

Article

Yield and Profitability of Crop Production in Mountain Less Favoured Areas

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Abstract: Agricultural production is a crucial part of policy issue in preventing depopulation of mountainous areas across Europe. However, soil and climate conditions are limiting yields and profitability of crop production in these regions. The European Union (EU) subsidizes agriculture in mountains by special payments (Less Favoured Area (LFA) subsidy) when areas match law-specified natural handicaps. This study aims to assess whether LFA subsidy in Poland is sufficient to cover losses caused by lower yields of crops cultivated in a mountainous region of Poland (Low Beskid Mountains in Carpathians) compared to lowland regions (non-LFA areas). The results indicated that LFA subsidy was adequate for crops (facultative wheat, winter wheat, field bean and spring barley) grown in the years 2015–2018.

Keywords: mountain LFA subsidy; cereals in mountains; field bean; different climatic conditions

1. Introduction

The effects of agricultural production are influenced by natural, organisational and economic factors. Soil conditions play a key role among natural factors [1,2]. In Poland, poor and very poor soils (valuation classes V and VI) occupy about 4.7 million ha, which is 32% of the total land area [3]. According to Witek [4], average cereal yields obtained in class VI soil conditions were on average three times smaller than on class I soils. These lands usually occur in areas with natural or other special handicaps (defined as Less Favoured Area (LFA)).

On the other hand, mountainous regions are very precious for national economy in historical, economic and social terms. Mountain culture consists of native life style, many original recipes, country traditions and landscape protection, appreciated by the tourism industry. However, due to the lower efficiency of farms, people move along an altitude gradient—to the lowlands. The European Union, in accordance with art. 31 and 32 of Council Regulation (EC) 1305/2013, define a mountain area as a less favoured area due to difficulties caused by a short growing season because of high altitudes, steep slopes at lower altitudes, or by a combination of the two [5]. Despite other activities performed by farmers to increase farm income (permanent pasture along with extensive cattle breeding [6] or owning lands in protected areas [7] and any additional non-agricultural activities of farm [8]), farm incomes remain insufficient for profitable agricultural production in these regions; therefore, it is justified to subsidize agricultural production in LFA areas, especially the mountain type [9]. In Poland, along with changes in LFA delimitation made in 2019, 308 900 ha of arable land were qualified to the mountain type LFA [10]. However, due to climate change and periodic droughts in regions outside LFA, a reverse phenomenon is sometimes observed. Szabo and Grznár [11] pointed out that farms in Slovakia from mountain LFA areas in 2012 gained an economic advantage (they were more profitable due to higher rainfall) compared to farms outside LFA, which were affected by the drought at that time. The authors

have argued that if climate change continues, areas with a higher sum of annual rainfall will remain a reserve in providing food for citizens and it will be even more important to maintain crop production within them. For that reason, it is necessary to assess economical effectiveness of LFA farms.

Despite many studies [12–14], evaluation of the efficiency of LFA subsidies in compensating the effects of adverse conditions on agricultural activity in these handicapped areas remains an open problem. This issue can be examined using various methodologies, including quantification of the size and quality of yield [15] or characteristics affecting the LFA delimitation—socio-economic aspects [16] as well as biotic factors [17]. It should also be noted that there were attempts in the literature to create models based on machine learning techniques [18] in order to make faster decisions regarding development directions of specific LFA areas and assessing agricultural systems implemented on their basis in relation to sustainability criteria and agricultural potential in the country.

The aim of the study was to assess the yield and economic efficiency indicators of crop production in mountain LFA areas and non-LFA areas.

2. Materials and Methods

2.1. Field Experiment

Research carried out in 2015–2018 included two one-factor field experiments based on the method of randomized blocks in four replications. A single plot had an area of 18 m². In the experiments, facultative wheat, winter wheat, field bean with determined growth habits and spring barley were grown annually. Potato cultivated on dung was the forecrop for facultative wheat. Yields were expressed as cereal units (t·ha^{−1}) to facilitate comparisons of different crops with each other [19]. The cereal units are calculated by multiplying crop yield (t·ha^{−1}) and conversion coefficients, which are as follow: 1.00 for cereals and 1.20 for field bean. Field experiments, in which the abovementioned crops were cultivated, were established in different climate and soil conditions, i.e., in the experimental station in Mydlniki near Kraków (lowland, outside the LFA, 270 m a.s.l.) and in the experimental station Czynna near Krynica (Low Beskids in Carpathians, in the LFA, 545 m a.s.l.), where LFA subsidy is equal to 104.65 Euro·ha^{−1}). The same fertilization for all crops was used at both stations: 72 kg·ha^{−1} N; 34 kg·ha^{−1} P; 55.6 kg·ha^{−1} K. Additionally, a starting dose of 25 kg·ha^{−1} N was used for field bean. Weeds were controlled in cereals at the end of the tillering phase with Granstar herbicide at a dose of 24 g·ha^{−1}. The Gallant Super 104 EC pesticide, in a dose of 0.7 l·ha^{−1}, was used in field bean after weed emergence. Pests in field bean were controlled twice with the Karate Zeon 050 EC insecticide (0.15 l·ha^{−1}) and once with Pirimor 500 WG (0.3 kg·ha^{−1}).

The experimental field is located in Carpathians (19,600 km² and approximately 70% mountain and sub-mountain area in Poland), in the southwest slope of Banicka Góra (696 m a.s.l.). In general, the upper limit of field crops coincides in the Carpathians with an isotherm + 6 °C, i.e., 600–700 m a.s.l. [20]; therefore, this field experiment location belongs to the commonly cultivated areas in mountain regions. In Poland, the share of mountainous farms cultivating only crops (without livestock) in Carpathians is calculated as 42% [21].

2.2. Soil Conditions

Soil in the experimental field at the station in Mydlniki was defined as brown soil derived from loess. This soil belongs to the second agricultural usefulness complex and is defined as ‘good for wheat’. In the Czynna station, there was brown soil formed of weathered flysch rocks with the grain size of gravelly loam. It was included in the 12th soil complex defined as ‘mountain oat-potato’.

2.3. Climatic Conditions

Characterizing the vegetation periods (VPs) (April to September, in the years 2015–2018) according to Kaczorowska [22], in relation to precipitation at the Czynna station, it can be concluded that VPs in 2016 and 2017 were average and VPs in 2015 and 2018 can be defined as dry (Table 1). The 2016 and

2017 VPs at Mydlniki were also average, but the 2015 VP was very dry and 2018 was dry. The mean annual precipitation sums for the analysed VPs in Czyrna were 20% higher than in Mydlniki (and 23% higher for the long-term mean of annual precipitation).

Table 1. Monthly precipitation distribution (mm) during the vegetation period in the years 2015–2018 in Czyrna (mountain Less Favoured Area—mountain LFA) and Mydlniki (non-LFA).

Years	Months					Total Precipitation	
	IV	V	VI	VII	VIII	IV–VIII	I–XII
mountain LFA (Czyrna)							
2015	50.5	123.8	43.5	52.1	83.7	353.6	719.7
2016	62.4	56.2	62.0	221.9	136.5	539.0	904.5
2017	121.6	69.1	38.5	100.3	89.7	419.2	1053.2
2018	25.1	82.4	85.2	118.6	85.4	396.7	722.0
1981–2002	62.0	99.6	118.6	111.2	91.0	482.3	838.9
non-LFA (Mydlniki)							
2015	42.2	103.9	35.8	42.4	69.1	293.4	584.3
2016	51.8	46.0	51.0	180.1	113.8	442.7	727.7
2017	106.7	58.7	30.0	85.1	78.0	358.5	929.7
2018	13.0	69.6	76.5	92.7	73.1	324.9	641.5
1981–2002	48.3	83.1	97.6	85.8	87.6	400.2	681.3

It could be assessed, by monitoring the temperature that the mean long-term annual temperature and the mean temperature for the VP in Mydlniki were, on average, 1.7 °C higher than in Czyrna. However, the value of the average annual temperature recorded in both stations allowed to place them in a moderately warm (6–8 °C) vertical climatic zone [23]. According to that, comparing our location (545 m. a.s.l.) to the East Alp Region, within the same climatic zone, it could be noted that due to the shift in latitude (toward the north direction for Carpathians), natural conditions of our location are worse than those located in the same level in the East Alps (270 m shift as negative difference in adequate altitude). Thus, due to the possibility for comparing our results with another location, the corresponding level of farms located in the East Alp Region was calculated to approximately 815 m a.s.l. [20,23]. Moreover, a cited author [23] stated that, for every 100 m increase in altitude, the average annual temperature decreases by 0.55 °C, the rainfall increases by 30–50 mm and the vegetation period is reduced by 8 days. The average length of the VP at the Mydlniki station was 227 days, while in Czyrna—180 days. Considering the results of the studies by Rudnicki [24], Klima and Pisulewska [25], Kościelniak and Dreczka [26] and Rojek [27], it can be stated that the most favourable precipitation conditions in 2015–2018 for cereal and field bean harvesting occurred in the 2018 VP at both stations.

2.4. Assessment of Economic Characteristics

The costs for LFA and non-LFA are assumed as the same in the experiment due to the fact that in the LFA areas, the experimental field inclined by 12% (or 6.8 degrees)—what is acceptable for tillage and does not cause enhanced costs and erosion. If the slope is above 8 degrees, it is not recommended to plough due to soil erosion and lower ploughing quality [28]. The same costs for the LFA area and outside the LFA area could allow one to accurately determine the impact on yield of natural conditions occurring in the LFA. Therefore, in this paper, the structure of all costs for both mountain LFA farm and non-LFA farm are the same, and adopted by calculations cited below.

The amount of investments in the means of production was taken as the basis for the costs of agrotechnical measures used in the experiment as well as the consumption of seed, fertilizers

and pesticides. The values of these means of production were calculated per 1 hectare, and the prices of individual means were taken from the last year of research (2018). The commodity value of harvested crops and the prices of means of production were adopted in accordance with market analysis data developed at the Market Research Institute IERiGZ-PIB [29]. An additional source of data was agricultural production calculations compiled by the Department of Economics and Agricultural Management of the Małopolska Agricultural Advisory Centre in Karniowice [30]. The calculations took into account the average for yields obtained in the years 2015–2018. The amount of human labour expenditure was adopted in accordance with Klikocka et al. [31].

The costs of cultivation were determined according to Muzalewski [32]. The direct surplus was calculated from the difference between the value of production obtained and direct costs incurred. The direct profitability index, which characterizes the ratio of the production value to direct costs, was determined according to the method of Klepacki and Gołębiewska [33]. The labour intensity in the cultivation of cereals and field bean was 9.5 man-hours·ha⁻¹. This value was based on labour intensity recorded during the experiment. When converting the values expressed in Polish Zloty into Euro, the exchange rate of 4.30 of the National Bank of Poland from 31 December 2018 was adopted.

2.5. Statistical Analyses

The experimental results were analysed statistically using two-factor analysis of variance. The first factor was two localities (Czyrna and Mydlniki), differing in climate and soil conditions (LFA area and non-LFA, respectively). The second factor was four crops (facultative wheat, winter wheat, field bean and spring barley). The significance of differences was tested using Fisher's LSD multiple comparison test with a level of significance of $\alpha = 0.05$.

3. Results

Unfavourable climatic and soil conditions occurring in the LFA area resulted in lower yields of cereal grain, on average by 0.56 t·ha⁻¹ (13.2%), and field bean seeds by 0.36 t·ha⁻¹ (11.2%). The yields were expressed as cereal units to facilitate comparisons of different crops with each other [19]; therefore, the average yield reduction in the LFA area was 12.7% (Table 2).

Table 2. Crop yield expressed in cereal units (t·ha⁻¹) depending on various climatic and soil conditions occurring in the LFA or non-LFA area.

Crops	Yield in Cereal Units ⁱ (t·ha ⁻¹)		
	LFA	Non-LFA	Average
Facultative wheat	3.54	3.89	3.71
Winter wheat	3.89	4.82	4.35
Field bean	3.44	3.87	3.65
Spring barley	3.71	4.12	3.91
Average	3.65	4.18	3.91
LSD $\alpha = 0.05$		0.106	0.161
LSD ⁱⁱ $\alpha = 0.05$		0.145	

ⁱ conversion coefficients are described in Section 2.1; ⁱⁱ for interaction (site x crops).

The obtained results were consistent with the conclusions of Szarek and Klima [15], Nietupski [34], and Klima et al. [35], who found that the reduction in cereal yields in LFA regions (compared to non-LFA) was 9%. Nietupski [34] cultivated cereals in the Sudety Mountains and reported that oat yields decreased by 13% and spring barley by 11% on an arable land above 300 m a.s.l. for every 100 m increase in altitude.

In terms of cereal unit, the highest average yield was obtained for winter wheat, and the lowest for field bean (Table 2). Among the tested crops, the least sensitive to cultivation in LFA areas was facultative wheat (9% reduction in grain yield) and spring barley (11% reduction in seed yield). There is no research available in the present literature on the cultivation of facultative wheat in LFA areas. It can be assumed that the results of facultative wheat yielding in LFA areas presented in this article are among the first.

Crop yields were obtained under specific cost structure (Table 3), which could be interpreted in economic terms (Table 4) describing farm efficiency and the role played by the LFA subsidy.

Table 3. Structure of production costs (Euro·ha^{−1}) of cultivated crops grown in the mountain LFA area and non-LFA area.

Type of Costs	Facultative Wheat	Winter Wheat	Field Bean	Spring Barley	Average
Cultural costs					
Tillage	49.3	49.3	49.3	49.3	49.3
Fertilization	16.5	16.5	16.5	16.5	16.5
Sowing	15.8	15.8	15.8	15.8	15.8
Weed management	31.3	31.3	94.1	31.3	47.0
Harvest and transport	135.5	135.5	135.5	135.5	135.5
Man labour	22.0	22.0	22.0	22.0	22.0
Total cultural costs	270.4	270.4	333.2	270.4	286.1
Material costs					
Mineral fertilizers	137.2	137.2	98.1	137.2	127.4
Seeds	95.1	87.2	136.7	53.0	93.0
Total material costs	232.3	224.4	234.8	190.2	220.4
Crop protection costs					
Seed treatment	5.5	5.5	6.9	5.5	5.9
Herbicides	11.6	11.6	27.9	11.6	15.7
Insecticides	0	0	23.2	0	5.8
Total crop protection costs	17.2	17.2	58.0	17.2	27.4
Overall direct costs	519.9	512.0	626.0	477.8	533.9

costs obtained in the LFA area and non-LFA area are the same; for explanation see Section 2.

Table 4. Economic efficiency indicators for crop production in the mountain LFA area and non-LFA area.

Type of Costs (Euro·ha ^{−1})	Facultative Wheat		Winter Wheat		Field Bean		Spring Barley		Average	
	LFA	non-LFA	LFA	non-LFA	LFA	non-LFA	LFA	non-LFA	LFA	non-LFA
Production value	600.9	660.2	678.3	840.6	653.9	736.0	569.3	632.3	625.6	717.3
Direct subsidies	283.0	178.3	283.0	178.3	450.6	346.0	283.0	178.3	324.9	220.2
Production value with direct subsidies	883.9	838.5	961.3	1018.9	1104.5	1082.0	852.3	810.6	950.5	937.5
Direct costs	519.9	519.9	512.0	512.0	626.0	626.0	477.8	477.8	533.9	533.9
Direct surplus without subsidies	81.0	140.3	166.3	328.6	27.9	110.0	91.5	154.5	91.7	183.4
Direct surplus with all subsidies	364.0	318.6	449.3	506.9	478.5	456.0	374.5	332.8	416.6	403.6
Share of subsidies in direct surplus (%)	78	56	63	35	94	76	76	54	78	55
Direct profitability index										
without subsidies	1.16	1.27	1.32	1.64	1.04	1.18	1.19	1.32	1.17	1.34
with subsidies	1.70	1.61	1.88	1.99	1.76	1.73	1.78	1.70	1.78	1.76

in the table ‘subsidies’ are related to all financial support (including LFA subsidy equals to 104.65 Euro·ha^{−1}).

4. Discussion

Winter wheat was most sensitive to cultivation in the LFA (19.3% reduction in grain yield). The strong reaction of winter wheat could be due to the high climate and soil requirements of this crop. In general, the sum and distribution of precipitation during the VP can significantly differentiate winter wheat yield [36]. The thickness of the snow cover in winter significantly affects wintering capacity and, thus, potential yield levels, as well as a strong negative reaction (expressed as a 31% reduction in grain yield) at sites characterized by a looser soil granulometric category (light loamy sands versus light clay) [37]. The yield of winter wheat is also dependent on proper forecrops. Bednarek et al. [38] reported that increased winter wheat yield (by 32%) was obtained after field pea compared to continuous winter wheat cultivation. Wanic et al. [39] found the similar tendency, i.e., enhanced yield of common wheat after pea as a forecrop by 17.5% together with significant increased protein content in wheat grain (by 7.9 g·kg⁻¹).

The average cost of cultivation, harvesting and transport, as well as man labour, accounted for 54% of the total direct costs (Table 3). The average cost of materials and means of production was 46%. Therefore, the average value of production obtained outside the LFA area in more favourable conditions around Krakow (Mydlniki) was on average 12.8% higher than in the LFA mountain area (Table 4). The average value of direct surplus without additional payments outside the LFA area was almost two-fold higher than in LFA mountain areas. The obtained results indicate that the introduction of payments for LFA areas in the European Union is valid.

Many publications contain different opinions on the amount of LFA subsidies. Model approaches to the issue of production profitability in LFA areas are described in the literature. Barath et al. [40] examined Slovak farms using the random parameter model technique and proposed to include a factor in the model of “production and technology specificity” of LFA and non-LFA farms, which had a significant impact on the conclusion about technical efficiency between adopted farm groups (with and without LFA areas). This means that the differentiation of economic characteristics based on the level of innovation on farms gives the possibility of more detailed inferences about the amount of LFA payments. The methodology adopted in this article was based, as mentioned earlier, on the assumption of no differences in crop production and technologies in order to be able to focus on the basic, and at the same time, the most important production results, i.e., the yield obtained simultaneously from two types of areas (mountain-LFA and non-LFA). However, here opens the possibility for further economic research more focused on differences among particular costs categories, namely, more precisely defining various characteristics of LFA- and non-LFA-located farm (i.e., not only their location, but also size, means of production, innovation level, etc.)

Considering the amount of subsidies in other European Union (EU) countries, it is worth mentioning that the countries included in the subsidy system for citizens living in the LFA mountain type are primarily: Finland, Slovakia, Slovenia, the Czech Republic, Sweden, Italy, Spain, Portugal, Poland, Greece, Lithuania, and Austria. These countries have different goals in terms of equalizing farm opportunities in LFA areas [41]. Lososova et al. [42] found that the largest subsidies for the production of mountain type LFAs were paid in 2012 for farms in Finland (1036 Euro·ha⁻¹), while the lowest in Spain, Romania and Bulgaria (300 Euro·ha⁻¹). The cited authors pointed to a directly proportional relationship between the share of LFA payments in farm revenues and their profitability. This relationship is more evident along with worsening farming conditions [8].

To express the difference in the economic results of LFA farms and outside LFA, Štolbová et al. [43] proposed the use of an economic indicator, i.e., gross farm income per 1 hectare of agricultural land, Annual Work Unit (AWU), and an assessment of the land owned (i.e., the ratio of own land to rented land). This approach has resulted in calculating the impact of the “natural constraints” factor found in LFA mountain regions (relative to other LFA areas) at just over 2000·ha⁻¹ CZK of arable land for farms involved in crop production in the LFA mountain area. In Portugal, where more than 50% of agricultural land belongs to the LFA areas, the known LFA mountain area ‘Centro’ (38% of the agricultural area located on an area with a slope above 15%) primarily focuses on entities farming on

permanent pastures and extensive cattle farming [44] after the cessation of special financial instruments for wheat from 1889 until 1996 [45]. The authors report wheat yields as oscillating around $1.20 \text{ t}\cdot\text{ha}^{-1}$.

The results of research by Poczta et al. [46] can be found in publications on Polish agriculture. The cited authors claimed that LFA payments at the current level did not compensate for smaller yields and larger outlays incurred in LFA areas, especially on small farms. However, Bereźnicka [47] argued that the amount of subsidies was sufficient at that time. The study by Jankowska-Huflejt et al. [48] demonstrated that crop production productivity of LFA mountain areas in relation to all other LFA areas under Polish agriculture was lower by 74%, and LFA lowland areas by 19 to 39% (compared to the national average for LFA areas). Based on research pools, Kata [8] confirmed the decreasing value of income from operational farm activity toward higher altitude: 10,697.3 Euro (lowland farms; 719 farms) > 7201.2 Euro (sub-mountain farms; 55 farms) > 5458.1 Euro (mountain farms; 82 farms).

In this research, the average value of direct surplus without subsidies outside the LFA area was $183.4 \text{ Euro}\cdot\text{ha}^{-1}$, while in the LFA area $91.7 \text{ Euro}\cdot\text{ha}^{-1}$ (Table 4). The difference is $91.7 \text{ Euro}\cdot\text{ha}^{-1}$, while the current LFA supplement equals $104.65 \text{ Euro}\cdot\text{ha}^{-1}$. It can therefore be concluded that LFA payment currently in force in Poland effectively compensates for the reduction of direct surplus in LFA regions. This statement applies only to cereals and field beans tested in the experiment. A broader conclusion about the amount of LFA subsidy should be based on the results of many years of research involving many crops and agricultural products (including milk and meat), and the prices of means of production.

A similar study was conducted by Oxouzi et al. [49] in a Greek mountain LFA region, where winter wheat is the main crop (above 70% in all crops). Comparing the results, it has been noted that subsidy farms reached on average a profit of 1714.6 Euro, in contrast to a loss of −10,852.1 Euro, if no LFA compensatory allowance was granted. Taking into account the above-mentioned farm (size on average 19.3 ha) direct surplus with subsidies equals to approximately $89 \text{ Euro}\cdot\text{ha}^{-1}$, and approximately $-562 \text{ Euro}\cdot\text{ha}^{-1}$ without subsidies. However, it is interesting that the LFA compensatory allowance share in gross revenue was 5.2%, comparing to 11% obtained in our results (Table 4). The production value of the Polish farm reached, on average, 65.8% of gross revenue, instead of the Greek mountain LFA farm, where 31.4% were assigned to crop-derived profits.

The available literature does not include data on the current Common Agricultural Policy funding period (2016–2020) related to the LFA mountain type. Hence, it can be assumed that the data contained in this publication are the first regarding the 2016–2020 funding period.

5. Conclusions

Low susceptibility of facultative wheat to cultivation in less favourable climate and soil conditions indicated the usefulness of this cereal for cultivation in mountain LFAs, instead of winter wheat, which exhibited the greatest yield reduction there. The average yield of cereal units of crops cultivated outside the LFA, in favourable conditions for agricultural production in the vicinity of Kraków, was higher by 12.7% compared to the LFA area in the mountainous conditions of the Low Beskids, Carpathians. Even though yield losses in the LFA area ranged from 9 to 19% (depending on the crop), subsidies in place brought all crops to equal productivity index. The similar results could be observed in other EU countries. In the LFA area, the highest average yield of cereal units was recorded for winter wheat and the lowest for field bean. In terms of economic results, the average value of direct surplus without subsidies obtained in the non-LFA area was twice as high as in the mountainous conditions of the Carpathians (LFA area). On the basis of this study, it could be concluded that LFA subsidy effectively compensated lower yields of Polish farmers in the LFA area.

As assumed earlier, the essence of the LFA subsidies is to compensate for the impact of worse natural conditions for agricultural production. Therefore, in this paper, for the transparency of inference about the impact of natural conditions, the diversity of technology and equipment in the farms were ignored, which could be of some limitation in this research. Moreover, farm size related to the overall farm profitability resulting from subsidies would be an interesting issue for further investigation.

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