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Land use optimization with respect to alternative costs of crop production choices – Case of Slovakia

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Abstract
The dominated agricultural sector in Slovakia is crop production. The major part of arable land is devoted to the cultivation of cereals (57%), followed by feed crops (20%) and industry crops (19%). There is possible to identify 4 agricultural production areas, all with different soil conditions, altitude and structure of cultivated crops. Aim of this paper is to identify the optimal land allocation within the each production area among the selected major crops cultivated in Slovakia. Furthermore it deals with modelling the production potentials with respect to policy programmes and production choices aimed on improvement of profitability in less-favoured areas. Objective is to provide land use alternative for each production area in order to maximize profit. The results suggest that the mountains areas have potentials to produce and supply feed crops, while lowlands are favourable for diverse crop production.

Key words: *production area,, inputs, total gross margins, economic optimization*

JEL classification: *C61, Q10, Q15*

1 Introduction

Changes in land use management represent the way to adapt to the future climatic conditions, including local adjustments of agricultural choices (Klein et al., 2013). Agriculture is a multifunctional activity and aims to fulfill specific functions in the society. The European model of multifunctional agriculture takes into account in addition to the primary (production) and environmental function, also the social and cultural functions related to agricultural activity (Labuda and Murtinova, 2014).

Current situation in agriculture of Slovakia is mostly affected by the process of intensification and specialization but also marginalization. Agriculture still struggles with remains of the former regime. In the period before the transformation, the intensification of production led to excessive use of fertilizers and increased requirements for livestock. The Slovak agriculture experienced complicated development after 1990, when the trade conditions have been changed and public subsidies were eliminated. The transition toward market economy after 1990 had led to change in the structure of agricultural sector causing the continuous decrease of livestock since 1993 (especially pigs). In the period between 2000 and 2011 there was a decline in the stocks of pigs by 61% (Kročková, 2013).

The dominated agricultural sector in Slovakia is crop production. The utilized agricultural land (UAL) is divided into arable land, land devoted to permanent crops, other area and permanent meadows and pastures. After the accession, the agricultural land became a part of European natural resources and therefore also the part of economic, ecological and social potential with requirements of functional soils, their protection and the accurate use. One of the priorities of multifunctional agriculture is optimal ways of using natural resources in field systems, input-output analysis and their ratios (Ministry of Agriculture and Rural Development, 2010). In Slovakia there is possible to identify 4 agricultural production areas, all with different soil conditions, altitude and structure of cultivated crops. Aim of this paper is to identify the optimal

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land allocation within the each production area among the selected major crops cultivated in Slovakia. Objective is to allocate the land among the crops in order to maximize profit.

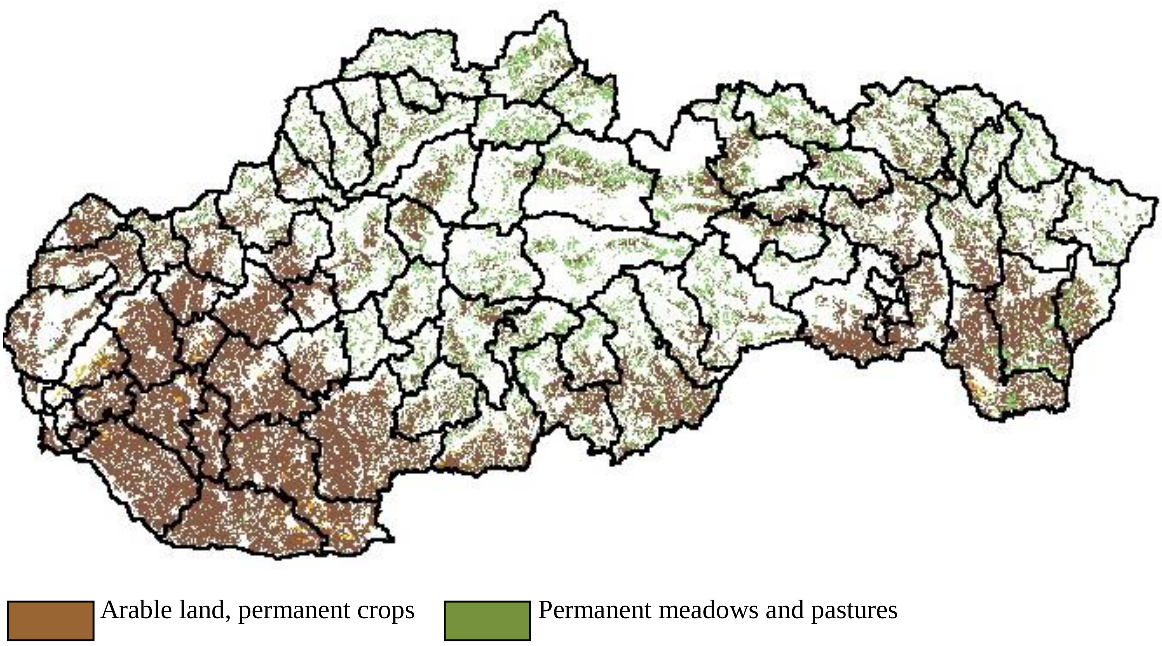
1.1 Characteristics of land use devoted to crop production in Slovakia

The utilized agricultural land (UAL) is divided into arable land, land devoted to permanent crops, other area and permanent meadows and pastures. More than 39% of total area of the Slovakia was covered by utilized agricultural area in 2014. UAL has a downward trend, which is environmentally negative phenomenon 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. Most of the agricultural activity is allocated in the Slovakia´s lowlands. This is due to the structure of agricultural soil. The productive types of soils are concentrated in the southern, south-west and western part of Slovakia, with lower altitude. Agricultural production is therefore concentrated in regions like Bratislava, Trnava and Nitra. This can be observed from Fig.1, which represents the structure of agriculture land use. The southern part of Slovakia has also the highest concentration of chernozems and mollic fluvisoils, which are the most fertile types of soils. The majority of arable land is devoted to cereals, followed by green fodder and industrial crops

Tab. 1: The use of arable land by crop groups 2004-2014 (% of total)

Use of arable land in total (%)/Time	2004	2006	2008	2010	2012	2014
Cereals	60.19	55.05	59.1	52.73	58.49	57.85
Legume	1.11	1.35	0.81	0.99	0.61	0.45
Root crops	4.54	3.57	1.95	2.24	2.16	2.24
Industrial crops	14.86	19	18.66	20.81	16.67	18.1
Vegetables	0.88	0.7	0.55	0.96	0.65	0.52
Green fodder from arable land	17.38	18.27	17.97	19.73	19.61	19.52
Other field crops	0.07	0.11	0.09	0.02	0.13	0.41
Flowers and ornamental plants	0.01	0.02	0.01	0.02	0.02	0.01
Seeds-plantations	0.17	0.1	0.1	0.13	0	0
Fallow land	0.79	1.83	0.76	2.37	1.66	0.89

Source: Slovstat, Use of Land (2015)



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Vineyards, hop-fields, other area including domestic gardens-plot

Fig. 1: Structure of agricultural land use in Slovakia

Source: SSCRI-Soil Portal, 2015

The cereals which are cultivated the most in Slovakia are wheat, barley, rye, oats and corn. Among the oil crops rapeseed and sunflower are of greatest importance. Industrial crops typical in Slovakia are hemp, sugar beet, flax seed, hops and others.

2 Data and methods

The paper is primarily focused economic data from agricultural sector. The optimization is provided for 12 major cultivated crops in Slovakia – wheat, rye, barley, oat, maize grain, green maize, annual fodder, perennial fodder, sunflower, rapeseed, soya and sugar beet. To identify the optimal land allocation within 4 production areas among crops, with respect to inputs, we can build the optimal programming model, with objective to allocate the available land among the crops in order to maximize total gross margins (TGM). The optimization model is programmed in General Algebraic Modeling System –GAMS.

2.1 Data and their sources

The economic dataset provides the calculations of gross margins for crop rotations on regional level. Data are extracted from Research institute of Agriculture and Food Economics (RIAFE). The reference situation is based on the standard gross margins calculation considering the difference between revenues and variable costs. Descriptive statistic of calculated TGM is showed in Tab.3. The reference year modelled is 2014. The crop rotations for 12 selected, major cultivated crops in Slovakia, were derived based on the observed historical crop shares for production areas (Tab.2). There were 3 crop mixes comprising convex combinations of crops, representing agronomic cropping patterns. Alternative crop mixes represent the alternative cost of each production choice.

Tab.2: Alternative crop mixes

Production area	Crop	M1	M2	M3	Production area	Crop	M1	M2	M3
maize_PA	wheat	0.32	0.26	0.31	potato_PA	wheat	0.31	0.31	0.33
maize_PA	rye	0.00	0.01	0.01	potato_PA	rye	0.01	0.01	0.01
maize_PA	barley	0.13	0.13	0.14	potato_PA	barley	0.05	0.06	0.09
maize_PA	oat	0.00	0.00	0.00	potato_PA	oat	0.01	0.01	0.02
maize_PA	maize_grain	0.17	0.18	0.16	potato_PA	maize_grain	0.05	0.06	0.07
maize_PA	maize_green	0.06	0.07	0.06	potato_PA	maize_green	0.17	0.20	0.09
maize_PA	annual_fodder	0.01	0.00	0.01	potato_PA	annual_fodder	0.03	0.02	0.02
maize_PA	prennial_fodder	0.08	0.09	0.08	potato_PA	prennial_fodder	0.20	0.19	0.19
maize_PA	sunflower	0.10	0.10	0.11	potato_PA	sunflower	0.00	0.00	0.04
maize_PA	rapeseed	0.08	0.09	0.06	potato_PA	rapeseed	0.15	0.14	0.15
maize_PA	soya	0.02	0.03	0.03	potato_PA	soya			
maize_PA	sugar_beet	0.02	0.02	0.03	potato_PA	sugar_beet			
rape_PA	wheat	0.33	0.32	0.33	mountain_PA	wheat	0.26	0.19	0.19
rape_PA	rye	0.01	0.01	0.01	mountain_PA	rye	0.02	0.03	0.02
rape_PA	barley	0.13	0.11	0.14	mountain_PA	barley	0.11	0.12	0.10
rape_PA	oat	0.01	0.01	0.01	mountain_PA	oat	0.02	0.04	0.03
rape_PA	maize_grain	0.09	0.09	0.08	mountain_PA	maize_grain			
rape_PA	maize_green	0.09	0.10	0.10	mountain_PA	maize_green	0.10	0.14	0.14
rape_PA	annual_fodder	0.01	0.00	0.01	mountain_PA	annual_fodder	0.07	0.07	0.08
rape_PA	prennial_fodder	0.11	0.11	0.11	mountain_PA	prennial_fodder	0.35	0.32	0.32
rape_PA	sunflower	0.03	0.04	0.03	mountain_PA	sunflower			
rape_PA	rapeseed	0.14	0.14	0.12	mountain_PA	rapeseed	0.07	0.10	0.11
rape_PA	soya	0.02	0.02	0.02	mountain_PA	soya			
rape_PA	sugar_beet	0.04	0.04	0.04	mountain_PA	sugar_beet			

Source: own, based on the historical cropping patterns RIAFE

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The variable costs of crop production are the expenditures for fertilizers - purchased and produced, chemical protection, agrochemicals and seed – purchased and produced (NPPC-RIAFE, 2015). The revenues per hectare from crop production have two components – market revenues and agri-environmental payments if applicable (Stürmer et al, 2013). In the current Slovak agri-environmental program, farmers receive subsidies in form of single area payment scheme (SAPS), the "green payment" (payments for agricultural practices beneficial for climate and environment) and payment for young farmers. The producer prices and input cost for the year 2013 are obtained from Statistical office of Slovak Republic (DATAcube).

Tab. 3: Descriptive statistics of indicator TGM for crops in 2014 (4 production areas)

Crop	Mean	Std. Dev.	Min	Max
wheat	509.56	154.27	352.22	684.22
rye	235.47	47.64	185.44	290.29
barley	547.08	171.95	309.99	679.98
oat	435.71	232.97	178.62	690.15
maize_grain	739.90	121.94	621.63	865.21
maize_green	388.01	21.48	367.75	410.61
annual_fodder	644.07	113.30	497.67	739.80
prennial_fodder	744.65	72.71	682.14	845.21
sunflower	413.99	178.19	287.99	539.99
rapeseed	882.60	20.64	864.19	908.34
soya	528.00	157.41	416.70	639.31
sugar_beet	1967.04	180.14	1839.66	2094.41

Source: own calculation

2.2 Land use optimization model

The linear program for bottom-up land use optimization model is simplified version of Austrian agricultural and forestry sector model PASMA (Schmid et al., 2007) adjusted for production areas of Slovakia:

$$\max\ f(d,X)=\sum_i (d_i X_i) \qquad (1)$$

$$\text{s.t.}\ \sum_i (A_{i,j} X_i) \le b_j \ \text{ for all } j$$

$$\sum_m (\theta_m M_{m,i}) \le X_i \ \text{ for all } i \qquad (1.1)$$

$$\sum_i (X_i) \le \sum_m \left(\theta_m \sum_i (M_{m,i}) \right) \qquad (1.2)$$

$$x_i \ge 0$$

where the equation (1) represents the objective function *f* set to maximizes TGM of optimal crop production choices. It is defined as the sum of the product of crop production choices (X) and their gross margins (d). The *i* denotes the dimensions of crop production choices production area *j*. The objective function is subject of land constrain (*b*) available for production area *j*. *A* represents the Leontief production function, the technology matrix to convert resources into

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crop products. In order to prevent overspecialization in a linear programming model, the balance equations (1.1) and (1.2) are used to include a convex set of alternative crop rotation systems based on alternative mixes of crop rotation system shares. θ stands for the choice variable for the crop rotation mix and M represents the parameter for available mixes, indexed by m. This ensures that crop rotation shares in model solutions are close to observed shares.

3 Results

3.1 Economic optimization

Considered the arable land constrained production areas, given the assumption of overspecialization prevention, the TGM is 73 485 507.46 €. Tab. 4 shows the abundance of each production area on the value of TGM. The maize production area, located in West-south plain and East plain, generates almost 50% of TGM, rape production area in West part of Slovakia, Košice hollow-basin, South-Slovakian hollow-basin, has 31% share. Potato area and mountain production area start form 500 m.a.s.l and have less favourable condition for crop production, therefore together contribute to TGM by less than 19%. The optimal cropping pattern was found to be M2 in case of maize production area, M1 in rape production area and potato production area and M3 in case of mountain production area.

Tab. 4: Land devoted to crops and share on TGM

Production area (PA)	Arable land devoted to selected crops (ha)	Share of TGM
maize_PA	50431	49.58%
rape_PA	33070	30.69%
potato_PA	14492	11.88%
mountain_PA	10676	7.86%

Source: own calculation

Maize and rape production area have the significant portion of arable land devoted to cultivation of selected crops and are suitable for diverse crop production. Potato and mountain production area have impaired condition for crop cultivation, therefore arable land is mostly covered by fodder crops.

Tab. 5 represents the optimal arable land allocation for each production area among the twelve selected crops. In order to maximize TGM in case of maize production area, 26% of arable land should be devoted to wheat, followed by grain maize (18%), barley (13%), sunflower (10%), rapeseed (9.5%), perennial fodder (9%) and green maize (7%). Other crops are cultivated in minor share.

The crop dominated in terms of TGM maximization for rape production area is again wheat with 33%, followed by rapeseed (14%), barley (12.5%), perennial fodder (11%), grain maize (9%) and green maize (9%). Rape production area has the most favourable cultivating condition for sugar beet. Other crops like rye, oat, annual fodder, sunflower and soya have only small share in terms of optimal cropping pattern.

Tab. 5: Optimal land allocation within the production areas among the selected major crops cultivated in Slovakia in 2014

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Production area	Crop	Optimal use of arable land in ha	Marginal value	Production area	Crop	Optimal use of arable land in ha	Marginal value
maize_PA	wheat	13194.95		potato_PA	wheat	4522.73	
maize_PA	rye	342.51		potato_PA	rye	204.09	
maize_PA	barley	6611.88		potato_PA	barley	766.38	
maize_PA	oat	112.03		potato_PA	oat	215.47	
maize_PA	maize_grain	9107.04		potato_PA	maize_grain	744.16	
maize_PA	maize_green	3638.05		potato_PA	maize_green	2406.86	
maize_PA	annual_fodder	232.27		potato_PA	annual_fodder	453.16	
maize_PA	prennial_fodder	4623.12		potato_PA	prennial_fodder	2936.66	
maize_PA	sunflower	5098.27		potato_PA	sunflower		
maize_PA	rapeseed	4755.50		potato_PA	rapeseed	2242.48	
maize_PA	soya	1563.37		potato_PA	soya		-908.34
maize_PA	sugar_beet	1152.02		potato_PA	sugar_beet		-908.34
rape_PA	wheat	10950.83		mountain_PA	wheat	2061.65	
rape_PA	rye	340.79		mountain_PA	rye	259.00	
rape_PA	barley	4161.98		mountain_PA	barley	1071.66	
rape_PA	oat	253.78		mountain_PA	oat	364.60	
rape_PA	maize_grain	3116.82		mountain_PA	maize_grain		-890.09
rape_PA	maize_green	2926.23		mountain_PA	maize_green	1497.93	
rape_PA	annual_fodder	344.93		mountain_PA	annual_fodder	847.44	
rape_PA	prennial_fodder	3580.87		mountain_PA	prennial_fodder	3451.60	
rape_PA	sunflower	911.53		mountain_PA	sunflower		-890.09
rape_PA	rapeseed	4532.81		mountain_PA	rapeseed	1122.11	
rape_PA	soya	542.78		mountain_PA	soya		-890.09
rape_PA	sugar_beet	1406.66		mountain_PA	sugar_beet		-890.09

Source: own calculation

In the potato production area the arable land is dominated by wheat (31%), perennial fodder (20%), green maize (17%), rapeseed (15%). In order to stay at maximum level of TGM, the other crops comprise only minor part of arable land. Sunflower, soya and sugar beet are not cultivated in this area. The marginal value means that the cultivation of soya or sugar beet would decrease profit by 908.34 € per ha of additional crop in this area.

Mountain production area is identified as "less-favoured" area, because of higher altitude and less productive types of soils. It also has minimum land occupied by arable land. The TGM in respective area is maximized by major involvement of perennial fodder which should be cultivated on 32% of arable land followed by wheat (19%), green maize (14%), rapeseed (11%), barley (10%), annual fodder (8%), oat (4%) and rye (2%). Other crops are not suitable for this production area. As suggests the marginal value from Tab. 5, cultivation of grain maize, sunflower, soya or sugar beet would decrease profit by 890.1 € per ha of additional crop in this area.

As for the TGM per individual crop production choices in each production area, the highest TGM is in maize and rape production areas. In terms of variable costs, maize production area has the highest costs and are approximately 1/3 higher compare to the rape production area (Tab.6). On the other hand potato and mountain production area have lower levels of TGM. Shadow prices in Tab.6 represent how much land must be added to respective production area in order to generate one euro of gross margin. In maize production area it would require 722.4 ha, in rape production area almost 682 ha, 602 ha in potato production area and 541 ha in mountain production area.

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Tab. 6: Resulting values of TGM and inputs

PA/indicator	TGM	Seed_E	Seed_P	Fer_E	Fer_P	CHEM	AGROCHEM	OH_P	ShadowP
maize_PA	36432039.7	4372777.4	489876.0	6863103.0	1772344.8	5873080.9	1782783.2	4150405.1	722.4
rape_PA	22549447.4	2539356.3	273300.5	4280302.7	1288441.0	3861481.7	1384118.9	3245582.5	681.9
potato_PA	8726891.0	1025896.4	115299.9	1546204.6	330260.6	1599731.7	414505.4	1061601.8	602.2
mountain_PA	5777129.5	562980.6	107284.9	817742.2	403081.0	567014.4	189032.8	660049.8	541.1

Notes: TGM – total gross margins, Seed_E – purchased seed, Seed_P – produced seed, Fer_E – purchased fertilizers, Fer_P – produced fertilizers, CHEM – chemical protection, AGROCHEM – agrochemical services, OH_P – production overheads, ShadowP – shadow price
Source: own calculation

3.2 Production potentials with respect to policy programmes in less-favoured areas

Less- favoured areas –potato and mountain production area- are agricultural areas in which the influence of unfavourable conditions, altitude, slope-and low soil fertility and other adverse natural conditions or in connection with specific local economic and social conditions, the costs per unit of production in agricultural activity are permanently higher than average.

Based on previously calculated economic optimization of arable land use allocation based on inputs utilization, the potato production area is suitable for cultivation of wheat, perennial fodder, green maize and rapeseed. Mountain production area has production potential for perennial fodder and in lower share for wheat, green maize and rapeseed. This area was identified to have the most favourable economic condition for oat cultivation, compared the other production areas.

The policy experiment is conducted in order to increase the profitability of less-favoured areas. In both areas we model the doubling of subsidies for crops which have the most favourable production potentials. In case of potato production area it is perennial fodder and green maize. In mountain production area it is perennial fodder, green maize and oat.

Tab. 7: Resulting values of TGM under the new policy scheme

PA/indicator	TGM	Subsidy increase(index)	TGM_subsidy_scenario
maize_PA	36432039.7	0	36432039.7
rape_PA	22549447.4	0	22549447.4
potato_PA	8726891.0	1	12867435.1
mountain_PA	5777129.5	1	9126180.0

Source: own calculation

The results (Tab.7) suggest that under the doubled subsidy scenario, the TGM in potato production area would increase by 4140544.1 € and in mountain production area it would lead to increase by 3349050.5 €.

4 Conclusion

Maximum TGM for all production areas with respect to optimal arable land allocation was 73.5 mil. €. The highest share on this result can be attributed to lowlands due to their high production potentials. Potato area and mountain production area start form 500 m.a.s.l and have less favourable condition for crop production, therefore achieved lower values of TGM. Structure of the cropping pattern was diverse in maize and rape production area and involved all 12 crops. In both areas the dominated crop was wheat and grain maize. In terms of variable costs, maize production area had the highest costs and were approximately 1/3 higher compare to the rape production area. In terms of economic optimization, potato and mountain production areas are suitable for fodder and other feed crops cultivation. Soya, sugar beet, sunflower and also the grain maize in case of mountain production area, are not cultivated in less-favourable areas. In mountain production area there is potential for rapeseed and oat production, which are the crops for feeding and industrial purposes. In maize production area to increase TGM by 1€ would require 722.4 ha increase in arable land, in rape production area almost 682 ha, 602 ha in potato production area and 541 ha in mountain production area.

In order to increase profitability in less-favoured areas, there was a subsidy increased policy scenario applied. The doubled subsidy scenario resulted in increase by 4 mil. € in TGM in potato production area and in mountain production area it led to increase by 3.3 mil. €. The doubled subsidy scenario was applied on perennial fodder and green maize in both production areas and on oat in case of mountain production area. These production areas have the economic potential for cultivation of feeding crops with respect to variable inputs.

In terms of production potential it is desirable to synchronize production and economic optimization to identify the environmental aspects of crop production. Lowlands might be the obvious choice from economic perspective, but exploitation of soils lead to high environmental pressures. On the other hand in less-productive areas there could be possible to identify the significant stocks of marginal land for cultivation of 2. generation biofuels feedstock.

References

[1] Klein, T., Holzkämper, A., Calanca, P., Seppelt, R., Fuhrer, J. 2013. Adapting agricultural land management to climate change: a regional multi-objective optimization approach. In: Landscape ecology. 2013, Vol. 28, No. 10, p. 2029-2047. ISSN: 1572-9761

[2] Kročková, B. Poľnohospodárstvo a jeho vplyv na životné prostredie v Slovenskej republike k roku 2011. 2013. In: . Banská Bystrica: Slovak environmental agency, No. 4.

[3] Ministry of Agriculture and Rural Development, 2010. Národný strategický plán rozvoja vidieka SR. Available on: http://www.rrasi.sk/images/stories/kniznice/Narodny_strategický_plán_rozvoja_vidieka_SR.pdf

[4] Murtinova, S., Labuda, M. 2014. Environmentálne hodonotenie multifunkčnosti poľnohospodárstva (Komparačná analýza). ACTA ENVIRONMENTALICA UNIVERSITATIS COMENIANAE (BRATISLAVA). 2014, 22(1), 25-36. ISSN 1335 - 0285.

[5] RIAFE, Research Institute of Agriculture and Food Economics. 2015. Sample survey of economic results in Slovak Farm Accountany Data Network [online]. Bratislava, 2015

[6] Schmid, E., Sinabell, F., Hofreither, M.F. 2007. Sustainability in practice: a case study on the reorientation of the Common Agricultural Policy in Austria. Sustainable Development in Europe: Concepts, Evaluation and Application. Book Chapter, pp. 109–122. ISBN: 978-184542831-0

[7] Strümer, B., Scmidt, J., Schmid, E. , Sinabell, F. 2012. Implications of agricultural bioenergy crop production in a land constrained economy – The example of Austria. Land use Policy, 30, p. 570-581, . ISSN: 0264-8377

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