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OPTIMAL UTILIZATION OF EUROPEAN UNION GRANTS – A CASE STUDY

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ABSTRACT

Following Poland's accession to the European Union, farmers were given new opportunities to make use of various form of support from EU funds. The goal of this work is to show the utilization of EU funds by an agricultural farm and optimization of its production. The task was made possible by means of two multicriteria linear-dynamic optimization models. The first model accounted for real production structure and EU subsidies. The subsidies were not included in the second model. The empirical material constituted real data on an agricultural farm located in the commune of Nowogard (West Pomeranian Voivodship). The results of the solutions indicated over a threefold increase of agricultural income, agricultural production and the amount of organic substance supplemented to the soil of an agricultural farm accounting for EU grants.

Key words: grants, multicriteria optimization models, agricultural income, agricultural production, soil organic matter

INTRODUCTION

Poland's admittance into the European Union (in 2004) gave rise to new conditions for development of agriculture and a wide range of opportunities for using various forms of support from EU funds. Acquiring subsides makes it easier for young farmers to make a start [Parlińska et al. 2014], allows for modernization of agricultural farms [Lorencowicz and Cupiał 2013, Grzelak and Kiełbasa 2014], supports farming in areas with unfavorable conditions [Musiał 2010], favors development of rural areas and services for rural population [Bórawski 2010]. Particular financial support is realized as part of agro-environmental programs which are related to environmental protection [PROW 2014].

The goal of this work is to show the utilization of EU funds by X agricultural farm and optimization of its production. The task will be made possible by means of two multicriteria linear-dynamic optimization models. Whereas the hypothesis to be verified in the undertaken research states that multicriteria linear-dynamic optimization models cab be a useful tool for supporting the planning of structure and profitability of production in an agricultural farm.

Within the professional literature, one can find confirmation for utilization of optimization models in agricultural production. For instance, the problem of field irrigation was tackled by Riesgo and Gómez-Limón [2006]. They built optimization models for agricultural farms located in the Douro river valley in Spain. Whereas Rodriguez et al. [2009] used a linear stochastic programming model for planning swine breeding. Manos et al. [2013], by use of multicriteria optimization models, researched sustainable development of agricultural production in the region of Tasalia (Greece).

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Zieliński and Ziętara [2017] also made an attempt at determining the economic situation of farms specializing in cultivation of cereals, oil and protein plants by means of linear-dynamic optimization models.

In this work, production in X agricultural farm located in the West Pomeranian Voivodship in the Nowogard commune was optimized in the years 2013–2016.

RESEARCH MATERIAL

The X agricultural farm has 344 ha of bonitation class IV agricultural land, including 225,11 ha of meadows and pastures, and 118.89 ha of arable land. The activities of this farm are concentrated around cultivation of cereals, rapeseed and horse bean, as well as hay harvest from meadows and pastures. Rapeseed is grown every year, whereas horse bean and wheat – every two years, similar to rye and triticale. Moreover, 3.89 ha of the farm's land is dedicated to cultivation of melliferous plants, such as: borage, phacelia and melilot. These plants are utilized by bees for production of honey which is used by the family members. Grasslands take up over 65% of the area, and 1/8 of their area is part of the Natura 2000 program. Species of plants and birds under protection can be found in these areas. The X farm does not deal with animal husbandry, and the harvested hay is sold to nearby fur animal farms.

Two people are engaged in work on the farm. Moreover, one additional worker is hired during the period of increased demand for manpower (harvest season).

The farm is equipped with basic agricultural machines and tools.

EU grants constitute a significant part of the analyzed farm's income. Within the examined period, the agricultural farm used such subsides as:

- uniform area payment,
- area payment for the area of leguminous and small-grained papilionaceous crops,
- payment for greening,
- payment for high protein crops.

Table 1 shows basic data on the X agricultural farm in the years 2013–2016.

Table 1. Characteristics of the X farm

Specification	2013	2014	2015	2016
Sown structure (%)	100	100	100	100
winter rye	42.48	–	42.48	–
beans	18.82	–	16.91	–
rape	35.43	42.48	37.34	19.67
melliferous plants	3.27	3.27	3.27	3.27
winter wheat	–	37.34	–	54.25
triticale	–	16.91	–	22.81
Crop yields ($dt \cdot ha^{-1}$)				
winter rye	40	–	50	–
beans	34	–	35	–
rape	35	37	34	35
winter wheat	–	65	–	62
triticale	–	56	–	50
hay from meadows and pastures	68	70	72	67
Selling prices of crops ($PLN \cdot dt^{-1}$)				
rye	55	–	57	–
beans	120	–	86	–
rape	160	140	150	170
wheat	–	70.20	–	72
triticale	–	54.30	–	62
hay from meadows and pastures	45	39	44	40

Table 1 – cont.

Specification	2013	2014	2015	2016
Plant cultivation costs (PLN·ha^{-1})				
winter rye	3 210.23	–	3 072.20	–
beans	4 152.00	–	3 502.20	–
rape	5 100.20	5 020.30	4 300.30	4 520.20
winter wheat	–	3 820.50	–	3 789.20
triticale	–	3 510.20	–	3 572.40
hay from meadows and pastures	3 420.10	3 152.82	3 203.80	2 890.30
Crop subsidies (PLN·ha^{-1})				
rye	830.30	–	758.01	–
beans	1 549.73	-	1 180.01	–
rape	830.30	910.87	758.01	772.15
wheat	–	910.87	–	772.15
triticale	–	910.87	–	772.15
melliferous plants	830.30	910.87	758.01	772.15
meadows and pastures	830.30	910.87	758.01	772.15
Agricultural income with subsidies (PLN·ha^{-1})				
winter rye	95.07	–	535.81	–
beans	1 477.73	–	687.81	–
rape	1 330.10	1 070.57	1 557.71	2 201.95
winter wheat	–	1 653.37	–	1 446.95
triticale	–	441.47	–	299.75
hay from meadows and pastures	470.20	488.05	722.21	562.15

Source: Own work based on Luter [2017].

Income acquired from honey production in the examined years covered the expenses of growing honey plants. Grants for these crops constituted the farmer's income. Other benefits for farming derived from the presence of bees were presented by Majewski [2010].

RESEARCH METHOD

The main research method are multicriteria optimization models. Their mathematical notation, adopted for agricultural (plant) production, takes the form of [Krawiec 1991]:

$\boldsymbol{ax}(t) \leq \boldsymbol{b}(t)$ – limiting conditions (1)

$\boldsymbol{x}(t+1) \leq \boldsymbol{x}(t) + f_t\,[\boldsymbol{x}(t), \boldsymbol{u}(t)]$ – dynamics equations (2)

$F = \max\,\{F_1, F_2, F_3\}$ – control criterion (3)

$\boldsymbol{x}(t) \geq 0,\ \boldsymbol{u}(t) \geq 0$ – boundary conditions (4)

where:

- t – states (in consecutive production years), $t = 0, 1, 2, ..., k$;
- $\boldsymbol{a}$ – vector of technical and economic parameters;
- $\boldsymbol{b}(t)$ – vector of limitations in subsequent states;
- $\boldsymbol{x}(t)$ – vector of state t;
- $\boldsymbol{u}(t)$ – control vector;
- $\boldsymbol{x}(t+1)$ – vector of state in the year $t + 1$.

It should be assumed that the initial state of the system at the moment of $t = 0$ is known and describes the plant area at the moment preceding the first year of research. In formula (1), there are state limitations which are related to the area of arable land and grassland.

The $\boldsymbol{u}(t) = u_{ij}(t)$ control vector presents flows within the farm or between the farm and the environment. Components of this vector described areas of consecutive plants at the time of the farm's transition from state t to $t + 1$. The i, j indices determine the order of consecutive crops, e.g. plant j will be frown after plant i.

Dynamics equations for plant production take the form of:

$$x_i(t+1) = \sum_p u_{pi}(t) \quad (5)$$

where:
$x_i(t + 1)$ – area i – of this plant grown in the year $t + 1$;
$u_{pi}(t)$ – area of various p forecrops after which i – this plant in the year – is grown $t + 1$.

The F_1 goal criterion relates to gross agricultural income and is expressed by the formula:

$$F_1 = \sum_t \left[\boldsymbol{m}(t)^T \boldsymbol{u}(t) + \boldsymbol{w}(t+1)^T \boldsymbol{x}(t+1) \right] \to \max \quad (6)$$

where:
$\boldsymbol{m}(t)$, $\boldsymbol{w}(t + 1)$ – unitary income vector for the variables of state and control indicating commodity activities.

The F_2 function is a control criterion maximizing the production volume by the forms of:

$$F_2 = \sum_t \left[\boldsymbol{g}(t)^T \boldsymbol{u}(t) + \boldsymbol{k}(t+1)^T \boldsymbol{x}(t+1) \right] \to \max \quad (7)$$

where:
$\boldsymbol{g}(t)$, $\boldsymbol{k}(t + 1)$ – unitary efficiency vector of control and state variables in the subsequent years;

The F_3 function maximized the amount of organic substance in the soil:

$$F_3 = \sum_t \left[\boldsymbol{o}(t)^T \boldsymbol{u}(t) + \boldsymbol{p}(t+1)^T \boldsymbol{x}(t+1) \right] \to \max \quad (8)$$

where:
$\boldsymbol{o}(t)$, $\boldsymbol{p}(t + 1)$ – vector of unitary coefficients of reproduction and degradation of soil for state and control variables.

Multicriteria optimization models of the X agricultural farm will be solved by means of objective programming. Its creators are Charnes and Cooper [1961], and the solution method was described by Szapiro [2001].

CONSTRUCTION AND SOLUTIONS OF OPTIMIZATION MODELS

Based on data on the X farm in the years 2013–2016, two linear-dynamic optimization models were constructed. These models were composed of 27 state and control variables, and 41 limiting conditions. The models' variables were related to the area of individual crops, whereas the area of arable land and permanent grassland are the models' constant terms. Limiting factors of the model described the state in each of the analyzed years (four stages of the model, and dynamics equations bound individual stages by means of plant rotation. The succession of crops in the subsequent years, reflecting the real sowing structure, is presented in Table 2.

Objective functions maximized the agricultural income and agricultural production, and minimized the loss of organic substance in the soil. Agricultural income constituted the income from individual crop along with grants minus production costs. Agricultural production are crops of plants for sale. Whereas the amount of organic substance in the soil was determined based on indices of reproduction and degradation by Eich and Kindler [Fotyma and Mercik 1992].

The first model accounted for EU grants. In the second model, the grants were omitted in order to show the differences in profitability of agricultural production.

Table 2. Crop rotation

Year	Field I	Field II	Field III	Field IV
2013	rape	beans	rye	melliferous plants
2014	triticale wheat	wheat	rape	melliferous plants
2015	rape beans	rape	rye	melliferous plants
2016	wheat	wheat	triticale rape	melliferous plants

Source: Own work.

The solution of the first model indicated the area of individual crops and the acquired value of agricultural income, agricultural production and the amount of organic substance supplemented to the soil in the analyzed years and over the entire examined period (Table 3).

The optimal solution is in line with the principles of the Code of Good Agricultural Practice [Duer et al. 2004] and accepted plant rotation. Plant succession ensures timely performance of all agro-technical work, and proper coverage of soils with plants. It also meets the requirements of the Agency for Restructuring and Modernization of Agriculture imposed on farmers applying for grants[1]. In agricultural production, there must be at least three different crops each year, out of which the main crop cannot exceed 75% of the sown area. A minimum of 5% of the crops must meet the pro-environmental conditions (e.g. cultivation of melliferous plants, papilionaceous plants and permanent grasslands in the area of Natura 2000). The consequence of not adhering to these requirements is lack of grants. The greatest income was achieved in the year 2016 (PLN 282,301.14). Mainly due to cultivation of wheat the area of which took up 54.25% of the general sown area this year. The volume of income in subsequent years were also significantly influenced by grasslands, especially grants for their area. Favorable agro-climatic conditions in the year 2014 contributed to the increase in agricultural commodity production. Positive balance of organic substance in the soil proves the natural environment is not degrading. The main source of supplementing the soils with organic matter is the X farm was plowed straw of rapeseed, cereal and meadows. Too much organic matter supplied into the soil is not desirable, either. It can lead to pollution of grounds and surface waters with biogens [Smagacz 2000]. The optimal solutions indicates that each hectare of soils in the farm was enriched every year with about 987 kg (1,357.60 t / 4 / 344 ha) of organic substance, which will not lead to pollution of waters.

Table 3. Optimal solution of a model of X farm using EU grants

Specification	2013	2014	2015	2016
Arable land (ha)	118.89	118.89	118.89	118.89
winter rye	50.50	–	50.50	–
beans	22.38	–	20.10	–
rape	42.12	50.50	44.40	23.38
melliferous plants	3.89	3.89	3.89	3.89
winter wheat	–	44.40	–	64.50
triticale	–	20.10	–	27.12
Meadows and pastures (ha)	225.11	225.11	222.11	222.11
Agricultural income (PLN)	202 967.93	249 749.07	275 564.59	282 301.14
Agricultural income (PLN)	1 010 582.74			
Agricultural production (dt)	19 562.71	21 486.27	20 946.17	21 255.67
Agricultural production (dt)	83 250.83			
Organic matter (t)	331.9186	341.2239	345.2761	339.1818
Organic matter (t)	1 357.60			

Source: Own calculations.

[1] ARiMR website, www.arimr.gov.pl.

For comparison, a second dynamic optimization model was built for the X farm, in which EU grants were not accounted for. The cost of rye, horse bean and triticale cultivation exceeded the income acquired from selling the seeds of these plants. Maintaining one's own permanent grassland with no farm animals turned out to be unprofitable. A possible optimal solution, not accounting for real production structure, is shown is Table 4.

Table 4. Optimal solution of a model of X farm not using EU grants

Year	Field I	Field II
2013	rape 115 ha	melliferous plants 3.89 ha
2014	wheat 115 ha	melliferous plants 3.89 ha
2015	rape 115 ha	melliferous plants 3.89 ha
2016	wheat 115 ha	melliferous plants 3.89 ha

Source: Own calculations.

The solution of model two indicates that rapeseed and wheat should be grown interchangeably, every two years. Too frequent cultivation of wheat on the same field is not beneficial. It can lead to crop rotation diseases and worsen the soil culture.

The cost of melliferous plant cultivation negated the income from honey sales. The acquired agricultural income in 2013–2016 (PLN 312,432) was three times lower than that achieved in the solution of the X farm with grants. Moreover, agricultural production (22,540 dt) was decreased by 73%, and the amount of organic substance supplied yearly to the soil was lowered to 0.28 $t \cdot ha^{-1}$ (391 t / 4 / 118.89 ha).

SUMMARY AND CONCLUSIONS

The work made an attempt at using linear-dynamic optimization models to determine the production structure in X farm. A model constructed based on real data meets the requirements of the Agency for Restructuring and Modernization of Agriculture imposed on farmers applying for EU grants. For comparison, a model not accounting for grants was constructed and solved.

The research leads to the following conclusions:

1. Production structure resulting from the X agricultural farm's model solution where grants were accounted for ensures proper plant rotation, timely execution of agro-technical work, and does not degrade the natural environment. The solution of the second model does not ensure biodiversity, and too frequent cultivation of wheat on the same field can lead to decreased harvest.
2. The acquired production results (agricultural income, agricultural production, the amount of organic substance supplied to the soil) in the X agricultural farm's model solution with grants in the years 2013–2016 were over three times higher than those for this farm without grants.
3. Multicriteria linear-dynamic optimization models can be an efficient tool supporting examination of production profitability in agricultural farms.

Moreover, the allow for determination of the degree of soil reproduction and degradation.

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OPTYMALNE WYKORZYSTANIE DOTACJI UNIJNYCH – STUDIUM PRZYPADKU

STRESZCZENIE

Po przystąpieniu Polski do Unii Europejskiej rolnicy uzyskali nowe możliwości korzystania z różnych form wsparcia z funduszy unijnych. Celem tego opracowania jest pokazanie wykorzystania dotacji unijnych przez gospodarstwo rolne w celu optymalizacji swojej produkcji. Realizację tego zadania umożliwiły dwa wielokryterialne liniowo-dynamiczne modele optymalizacyjne. Pierwszy model uwzględniał rzeczywistą strukturę produkcji i dopłaty unijne. W drugim modelu pominięto dotacje. Materiał empiryczny stanowiły rzeczywiste dane o gospodarstwie rolnym znajdującym się w gminie Nowogard (województwo zachodniopomorskie). Wyniki rozwiązań wskazały ponadtrzykrotny wzrost dochodu rolniczego, produkcji rolniczej i ilości substancji organicznych dostarczanych do gleby gospodarstwa uwzględniającego dotacje unijne.

Słowa kluczowe: dotacje, wielokryterialne modele optymalizacyjne, dochód rolniczy, produkcja rolnicza, materia organiczna gleby