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# FOOD SECURITY FACETS: CASE OF SLOVAKIA REGIONS

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**Abstract.** Natural conditions and traditions of agriculture production are challenging by sustainable development in Slovakia. The significant portion of arable land is devoted to the cultivation of crops, especially cereals, feed crops and industry crop. There is a high representation of mountains 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 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. Such kind of optimization targets to create a better condition to reach environmental and economic balance of crop production.

**Key words:** crops production optimisation, management practices, water use efficiency, net returns, environmental implication, sustainable development, bottom up optimization model

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**JEL codes:** A12, C61, Q19, Q15

## 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; Ryabchenko et al., 2013, Tvaronavičienė, 2016). 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 (Božik, 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; Czyżewski, Smędzik-Ambroży, 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; Reiff et al., 2016). 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; Velychko, 2015). 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; Urbaniec, 2015; Ivanová, Masárová, 2016).

### *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.

## 2. Methodology

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.

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. Information 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

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**Table 1**. Input of nitrogen 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

Rate of nitrogen (NRate) from table 1, represent nitrogen input 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 model PASMA (Schmid and Sinabell, 2007) adjusted for small regional model of Slovakia in form:

$$\pi_{r,c} = \sum_{c=1}^{C} \left( YLDG_{r,c,m} * price \right) - \left( DirCost_{r,c} + FerCost_{r,c} + IrCost_{r,c} \right) \quad (1)$$

$$max\pi = \sum_{r=1}^{R} \sum_{m=1}^{M} \left( \pi_{r,m} * x_{r,m} \right) \quad (2)$$

$$s.t. = \sum_{r=1}^{R} \sum_{m=1}^{M} (a_{r,m} * x_{r,m}) \leq b_p \quad (3)$$

where:
$\pi$ - 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.

**Table 3.** Net returns (NReturn) of crop mix per regions, under different management practices (Mana) €/ha

| Region.Mana | NRetum | Region.Mana | NRetum |
|---|---|---|---|
| BA.N0I | 4786.256 | NR.N0I | 3563.201 |
| BA.N0R | 5891.86 | NR.N0R | 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.N0I | 4614.599 | NZ.N0I | 4228.257 |
| MA.N0R | 5326.568 | NZ.N0R | 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 |

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

| | | | |
|---|---|---|---|
| MA.NPR | 5000.58 | NZ.NPR | 6260.416 |
| PK.N0I | 3851.434 | SA.N0I | 4574.765 |
| PK.N0R | 5187.931 | SA.N0R | 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.N0I | 4312.505 | TO.N0I | 3039.28 |
| SC.N0R | 5750.424 | TO.N0R | 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.N0I | 4486.23 | TO.NPR | 5164.053 |
| KN.N0R | 5871.699 | ZM.N0I | 3279.228 |
| KN.NHI | 6247.405 | ZM.N0R | 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.N0I | 3597.464 | ZM.NPR | 5184.193 |
| LV.N0R | 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.N0I | -2273.505 | NR.N0I | -2983.182 | SC.N0I | -2570.2 | TO.N0I | -2786.847 |
| BA.N0R | -1167.9 | NR.N0R | -1309 | SC.N0R | -1132.281 | TO.N0R | -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.N0I | -1188.723 | NZ.N0I | -2729.199 | KN.N0I | -2416.934 | ZM.N0I | -2653.773 |
| MA.N0R | -476.755 | NZ.N0R | -1223.427 | KN.N0R | -1031.465 | ZM.N0R | -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.N0I | -2622.355 | SA.N0I | -2625.888 | LV.N0I | -2913.285 | | |
| PK.N0R | -1285.859 | SA.N0R | -1235.284 | LV.N0R | -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 N0I. 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.

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**Table 5.** Water use efficiency in regions for selected crops mix kg/mm

| Region. Mana | WUEF | Region. Mana | WUEF |
|---|---|---|---|
| BA.N0I | 142.684 | NR.N0I | 124.136 |
| BA.N0R | 152.068 | NR.N0R | 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.N0I | 146.307 | NZ.N0I | 130.347 |
| MA.N0R | 158.661 | NZ.N0R | 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.N0I | 126.214 | SA.N0I | 134.303 |
| PK.N0R | 136.659 | SA.N0R | 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.N0I | 136.376 | TO.N0I | 118.196 |
| SC.N0R | 147.07 | TO.N0R | 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.N0I | 138.273 | ZM.N0I | 120.537 |
| KN.N0R | 153.268 | ZM.N0R | 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.N0I | 120.738 | | |
| LV.N0R | 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

Our analysis was focused on south- west regions from maize production areas with the most fertile soil type. 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 mix 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. Investments into the improved technology might motivate the farmers to shift toward lower input, sustainable management practices, which still ensure the high economic returns from crop productions.

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