Article

Area under Rapeseed Cultivation as a Factor Differentiating the Economic Performance of Biodiesel Producers

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Abstract: The aim of this study was to assess the impact of the area under rapeseed cultivation on the economic performance and organization of farms. The study was conducted in 164 rapeseed farms in different Polish voivodeships. A targeted sampling procedure was used to select farms for the study. The studied population was divided into four groups depending on area under rapeseed cultivation rates. The selected farms were located in voivodeships with the highest rapeseed acreage rates of the total cropped area. The economic performance of the examined farms improved with increases in rapeseed area. Farms with larger rapeseed areas were characterized by higher production values and better economic performance. On average, the total production value per farm was highest in the group of farms with rapeseed areas of 20.1–30 ha. Similar results were noted when total production values were expressed per ha of arable land, per full-time employee and per man-hour. Total production value was lowest in farms with the smallest rapeseed areas. Farms with the largest areas under rapeseed cultivation achieved the highest farm household income. The farm household income values per full-time employee and per man-hour were highest in farms with the largest areas under rapeseed cultivation. The values of fixed assets and current assets increased with increases in rapeseed area. Most farms were run by owners with secondary school education. The highest percentages of farmers with university education were noted in farms with rapeseed areas of 10–20.1 ha (37.5%) and above 30 ha (30.4%). The vast majority of farms from all groups were run by male farmers. The research results could be useful for policy makers, because they indicate that rapeseed production can not only be profitable but can also be used for biofuel production.

Keywords: rapeseed; farms; economic performance; fixed and current assets

1. Introduction

Renewable energy sources (RES) are playing a key role in replacing energy from fossil fuels. The increasing demand for energy around the world is forcing the human race to search for new sources of energy [1]. RES are being used to fight against climate changes and to reduce the demand for fossil-based energy. RES contribute to energy security, safety and human health [2].

Zero-emissions energy sources can improve energy efficiency but can also affect internal national demand and improve the economic situation for producers. This is why it is also important to evaluate cost-efficiency reductions from GHG (greenhouse gasses) emissions [3].

The traditional economy is based on coal, oil and natural gases, which could have severe consequences, causing environmental problems and forcing the use of green power plants with advanced technologies [4,5].

One of such green energy sources is biofuels. The problem of biofuel production has been described in existing literature. Wicki [6] claimed that biodiesel and bioethanol are the most important first-generation biofuels, not only in Poland, but also globally. However, the production of biodiesel has caused food price increases. The problem can be solved at least partially by using second-, third- and fourth-generation biofuels. Second-generation biofuels were discussed by Miscanthus and Willow [7]. The demand for renewable energy can be filled by third- and fourth-generation biofuels, which include engineered energy crops, such as algae and feedstock [8].

The literature regarding rapeseed cultivation and the associated effects on the economy is very rich. Rapeseed is one of the most widely cultivated crops in Poland, and winter oilseed rape accounts for 97% of total oilseed crops grown in the country [9]. Other oilseed crops that are produced in Poland include spring oilseed rape, sunflower, flax, soybean, poppy and mustard [10]. Poland ranks third in the European Union in terms of the area under rapeseed cultivation, and it supplies 11% of rapeseed and 9% of rapeseed oil and rapeseed meal on the European market [11]. Poland is the sixth largest rapeseed producer in the world [12]. In Poland, the share of winter oilseed rape of the total cropped area increased from 3.6% in 2000 to 9% in 2015 [9,11].

Rapeseed plays a very important role in food production and energy generation. It is processed into food and feed and is also used in the petrochemical industry. After Poland joined the European Union and introduced biofuel policies, the area under rapeseed cultivation increased by 359,800 ha between 2005 and 2007 [9]. The increase in rapeseed area resulted mainly from a greater demand for biofuels [13]. Rapeseed is used in the biodiesel sector and in renewable energy generation [14–16]. The demand for rapeseed in the petrochemical and food industries leads on increases in production and in the prices of both rapeseed oil and biodiesel [17].

Rapeseed is presently regarded as one of the most profitable agricultural crops, and it is produced not only in large-scale farms specializing in crops, but also in small family farms that raise livestock. The number of rapeseed producers increased from 45,000 in 2005 to around 90,000 in 2017, showing the significance of this oilseed crop in Poland. Rapeseed production was highest in farms where the average area under rapeseed cultivation exceeded 20 ha [18].

Rapeseed cultivation is becoming the most profitable type of agricultural activity in Poland and the EU. Rapeseed is widely used in food and feed production and in the petrochemical industry, and it creates numerous opportunities for farmers relative to other crops, such as wheat. However, farmers require access to high-quality soils to derive the expected benefits from rapeseed production [19].

Analysis of the Polish and international literature proves the positive benefits of rapeseed cultivation for agriculture and the economy. In most of the literature, winter oilseed rape is considered to be the main source of first-generation biofuels [20]. Moreover, information regarding the area under rapeseed cultivation and number of rapeseed producers is available. In addition, the information regarding biodiesel production in Poland and Europe is known. Previous papers have presented environmental and economic factors shaping the efficiency of rapeseed farms in Poland [19]. Fertilization as a factor shaping the yield of oilseed rape is also described in the literature [21,22]. Attention has also been focused on the optimization of rapeseed production [23]. However, little attention has been paid to the economic performance of rapeseed producers. This article covers the gaps in terms of the economic performance of biodiesel producers, the values of fixed and current assets and the profile of farm owners. This knowledge in not accessible in the Polish and European literature, meaning our paper fills in gaps in the existing literature.

In view of rapeseed's important role in the production of biofuels, edible oils and rapeseed meal, this study was undertaken to determine the extent to which the area under rapeseed cultivation influences the economic performance of farms. The main aim of this study was to assess the economic performance of Polish rapeseed farms differing in rapeseed cultivation area. The following specific objectives were pursued as part of the

main research aim, namely evaluating the economic performance of Polish rapeseed farms, determining the values of fixed and current assets in rapeseed farms and determining the profile of rapeseed farm owners.

To achieve this goal we had to answer the following questions:

1. What is the rapeseed cultivation area?
2. What is the economic situation for rapeseed farmers?
3. What is the profile of rapeseed farm owners?

Hypothesis 1 (H1). *Increases in rapeseed area in farms determine their economic performance.*

Hypothesis 2 (H2). *The average area of rapeseed cultivation is larger than average farm area in Poland, and the increase in farm area under study is the effect of energy policies of the EU (European Union).*

The information obtained from the research results could be useful for farmers because it indicates that rapeseed production is profitable. However, the contribution of rapeseed does not exceed 30% in the cultivation area. Information can be dervied regarding for which farmers and at which scale of production should rapeseed cultivation be subsidized. The research results could also be useful for academics because they show that rapeseed production holds scientific promise.

This article is divided into six sections. The introduction is followed by a description of environmental conditions that favor rapeseed production. The third section describes the research materials and methods. The results, including the organization and economic performance of the analyzed farms, are presented in the fourth section. The profile of the surveyed rapeseed producers is also presented in this chapter, while the discussion is presented in the fifth section. The results are summarized and conclusions are formulated in the sixth section.

2. Environmental Conditions in Rapeseed Production

Human activities and agricultural production are determined by environmental conditions, including the climate, soil, landform and water supply [24,25]. Environmental conditions influence agricultural production technologies and management systems. These change over time and have manifested as global warming. As a result, the area under crops that thrives at high temperatures has increased and the growing season has been prolonged [26].

Agricultural land-use practices and agricultural landscapes are largely shaped by the availability of water. Land drainage systems that regulate water supply and remove excess water are built to create supportive conditions for crop production. However, ineffective drainage can lead to excessive soil drying or water logging [27]. Rapeseed has relatively high water requirements and should be grown in soils with moisture contents corresponding to a minimum of 32–35% field water capacity [28]. According to Muśnicki et al. [29], the optimal precipitation for rapeseed germination and emergence is 10–20 mm. Short dry spells only compromise rapeseed growth in fall, when well-developed taproots absorb water in deeper soil horizons [30].

Rapeseed is particularly sensitive to temperature fluctuations in spring. Plants break dormancy and begin to accumulate water, while spring frosts can damage crops [31]. The youngest (lowest) part of the root is most susceptible to frost, and if damaged it can delay maturation, lead to changes in plant habit, or even decrease yields by more than 10%. Rapeseed is temperature-sensitive, although the effects of the thermal factor on germination and rosette formation can be reduced by selecting an optimal sowing date [30]. Healthy and well-formed rapeseed plants enter winter dormancy at temperatures as low as −15 °C without snow cover [32].

Polish voivodeships experience different temperatures during the year. The risk of rapeseed freezing is highest (20%) in Podlasie, in the eastern parts of Lublin and Warmia

and Mazury and in the northern part of Mazovia [33]. Between 2005 and 2017, the lowest mean annual temperature was noted in 2010 (7.5 °C), while the highest mean annual temperature was in 2014 (9.6 °C) [34]. In Poland, rapeseed production is largely determined by soil quality, the risk of climate change and the production system. Winter oilseed rape cultivation is rare in north-eastern Poland, Scandinavia, or the Baltic countries on account of the high freezing risk [35].

In spring, temperature plays a less important role, and the significance of the rainfall distribution increases. The optimal precipitation for rapeseed cultivation is 220 mm, including 45 mm in April, 70 mm in May, 75 mm in June and 30 mm in July. The water deficit between the beginning of the growing season and bud development is least detrimental to rapeseed yields. However, insufficient rainfall during maturation can inhibit silique and seed formation, thereby compromising seed yields and seed oil contents [32]. In 2004–2014, the mean annual precipitation reached 644 mm.

Soil quality is also an important consideration in rapeseed production. The granulometric composition of the soil determines its fertility and water-holding capacity. Polish soils differ considerably in terms of their physical, chemical and physicochemical properties. Light soils (loose sand and slightly loamy sand—34.6%; light loam—15.8%; loamy sand—10.2%) with low contents of colloids (humus and clay) are predominant, which explains the lower crop yields and the presence of periodically and permanently dry soils in Poland [36]. According to the Polish soil quality classification system, 35.2% of arable land belongs to soil quality classes IV a and b, 18% to classes III a and b, 37.3% to classes V and VI and 3.7% to classes II and I, while 5% of arable land is classified as mountain soil [37].

Rapeseed thrives in soils that are able to retain sufficient amounts of water but eliminate excess water. Fertile soils with good tilth that are free of weeds and rich in nutrients are particularly recommended, in contrast to light, compact and flooded soils.

The preceding crops play an important role in rapeseed production. The most suitable preceding crops for rapeseed include winter cereals, legumes, cereal and legume mixtures, early potatoes, pasture grasses, red clover, alfalfa and other perennial plants.

The required tillage treatments for rapeseed cultivation include plowing to a depth of 20–22 cm and presowing treatments, including harrowing, to avoid the loss of soil moisture that is accumulated in fall. These treatments create the optimal conditions for seed sowing at an appropriate depth. Soil should be cultivated but not dry. Deep plowing prevents germinating seedlings from breaking the soil surface, weakens seedlings and increases the risk of disease.

The sowing date is yet another important consideration in rapeseed production. In Poland, winter oilseed rape is usually sown between the 15th and 25th of August. It is sown earliest (15 August) in north-eastern Poland and latest (25 August) in western Poland.

Rapeseed should be protected against dicotyledonous, monocotyledonous and self-seeding weeds before or immediately after sowing. The most dangerous diseases of rapeseed include seedling blight (controlled by seed dressing), dry rot, Alternaria leaf spot and gray rot [38].

3. Materials and Methods

3.1. Data Sources

The study involved 164 rapeseed farms. Farm performance statistics for 2017 were acquired in 2018 with the use of a questionnaire. Farms from different Polish voivodeships were selected for the study based on the share of rapeseed acreage from the total cropped area.

Arable land was the predominant category of agricultural land, which ranged from 87.9% of agricultural land in the first group to 96.4% in the third group of farms. Farms where the rapeseed areas exceeded 30 ha were characterized by the largest areas of meadows and pastures, which could be explained by the fact that these farms also produced

livestock, including dairy cows and cattle. Grasslands are an important source of roughage for ruminants. Meadows and pastures are a cheap source of feed in milk and beef production.

The soil quality index, also referred to as the soil valuation classification, is based on the evaluation of the usable quality and the classification of soil suitability for agricultural purposes based on the fertility of this soil, water relations in the soil, the degree of soil culture and the soil production capacity in specific habitat conditions, which depend mainly on the climate, topography and economic elements (growing conditions) [39]. The evaluated farms were characterized by a predominance of moderate-quality (IV a and IV b) and high-quality soils (III a and III b) (Table 1).

Table 1. Soil quality classes and soil quality index values.

Soil Quality Class	Area under Rapeseed Cultivation (ha)			
	Up to 10	10.1–20	20.1–30	Above 30
I—the best	0.3	0.56	2.86	5.78
II—very good	3.29	12.41	4.82	30.17
III a—good	7.58	16.31	24.50	45.17
III b—medium good	10.86	19.61	30.94	58.17
IV a—medium quality, better	10.23	24.72	41.80	89.67
IV b—medium quality, inferior	6.30	21.44	24.90	46.92
V—weak	3.02	18.00	8.67	25.11
VI—weakest	0.19	4.16	2.16	15.53
Total	41.77	117.21	140.65	315.52
Soil quality index	1.13	1.09	1.08	1.08

Source: own elaboration.

The selected farms were located in voivodeships with the highest area under rapeseed cultivation rates. The greatest numbers of farms were surveyed in the voivodeships of Lower Silesia (13.7%, 19 farms), Wielkopolska (12.4%, 18 farms), Kuyavia-Pomerania (12.1%, 18 farms), Western Pomerania (11.7%, 18 farms), Pomerania (8.7%, 17 farms), Opole (8.0%, 17 farms), Warmia and Mazury (7.9%, 17 farms), Lublin (7.5%, 12 farms), Mazovia (4.1%, 12 farms), Lubusz (3.6%, 8 farms) and Łódź (3.1%, 7 farms). Farms where rapeseed cultivation areas accounted for less than 3% of the total cropped area were not considered. Farms were selected by targeted sampling based on two criteria: rapeseed production and the farmer's consent to participate in the study. Data were acquired with the assistance of Agricultural Advisory Centers.

3.2. Methods

The analyzed farms were divided into four groups based on rapeseed area: up to 10 ha (50 farms), 10.1–20 ha (40 farms), 20.1–30 ha (28 farms) and above 30 ha (46 farms). This classification supported the evaluation of differences in resources, organization of crop and livestock production and economic performance in farms with different area under rapeseed cultivation rates.

We analyzed different parameters relating to the economic performance of rapeseed farms. We evaluated the fixed and current assets, livestock production, crop production, gross income, total costs, total production and farm household income.

All parameters in the paper were based on the FADN (Farm Accountancy Data Network) methodology [40].

Fixed assets are some of the factors that determine the performance of agricultural farms. Fixed assets include land, residential buildings, farm buildings, machines, equipment and breeding stock. We measured the fixed asset values in Polish currency (PLN).

In farms, current assets are the resources that are used in agricultural production during the year. According to the FADN methodology, current assets in agriculture include

non-breeding stock and inventories of agricultural products (stocks of all plant- and animal-based products). Current assets were measured in Polish currency (PLN).

Total production includes livestock production and crop production. Livestock production includes the livestock production value as well the value of animal products (Figure 1). Livestock production includes sales and differences in animal values in the accounting year and in handing over to the household. Livestock production is diminished with the purchase of animals. The calculation is carried out for Equidae, cattle, sheep, goats, pigs, poultry and other animals. Regarding livestock animals, the value is estimated via the difference in the value of the animals due to changes in prices and is also considered during the accounting year. The production of animal products includes the sales, transfer to the household, internal consumption and stock difference. Animal products include: milk and milk products from cows, sheep and goats; wool; chicken eggs, honey; and other animal products (manure, other eggs and other) [40].
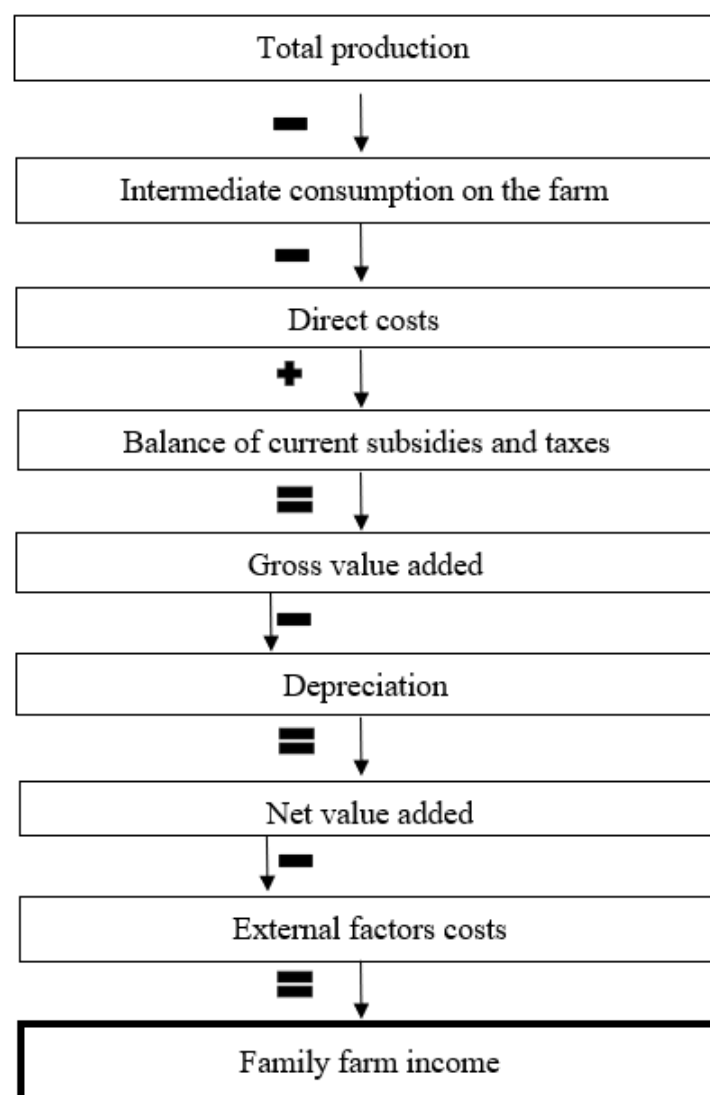
Figure 1. Block diagram of family farm income. Source: studies based on [40].

Crop production includes sales, internal consumption, handing over to the household and the inventory difference for all animals products on the farm. This was measured in PLN [40]. The total production value, gross value added, net value added and agricultural income were determined for the analyzed farms. The farm income was calculated according to the scheme shown in Figure 1.

The total costs include direct costs, general economy costs, depreciation and external factor costs. Operating expenses are included here for an agricultural holding incurred during production in the accounting year. Inputs include potential commodity products manufactured in a farm and consumed as part of the operational activity for production purposes (seeds and seedlings and feed for the animals). Farm taxes and other charges are not included in the total costs but are included when calculating the balances of subsidies and taxes related to operating and investment activities. Purchase values are not included in the total animal costs due to their inclusion in the calculation of value production [40].

The total production includes sales, transfers to the farm household consumption, household consumption agriculture, inventory differences and value differences for animals resulting from changes in prices, which are reduced when buying animals [40].

Farm household income includes fees for manufacturing (for farms with legal land personality only and capital), the operating activity of the agricultural sector and the risk taken in running a farm in the accounting year. This income is calculated by adding the balance of payments to the net value added and taxes on investments and subtracting the cost external factors [40].

The presence of associations between the studied variables was determined using the chi-squared test of independence, and the strength of these correlations was measured by calculating Cramer's V value. The calculated values of the correlation coefficient were interpreted as follows [41]:

− Below 0.2—no linear correlation between the analyzed attributes;
− 0.2 to 0.4—low (distinctive) linear correlation;
− 0.4 to 0.7—moderate correlation;
− 0.7 to 0.9—strong correlation;
− Above 0.9—very strong correlation.

In order to determine the impacts of the chosen factors on the income of rapeseed farms, a regression method was used. We used multiple regression, which is described by the following formula [42]:

$$y = a \times x + b \tag{1}$$

a—directional factor of the straight regression;
b—free expression of a simple regression r_{xy};
where:

$$a = \frac{\sum \left(X_i - \dot{X} \right) \times \left(Y_i - \dot{Y} \right)}{\sum \left(X_i - \dot{X} \right)^2} = \frac{\text{cov}(X, Y) x^2}{\sigma_{\dot{x}}^2} = r_{xy} \times \frac{\sigma_y}{\sigma_x}$$

$b = \dot{Y} - a\dot{X}$

$$X_i, Y_{i,} - variable\ values\ X,\ Y$$

$\dot{X}, \dot{Y}$—average of variables X, Y;
cov (X, Y)—covariance of variables X *i* Y;
σ_x, σ_y—standard deviations X *i* Y;
r_{xy}—correlation coefficient between X *i* Y;

Variables were sequentially explained for Y_1 (household farm income for each person fully employed), Y_2 (household farm income) and Y_3 (household farm income per ha farmland). However, the explanatory variables were X_1 (farm area), X_2 (rapeseed area), X_3 (value of fixed assets), X_4 (value of current assets) and X_5 (total costs). We used the least squares method to conduct the linear regression analysis.

Based on the regression equation, the strength of the relationship (multiple regression coefficient) between the described (dependent) variables and the individual describing (independent) variables was calculated. The obtained results of the analyses were collected for three types of tables containing the appropriate means and standard deviations (SD) of the examined features, the linear correlation coefficient between the examined features and multiple regression equations, taking into account the types of farms (Figure 2). The

regression equation was assessed with the F-test, which informs whether a regression model provides a better fit to the model than a model having no independent variables. R-squared is related to the F test and informs how well a model fits to the data. The standard deviation (SD) and standard error of the mean describe the characteristics of sample data and are useful in explaining statistical results. The significance assessment was made at a *p*-value level of 0.05. The *p*-value was used as an alternative to rejection points, whereby a smaller value indicates that there is stronger evidence in favor of the alternative hypothesis [42].
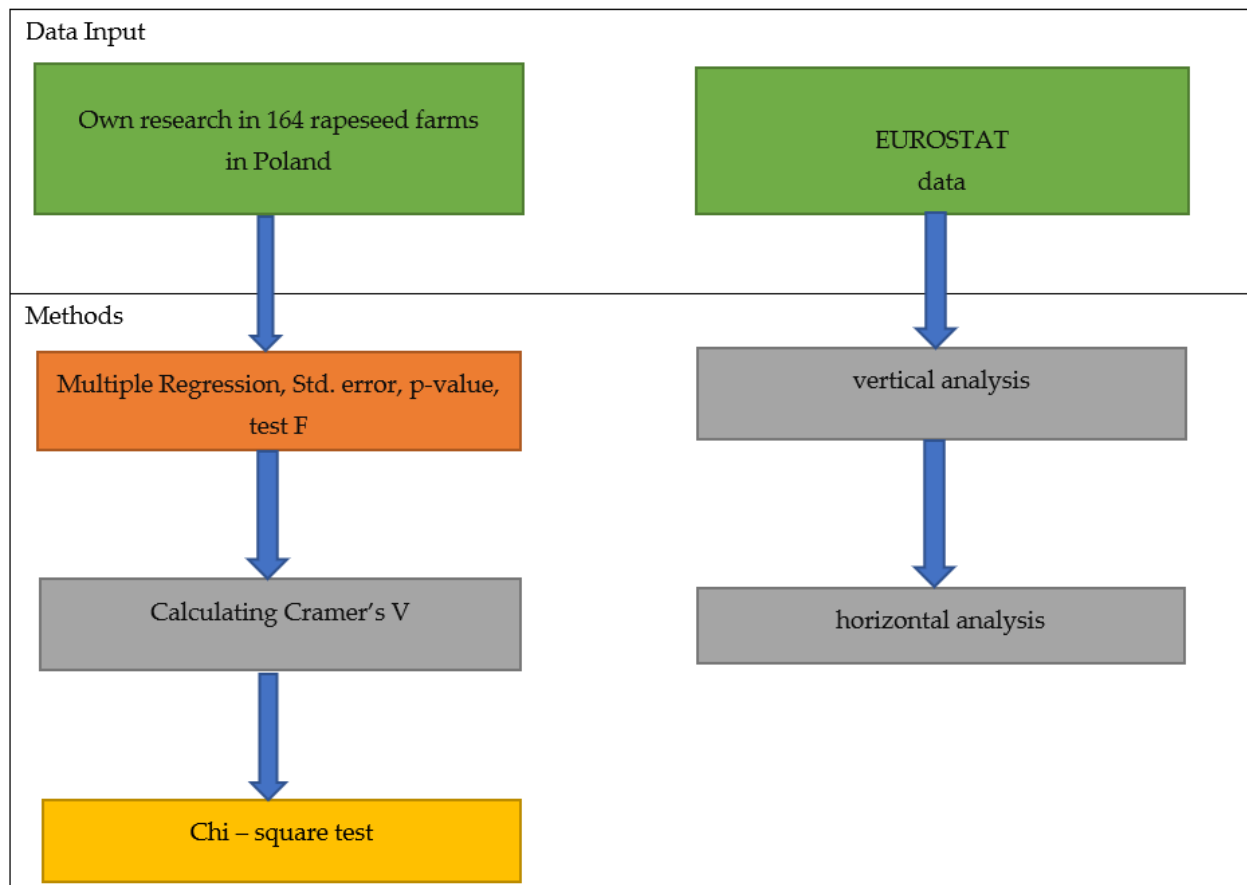

Figure 2. Overview of the methods. Details can be found in the text. Source: own study.

4. Results

4.1. Development of Biodiesel in Poland

Rapeseed is one of the most important sources for biodiesel production. It is a demanding plant and requires good quality land. Europe is the most important producer of rapeseed [43]. The rapeseed plant is called canola in the US and Canada and is used to produce biodiesel in these countries also. The cultivation of these plants for biodiesel purposes can be considered economically, energetically and environmentally acceptable [44]. Biodiesel can also be produced from soybean and sunflower plants. The production of theses crops can be important for several reasons, namely it can reduce carbon dioxide (CO_2) emissions and the biodiesel can be used for heating in houses and as a fuel in combustion engines [45,46]. The biodiesel used in engines provides satisfactory results, even as an alternative fuel for marine diesel engine applications [47]. There are increasingly lower supplies of fossil energy sources, while the interest in renewable energy sources is increasing. This group of energy sources includes wind energy, solar energy, waterpower, geothermal energy, biomass energy and biofuels. Oil from energy crops is considered to be the most important energy of the 20th century [48,49]. Another reason for the biodiesel

growth in Europe is environmental protection [50]. Increasing greenhouse gas (GHG) levels have created problems in the environment. Diesel from fossil fuels has contributed to environmental pollution problems, while biodiesel is a source of energy that can decrease these problems [51]. Another issue is energy security. The EU is highly dependent on huge imports of fossil oil as an energy source, while the EU's own production of biodiesel can fill in the increasing demand [52]. The prices of fossil fuels are also increasing and the world petroleum reserves (petrol and diesel) are depleting. The direct use of biofuels is also difficult because of their higher viscosity. The viscosity can by reduced by applying different methods, such as blending, pyrolysis, microemulsification and transesterification [53]. However, biodiesel is environmentally beneficial because it is biodegradable and nontoxic. It also has a low emissions profile. [54,55]. The production of biodiesel is expensive and there are different methods that can reduce the costs of production [56]. The reduction of biodiesel production costs can be achieved by improving the production technologies and productivity yields of plants and reducing the raw material costs and capital costs [57,58].

Figure 3 depicts figures relating to pure biodiesel production in European countries in 2019 based on Eurostat data [59]. The biggest producers of pure biodiesel in Europe are France, Poland, Germany and the United Kingdom. Countries such as Croatia, Cyprus, Denmark, Estonia, Iceland, Ireland, Luxemburg, Malta, Norway, Portugal and Slovenia did not produce pure biodiesel in 2019.
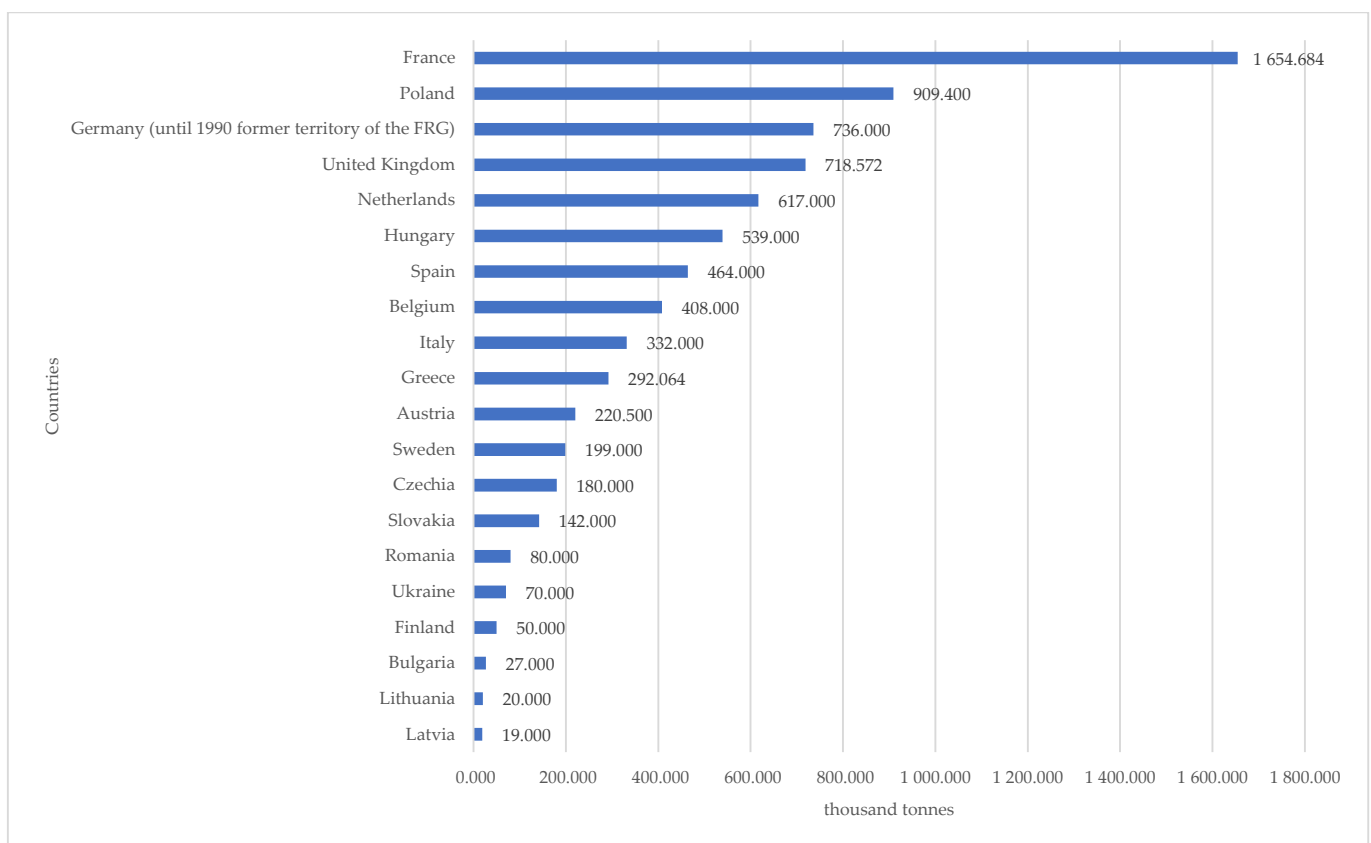
Figure 3. Pure biodiesel production in EU in 2019 (thousand tons). Source: own elaboration based on Eurostat data [55].

The increase in biodiesel production in Europe is due to wide application of biodiesel in engines. However, the higher viscosity of biodiesel is a factor making it difficult to directly use vegetable oil. This is why different methods are used to reduce the viscosity of vegetable oils, such as blending, pyrolysis, microemulsification and transesterification [60–62].

The European Union (EU) has made a decision to increase the share of biofuels up to 10% of the total transport fuel consumption by 2020 (Figure 4). Poland has also increased its production of biodiesel. Pure biodiesel production increased in Poland from 476,000 tons in 2006 to 909,400 tons in 2019 [63]. This increase can be attributed to the increase in rapeseed production in Poland, as it is the main source of biodiesel in the country.

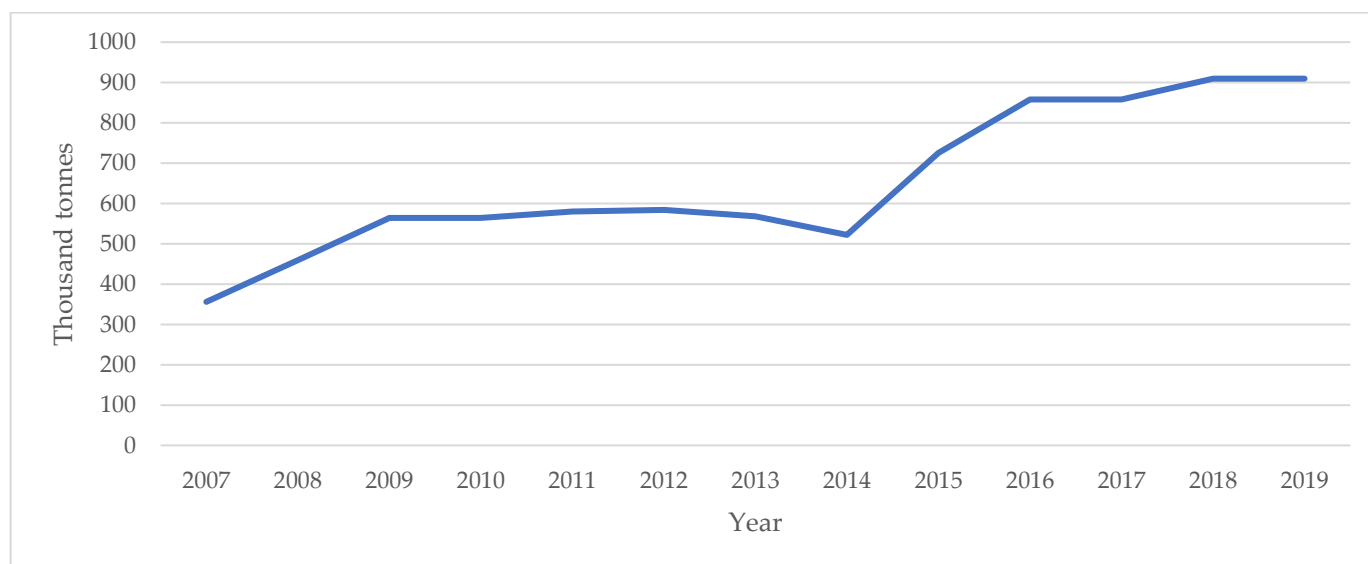**Figure 4.** Pure biodiesel production in Poland in 2007–2019 (thousand tons). Source: own elaboration based on Eurostat data [55].

4.2. Characteristics of Fixed and Current Assets of Rapeseed Farms

In the analyzed farms, the values of most fixed assets increased with increases in the rapeseed cultivation area (Table 2). The breeding stock (female animals) was the only fixed asset value that was lower in farms with rapeseed areas of 10.1–20 ha than in farms where with rapeseed areas of up to 10 ha.

Table 2. Values of fixed and current assets vs. area under rapeseed cultivation for the analyzed farms.

Asset	Area under Rapeseed Cultivation (ha)			
	Up to 10	**10.1–20**	**20.1–30**	**Above 30**
Fixed assets				
Land (PLN)	1,620,830.4	2,228,065.0	4,395,325.0	9,397,173.9
Residential buildings (PLN)	242,016.5	323,445.0	456,178.6	395,160.9
Farm buildings (PLN)	229,746.4	403,760.0	667,785.7	803,239.1
Other buildings (PLN)	32,226.5	36,512.5	64,250.0	42,782.6
Tractors and machines (PLN)	387,084.0	548,455.0	829,591.1	1,101,024.0
Breeding stock (PLN)	36,248.0	23,950.0	49,285.7	199,143.5
Total fixed assets	2,548,151.8	3,564,187.5	5,715,784.1	11,938,524.0
Current assets				
Non-breeding stock (PLN)	80,386.2	69,287.0	138,960.7	52,493.3
Product inventories (PLN)	54,023.0	88,685.1	51,501.6	169,366.3
Inventory purchases (PLN)	25,501.7	28,249.7	66,515.3	125,790.0
Total current assets	159,910.9	186,221.8	256,977.6	347,649.6

Source: own elaboration.

The relationship between rapeseed area and the value of fixed assets was analyzed in the chi-squared test, whereby two research hypotheses were verified. The null hypothesis (H_0) postulated that no statistical relationship exists between the tested variables, whereas the alternative hypothesis (H_1) postulated the presence of such a relationship. The hypothe-

ses were verified at a significance level of $\alpha = 0.05$ (Table 2). The *p*-value in the chi-squared test was lower ($p = 0.025$) than the alpha level ($\alpha = 0.05$). Therefore, the null hypothesis postulating the absence of a statistical relationship between the value of fixed assets and the rapeseed area was rejected. The above indicated that a statistically significant relationship existed between the rapeseed area and the value of fixed assets. Cramer's V showed a positive value (0.579), which pointed to a positive and moderate correlation.

In the studied group of farms, the current assets increased with the rise in the rapeseed area (Table 2). The non-breeding stock was the only current asset value that was lower in farms with rapeseed areas above 30 ha than in farms with smaller rapeseed areas. Current assets play an important role in agricultural farms. Similarly to inventories, current assets decrease a farm's liquidity; therefore, their volume and value should not be excessive. Agricultural products are perishable goods, which is why high inventories and other current assets can generate losses in farms. The value of purchased stocks was the highest in farms with rapeseed areas above 30 ha (PLN 125,790.0).

The relationship between the value of current assets and the area under rapeseed cultivation was analyzed in the studied farms with the use of the chi-squared test of independence. The *p*-value in the chi-square test was lower ($p = 0.0045$) than the alpha level ($\alpha = 0.05$); therefore, the null hypothesis postulating the absence of a relationship between these variables was rejected. The above implied that current assets were influenced by the rapeseed area. The calculated value of Cramer's V (0.453) pointed to a moderate correlation between these variables.

4.3. Livestock and Crop Production for Rapeseed Farms

Livestock production rates differed in the studied farms. The livestock populations (cattle and pigs) generally increased with increases in rapeseed area. However, the pig populations were smaller in farms with rapeseed areas above 30 ha than in farms with rapeseed areas of 20.1–30 ha (Table 3).

Table 3. Livestock production and area under rapeseed cultivation in the analyzed farms.

Item	Area under Rapeseed Cultivation (ha)			
	Up to 10	10.1–20	20.1–30	Above 30
Cows (head)	8.4	3.8	7.0	25.4
Milk yield per cow (L)	6583	5560	6500	7267
Pigs, including sows (head)	116.5	105.0	339.0	8.0
Piglets per sow (head)	16	20	19	20
Other cattle (head)	5.0	1.2	0.0	7.6
Calves (head)	3.0	2.5	3.2	19.9
Large livestock (head)	47.8	74.0	111.3	43.9
Large livestock per 100 ha of farmland (head)	115.7	116.9	93.8	16.8

Source: own elaboration.

The presence of statistical relationships between rapeseed area and livestock population (large animals) was analyzed in the studied farms with the use of the chi-squared test of independence. The *p*-value in the chi-square test was higher ($p = 0.065$) than the alpha level ($\alpha = 0.05$); therefore, the null hypothesis postulating the absence of a relationship between these variables could not be rejected. The above implied that the livestock population increased with an increase in rapeseed area. The calculated value of Cramer's V (0.009) pointed to a positive but very weak correlation between these variables.

The studied farms differed in their areas under cereal cultivation. The increase in rapeseed area was accompanied by an increase in the area under wheat, triticale and barley cultivation. In turn, the area under oat and rye cultivation, cereals that are used as animal feed, was smaller in farms with the largest rapeseed area (Table 4).

Table 4. Crop production in the analyzed farms with different area under rapeseed cultivation rates.

Crop Production	Area under Rapeseed Cultivation (ha)			
	Up to 10	10.1–20	20.1–30	Above 30
Area under wheat (ha)	12.1	20.9	39.2	119.7
Area under rye (ha)	0.7	2.3	4.4	2.6
Area under oats (ha)	0.1	1.6	0.0	0.0
Area under barley (ha)	3.9	5.3	5.1	11.0
Area under triticale (ha)	4.4	5.1	5.0	5.5
Area under rapeseed cultivation (ha)	7.4	16.3	26.5	77.4
Share of rapeseed in crop structure (%)	27.5	31.2	27.3	33.6
Share of cereals in cropped area (%)	63.2	62.7	67.7	55.4
Value of mineral fertilizers (PLN)	42,284.0	63,740.8	128,248.2	287,510.0
Average cereal yield (t/ha)	6.0	5.7	6.7	6.9
Average rapeseed yield (t/ha)	4.0	4.2	4.0	4.3

Source: own elaboration.

4.4. Economic Situation for Rapeseed Farms

The costs associated with the purchase of fertilizers and crop protection agents also increased with the increase in rapeseed area, which was accompanied by higher cereal yields. The cereal yields were highest in farms with rapeseed areas above 30 ha (6.9 t/ha).

The gross farm income levels differed across the analyzed groups of farms. In all farms, the sale of crops was the predominant source of income, which increased with the increase in rapeseed area. The sale of crops had the smallest share of the total income of farms with rapeseed areas of up to 10 ha (48.5%), and its share in the income of farms with rapeseed areas above 30 ha reached 74.7% (Table 5).

Table 5. Gross income values and area under rapeseed cultivation rates in the analyzed farms (PLN).

Source of Income	Area under Rapeseed Cultivation (Ha)			
	Up to 10	10.1–20	20.1–30	Above 30
Sale of crops	165,499.8	248,869.5	1,946,232.0	1,328,607.0
Sale of livestock	115,310.5	107,422.8	251,889.9	251,299.8
Sale of other products	0.0	0.0	0.0	0.0
Sale of machines, scrap metal, etc.	170.0	1357.5	607.1	2195.7
Sale of fruit	150.0	450.0	0.0	6957.0
Employment outside the farm	3092.0	225.0	3571.0	3195.7
Machine services (tractors, combine harvesters)	1960.0	11,950.0	16,164.3	8521.8
Machine repair services	0.0	250.0	5357.1	217.4
Rents, insurance compensation, pension	424.0	4166.3	114.3	717.4
Direct payments	53,753.8	50,901.6	113,751.5	175,384.5
Other farm-related income, such as agritourism	848.0	4775.0	1571.4	1434.8
Total	341,208.1	430,367.7	2,339,258.6	1,778,531.1

Source: own elaboration.

Another source of income was the sale of livestock. An analysis of livestock production revealed a different correlation compared with crop production. The share of farm income derived from the sale of livestock decreased with an increase in rapeseed area. Livestock production accounted for the highest share of total income of farms with rapeseed areas of up to 10 ha (33.8%) and 10.1–20 ha (25.0%). The analyzed parameter was determined at 10.8% in farms with rapeseed areas of 20–30 ha and at 14.0% in farms where the area under rapeseed cultivation exceeded 30 ha. In turn, the income generated by machine services (tractors and combine harvesters) was the highest in farms with rapeseed areas of 20.1–30 ha (PLN 16,164.3) and 10.1–20 ha (PLN 11,950.0).

Direct payments accounted for a large portion of farm income. The proportions of direct payments in farm income differed across groups and ranged from 4.9% in farms with rapeseed areas of 20–30 ha to 15.8% in farms with rapeseed areas of up to 10 ha. However, due to their type, the value of direct payments per farm increased with increases in the area under rapeseed cultivation and was the highest in farms with rapeseed areas above 30 ha (PLN 175,384.5). Direct payments are an important source of agricultural income in Poland [64].

The presence of statistical relationships between rapeseed area and income from the sale of crops was also investigated. The *p*-value in the chi-squared test of independence ($p = 0.0023$) was below the alpha level ($\alpha = 0.05$); therefore, the null hypothesis was rejected in favor of the alternative hypothesis postulating that the analyzed variables are bound by a statistical relationship. The presence of a positive although weak correlation was confirmed by the calculated value of Cramer's V (0.223).

Concentrate purchase was the largest expense out of the total costs of farms with the smallest area under rapeseed cultivation, which can be attributed to livestock production. The costs associated with concentrate purchase decreased with increases in rapeseed area, which indicated that larger farms tended to specialize in crop production.

Mineral fertilizers (calcium, nitrogen, phosphorus and potassium fertilizers) were also significant cost items in all groups of farms. The value of mineral fertilizer purchases increased with an increase in rapeseed area (Table 6). The costs of nitrogen fertilizers were highest in farms with rapeseed areas of up to 30 ha, whereas the costs of phosphorus fertilizers predominated in farms with a larger rapeseed area. This indicates that the costs associated with the purchase of phosphorus fertilizers were the highest in farms with the largest area under rapeseed cultivation. These results are consistent with the findings of Jankowski et al. [65], who observed that phosphorus significantly contributes to rapeseed yields and the quality of rapeseed biomass.

Table 6. Total annual costs in the analyzed farms (PLN).

No.	Type of Cost	Area under Rapeseed Cultivation (ha)			
		Up to 10	10.1–20	20.1–30	Above 30
1	Purchase of seeds and seedlings	6990.5	8844.25	17,710.0	22,963.0
2	Purchase of calves, heifers and other livestock	2598.0	8667.5	4135.7	6260.9
3	Purchase of concentrate	20,590.8	19,900.0	43,892.9	29,940.9
4	Purchase of straw and hay	3182.8	0.0	0.0	0.0
5	Calcium fertilizers	4106.0	9060.0	29,885.6	18,709.1
6	Nitrogen fertilizers	18,055.6	27,708.7	56,201.1	94,334.8
7	Phosphorus fertilizers	9201.0	18,490.0	46,015.0	105,813.0
8	Potassium fertilizers	8907.5	16,012.5	30,101.8	56,524.8
9	Crop protection agents	11,243.3	13,580.0	35,539.3	64,417.4
10	Veterinary drugs and services	2638.0	3815.0	4678.6	15,304.3
11	Cleaning products	990.4	980.0	810.7	695.6
12	Solid fuel (coal, wood, coke)	2227.8	2265.0	3042.9	2626.1
13	Gas (LPG cylinders, autogas)	690.0	503.5	976.8	434.3
14	Leaded gasoline	1780.4	891.5	1439.3	803.3
15	Diesel oil	20,781.9	28,038.7	56,116.8	11,8094.9
16	Fuel oil	1092.0	1300.0	1475.0	934.8
17	Lubricants	994.6	1814.7	2582.1	4430.4
18	Mains water	2150.6	2445.0	3653.9	2910.9
19	Electricity (kWh)	4904.3	5893.5	7507.1	7154.5
20	Telephone, radio and television license fees	1334.8	2008.5	2050.0	1291.3
21	Spare parts	3223.0	6000.0	12,214.3	7239.1
22	Other repair items	742.0	1157.5	1800.0	2293.5
23	Machine consumables	542.8	1912.5	4003.6	2565.2
24	Paint, varnish, etc.	304.0	486.2	910.7	808.7
25	Construction materials for building repairs	518.0	1230.0	1428.6	4934.8
26	Construction and repair services	150.0	600.0	1071.4	141.3
27	Workshop services (technical, repair, etc.)	326.0	1787.5	2178.6	1434.8
28	Tractor services	20.0	625.0	71.4	543.5
29	Harvester services	1276.2	1205.0	2000.0	1000.0
30	Transport services	210.0	347.5	250.0	717.4
31	Other inputs	200.0	375.0	535.7	0.0
32	Total material costs	132,488.4	222,672.3	366,485.5	565,668.6
33	Land purchases	31,000.0	20,125.0	18,035.7	67,695.6
34	Machine purchases	28,180.0	25,775.0	104,821.4	106,739.1
35	Construction materials	16,300.0	17,150.0	3928.6	3260.9
36	Construction services	100.0	500.0	1428.6	3260.9
37	Other costs	200.0	375.0	714.3	0.0
38	Capital replacements and investments	86,080.0	63,925.0	128,928.6	180,956.5
39	Agricultural tax and real estate tax	8232.6	5944.0	16,443.1	32,088.6

Table 6. *Cont.*

No.	Type of Cost	Area under Rapeseed Cultivation (ha)			
		Up to 10	10.1–20	20.1–30	Above 30
40	Third-party liability insurance and other mandatory insurance	1951.5	2030.0	5929.9	4902.2
41	Fixed assets insurance	849.6	1793.7	2628.6	3476.1
42	Social security premiums	2209.7	3505.0	4574.3	10,832.6
43	Other insurance	562.0	1500.0	518.7	1630.4
44	Short-term loan payments (up to 1 year), including interest	860.0	8375.0	5714.3	11,195.6
45	Long-term loan payments (more than 1 year), including interest	20,572.8	11,375.0	30,560.7	25,260.9
46	Other intangible costs	740.0	500.0	178.6	434.8
47	Total intangible costs	18,072.1	34,227.7	73,608.9	88,686.4
48	Total costs	191,688.3	280,420.5	538,725.1	857,675.8

Source: own elaboration.

Diesel oil was also an important item in the structure of farming costs because rapeseed cultivation requires numerous field operations and mechanized treatments. Other material costs included the purchase of lubricants for tractors, plows, harrows, cultivators, seeders, sprayers and combine harvesters for rapeseed production.

Rapeseed producers have to replace worn-out equipment and invest in farm development in order to maintain a competitive advantage on the market. Investments generally increased with increases in rapeseed area and were the highest in farms where the area under rapeseed cultivation exceeded 30 ha. The main categories of investments were land (PLN 67,695.6) and machine (PLN 106,739.1) purchases. These investments enabled the surveyed farms to expand their operations. In turn, investments in buildings were not correlated with the area under rapeseed cultivation.

Intangible costs such as taxes, insurance and short-term and long-term loan payments accounted for a significant portion of operating expenses in rapeseed farms. Intangible costs increased with increases in the area under rapeseed cultivation. They were determined at PLN 18,072.10 in the first group and were four times higher in the fourth group of farms (Table 6).

The present study demonstrated that operating costs increased with increases in rapeseed area and farm area. The reverse was noted in an analysis of the total operating costs per ha of farmland, which were lowest (PLN 3277.2/ha) in farms where the area under rapeseed cultivation exceeded 30 ha. In farms with a smaller rapeseed area, the total costs per ha of agricultural land were higher, which were determined at PLN 4537.8 ha in farms with rapeseed areas of 20–30, PLN 4425.8/ha in farms with rapeseed areas of 10–20 ha and PLN 3912.1/ha in farms with rapeseed areas under 10 ha (Table 6).

The presence of statistical relationships between the rapeseed area and total operating costs was also analyzed. The *p*-value in the chi-squared test of independence ($p = 0.0023$) was below the alpha level ($\alpha = 0.05$); therefore, the null hypothesis was rejected in favor of the alternative hypothesis postulating the presence of a statistical relationship between the examined variables. This observation was confirmed by the calculated value of Cramer's V (0.758), which pointed to a positive and strong correlation between the studied parameters.

The average value of total agricultural production per farm was the highest in farms with rapeseed areas of 20.1–30 ha (Table 7). This group of farms was also characterized by the highest total production per ha of agricultural land, per full-time employee and per man-hour. Total productive output was lowest in farms with the smallest area under rapeseed cultivation. These observations indicated that an increase in rapeseed area to 30 ha contributed to the total productive output of the analyzed farms.

Table 7. Total production and farm household income values for the analyzed farms with different area under rapeseed cultivation rates.

Item	Area under Rapeseed Cultivation (ha)			
	Up to 10	10.1–20	20.1–30	Above 30
Average total production per farm (PLN)	368,144.5	438,457.9	2,280,204.0	1,783,189.0
Total production per ha of agricultural land (PLN)	8907.4	6920.1	19,353.3	6813.6
Total production per full-time employee (PLN)	202,277.2	219,228.9	912,081.6	702,042.9
Total production per man-hour (PLN)	106.6	120.6	359.7	204.8
Average farm household income (PLN)	149,614.0	185,178.0	370,512.7	944,895.7
Per ha of agricultural land (PLN)	3619.9	2922.6	3120.9	3610.5
Per full-time employee (PLN)	82,205.5	92,589.0	148,205.1	372,006.2
Per man-hour (PLN)	43.3	50.9	58.4	108.5

Source: own elaboration.

The farm household income represents the difference between the net added value and external costs. External costs include loan payments, employment costs and service costs in farms that do not own agricultural machinery and capital, and in farms where family members do not provide labor [66]. The highest farm household incomes were noted in farms with the largest areas under rapeseed cultivation, which pointed to the positive effects of economies of scale. Farm household incomes per full-time employee and per man-hour also increased with increases in rapeseed area. The reverse was noted for farm household income per ha of agricultural land, which was the highest in the farms with the smallest rapeseed areas. A similar level of household income per ha of agricultural area was achieved by farms where rapeseed area exceeded 30 ha. These observations indicated that the productive output was influenced not only by the effects of economies of scale, but also by a reduction in external costs per unit area.

4.5. Profile of Farms Owners

The owners of the analyzed farms were surveyed to determine the presence of potential relationships between the farmers' educational attainment and rapeseed area (Table 8). The highest percentage of farmers with university education was noted in farms with rapeseed areas of 10–20.1 ha (37.5%). The percentage of farmers with secondary school education was the highest in farms where rapeseed areas exceeded 30 ha (60.9%). In turn, the highest percentage of farmers with primary school education was observed in farms with the smallest rapeseed areas (8%).

Table 8. Age, education and employment status of farmers in the analyzed farms with different area under rapeseed cultivation rates.

Item (%)	Area under Rapeseed Cultivation (ha)			
	Up to 10	10.1–20	20.1–30	Above 30
Primary school education (%)	8	-	-	1.8
Vocational education (%)	18	12.5	21.4	6.5
Secondary school education (%)	60	50	53.8	60.9
University education (%)	14	37.5	25	30.4
Female farm owners (%)	10	5	7.1	4.4
Male farm owners (%)	90	95	92.5	95.6
Mean age (years)	42	41	42	44
Employment in agriculture	4.18	4.48	4.71	4.63
Working on the farm	1.82	2.0	2.5	2.54
Working outside the farm	0.42	0.76	0.29	0.35
Disability pension	0.32	0.4	0.57	0.30
Retirement pension	0.16	0.08	0.0	0.07
Children	1.06	1.4	1.57	1.24

Source: own elaboration.

The study demonstrated that the educational attainment of the surveyed farmers exceeded the national average. In 2010, the highest percentage of Polish farmers had

primary school education (35.6%), followed by vocational education (29%) and secondary school education (26.6%). Only 8.8% of Polish farmers were university graduates [67]. Employment in the analyzed farms generally increased with increases in rapeseed area (Table 8). On average, farms with rapeseed areas of up to 10 ha employed 1.82 workers, while farms with rapeseed areas above 30 ha employed 2.54 workers.

The presence of a statistical relationship between rapeseed area and the number of farm employees was analyzed. The *p*-value in the chi-squared test of independence ($p = 0.055$) was above the alpha level ($\alpha = 0.05$), which validated the null hypothesis postulating the absence of a statistical relationship between the examined variables. This observation indicated that farm employment did not increase with increases in rapeseed area. The calculated value of Cramer's V (0.168) pointed to a positive although weak correlation between rapeseed area and the number of farm employees.

First of all the authors of the paper conducted the correlation analysis. Table 9 shows that X_1 (farm area) was correlated with X_2 (rapeseed area), X_5 (total costs) and X_3 (value of fixed assets). Even though the correlation was quite high, we decided to analyze these variables because they are important for the economic situation of rapeseed farms.

Table 9. Correlation analysis.

Variables	X_1 (Farm Area)	X_2 (Rapeseed Area)	X_3 (Value of Fixed Assets)	X_4 (Value of Current Assets)	X_5 (Total Costs)
X_1 (farm area)	1.000	0.893	0.696	0.448	0.745
X_2 (rapeseed area)	0.893	1.000	0.568	0.444	0.624
X_3 (value of fixed assets)	0.696	0.568	1.000	0.341	0.585
X_4 (value of current assets)	0.448	0.444	0.341	1.000	0.759
X_5 (total costs)	0.745	0.624	0.585	0.759	1.000

Source: own calculation.

At a further stage of the research, the influence of exogenous variables on the level of household farm income was analyzed. For this purpose, a regression equation was used. Due to the high correlation coefficients between the analyzed variables (Y_1–Y_3), the assumption was made that the influence of each variable should be examined separately. The tables show the regression, R^2 (R-squared), standard error, F test and *p*-value results.

The household farm income per full-time employee depended on X_4 (value of current assets) and X_5 (total costs).

The variables influencing the household farm income (Table 10) included X_1 (farm area), X_4 (value of current assets) and X_5 (total costs). The last variable X_5 (total costs) had a negative impact on household farm income. The rapeseed area was not the variable with the strongest impact on household farm income.

The household farm income per ha farmland depended on X_4 (value of current assets).

These results could be useful for farmers in Poland because they point out which factors impact household farm income. Our research demonstrated that the farmers should increase their rapeseed area cultivation, fixed assets and current assets. Household farm income is decreased by total costs. Farmers should decrease their costs of production of rapeseed by chosing technological production and cultivation methods using their own machinery. The research also confirmed the positive impact of the farm area on household farm income, calculated per farm, per full-time employee and per ha farmland. These results demonstrated that an increase in rapeseed area should always be connected with an increase in farm area. This will maintain a proper balance between the rapeseed area and farm area.

Table 10. The regression analysis.

Variables	Coefficient	Std. Error	F Test	*p*-Value	R-Squared
Y_1 (household farm income for each person fully employed)					
X_1 (farm area)	0.340				
X_2 (rapeseed area)	−0.000				
X_3 (value of fixed assets)	0.009	347,311.273	0.609	0.000	0.370
X_4 (value of current assets)	0.678				
X_5 (total costs)	−0.350				
Y_2 (household farm income per farm)					
X_1 (farm area)	0.549				
X_2 (rapeseed area)	−0.150				
X_3 (value of fixed assets)	−0.040	722,390.286	22.827	0.000	0.646
X_4 (value of current assets)	0.655				
X_5 (total costs)	−0.030				
Y_3 (household farm income per ha farmland)					
X_1 (farm area)	0.099				
X_2 (rapeseed area)	−0.250				
X_3 (value of fixed assets)	0.011	12,595.272	9.203	0.000	0.474
X_4 (value of current assets)	0.668				
X_5 (total costs)	−0.280				

Source: own elaboration on the basis of own research.

5. Discussion

The key element in the development of renewable energy and biofuels is the stability policy. This development should be guided by relevant government legislation [68].

The policy makers should take into account global changes such as environmental pollution increases, population growth, increases in electricity need, urbanization and industrialization [69]. Renewable energy sources play a key role in solving these problems because they are sources of energy and have less emissions and greenhouse gases [70].

The EU has undertaken a legal framework for a Renewable Energy Directive (RED II), the aim of which was to increase the utilization of RES [71].

The organization of crop production plays an important role in farms that produce rapeseed because it indicates which crop species are cultivated and in what proportions. In turn, agricultural inputs are influenced by natural conditions as well as economic and organizational factors [72]. According to Ziętara and Zieliński [73], many crop farms do not produce livestock, which can increase the share of cereals and oilseed crops and decrease the share of root and tuber vegetables in the cropped area. Crop farming without animal production may lead to a decrease in soil organic matter content. However, crop farms play an important role in the Polish agricultural sector by supplying raw materials for the food and feed processing industries, and crop producers adapt their operations and productive output to market requirements.

Many farms have specialized in rapeseed production by investing heavily in machines and technologies, increasing the demand for agricultural equipment [74,75].

Fixed assets play an important role in the development of rapeseed farms. According to legal regulations, fixed assets are assets with a useful life of more than one year and a book value higher than PLN 3500 [76]. Fixed assets are resources that are purchased with the legal right of ownership [77]. Fixed assets are used in the production process and their value is transferred to the produced goods. Depreciation is the systemic reduction in the value of a fixed asset, which is charged into the cost of production [78,79].

New cultivars that have been introduced to the market play an important role in rapeseed cultivation. These cultivars differ in quantitative traits such as fat and fiber contents, yield and growth potential. Cultivars with genetic and phenotypic modifications often require changes in the production technology [8].

The economic aspects of rapeseed cultivation were explored by Jankowski et al. (2016), who found that the benefit–cost ratio was higher in the production of winter oilseed rape

than spring oilseed rape. On average, the benefit–cost ratio was 62–75% lower in spring oilseed rape than in winter oilseed rape production [80].

6. Conclusions

The present study revealed considerable variations in the economic performance and organization of farms with different area under rapeseed cultivation rates.

The values of fixed assets and current assets were highest in farms with the largest areas under rapeseed cultivation, which can be explained by the fact that the demand for agricultural machinery and working capital is the highest in the largest agricultural enterprises.

Diesel oil, fertilizers, crop protection agents and feed were the major operating costs in the surveyed farms. Rapeseed farms also produce livestock, and organic fertilizers can be utilized in rapeseed cultivation. An excessively high proportion of rapeseed in the crop structure can also compromise soil fertility.

The sale of crops was the main source of farm income. Crop production accounted for the highest proportion of income in the largest farms (74.7%). The proportion of income derived from livestock production decreased with an increase in the area under rapeseed cultivation. The rapeseed area influenced the total productive output of the surveyed farms. The total production value was the highest in farms with the largest rapeseed area. This observation suggests that an increase in rapeseed area to 30 ha had a positive impact on total production in the studied farms.

Farm household income increased with increases in the area under rapeseed cultivation, confirming the positive effects of economies of scale. Farm household income per full-time employee and per man-hour also increased with increases in rapeseed area.

The vast majority of the surveyed farmers had secondary school and university education. The educational attainment of the analyzed farm owners exceeded the national average.

Statistical analysis showed that the group of factors influencing the level of agricultural income included X_1 (farm area), X_4 (value of current assets) and X_5 (total costs). The last variable X_5 (total costs) had a negative impact on household farm income. X_2 (rapeseed area) did not have an important impact on household farm income.

The analysis of the information and Eurostat data proved the value of the development of biodiesel production in Europe. Rapeseed is the main source of first-generation biodiesel, which is renewable, natural, has superior emissions properties and is easy to manufacture [81]. The production of biodiesel depends on policies. Changeable policies are not good for biodiesel producers. Policy makers should support biodiesel production and incomes based on oil crops [82]. The policies should include not only biodiesel but also food security worldwide. Strong competition for rapeseed in the food, petrochemical and feed industries may create price increases. This is why the production of second-, third- and fourth-generation biofuels should also be supported [83]. Even though biodiesel production creates stronger competition for feedstock and depends on the availability of land, it has many advantages, such as the utilization of stationary machinery and the associated reductions in greenhouse gas emission [84].

Our research demonstrates the dependence of the rapeseed area on the education of farmers. Farmers having higher and secondary education was associated with farms with average and high areas of rapeseed cultivation. In turn, the highest percentage of farmers with primary school education was observed in farms with the smallest rapeseed areas. This means that education is a factor shaping the economic situation for farmers [85].

The cultivation of rapeseed requires financial subsidies from governments and the Common Agricultural Policy (CAP) of the European Union (EU). Such policies could increase the willingness of farmers to cultivate rapeseed. However, the subsidies should be adjusted to the share of rapeseed in the sown area. Farms exceeding 30% of rapeseed in the sown area should receive smaller subsidies. This is because of the negative impacts of

large shares of rapessd cultivation in sown areas in farms. A farm's increase in rapeseed cultivation should be linked to an incresase in farm area.

Nomenclature

UAA	Utilized agricultural area
PLN	Polish currency zloty
RES	Renewable energy sources
°C	Degrees Celsius
MM	Millimeters, used to define rainfall
CO_2	Carbon dioxide
Ha	Hectares
RED	Renewable energy directive

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