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CLASSIFICATION OF SPECIALIZED FARMS APPLYING MULTIVARIATE STATISTICAL METHODS

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Abstract

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Classification of specialized farms applying multivariate statistical methods
The paper is aimed at application of advanced multivariate statistical methods when classifying cattle breeding farming enterprises by their economic size. Advantage of the model is its ability to use a few selected indicators compared to the complex methodology of current classification model that requires knowledge of detailed structure of the herd turnover and structure of cultivated crops. Output of the paper is intended to be applied within farm structure research focused on future development of Czech agriculture. As data source, the farming enterprises database for 2014 has been used, from the FADN CZ system. The predictive model proposed exploits knowledge of actual size classes of the farms tested. Outcomes of the linear discriminatory analysis multifactor classification method have supported the chance of filing farming enterprises in the group of Small farms (98 % filed correctly), and the Large and Very Large enterprises (100 % filed correctly). The Medium Size farms have been correctly filed at 58.11 % only. Partial shortages of the process presented have been found when discriminating Medium and Small farms.

Keywords: discriminatory analysis, linear discriminant analysis, classification of farms, economic size, canonical analysis, Farm Accountancy Data Network

INTRODUCTION

Size of farms is a basic quantitative measure when studying their structure. Zimmerman *et al.* (2009) present a comprehensive reading search of the relevant modeling methods aimed at measuring the structure of farms in terms of their size and type of farming. Vrolijk *et al.* (2010) found that, the economic size belongs among important predictors assisting at explaining farm viability, and finding appropriate conclusions for the separate 25 EU Countries. Changes in farm size distribution across the OECD Countries have currently been analyzed within the Network for Farm Level Analysis, at the OECD (2016). Information on farm size is frequently exploited, too, in the agriculture policy analysis. Prášilová *et al.* (2011) consider the subsidy policies as related to size structure of farms. Štolbová and Hlavsa (2008) use comparison of income indicators and LFA (Less-Favoured Areas) payments according to size groups based on eligible land. Concerning production efficiency analysis, Mugera and Langemeier (2011) proved that, the technical efficiency scores vary by farm size. Čechura (2014) identified the 1,000 hectares limit distinguishing Czech farms operating in LFA, having high or low technical efficiency.

Cattle breeding and fattening has been a traditional but currently marginal livestock production branch. As the Farm Structure Survey (FSS, Eurostat 2005, 2013) outcomes show it, the importance of aiming at cattle breeding and fattening within Czech farming is increasing. The FSS outcomes say that, during 2005 to 2013 the share of farms specialized in cattle breeding and fattening has been doubled, according to selected indicators, as compared with results of farming enterprises of all production branches.

The share of farms specialized in cattle breeding and fattening in the Czech Republic has grown to 13.2 %, the livestock units' share to 10.5 % and the share of Annual Working Units (AWU) to 7.4 %. Grouping of size groups in a selected production branch, offering a more detailed analysis of the farms under study, is being applied, e.g.,by MacDonald *et al.* (2013).

The paper is offering a model construction for classification of farms specialized in cattle breeding and fattening into classes by size. The procedure offered makes it possible to estimate the economic size of farms under a change of the determinants (land, numbers of head of cattle). The solution makes it possible to predict the economic size type of the farm without knowledge of the Standard Output value and other detailed data on production of the farm, that are part of the harmonized computation of economic size by the Community Typology for Agricultural Holdings in the European Union.

Standard Output (SO) is an economic criterion, established by European Union for typology calculation, enabling agricultural holdings' comparison among diverse systems and structures of the EU member states agriculture. Standard Output coefficients correspond to a production period of 12 months. SO is an average value of gross agricultural production at farm-gate price in a given region calculated over five year period for each agricultural characteristic (crops, livestock categories and agricultural products). Total of all idividual SO values on farm is classified into one of the 14 economic size classes. SO values are updated with new farm structure survey. As it is prescribed by the EU (2008) the determination of the SO values requires knowledge of the agricultural products prices therefore it is not applicable for the economic size class estimation in the years to come. With the knowledge of this weak point this work has been launched to provide the way of economic size class estimation within future agriculture structure projection. As it has been mentioned already, the knowledge of the farm economic size an important classification measure and its estimates for the coming years can be sucessfuly embodied in the economic results forcast analysis.

A classification model has been designed in the study, according to which the farms could be grouped into four size groups. Prediction of filing a farm into an economic size group facilitates a more suitable comparison of its results with information resources such as, e.g., the Eurostat or the Farm Accountancy Data Network (FADN) and it is assumed to be used for further analysis of agriculture. Discriminant analysis has been applied in grouping of the farms by their economic size and prediction model has been designed using a multivariate classification method. It will apply the knowledge of inclusion of separate farms, specialized in cattle breeding and fattening, into groups by their economic sizes.

MATERIALS AND METHODS

Data from the FADN database have been applied in processing of the paper. FADN collects data on economic and production development in the agricultural sector using a special sampling survey based on a representative sample of farms. Data obtained have been applied on a long-term basis in establishing levels of incomes in agriculture (Hanibal *et al.*, 2016), in preparation and assessment of agricultural policy measures (DEFRA, 2014; European Court of Auditors, 2016), in delimitation of LFA (Štolbová, Hlavsa, 2008) and for many other analytical purposes.

FADN survey covers enterprises the economic size of which exceeds the prescribed minimal economic threshold. For the Czech Republic this is established by European Commission ordinance at 8,000 Euro of Standard Output (European Commission, 2008). The three dimensions at which data representativity is to be secured, include Region (CZ), Economic size (14 classes) and Production farm type (21 principal types). This ordinance facilitates covering of the most significant part of farming activities in each EU Member State. In order to satisfy FADN survey the same rules of accountancy have to be kept to, fulfilment of which makes it possible to create such unique fully harmonized microeconomic database (European Commission, 2015).

Within FADN survey scope individual data are collected to be entered in the questionnaires. As the basic database contains vast amount of information derived indicators so-called FADN standard results are then computed to be used for the subsequent analytical work. List of standard results contains around 190 variables divided into several parts describing farm structure and yields, agricultural outputs, costs, subsidies, income from agricultural business, balance sheet and section of financial indicators. Computation of these variables has been harmonized by the European Commission ensuring comparability of the results among the EU member states (European Commission, 2012). A selection of these indicators focused on the farm structure has been employed in formation of discriminators in the paper presented.

Separate FADN survey outcomes have been extrapolated using weighting system based on the EU method, in order to obtain fully represenatative results aggregated for the whole of the Czech Republic. Statistical representativity of the FADN CZ sample has been confirmed repeatedly (Prášilová, Zeipelt, 2011; Prášilová *et al.*, 2013). It follows from the wording given above that, data on agricultural enterprises are representative when classified by economic size and production focus type.

In multivariate data processing the discriminatory analysis (DA) has been applied, belonging among classification methods. This method has been used, too, e.g., when trying to predict a firm's economic development (Sousedíková *et al.*, 2012). It is a method examining relationships between one dependent variable forming classes and several independent variables serving information on objects. Using a predictive model the discriminatory analysis facilitates finding an optimal (discriminating) function for classifying separate objects in classes according to the rate of maximal similarity.

A simpler method, when $f_1(x)$, $f_2(x)$, $f_3(x)$ and $f_4(x)$ differ by mean values only, is called linear discriminatory analysis (Meloun, Militký, 2004). Linear discriminating function can be generaly expressed as

$$L_j(x) = a_{1j}x_1 + a_{2j}x_2 + a_{3j}x_3 + a_{4j}x_4 + + a_{5j}x_5 + \ldots + a_{nj}x_n + a_{0j}, \quad (1)$$

where n is the number of discriminators, j is the number of classes and $x_1, x_2, x_3, x_4, x_5, \ldots, x_n$ are the standardized discriminator values.

The coefficients a_{ij} of the discriminating function are selected such that a priori probability of diagnostic classes and a loss caused by wrong classification are considered.

Linear discriminatory function is subject to several assumptions. The variables are of quantitative nature and are normally distributed in each class, the correlation structures in classes are similar (Hendl, 2009).

Selection of variables included in the analysis has been performed using the Wilks' λ criterion. Excluded were those reducing the Wilks' λ. This way a more suitable model can be obtained. The Wilks' criterion describes the degree of interlining density and it can be expressed as

$$\lambda = \prod_{i=1}^{m} \frac{1}{1+\lambda_i}, \quad (2)$$

where λ_i is the i-th biggest eigenvalue corresponding to the eigenvector, and m is the minimum of the two numbers, $n - 1$ and m, where n corresponds to the number of classes (Meloun, Militký, 2006).

For graphical representation of results multivariate canonical analysis can be employed in the following, whereby canonical variables are created capable of being drawn in the graph. Canonical analysis is focused in determining the relationships between groups of objects described by some mutual characteristics. Statistical significance test of the discriminant functions found is done first by simple and standardized coefficients for the canonical variables computed after. By means of drawing the canonical score into the dot diagram the filing of objects in groups is then represented graphically.

Number of canonical discriminant functions (so called canonical roots) is given by the number of groups less one or 3 in the case of higer number of groups then 4. First root gives the largest discrimination between centroids of the groups, second root expresses smaller discrimination, third root shows third largest dicrimination etc.

Probability of filing in a group for the separate cases has been found using the Mahalanobis distance and the posterior classification probability. Posterior probabilities are combination of a priori probabilities and Mahalanobis distances of objects from the group centroids.

Mahalanobis distance between two groups of objects is calculated as

$$D_{1,2}^2 = (n-g)\sum_{i=1}^{m}\sum_{j=1}^{m} w_{i,j}(\bar{x}_{i1} - \bar{x}_{i2})(\bar{x}_{j1} - \bar{x}_{j2}), \quad (3)$$

where m means number of discriminants in the model, $w_{i,j}$ is an element of the inverse covariance matrix and $\bar{x}_{i1}$ is average of the i-th discriminant in the class 1 (Meloun, Militký, 2006).

Data from farms specialized in rearing and fattening cattle have been applied in the research. The fourteen economic classes have been combined in the four groups following :

G_1:1 – Small (8,000–50,000 Euro of Standard Output)

G_2:2 – Medium (50,000–500,000 Euro of Standard Output)

G_3:3 – Large (500,000–1,000,000 Euro of Standard Output)

G_4:4 – Very Large (higher than 1,000,000 Euro of Standard Output)

Using the EU Farm Typology method (since 2010 modified computation has been applied, accompanying the Common Agricultural Policy's developing needs), in this paper, too, similar as in the international comparison of economic outcomes (Hanibal *et al.*, 2009) a combination of economic sizes into four similar size groups has been provided. Andersen *et al.*, (2006) offers an expanded typology where a combination of economic sizes of farms into three groups is being considered.

File consisting of the total of the agricultural enerprises $n = 185$ was used to build the model. The number of objects in each group is varying. Unequal numbers of farms in size groups in the sample are a reflection of the true distribution in the population. In the "Small" group there are 102 farms, in the group "Medium" 74 objects, in the group "Large" 7 objects and in the "Very Large" group there are 2 farms.

The model was validated using a different set of data containing 169 farms from the accounting year 2015 of the same database (93 farms in the group of small farms, 72 farms in the group of medium farms and 4 holdings in the group of large enterprises) where "Very Large " group was not represented.

Eight discriminators related directly to farm size are then employed in order to describe farms for the purpose:

- Total utilized agricultural area – UAA
- Forage crops area – FCA
- Number of dairy cows - DC
- Other cattle in livestock units – OC

- Stocking density of ruminant grazing livestock – SD
- Share of other gainful activities in % – OGA
- Milk yield in kgs/dairy cow/year – MY
- Family working unit – FWU

The data from FADN CZ database for the 2014 accounting year have been exploited in the design of the model. Data file consisting of cattle breeding and fattening farms gathered from FADN database for 2015 accounting year was used for final model validation. STATISTICA 12 programme has been used in statistical processing.

RESULTS AND DISCUSSION

Statement of significant variables

According to the EU international classification method, computation of the economic size of enterprise is derived from the kind of crop grown, the extent of its area cultivated, the kind and category of animals bred and the number of these (expressed in livestock units). Eight basic features (variables) were introduced in the analysis first. Choice of the discriminators was then reduced to five by means of a change of Wilks' λ criterion, during the discriminatory analysis.

Three variables included into the analysis at the begining (Number of dairy cows, Stocking density of ruminant grazing livestock and Share of other gainful activities in %) raised the Wilks' λ. During their step-by-step elimination the λ fell down to 0.09345 value. The exclusion of any other features of the five remaining discriminators ended in raising the Wilks' λ again. A low result of l indicates that the average values of the groups are very different. Therefore, for the continued analysis the five variables following have been chosen:

Total utilized agricultural area (UAA), Forage crops area (FCA), Other cattle in livestock units (OC), Milk yield in kgs/dairy cow (MY) and Family working unit (FWU).

Discriminatory analysis results confirm that all discriminators chosen are statistically significant. Result of the total Wilks' lambda (0.093) shows good overall quality of the model including all discriminants. Wilks' lambda given for each variable within the range from 0.102 for Other cattle to 0.229 for UAA describes total quality of the model while the variable given is excluded. Partial lambda, expressing contribution of the given variable to the discrimination, resulted in the scale from 0.408 for UAA to 0.913 for Other cattle.

Classification of units

The classification matrix (Tab. I) shows percentages of correctly and wrongly classified enterprises. The best filing has been done with the Large and Very Large ones. A comparatively good estimate of filing has been reached with the Small farms in the first group. On the other hand, the worst results have been obtained with the Medium sized enterprises where 58.11 % have been correctly classified only. Based on these outcomes it can be stated, too, that the model offered is acceptable for grouping of enterprises in 4 size groups with an 82.16 % total likelihood of correct classification. Data set devoted to model design, as described above, was used for this computation.

The model is set up of four classification functions, each for one group from the group of Small farms to Very large farms, by the use of which the classification score can be found for the new objects considered:

$$L_1(x) = -0.00259x_1 + 0.00665x_2 + 0.00027x_3 + 1.77664x_4 + 0.00572x_5 - 2.18718, \quad (4)$$

$$L_2(x) = -0.01234x_1 + 0.02182x_2 + 0.00065x_3 + 2.59531x_4 + 0.01978x_5 - 6.30445, \quad (5)$$

$$L_3(x) = -0.0572x_1 + 0.0514x_2 + 0.0025x_3 + 2.8246x_4 + 0.0797x_5 - 36.3176, \quad (6)$$

$$L_4(x) = -0.437x_1 + 0.061x_2 + 0.002x_3 + 3.762x_4 + 0.453x_5 - 154.452, \quad (7)$$

where, x_1 is Forage crops area, x_2 is Other cattle in livestock units, x_3 is Milk yield in kgs/dairy cow, x_4 is Family working unit and x_5 is Total utilized agricultural area.

The classsification functions (4–7) were used for the following verification of the model. Equations were calculated for all farms in the file considered as a validation set of data. The holdings were classified, as estimated economic size was defined, based on the highest result of the equations referring

I: *Classification matrix*

Groups	ROWS: observed classification Columns: estimated classification				
	% correct	G_1:1 (Small) p = 0.55135	G_2:2 (Medium) p = 0.40000	G_3:3 (Large) p = 0.03784	G_4:4 (Very Large) p = 0.01081
G_1:1 (small)	**98.0392**	100	2	0	0
G_2:2 (medium)	58.1081	28	43	3	0
G_3:3 (large)	100.0000	0	0	7	0
G_4:4 (very large)	100.0000	0	0	0	2
Total	82.1622	128	45	10	2

Source: Own survey

to the assigned size group. From the results it can be concluded that 98.9 % of Small farms, 56.9 % of Medium farms and 100 % of Large farms were correctly classified. The group of Very large farms was not in the validation test represented due to no farm in the set of data used for validation. Results of the model validation clearly confirmed good quality of the model designed with the 81 % of the total probable success of correct classification.

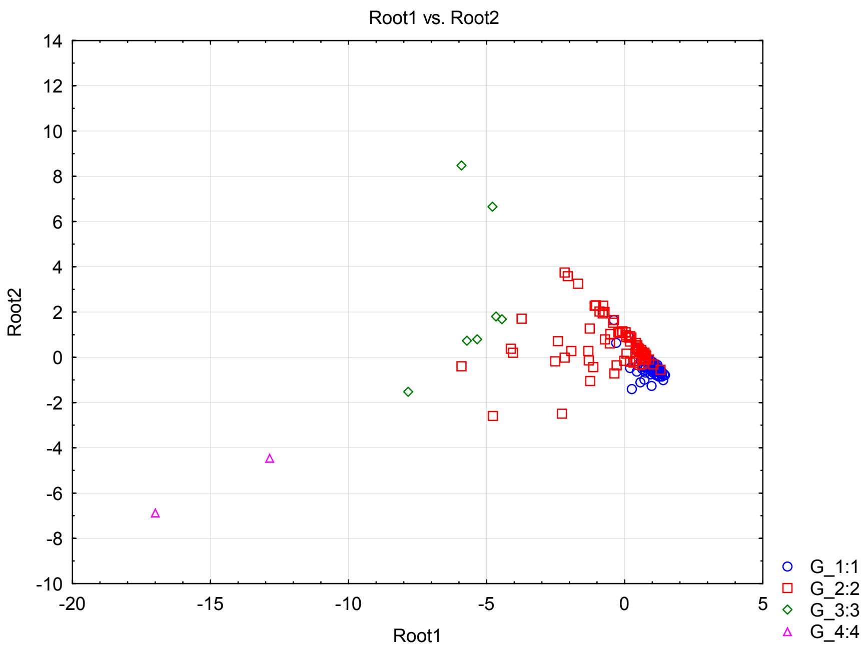
Canonical analysis

Significant variables in the FADN sample of farming enterprises facilitated forming of three discrimination functions the statistical significance of which has been tested. The c^2 test confirms statistical significance of all detected functions (roots) because the calculated significance levels (0.000, 0.000, 0.003) is less then $\alpha = 0.05$.

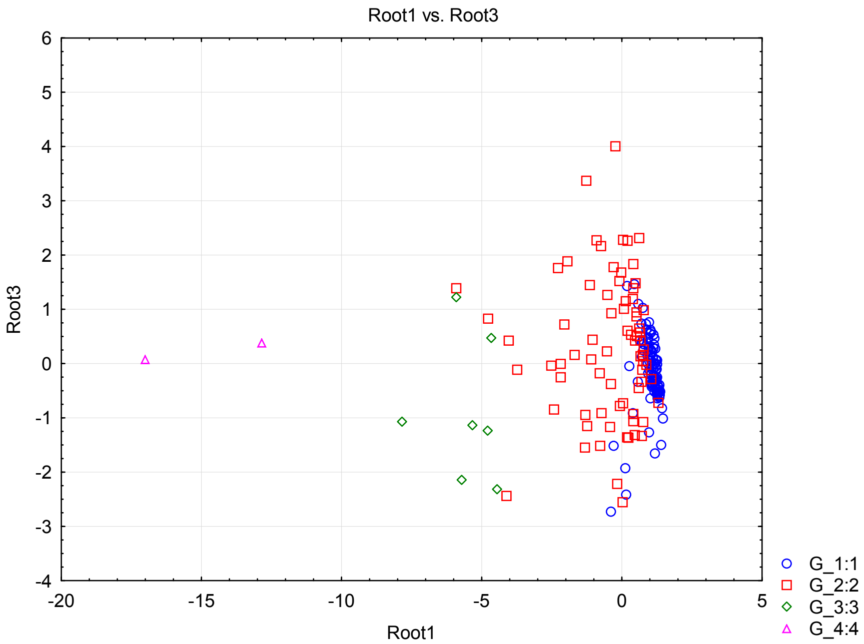
Calculation of simple and standardized coefficients evaluated for canonical variables confirmed the conclusion that all the discrimination functions have been considered for further processing. The highest weight of standardized coefficient has been reached for the Forage Crops Area and the Utilized Agricultural Area indicators in the root 1 and 2 with the opposite contribution. The Other Cattle and the Milk Yield have analogous weights within all the three roots but only for the root 2 they have a positive contribution. The Family Working Unit has the lowest impact from all discriminators with the highest weight in the second root and a lower one in the third root. Family Working Unit helps to discriminate Small farms from the Medium ones. Root 1 allows distinquishing of the classes of economic size based mainly on the area and root 2 is influenced apart from area also by livestock on the farm.

Results of canonical variable averages refer to the fact that, the first function clearly distinguishes Very large enterprises from the others. Distinction of Small and Medium farms is supported by the first and second functions, nevertheless, the distinction of these is more inclined to faultiness already. The third function assists at the distinction of Medium sized farms.

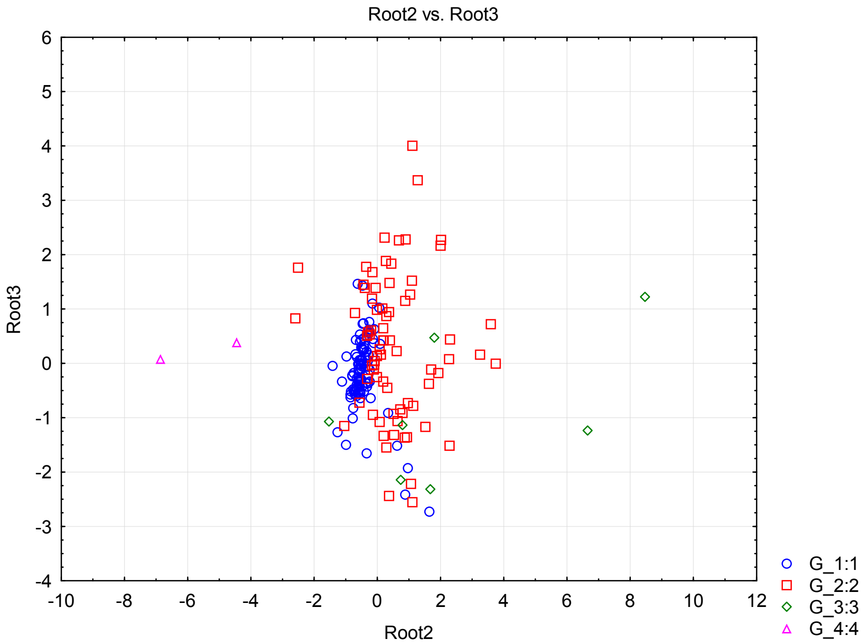
Last but not least, the unstandardized canonical score has been evaluated for all the roots, on basis of which the enterprises have been classified into classes. Canonical score has been applied in construction of scatter charts (Fig. 1–3) demonstrating the distribution of separate farming enterprises by size groups. The diagrams 1–3 show a comparatively high differentness of the Large and Very Large (Groups 3, 4) enterprises, facilitating good classification, and they show, too, problems with classifying the Small and Medium sized farms (Groups 1, 2) the canonical score of which in many cases crosses the borders. The first discriminant function (root 1) pointed out the effect of the farm size as it clearly distinguishes Very large enterprises (Group 4) on the left, crossing Large holdings (Group 3) with Medium farms (Group 2) and ending on the right side of the chart displaying Small farms (Group 1). Distinction of Small and Medium farms is supported by the first and second discriminant functions, nevertheless, the distinction of these is more inclined to faultiness already. Second discriminant function (root 2) also helps to detect two outlier subjects in the group of Large holdings. The third discriminant function (root 3) assists at the distinction of Medium sized farms, which as it is shown in the diagram 2 and diagram 3 is problematic due to larger variability extended into group of Small farms.



1: *Canonical score for the roots 1 and 2*



2: *Canonical score for the roots 1 and 3*



3: *Canonical score for the roots 2 and 3*

DISCUSSION

The classification problem has been dealt with in complex by Van Der Ploeg *et al.* (2009), who identified a broad scale of determinants, inclusive of the farm size. Significance of defining and exploiting the knowledge of farm size was expressed already by Feder (1985) in his work or by Barrett (1996). E.g., Feder (1985) proved the independence of farm crop yields data on the farm size. The size of farming enterprises falls among important determinants when studying structural changes of agriculture. E.g., MacDonald, J. M. *et al.* (2013) discovered a trend of farming enterprises enlargement in the USA.

European typology of farming enterprises looks at the farm size not only in view of the acreage of land cultivated which is frequently applied in farm size measurement (MacDonald 2013; Bartolini, Viaggi, 2013), but also as at a complex information taking into account varying demands of separate agricultural production types inclusive of livestock breeding enterprises. This idea has been considered when preparing the predictive model presented which facilitates filing the farming enterprises specialized in grazing livestock in classes by economic size without knowledge of the individual crops cultivated area and number of livestock in the livestock categories aimed at the future projection of agricultural development.

The paper presented is referring to capabilities of the multivariate statistical methods in filing of farming enterprises in classes by the economic size of these as described by the five significant features. The outcomes demonstrate the chance of successful filing of the Very large, Large and Small enterprises. Insecure outcomes have been obtained when filing the Medium sized enterprises showing a tendency to be filed in the Small farms group.

CONCLUSION

The paper is demonstrating predictive capability of the multivariate statistical methods when classifying 185 farming enterprises specialized in grazing livestock breeding in four groups by their economic size. Applying the results of linear discriminatory analysis it has been found that, the classification of Very Large and Large enterprises was done with 100 % reliability. Filing of Small sized farms has presented an acceptable error rate when 98 % of farms were filed correctly. The Medium sized enterprises were correctly filed at 58 % only. When processing data on farms of this type we have to take into account a higher likelihood of wrong filing of the Small sized farms, especially. It could be probably recommended to merge group of Small and Medium size farms together to receive more accurate results while reliable division of agricultural holdings into the economic size groups is requested. Altogether, 82 % of enterprises have been filed correctly within the model building.
Validation of the model has been done using a different set of data with an equally good result of 81 % likehood of the correctly classified holdings. The solution demonstrates further chances of statistical methods' application in the area of structural changes in agriculture. The model is designed to be incorporated into the analysis of future development in cattle breeding and fattening area. The purpose of the model usage is to support forecasting of the economic course of agriculture holdings and studies of the farms' future behaviour.

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