AN INDEX DECOMPOSITION ANALYSIS MODEL FOR IDENTIFICATION OF STRATEGIC CHANGES: THE CASE OF CEREAL HARVEST IN LITHUANIAN COUNTIES

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In this study we analysed harvest of the two broad groups of grain crops, namely winter and spring cereals. The aim of the research was to develop and apply an index decomposition analysis model for assessment of changes in crop harvest. Consequently, we defined four factors quantifying effects of amount of cropped area, crop spatial distribution inter counties, species mix within counties, and yield. This study focuses on changes in harvest of grain crops, namely winter and spring cereals, in Lithuania. These two broad categories were analysed at the county level throughout the period of 2000–2010. The area effect was the driving force causing increase in cereal harvest. The structure effect (re-location of crop areas among different counties of Lithuania) resulted in increase in total cereal harvest. The alteration of proportions of the area under different cereal species in certain county lead to positive species mix effect. Hence, these decisions can be considered as rational ones. Nevertheless, unfavourable climatic conditions lead to decrease in yields, i. e. negative yield effect was observed. Further modifications of the proposed model, hence, might be useful tools for decision aiding.

Key words: index decomposition analysis, Divisia index, harvest, yield, cereals, strategic management, index method, Lithuania.
JEL codes: C430, Q100, Q150.

Introduction

Topicality of the research. The total harvest of winter and spring cereals increased by 4,1 per cent during 2000–2010 in Lithuania. Meanwhile, the cropped are increased by 5,8 per cent during the same period. Hence, one can conclude that underlying causes of changes in harvest encompass both qualitative and quantitative factors. These factors need to be revealed by applying index decomposition analysis (IDA). The IDA is widely applied method aimed at quantifying the underlying factors, which, in turn, influence certain phenomenon. B. W. Ang (2005) has developed and applied the IDA in energy studies. In addition, IDA has been applied in studies on gross domestic product analysis (Mackevičius, 2009; Valkauskas, 2006). As for agricultural economics the discussed method was applied in analysis of crop harvest (Genienė, 1998; Čiulevičienė, 2006) and earnings (Baležentis, 2011b). D. Makutėnienė (2003) analysed cereal cultivation issues at a county level. The novelty of this study lies in fact that we are going to analyse winter and spring cereal harvest at both national and county level. A new factor, namely that of inter–county distribution of crops, will therefore be introduced in the analysis.

The problem of the research. Our study is aimed at quantification of the underlying factors causing changes in crop harvest. More specifically, crop harvest is influenced by amount of cropped area, yield, and species mix in certain area. For an irrational allocation of crop species might lead to reduction in harvests.

The aim of the research is to develop and apply an IDA model for assessment of strategic changes in crop harvest. The following **tasks** are therefore set: 1) to extend the logarithmic mean Divisia index for harvest analysis; 2) to assess the recent changes in cereal crop indicators in Lithuania; 3) to apply IDA for explaining changes in cereals harvest.

The object of the research is harvest of winter and spring cereals in Lithuania.

The following **methods** were applied for the research: logarithmic mean Divisia index, statistical analysis. The **data** were collected from Statistics Lithuania database (Rodiklių …, 2011), namely table M5010303. The **research period** covers years 2000–2010.

1. The principles of index decomposition analysis

In this study the logarithmic mean Divisia index (LMDI), type I, will be employed for index decomposition analysis (IDA). The following computations were reported by Ang (2005). Let V be an aggregate variable with n factors influencing changes in V over time and each is associated with respective variable from set $x_1, x_2, \ldots, x_n$. Let there is the i–th sub-category of the aggregate. For the i–th sub-category, the following equation holds: $V_i = \prod_{j=1}^{n} x_{ji}$. The general IDA identity is therefore given by:

$$V = \sum_i V_i = \sum_i \prod_j x_{ji} , \tag{1}$$

where $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$. Hence, the agregate changes from $V_i^0 = \prod_{j=1}^{n} x_{ji}^0$ in period 0 to $V_i^T = \prod_{j=1}^{n} x_{ji}^T$ in period T. In case of additive decomposition, we decompose the difference:

$$\Delta V = V^T - V^0 = \Delta V_{x_1} + \Delta V_{x_2} + ... + \Delta V_{x_n} . \tag{2}$$

As for multiplicative decomposition, we decompose the ratio:

$$D = V^T / V^0 = D_{x_1} D_{x_2} \ldots D_{x_n} . \tag{3}$$

Indeed, the terms on the right–hand side are the effects associated with respective factors in Eq. (1).

In the LMDI approach, the following generalized equations describe the effect of the k–th factor in Eqs. (2) and (3), respectively:

$$\Delta V_{x_k} = \sum_i \frac{V_i^T - V_i^0}{\ln V_i^T - \ln V_i^0} \ln\left(\frac{x_{ki}^T}{x_{ki}^0}\right), \tag{4}$$

$$D_{x_k} = \exp\left(\sum_i \frac{\left(V_i^T - V_i^0\right) / \left(\ln V_i^T - \ln V_i^0\right)}{\left(V^T - V^0\right) / \left(\ln V^T - \ln V^0\right)} \ln\left(\frac{x_{ki}^T}{x_{ki}^0}\right)\right), \tag{5}$$

where $k = 1, 2, \ldots, n$. These generalized formulae, however, need to be customized for each particular case.

The changes in the overall harvest of certain crops can be analysed by quantifying changes in the following four factors:

1) Q – area effect, i. e. changes in the amount of are under crops (an extensive factor);

2) S – spatial distribution of area under crops effect, i. e. the share of area in certain region compared with the total cropped area (structure effect);

3) M – species mix effect, i. e. the impact of different composition of crops in certain region;

4) Y – yield effect, i. e. changes in harvest caused by respective changes in yield (an intensive factor).

Noteworthy, all but the second effects were analyzed in previous researches (Čiulevičienė, 2006). Indeed, the spatial distribution effect obviously plays an important role for Lithuanian counties tend to differ in climatic conditions and soil. Furthermore, let us consider *m* regions with *n* possible species of crops in each of them. Then, the following equation shall describe the changes in total harvest:

$$C = \sum_{ij} Q \cdot \frac{Q_i}{Q} \cdot \frac{Q_{ij}}{Q_i} \cdot \frac{C_{ij}}{Q_{ij}} = \sum_{ij} Q S_i M_{ij} Y_{ij} , \tag{6}$$

where C and Q denote the total harvest (tonnes) and total area under crops (ha); where $Q_i = \sum_j Q_{ij}$ is the total area under crops in certain region; and where Q_{ij} and C_{ij} denote area and harvest of the *j*–th crop species in the *i*–th region, respectively, for $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$.

Consequently, the following formula describes changes in additive decomposition:

$$\Delta C = C^T - C^0 = \Delta C_Q + \Delta C_S + \Delta C_M + \Delta C_Y , \tag{7}$$

where:

$$\Delta C_Q = \sum_{ij} \frac{C_{ij}^T - C_{ij}^0}{\ln C_{ij}^T - \ln C_{ij}^0} \ln\left(\frac{Q^T}{Q^0}\right), \tag{8}$$

$$\Delta C_S = \sum_{ij} \frac{C_{ij}^T - C_{ij}^0}{\ln C_{ij}^T - \ln C_{ij}^0} \ln\left(\frac{S_i^T}{S_i^0}\right), \tag{9}$$

$$\Delta C_M = \sum_{ij} \frac{C_{ij}^T - C_{ij}^0}{\ln C_{ij}^T - \ln C_{ij}^0} \ln\left(\frac{M_{ij}^T}{M_{ij}^0}\right), \tag{10}$$

$$\Delta C_Y = \sum_{ij} \frac{C_{ij}^T - C_{ij}^0}{\ln C_{ij}^T - \ln C_{ij}^0} \ln\left(\frac{Y_{ij}^T}{Y_{ij}^0}\right). \tag{11}$$

Similarly, the following formula describes changes in multiplicative decomposition:

$$D = C^T / C^0 = D_Q D_S D_M D_Y , \tag{12}$$

where:

$$D_Q = \exp\left(\sum_{ij} \frac{\left(C_{ij}^T - C_{ij}^0\right) / \left(\ln C_{ij}^T - \ln C_{ij}^0\right)}{\left(C^T - C^0\right) / \left(\ln C^T - \ln C^0\right)} \ln\left(\frac{Q^T}{Q^0}\right) \right), \tag{13}$$

$$D_S = \exp\left(\sum_{ij} \frac{\left(C_{ij}^T - C_{ij}^0\right) / \left(\ln C_{ij}^T - \ln C_{ij}^0\right)}{\left(C^T - C^0\right) / \left(\ln C^T - \ln C^0\right)} \ln\left(\frac{S_i^T}{S_i^0}\right) \right), \tag{14}$$

$$D_M = \exp\left(\sum_{ij} \frac{\left(C_{ij}^T - C_{ij}^0\right) / \left(\ln C_{ij}^T - \ln C_{ij}^0\right)}{\left(C^T - C^0\right) / \left(\ln C^T - \ln C^0\right)} \ln\left(\frac{M_{ij}^T}{M_{ij}^0} \right) \right), \quad (15)$$

$$D_Y = \exp\left(\sum_{ij} \frac{\left(C_{ij}^T - C_{ij}^0\right) / \left(\ln C_{ij}^T - \ln C_{ij}^0\right)}{\left(C^T - C^0\right) / \left(\ln C^T - \ln C^0\right)} \ln\left(\frac{Y_{ij}^T}{Y_{ij}^0} \right) \right). \quad (16)$$

Hence the aforementioned formulae enable to quantify area, structure, species mix, and yield effects both in additive and multiplicative index decomposition.

2. Statistics of cereal growing area and harvest in Lithuania

In our study we analysed the changes in harvest of grain crops, namely winter and spring cereals. These two broad categories were analysed at the county level throughout the period of 2000–2010. Additionally, the two variables – area under crops and harvest – were extracted from Statistics Lithuania database. More specifically, the yield was computed for each county and crop species by dividing harvest from the total area under certain crop species.

The main trends in dynamics of amount and structure of area under winter and spring cereals are presented in Table 1. As one can see, the total are under these species increased by some 5,8 per cent from 980 thousand ha in 2000 up to 1036 thousand ha in 2010.

As for winter cereals, their area increased by 18,3 per cent. More specifically, the share of winter crops compared to whole area in the Republic of Lithuania increased for counties of Marijampolė, Šiauliai, Telšiai, Panevėžys, and Tauragė. On the other side, this share decreased for counties of Kaunas, Vilnius, Utena, Alytus, and Klaipėda. As for spring cereals, their area has decreased by 4,8 per cent, i. e. 25,5 thousand ha during 2000–2010. At the counties level the following shifts in structure were observed. The share of counties of Panevėžys, Kaunas, Vilnius, Telšiai, Šiauliai, and Alytus has increased, whereas that of counties of Marijampolė, Tauragė, Klaipėda, and Utena has decreased. Indeed, the previous research (Baležentis, 2011a) has reported that the most efficiently operating farms were those in counties of Marijampolė, Šiauliai, and Klaipėda. Hence, it might be concluded that efficient farming is associated with growing of winter cereals and therefore counties of Marijampolė and Šiauliai were those managed to increase their share in total area of winter cereals in Lithuania (increases of 3,1 and 2,9 percentage points, respectively, were observed). Indeed, these findings can be based on commonly known advantages of winter cereals.

As the following Table 2 exhibits, the different trends both in harvest and yield of crops were observed throughout counties of Lithuania. The overall harvest of cereals increased by 4,1 per cent, i. e. some 110 thousand tonnes (t). The mean yield decreased by 0,04 t/ha, i. e. 1,5 per cent. These changes, meanwhile, had differed in counties and crop species.

Considering the winter cereals, their harvest has increased by 12 per cent (169 thousand t) in Lithuania throughout 2000–2010. The highest rates of increase were observed in counties of Telšiai, Marijampolė, Tauragė, and Šiauliai. At the other end of spectrum, counties of Vilnius, Utena, and Alytus exhibited the highest rates of decrease in harvest. The yield values have also been varying across different counties.

For instance, in 2010 the indicator values ranged between the lowest value of 1,66 t/ha in Vilnius county and the highest one of 4,01 t/ha in Marijampolė county. More specifically, yields have increased in counties of Telšiai, Tauragė, and Marijampolė during 2000–2010. However, the mean yield of winter cereals has dropped down by some 5,3 per cent in Lithuania.

Table 1. Dynamics of area under winter and summer cereals in Lithuania for years 2000 and 2010.

County	Amount of area under crops				Structure of area under crops		
	Area, ha		Change		Share of area, per cent		Change, p. p.
	2000	2010	Absolute, ha	Relative, per cent	2000	2010	
Winter cereals							
Alytus	20808	20264	-544	97,4	4,6	3,8	-0,8
Kaunas	83257	80120	-3137	96,2	18,5	15,1	-3,5
Klaipėda	21909	23970	2061	109,4	4,9	4,5	-0,4
Marijampolė	54944	81529	26585	148,4	12,2	15,4	3,1
Panevėžys	73340	91039	17699	124,1	16,3	17,1	0,8
Šiauliai	93549	126262	32713	135,0	20,8	23,8	2,9
Tauragė	22912	29734	6822	129,8	5,1	5,6	0,5
Telšiai	14944	28774	13830	192,5	3,3	5,4	2,1
Utena	20976	17094	-3882	81,5	4,7	3,2	-1,5
Vilnius	42295	32212	-10083	76,2	9,4	6,1	-3,4
Total (winter cereals)	448934	530998	82064	118,3	100,0	100,0	
Spring cereals							
Alytus	26125	25535	-590	97,7	4,9	5,1	0,1
Kaunas	71842	78652	6810	109,5	13,5	15,6	2,0
Klaipėda	41003	32656	-8347	79,6	7,7	6,5	-1,3
Marijampolė	65174	47741	-17433	73,3	12,3	9,5	-2,8
Panevėžys	81462	95814	14352	117,6	15,4	19,0	3,6
Šiauliai	96635	94452	-2183	97,7	18,2	18,7	0,5
Tauragė	37211	22702	-14509	61,0	7,0	4,5	-2,5
Telšiai	26437	28437	2000	107,6	5,0	5,6	0,6
Utena	31963	24349	-7614	76,2	6,0	4,8	-1,2
Vilnius	52841	54840	1999	103,8	10,0	10,9	0,9
Total (spring cereals)	530693	505178	-25515	95,2	100,0	100,0	
Total	979627	1036176	56549	105,8			

As for spring cereals, their harvest increased decreased by some 59 thousand t, which constitute 4,7 per cent of the initial harvest. The harvest of spring cereals increased in counties of Kaunas, Panevėžys, and Telšiai, whereas decreased in counties of Alytus, Tauragė, Utena, Marijampolė, and some others. The yield of spring cereals, however, remained virtually unchanged in Lithuania. As of 2010, the yield ranged between 1,24 t/ha in Alytus county and 3,15 t/ha in Marijampolė county.

Table 2. Cereal harvest and yield in Lithuania for years 2000 and 2010.

County	Harvest				Yield			
	Amount, t		Change		Amount, t/ha		Change	
	2000	2010	Absolute, t	Relative, per cent	2000	2010	Absolute, t/ha	Relative, per cent
Winter cereals								
Alytus	48390	40385	-8005	83,5	2,33	1,99	-0,33	85,7
Kaunas	268765	233018	-35747	86,7	3,23	2,91	-0,32	90,1
Klaipėda	62373	57266	-5107	91,8	2,85	2,39	-0,46	83,9
Marijampolė	213808	326989	113181	152,9	3,89	4,01	0,12	103,1
Panevėžys	266098	243492	-22606	91,5	3,63	2,67	-0,95	73,7
Šiauliai	335610	434455	98845	129,5	3,59	3,44	-0,15	95,9
Tauragė	59259	84925	25666	143,3	2,59	2,86	0,27	110,4
Telšiai	34157	74924	40767	219,4	2,29	2,60	0,32	113,9
Utena	39058	30244	-8814	77,4	1,86	1,77	-0,09	95,0
Vilnius	82537	53576	-28961	64,9	1,95	1,66	-0,29	85,2
Total (winter)	1410055	1579274	169219	112,0	3,14	2,97	-0,17	94,7
Spring cereals								
Alytus	47350	31706	-15644	67,0	1,81	1,24	-0,57	68,5
Kaunas	168360	208854	40494	124,1	2,34	2,66	0,31	113,3
Klaipėda	88842	72027	-16815	81,1	2,17	2,21	0,04	101,8
Marijampolė	193968	150434	-43534	77,6	2,98	3,15	0,17	105,9
Panevėžys	207803	237027	29224	114,1	2,55	2,47	-0,08	97,0
Šiauliai	276721	268372	-8349	97,0	2,86	2,84	-0,02	99,2
Tauragė	76125	53647	-22478	70,5	2,05	2,36	0,32	115,5
Telšiai	52288	53537	1249	102,4	1,98	1,88	-0,10	95,2
Utena	48352	36188	-12164	74,8	1,51	1,49	-0,03	98,2
Vilnius	87761	76700	-11061	87,4	1,66	1,40	-0,26	84,2
Total (spring)	1247570	1188492	-59078	95,3	2,35	2,35	0,00	100,1
Total	**2657625**	**2767766**	**110141**	**104,1**	**2,71**	**2,67**	**-0,04**	**98,5**

The discussed changes in harvest stress the need for analysis of the underlying causes thereof. More specifically, the total change in cereal harvests (Table 2), namely increase of 110141 t, will be decomposed by quantifying area, structure, species mix, and yield effects.

3. Index decomposition analysis for cereal harvest analysis

The data from Tables 1 and 2 were used for IDA. As it was mentioned before, LMDI analysis was performed in two ways, namely additive and multiplicative.

For additive decomposition, Eqs. 8–11 were employed. The results are presented in Fig. 1. Obviously, all the effects but yield effect caused positive changes in harvest. The area effect, more specifically, caused the increase of some 212 thousand

t. The yield effect, nevertheless, suppressed growth of harvest. As a result, the overall harvest of crop cereals increased by over 110 thousand t during 2000–2010.

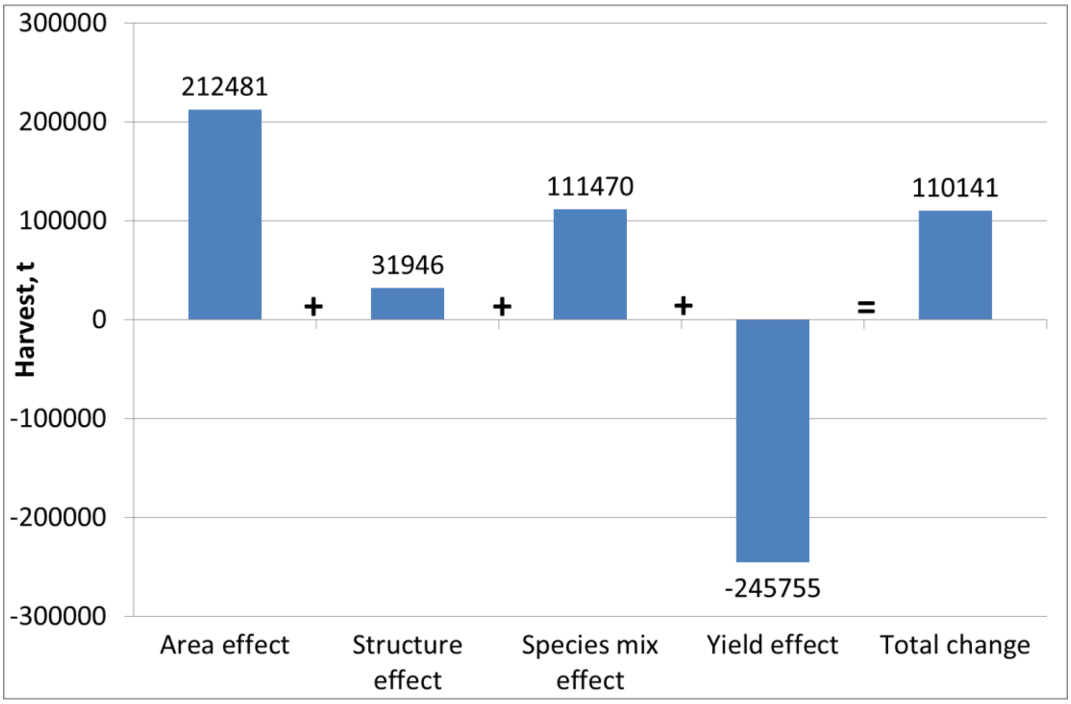

Figure 1. The additive decomposition of changes in crop harvest, 2000–2010

The multiplicative IDA enabled to identify the relative impact of respective factor on changes in harvest. Eqs. 13–16 were employed for that purpose. The results of multiplicative IDA for cereal crop harvest in Lithuania are presented in Fig. 2. As the results suggest, the area effect caused increase in harvest of some 6 per cent. Meanwhile, species mix effect led to increase in harvest of 3 per cent, whereas structure effect – to that of 2 per cent. The yield effect caused decrease of some 6 per cent. The total harvest, therefore, grew by 4 per cent.

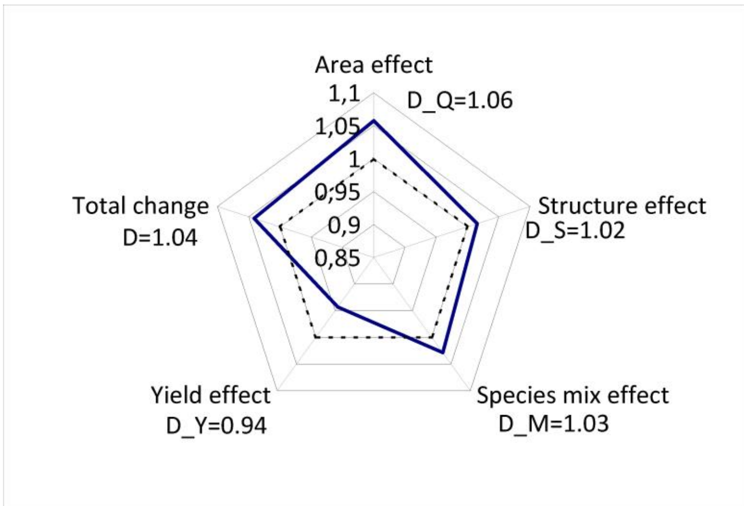

Figure 2. The multiplicative decomposition of changes in crop harvest, 2000–2010

Considering the results of IDA analysis, it can be concluded that the area effect was the driving force causing increase in cereal harvest (212 thousand t in absolute terms or 6 per cent relative growth). Meanwhile, these changes were interrelated with respective shifts in cereal prices (Bradūnas, 2011). The structure effect caught changes in the spatial distribution of crop areas. In this case, the re-location of crop areas among different counties of Lithuania resulted in 2 per cent increase in total cereal harvest (32 thousand t). The alteration of proportions of the area under different cereal species in certain county lead to positive species mix effect. Hence, these changes can be considered as rational ones. Nevertheless, unfavourable climatic conditions lead to decrease in yields. Yield effect, hence, caused decline of 6 per cent or 246 thousand t in total harvest. These four effects caused the increase of 4 per cent in the total harvest or cereals.

Conclusions

1. The changes in harvest can be explained by quantifying the related factors. In this study, we have modified logarithmic mean Divisia index to tackle four factors, namely area, structure, species mix, and yield effects. An additive and multiplicative index decomposition analysis enables to identify absolute and relative changes, respectively.

2. The total harvest of winter and spring cereals increased by 4,1 per cent between 2000 and 2010 in Lithuania. Meanwhile, the cropped area increased by 5,8 per cent during the same period. The underlying causes of changes in harvest were revealed by applying index decomposition analysis.

3. The area effect was the driving force causing increase in cereal harvest. The structure effect (re-location of crop areas among different counties of Lithuania) resulted in increase in total cereal harvest. The alteration of proportions of the area under different cereal species in certain county lead to positive species mix effect. Hence, these changes can be considered as rational ones. Nevertheless, unfavourable climatic conditions lead to decrease in yields, i. e. negative yield effect was observed.

4. The proposed model is, however, a generalized one. Further modifications, hence, might be useful both for interested decision makers. Moreover, the further studies might be aimed at chain–linked analysis. Finally, it is important to determine and forecast future adjustments of crop area allocation to changing economic and environmental conditions.

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INDEKSINIO IŠSKAIDYMO ANALIZĖS MODELIS STRATEGINIŲ POKYČIŲ IDENTIFIKAVIMUI: JAVŲ DERLIUS LIETUVOS APSKRITYSE

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Šiame straipsnyje analizuoti dviejų grūdinių augalų rūšių grupių – žieminių ir vasarinių javų – derliaus pokyčiai. Tyrimo tikslas – pasiūlyti ir pritaikyti naują indeksinio išskaidymo analizės modelį vertinant derliaus pokyčius. Tyrime pritaikyti logaritminio vidurkio Divisia indekso ir statistinės analizės metodai. Derliaus pokyčiai tirti analizuojant keturis veiksnius, apibūnančius pasėlių ploto, javų rūšių erdvinio pasiskirstymo (tarp apskričių ir apskrityse) bei derlingumo pokyčius. Šio tyrimo objektas – žieminių ir vasarinių javų derlius Lietuvoje. Tyrimui naudoti apskričių lygio duomenys, apimantys 2000–2010 m. laikotarpį. Pasėlių ploto efektas stipriausiai veikė javų derliaus padidėjimą. Tai gali būti paaiškinta javams skirtų ir naudojamų žemės ūkio naudmenų plotų padidėjimu. Struktūros (pasėlių paskirstymo tarp apskričių) efektas taip pat lėmė derliaus augimą. Be to, javų rūšių proporcijų kitimas atskirose apskrityse didino javų derliaus apimtį. Taigi minėti pokyčiai gali būti laikomi racionaliais prisitaikymo prie besikeičiančių gamtinių ir ekonominių sąlygų sprendimais. Nustatytas neigiamas derlingumo efekto poveikis, viršijantis teigiamą ploto efektą. Tolimesnės pasiūlyto modelio modifikacijos būtų neabejotinai naudingos priimant strateginio valdymo sprendimus.

Raktiniai žodžiai: indeksinio išskaidymo analizė, Divisia indeksas, derlius, derlingumas, javai, strateginis valdymas, indeksų metodas, Lietuva.
JEL kodai: C430, Q100, Q150.