The Effect of CAP Policy Incentives for the Environmental and Economic Performance of Cereal Farms in South-Central Bulgaria

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Abstract

This paper aims to assess the effects of three mechanisms of the Common Agricultural Policy incentivizing environmentally friendly farming practices, on a model cereal farm's environmental and economic performance. Based on linear goal programming method and input data on the farm's size, production system, crop yield and gross margin per crop, the model optimizes the farm's production structure. The results indicate that the availability of support is essential for the economic results of cereal farms in South-Central Bulgaria. Generally, higher gross margin corresponds to higher greenhouse gas emissions and vice versa. Nevertheless, the addition of policy support decreases the degree of this dependency by improving the profitability of some less GHG-intensive crops. This allows farmers to consider more environmentally-friendly crops and production practices without having to cut profits. An optimal balance between farms' environmental and economic performance is crucial in order for agriculture to continue to support vital ecosystem services.

Keywords: Common Agricultural Policy, cereal farm, greenhouse gas emissions, multi-criteria optimization

INTRODUCTION

The agricultural production is essential for the health, prosperity and development of the human population. The sector provides food, clothing, feed and other products of primary importance. Furthermore, agriculture is a provider, but also a recipient of vital ecosystem services, such as carbon sequestration and biodiversity conservation among others (Swinton *et al.*, 2007). However, the rapid growth and development of the sector in response to the growing population, has brought some serious negative environmental impacts. Nowadays the sector is the world's second largest emitter of greenhouse gas emissions and causes significant water pollution, soil degradation and biodiversity loss (Allen *et al.*, 2014; Leip *et al.*, 2017). A lot of research efforts have been

invested in the recent years in the search for more environmentally friendly ways for agricultural production, assessing farms from different sectors, production systems and practices on the basis of multiple environmental and economic criteria (Bachev *et al.*, 2017; Meier *et al.*, 2015; Nemecek *et al.*, 2015; Audsley, and Wilkinson, 2014).

In response to the sector's burden on the environment, the Common Agricultural Policy of the European Union (CAP) has been providing farmers with economic incentives for following environmentally sustainable farming practices since 1992. The CAP's environmental mechanisms have been evolving ever since and currently include the Pillar II organic farming compensatory payments (OF), the Green direct payments under Pillar I (CAP "Greening"), as well as the cross

compliance obligatory rules, accompanying all Pillar I support schemes. The advisability and effectiveness of these measures, however, have been subject to discussion (Gocht *et al.*, 2016; Pe'er *et al.*, 2017; Concepción *et al.*, 2020; Trapp, and Lakner, 2018).

This paper aims to assess the effects of the three CAP mechanisms supporting environmental measures, namely: the Single Area Payment Scheme (SAPS), the Green direct payments and the organic farming compensatory payments, on a model cereal farm's environmental and economic performance. The model optimizes the production structure of the farm, which includes some of the most common cereal crops and production systems in Bulgaria. The optimization is performed under a combination of environmental and economic goals, allowing to compare the trade-offs between the most environmentally friendly, the most profitable, as well as the optimal environmental-economic crop combinations. The three scenarios consider different economic reality: with or without policy support. This allows to assess the effect of the different policy support mechanisms on the farm's production structure and its related environmental and economic performance.

MATERIALS AND METHODS

The research method is linear goal programming with single/multi-criteria optimization. It is aimed at optimizing the production structure of a model cereal farm under economic and environmental goals. Linear goal programming has been used for the optimal allocation of resources in agriculture for decades (Shmelev *et al.*, 2012). The challenges related to agricultural pollution and the agricultural-environmental linkages led to a new direction of the application of the classical crop simulation models, allowing for some of the negative environmental externalities to be included (Zekri and Boughanmi, 2007). The model developed for this research is based upon the linear goal programming method as described by Nikolov *et al.* (1994), to which an environmental dimension of crop production has been added with the support of LCA data. For the needs of the model, the territory of the South-Central region in Bulgaria (NUTS II) used for cereal crop production, is considered as one farm unit. The crop profile is based on data on the specialized cereal farms in the region (Ministry of Agriculture and Food,

2016). Therefore, the model contains 6 major crops: wheat, barley, maize, rapeseed, sunflower, alfalfa as nitrogen-fixing crop, and fallow land. All crops are included under two alternative production systems: conventional and organic. The variables of the model stand for the area referring to each crop in each of the two production systems.

In mathematical terms, the goal programming model is expressed as:

$$\text{MAX } F = d^+ + d^- \quad (1)$$

with target constraints: $A \cdot X - d^+ + d^- = M$ (2)

and resource constraints: $B \cdot X \geq \text{or } \leq b$ (3); $X \geq 0$; $d^+ \geq 0$; $d^- \geq 0$.

where:

F represents the goal function,

d^- – vector ($m \times 1$) of negative deviations from achieving goal “m”;

d^+ – vector ($m \times 1$) of positive deviations from achieving goal “m”;

A – matrix ($m \times n$) of coefficients of the target constraints;

X – vector ($n \times 1$) of variables in the model;

M – vector ($m \times 1$) of goals that have to be achieved;

B – matrix ($p \times 1$) of coefficients of the resource constraints;

b – vector ($p \times 1$) of the resources of the resource constraints.

In order to examine the role of policy incentives for the optimization of the farm's environmental and economic performance, the optimization is conducted under three scenarios:

- (1) without any support;
- (2) with direct payments under the CAP Pillar I (SAPS and the CAP “Greening”);
- (3) with CAP Pillar I direct payments (SAPS and CAP “Greening”) and CAP Pillar II compensatory payments (OF).

All optimization scenarios are conducted under three independent goals:

- i. best environmental performance (single criteria optimization with goal to minimize the farm's emissions of greenhouse gases (GHG)). Agriculture is simultaneously contributing to climate change but also severely affected by it. The GHG emission intensity per crop and production system based on LCA data allows

- the model to simulate and minimize this contribution;
- ii. best economic performance (single criteria optimization with goal to maximize the farm's gross margin). Despite the sector's specificities, profits are the main goal in business, as they secure development and continuance of operation;
 - iii. optimal environmental-economic performance (multi-criteria optimization with the environmental and economic goals simultaneously). An optimal balance between farms' environmental and economic performance is crucial in order for agriculture to continue to support vital ecosystem services.

Two *target constraints* are used for the optimizations. The target constraint for the farm's environmental performance equals 1 084 525 204 kg CO₂-eq and presents the emissions of greenhouse gases of the South-Central region in Bulgaria by keeping the recommended crop diversification for both conventional and organic arable land in the region (National Statistical Institute, 2018; Ministry of Agriculture and Food, 2013; Wernet *et al.*, 2017). The target constraint for the farm's economic performance equals 133 424 160 Bulgarian leva (BGN) and is calculated by multiplying the land used for cereal farming in the region by an average gross margin of 40,8 BGN per dka (amount without subsidies) (National Statistical Institute, 2018; Ministry of Agriculture and Food, 2013).

The *landuse constraint* of the model equals the arable land used for production of the aforementioned crops in the South-Central region in Bulgaria (3 300 000 dka) (National Statistical Institute, 2018). The model involves crop diversification constraints for all crops and land uses ($25\% \leq \text{wheat} \leq 40\%$; $5\% \leq \text{barley} \leq 15\%$; $5\% \leq \text{maize} \leq 40\%$; $0\% \leq \text{rapeseed} \leq 20\%$; $0\% \leq \text{sunflower} \leq 25\%$; $0\% \leq \text{alfalfa} \leq 25\%$; $0\% \leq \text{fallow land} \leq 15\%$), included in all scenarios (Ministry of Agriculture and Food, 2013; National Service for Plant Protection, 2008).

The *requirements of the CAP "Greening"* on crop diversification (no crop shall exceed 75% of the land) and ecological focus areas (EFA $\geq 5\%$ of the land) are included in Scenarios (2) and (3) (Ministry of Agriculture, Food and Forestry, 2018). Scenario (3) includes a requirement for the organic area to exceed 8% in accordance with the national target set in the National Action Plan on

Development of the Organic Farming in Bulgaria by 2027 (Ministry of Agriculture, Food and Forestry, 2019).

The *economic coefficients* in the model present data on the gross margins for the different crops and production systems (Ministry of Agriculture and Food, 2013), as well as rates for the direct payments under the SAPS and CAP "Greening" and the rate for organic farming compensatory payments (Tab. 1). The rates for subsidies and compensatory payments refer to year 2015 for Bulgaria: 83,80 euro/ha under the SAPS (Ordinance № RD 09-341 of 03.06.2016 of the Minister of Agriculture and Food); 65,04 euro/ha under the CAP "Greening" (Ordinance № RD 09-240 of 26.04.2016 of the Minister of Agriculture and Food); 168 euro/ha organic farming compensatory payment (Ordinance № 4 of 24.02.2015).

The *environmental coefficients* in the model present the generated amount of GHG emissions for the different crops and production systems (Tab. 1). They have been secured through the ecoinvent database v. 3.4, LCIA model ReCiPe Midpoint (H) (Wernet *et al.*, 2017) and have been adapted with the yields per crop and production system (average yields at NUTS II level for the period 2012-2016) (National Statistical Institute, 2018).

The optimizations have been performed through LINGO v.18.0 optimization software of LINDO Systems.

RESULTS AND DISCUSSIONS

The results for the environmental and economic performance of the model farm in the different scenarios are presented in Tab. 2. Best environmental results for the model farm are achieved under the Environmental goal in Scenario 2 and Scenario 3, namely: 245 822 000 kg CO₂-eq (equivalent of 22,67% of the environmental target constraint) (Figure 1). In terms of production structure, the solution does not vary in the different scenarios, and involves: organic wheat (40%), organic barley (15%), organic maize (5%), alfalfa (25%) and fallow land (15%). Organic production system is preferred and wheat, barley and alfalfa are selected in their highest percent allowed, due to their lower intensity of GHG emissions per dka. Sunflower and rapeseed are not included in the production structure, while maize is included in the lowest percent allowed, organically produced.

Table. 1. Environmental and economic coefficients applied in the model

Crops:	GHG emissions, kg CO ₂ -eq per dka	Gross margin, BGN per dka		
	In all scenarios	Scenario 1: No subsidies	Scenario 2: SAPS and CAP “Greening”	Scenario 3: SAPS, CAP “Greening”, OF
Conventional wheat	262,45	54,00	83,11	83,11
Organic wheat	96,41	30,00	59,11	91,97
Conventional barley	276,97	49,00	78,11	78,11
Organic barley	49,38	7,20	36,31	69,17
Conventional maize	607,12	77,50	106,61	106,61
Organic maize	136,75	32,90	62,01	94,87
Conventional rapeseed	230,77	68,00	97,11	97,11
Organic rapeseed	159,04	25,55	54,66	87,52
Conventional sunflower	231,90	64,00	93,11	93,11
Organic sunflower	154,73	24,04	53,15	86,01
Conventional alfalfa	84,50	54,84	83,95	83,95
Organic alfalfa	79,67	20,06	49,71	82,57
Fallow land	11,77	0,00	29,11	29,11

Source: ecoinvent database (Wernet et al., 2017); Ministry of Agriculture and Food (2013); Ordinance № 4 of 24.02.2015; Ordinance № RD 09-240 of 26.04.2016 of the Minister of Agriculture and Food; Ordinance № RD 09-341 of 03.06.2016 of the Minister of Agriculture and Food.

Although the GHG emissions under the Environmental goal in all scenarios are relatively constant, their corresponding gross margin values are subject to significant increase (nearly 290%) (Figure 2). On the other side is the highest level of GHG emissions achieved. It is observed in Scenario 2 under the Economic goal of the model, which generated more than 4 times more GHG emissions. The corresponding production structure of the farm involves: conventional wheat (24,79%), conventional barley (5%), conventional maize (40%), conventional rapeseed (20%), conventional sunflower (5%), conventional alfalfa (5%) and organic wheat (0,21%). Here on the opposite, conventional production is preferred and maize and rapeseed are at their highest level allowed, while wheat, barley and alfalfa are at their lowest.

Best results in terms of gross margin of the model farm are achieved under the Economic goal in Scenario 3: 321 235 900 BGN (equivalent of 241% of the target constraint), followed closely by the amount in Scenario 2 (Tab. 2, Figure 2). In terms of production structure of the farm, the

best results from economic perspective include: conventional maize (37%), organic wheat (25%), conventional rapeseed (20%), conventional sunflower (5%), conventional barley (3,96%), conventional alfalfa (3%), organic maize (3%), organic alfalfa (2%) and organic barley (1,04%). The gross margin achieved in Scenario 3 is 80% higher than the gross margin in the “No support” Scenario and this difference illustrates the contribution of the CAP incentives for the improvement of the economic results of the model farm. Furthermore, the inclusion of compensatory payments for organic farming makes some of the organically produced crops more profitable than their conventional alternatives, which has led to 30% growth in the share of organic production, compared to Scenario 2. This production structure reduced GHG emissions by 15% while increasing the corresponding gross margin by 2%. The lowest gross margin of the farm is observed in the “No support” scenario under the Environmental and Optimal goals, where it does not manage to exceed the economic target constraint. However, this

situation is overcome in the two other scenarios with the support provided by the CAP.

Effect of CAP incentives on the optimization of the model farm's economic and environmental performance

There is a beneficial effect of the CAP incentives not only on the model farm's economic per-

formance but also on its environmental results. In evidence hereof, the best environmental solution in Scenario 3 results in 43% higher gross margin than the best economic performance in Scenario 1, while cutting GHG emissions more than half. The addition of the CAP direct and compensatory payments in the model results in improvement

Table 2. Model farm's environmental and economic performance in the different scenarios and goals

Scenario	Parameter	Economic goal		Environmental goal		Optimal goal	
		Result	% of target	Result	% of target	Result	% of target
1: No support	GHG, CO ₂ -eq, kg	751 871 900	69,33	245 880 300	22,67	299 460 100	27,61
	Gross margin, BGN	176 600 800	132,36	65 581 540	49,15	63 772 500	47,80
2: SAPS, Greening	GHG, CO ₂ -eq, kg	1 266 990 000	116,82	245 822 000	22,67	249 806 700	23,03
	Gross margin, BGN	315 321 200	236,33	161 650 500	121,16	189 898 500	142,33
3: SAPS, Greening, OCP	GHG, CO ₂ -eq, kg	1 076 455 000	99,26	245 822 000	22,67	245 822 000	22,67
	Gross margin, BGN	321 235 900	240,76	253 822 800	190,24	253 822 800	190,24

Note: The percent of target has been calculated as share of the achieved results of the target constraints (1 084 525 204 kg CO₂-eq and 133 424 160 BGN). Source: Own calculations

Figure 1. Carbon footprint of the farm in the different scenarios and goals, kg CO₂-eq.

Source: Own calculations and presentation

of the profitability of some of the crops that have better environmental performance. This reduces the large disparity between the best economic and best environmental results by bringing them closer. This can be observed by the Optimal solution results in the three scenarios: the first two optimal solutions provide transitional results – slightly higher GHG emissions and slightly lower to moderately higher gross margin, in comparison with the results under the environmental goal. In the third scenario, however, this difference has been overcome, as the optimal solution replicates the environmental solution completely. Thus, the addition of the direct and compensatory payments to the farm's gross margin, results in obtaining gross margin of 253 822 800 BGN at farm level (equivalent to 190% of the economic target constraint), by generating only 23% of the GHG emissions target constraint. Furthermore, the results under Scenario 3 outperform the other two scenarios under all goals (economic, environmental and optimal) by achieving higher gross margin at the same or lower GHG emission level. These results indicate that the organic farming compensatory payments build on the CAP Pillar I direct payments and improve further the farm's economic and environmental performance, achieving the best results among the modeled scenarios.

In terms of production structure, the influence of the CAP incentives is best seen in the results under the Economic and Optimal goals in the different scenarios (Tab. 3).

In the "No support" scenario's Economic goal, the production structure includes 82% conventional crops and 18% organic crops. The SAPS and Green direct payments's rates are area-based and

do not differentiate conventional and organic production, which results in even higher share of conventional production in Scenario 2 (99,79%). In terms of GHG emissions, however, this production structure generates 69% more emissions than Scenario 1. The inclusion of the organic farming compensatory payments changes the results under the Economic goal and devotes 31% of the land to organic crops. This production structure results in 18% lower GHG emissions than in Scenario 2, but still 43% higher GHG emissions than in Scenario 1. The reason for the increase in the GHG emissions is the increased share of maize (from 2% conventional maize and 17% organic maize in Scenario 1 to 37% conventional maize and 3% organic maize in Scenario 3), owing to the increased profitability of this GHG-intensive crop.

CONCLUSION

The multifunctionality of agricultural land imposes making a choice between various and often mutually exclusive uses of the land. Each of these uses is characterized by differing outputs, environmental impacts and economic profit. This is why the choice between the different uses of the land requires the consideration of multiple goals and criteria. The performed optimization of the production structure of a model cereal farm showed that the availability of support is essential for the economic results of cereal farms in South-Central Bulgaria. Also, there is wide variation in the economic and environmental results, achieved by the model farm, under the different goals and scenarios. Generally, higher gross margin corresponds to higher emissions of greenhouse

Table. 3. Production structure of the farm in the different scenarios, share of conventional and organic production

Scenario	Production structure	Economic goal	Environmental goal	Optimal goal
1: No subsidies	Conventional production,%	82,24	0,00	10,21
	Organic production, %	17,76	100,00	89,79
2: SAPS, GDPS	Conventional production,%	99,79	0,01	40,00
	Organic production, %	0,21	99,99	60,00
3: SAPS, GDPS, OCP	Conventional production,%	68,96	0,01	0,01
	Organic production, %	31,04	99,99	99,99

Source: Own calculations

gases and lower greenhouse gas emissions correspond to lower gross margin. Nevertheless, the addition of policy support decreases the degree of this dependency by improving the profitability of some less GHG-intensive crops. This allows cereal farmers to consider more environmentally-friendly crops and production practices without having to cut economic profits. However, the design of the support mechanisms is very important for the achievement of the desired outcomes. The compensatory payments for organic farming under the CAP showed better results in terms of GHG emissions and gross margin of the model farm compared to the direct payments under the Single Area Payment Scheme and the Green Direct Payments. This indicates that support mechanisms designed for particular production practices show better results and are more efficient than more generally designed policy tools. In conclusion, agriculture plays an essential role for the delivery of some public goods and ecosystem services, but it can also cause severe negative impacts to the environment. In order to continue to provide these services, it is crucial for farms to achieve an optimal balance between their environmental and economic performance. The results of this model simulation showed that the created model can support farmers in these efforts, providing them with in-time information about possible decisions and related impacts. This is in line with the result-based management concept, underlying the new CAP support mechanisms currently discussed.

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