ENERGY CROPS IN POLISH AGRICULTURE BASED ON RESULTS OF AGRICULTURAL CENSUS OF 2010

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Abstract. The article presents the spatial distribution of energy crops in the Polish farming sector in view of the results of the Agricultural Census of 2010. The total area dedicated to energy crops (154,000 ha) is divided into two categories: (1) total forest area occupied by trees and shrubs grown for biomass material (137,000 ha) and (2) total agricultural area occupied by energy crops (17,000 ha). The article discusses the results of research into the spatial distribution of energy crops in the Polish farming sector (across regions and counties), their share in total agricultural area (0.85 % on average, ranging from 0.3 % in the Region of Podlasie to 2.6 % in the Region of Kujawy and Pomorze) and structural variation. The influence of the natural factors affecting the distribution of energy crops was analyzed.

Keywords: energy crops, renewable energy sources, rural areas.

Introduction

With the world population still growing the demand for food and energy sources is on the increase. The phenomena which hinder the development of civilisation and improvements in standards of life are gaining momentum. An important role here is played by both depletion of the natural sources which are not renewable and by rising costs of their production or extraction. The need for making decisions on the direction of developments in the power industry stems also from the current situation in the energy sector and from the measures undertaken by the European Union. The growth of the renewable energy sector is one of the EU priorities. According to the Directive 2009/28/EC [1] the Member States are to gradually increase the share of energy obtained from renewable energy sources in the total energy consumption and in the transportation sector. The authors of the document assume that by 2020 the consumption of energy from renewable sources will have reached 20 % of the overall balance of energy consumption in the EU [2]. It is also presumed that by that time energetic efficiency will have improved by 20 % and that the use of biofuels will have risen by up to 10 %. As far as Poland is concerned, by 2020 15 % of all energy consumption is supposed to have come from renewable energy sources.

In the case of Poland, the use of biomass material of agricultural origin provides the best opportunities for obtaining renewable energy [3]. Sources of renewable energy are mainly to be found in rural areas. One of the arguments for optimisation of the use of agricultural land for energy production points to the fact that the lands of class V and VI, which have little agricultural value, occupy over 30 % of the agricultural acreage. At the same time, in agriculture of the developed countries an excessive production of agricultural material has been noted. As a result, profitability has decreased and incomes from agricultural activity have declined [4]. Thus, renewable energy sources are a possible solution for many farmers who wish to rationalise production.

Agriculture and policy on power and energy constitute two closely-related elements. In the future energy crops may become strategic for agricultural production [5]. In fact, the significance of renewable energy in Poland is steadily on the upward movement. The authors of the accepted long-term strategy for the development of the energy sector broach the issue of how the potential production capacity of arable land may be taken advantage of in compliance with sustainable development principles pertaining to natural environment protection [6]. In practice, the market of agricultural biomass materials in Poland is in its cradle as, so far, the dominant position has been appropriated mainly by forest biomass. The aim is that agriculture, agriculture and food industry and municipal waste management sectors will be the major suppliers of biomass for energy provision. In Poland in 2009 solid biomass was the largest source of renewable energy (over 85 %), while its share in the European Union was below 50 % [7]. Although biomass has a substantial energetic potential on the national scale, it is dispersed [8]. The pace of progress in production of tools and equipment for the renewable energy sector and their agricultural use in different countries predominantly depend on state

subsidies. It seems that nowadays the state is supposed to create favourable price conditions for biomass producers and to support the use of renewable energy sources in power industry [9].

However, it is important for some agricultural holdings to change their production profile on account of, for example: unfavourable production conditions; location of the agricultural holding within the marketing area of raw material suppliers; development of on-site infrastructure, etc. Such a direction of changes forces Polish farmers to search for new opportunities for diversification of their agricultural activities [10] and one of the possible options, besides non-agricultural business activity, assumes a new production profile or concentration on new markets. Here the instruments of the Common Agricultural Policy are of particular significance [11].

The paper is to present the results of the research conducted into the spatial diversification of energy crops in the Polish agriculture, a new element in the structure of agricultural land use in Poland (across voivodships and poviats) – in terms of a variety of species and their share in the overall area of agricultural holdings – mostly with reference to the natural factors and management conditions observed during the Polish membership in the EU. The aim of this study was definition of the direction of growth in the renewable energy sector and determination of the importance of agricultural biomass.

Materials and methods

The study was based on the results of the Agricultural Census of 2010 which were compiled according to the location of the farmsteads. The analysis of agricultural land and forest areas occupied by fast-growing trees and shrubs, which are sources of biomass, accounts for plantations of fast-growing trees and shrubs (including willow, poplar, black locust and others) and the remaining species of fast-growing trees and shrubs. The energy crops grown on agricultural land were further classified into annual (cereals, maize, rapeseed, sugar beets and others) and perennial crops (multiflora rose, Virginia mallow, Miscanthus giganteus, Sakhalin knotweed, reed canary grass and others).

For the analysis the former agricultural production area quality index (average for Poland: 66 points) by the Institute of Soil Science and Plant Cultivation (*Instytut Upraw i Nawożenia*) in Puławy and the application criteria for the Rural Development Programme (PROW) – Aid to Farmers in Less Favoured Areas (LFA) have been used; the following kinds of areas have been differentiated: areas with unfavourable conditions (below 52 points of the index mentioned above); areas with moderate conditions (52-72 points); and areas with favourable conditions (above 72, excluding subsidies for LFA, [12]). The statistical analyses were completed with a monographic review of the development of renewable energy sources and worldwide which aims at the definition of the direction of growth in the renewable energy sector and at the determination of the importance of agricultural biomass in Poland.

Results and discussion

According to the Directive 2009/28/EC of the European Parliament and of the Council, Article 2, letter (e) [1], the term "biomass" is to be interpreted as "the biodegradable fraction of products, waste and residues from biological origin from agriculture (including vegetal and animal substances), forestry and related industries including fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste".

The energy stored in biomass is the least capital-intensive renewable energy source. The attractiveness of this source increases if one takes into account the fact that Poland is rich in these sources [13]. Decisions on dedication of the main crops for biomass for the purposes of energy provision depend on estimations of the economic profitability of such specialisation which is measured by the ratio of the incomes from the sales to the production costs. This is one of the fundamental conditions for having a competitive edge in the globalising market of agricultural products. However, this production trend gives rise to concerns about natural environment degradation and about the tendency to replace traditional agricultural production in areas with favourable conditions with energy crop production. The current structure of the Polish agriculture is considered a guarantee of food security and there is a common opinion that any other orientation will not ensure such security.

Cultivation of traditional crops for the purposes of energy provision or setting up of energy crop plantations lays the foundations for provision of agricultural biomass. Due to a growing deficit in wood from forestry and to the need for dedicating wood for more valuable purposes, it is necessary to obtain wooden biomass from alternative sources – field plantations. The plantation is a one-function area, organized for production of particular wood on the largest scale possible and used for a short time. It involves only carefully selected species of fast-growing trees. Until recently, and on a large scale, Poland had a lot of poplar plantations where thick wood assortments were grown (with wood production cycle amounting to 25-40 years) as well as plantations of fast-growing forest trees, the wood production cycle of which lasts for 40-60 years. The category of fast-growing trees includes basic species (larch, birch, Douglas fir) and complementary species which are characterised by a large potential for offshoot production [14]. Production of small-size wood in short rotations of willow, poplar and false acacia may lessen the deficit for this wood in the market and constitute an attractive raw material for the purposes of energy [15].

Among weighty arguments for the use of biomass for energy provision there are, for example, constant and reliable deliveries of the national energy carrier and a guarantee of income which – with the overproduction of food – would be difficult to generate. Non-food crops, i.e. crops cultivated for the purposes of industry and energy, should pave the way for the age of a new agriculture [16]. At the moment, agricultural biomass includes mostly straw. However, in order to ensure reliability of agricultural biomass deliveries in the future it is inevitable to develop the sector of energy crop plantations. The basic criterion of energy crop usefulness for energy provision is the crop yield of biomass in the dry mass and its calorific value [17]. Other important criteria are as follows: yielding, harvest methods, multiplicity of biomass harvests during the vegetation period, plantation permanence, etc. [18]. Yet, the most important in biomass production are: the price of energy-providing raw materials and long-lasting guarantee of marketability [9].

In the Polish climate there are three groups of plants which may provide raw material base for biomass dedicated for energy:

- trees and shrubs: willow (*Salix* L.), poplar (*Populus* L.), false acacia (*Robinia pseudoacacia* L.), Japanese rose (*Rosa multiflora*);
- grasses: Elephant Grass (*Miscanthus* × *giganteus* J.M.Greef & M.Deuter), *Miscanthus sinensis* (Andersson), *Miscanthus sacchariflorus* ((Maxim.) Hack.), Prairie Cord-grass (*Spartina pectinata* Bosc ex Link);
- perennial plants: Virginia Mallow (*Sida hermaphrodita Rusby* L.), Cup Plant (*Silphium perfoliatum* L.), sunchoke (*Helianthus tuberosus* L.).

Energy crops are characterised by large growth rings, high calorific value, considerable immunity to diseases and pests, as well as relatively high potential for growth in poor soil [19]. However, they are sensitive to weather, which particularly applies to the *Miscanthus* family [4], and they require proper humidity, which refers mostly to the willow, *Miscanthus* and Virginia Mallow [20]. Perennial energy crops cultivated on arable land, depending on the species, may provide biomass in form of wood, semi-lignified materials or straw with diverse energetic parameters.

So far, the most popular perennial plants cultivated in Poland have included: poplar, osier, Elephant Grass and Virginia Mallow. Apart from the perennial plants, there are also annual plants grown for the purposes of energy, such as: oilseed rape, sugar beet, grains and other. Grains, that are mostly oats [21] and corn, are more and more popular energy sources both in Poland and worldwide. Nevertheless, as shown by Burczyk [22], the usefulness of arista grains as renewable energy sources is very small and their use for the purposes analysed in this paper is pragmatically unjustified.

Subsidies for energy crops provided a good opportunity for cultivating the perennial plants mentioned above [23]. The subsidies were fully funded from the European Union budget. They were accessible for the farmers who grew energy crops dedicated for processing into energy-providing products and who had signed a contract for delivery of energy-rich raw material to approved buyers. The farmers who used or processed their crops for energy provision in their own agricultural holdings could also apply for the subsidies. Since 2005 the subsidies to those energy crops which were considered renewable energy sources have been at the level of PLN 213.4 per 1 ha of plantation (it applied to the osier and Japanese rose). The list of the subsidised crops enlarged in subsequent years,

but the amount of the subsidy decreased in 2009 to PLN 190. 33 per 1 ha [24]. Due to the amendment to the European regulations, the subsidies ceased in 2010. Therefore, an increase in or maintenance of biomass production with the use of the perennial plants will be difficult. Yet, the annual plants in the main yield may come as a good alternative, especially milo and corn [25]. Table 1 presents the energy crops cultivated in agricultural holdings across voivodships (regions) on the basis of the Agricultural Census of 2010.

Energy crops in Poland

According to the data presented in the Agricultural Census of 2010, there were 6.5 thousand agricultural holdings in Poland where energy crops were cultivated (14.6 per 1000 of the total number of agricultural holdings), which amounted to the area of 29.6 thousand ha (1.6 ha per 1000 ha of the total area of all agricultural holdings). The analysed energy crops were referred to in the study and grouped in the following two categories (see Table 1):

1. plantations of fast-growing trees and shrubs in forests and forest lands used for energy provision – 5.6 thousand agricultural holdings (85 %) and 12.5 thousand ha (42 %); the osier was the most common in this category – it occupied on average 70 % of its total habitat in Poland, with the staggering 93 % in the Dolnośląskie Voivodship; other energy crops (poplar, false acacia and other) constituted the majority of crops in three other voivodships only: Małopolskie (85 %), Mazowieckie (56 %) and Podlaskie (72 %);
2. cultivation of energy crops on arable land – almost 1 thousand agricultural holdings (15 %) and 17.1 thousand ha (58 %), with the annual plants taking 14.6 thousand ha (including: grains – 3.4 thousand ha, corn – 4.5 thousand ha, oilseed rape – 5.4 thousand ha, sugar beet 140 ha and other annual plants – altogether 1.3 thousand ha) and the perennial plants taking – 2488 ha (including: Japanese rose – 5 ha, Virginia Mallow – 80 ha, Elephant Grass – 1930 ha, sunchoke and Sakhalin Knotweed (*Fallopia sachalinensis* L.) – 39 ha , reed canarygrass (*Phalaris arundinacea* L.) – 215 ha and other perennial plants grown for energy purposes – 218 ha). The results of the Agricultural Census of 2010 demonstrate that among the above-mentioned crops oilseed rape (37 % of the area in the category of annual plants) and Elephant Grass (78 % of the area in the category of perennial plants) enjoyed the highest popularity. Remarkably, the Sakhalin Knotweed was cultivated in the Warmińsko-Mazurskie Voivodship only (north-east Poland).

Table 1 presents also the agricultural production area quality index which reflects the usefulness of agricultural land for agricultural production. The regional diversification in this respect noted in Poland results from different local soils, landforms, precipitation and temperature. Noteworthy is the fact that the so-called marginal lands have a considerable share in the total area of light soils. According to the Institute of Soil Science and Plant Cultivation [*Instytut Upraw i Nawożenia*] in Puławy the marginal land is to be interpreted as the land remaining in agricultural use or in the official records of agricultural acreage which, due to unfavourable natural and man-made conditions, has poor production potential or is not suitable for healthy food production. It would be advisable to change qualification of such land, so that it is used for other purposes or is dedicated for energy crop production.

Energy crops have a minor share in the total number and area of agricultural holdings, which indicates that the trend related to their development is at its initial stage in Poland. Polish farmers mostly take interest in this direction of development due to the Polish membership in the EU and to the availability of an array of Common Agricultural Policy instruments, including – as of 2005 – the Single Area Payment Scheme for the energy crops which constitute renewable energy sources and which are dedicated for biofuel production. The first year of this instrument being in effect saw payments for the osier and Japanese rose only; the following years saw an enlarged list of subsidised crops (e.g., oilseed rape, sugar beet); and since 2010 energy crops have been included in the general scheme of direct payments in agriculture.

The group of plants under analysis is characterised by a considerable spatial diversification, both at the regional level (from 0.3 ha in the Podlaskie Voivodship to 4.2 ha per 1000 ha of the total area of agricultural holdings in the Lubuskie and Zachodniopomorskie Voivodships; see Table 1) and at the level of the *poviat* (with no such plantations in 3 *poviats* on the one end of the scale and 32 ha per

1000 ha in the *poviat* of Zgorzelec in the Dolnośląskie Voivodship on the other end of the scale; see Fig. 1).

Table 1

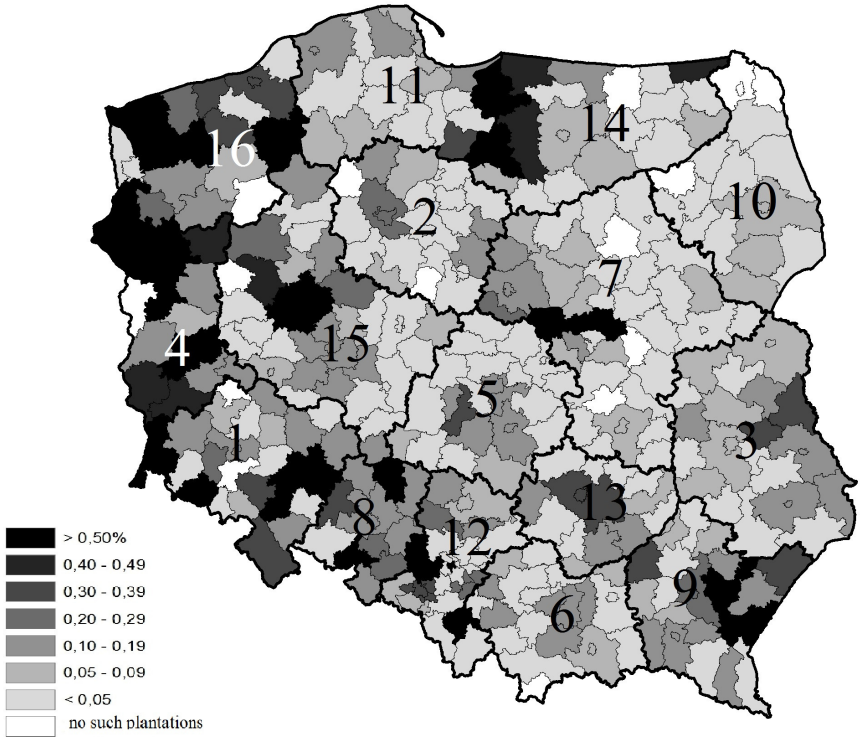
Energy crops in agricultural holdings in Poland

Spatial specification	Agricultural production area quality index	Agricultural holdings with energy crops					Acreage under cultivation – structural analysis			
		Number		Area		Average plantation area	including			
							Plantations in forests	Plantations on arable land		
									including	
		Total	per 1000 agricultural holdings	ha	per 1000 ha			Total	Annual plants	Perennial plants
Poland	66.6	**6 509**	**14.6**	**29,601**	**1.6**	**4.5**	**42.1**	**57.9**	**85.5**	**14.5**
including voivodships										
Dolnośląskie	74.9	266	42.9	3 386	3.0	12.7	23.2	76.8	96.5	3.5
Kujawsko-Pomorskie	71.0	335	9.0	617	0.5	1.8	82.9	17.1	86.0	14.0
Lubelskie	74.1	903	9.1	1 303	0.8	1.4	59.7	40.3	98.9	1.1
Lubuskie	62.3	168	20.2	2 232	4.2	13.3	46.6	53.4	98.7	1.3
Łódzkie	61.9	432	13.9	729	0.6	1.7	68.3	31.7	95.1	4.9
Małopolskie	69.3	815	4.9	498	0.6	0.6	74.4	25.6	97.3	2.7
Mazowieckie	59.9	509	21.0	2 712	1.2	5.3	17.2	82.8	39.9	60.1
Opolskie	81.4	219	37.9	1 562	2.8	7.1	28.6	71.4	76.0	24.0
Podkarpackie	70.4	1 234	8.1	3 342	3.9	2.7	80.8	19.2	96.0	4.0
Podlaskie	55.0	162	4.3	338	0.3	2.1	94.5	5.5	85.5	14.5
Pomorskie	62.2	201	14.9	703	0.7	3.5	75.4	24.6	48.9	51.1
Śląskie	64.2	311	13.8	869	1.7	2.8	33.1	66.9	98.2	1.8
Świętokrzyskie	69.3	280	7.1	692	1.0	2.5	72.2	27.8	97.5	2.5
Warmińsko-Mazurskie	66.0	219	14.6	2 804	2.2	12.8	55.8	44.2	61.3	38.7
Wielkopolskie	64.8	303	35.6	3 179	1.6	10.5	18.0	82.0	96.1	3.9
Zachodniopomorskie	67.5	152	39.5	4 636	4.2	30.5	23.7	76.3	99.6	0.4

The analysis of the spatial diversification of energy crops points to a higher concentration of these crops in western Poland - in regions characterised by larger agricultural holdings, which are often leased and which used to be state agricultural farms. This phenomenon evinces substantial differences between an average plantation area (4.5 ha in Poland) – from 0.3 ha in the Podlaskie Voivodship to as many as 30.5 ha in the Zachodniopomorskie Voivodship. Such a spatial structure is irrational, which is shown by a high ratio of energy crops in the *poviats* with favourable natural conditions (2.3 ha), particularly in comparison to the less favoured *poviats* (0.3 ha).

A pronounced spatial diversification is also typical of the structure of energy crop plantations. These in forests and forest land make up the average of 42 % of all energy crop plantations, with the largest share in the central and eastern Poland (the largest share noted in Podlaskie Voivodship – 94.5 %). These are usually small plantations (2.2 ha on average), which are part of family-run agricultural holdings. A remarkably higher ratio of the average acreage regards energy crops cultivated on arable land (58 % of all energy crops under analysis – average plantation area: 18 ha). It is mostly observed in the central and western Poland, often within the scheme of large farm management, particularly in the following voivodships: Dolnośląskie (76.8 %), Opolskie (71.4 %), Wielkopolskie (82 %) and Zachodniopomorskie (76.3 %; see Table 1).

In spite of the distinct dominance of annual plantations in the total area of energy crop plantations on arable land (average for Poland: 85.5 %), there are some areas where energy crops cultivated on arable land are mostly based on perennial plants (average for Poland: 14.5 %), particularly in the Mazowieckie Voivodship (60 %), Pomorskie Voivodship (51 %) and Warmińsko-Mazurskie Voivodship.



1…16 – name of voivodships (see Table 1)

Fig. 1. **Cultivation of energy crops per 1000 ha of the total area of agricultural holdings**

Conclusions

The importance of renewable energy in Poland is on the increase. At the moment biomass constitutes the most significant source of renewable energy. Ultimately, biomass for energy provision will be mostly supplied by agriculture, food and agriculture industry and municipal waste management sectors. Poland enjoys a large potential for renewable energy. On the basis of the analyses conducted it can be stated that the biomass originating from field crops or perennial plantations constitutes a negligible percentage of solid biomass:

1. Poland has very good conditions for cultivation of energy crops. However, the potential is not used fully. Areas exist where crop energy does not exist in practical terms (especially the north-eastern part of the country).
2. In the future energy crops may become a strategic solution for agricultural production. To a large extent, the development of energy crop plantations will depend on external factors, including mostly profitability of production or possibilities to acquire financial support for the development of renewable energy sources. Polish farmers are not averse to changing production profiles of their agricultural holdings or to focussing on new markets.
3. The study based on the results of the Agricultural Census of 2010 demonstrated that energy crops have an insignificant share in the total area of agricultural holdings (on average 1.6 ha per 1000 ha of the total area of agricultural holdings). However, the acreage of energy crop plantations is characterised by a large spatial diversification, with a higher concentration of these crops in the regions located along the western Polish border, often on the privatised land of the former state agricultural farms.
4. It has been also discovered that the areas with less favourable natural conditions for agriculture are distinguished by poor use of land for the purposes of energy crops. It is a negative phenomenon requiring changes in the agricultural policy. These areas, due to low profitability of agricultural production there, should prioritise energy crop plantations.
5. Poland has good natural conditions for the development of energy crop plantations; however, these conditions have not been fully taken advantage of yet. Another vital problem is related to

the development and use of energy crop plantations in a local – dispersed structure, which would allow for a more efficient use of energy sources.

Acknowledgement

The paper has been written within the research project of the National Science Centre [Narodowe Centrum Nauki] (no. 2011/03/B/HS4/04952).

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