
ECONOMIC AND ENVIRONMENTAL ASPECTS OF CROP PRODUCTION IN SLOVAKIA

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ABSTRACT

The significant part of arable land in Slovakia is devoted to the cultivation of crops, especially cereals, feed crops and industry crop. There is a high representation of mountain areas in country, therefore the fertile lowlands in west-south and east part are the primary locations of almost all agricultural production. The main objective of this work is to integrate the bio-physical crop data on yields with the economic data enabling to calculate net returns, in order to identify alternative costs of agricultural management practices for cultivation of 13 most important crops in selected west-south regions of Slovakia. We use the integrated bottom up optimization model which is based on linear programming. Management practices are differentiated according to nutrient input and irrigation application in order to evaluate yields as well as environmental factor – water use efficiency. Results suggest that in terms of net returns the management practices with high and medium nutrient input without irrigation are the most profitable but can represent a potential environmental pressure for soil.

1. INTRODUCTION

1.1. Economy of crop production in Slovakia

For the agricultural industry in Slovakia, the dominated sector is crop production. The major part of arable land is devoted to the cultivation of cereals, feed crops and industry crop. Current situation in agriculture of Slovakia is mostly affected by the process of intensification and specialization but also marginalization. Because of declining trend in livestock production the crop production has become the more significant sector from the viewpoint of farms' economy.

In the long term, the growing area of cereals in Slovakia achieve more than 50 % from total arable land area (Jamborová, Trubačová; 2016). Among the most important cereal commodities are wheat, barley and grain corn. When comparing the cost and revenues of crop commodities among the farms, the results are influenced by technologies, the farm size, subsidies and the internal and external prices (Jantová, Bodný; 2013). The cereal sector provides sufficient resources to meet the needs of agri-food market in Slovakia for the food, feed and energy purposes (Jamborová, Trubačová; 2016).

Following the cereals, another important commodity belonging to the category of industrial crops are the oil crops. The growing area is around 18% from total arable land (VUEPP, 2015). Increased growing areas of oil crops is affected by their market character, back-up system of purchase, persistent world economic production, penetration into technical fields, feed industry, the construction industry and increasing demand on the European and world market (Božík, 2011). Increased area is related to the increasing demand for these commodities mainly due to the production of energy from renewable sources (Récky, Dobák; 2011).

Economic results of farms are annually affected by cost and production-economic effect, on the one hand, the level of cost (material and labour inputs) to achieve mass production of crop and livestock production and on the other hand, the selling of production through prices, which is reflected in sales (Chrastinová, 2015). One of the current characteristic of economic results of agriculture is the fact that farm as the producer of raw materials for manufacturing the food and non-food production is losing its controlling influence over the food market and is increasingly influenced by the external environment (Veselská, 2006). Therefore the farms try to maximize the economic results by achieving the maximum crop yields. The yield of individual crops is influenced by management practise performed by agricultural establishment.

1.2. Environmental aspect of crop production in Slovakia

In Slovakia there is possible to identify 4 agricultural production areas, all with different soil conditions, altitude and structure of cultivated crops. Maize production area (West-south plain, East plain) has the most favourable condition for maize and wheat cultivation, rape production area (West part of Slovakia, Košice hollow-basin, South-Slovakian hollow-basin) with wheat cultivation and appropriate condition for sugar beet cultivation, potato-oat area (500-600 m.a.s.l.) with potato, wheat and perennial forage cultivation and mountains production area (from 600 m.a.s.l. – less favoured areas) with perennial forage and less demanding cereals.

The most widely spread soil type in Slovakia is cambisols. Because of the high representation of mountains areas the fertile lowlands are primary locations of almost all agricultural production. On the other hand extensive crop production in lowlands causes the losses of soil

organic carbon. According to SSCRI (Soil Science and Conservation Research Institute), the lowest concentration of soil organic carbon is in the arable land in south and south-west part of Slovakia (23.25 t/ha) despite of having the most fertile types of soil. This is clearly the negative effect of extensive crop production.

More than 39% of total area of Slovakia was covered by utilized agricultural area (UAL) in 2014. UAL has a downward trend, which is environmentally negative phenomenon as well, especially when it comes to set-aside areas of UAL and subsequent re-classification it into built-up areas, what is a case of Slovakia. Loss of the UAL land in recent years is approximately 1000 ha of agricultural land per year according to Soil Service.

On the other hand, intensive farming is usually accompanied by stronger mechanisation, higher fertiliser and pesticide use and irrigation. This does not only lead to higher greenhouse gas (GHG) emissions but also has adverse impacts on soil, water and air quality, depletion of fresh water resources, and loss of biodiversity (Elbersen et al., 2013; Foley et al. 2011).

Crop yield variability is heavily controlled by fertilizer use, irrigation and climate (Mueller et al., 2012) and intensification of production raise a question of more sustainable crop management practices. To minimize the environmental impacts of production intensification, increased irrigation and nutrient application to close crop yield gaps should be complemented by efforts to decrease overuse of crop inputs wherever possible. Agricultural production can benefit even from small changes in management practices as adjustments in sowing dates and fertilization intensity (Torriani et al. , 2007, Lehmann et al. 2011). The use of bioeconomic models linking crop bio-physical models with economic decision models has been suggested in various studies as a way toward integrated assessments (Challinor et al., 2009, Finger et al., 2011, Olesen et al., 2011).

1.3. Research objectives

The main objective of this paper is to integrate the bio-physical crop data with the economic data to identify opportunity costs of agricultural production choices for cultivation of 13 most important crops cultivated in Slovakia. The obvious benefits of this integration is the identification of the most profitable management practise, with respect to environmental implication reflected in water use efficiency of selected crops. We identify the net returns for crop mix of 13 commodities and focus on the crop production on level of regions, with special focus put on most fertile regions of south-west Slovakia.

The crops under consideration are: alfa (ALF), barley (BAR), wheat (WHE), grain maize (MAI), green maize (GMAI), rye (RYE), rapeseed (RAP), oat (OAT), peas (PEA), sunflower (SNF), soy (SOY), sugar beet (SGB) and potato (POT). The management practices are focused on nitrogen input and irrigation. We use the average economic and biophysical data for the period 2004-2014. The selected regions are regions mainly from maize production are Bratislava (BA), Malacky (MA), Senec (SC), Pezinok (PK), Nitra (NR), Nové Zámky (NZ), Levice (LV), Komárno (KN), Šala (SA), Topolčany (TO), Zlaté Moravce (ZM).

We employ integrated bottom up optimization in order to identify the most profitable management practises and evaluation of water use efficiency (WUEF). The integrated model links economic data of selected crops and regions with bio-physical crop data, which were simulated and aggregated on the regional level.

2. Methodology

The input data for regional bottom up integrated model are divided into economic and biophysical dataset. The economic dataset consists of direct costs (DirCost) and price for

crops and regions. The direct costs per hectare are the expenditures for fertilizers - purchased and produced, chemical protection, agrochemicals and seed – purchased and produced and are provided by Research Institute of Agricultural and Food Economics (NPPC-RIAFE, 2015). Direct costs were calculated for thirteen selected crops. These crops represent all major categories cultivated in Slovakia (cereals, feed crops, oil crops).

The biophysical data set is based on EPIC (environmental policy integrated climate model) simulation for selected crops. It provides information on crop yields under eight selected management practices as the average for time period 2004-2014. The crop yield data are provided on $1 \times 1 \text{ km}^2$ HRU in regions. The HRU were aggregated and crop data averaged on regional basis.

Management practices (Mana):

N0I – low nutrient input, full irrigation

N0R – low nutrient input, no irrigation

NHI – high nutrient input, full irrigation

NHR – high nutrient input, no irrigation

NMI – medium nutrient input, full irrigation

NMR – medium nutrient input, no irrigation

NPI – not limited nutrient input, full irrigation

NPR – not limited nutrient input, no irrigation

Table 1: Nutrient input under different management practices kg/ha

Crop	Mana	NRate	Crop	Mana	NRate
ALF	N0	20	RAP	NM	120
BAR	N0	40	RYE	NM	80
GMA	N0	40	SGB	NM	120
MAI	N0	80	SNF	NM	80
PEA	N0	40	SOY	NM	80
POT	N0	40	WHE	NM	80
OAT	N0	40	ALF	NH	80
RAP	N0	80	BAR	NH	120
RYE	N0	40	GMA	NH	120
SGB	N0	80	MAI	NH	200
SNF	N0	40	PEA	NH	120
SOY	N0	40	POT	NH	120
WHE	N0	40	OAT	NH	120
ALF	NM	40	RAP	NH	200
BAR	NM	80	RYE	NH	120
GMA	NM	80	SGB	NH	200
MAI	NM	120	SNF	NH	120
PEA	NM	80	SOY	NH	120
POT	NM	80	WHE	NH	150
OAT	NM	80			

Source: EPIC data

NRate from table 1, represents nitrogen allowance in kg per hectare for selected crop. The nitrogen input in case of N0 is up to lowest levels of crop yields in Slovakia and NH is up to

optimal crop yields observed in Slovakia. NM represents the medium nitrogen stress. NP represents unlimited nitrogen input, therefore it is not stated in table.

Table 2: Average irrigation water use in selected regions mm/ha

Region	Irrigation	Region	Irrigation	Region	Irrigation	Region	Irrigation
BA	130.19	BA	130.18	BA	129.52	BA	130.55
KN	172.38	KN	172.40	KN	172.40	KN	172.22
LV	169.55	LV	169.50	LV	169.52	LV	169.44
MA	170.04	MA	170.04	MA	170.04	MA	170.54
NR	177.94	NR	177.91	NR	177.91	NR	177.78
NZ	160.93	NZ	160.88	NZ	160.89	NZ	160.37
PK	145.90	PK	145.93	PK	145.89	PK	145.47
SA	148.30	SA	148.28	SA	148.30	SA	147.03
SC	143.76	SC	143.77	SC	143.76	SC	143.12
TO	177.93	TO	177.96	TO	177.95	TO	179.02
ZM	163.71	ZM	163.68	ZM	163.69	ZM	164.24

Source: EPIC data

The linear program for bottom-up optimization model is simplified version of Austrian agricultural and forestry sector model PASMA (Schmid et al., 2007) adjusted for small regional model of Slovakia in form:

$$\pi_{r,c} = \sum_c (YLDG_{r,c,m} * price) - (DirCost_{r,c} + FerCost + IrCost) \quad (1)$$

$$max \pi = \sum_{r,m} (\pi_{r,m} * x_{r,m}) \quad (2)$$

$$s. t. = \sum_m (a_{r,m} * x_{r,m}) \leq b_p \quad (3)$$

where:

π - net return

r – region

c – crop

m – management practice

x – positive variable representing crop production choice

a – hectare

b_p - land constraint

$DirCost$ – direct cost of crop in region

$FerCost$ – fertilizer cost (1.2€/kg nitrogen fertilizer, 1.6€/kg phosphorus fertilizer)¹

$IrCost$ – irrigation cost (1€/mm irrigation water)

2. Results

The west south part regions of Slovakia belong to the most productive ones in terms of crops cultivation. Because of irrigation cost the most profitable management practices appear to be management with high or medium nutrient input without irrigation. Irrigation cost (table 2) would lead to losses, as the south west part of Slovakia has sufficient water resources available from crops, without the need to use additional irrigation. The net returns of crop production per regions may be observed in table 3. The most profitable regions under high and medium nitrogen input are BA, SC, SA, NZ and NR. All of them achieve the net return higher than 6500€/ha.

¹ Cost of fertilizers and irrigation cost were estimated based on the RIAFE data

Table 3: Crop production net returns (NReturn) per regions, under different management practices €/ha

Region.Mana	NReturn	Region.Mana	NReturn
BA.NOI	4786.256	NR.NOI	3563.201
BA.NOR	5891.86	NR.NOR	5237.383
BA.NHI	6418.75	NR.NHI	5512.524
BA.NHR	7059.761	NR.NHR	6546.383
BA.NMI	5887.631	NR.NMI	4901.749
BA.NMR	6726.877	NR.NMR	6271.949
BA.NPI	5483.044	NR.NPI	4891.592
BA.NPR	6242.502	NR.NPR	5926.876
MA.NOI	4614.599	NZ.NOI	4228.257
MA.NOR	5326.568	NZ.NOR	5734.03
MA.NHI	5803.323	NZ.NHI	6030.015
MA.NHR	5696.754	NZ.NHR	6957.457
MA.NMI	5507.561	NZ.NMI	5422.634
MA.NMR	5748.36	NZ.NMR	6666.115
MA.NPI	4570.738	NZ.NPI	5174.293
MA.NPR	5000.58	NZ.NPR	6260.416
PK.NOI	3851.434	SA.NOI	4574.765
PK.NOR	5187.931	SA.NOR	5965.369
PK.NHI	5539.762	SA.NHI	6366.221
PK.NHR	6473.79	SA.NHR	7200.653
PK.NMI	5072.942	SA.NMI	5753.218
PK.NMR	6162.583	SA.NMR	6897.564
PK.NPI	4825.339	SA.NPI	5535.392
PK.NPR	5775.966	SA.NPR	6449.172
SC.NOI	4312.505	TO.NOI	3039.28
SC.NOR	5750.424	TO.NOR	4727.731
SC.NHI	5693.016	TO.NHI	4822.944
SC.NMI	5398.169	TO.NHR	5826.127
SC.NMR	6581.264	TO.NMI	4296.01
SC.NPI	5050.791	TO.NMR	5624.083
SC.NPR	6119.678	TO.NPI	4054.702
KN.NOI	4486.23	TO.NPR	5164.053
KN.NOR	5871.699	ZM.NOI	3279.228
KN.NHI	6247.405	ZM.NOR	4770.471
KN.NHR	6903.164	ZM.NHI	5122.859
KN.NMI	5642.11	ZM.NHR	5933.001
KN.NMR	6645.596	ZM.NMI	4528.965
KN.NPI	5328.401	ZM.NMR	5655.536
KN.NPR	6105.257	ZM.NPI	4178.232
LV.NOI	3597.464	ZM.NPR	5184.193
LV.NOR	5199.205		
LV.NHI	5498.689		
LV.NHR	6510.748		
LV.NMI	4893.495		
LV.NMR	6204.581		
LV.NPI	4719.942		
LV.NPR	5855.802		

Source: own processing

For the BA the management practice with high nitrogen input and no irrigation lead to highest net returns. Same management practice cause highest net return in regions of PK, KN, LV, NR, NZ, SA, TO and ZM. For regions MA and SC the highest net returns can be observed under the management practise with medium nitrogen input without irrigation.

The net returns represent the output of crop production in selected regions in monetary expression (€/ha). Taking in account only thirteen selected crops, the region with highest returns is region SA. This region has the crop production net return 7200€/ha.

The lowest levels of net return are achieved under the management practice with low nitrogen input and irrigation (lowest in ZM 3279.228€/ha).

Table 4: Shadow prices of management practices in selected regions (€/ha)

Region. Mana	Marginal	Region. Mana	Marginal	Region. Mana	Marginal	Region. Mana	Marginal
BA.NOI	-2273.505	NR.NOI	-2983.182	SC.NOI	-2570.2	TO.NOI	-2786.847
BA.NOR	-1167.9	NR.NOR	-1309	SC.NOR	-1132.281	TO.NOR	-1098.396
BA.NHI	-641.011	NR.NHI	-1033.859	SC.NHI	-1189.688	TO.NHI	-1003.183
BA.NHR	.	NR.NHR	.	SC.NHR	.	TO.NHR	.
BA.NMI	-1172.13	NR.NMI	-1644.634	SC.NMI	-1484.536	TO.NMI	-1530.117
BA.NMR	-332.884	NR.NMR	-274.434	SC.NMR	-301.441	TO.NMR	-202.044
BA.NPI	-1576.716	NR.NPI	-1654.791	SC.NPI	-1831.914	TO.NPI	-1771.425
BA.NPR	-817.259	NR.NPR	-619.507	SC.NPR	-763.027	TO.NPR	-662.074
MA.NOI	-1188.723	NZ.NOI	-2729.199	KN.NOI	-2416.934	ZM.NOI	-2653.773
MA.NOR	-476.755	NZ.NOR	-1223.427	KN.NOR	-1031.465	ZM.NOR	-1162.53
MA.NHI	.	NZ.NHI	-927.442	KN.NHI	-655.759	ZM.NHI	-810.142
MA.NHR	-106.568	NZ.NHR	.	KN.NHR	.	ZM.NHR	.
MA.NMI	-295.762	NZ.NMI	-1534.822	KN.NMI	-1261.054	ZM.NMI	-1404.036
MA.NMR	-54.963	NZ.NMR	-291.341	KN.NMR	-257.568	ZM.NMR	-277.465
MA.NPI	-1232.585	NZ.NPI	-1783.164	KN.NPI	-1574.763	ZM.NPI	-1754.769
MA.NPR	-802.743	NZ.NPR	-697.041	KN.NPR	-797.907	ZM.NPR	-748.808
PK.NOI	-2622.355	SA.NOI	-2625.888	LV.NOI	-2913.285		
PK.NOR	-1285.859	SA.NOR	-1235.284	LV.NOR	-1311.543		
PK.NHI	-934.028	SA.NHI	-834.432	LV.NHI	-1012.059		
PK.NHR	.	SA.NHR	.	LV.NHR	.		
PK.NMI	-1400.848	SA.NMI	-1447.435	LV.NMI	-1617.253		
PK.NMR	-311.206	SA.NMR	-303.089	LV.NMR	-306.167		
PK.NPI	-1648.45	SA.NPI	-1665.261	LV.NPI	-1790.806		
PK.NPR	-697.824	SA.NPR	-751.481	LV.NPR	-654.947		

Source: own processing

Table 4 present the shadow prices of individual management practices in selected regions. Shadow price (Marginal) of crop production represents how would the net return per hectare in region changed if the crops where cultivated under different management practice. From the table it is clear that the net returns in all regions would decrease by significant proportion in case of NOI. This suggest that the combination of low nitrogen input with use of irrigation would lead to lower crop yields and increased cost for irrigation water.

Management practice NMR representing medium nitrogen input without irrigation represents the smallest decrease in net returns of all regions. Support of lower nitrogen use could lead to sufficient returns with respecting the environmental pressures mitigation.

Table 5 represents the water use efficiency per hectare in selected regions for thirteen selected crops on average. WUEF measures how many kilograms of crops can be produced per 1 millimetre of irrigation water. From the table it is clear that the highest WUEF is achieve for the management practice with unlimited nitrogen input (± 200 kg/mm). However, the unlimited nitrogen input isn't sustainable from the viewpoint of cost and therefore cannot be considered in any region. In terms of most efficient use of water, the most suitable management practice appears to be the high nitrogen input without irrigation. However, NMR

also lead to relatively high WUEF (± 170 kg/mm) and therefore is an alternative for regions in terms of preventing intensive use of fertilizers.

Table 5: Water use efficiency per regions for selected crops sum kg/mm

Region.Mana	WUEF	Region.Mana	WUEF
BA.NOI	142.684	NR.NOI	124.136
BA.NOR	152.068	NR.NOR	137.631
BA.NHI	191.328	NR.NHI	176.212
BA.NHR	195.741	NR.NHR	183.703
BA.NMI	171.068	NR.NMI	154.926
BA.NMR	178.692	NR.NMR	167.191
BA.NPI	204.594	NR.NPI	194.689
BA.NPR	206.064	NR.NPR	196.764
MA.NOI	146.307	NZ.NOI	130.347
MA.NOR	158.661	NZ.NOR	142.164
MA.NHI	185.388	NZ.NHI	178.446
MA.NHR	185.558	NZ.NHR	184.325
MA.NMI	170.138	NZ.NMI	158.35
MA.NMR	177.026	NZ.NMR	168.839
MA.NPI	192.594	NZ.NPI	192.227
MA.NPR	189.408	NZ.NPR	194.551
PK.NOI	126.214	SA.NOI	134.303
PK.NOR	136.659	SA.NOR	145.556
PK.NHI	176.829	SA.NHI	182.861
PK.NHR	182.165	SA.NHR	188.462
PK.NMI	156.165	SA.NMI	162.495
PK.NMR	165.252	SA.NMR	172.447
PK.NPI	194.508	SA.NPI	197.098
PK.NPR	196.179	SA.NPR	199.504
SC.NOI	136.376	TO.NOI	118.196
SC.NOR	147.07	TO.NOR	130.973
SC.NHI	183.696	TO.NHI	167.86
SC.NHR	189.555	TO.NHR	173.499
SC.NMI	164.208	TO.NMI	148.054
SC.NMR	173.434	TO.NMR	158.732
SC.NPI	196.199	TO.NPI	183.21
SC.NPR	199.944	TO.NPR	184.884
KN.NOI	138.273	ZM.NOI	120.537
KN.NOR	153.268	ZM.NOR	132.8
KN.NHI	186.052	ZM.NHI	171.04
KN.NHR	192.756	ZM.NHR	175.611
KN.NMI	165.674	ZM.NMI	150.417
KN.NMR	177.747	ZM.NMR	159.841
KN.NPI	199.103	ZM.NPI	187.22
KN.NPR	201.357	ZM.NPR	188.262
LV.NOI	120.738		
LV.NOR	132.548		
LV.NHI	170.653		
LV.NHR	176.729		
LV.NMI	150.1		
LV.NMR	160.585		
LV.NPI	186.695		
LV.NPR	188.718		

Source: own processing

3. Conclusion

The fertile lowlands are primary locations of almost all agricultural production in Slovakia. The major part of arable land over the observed period 2004-2014 was devoted to the cultivation of cereals, followed by feed crops and industry crops.

Our analysis was therefore focused on south- west regions from maize production areas with the most fertile soil type (BA, MA, SC, PK, NR, NZ, LV, KN, SA, TO, ZM). We employed only thirteen crops representing the typical cropping pattern in Slovak regions: wheat, grain maize, green maize, rapeseed, rye, oat, barley, peas, alfa, potato, soy, sunflower, sugar beet. The aim of analysis was to develop bottom-up integrated optimization, integrating economic and biophysical data. The economic data comprised direct cost and prices of selected crops for regions and biophysical data provided information on yields under the different management practices. The management practices were focused on nitrogen input and irrigation. We used the average economic and biophysical data for the period 2004-2014.

Results showed that the regions produce the highest net returns when the crop production is managed with use of high nitrogen input. Management practice with high nitrogen input without irrigation proved to be most suitable for all regions except of MA and SC where the most suitable crop production choice is medium nitrogen input without irrigation. The low input management with irrigation seemed to be the least profitable choice as under this management practise selected crops achieve the lowest yields and the low yield with combination with direct costs cause low net returns. In terms of most efficient use of water, the most suitable management practice is the high nitrogen input without irrigation.

High nitrogen input and irrigation represent conventional way of managing the crop production, which might lead to environmental pressures in terms of depletion of water resources and soil degradations. The initiative in form of policy premiums might motivate the farmers to shift toward low input, sustainable and ecological management practices, while ensuring the high returns from crop productions.

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