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BIOLOGICAL BENEFITS FROM GROWING LEGUME CROPS IN THE CONTEXT OF PROTECTING PRODUCTION FACTORS[1]

Key words: economic account, biological benefits, legume crops, production factors

ABSTRACT. The purpose of this paper was to show the economic rationale behind growing legume plants in crop rotation. To pursue that objective, this paper presents a modified profitability accounting method for agricultural production which takes biological benefits into consideration. The following sequence of crop rotation was used in this study: forage pea – winter rape – winter wheat. An assumption was made that, from an economic point of view, the after-effect of legume crops on soil and yields of subsequent crops is an important factor which, however, is disregarded in calculations. Research suggests that legume crop growing brings measurable benefits in following years. As regards forage pea, rape and wheat, biological benefits represented 2%, 19% and 12% of total income, respectively, in the study period. Feedback from respondents suggests that 25% of the interviewees do not reduce nitrogen fertilization input in the years after growing legume crops. In turn, as much as 83% of farmers surveyed do not reduce their phosphorus and potassium fertilization rates for subsequent crops. However, agricultural producers usually fail to take account of additional biological benefits brought about by legumes when assessing their economic competitiveness against cereals and rape.

INTRODUCTION

The agricultural production process requires the interoperation of three productive inputs: land, labor and capital. They can substitute each other, though to a limited extent [Rychlik 1983]. The amount and type of productive input used is decisive for output [Kołodziejczak 2014]. Faced with changing economic conditions and growing market competition, agricultural producers must rationally manage their resources. Land, as the fundamental productive input in agriculture, cannot grow. Meanwhile, per-hectare yield of many plant species reaches maximum level. On the other hand, an even more intensive and unsustainable agricultural production method could result in a major disturbance to

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the environment. Hence, appropriate environmental management enables the sustainable use of resources [Ganowicz-Bączyk 2013].

The economic efficiency of farming is determined by comparing the value of production (production volume and market prices) against the value of the productive input used [Kierul 1986]. Production profitability is one of the key factors deciding whether or not a farmer would be interested in growing a given plant species. In agriculture, the importance of production profitability calculations primarily results from the need for a rational use of all productive factors. To engage in a production activity which is sustainable, economically viable and socially acceptable at the same time, agricultural producers must take measures to ensure the maximum protection of productive input. If properly managed, even intensive agricultural production methods should not result in degrading the production potential of soil. In a quest for value added, farmers look for solutions that bring profits by increasing the production volume while reducing labor input and production costs [A. Mickiewicz, B. Mickiewicz 2014]. As shown by agricultural practice and scientific findings, appropriate crop rotation patterns have a beneficial effect on crop production performance (including a reduction in yield fluctuations), while also having a positive environmental impact [Majewski 2010]. After 1989, the shift towards a market economy resulted in moving away from crop rotation practices. When selecting crops, the main criterion was the maximization of economic profits. This means that farmers opted for plants which ensure maximum levels of profitability [Florek, Czerwińska-Kayzer 2018]. Environmental impacts and enhancing the properties of the farming site were secondary problems. This resulted in reducing the number of plant species grown. As a consequence, the share of cereals in the cropping mix went up to as much as 80% in some regions of the country. Measures taken to counteract the adverse effects of a disadvantageous cropping mix may include growing legume crops. In addition to enriching the soil with nitrogen, the cultivation of legumes brings many other biological benefits which usually include: the ability to absorb water and nutrients from deeper layers of soil thanks to a well-developed root system; improvements in soil texture due to aeration channels left in the soil; increased sorption capacity of particular soil types; increased humus content resulting from a large quantity of crop residue as well as a reduced spread of pathogens and certain weed species [Jerzak et al. 2012]. The factors listed above also contribute to a higher yield of subsequent crops [Dzienia et al. 1989, Buczek et al. 2009]. According to research carried out by Joanna Florek [2017] and Dorota Czerwińska-Kayzer et al. [2015], agricultural producers increasingly often cite these benefits as an environmental advantage of legume crops. Despite their numerous advantages, legume crops attract little interest, as reflected by their small share in the cropping mix - in 2018 2.5% [Central Statistical Office 2019]. Moreover, these benefits are not taken into consideration in economic accounts currently kept to assess the profitability of crop production [Czerwińska-Kayzer 2015b].

Therefore, the purpose of this paper was to present the economic rationale behind growing legume plants in crop rotation. To pursue that objective, this paper presents a modified profitability accounting method for agricultural production which takes biological benefits into consideration.

MATERIALS AND METHODOLOGY OF STUDIES

Currently, competitiveness of different agricultural businesses is gauged and compared based on an incomplete cost accounting routine. This results in calculating the gross margin defined in accordance with the methodological assumptions of the Farm Accountancy Data Network (FADN) as the output per hectare minus direct costs necessary to be incurred in the production process in average conditions for the region concerned [Denisowska, Jagła 2000, Mostowski 2013]. Note, however, that such a simplified account makes it impossible to take into consideration all revenue and cost items related to the activity. According to Wojciech Ziętara [2009], selected types of agricultural production should be assessed and compared based on income which, as provided for the assumptions of the AGROKOSZTY Data Collection System for Agricultural Products, is calculated as follows:

I		Production value
II	-	Direct costs
III	=	Gross margin without subsidies
IV	-	Real indirect costs
V	=	Gross value added of the activity
VI	-	Estimated indirect costs
VII	=	Net value added of the activity
VIII	-	Costs of externalities
IX	=	Income without subsidies
X	+	Subsidies
XI	=	Income

When assessing the profitability of growing legume crops, the cost accounting method presented above fails to take account of an important element, i.e. biological benefits derived from introducing legume crops to the crop rotation pattern. Account is neither taken of the increase in yield of subsequent crops, nor of the savings on productive input (reduced use of fertilizers and plant protection products). Edward Nowak [2001] emphasizes that when making the decision on an alternative line of production, account must be taken not only of costs incurred in relation to that activity (or of the revenue derived from it) but also of any additional benefits or lost profits involved in the selection of another activity. In view of the above, a modified income calculation routine is proposed in this paper to include the biological benefits when assessing the profitability of growing legume crops [Czerwińska-Kayzer, Florek 2012, Czerwińska-Kayzer 2015b, Florek, Czerwińska-Kayzer 2018]:

I		Production value
II	-	Direct costs
III	=	Gross margin without subsidies
IV	-	Total indirect costs
V	=	Income without subsidies
VI	+	Subsidies
VII	=	Income plus subsidies
VIII	+	Biological benefits (cost savings)
IX	=	Total income

Profitability was assessed using data delivered by the Agricultural Consultancy Centers of the Wielkopolskie and Kujawsko-Pomorskie voivodeships [K-PODR 2015-2017]. The investigation used two scenarios of crop growing. In the first one, forage pea was grown in 2015; independently, winter rape and winter wheat was grown in another field in 2016 and 2017, respectively. In the second scenario, crop rotation was used: forage pea was grown in 2015, followed by winter rape in 2016 and winter wheat in 2017.

Additionally, data retrieved from empirical studies carried out in selected farms in the Wielkopolskie and Kujawsko-Pomorskie voivodeships was used. The survey was conducted in 2018 based on purposive sampling. The sample selected for this study were farms engaged in legume production who had declared to be provided with a crop specific payment for legumes in previous years, and who agreed to take part in the study. As a consequence, the survey covered 104 farms, including 8% of small farms with up to 50 ha of land (40 ha on average), 8% of farms with 50 to 100 ha of land (88 ha on average), 34% of farms with 100 to 500 ha of land (138 ha on average); large farms (over 500 ha of land, 1,110 ha on average) made up 50% of the population surveyed. The measurement method employed was a direct interview based on a standardized survey questionnaire. Once collected, the data was analysed in detail and described with the use of descriptive statistics methods.

RESULTS AND DISCUSSION

So far, the growing of legume crops has been regarded as poorly profitable and of limited utility for the farm. Farmers have shown little interest in this species, mainly because of low demand for legume crops as a raw material in the forage market. The fact that legume yield is unstable and lower than cereal yield, and that legume crops are more sensitive to temperature fluctuations and precipitation, are important factors when making the production decision. However, research suggests that the growing of legume crops does become economically viable. Table 1 presents a summary of primary production value

Table 1. Main production value and direct costs

Specification	Scenario 1			Scenario 2		
	forage pea	winter rape	winter wheat	forage pea	winter rape	winter wheat
	PLN/ha					
Value main production	2,700	4,000	3,745	2,700	4,800	4,120
Direct costs, including:	2,455	3,370	3,128	2,375	3,022	2,960
- seed	550	207	440	550	207	440
- mineral fertilizers	382	1,316	966	302	1,175	889
- plant protection products	659	919	794	659	735	715
- agri-technical costs	864	928	928	864	905	916

Source: own study based on data delivered by Agricultural Consultancy Centers of the Wielkopolskie and Kujawsko-Pomorskie voivodeships [K-PODR 2015, 2016, 2017] and selected cost items for forage pea, winter rape and winter wheat grown independently (scenario 1) and on a rotating basis: forage pea – winter rape – winter wheat (scenario 2).

When comparing the primary production volume with the amount of direct costs (Table 1), the conclusion is that pea growing is less profitable than rape or wheat growing in both scenarios. This is mainly due to lower buying-in prices of pea. Biological profits (cost savings) may prove to be an important factor when making the decision to grow legume crops. In practice, these values are relatively difficult to calculate. Nevertheless, this paper attempts to provide a relatively precise estimation thereof. As mentioned earlier, legumes have the capacity to biologically fix nitrogen. When dug in, pea residues leave ca. 55 kg N per hectare [Kulig 2011]. Also, post-harvest residue of legumes provides an additional source of phosphorus and potassium. According to various research, pea residue leaves ca. 15 kg P per hectare and 35 kg K per hectare. In this study, the value of biological benefits was calculated by multiplying the price per kg of N, P, K and the amount of the corresponding element fixed in the soil after the crop residues are ploughed in. Hence, legume crops, in the form of post-harvest residue, may gradually supply nutrients to subsequent plants (winter rape, for instance). A part of it can still be used in the next year by another plant, e.g. wheat. This analysis assumes that, respectively, 40%, 30% and 50% of nitrogen, phosphorus and potassium contained in pea residue is used after the first year. In the second year, the plants are capable of absorbing 20%, 10% and 30%, respectively, of nitrogen, phosphorus and potassium[2]. In view of the above, in the era of intensive crop production, where fields are dominated by cereal crops, there is no need to increase the ever growing fertilization and protection costs.

As shown by data presented in Table 2, already in the first year of growing legume crops, production costs can be reduced by PLN 79 per hectare. Rotation with legume crops also drives savings in the growing of subsequent plants. In the case of rape, it became possible to reduce mineral fertilization, and therefore direct production costs went down by PLN 141 per hectare (PLN 77 per hectare in the case of wheat). Post-harvest legume residue left in the soil not only contributes to increased humus content but also

Table 2. Biological benefits from growing legumes in crop rotation

Specification	Forage Pea (1 year)	Winter Rape (2nd year)	Winter Wheat (3rd year)
	PLN/ha		
Savings on fertilizers	79	141	77
Increased yield	0	800	375
Savings on plant protection products	0	184	79
Savings on agri-technical procedures	0	23	11
Total biological benefits	79	1,148	543

Source: compilation based on the results of the authors' own study

2 The shares of fertilizers used by subsequent plants were specified based on the outcomes of the multiannual project co-managed by the authors.

has an effect on the yield of subsequent crops. Despite a reduction in mineral fertilization, the yield of subsequent plants (wheat, rape) grow by 0.5 to 1.0 t per hectare without involving any additional expenditure [Prusiński 2017]. This results in an increase in the primary production of rape and wheat by PLN 800 and PLN 375, respectively. Also, crop rotation with legumes is a way to reduce the costs of pesticides for subsequent plants by 20% to 25% [Prusiński 2017]. This is due to several factors, including the discontinuation of the improper sequence of cereals which follow each other. The calculation (Table 2) suggests that savings on plant protection products can reach PLN 184 per hectare if rape is grown after pea. If wheat is sown afterwards, the savings will amount to PLN 79 per hectare. The reduction in the use of fertilizers and pesticides translates into lower costs of treatment of soil for subsequent crops by another 20% (approximately), i.e. by PLN 23 and PLN 11 per hectare of rape and wheat, respectively. The study by Janusz Prusiński [2017] resulted in similar findings.

The conclusion from this research is that legume crop growing brings measurable benefits in the year legumes are sown and in following years. Table 3 presents the value of biological benefits and different incomes in the 'forage pea – winter rape – winter wheat' rotation pattern.

Table 3. Value of biological benefits and different incomes in the crop rotation procedure

Specification	Forage Pea	Winter Rape	Winter Wheat
	PLN/ha		
Gross margin without subsidies	245	630	619
Income without subsidies	-57	281	280
Income plus subsidies	1,246	1,053	1,144
Biological benefits	79	1,148	543
Total income	1,325	2,201	1,687

Source: compilation based on the results of the authors' own study

When comparing the production value with total costs incurred (income without payments), it can be noted that the growing of rape and wheat is a way to offset costs. In turn, the loss from growing pea is PLN 57 per hectare. Only after production subsidies are included in the calculation, it turns out that pea growing is more competitive than rape and wheat growing. This, primarily, results from the important role of that instrument in generating income. According to research by Dorota Czerwińska-Kayzer [2015a], financial support from the government, as available to legume producers, covers more than 60% of production costs incurred. In this situation, biological benefits could be an important factor when making the decision to grow legume crops.

After including this item in the cost accounting procedure for decision makers, it turns out that the final income from pea production is PLN 1,325 per hectare, whereas the respective amounts for rape and wheat are PLN 2,201 and PLN 1,687 per hectare. The importance of biological benefits from growing legume plants in crop rotation, measured as a contribution to total income, is presented in Figure 1.

It follows from the above that as regards forage pea, rape and wheat, biological benefits represented 2%, 19% and 12% of total income, respectively, in the study period. Based on this data, it can be concluded that when expressed in value, biological benefits from growing legume plants do not contribute much to profitability. Nevertheless, it does not diminish the agri-technical and ecological importance of these crops. Legume crop growing brings measurable benefits in following years. When included in the crop rotation pattern, legume plants can translate into savings of PLN 1,770 per hectare.

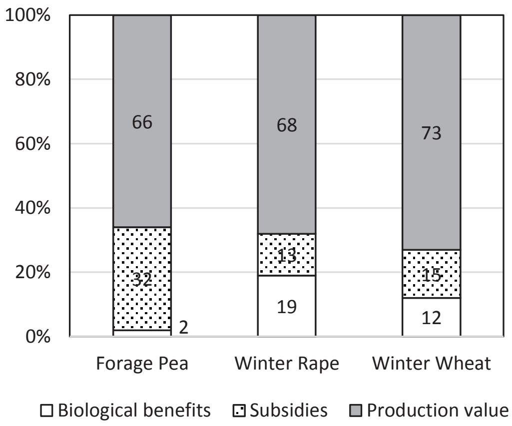

Figure 1. Contribution of biological benefits to total income

Source: compilation based on the results of the authors' own study

The survey shows that when assessing profitability, farmers usually fail to take account of future benefits, i.e. improvements in soil texture, a higher yield of subsequent crops or savings due to lower use of fertilizers and plant protection products. Feedback from respondents suggests that 1/4 of agricultural producers do not reduce nitrogen fertilization input in the years after growing legume crops (Figure 2). In turn, as much as 83% of farmers surveyed do not reduce their phosphorus and potassium fertilization rates for subsequent crops. As a positive finding, 67% of interviewees consider legume plants to be a "free nitrogen factory" [Szukała 2012] and use it as a way to reduce fertilization costs by 5% to 10% when growing legumes and subsequent plants.

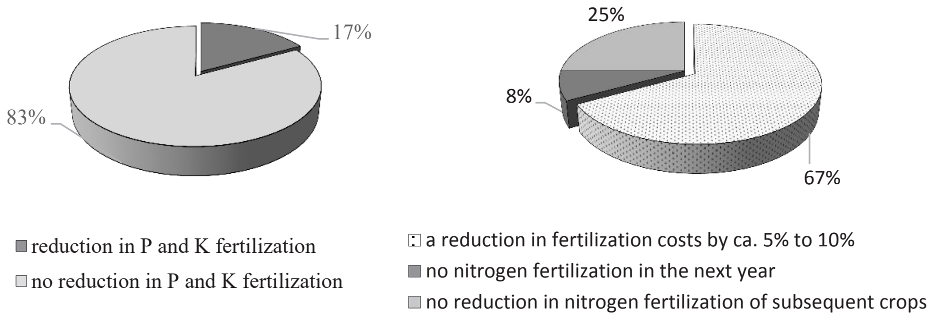

Figure 2. Reduction in the use of N, P, K mineral fertilizers after the cultivation of legumes in farms surveyed

Source: compilation based on the results of the authors' own study

SUMMARY

According to the theory of sustainable development, the adequate allocation and saving of productive input plays a key role in the management of each farm. The ability to properly use the productive resources at different production stages is an important aspect which affects the efficiency and profitability of agricultural production. However, farmers usually fail to take account of additional (biological) benefits brought about by legumes when assessing their economic competitiveness against cereals and rape. As shown by this study, the growing of legumes is, primarily, a way to reduce the use of expensive mineral fertilizers and pesticides with a detrimental effect on health and the environment; the ability to use a simplified routine in the growing of subsequent crops; and an increase in yield of subsequent crops. Considering the prices and costs of using mineral fertilizers, the inclusion of legume plants in crop rotation is a specific value added which needs to be taken into consideration in the final economic account and when planning the farm's crop production. When included in the crop rotation pattern, legume plants can translate into savings of PLN 1,770 per hectare. As regards forage pea, winter rape and winter wheat, biological benefits represented 2%, 19% and 12% of total revenue, respectively, in the study period.

Therefore, biological benefits should be included in profitability accounting when making production-related decisions. Furthermore, this approach addresses the concept of the extended cost/benefit analysis, which is consistent with the currently widely accepted theory of sustainable development.

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KORZYŚCI BIOLOGICZNE Z UPRAWY ROŚLIN BOBOWATYCH W ASPEKCIE OCHRONY CZYNNIKÓW WYTWÓRCZYCH

Słowa kluczowe: rachunek ekonomiczny, korzyści biologiczne, rośliny bobowate, czynniki wytwórcze

ABSTARKT

Celem artykułu jest ukazanie ekonomicznego uzasadnienia zastosowania w płodozmianie roślin bobowatych. Zaprezentowano zmodyfikowany rachunek ekonomiczny produkcji rolniczej, w którym uwzględniono korzyści biologiczne. Do badań przyjęto następującą kolejność roślin w płodozmianie: groch pastewny – rzepak ozimy – pszenica ozima. Założono, że z ekonomicznego punktu widzenia, nie bez znaczenia jest nieuwzględniany w kalkulacjach wpływ następczy roślin bobowatych na glebę i plonowanie roślin uprawianych po nich. Z badań wynika, że uprawa roślin bobowatych w gospodarstwie przynosi wymierne korzyści w latach następnych. W uprawie grochu pastewnego w badanym okresie korzyści biologiczne stanowiły 2% dochodu z działalności ogółem, w uprawie rzepaku 19%, a pszenicy 12%. Z odpowiedzi uzyskanych od respondentów wynika, że 25% ankietowanych nie zmniejsza nawożenia azotem w kolejnych latach po uprawie roślin bobowatych. Nawożenia fosforem i potasem przy roślinie następczej nie redukuje aż 83% badanych rolników. Producenci rolni przy ocenie ekonomicznej konkurencyjności roślin bobowatych w stosunku do roślin zbożowych i rzepaku często nie uwzględniają dodatkowych korzyści biologicznych wynikających z uprawy tych roślin.

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