POTENTIAL ABILITY TO INCREASE THE AREA OF WINTER RAPESEED CULTIVATION FOR BIOFUEL PRODUCTION IN POLAND

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Abstract. This article is an overview of potential opportunities for increasing the total acreage cropped with winter oilseed rape in Poland. Production of oilseed rape, which is additionally used as substrate for making biofuel, should first of all cover the demand for this crop as food and feed. The total area of farmland under oilseed rape in Poland should be about 1.3 million ha. The growing share of liquid fuel biocomponents (in line with the National Index Target) will force us to spare much higher quantities of oilseed rape seeds for energy purposes. Any further increase of the arable land cropped with winter oilseed rape is hindered by certain organizational and economic limitations; hence it will be necessary to improve the yields of this crop in order to satisfy the domestic demand for oily seeds. Although this goal is realistic, it is not an easy one to achieve.

Keywords: methyl esters, renewable energy sources, vegetable oils.

Introduction

The ongoing changes, already termed as "a revolution", are driven by the development of technologies used for production and processing of agricultural produce for energy generation [1]. A new branch of agriculture, referred to as energy agriculture, is developing rather dynamically [2]. The assumptions underlying The Energy Policy of Poland until 2030 place emphasis on supporting the sustainable use of energy from renewable resources (RES). The policy mentions improved energy security owing to the diversification of energy resources among other positive effects of the growth of RES [1]. In Poland, renewable energy sources can make an essential contribution to the country's energy balance and to the improvement of energy supply in areas with poorly developed energy infrastructure. Potentially, the biggest RES energy consumer is agriculture, followed by housing infrastructure and transportation [3].

Agricultural biomass (a major renewable energy resource) is perceived as a source with the highest energy potential [4]. In terms of the degree of processing, agricultural biomass can be divided into primary (annual and perennial energy crops, surplus biomass from permanent grassland, not used for animal fodder) and secondary one (waste and organic residue from agricultural production and food processing industry, liquid and solid animal faeces, organic residue from agricultural and food industries, e.g., glicerine, brewing and distilling dregs, post-slaughter waste, dairy wastewater, etc.). The highly important role of agricultural biomass in the production of bioenergy is unquestionable, but there are quite notable discrepancies between the estimates of its actual potential [5; 6].

Currently, petroleum serves as the principal raw material for fuel production and its consumption has grown by several hundred per cent over the past sixty years. The specific nature of technical solutions implemented in vans, lorries as well as in agricultural vehicles and machines necessitates the use of a Diesel engine as the dominant driving motor in road transport and agricultural production [7]. The geopolitical and economic situation in Poland is such that most crude oil for production of petroleum fuels must be imported. This leads to numerous negative consequences, such as highly volatile fuel prices [8].

Biodiesel is an alterative fuel to conventional diesel oil [9]. Biodiesel may be produced from plant oils, both edible ones such as soybean, oilseed rape, sunflower, camelina or palm trees, or cotton seeds [10], and from inedible ones, for example – castor, neem or Barbados nut oil, tall oil or any waste oil [11]. The use of animal fats (from pork, beef or poultry) is limited due to their solid consistency [12]. Fish fat is not used at all because it contains long-chain, oxidation unstable fatty acids.

The direct use of oil from oilseed rape seeds raises several technical difficulties, caused by its specific physicochemical properties, which is why it cannot be fed to an unmodified Diesel engine [13]. In contrast, biodiesel can be used in conventional engines following very small adaptations or even without any changes in the engine construction [14]. It is therefore necessary to adjust fuel (such as crude plant oil) to engines currently in use. Transestrification is a popular solution

that makes oil ready to be combusted in high-pressure engines [15]. However, the economic and energy effectiveness of producing and using RME (Rape Methyl Ester) is often dubious [16; 17].

Biodiesel is an eco-friendly fuel since its use diminishes the emission of harmful compounds (as well as emitting less soot, biodiesel oils are free from sulphur or aromatic compounds). The ecological benefits of using biodiesel have promoted its rapid spread all over the world [18; 19]. Apart from ecological advantages, biofuels generate many economic benefits in terms of their production and use, of which the following are the most important ones: contribution to sustainable development, diversity of fuels, more workplaces in rural areas for people engaged in biofuel production, higher income taxation revenue, more investment in durable assets in agriculture, gaining an international competitive edge [20]. Proponents of biofuels claim that cultivation of energy crops stimulates the development of rural areas owing to a more efficient use of land for production of biomass [21].

The purpose of this paper has been to analyze the conditions, in terms of the natural environment as well as organisation of production, which create potential opportunities for growing oilseed rape in Poland. Our analysis is hoped to facilitate estimates of the volume of oilseed rape seed production which will satisfy the demand of the food industry and supply enough seeds for technical solutions, especially as a biocomponent for liquid fuels.

Methods

The analysis relies on the data collected from statistical yearbooks published by the Central Statistical Office as well as the Provincial Statistical Offices in Poland, the information gathered during the agricultural general census, relevant books and own calculations. The current state of rape seed production in the whole country (the average production from 2011-2013) and the average yields in individual provinces have been assessed. The analysis pertaining to a possible increase in the volume of harvested yields includes natural factors affecting the cultivation of oilseed rape in individual provinces in Poland, such as the climatic conditions (the main climatic factor limiting the cultivation of oilseed rape in a given province is claimed to be frost-kill damage), soil resources suitable for cultivation of this plant species (divided between the Polish provinces). Among the organisational and economic factors, the following were chosen as the essential ones: the agrarian structure of farms and the highest permissible share of oilseed rape in the structure of crops, paying particular attention to maintaining an adequate crop rotation system with respect to nature preservation. The domestic demand for methyl esters of fatty acids as well as the potential production of oil raw material in Poland have been identified, having first determined the total acreage of farmland cropped with oil plants, possible production output and types of use of the harvested yields.

Results and discussion

Prior to Poland's access to the European Union, almost all of the oilseed rape production was processed by the domestic fats and oils industry. Any surplus was exported. In the past years, the demand for oilseed rape seeds has been growing, stimulated by the petroleum chemical industry, which uses the oil to make liquid fuel biocomponents. Regulations of the European Commission oblige the EU member states to raise the share of biocomponents in the transport fuel market.

It is not easy to estimate the potential acreage of farmland in Poland to be cropped with oilseed rape because several factors that limit its cultivation must be taken into consideration. The most important ones are: the soil quality, the agrarian structure of farms, the allowable share of oilseed rape in the structure of crops (in crop rotation) and the risk of frost [22]. Each of these factors plays a specific role.

Quality of soils

Oilseed rape belongs to plants which demand good-quality soils, hence large and stable yields are attainable only on very good and good soils. Some oilseed rape can also be grown on medium-quality soils, which in Poland cover 2.4 million ha (16% of the total arable land), but there seed yields will be lower [22]. The highest oilseed rape yields are obtained on very good and good wheat complex soils and on very good rye soils.

It is estimated that oilseed rape yields on very good soils can exceed 3.5 t·ha^{-1}, while oscillating around 3.0 to 3.5 t·ha^{-1} on good soils (table 1). On medium soils, potential yields are within 2.5-3.0 t·ha^{-1}, but they can fluctuate from year to year. On poor and very poor soil, which in Poland make up around 5 million ha (43 % of the total arable land), rape yields are low and changeable [23].

Table 1

Suitability of soils for cultivation of oilseed rape and its potential yields

Soils	Agricultural suitability complex	Area		Potential yield, dt·ha^{-1}
		mln ha	%	
Very good [1]	1, 2, 10	3.65	24	36-40
Good [2]	3, 4, 8, 11	3.89	26	30-36
Medium [3]	5	2.42	16	25-30
Poor [4]	6, 9	3.19	23	20-25
Very poor [5]	7	1.64	12	15

Agricultural soil suitability complexes: 1 – wheat very good (1), wheat good (2) and wheat in mountainous areas (10); 2-wheat defective (3), rye very good (4), cereal and fodder strong (8), cereal in mountainous areas (11); 3 – rye good (5); 4 – rye weak (6), cereal and fodder weak (9), 5 – rye very weak (7).
Source: Kuś 2002a

In Poland, there are about 7.5 million very good and good soils, on which oilseed rape could be grown. This acreage corresponds to 50% of the total area of arable lands in the country. The distribution of these soils is extremely uneven. Their smallest percentage can be found in the following provinces: Śląskie, Opolskie and Świętokrzyskie, while the highest share is in the provinces: Lubelskie, Warmińsko-Mazurskie, Mazowieckie and Dolnośląskie (Table 2).

Table 2

Area of soils on which oilseed rape can be sown and the current acreage cropped with the plant

Specification	Area of soils suitable to grow oilseed rape	Area minus farms less than 10 ha in size	Area including oilseed rape cultivation limits		Current area cropped with oilseed rape
			20 % share in area of cropped fields	25 % share in area of cropped fields	
Poland	7539	4779.7	955.9	1194.9	951.1
Dolnośląskie	617	467.7	93.5	116.9	131.7
Kujawsko-pomorskie	549	438.7	87.7	109.7	115.6
Lubelskie	824	402.9	80.6	100.7	71.0
Lubuskie	120	98.4	19.7	24.6	37.3
Łódzkie	361	173.6	34.7	43.4	21.9
Małopolskie	531	79.7	15.9	19.9	8.3
Mazowieckie	657	369.2	73.8	92.3	39.0
Opolskie	353	274.6	54.9	68.7	76.6
Podkarpackie	486	109.4	21.9	27.3	20.7
Podlaskie	352	269.3	53.9	67.3	10.5
Pomorskie	367	307.2	61.4	76.8	82.6
Śląskie	235	87.0	17.4	21.7	21.4
Świętokrzyskie	371	101.7	20.3	25.4	8.6
Warmińsko-mazurskie	659	593.8	118.8	148.4	76.1
Wielkopolskie	616	479.2	95.8	119.8	118.8
Zachodnio-pomorskie	441	395.1	79.0	98.8	110.8

Source: the Main Statistical Office data and own calculations.

The area structure of farms

The size of a farm is crucial for the costs of production and levels of yields. As the acreage increases, the efficiency of work done by machines and tools improves. Furthermore, pests cause more damage on small plantations (the edge effect covers the whole plantation). Finally, it is more difficult to operate modern machinery, which is why small, fragmented farms are unable to implement adequate technology of oilseed rape seed production, making it uneconomical. Oilseed rape should be grown on farms where the area covered by a single field cropped with this plant is over 2 ha [24; 25]. Thus, to ensure the minimum area of a single oilseed rape field corresponding to the crop rotation requirements, a farm should have at least 10 ha of arable land. The fragmentation of farms means that only some can run large-scale cultivation of this crop, and large-scale cultivation is what ensures cost-effective production. The share of farms with more than 10 ha of arable fields in Poland is varied across Poland. The smallest percentage of such farms, just 10%, is in the Warmińsko-Mazurskie province, while the largest one, 85 %, can be found in the Małopolskie province. Having subtracted the total area covered by farms less than 10 ha large, the acreage of soils suitable for production of oilseed rape diminishes down to 4 779.7 thousand ha (Table 2).

The share in crop structure at farms

Oilseed rape belongs to crops with moderate crop rotation requirements. A large contribution of this plant to all sown crops leads to more damage caused by plant diseases and pests. In addition, it makes weed control more difficult. Budzyński and Zając [26] state rather firmly that oilseed rape should not be grown in continuous sequence, as these results in an inferior phytosanitary state and worse seed quality. The share of oilseed rape in crop rotation should not exceed 25 % (growing this plant on the same field every four years or less often). Considering the limiting factor, i.e. the structure of cropped plants, in which the share of oilseed rape should be no more than 20-25 %, the total acreage of soils in Poland on which this plant can be grown annually falls to 955.5-1 194.9 thousand ha. This means that the area of oilseed rape fields in the whole country, including organisational and economic considerations, could be increased by about 250 thousand ha. The data included in Table 2 indicate that no such increase is possible in the following provinces: Dolnośląskie, Kujawsko-Pomorskie, Lubuskie, Opolskie, Pomorskie, Wielkopolskie or Zachodnio-Pomorskie, where the total area of oilseed rape fields is already higher than an area defined by the factors limiting its cultivation.

Estimates of the acreage of farmland under energy crops are divergent [27; 28]. According to the Regulation of the Council of Minister of 23 July 2013 (Journal of Law, item 918) on the National Index Targets, and the authors' own calculations, the demand for biodiesel in 2015 equals 980 million l. With the current seed yield levels of this plant at 28.9 $dt \cdot ha^{-1}$ (a three-year average), about 984 thousand ha of fields should be dedicated to growing oilseed rape for biofuel purposes. Taking into account the acreage of fields on which rape is grown for the food industry (about 350 thousand ha), the total area of farmland cropped with this plant should be about 1.3 million ha. If the total area of oilseed rape fields remains unchanged, further development of using biofuels made from oil plant esters will experience problems due to the shortage of domestic raw materials.

Climatic conditions

In Poland, 95 % of oilseed rape fields are cropped with winter cultivars of this species, which is highly sensitive to temperatures in winter and early spring. Plants which have been well-hardened before winter can stand freezing temperatures down to -15 ºC without snow cover and will survive frosts down to -25 ºC under snow. However, oilseed rape plantations can also be damaged by subzero temperatures in spring. The plant is most susceptible to frost-kill damage in the last decade before flowering and the first two decades when in bloom [29]. Oilseed rape can be grown everywhere in Poland, but its production concentrates in the following provinces: Dolnośląskie, Kujawsko-Pomorskie, Lubelskie, Warmińsko-Mazurskie, Wielkopolskie and Zachodnio-Pomorskie. Figure 1, derived from long-term observations conducted by the IUNG Institute of Agrometeorology, illustrates the likelihood of frost damage to oilseed rape fields in different parts of Poland. The estimated data indicate that in the Podlaskie province frost damage occurs every 5 years on average, while in much of the area covered by the Mazowieckie province and the northern part of the Lubelskie province, rape

fields can be affected by frosts every 6 to 7 years. Consequently, these regions should be considered as less suitable for oilseed rape cultivation due to the frequent occurrence of frost damage.

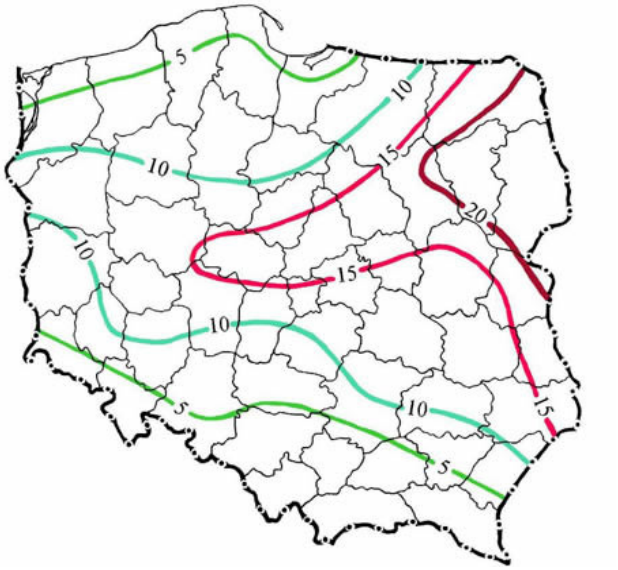

Fig. 1. **Probability (%) of the frost-kill damage to winter oilseed rape in different parts of Poland (IUNG 2001)**

Conclusions

1. The total acreage of soils on which oilseed rape could be grown in Poland (having considered the factors which limit its production) is no less than 955.5 thousand ha (at 20% share of this plant in the structure of grown crops). Should oilseed rape be sown on the same field every four years, this acreage increased to almost 1 195 thousand ha.
2. Oilseed rape can be cultivated all over Poland, but at present its production concentrates in the provinces of Dolnośląskie, Kujawsko-Pomorskie, Lubelskie, Opolskie, Pomorskie, Warmińsko-Mazurskie and Wielkopolskie.
3. In order to satisfy the demand of oilseed rape seeds both for production of food and fuels, it will be necessary to increase the acreage of fields cropped with this plant in the near future, which might not be possible due to certain organisational and economic constraints. The shortage of domestic production of an adequate amount of seeds will have to be compensated for by an increase in the yields of winter oilseed rape.

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