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Mathematical approaches for assessment and classification of the European Union member states based on the average yield of vegetables for the period 1961-2014

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Abstract. *The objective of this work is to analyze the statistical data on the average yield of vegetables in the European Union member states for the period 1961 - 2014. The EU countries are classified and grouped through hierarchical cluster analysis based on the average yield of vegetables. A mathematical model for evaluation of the received data is composed through a single-factor analysis of variance (ANOVA). The results show that the countries with the highest yields are Belgium (33.81 t/ha), Austria (29.39 t/ha) and the Netherlands (27.76 t/ha), while the lowest yields are in Bulgaria (4.05 t/ha) and Luxembourg (0.19 t/ha). Dependencies have been identified between the change in the average yields in Bulgaria, Greece and Romania and time. It was found that they were modeled by polynomial regression models of second degree.*

Keywords: hierarchical cluster analysis, mathematical model, vegetables

Introduction

Vegetable farming has been a traditional brunch of plant-growing in our country. The reasons for this are the favorable environmental conditions as well as the experience of our population. After exploring the foreign experience, it has been found that such large-scale studies in the field of average yields of vegetables haven't been carried out (on the one hand – the long period, on the other – all EU member states). There are many studies in the field of agrarian sciences based on mathematical-statistical methods, but they are oriented to more specific objects. Pagluanan and Anical (1995) apply statistical methods to study the yields of several types of vegetables over a five-month period. The study was conducted to determine the effects of organic fertilizers on the growth of different vegetables and to find out which among the different vegetables will give the best yield when applied with organic fertilizers. The study was conducted from October 2009 to February 2010 at ASIST (Abra State Inst. of Sciences and Technology) Main Campus, Lagangilang, Abra (Philippines). The experiment was laid out following a Randomized Complete Block Design. The five different vegetables were tomato, mungbean, cowpea, pepper and eggplant set in each treatment with three blocks.

In another publication (Auwalu et al., 2007) correlation and regression analyses were applied to study data on the growth and yields of vegetable sesame after treatment with nitrogen and phosphorus. It was found that the yield in this case is strongly dependent on the height of the plant, the number of leaves and their index. In 2009, the quantity of arable lands and the average yields of vegetables in the EU countries and in Serbia were analyzed for the period 2003-2007 (Puskaric et al., 2009). The research is based on available data and uses the desk research method. There is no grouping of the EU countries according to statistically proven similarity in the explored indicator or a comparative analysis between them (based on mathematical and statistical methods and relevant criteria).

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The main objectives of the present work could be summarized in the following directions:

- to group the EU countries according to a degree of similarity in the average yields of vegetables from 1961 to 2014;
- to make a comparative assessment based on the given criterion;
- to explore in greater depth and detail the alteration in the average yields in Bulgaria, Romania and Greece through a combination of the following methods: building of graphs, establishing the degree of relation between the output and the year, and presenting the resulting relations in analytical form.

Material and methods

The evaluation and analysis in this work are based on data on the average yields of vegetables in all member states of the European Union for the period 1961-2014. The research is based on data extracted from the relational database FAOSTAT. Microsoft Access provides the possibility to export tables from the corresponding database directly into the medium of MS Excel or SPSS by which the statistical processing is performed (Dimova, 2013).

One of the methods of grouping of the EU countries by indicator "average vegetables yield" for the period 1961-2014, used in the present work, is a hierarchical cluster analysis (Ho, 2013). The method of intergroup connection is used and the criterion of similarity according to which it is realized is the Euclidean distance. It is known that in the method of intergroup connection the distance between two clusters A and B is defined as the average value of nA.nB of a number of distances between nA points from A and nB points from B:

$$D(A,B) = \frac{1}{n_A n_B} \sum_{i=1}^{n_A} \sum_{j=1}^{n_B} d(x_i, x_j) \quad (1)$$

and $d(x_i, x_j) = \sqrt{\sum_{m=1}^{p} (x_{im} - x_{jm})^2}$, $i, j = \overline{1,n}$ (2)

is the ordinary Euclidean distance between two vectors $x_i(x_{i1},x_{i2},...,x_{ip})$ and $x_j(x_{j1},x_{j2},...,x_{jp})$. A dendrogram is built presenting graphically the formed clusters. It was found that the organization of the EU countries in clusters by this method corresponds to the assessment obtained by a single-factor analysis of variance (Genchev et al., 1975; Barov, 1982). Mathematical models were built, using regression analysis, giving the connection in the change in the average yields of vegetables over time. The data processing was performed through the statistical program IBM Statistics SPSS 24 (Abramowitz et al., 2016; Cronk, 2016; Ganeva, 2016).

Results and discussion

The data on the average yield of vegetables in the Member States of the European Union from 1961 to 2014 are processes and analyzed by several mathematical methods. We use hierarchical cluster analysis to organize the countries in groups according to the quantity of the produced output.

Bulgaria, Greece and Romania are countries with similar geographical and climatic features. Therefore, this work studies the change in the average yields of vegetables from 1961 to 2014 in these countries. Mathematical models describing the statistical data were built. The coefficients of correlation and determination of these data were defined. It was found that the dependence of the changes in the average yields on time for these countries is modeled by polynomial regression models of second degree.

As a result of its implementation, the EU Member States were grouped into 8 clusters according to the degree of similarity of the average yields of vegetables from 1961 to 2014, which are depicted on the dendrogram in Figure 1.

Since in the cluster analysis no tests for statistical significance are made, we apply a single-factor analysis of variance (ANOVA). The results show that the countries with the highest yields are Belgium (33.81t/ha), Austria (29.39 t/ha) and the Netherlands (27.76 t/ha), while the lowest yields are in Bulgaria (4.05 t/ha) and Luxembourg (0.19 t/ha).

The assessment of the EU countries in the average yield of vegetables according to their belonging to the respective cluster is presented in Table 1.

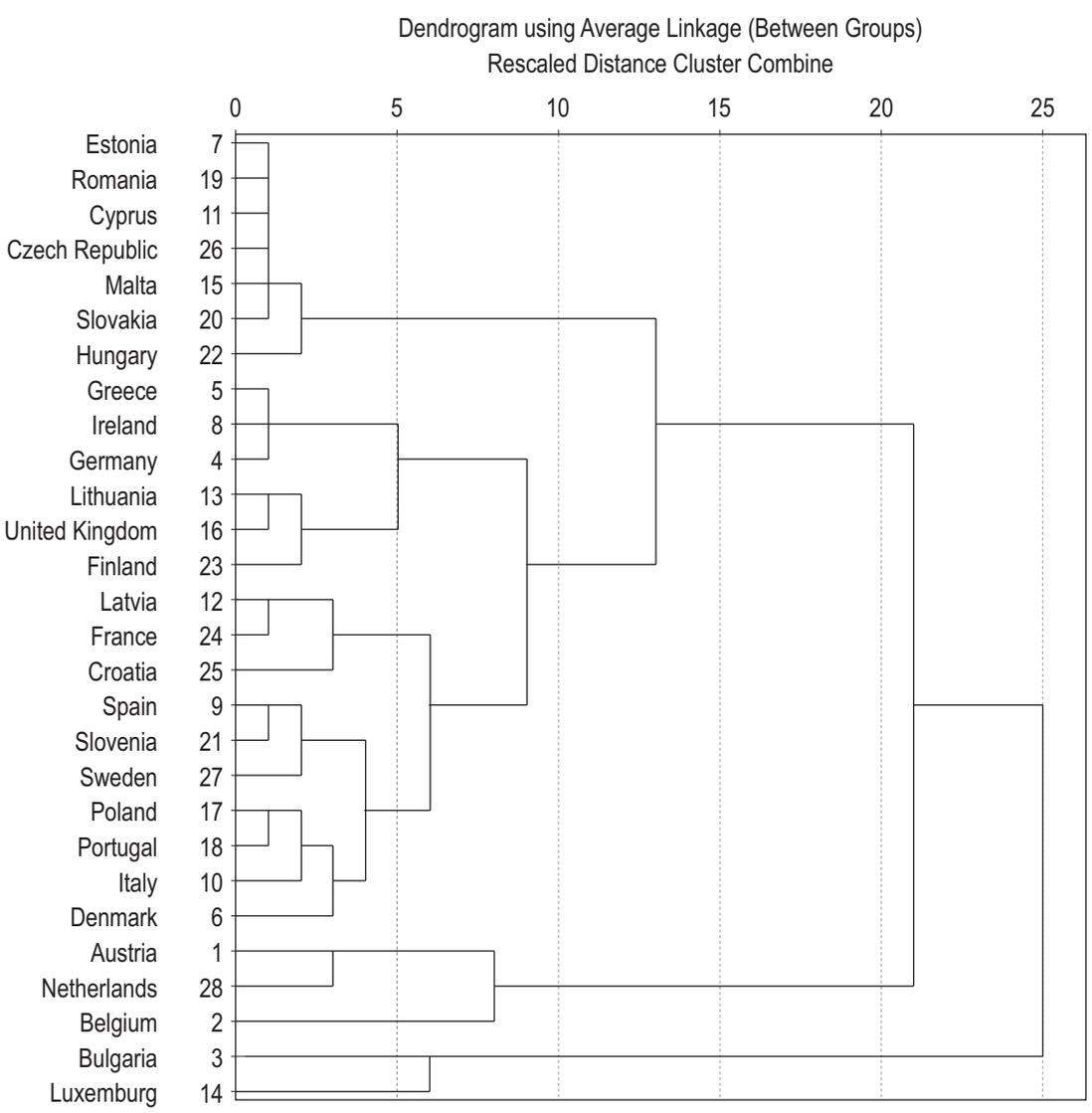

Figure 1. Hierarchical cluster analysis according to the average yield (t/ha) of vegetables for the period 1961-2014

Clusters 5 and 6 include the countries with the highest average yields of vegetables – Austria, the Netherlands and Belgium.

Cluster 2 includes the countries which follow, based on their volume of production, with average yields, statistically different from the average yields of the countries from clusters 5 and 6. The highest yields are in the United Kingdom, Lithuania and Finland. The first two of them, however, have unsustainable production of vegetables, which is evident from the statistical indicator of variation, which is 11.0 and 11.613, respectively. Bulgaria has the lowest average yield of vegetables (4.05 t/ha) and can be viewed as a standalone cluster or can form a generalized cluster together with Luxembourg. These two countries have sustainable production of vegetables. Their indicator of variation is one of the lowest.

Clusters 3 and 4 have higher level of similarity in the average yield and can be considered as a generalized cluster.

According to the results of Levene's test for homogeneity, we can say that the data on the yield of vegetables in the respective countries have equal dispersion, and can be compared according to the selected criteria.

Table 1. Evaluation of the average yields of the EU countries by the method of Duncan, a, b, c, ... – degree of proof at significance level α = 0.05

Cluster No.	Country	Average yield (t/ha)	Standard deviation
1	Estonia	11.44 ^{lm}	4.848
	Cyprus	11.35 ^{lm}	3.571
	Romania	11.44 ^{lm}	3.158
	Slovakia	10.79 ^{lm}	1.726
	Malta	11.69 ^{lm}	1.798
	Czech Republic	11.2 ^{lm}	3.516
	Hungary	10.03 ^{m}	3.786
2	Germany	21.79 ^{efg}	13.008
	Greece	21.52 ^{fg}	5.556
	Ireland	21.5 ^{fg}	2.18
	Lithuania	24.7 ^{de}	11.613
	United Kingdom	25.26 ^{cd}	11
	Finland	23.89 ^{def}	5.43
3	Latvia	15.44 ^{jk}	7.32
	France	15.53 ^{jk}	5.09
	Croatia	14 ^{kl}	4.012
4	Spain	16.96 ^{ijk}	2.851
	Slovenia	16.96 ^{ijk}	3.985
	Sweden	17.63 ^{hij}	3.029
	Poland	18.6 ^{ghij}	6.602
	Portugal	18.6 ^{ghij}	1.988
	Denmark	20.19 ^{gh}	3.14
	Italy	19.3 ^{ghi}	3.441
5	Austria	29.39 ^{b}	6.644
	The Netherlands	27.76 ^{bc}	5.98
6	Belgium	33.81 ^{a}	1.354
7	Bulgaria	4.05 ^{n}	2.109
8	Luxembourg	0.19 ^{o}	0.06

The overall statistical evaluation shows level of significance less than the error α = 0.05, which is enough to consider that the average yields of vegetables in the 28 member states of the EU have statistical differences and that the overall model is statistically significant.

The standard deviation characterizes the average value of scattering around the average yield of the respective production. The high standard deviations of Germany, Lithuania and the United Kingdom are proof of the temporal unsustainability of the quantity of the produced vegetables. The average yields in Luxembourg, Belgium and Slovakia are comparatively more sustainable.

Figure 2 shows graphically the changes in the average yields of vegetables in Greece, Bulgaria and Romania with the purpose of determining the degree of influence of the geographical and climatic characteristics of the region on the studied indicator. It turns out that for the entire period 1961-2014 the production of Greece exceeds that in Romania and Bulgaria. Unfortunately, it appears that our country has the lowest production levels for the entire period, regardless of the ups and downs in the average yields of the other two countries over time.

Two periods can be observed in Greece: the first one covers the period from 1961 to 1975, when there is a clear increase in the average yields, while in the second period – till 2014, there are smooth ups and downs, but as a whole there is a tendency of growth in the production of vegetables.

In Bulgaria, from 1974 to 1995, we have relatively constant yields. From 1995 to 1997 there was a strong growth in production and from 1998 to 1999 – a decline. From 2000 to 2010 the production is relatively stable over time. In 2010 there was a sharp rise in yields, which was unfortunately followed by a sharp decline a year later.

Three periods stand out in the average yields of Romania. The first covers the time from 1961 to 1988 when there are smooth peaks and drops, but as a whole the output is stable. The period from 1989 to 2010 is characterized by strong peaks and decreases in the quantity of the produced vegetables (this fact is also evidenced by the value of the standard deviation from Table 1, showing instability of the yields over time). After 2010, there were again smooth ups and downs.

The statistical data in the present work are modeled by regression equations, giving the dependence of the average yields

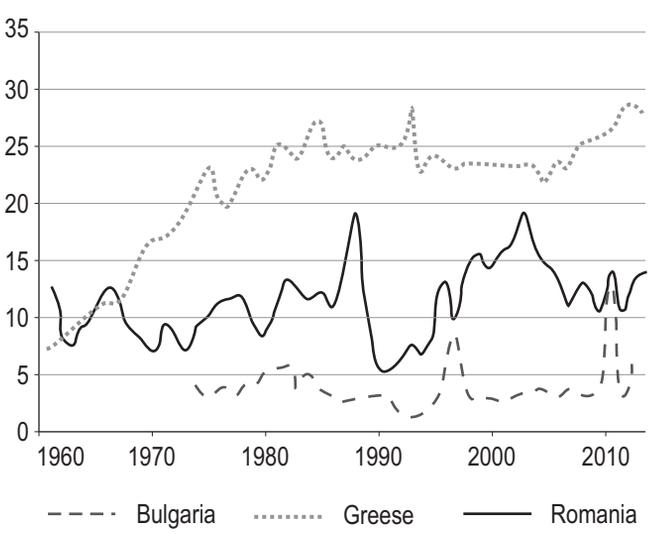

Figure 2. Graphical presentation of the changes in the average yields of vegetables in Greece, Bulgaria and Romania

Table 2. Results from regression analysis of the average yield of vegetables in Bulgaria, Romania and Greece

Country	Regression equation
Bulgaria	$y = 0.0063x^2 – 25.272x + 25174$
Romania	$y = 0.0009x^2 – 3.4483x + 3350.2$
Greece	$y = -0.0118x^2 + 47.145x - 47103$

of vegetables in Bulgaria, Greece and Romania on time. The results of this analysis are shown in Table 2. It has been established that for all three countries, the vegetable yields are modeled by polynomial regression models of second degree.

From the obtained mathematical models and the evaluations of the statistical data, we can conclude that the average yields of vegetables are not dependent on the EU and the support policy that it leads towards farmers. Proof of this are the differences in the yields of Bulgaria and Romania, which joined the EU at the same time, as well as the close yields between Bulgaria and Luxembourg (joined in 1958). On the grounds of these conclusions we can consider that the reasons for the low yield of vegetables in Bulgaria are due to the national policy in this sector rather than to global European policies. The factors that led to this state of vegetable production could be the financing of manufacturers, the provision of markets for the finished products, the transport infrastructure (due to the perishability of the vegetable production), the return of a large part of the agricultural land to the owners, etc.

Conclusion

The mathematical models that are built not only present in analytical form the relation between the average yields of vegetables and the respective year of research. They allow each researcher to predict the alteration of this indicator in the near future. The graphical presentation, in turn, visualizes the flow of the average yields over time. This is another mathematical approach for comparative analysis of the yields between the countries. The countries with the highest average yields of vegetables are Austria, the Netherlands and Belgium, while the lowest yields are in Bulgaria and Luxembourg. The regression analysis has established that for Bulgaria, Greece and Romania data for the vegetable yields are modeled by polynomial regression models of second degree.

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The manuscript should be structured as follows: Title, Names of authors and affiliation address, Abstract, List of keywords, Introduction, Material and methods,Results, Discussion, Conclusion, Acknowledgements (if any), References, Tables, Figures.

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