ECONOMIC OPTIMIZATION OF CROP PRODUCTION AND ITS ENVIRONMENTAL ASPECT IN SELECTED REGIONS OF SLOVAKIA

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ABSTRACT

Agricultural is an important part of the economy of Slovakia. Crop production is the dominant sector for the agricultural industry. The major part of arable land is devoted to the cultivation of crops, especially cereals, feed crops and industry crops. The main objective of this paper is to integrate the biophysical crop data with the economic data to identify opportunity costs of agricultural management practices for cultivation of thirteen most important crops cultivated in five selected region in Slovakia - Bratislava, Levice, Malacky, Nitra, Nové Zámky for the period 2004-2014. We employ integrated bottom up optimization model based on linear programming. Management practices consider nutrient input and irrigation in order to evaluate yield as well as environmental factor - water use efficiency.

KEY WORDS

Crop production. Net returns. Water use efficiency. Regions of Slovakia.

JEL CLASSIFICATION

C61, Q10, Q15

INTRODUCTION

Slovak agricultural passed through a difficult development after the year 1990, when it had to adapt to conditions of the market economy and restriction of public support. Nowadays, agricultural is an important part of Slovak economy. Agricultural in Slovakia we can divided in two groups: a crop production and a livestock production. The livestock production became less profitable, because of cheap imported meat (Bielik, 2000). Because of the overall decline in livestock production, the crop production has became a major agricultural sector. The major part of arable land is devoted to the cultivation of cereals, feed crops and industry crops.

1 THEORETICAL BASIS

The total area of the Slovak Republic is 49 035 km². 40 % of the territory is up to 300 meters above sea level, 45 % is between 300 - 800 meters above sea level, 14 % is at a height of 800 - 1500 meters and 1 % is at altitude over 1 500 meters. Climatic conditions of Slovakia which vary considerably are also connected with this fact. In Slovakia there is possible to identify 4 agricultural production areas, all with different soil conditions, altitude and structure of cultivated crops. From the agricultural point of view, the maize area represents 51 % of the total amount of arable land, the rape production are represents 23 %, potato land 15 % and potato - oat areas 4% and mountain landscape represents 7 % of total area of arable land (Ministry of Agriculture and Rural Development of the Slovak Republic, 2003).

1.1 Crop production in Slovakia

In the long term, the growing area of cereals in Slovakia achieve more than 50 % from total arable land area (Jamborová a 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 a 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 (Božik, 2011). Increased area is related to the increasing demand for these commodities mainly due to the production of energy from renewable sources (Récky a Dobák, 2011).

2 OBJECTIVE AND METHODS

The main objective of this paper is to integrate the biophysical 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 (the management practices are

focused on nitrogen input and irrigation), with respect to environmental implication reflected in water use efficiency of selected crops. We identify the net returns for crop mix of 13 commodities - alfa (ALFA), 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). We use the average biophysical and economic data for the period 2004-2014. The selected regions are: Bratislava (BA), Levice (LV), Malacky (MA), Nitra (NR) and Nové Zámky (NZ).

We employ integrated bottom up optimization in order to identify the most profitable management practises and evaluation of water use efficiency. The input data for regional bottom up integrated model are divided into economic and biophysical dataset:

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

- biophysical dataset → The biophysical dataset is based on environmental policy integrated climate model (EPIC) simulation for selected crops and 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 1x1 km^2 HRU in regions. The HRU were aggregated and crop data averaged on regional basis.

management practices:

- 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	Management practices	NRate	Crop	Management practices	NRate	Crop	Management practices	NRate
ALFA	N0	20	ALFA	NM	40	ALFA	NH	80
BAR	N0	40	BAR	NM	80	BAR	NH	120
GMA	N0	40	GMA	NM	80	GMA	NH	120
MAI	N0	80	MAI	NM	120	MAI	NH	200
PEA	N0	40	PEA	NM	80	PEA	NH	120
POT	N0	40	POT	NM	80	POT	NH	120
OAT	N0	40	OAT	NM	80	OAT	NH	120
RAP	N0	80	RAP	NM	120	RAP	NH	200
RYE	N0	40	RYE	NM	80	RYE	NH	120
SGB	N0	80	SGB	NM	120	SGB	NH	200
SNF	N0	40	SNF	NM	80	SNF	NH	120
SOY	N0	40	SOY	NM	80	SOY	NH	120
WHE	N0	40	WHE	NM	80	WHE	NH	150

Source: EPIC (environmental policy integrated climate model) 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 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
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

Source: EPIC (environmental policy integrated climate model) 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:

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

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

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

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)
IrCost	- irrigation cost (1€/mm irrigation water)

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

3 RESULTS AND DISCUSSION

Table 3 shows net returns of five selected regions and thirteen mix of commodities under different management practices per hectare. From the table is clear that the highest and the lowest value from all selected region is in Nitra. The highest net returns is 1407,833 €/ha - potato under medium nitrogen input without irrigation. The lowest net returns is -368,670 €/ha - sugar beet under unlimited nutrient input with full irrigation. Commodities - alfa, barley, grain maize, oat, peas, potato, rye, sunflower and soy are profitable under all management practices. Wheat is profitable, besides low nutrient input with full irrigation management practices. Other commodities have lot of value with mark minus - they are not profitable. The most profitable regions under high and medium nitrogen input are Bratislava and Nové Zámky. All of them achieve the net return higher than 12 000 €/ha.

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

Crop	Management practices	Net return Bratislava	Net return Levice	Net return Malacky	Net return Nitra	Net return Nové Zámky
ALFA	N0I	185,321	127,203	123,621	110,622	143,629
ALFA	N0R	233,789	222,991	206,415	224,791	234,519
ALFA	NHI	185,321	127,203	123,621	110,622	143,629
ALFA	NHR	233,789	222,991	206,415	224,791	234,519
ALFA	NMI	185,321	127,203	123,621	110,622	143,629
ALFA	NMR	233,789	222,991	206,415	224,791	234,519
ALFA	NPI	182,890	129,139	116,595	112,297	150,482
ALFA	NPR	235,247	224,210	207,601	224,790	235,208
BAR	N0I	226,367	127,570	220,836	137,190	179,372
BAR	N0R	301,697	262,447	279,181	266,130	301,100
BAR	NHI	325,523	272,821	281,353	292,782	294,580
BAR	NHR	382,429	372,388	281,796	386,940	386,463
BAR	NMI	307,919	239,236	280,615	253,920	273,703
BAR	NMR	379,318	350,769	302,144	360,495	377,621
BAR	NPI	198,197	151,372	168,689	169,889	181,392
BAR	NPR	290,114	271,660	226,177	280,856	286,534
GMA	N0I	711,246	564,417	808,381	538,423	643,885
GMA	N0R	842,246	729,616	837,966	725,895	804,307
GMA	NHI	1165,995	1071,651	1054,369	1057,510	1157,662
GMA	NHR	1161,551	1064,894	897,511	1059,257	1142,241
GMA	NMI	997,623	876,659	997,679	855,147	954,328
GMA	NMR	1074,382	969,774	908,375	968,381	1042,745
GMA	NPI	1070,929	979,721	920,853	972,386	1063,504
GMA	NPR	1071,084	991,579	819,159	975,931	1069,78
MAI	N0I	623,226	471,040	612,527	465,298	541,476
MAI	N0R	690,788	584,327	630,742	579,482	651,216
MAI	NHI	868,455	755,773	796,441	755,663	834,893
MAI	NHR	804,145	707,084	635,825	680,678	767,285
MAI	NMI	768,427	636,542	736,207	638,464	701,207
MAI	NMR	772,882	680,070	669,197	658,947	739,755
MAI	NPI	763,657	653,615	660,830	688,799	710,150
MAI	NPR	723,325	649,905	616,207	622,164	704,982
OAT	N0I	231,943	128,277	232,328	132,199	176,515
OAT	N0R	309,634	251,429	286,072	257,445	291,961
OAT	NHI	401,729	339,445	359,090	353,598	366,974
OAT	NHR	451,699	427,779	337,841	438,997	453,171
OAT	NMI	344,681	255,303	324,050	260,876	298,937
OAT	NMR	414,326	371,837	340,406	375,743	408,513
OAT	NPI	255,922	185,235	182,408	216,504	206,845
OAT	NPR	317,147	296,621	220,740	310,475	320,993
PEA	N0I	635,020	612,860	604,740	649,697	618,608
PEA	N0R	680,337	702,850	562,785	729,028	702,440
PEA	NHI	635,020	612,860	604,740	649,697	618,608

PEA	NHR	680,337	702,850	562,785	729,028	702,440
PEA	NMI	635,020	612,860	604,740	649,697	618,608
PEA	NMR	680,337	702,850	562,785	729,028	702,440
PEA	NPI	636,973	612,860	601,156	655,848	620,275
PEA	NPR	678,222	702,850	563,130	725,098	700,999
POT	N0I	1282,864	1191,654	1202,012	1196,757	1290,926
POT	N0R	1306,250	1264,368	1225,832	1284,952	1337,145
POT	NHI	1288,058	1294,362	1205,389	1309,112	1319,928
POT	NHR	1305,746	1354,142	1219,920	1374,973	1370,374
POT	NMI	1317,337	1322,190	1225,524	1339,706	1347,665
POT	NMR	1332,876	1380,114	1232,408	1407,883	1392,92
POT	NPI	1276,426	1261,098	1128,458	1284,709	1295,928
POT	NPR	1297,055	1335,822	1161,103	1376,114	1350,293
RAP	N0I	-95,601	-211,918	-31,652	-209,626	-161,839
RAP	N0R	20,388	-50,523	26,206	-43,206	-7,592
RAP	NHI	-15,188	-117,501	57,869	-119,495	-80,261
RAP	NHR	86,185	35,979	71,274	47,542	76,454
RAP	NMI	-19,368	-112,823	37,461	-106,725	-81,927
RAP	NMR	45,490	7,844	55,013	31,763	43,650
RAP	NPI	53,040	-14,851	46,221	6,381	13,405
RAP	NPR	123,010	78,824	58,543	95,248	109,989
RYE	N0I	87,8560	4,462	98,020	6,445	41,969
RYE	N0R	201,908	146,235	203,942	146,813	179,642
RYE	NHI	249,201	128,595	236,428	126,125	180,851
RYE	NHR	330,529	241,756	274,768	242,727	286,850
RYE	NMI	191,228	85,159	195,980	91,578	140,126
RYE	NMR	288,060	215,928	269,364	226,324	263,970
RYE	NPI	40,386	-11,392	33,159	9,348	23,631
RYE	NPR	131,107	105,214	136,008	116,481	137,717
SGB	N0I	-169,386	-240,139	-211,919	-250,533	-225,196
SGB	N0R	39,153	26,690	34,555	26,648	36,529
SGB	NHI	-239,870	-299,388	-298,304	-306,641	-287,556
SGB	NHR	-62,836	-73,261	-59,754	-78,724	-66,050
SGB	NMI	-180,930	-251,25	-230,899	-262,085	-235,688
SGB	NMR	12,858	2,186	-1,837	2,571	11,529
SGB	NPI	-311,567	-366,668	-362,596	-368,666	-357,271
SGB	NPR	-91,988	-95,162	-65,175	-95,656	-91,729
SNF	N0I	196,753	98,766	214,278	71,506	147,032
SNF	N0R	293,744	226,351	306,763	224,067	275,526
SNF	NHI	486,227	401,078	456,451	378,857	456,336
SNF	NHR	557,956	499,156	449,567	503,024	556,314
SNF	NMI	359,260	263,456	363,839	236,989	315,302
SNF	NMR	445,790	381,684	413,467	382,338	432,836
SNF	NPI	389,099	334,559	324,687	325,745	379,318
SNF	NPR	470,880	428,089	356,842	436,220	480,502
SOY	N0I	816,524	734,732	662,530	717,519	805,029
SOY	N0R	784,134	685,424	530,954	667,913	749,793
SOY	NHI	816,524	734,732	662,530	717,519	805,029

SOY	NHR	784,134	685,424	530,954	667,913	749,793
SOY	NMI	816,524	734,732	662,530	717,519	805,029
SOY	NMR	784,134	685,424	530,954	667,913	749,793
SOY	NPI	812,585	729,391	660,810	710,866	799,727
SOY	NPR	783,256	686,607	531,381	668,612	751,319
WHE	N0I	54,1230	-11,460	78,897	-2,297	26,852
WHE	N0R	187,793	146,999	195,155	147,425	177,444
WHE	NHI	251,755	177,060	263,346	187,174	219,343
WHE	NHR	344,095	269,567	287,852	269,237	297,602
WHE	NMI	164,589	104,228	186,213	116,041	141,716
WHE	NMR	262,634	233,109	259,670	235,770	265,824
WHE	NPI	114,508	75,863	89,467	107,486	86,906
WHE	NPR	213,043	179,582	168,864	190,543	203,829

Source: own processing.

Water use efficiency represents how many kilograms of crops can be produced per one milimetre of irrigation water. Table 4 shows the water use efficiency per hectare in selected regions (Bratislava, Levice, Malacky, Nitra, Nové Zámky) for thirteen selected crops on average. From this table is clear, that the lowest water use efficiency is achieve for management practices with low nutrient input (with full irrigation and without irrigation, too) in all selected regions. On the other side, the highest water use efficiency is achieve for management practice with unlimited nitrogen input, especially in Bratislava (204,594 kilograms of crops were produced per one milimetre for management practice with full irrigation and 206,064 kilograms without irrigation). In Nitra, there is water use efficiency for all management practices about 170 kg/mm on average.

Table 4 Water use efficiency per regions for selected crops sum kg/mm

	WUEF Bratislava	WUEF Levice	WUEF Malacky	WUEFF Nitra	WUEF Nové Zámky
N0I	142,684	120,738	146,307	124,136	130,347
N0R	152,068	132,548	158,661	137,631	142,164
NHI	191,328	170,653	185,388	176,212	178,446
NHR	195,741	176,729	185,558	183,703	184,325
NMI	171,068	150,100	170,138	154,926	158,350
NMR	178,692	160,585	177,026	167,191	168,839
NPI	204,594	186,695	192,594	194,689	192,227
NPR	206,064	188,718	189,408	196,764	194,551

Source: own processing.

CONCLUSION

Our analysis was focused on five selected regions in the Slovak Republic - Bratislava, Levice, Malacky, Nitra and Nové Zámky and thirteen crops representing the typical cropping pattern in Slovak regions - alfa, barley, wheat, grain maize, green maize, rye, rapeseed, oat, peas, sunflower, soy, sugar beet and potato.

The aim of analysis was to develop bottom - up integrated optimization, where we use the average biophysical and economic data for the period 2004 - 2014. Biophysical data provided information on yield under the different management practices. The economic dataset consists of direct costs and price for crops and regions.

The highest and the lowest value of net returns from all selected region is in Nitra and the most profitable regions under high and medium nitrogen input are Bratislava and Nové Zámky.

Water use efficiency represents how many kilograms of crops can be produced per one milimetre of irrigation water. The lowest water use efficiency is achieve for management practices with low nutrient input (with full irrigation and without irrigation) in all selected regions. On the other side, the highest water use efficiency is achieve for management practice with unlimited nitrogen input, especially in Bratislava.

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 migh 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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