e.g. the same farmer may possess both agricultural and forest land). In Torun, almost half of the respondents possessed agriculture land and the other half possessed a mix of land types, while the majority (81%) of Upper Silesian respondents possessed agriculture land and the remainder held a mix of land types. The *land size* varied substantially from less than 5 hectares to over 60 hectares. Nearly 80% of the respondents from Torun and 83% from Upper Silesia indicated a land size between 5 and 30 hectares. Wheat was the major crop planted by the farmers in both locations, with corn, barley, oats, rye, triticale and potato also planted.

Existing uses of biomass at the household level

In 2009, a survey that examined consumption patterns in urban and rural areas of Poland found that 5.7 million households used wood fuel for both cooking and water heating [18]. In our survey-based study (2015), the results indicated that the majority of biomass materials in both locations were used within the wider farming enterprise. In Torun province, 15% of the biomass was used for cooking and heating and 74% was used for animal feeding and animal bedding, and incorporated into the soil, leaving approximately 10% for sale. In Upper Silesia, over 90% of the biomass materials were used for feeding domestic animals, bedding and incorporation into the soil, leaving a small amount for sale (1%). Due to the wide availability of coal, biomass is not used for cooking and heating in Upper Silesia (Figure 2). Moreover, Silesian miners are also able to purchase coal at favorable prices for their own use. During data collection and field excursions, the farmers expressed some grievance toward the current biomass market, especially the low prices. Therefore, it is likely that the farmers increased the share of biomass used within the farm as it would be more costly to transport and sell the biomass. Furthermore, a 2-month drought period during 2015 may have substantially reduced the biomass quantities available for sale. The farmers were asked to indicate other sources of energy used at the household level (Figure 3). Residents in Torun province used multiple sources of household energy, with coal, firewood and district heating the most commonly used energy sources. This indicates that fuels are used interchangeably and according to the needs, price and season. In Upper Silesia, coal and firewood were the main energy sources with smaller amounts of natural gas also used. Coal

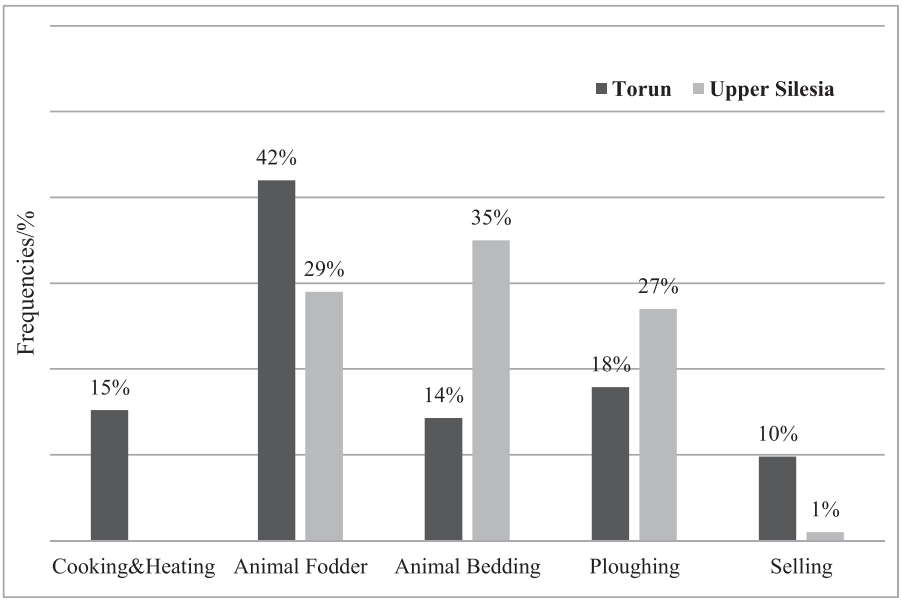

Figure 2. Uses of biomass at the household level and after harvesting in both locations.

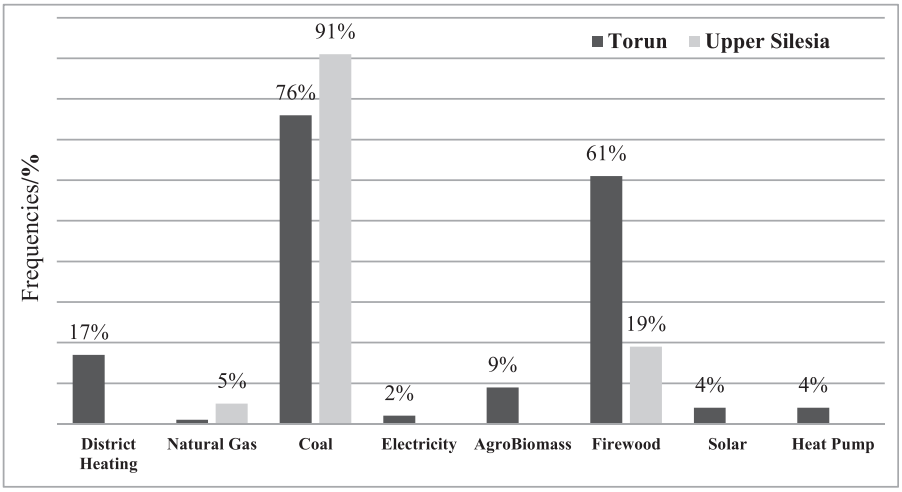

Figure 3. Energy sources used for household use in both locations.

is easily accessible at affordable prices and the region has the highest proportion of forest cover in the country (30%). Forest operations by public forest institutions offer wood thinnings at a very low price for locals. Torun province also has the highest proportion of renewable energy installations in the country. The high adoption of wind energy, biogas installations and other renewables such as solar photovoltaics (PV) and heat pumps [17] make access to renewable energy possible.

Farmers' willingness to supply biomass for energy generation: background information

An important consideration when examining the farmers' willingness to supply biomass to the market is the availability of farm machinery, and how the farmers perceive their farming practices (source of income vs. cultural heritage). Figure 4 indicates that the majority of farmers in both locations own a tractor and plower, almost half of them own a harvester and baler, and about 15% own a transport truck. Tractor and plower are the two main farm machines and tools used to prepare the land for seasonal planting, while the others are used for harvesting and post-harvesting activities. Ownership of a baler is critical for biomass collection and transportation. Since half of the farmers own a baler, this might have increased the biomass quantities left on the land, especially on small land holdings. How is farming perceived? Approximately half of the farmers in both locations consider farming their only source of income and, interestingly, about 75% considered it a *cultural heritage* (Figures 5 and 6). Similar findings were found with UK farmers [10], which has led to less interest in the growing of feedstock for bioenergy production. Three statements were presented to assess the farmers' willingness to supply biomass. A further three statements were then presented to assess the preferred choice of contract (Table 1). Although 32% of

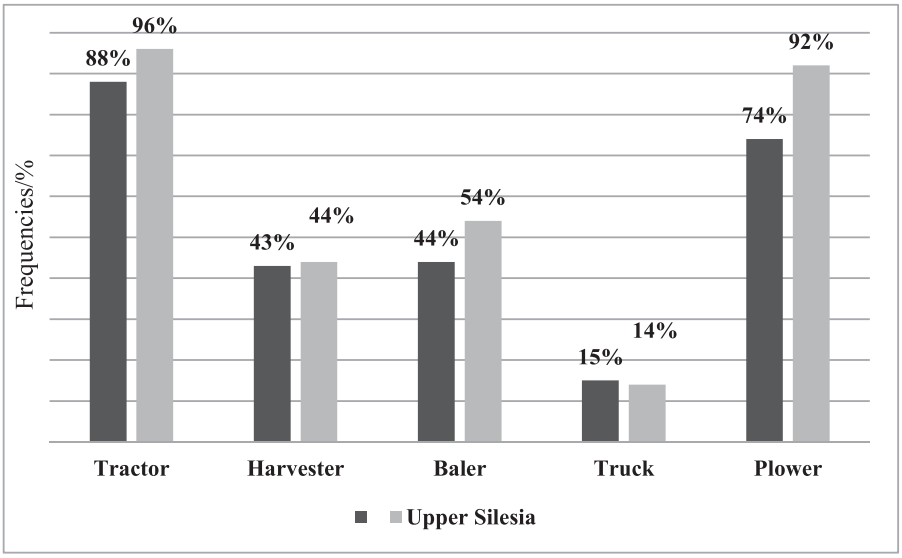

Figure 4. Availability of farm machinery: farmers possess multiple machines.

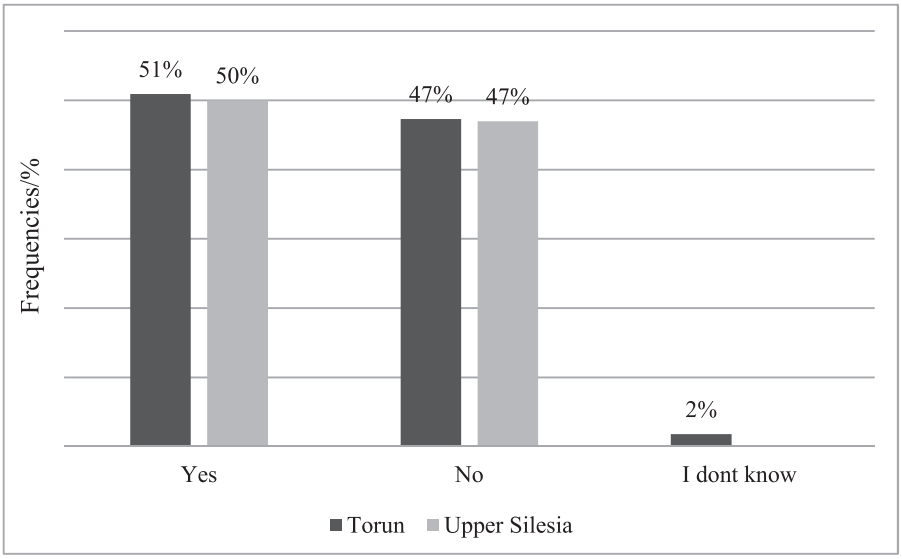

Figure 5. Percentage of farmers considering farming as their only source of income.

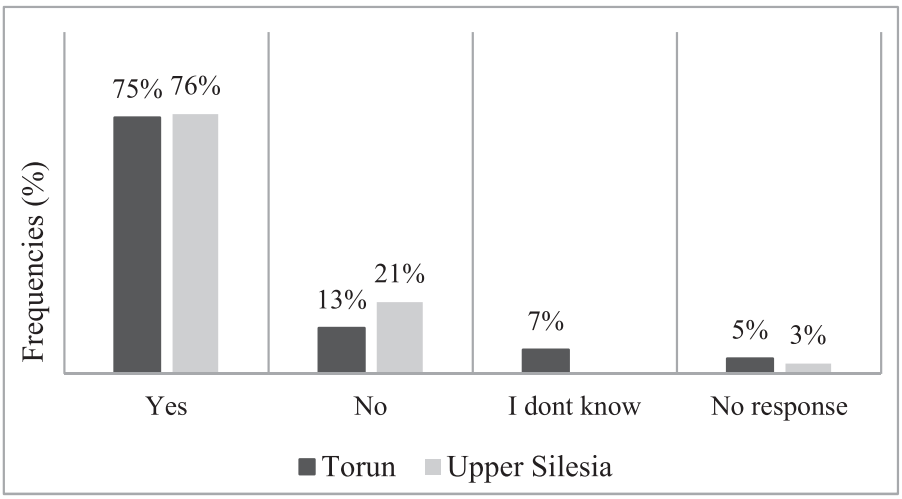

Figure 6. Percentage of farmers considering farming as a cultural heritage.

Table 1. Farmers' willingness and contract preference to supply biomass for energy generation (N = 210).

Item no.	Statement	Yes (%)	No (%)	IDK[1] (%)	NR[2] (%)
Willingness	I have surplus agro-biomass for selling	32	**53**	13	2
	I can transport agro-biomass to the purchaser with my own vehicle	22	**67**	10	2
	I can collect and store the agro-biomass in my farm until it is picked up by the purchaser	26	**60**	12	1
Contract choice	I would like to sell my agro-biomass via binding contract	30	40	28	2
	I would like to sell my agro-biomass via fixed price	34	41	23	2
	I would like to sell my agro-biomass via market price	24	45	28	3

[1] IDK = I don't know; [2] NR = No response.

the farmers may have surplus biomass for sale, over 60% showed no interest in the collection, storage and transportation of biomass to an energy-generation facility. This is a key finding in this study and a reflection of the current biomass market situation in Poland.

To compare the two regions, the cross-tabulation method was used with Chi-square to determine the statistical significance (Table 2). A slightly higher share of farmers indicated an availability of surplus biomass (SUR) in Torun province. However, 65% of farmers in Torun and 68% in Upper Silesia clearly showed no interest in the transportation (TRAN) of biomass to an energy production facility, with no statistical significance observed between the two locations. A highly significant difference ($P = 0.001$) was found for the willingness to 'collect and store biomass until it is picked up' (COL). The farmers in Upper Silesia showed a higher willingness to collect and store biomass (37%) compared to only 16% in Torun. It is probable that the

Table 2. Statistically significant differences between the two locations regarding willingness to supply biomass to the market: Cross-tabulation method (N = 210).

	Ability and willingness											
	Surplus			Transport			Collect and store			Chi-square (asymp. Sig. (2-sided)		
Location	Yes	No	DK[2]	Yes	No	DK	Yes	No	DK	SUR[4]	TRAN	COL
Torun (count)[1]	34	59	17	25	73	13	18	75	18	NS[3]	NS	0.001
Within location (%)	**30**	**53**	**15**	**22**	**65**	**12**	**16**	**68**	**16**			
US[5] (count)	33	53	11	21	68	8	37	52	8			
Within location (%)	**33**	**53**	**11**	**21**	**68**	**8**	**37**	**52**	**8**			

[1] Number of farmers = total (110 in Torun, and 100 in US), no response not reported.
[2] DK = I don't know. [3] NS = Not significant. [4]SUR (surplus), TRAN (transport), COL (collect and store). [5]US = Upper Silesia region.

farmers in Upper Silesia also use coal for domestic use, which allows them to spare more biomass for sale, and/or the farmers may have the machinery and facilities to collect and store smaller amounts of surplus, especially from smaller land holdings such in Upper Silesia.

Farmers' preferred choice of biomass selling contracts

Few studies have analyzed the influence of contracts on the overall biomass supply cost-competitiveness [15,16]. In a recent study, variations in biomass supply and overall biomass costs were shown to be reduced through the use of an optimal contracting strategy between bio-refineries and suppliers. An optimal contract suggests the use of a 'fixed price' with an 'inflexible quantity' to offer the lowest risk [15]. The authors further suggest that the ultimate goal of contracts should not focus on the reduction of transportation costs or the maximization of profit in the short term [15]. In this study, about one-third of the farmers appear confused in regard to contracts, and currently there is no tangible interest in any kind of contracts. However, a 34% interest in fixed contracts provides hope for the future (Table 1). Indeed, fixed contracts are the most common form of biomass procurement system used in Poland. Many farmers who grow feedstock (willow and miscanthus) for energy generation are in fixed contracts with coal-based power plants that use biomass in the co-firing process. However, the collapse of the biomass market in 2012 has led to a suboptimal supply chain between biomass suppliers and energy producers and, in some cases, has led to some farmers giving up energy crop plantation, or energy companies cancelling contracts with the biomass suppliers [19].

A cross-tabulation method was also used to compare the two locations. The results are presented in Table 3. There was no notable statistical difference between the two locations. About 51% of the farmers in Torun province expressed no preference for the market-based mechanism for contracts. A fixed contract was the preferred choice for the farmers in Torun province (38%), followed by a binding contract (35%). About one-third of the farmers in Upper Silesia preferred a fixed contract, followed by a market-based contract. It is difficult to explain these findings as it was not explained to the farmers what each category of contract means or that previous experience with contracts may have a negative influence on the preferred choice of contract. It is probable that an attractive biomass price and high demand remain key factors in determining the dynamics of the biomass market.

The significance of the factors that influence the farmers' willingness to collect, store, and transport biomass in central (Torun) and south Poland (Upper Silesia).

A number of independent variables were selected to examine the farmers' willingness to 'collect and store biomass until it is picked up' (COL). This variable was selected for further examination because it showed significant statistical difference as shown in Table 2. The independent variables included: *gender*, *age*, *land ownership* (OWN), *availability of farm*

Table 3. Statistically significant differences between the two locations regarding the farmers' preferred choice of selling contracts: Cross-tabulation method (N = 210).

	Willingness											
	Binding			Fixed			Market-based			Chi-square (asymp. Sig. (2-sided)		
Location	Yes	No	DK[2]	Yes	No	DK	Yes	No	DK	BIN[4]	FIX	MAR
Torun (count)[1]	39	45	27	43	38	30	21	57	31	NS[3]	NS	NS
Within location (%)	**35**	**40**	**24**	**38**	**34**	**27**	**19**	**51**	**28**			
US (count)	24	40	33	30	48	19	29	39	29			
Within location (%)	**24**	**40**	**33**	**30**	**48**	**19**	**29**	**39**	**29**			

[1] Number of farmers from the total (Torun = 110, and Upper Silesia 100).
[2] DK = I don't know.
[3] NS = Not significant.
[4] BIN = binding; FIX = fixed; MAR = market-based.

Table 4. Farmers' willingness to collect and store biomass: Cross-tabulation method.

	Gender			Age			Land ownership			Chi-square (asymp. Sig. (2-sided)		
	Male (%)			Young (%)[1]			Own (%)					
Location	Yes	No	DK[2]	Yes	No	DK	Yes	No	DK	Male	Young	OWN
Torun	19	65	16	14	73	14	17	69	14	0.003	0.038	0.003
US[1]	**43**	45	8	**41**	45	10	**38**	52	8			

[1] Upper Silesia province, [2]DK = I don't know; Young = less than 40 years; Own = own land.

Table 5. The farmers' willingness to collect and store biomass: Cross-tabulation method.

	Machinery			Energy source			Perception			Chi-square (asymp. Sig. (2-sided)		
	Tractor			Fossil fuels			Cultural heritage					
Location	Yes	No	DK[1]	Yes	No	DK	Yes	No	DK	MACH	ENS	PERC
Torun	16	67	16	15	64	21	18	66	17	0.002	0.001	0.001
US	**39**	53	8	**39**	53	9	**42**	53	5			

[1] DK = I don't know; MACH = machinery; ENS = energy source; PERC = perception.

machinery (MACH), *energy source used at home* (renewables vs. fossil fuels; ENS) and *the perceived value of farming* (source of income vs. cultural heritage; PERC). Frequencies and the results of the cross tabulation method are presented in Tables 4 and 5. Considering gender, male farmers in Upper Silesia appeared more willing (43%) to collect and store biomass until it is picked up compared to 19% in Torun ($P = 0.003$; Table 4). As alluded to above, small land holdings, the availability of farm machinery, and coal availability in Upper Silesia may have allowed the farmers to spare more biomass for sale in this region. With no statistical difference, 66% of the female respondents in Torun and 73% in Upper Silesia appeared unwilling to collect and store biomass. The aforementioned figures are not reported in Table 4. This is probably due to the notion that farm decisions are mainly made by males. However, an increasing number of women run their own farms, particularly after children move out, or if the husband dies or becomes disabled.

Regarding age, young male farmers (less than 40 years old) had a slight statistical significant effect on the farmers' willingness to collect and store biomass (Table 4). The statistical significance arose from the Upper Silesian farmers who showed a greater willingness to collect and store biomass: 41% compared to 14% in Torun ($P = 0.038$). With no statistical significance observed between the two locations, 48% of middle-aged (41–50 years old) farmers in Upper Silesia were willing to collect and store biomass, compared to 27% in Torun. However, older farmers (over 51 years old) in both locations appeared unwilling to engage in the collection and storage of biomass: 76% in Torun and 69% in Upper Silesia. This can be probably explained by the increasing lack of physical ability to operate machines at older age, especially if no children are around to help.

In regard to land ownership, farmers who own their land appeared slightly more willing to collect and store their biomass until the picking-up appointment, compared to farmers who leased their lands. A clear statistical difference was allocated to farmers from Upper Silesia, where 38% showed higher willingness to collect and store biomass compared to 17% of the farmers from Torun province ($P = 0.003$; Table 4). The authors do not know the exact cost of leasing land in Poland; however, owning the land might spare more resources to collect and store surplus biomass. For farmers who lease their lands, 25% of farmers in Upper Silesia appeared slightly more willing to collect and store biomass compared to 14% of the farmers in Torun province.

Another set of three independent variables was chosen to examine the willingness to collect and store biomass. These variables refer to the possession of a tractor, type of energy used at the household level, and how farming is perceived by the farmers (Table 5). The possession of a tractor appeared important for 39% of the farmers from Upper Silesia to collect and store biomass, compared to only 16% for the farmers from Torun province, with a clear statistical difference ($P = 0.002$). For smaller land holdings, as in Upper Silesia, a tractor is essential whilst in larger land holdings collecting biomass might be outsourced to a middleman.

In regard to energy sources at home, a clear statistical difference was found for the farmers who use fossil fuels, particularly in the Upper Silesia region ($P = 0.001$). Fossil fuels can be expensive; therefore, collecting and storing biomass could reduce the use of fossil fuels especially in winter time. Even though Upper Silesia is rich in coal, coal might be still expensive for many to buy and use at home, leading to an increasing use of biomass. What is interesting here is that 71% of the farmers in Torun province who uses renewables at home were unwilling to collect and store biomass. In this case, probably access to renewable energy may have reduced interest in the collection and use of biomass at the household level.

In regard to the effect of the perceived value of farming on the willingness to collect and store

biomass, a clear statistical difference was found for those farmers who consider farming a cultural heritage, particularly for 42% of the respondents from Upper Silesia region compared to only 18% in Torun province ($P = 0.001$). It might be that collecting and storing biomass mainly for feeding domestic animal and cooking is, traditionally, an integral part of the cultural heritage accumulated through traditional farming, and not necessarily associated with merely generating extra income. On the other hand, and to a lesser extent, 36% of farmers in Upper Silesia who consider farming their only source of income were willing to collect and store biomass, compared to 18% in Torun province. That also means that biomass has recently become an important source of income for those with no off-farm income.

In regard to the farmers' willingness to transport biomass with their own vehicles, no statistically significant differences were found between the two locations when considering the variables mentioned above. Although male and female farmers in both locations appeared unwilling to transport biomass, female farmers showed a much higher unwillingness to do so: 78% in Torun and 77% in Upper Silesia. In regard to age, middle-aged farmers (41–50 years) appeared more willing to transport the biomass (approx. 30% in both locations). Older farmers in Upper Silesia (over 51 years) and younger farmers in Torun (less than 40 years) were the least willing to transport biomass: 83% and 73%, respectively. Farmers who owned their land showed a higher unwillingness to transport biomass (66% in Torun and 69% in Upper Silesia); however, farmers who leased their land showed a higher willingness to transport biomass (36% in Torun and 25% in Upper Silesia). In regard to the perceived value of farming, farmers who consider farming their only source of income and a cultural heritage were included in the cross-tabulation method. In both locations, 58% of the farmers who perceived farming as their only source of income were unwilling to transport their biomass. Moreover, 74% of the farmers in Upper Silesia who perceived farming as a cultural heritage were unwilling to transport biomass, compared to 64% in Torun. Another finding is related to the type of energy source at the household level. Farmers who use renewables at the domestic level were more unwilling (72% in Torun and 79% in Upper Silesia) to transport biomass compared to those who use fossil fuels (62% in Torun and 69% in Upper Silesia). Ownership of a tractor did not promote farmers' willingness to transport their biomass; 64% of the farmers in Torun and 70% in Upper Silesia showed an unwillingness to transport biomass. As was explained in the introduction, this would be a natural result of the current biomass market in Poland: low demand and low biomass prices, especially when transporting cheap biomass is often associated with extra, sometimes unnecessary, costs.

Conclusion

The objective of this survey-based study was to examine farmers' willingness to collect, store and transport their surplus biomass to an energy production facility, in a coal-rich region (Upper Silesia) and a renewable energy-driven province (Torun). Due to the current biomass situation in Poland, which is marked by low demand and low biomass prices accompanied by biomass imports and a glut in 'green certificates' with low market prices, Polish farmers appeared unwilling to engage in the supply of surplus biomass for energy generation. Young and middle-aged farmers from the southern part of Poland (Upper Silesia) who own their farms appeared to be slightly more willing to supply biomass. It might be that the availability of coal for domestic use, small land acquisitions, and the juxtaposition to coal-based power plants in the Upper Silesia region have influenced the farmers' motives in this region. Although level of education was not identified in this study, it may be possible that as young farmers are more educated they may be more willing to supply biomass under favorable market conditions. It may also be that the possession of a tractor, the use of fossil fuels for domestic purposes, and the perception of farming as a cultural heritage may have encouraged the farmers' willingness to collect and store biomass, as was the case with the participants from Upper Silesia, although not the case in the central part of Poland (Torun province). There also seems to be a clear difference between the willingness to collect and store, and the willingness to transport, biomass. It may be that collection and storage requires less effort and resources compared to loading/unloading and transporting biomass over long distances. The independent variables employed in this study did not have a significant influence on the farmers' willingness to supply biomass for energy generation. It could be argued that the socio-demographic factors, farming outlook, and psychological constructs (perceptions) used in this study are not the only factors that need to be examined and understood. Other factors such as level of education, household and family size, net income level, bank loans/credits for either farming or home purchase, political orientation, and degree of political trust in the ruling party also need to be investigated in future studies. However, and from the authors' perspective, the prime reason for the unwillingness to engage in the biomass supply chain was shown to be the current chaotic biomass market situation. This also highlights the role of public policies in the creation of stable market conditions or in the devaluation of natural resources. Based on the findings of this study, we would argue that new policies are needed to create stable market conditions and a tangible long-term incentivizing mechanism in order to regain the farmers' confidence in the bioenergy supply chain. It is also critical

that a fair and win–win partnership between farmers and bioenergy industries can be established through so-called optimal contracting to minimize the financial risks to both farmers and industries.

Acknowledgments

The work was carried out in the Sustainable Bioenergy Solutions for Tomorrow (BEST) research program coordinated by CLIC Innovation with funding from the Finnish Funding Agency for Innovation, Tekes (www.clicinnovation.fi). The authors would like to sincerely thank Elena Fedorova and Eva Pongracz from Oulu University, and Petri Latva-Käyrä from Arbonaut, for commenting on and improving earlier versions of the questionnaire.

Disclosure statement

No potential conflict of interest was reported by the authors.

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