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IDENTIFICATION OF OPTIMAL PRODUCTION STRUCTURES IN MAIZE PRODUCTION AREAS OF THE SLOVAK REPUBLIC AND THE CZECH REPUBLIC UNDER CONDITIONS OF UNCERTAINTY

Martina Šoporová[1], Jozef Repiský[2]
Slovak University of Agriculture in Nitra[1,2]
Faculty of economics and management, Department of Statistics and Operations Research
Trieda A.Hlinku 2
Nitra, Slovak Republic
e-mail[1,2]:martina.soporova@gmail.com, jozef.repisky@uniag.sk

Abstract

In this document issues of decision-making process are solved, demonstrated in the case of difficult problems solutions and the most suitable alternatives for personal benefits are determined. This document is focused on conflicting situations with several participants. These situations are called in the game theory games with nature. In general, several models exist, but our intention was to use a model which is typical for games in conditions of uncertainty, where the only opponent of every single subject is the nature with its random effects. The objective is to achieve the highest level of profit with combination of growing types of plants and independent of natures behavior. Slovak territory is diversified and therefore splited into several agricultural subcategories. To assure that results of the analysis are as reliable as possible, we choose one area with more narrow characteristics. We paid attention to corn area of Slovak Republic and Czech Republic. The aim is to compare this production area in two countries based on making optimal seeding structure of plants and maximization of the benefits by using game theories approaches. It means Wald model, Savage model and Agrawal - Heady principle, which are based especially dedicated for linear programming. Using these models, we can interpret also the impact of a possible deviation from the recommended strategy through shadow price and reduced cost. The research used four databases of economic indicators per hectare. The above-mentioned criteria are not only applied for input data of the Slovak

Republic and the Czech Republic, but also for data cleaned from subsidies. The main goal is the comparison between effectiveness of cultivation in the Slovak Republic and the Czech Republic, as well as assesing the impact of subsidies to determine the optimal plan of plant production and obtained benefits.

Keywords: *decision-making, seeding plan, subvention, profit.*

JEL classification: *C61, C72, Q15*

1 Introduction

Producers, which are on competitive market, are looking for possibilities to maximize profit by growing of yield from range (Bezat-Jarzębowska and Rembisz, 2013). Increasing of production contributes to economic growth and thereby to growth of overall economic prosperity. However, in most markets with high GPD per inhabitant, the rate of growth of production in the sector is determined by an increase of low demand. According to Fiegiel and Remimbisz (2013), research confirms that the increase of demand for agri-products that occurs in a certain period also determines the growth of production in agri-food sector. A low rate of growth in demand for agricultural products can limit growth in the agri-food sector. Therefore, must be determined a change in efficiency-based relationships, which is considered as the main growth factor in this sector. The authors suppose that the growth of inputs is not main factor of competitiveness, but the efficiency of using these inputs is the major factor of competitiveness, which is expressed by ability of long-term efficient growth and by performance.

The key to efficiency of the production is the ability of management to respond to new market conditions, objective analysis and evaluation of own possibilities and own results. Also making the right decisions is very important. Identification of an optimal production structure is one of the key issues. Successful solution of these issues is conditional on the economic performance of agricultural business entities. For objectification of solution in case of complex problems solving, various support systems and related information systems are available nowadays. McCown (2002) describes in his publication the development of these systems. Different researches and managers from different areas have changed their way of thinking due to the development of information technologies. He recommends more studying of own history and own roots, which will provide fewer problems and greater success. The knowledge obtained this way, can be still useful for understanding past problems and for reassessing which agricultural models of information systems could be more useful for managing the agricultural plants. Dantzig (1951) mentions in his study a theoretical game model, which can be

used to solve problems in the field of agriculture as well. The model with one criterion is often unsatisfactory and cannot capture the reality of decision making in the theoretical game model. Therefore, is appropriate to use a mix of multiple criteria, like maximizing of the minimum value, minimizing of the greatest loss and maximizing of the minimum batch as Romero and Rehman (2006) are mentioning. For agricultural decision-making models, the most used criterion is maximin Wald, minimax Savage and Agrawal-Heady, which represents a compromise between the previous two.

The article is focused on decision-making in indefinite conditions and on finding an optimal strategy. The optimal strategy in agriculture represents commodity ratio that can ensure efficiency of using the sources and maximal benefit. Opponent of these model games is nature, which creates conditions of indeterminacy. These conditions consist from the fact, that we don't know the probability of behaviour of nature.

2 Data and Methods

The aim of the article is to identify an optimal strategy in determining of the appropriate production structure in the corn region of the Slovak Republic and the Czech Republic under condition of uncertainty and comparison of the obtained results between the Slovak Republic and Czech Republic, without taking into account the subsidies and also with taking into account the subsidies. Corn region is the best area for cultivation of crops because of its conditions. The solution is applied in the theory of games, namely matrix games with nature, using the criteria of the Wald and the Agrawal-Heady.

The Wald criterion ensures the greatest minimum of benefit, regardless of the state of nature. The optimal decision of an intelligent participant in a game is given by a combination of its individual strategies, for which the median of winning or benefits, expressed by formula

$$min(x_1 a_{1j} + x_2 a_{2j} + \ldots + x_m a_{mj}) \text{ for } j=1,2,\ldots,n \quad (1)$$

obtains the maximum value and no matter what strategy nature chooses. Here: a_{ij} (i = 1, 2, ..., m; j = 1, 2, ..., n) represents benefits (profit per hectare) for the intelligent participant of the game in case of the selection of the i-th strategy and the occurrence of j-th status of nature

elements x_1, x_2, ..., x_m, for which is valid $0 \leq x_i \leq 1 \sum_{i=1}^{m} x_i = 1$ (2)
indicates frequency with which an intelligent participant can choose individual strategies A_1, A_2, ..., A_m.

Base of **the Savage criterion** is the principle of mini maximal loss. The optimal decision of intelligent participant will be decision, which protect him from big losses, compared to the decision, which he will made if he knew pure nature strategies. The basis is modified payment matrix, a matrix of losses, which represents loss over the best option in the actual nature status (in the actual year)

$$S = (S_{ij})_m^n \quad (3)$$

$$\text{with elements } s_{ij} = \max_k a_{kj} - a_{ij}\left(k^{\in}\{1,2,\dots,m\}; j = 1,2,\dots,n\right) \quad (4)$$

Elements of matrix S are indicating the amount of loss, which intelligent participant will suffer, if he choose i-th strategy compared to his best choice, in supposition that he know the nature behaviour in advance. An optimal strategy is the strategy where the median of the win expressed by formula

$$\max_j (x_1 s_{1j} + x_2 S_{2j} + \dots + X_m S_{mj}) \text{ for j=1,2,...,n} \quad (5)$$

obtains the minimal value.

The Agrawal-Heady criterion is based on the principle of maximization of minimal profit. Beneficial decision is decision which ensure for intelligent participant maximal profit against worst decision, which he will made if he knew the nature behaviour in advance, so the pure strategies. The basis is the calculation of the profit matrix. Elements of this matrix we obtain by the following: In each column of matrix, we deduct the minimum element from all elements of this column. Therefore, we define a new matrix

$$Z = (Z_{ij})_m^n \quad (6)$$

$$\text{with element } Z_{ij} = a_{ij} \min_k a_{kj}\left(k^{\in}\{1,2,\dots,m\}; j = 1,2,\dots,n\right) \quad (7)$$

Elements of matrix Z are indicating the amount of a profit, which intelligent participant will get, if he choose i-th strategy compared to his worst choice, in supposition that he know the nature behaviour in advance. An optimal strategy is the strategy where the median of the win expressed by formula

$$\min_j (x_1 Z_{1j} + x_2 Z_{2j} + \dots + x_m Z_{mj}) \ (\text{for } j = 1,2,\dots,n) \quad 8$$

obtains the maximal value.

Optimal strategies are identified by using the linear programming model. For model solution, MS Excel is used. Part of MS Excel is program "Solver", which identifies optimal strategies. Data for research are obtained from publications of

own costs and performance results of agricultural plants in Slovak Republic and Czech Republic, in years 2006-2014 for corn region, published by Slovak Research institute of agricultural and agri-food economics (VÚEPP), Czech Institute of agricultural economics and information (ÚZEI) and Ministry of agriculture and rural development of the Slovak Republic (MPRV SR).

3 Results and Discussion

Results consist from interpretation of obtained results, which are focused on appropriate crop sowing structure of each crop and on information resulting from potential changes in the restrictive conditions of individual crops in the corn production region. Because of space constraint, highlighted will be interpretations of commodities, which would bring the greatest changes by departing from optimal percentage representation.

Input data correspond to years 2006 and 2014, which are reflecting the gross profits of commodities for 1 hectare.

Table 1 **Gross profits of selected crops in years 2006 - 2014 in EUR. ha^{-1} without taking into account the subsidies, SR**

REVENUE-VARIABLE COSTS	2006	2007	2008	2009	2010	2011	2012	2013	2014
wheat	109,54	329,91	201,92	-119,81	123,90	213,52	236,90	138,30	189,68
barley	165,34	313,62	224,09	16,26	4,58	310,86	182,01	124,04	138,50
oat	187,01	129,82	-25,49	-96,18	-205,37	46,18	64,93	257,94	8,21
corn for grain	183,83	177,02	181,07	51,46	119,26	491,86	493,86	129,62	171,32
other crops	360,32	667,70	702,38	-58,19	-45,78	-38,47	280,65	350,54	320,87
edible peas	-0,66	61,74	9,00	-228,92	-141,80	146,41	-365,22	-157,49	-84,62
corn for green	32,00	-30,74	-12,75	-126,81	-82,80	-240,48	-137,10	-203,20	-10,45
other one-year feed	97,46	-11,95	-41,46	-32,24	-190,14	-123,72	-9,97	304,56	20,52
multi-annual feed	70,27	61,11	12,85	24,74	4,93	-133,32	-3,60	14,21	59,30
permanent grassland	24,43	-16,03	-54,64	-0,13	-0,06	-33,03	-24,59	-25,75	-16,23
pasture lands	-14,89	-9,25	-6,97	-15,24	-11,24	-3,90	-7,81	-14,22	-15,26
oil-seed rape	256,92	81,79	524,83	-97,97	71,71	406,80	-20,45	431,52	266,67
sugar rape	992,70	722,47	761,00	1165,66	716,80	1558,11	-760,33	-497,76	992,86
grape	-773,09	-860,52	-1131,05	-1487,94	-1589,62	2046,81	87,72	1825,06	330,72
sunflower	27,52	288,12	136,79	-159,98	220,81	378,91	376,00	244,77	35,00

Source: Own data processing from VÚEPP and MPRV SR.

The structural variables of the model represent selected crops of chosen agricultural region. From table 1 is visible which commodities are involved. In the model are expressed only as variables x1 (wheat) - x15 (sunflower). Profit respectively loss; reflect the difference of revenues for 1 hectare and variable costs for 1 hectare of chosen crops without taking into account the subsidies. Model for the Czech Republic is similar, with small change of some crops is visible in table 2. For both countries, to better comparison, model was also quantified with data including subsidies.

Table 2 **Gross profits of selected crops in years 2006 - 2014 in EUR. ha^{-1} without taking into account the subsidies, ČR**

REVENUE-VARIABLE COSTS	2006	2007	2008	2009	2010	2011	2012	2013	2014
winter wheat	7,10	286,03	391,42	-69,51	148,71	358,90	142,38	245,26	301,13
spring wheat	-25,52	38,80	297,28	-69,17	144,63	36,78	200,93	337,70	65,38
rye	35,88	240,20	205,71	-61,70	-55,12	-55,85	98,83	-182,28	107,29
winter barley	58,76	170,79	252,25	-102,38	-16,17	233,61	-95,83	32,33	191,61
spring barley	26,76	234,27	672,12	180,72	114,31	428,92	167,73	415,44	516,60
oat	-25,39	165,82	112,20	246,85	-31,49	250,44	178,76	65,81	19,88
triticale	-45,86	104,00	127,85	-52,39	79,58	102,62	178,37	695,29	601,11
corn for grain	63,01	510,56	504,78	15,46	295,14	552,74	550,30	354,61	220,61
peas	-130,68	-128,90	33,78	-162,87	-154,96	17,55	-21,64	65,81	-107,61
oil-seed rape	175,12	148,35	425,46	87,36	118,58	163,52	186,26	399,57	343,26
poppy	147,17	528,79	746,27	-320,94	75,82	-141,39	460,38	1012,07	842,62
sunflower seed	-102,98	56,89	-9,97	-216,71	-45,67	171,09	153,53	3,43	-117,21
sugar beet	453,98	29,96	38,06	181,97	178,19	777,04	497,29	488,03	396,32
corn for green	-60,19	-111,95	1,14	4,78	-4,81	65,06	-87,20	90,01	80,28
other one-year feed	-102,18	-81,96	-99,26	-172,13	-29,14	-96,63	-86,00	-69,39	-182,96
multi-annual feed	100,06	186,78	187,47	215,00	89,64	50,42	-32,68	44,90	58,99
permanent grassland	84,40	46,76	49,47	28,20	176,56	78,13	15,08	16,67	8,58
other ware potatoes	899,25	521,86	166,17	221,18	271,75	493,22	264,77	87,39	-479,87
hop	-1931,16	994,43	2793,59	1089,78	405,29	360,69	-2393,47	-187,07	652,39

Source: Own data processing from ÚZEI and MPRV SR.

When the Wald criterion is applied on data for SR, linear programming model consist of a function which is representing maximizing of the price of game *v (max v),* taking into account the limiting conditions, which ensure that the expected hectare profit is (respecting the nature status in monitored years) bigger or minimally the same as the price of the game.

$$2006 : 109{,}54\boldsymbol{x}_1 + 165{,}34\boldsymbol{x}_2 + 187{,}01\boldsymbol{x}_3 + 183{,}83\boldsymbol{x}_4 + 360{,}32\boldsymbol{x}_5 + 0{,}66\boldsymbol{x}_6 + 32\boldsymbol{x}_7 +$$

$$+ 97{,}46\boldsymbol{x}_8 + 70{,}27\boldsymbol{x}_9 + 24{,}43\boldsymbol{x}_{10} - 14{,}89\boldsymbol{x}_{11} + 256{,}92\boldsymbol{x}_{12} + 992{,}7\boldsymbol{x}_{13}$$

$$- 773{,}09\boldsymbol{x}_{14} + 27{,}52\boldsymbol{x}_{15} \geq$$

$$2014 : 189{,}68\boldsymbol{x}_1 + 138{,}5\boldsymbol{x}_2 + 8{,}21\boldsymbol{x}_3 + 171{,}32\boldsymbol{x}_4 + 320{,}87\boldsymbol{x}_5 + 84{,}62\boldsymbol{x}_6 - 10{,}45\boldsymbol{x}_7 +$$

$$+ 20{,}52\boldsymbol{x}_8 + 59{,}3\boldsymbol{x}_9 - 16{,}23\boldsymbol{x}_{10} - 15{,}26\boldsymbol{x}_{11} + 266{,}67\boldsymbol{x}_{12} + 992{,}86\boldsymbol{x}_{13}$$

$$+ 330{,}72\boldsymbol{x}_{14} + 35\boldsymbol{x}_{15} \geq$$

Similar for years 2007-2013 . $\sum_{i=1}^{15} x_i = 1$

For the more realistic results, which correspond to requirements of animal production, principles of crop plans and to the sales possibilities, the additional restrictive conditions were added to basic restrictive conditions.

Wheat must be planted at least on 28,6% of field, barley should occupy 13% of field or more, oat can´t exceed 0,1% of the total area, corn (for grain) should be sown on maximum 16,6% of field, other grain should occupy a maximum 0,9%, corn (for green) is necessary to have at least on 6,3% of field, other one-year feed can be sown at least on 0,6%, multi-annual feed can´t exceed 8,5%, permanent grassland at least 2,1%, lower limit for pasture lands is 1,5%, oil-seed rape should have a minimum percentage of 8,9%, sugar rape may be maximum 5,5% and sunflower should occupy at least 10% of the area.

With similar procedure is constructed also model for Czech Republic. However, the additional conditions must be adapted to exact area. Based on obtained outputs is possible to compare optimal sowing programmes of Slovak Republic and Czech Republic.

Table 3 **Comparison of optimal sowing plans based on the Wald criterion**

The Wald criterium					
Slovak republic	grants		Czech republic	grants	
	without	with		without	with
wheat	28,60%	28,60%	winter wheat	27,32%	29,80%
barley	12,00%	13,00%	spring wheat	2,48%	0,00%
oat	0,00%	0,00%	rye	0,00%	0,00%
corn for grain	16,60%	16,60%	winter barley	0,00%	13,00%
other crops	0,00%	0,00%	spring barley	13,00%	0,00%
edible peas	0,00%	0,00%	oat	0,10%	0,00%
corn for green	6,30%	6,30%	triticale	0,00%	0,00%
other one-year feed	0,59%	0,59%	corn for grain	16,00%	16,00%
multi-annual feed	7,89%	6,89%	peas	0,00%	0,00%
permanent grassland	2,16%	2,16%	oil-seed rape	8,90%	9,00%
pasture lands	1,47%	1,47%	poppy	1,00%	1,00%
oil-seed rape	8,90%	8,90%	sunflower seed	10,00%	10,00%
sugar rape	5,50%	5,50%	sugar beet	0,69%	2,50%
grape	0,00%	0,00%	corn for green	6,30%	6,30%
sunflower	10,00%	10,00%	other one-year feed	0,59%	0,59%
			multi-annual feed	8,47%	7,65%
			permanent grassland	3,16%	3,16%
			other ware potatoes	1,00%	1,00%
			hop	1,00%	0,00%

Source: Own data processing from ÚZEI, VÚEPP and MPRV SR.

Table 3 shows a comparison of recommended seeding plans by using the Wald criterion. In Slovak Republic, if we don´t consider subsidies, it is not advisable to occupy the area by oats or edible peas. In Czech Republic is not advised oats and

edible peas, but also rye and triticale. If in the Slovak model is included rye, it can be assumed that rye will not get to sowing plan, because of its weak economic stability and triticale as well, because the Slovak data about wheat are including three types of wheat and is not divided as in Czech Republic. Looking to the results for wheat in the Czech Republic and in Slovak Republic, the percentage is only slightly higher for the Czech Republic. In the Slovak Republic is value about 1% lower. Taking into account possible limitations and requirements, on the largest field should be wheat, corn for grain, barley and sunflower in both countries. Comparing to Slovak Republic, in Czech Republic in corn region is more effective to grow poppy, which is very lucrative crop, other ware potatoes or hop.

If we are not taking into account state support, with the Wald criterion and by the optimal production structure in the Slovak Republic will be achieved profit 9,17 EUR per 1 hectare.

With the Wald criterion based on dual prices was found, that the bigger increase of expected profit by 1% of overall area will be because of sugar rape, namely by 11,41 EUR. ha^{-1} and the biggest decrease because of sunflowers for seed, namely by 1,85 EUR. ha^{-1}.|

From the reduced costs it can be assumed that if oats (which not reached this model in corn region) will be grown on 1% of field, the expected profit would decrease by 2,54 EUR. ha^{-1}. Other crops would also bring a negative change to the expected profit, as it could decrease 0,83 EUR. ha^{-1}.

In Czech Republic, the implementation of the Wald strategy will bring a benefit (not taking into account subsidies) of 21,14 EUR. ha^{-1}.

Using the above-mentioned principle, the expected profit in Czech Republic will be affected the most by 1% of potatoes, which would bring an increase by 0,34 EUR. ha^{-1} and sunflower for seed, which would bring decrease of expected profit by 4,11 EUR. ha^{-1}. This is resulting from dual prices.

If in the Czech Republic will be sown edible peas (which is not in optimal solution) on 1% of overall area in corn region, it will cause decrease of maximal profit by 3,47 EUR. ha^{-1}. Also, negative would be sowing of triticale on 1% of area, because expected profit would decrease by 2,37 EUR. ha^{-1}.

Also, with the following results, based on all criteria, is true that if crops which are not in optimal solution, will be in sowing plan, there would be a worsening of the purpose function, that represents in the Wald criterion expected maximal profit, in the Savage criterion minimal loss over the best variant and in the Agrawal-Headey criterion maximal profit over the worst variant, which should happen in conditions of uncertainty.

Table 4 **Comparison of optimal sowing plans based on the Savage criterion**

The Savage criterium					
Slovak republic	grants		Czech republic	grants	
	without	with		without	with
wheat	30,00%	30,00%	winter wheat	30,00%	30,00%
barley	13,00%	13,00%	spring wheat	2,00%	2,00%
oat	0,10%	0,00%	rye	7,35%	7,35%
corn for grain	16,60%	16,60%	winter barley	0,00%	0,00%
other crops	0,90%	0,00%	spring barley	13,00%	13,00%
edible peas	0,31%	2,59%	oat	0,00%	0,00%
corn for green	6,30%	6,30%	triticale	0,00%	0,00%
other one-year feed	1,86%	0,59%	corn for grain	16,60%	16,60%
multi-annual feed	0,00%	0,00%	peas	0,00%	0,00%
permanent grassland	2,16%	2,16%	oil-seed rape	8,90%	8,90%
pasture lands	1,47%	1,47%	poppy	1,10%	1,10%
oil-seed rape	9,70%	9,70%	sunflower seed	10,00%	10,00%
sugar rape	5,50%	5,50%	sugar beet	0,00%	0,00%
grape	1,10%	1,10%	corn for green	6,30%	6,30%
sunflower	11,00%	11,00%	other one-year feed	0,59%	0,59%
			multi-annual feed	0,00%	0,00%
			permanent grassland	3,16%	3,16%
			other ware potatoes	0,00%	0,00%
			hop	1,00%	1,00%

Source: Own data processing from ÚZEI, VÚEPP and MPRV SR.

By using the Savage process of subsidies, multi-year feed in both areas has fallen out from optimal crop production, if we are not taking into account subsidies. The oat is not worth it to grow. In the Czech Republic peas is not in the solution, because it shows high instability and often is in negative values. However, in Slovak Republic is advised by the Savage process in small extent. In the Czech Republic, it is not advisable to grow sugar rape and also not effective is winter barley. Other crops as well on the Czech as well on the Slovak side have very similar percentages. Sunflower is better in the Slovak Republic, also oil rape. On the Czech side, there is a better representation of wheat. In the corn region of the Slovak Republic is good to pay attention to the vineyard and in the Czech Republic especially the poppy and the hops.

By application of the Savage criterion in corn region of Slovak Republic can be expected without subsidies minimal loss 1689,41 EUR. ha^{-1}. By using mentioned principle by additional 1% of area for grain corn could bring decrease of expected loss by 0,71 EUR. ha^{-1} and corn for green could bring increase by 2,61 EUR. ha^{-1}, as dual prices are indicating.

For this criterion in Czech Republic is possible to expect the lowest loss of 2047,32 EUR. ha^{-1} compared to the best option. Resulting the dual prices in model, for data of the Czech Republic, expected loss could be decreased by another 1% of the hops, by 25,88 EUR. ha^{-1} and increased by another 1% of field for sunflower, by 7,56 EUR. ha^{-1}.

Table 5 **Comparison of optimal sowing plans based on the Agrawal-Heady criterion**

The Agrawal-Heady criterium					
Slovak republic	grants		Czech republic	grants	
	without	with		without	with
wheat	30,00%	30,00%	winter wheat	27,80%	27,80%
barley	13,00%	13,00%	spring wheat	2,00%	2,00%
oat	0,00%	0,10%	rye	0,00%	0,00%
corn for grain	16,60%	16,60%	winter barley	0,00%	0,00%
other crops	0,90%	0,90%	spring barley	13,00%	13,00%
edible peas	0,00%	0,00%	oat	0,00%	0,00%
corn for green	6,30%	6,30%	triticale	0,00%	0,00%
other one-year feed	0,59%	2,18%	corn for grain	16,60%	16,60%
multi-annual feed	2,69%	0,00%	peas	0,00%	0,00%
permanent grassland	2,16%	2,16%	oil-seed rape	8,90%	8,90%
pasture lands	1,47%	1,47%	poppy	1,00%	1,00%
oil-seed rape	9,70%	9,70%	sunflower seed	10,00%	10,00%
sugar rape	5,50%	5,50%	sugar beet	2,50%	2,50%
grape	1,10%	1,10%	corn for green	6,30%	6,30%
sunflower	10,00%	11,00%	other one-year feed	0,59%	0,59%
			multi-annual feed	0,00%	0,00%
			permanent grassland	9,31%	9,31%
			other ware potatoes	1,00%	1,00%
			hop	1,00%	1,00%

Source: Own data processing from ÚZEI, VÚEPP and MPRV SR.

The Agrawal-Heady expression is not accepting grow of oats and peas. In the Czech Republic, neither multi-annual feeds, rye, winter barley nor triticale is sown. The leading position maintains wheat, followed by spring barley, corn for grain or sunflower. Higher percentages have in this criterion permanent grassland in the Czech Republic. The percentages of oil-seed rape are lower about 1% in the Czech Republic. Potatoes were returned by 1% and sugar rape by 2,5% in Czech Republic. Other plant representation is more or less without any change. Comparing with the Slovak Republic, in the Czech Republic is worth to grow of poppy, potatoes and hops in the corn region, if we are not taking into account subsidies.

The optimal structure based on Agrawal-Heady principle will provide the highest profit against the most inappropriate option 278,95 EUR. ha^{-1} without subsidies in Slovak Republic. Based on the principle, an increase of sugar rape area by 1%, would be expected increase of profit by 9,34 EUR. ha^{-1} and in case of permanent grassland decrease by 0,76 EUR. ha^{-1}.

The maximum profit of 296,98 EUR. ha^{-1} can be ensured by optimal combination of growing in Czech Republic. By increasing of the hops area by 1%, it can be expected increase of profit by 2,29 EUR. ha^{-1} and corn for green decrease by 2,06 EUR. ha^{-1}.

Taking into account the subsidies, using the Wald criterion in the Slovak region led to the increase of barley and the reduction of multi-annual feeds. In the Czech Republic, spring wheat has disappeared, perhaps because of less yield stability than the winter wheat during dry spring. Spring barley, which looks more favourable, was replaced by winter barley. The area of oil-seed rape and sugar rape has increased, because of its economic stability of production. The area for multi-annual feeds should be also reduced. Hops, which is characterized by high fluctuation in economic production, has disappeared from the solution. Representation of other crops did not changed.

In Slovak corn region, the optimal sowing plan would achieve expected maximum profit 101,03 EUR. ha^{-1} by using the first criterion, taking into account subsidies. On the basis of dual pricing, the biggest impact on the expected profit would have an increase of 1% in the area of sugar rape, which would bring an increase of expected profit by 12,84 EUR. ha^{-1}, but an additional 1% of the area of corn for green causes a decrease by 1,96 EUR. ha^{-1}.

By monitoring of the Czech Republic, using the Wald criterion, decision-maker would have profit 297,64 EUR. ha^{-1} using optimal crop structure, with taking into account the subsidies. By using the Wald criterion, the value of expected profit would be mostly affected, if the potatoes expand to another 1% of field, an increase by 7,99 EUR. ha^{-1} would occur. On the other hand, the one-year feeds will decrease by 2,02 EUR. ha^{-1}.

The policy of subsidies in case of the Savage criterion did not significantly change the percentage of individual crops. The impact was visible only for Slovak data, but at minimum level.

In the Slovak Republic area, by optimal sowing plan obtained by using the Savage principle will reach the expected loss corresponding to minimum 1830,86 EUR. ha^{-1} with taking into account the subsidies. Shadow prices are showing, that expanding of growing the sugar rape on additional 1% of area would decrease expected loss by 17, 82 EUR. ha^{-1} and another additional 1% of corn for green will increase expected loss by 4,35 EUR. ha^{-1}.

If the optimal crop structure in corn region of Czech Republic corresponds to the Savage solution, the decision-maker will ensure minimal loss 2409,86 EUR. ha^{-1}. By using this procedure, an increase of hops by 1% would decrease the minimal loss by 25,88 EUR. ha^{-1}. Other one-year feeds would increase expected loss by 3,05 EUR. ha^{-1}, if we are not taking into account subsidies.

Expression of subsidies should not have again aggressive intervention for outputs of individual models, constructed based on the Agrawal-Heady criterion. Also, can be stated that the percentage distribution of commodities did not change. Little differences are making values, which are representing oats, feeds and sunflower in Slovak Republic.

Taking into account the subsidies, applying of this criterion, we can expect the biggest profit against the worst inexplicable variant 399,44 EUR. ha^{-1} in Slovak Republic. Increasing of the area by another 1% for sugar rape can increase expected profit by 16,45 EUR. ha^{-1} and in case of extension of grass field, can be expected decreas by 0,92 EUR. ha^{-1} as resulting from dual prices.

The decision maker in the Czech Republic can expect achieving of the best benefit against the worst option 298,86 EUR. ha^{-1} with taking into account subsidies. The Agrawal-Heady criterion founded that an additional 1% of hops can bring in this case increase by 2,29 EUR. ha^{-1} and other one-year feeds can bring decrease by 2,06 EUR. ha^{-1}.

4 Conclusion

In the presented article, three decision-making criteria were used. Based on that, optimal sowing plans were identified. By using all principles, growing wheat on the largest area is considered as best solution. It should represent more than quarter of the disposition area. While there is single statistic for wheat in Slovak Republic, in Czech Republic is divided for winter, spring and triticale. The winter wheat had better parameters from the model construction point of view, therefore is a large proportion in the solution. Spring wheat had lower yield stability and because of that represents only small percentage in the solution. The second biggest sowing area is corn for feed and shows the best economical results of crops. It is probable due to the fact, that it is not so sensitive for dry periods of year, climate warming is helpful. Third in the row, barley should be sown in a large amount compared to other crops. Based on results, spring barley is more advantageous in Czech Republic because from the gross hectare profit point of view it is better than winter barley. Sunflower or oil-seed rape should cover a sufficient percentage of the area. Sunflower has a lower long-term economic return than rape, which achieves high stability and is better in terms of production economics. Feeds on

arable land have a lower economic advantage that thick sown crop. Also because of this factor, the results recommend sowing corn for green on a smaller area than previous commodities. However, when sowing is being determined, animal production requirements should also be considered. If the possibilities of sugar rape growing are not limited, its area would be very large compared to the last determined area. The reason is its high economic value and special additional titles. Permanent grassland, pastures, vineyard, other one-year feeds and multi-annual feeds should be grown in the smallest percentage distribution. In Czech Republic, hops, other potatoes and poppy, are also very important. Czech Republic has a leading position in EU. Growing of remaining crops was identified as ineffective. Oats belongs to marginal crops in terms of growing areas and they appear as more profitable than rye, which also is not in the optimal sowing program. Also, edible peas are not in this program because is highly unstable and show long-term negative numbers from economic point of view. Neither triticale nor other crops are significant to be in the classification. Their inclusion would lead to a decrease of expected profit. The described optimal distribution of agricultural commodities corresponds to both area. We can say that they do not differ in optimal combination, except for negligible deviations. Regarding the impact of changes in the structure, the biggest effects would be the change of area by additional % from overall land used in corn region. In Slovak Republic, the greatest positive effect in terms of all criteria on the value of expected benefits would be mainly caused by sugar rape, particularly corn for feed and oil-seed rape with higher values. The sowing of corn for green, sunflower for seed or wheat would have a negative impact. Also, grasslands and pastures would have negative impact on the game result. By the analysis of results in Czech Republic, we found that the most rewarding would be the expansion of the area for growing mainly hops and potatoes, as well as corn for feed. It would be inappropriate to increase sowing of sunflower for seed, other one-year feed and corn for green are. The permanent grassland would bring the lowest negative impact. By the analysis, we found that to identify optimal sowing on the land, subsidies would not have significant affect no either Slovak or Czech Republic. The effect would only be reflected in the expected profits over the worst variant in appropriate nature status or in case of loss over the best option in appropriate nature state. With mixed strategies, the positions of both areas are balanced. The Slovak Republic corn region appears as more effective and in case of another rule, Czech Republic is more effective.

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