Methodology for Assessing the Size and Liquidation of the Outer Patchwork of Land

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Abstract. A patchwork of land ownership is one of the factors that exert a negative influence on both the organization and the level of agricultural production. Excessive land fragmentation decreases the intensity of agricultural practices and increases production costs, thus leading to a continuous reduction in income. In many areas of Poland, over the years, fields have been divided into smaller and smaller parcels, which, along with the mass migration of people to towns and abroad, resulted in a faulty land ownership structure. Nowadays, it is recommended that measures be taken to eliminate both internal and external patchworks of farmland. Two such agricultural land management measures are land consolidation and land exchange. Rural areas in Poland require profound structural changes related to agricultural production, the size of agricultural holdings, the distribution of farmland in an agricultural holding, as well as demographic, spatial and institutional structure. Land consolidation and land exchange not only result in improved living and working conditions for farmers, but also contribute to enhancing the environmental and cultural assets of a village. The study allowed conducted using checkerboard matrix tables which allow one to determine the share of farmland owned by local and out-of-village non-residents. Research based on data from the estate cadastre. The research used information on the number of land owners, the number of parcels of land, the area of these parcels. The study computed the distance between 34 villages located in Slawno municipality, Opoczno County, Lodz voivodeship. An approach like this allows one to establish a program of exchange of land between these two groups of owners and to eliminate the problematic patchwork of land ownership through land exchange and consolidation.

1. Introduction

The existence of a land patchwork is a phenomenon harmful for economy, manifesting itself in reduced productivity due to loss of time intended for getting to parcels of land scattered on large spaces and on walk from one parcel to another. As a result, transport costs, and therefore costs of the whole agricultural production, are rising. In addition, it hinders the use of proper rotation of the crop and forces the irrational use of land [15].

Land ownership patchwork is divided due to administrative boundaries, into the internal patchwork (existing inside the village) and the external one. Outdoor chessboard can be found between villages, communes, counties, voivodships, and even between states. As an example, let us use the patchwork
of land between Poland and Slovakia, Poland and the Czech Republic, which came into being during the partitions, when there was no border between them [3]. Rabczuk [16] defined the owners of land in the patchwork as non-resident owners. The concept was clarified by Noga [11].

The owners of land in the outer patchwork can be described as non-resident local and external owners due to their different nature. The owners who own their land outside the examined village will be named local non-resident owners. On the other hand, external non-residential owners are those who have their land in the studied village and live in other localities [7], [18].

In the research conducted so far, the method of chessboard tables developed by Noga was used, and was applied in his many studies. [11], [12], [13], [14]. The use of chessboard type tables enables creation any degree of matrix for one or several villages or communes depending on the territorial coverage of occurrence of land in the patchwork. To obtain a matrix of information, it is first necessary to determine the area to be analyzed. Then collect the relevant data from the land registers. For each of the selected information, a separate matrix is prepared. The created matrices are arranged so, that the largest values are placed along the diagonal, what makes possible to visualise of the areas of concentration of the land patchwork. The method applied by Noga can be compared to the graphical method of cluster analysis, and in particular to Czekanowski's method [1], [2].

Taxonomic methods are used in many areas, especially in social and economic sciences research. Within taxonomy two groups of methods are distinguished: clustering methods, or clustering analysis - to isolate clusters of objects similar in many respects, and grading or sorting methods that are used to create a ranking of objects because of their features. Methods from the group mentioned as the second have been applied to create the rankings of the urgency of the land consolidation works, also in the area used in this publication, as an example [8], [9].

Cluster analysis methods group objects in terms of similarity analyzed on the basis of the information on their features. The basis for the analysis is a symmetric matrix of the objects distances from each other. The distance matrix includes measures of object similarity expressed as the distances between sets of characteristic features in multidimensional space. In practice, at least several types of distance measures are used [10]. The basic classification distinguishes between hierarchical and non-hierarchical methods. In hierarchical methods, the levels on which individual objects are clustered are separated. And for non-hierarchical methods, the order of clustering is not taken into account. Objects that are in one cluster do not necessarily have to stay together. The objects can move from one cluster to another [4]. Czekanowski's method can in principle be classified as non-hierarchical, but it has the advantage over them that the number of clusters does not need to be predefined. In addition, it provides a more clear graphical presentation of results than dendrograms in hierarchical methods.

In this publication, the authors propose some modification and development of the Noga's chessboard matrices basing on taxonomic methods and Czekanowski's diagram for making the multidimensional analysis. The proposed concept will be discussed on the example of the Sławno municipality in the Opoczno district, in which there are 34 registry precincts.

2. Proposal of the method of the areas of concentration of the outer land patchwork clustering

In cluster analysis the input data are in the form of an array containing in the rows the values of the individual features corresponding to the selected objects. The number of rows corresponds to the number of objects being analyzed, and the number of columns to the number of features that characterize them. The first step is to create the distance matrix of the objects according to the distance meter used. The smaller the distance the objects are more similar to each other and vice versa. Therefore, sometimes this matrix is called the matrix of similarity. It is a symmetric matrix, containing zeros on the main diagonal (the distance from the object itself is zero). This matrix is further the subject to cluster analysis according to the selected algorithm.

In the Noga approach, initial data with numerical values of one selected land feature in the examined area are included in a square matrix of size corresponding to the number of objects. Due to the nature of the problem in question the values contained in the matrix refer directly to the
relationship between the objects studied and express their mutual dependence on each other in terms of the analyzed feature. In the given example, four such matrices were used (Figure 1) expressing respectively:

A. – percentage of the number of non-resident registry units among the all registry units of natural persons,
B. – percentage of non-resident owners plots among the number of all plots of private land owners within the precinct,
C. – percentage of plots of non-resident land owners in the area of individual farms land,
D. – distances of individual villages from each other.

\[
\mathbf{W} = \alpha_{ij} \cdot b_{ij} \cdot c_{ij} \cdot \frac{1}{a_{ij}}
\]  

This is an approach similar to Kolman's proposal [Kolman 1973, Juran, Gryna 1974]. The product form of the formula (1) makes it sufficient that one of the parameters is zero, and then regardless of the remaining values, the index will be zero. In such situation, there will be no dependence for a given pair in the surveyed precincts. The last of the attributes (included in the matrix D) is a destymulant, hence its inverse. Multiplication of features results in a sharper index differentiation and a stronger distinction between those pairs of registry precincts, for which the difference in respect to the non-resident owners is greatest, and the patchwork of the land the most unfavorable.

To create a Czekanowski diagram, the similarity matrix should be symmetric. So our matrix of dependencies \( \mathbf{Z} = [z_{ij}] \) will have the following form:

\[
\mathbf{Z} = \mathbf{W} + \mathbf{W}^T
\]  

\( \mathbf{Z} \) is a symmetric matrix with zero values on the main diagonal. Specific matrix cells lying outside the main diagonal reflect the mutual relation of a given pair of villages in terms of analyzed features. The matrix \( \mathbf{Z} \) is the starting point for the Czekanowski’s method. In the next step, the distance meters included in this matrix are divided into object similarity classes (here, they are interdependencies of objects). Particular classes of object similarity are assigned the corresponding graphic symbols, receiving an unordered Czekanowski’s diagram. In this example objects are divided into 5 classes of
similarity in such a way that the range of index values from the Z dependency matrix for each lower dependency class was of an order of magnitude smaller than the range for the higher dependency class. Empty fields in the diagram indicate lack of connection between the precincts. The percentage quantitative distribution of the classes together with the corresponding graphical symbols and the scale of the objects' interdependence in each class is shown on Figure 2.

![Figure 2. Division of objects into classes (intervals) of similarity](image)

The arrangement of objects in clusters was done by changing the order of the rows and the corresponding columns in the diagram so that the graphical symbols representing the possible largest interdependencies center along the main diagonal, moving away from the main diagonal, graphical symbols corresponding to the declining relationships appear.

The arrangement of the diagram was carried out according to the algorithm that included the optimization function proposed by Sołtysiak [Sołtysiak, Jaskulski 1999]. The final result is a graphical image of the clusters that is subject to further visual evaluation, Table 1.

3. Results and discussions
The applied method, based on the dependency matrix and the Czekanowski’s diagram, allowed determining the intensification of the phenomenon of dispersion of land of individual farms in the villages of the Sławno municipality. An analysis of the arranged diagram shows that in the studied commune there are 8 clusters of villages heavily interdependent on the percentage share in terms of the number of registration units, registry parcels and their areas as well as the distance between villages (Table 2). It can also be noted that Sławno is the village with the most unfavorable patchwork of non-resident owners land among all analyzed areas. The line corresponding to this village contains the highest number of symbols representing the high and medium level of interdependence with other villages in the commune.
Table 1. Matrix of a patchwork of land in the villages of the Sławno commune

| Village       | A | B | C | D | E | F | G | H | I | J |
|---------------|---|---|---|---|---|---|---|---|---|---|
| Bratków      | * | * | * | * | * | * | * | * | * | * |
| Grudziąt Kolonia | * | * | * | * | * | * | * | * | * | * |
| Celestynyów   | * | * | * | * | * | * | * | * | * | * |
| Grudziąt Las  | * | * | * | * | * | * | * | * | * | * |
| Szydłowiec    | * | * | * | * | * | * | * | * | * | * |
| Grąbówek      | * | * | * | * | * | * | * | * | * | * |
| Przymorze Wola | * | * | * | * | * | * | * | * | * | * |
| Ulemał        | * | * | * | * | * | * | * | * | * | * |
| Antonówka     | * | * | * | * | * | * | * | * | * | * |
| Kunice        | * | * | * | * | * | * | * | * | * | * |
| Gawrony       | * | * | * | * | * | * | * | * | * | * |
| Łudziów       | * | * | * | * | * | * | * | * | * | * |
| Ostrów         | * | * | * | * | * | * | * | * | * | * |
| Antonów       | * | * | * | * | * | * | * | * | * | * |
| Dąbrowska      | * | * | * | * | * | * | * | * | * | * |
| Trojanów      | * | * | * | * | * | * | * | * | * | * |
| Kamień         | * | * | * | * | * | * | * | * | * | * |
| Kamień Odrzańc | * | * | * | * | * | * | * | * | * | * |
| Koźmin        | * | * | * | * | * | * | * | * | * | * |
| Piotrowy      | * | * | * | * | * | * | * | * | * | * |
| Zachowiceł    | * | * | * | * | * | * | * | * | * | * |
| Olszowice      | * | * | * | * | * | * | * | * | * | * |
| Sęgno Radonia  | * | * | * | * | * | * | * | * | * | * |
| Wygnańców     | * | * | * | * | * | * | * | * | * | * |
| Sławno Kolonia | * | * | * | * | * | * | * | * | * | * |
| Sławno        | * | * | * | * | * | * | * | * | * | * |
| Owałów        | * | * | * | * | * | * | * | * | * | * |
| Jędrzejów     | * | * | * | * | * | * | * | * | * | * |
| Zachowiceł-Kolonia | * | * | * | * | * | * | * | * | * | * |
| Tomaszkowicek | * | * | * | * | * | * | * | * | * | * |
| Wieceńcow    | * | * | * | * | * | * | * | * | * | * |
| Janów Pały    | * | * | * | * | * | * | * | * | * | * |
| Dąbrowska      | * | * | * | * | * | * | * | * | * | * |
| Olszowice      | * | * | * | * | * | * | * | * | * | * |

In the studied area, the most influential cluster of villages consists of 5 villages located in the western part of the commune. This cluster consists of villages: Olszowice, Sepno Radonia, Wygnańców, Sławno Kolonia and Sławno. The next 4 clusters consist of three registry precincts, while the next 3 clusters consist of two villages. Spatial picture of villages clusters illustrates Figure 3.

Based on the drawn up diagram, it is possible to determine the amount of land area. It should be closer by exchanging the land of the inhabitants of the examined villages (Table 1). According to the research conducted in the Sławno municipality there are regularities of clusters of localities in the immediate vicinity.

The obtained results of villages clusters in terms of the dispersion of land of individual farms correlated with the results of the studies described in the works [Leń, Mika 2016; Leń et al. 2016], where independently developed rankings of urgency of undertaking land consolidation and exchange works have been developed. To elaborate the rankings, the features characterizing the studied villages in terms of their structure, usage, demographic conditions, land fragmentation of individual farms and parcels without access to roads were used. The scope of this information enabled the creation of two independent rankings that enabled determination of the hierarchy of land consolidation works. The results of these studies have made possible to indicate those areas where the defective spatial structure is the most unfavourable. Supplementing these rankings with information on the dispersion of land in the studied commune will allow to indicate those villages where the land consolidation should be carried out simultaneously, what will enable the achievement of even better integration effects by eliminating a faulty land patchwork. Table 2 presents the ranking of the urgency of the land consolidation works, in which the indicated village clusters were also read out from the diagram.
**Figure 3.** Spatial image of clusters of villages in Sławno commune

**Table 2.** The Hellwig’s and ZUM method ranking, [8], [9]

| Ranking position | According to Hellwig’s synthetic measure | According to ZUM synthetic measure | Ranking position | According to Hellwig’s synthetic measure | According to ZUM synthetic measure |
|------------------|----------------------------------------|-----------------------------------|------------------|----------------------------------------|-----------------------------------|
| 1                | Gawrony                                | Gawrony                           | 18               | Unewel                                 | Wincentynów                       |
| 2                | Kunice                                 | Janków Psary                      | 19               | Szadkowice                             | Dąbrówka                          |
| 3                | Kolonia Zachorzów                      | Kunice                            | 20               | Dąbrówka                              | Olszowiec                         |
| 4                | Janków Psary                          | Grążowice                         | 21               | Grudzień Las                          | Bratków                           |
| 5                | Prymusowa Wola                        | Szadkowice                        | 22               | Bratków                               | Wygnanów                          |
| 6                | Zachorzów                             | Kolonia Zachorzów                 | 23               | Wincentów                             | Sławno Kolonia                    |
| 7                | Antoniówka                            | Ostrożna                          | 24               | Wygnanów                              | Grudzień Kolonia                  |
| 8                | Grążowice                             | Sławno                            | 25               | Sławno Kolonia                        | Tomaszówek                        |
| 9                | Kamień                                | Prymusowa Wola                    | 26               | Kamilówka                            | Unewel                            |
| 10               | Sławno                                | Zachorzów                         | 27               | Tomaszówek                            | Poplawy                           |
| 11               | Ostrożna                              | Owadów                            | 28               | Grudzień Kolonia                      | Grudzień Las                      |
| 12               | Kozenin                               | Józefów                           | 29               | Trojanów                              | Ludwinów                          |
| 13               | Olszowiec                             | Antoniówka                        | 30               | Poplawy                               | Celestynów                        |
| 14               | Dąbrówka                              | Dąbrówka                          | 31               | Ludwinów                              | Kamilówka                         |
| 15               | Józefów                               | Kozenin                           | 32               | Olszowiec                             | Trojanów                          |
| 16               | Owadów                                | Kamień                            | 33               | Sepno Radonia                         | Sepno Radonia                      |
| 17               | Antoniówń                             | Antoniówń                         | 34               | Celestynów                            | Olszowiec                         |
As seen above the villages belonging to the clusters: Gawrony, Kunice, Antoniówka and Grążowice, Prymusowa Wola get the highest positions in the ranking of the urgency of performing the consolidation works, so, it is concluded that these areas should be consolidated in the first place, preferably in a common consolidation procedure, what will help to achieve better land consolidation effects.

4. Conclusions

The method based on the dependency matrix and the Czekanowski's diagram enabled clustering these villages, which are most influenced by each other in terms of lands of non-residential owners. The obtained results allow for the selection of those areas of the commune, where the land exchange works should be first carried out, in order to eliminate the external patchwork of the land.

The results of the calculations have proved the possibility and validity of the application of cluster analysis methods to the analysis of urgency and the need for performing land consolidation works in a given area. On the other hand, the proposed method will be subject to further testing and evaluation in terms of clustering algorithms and interpreting their results and above all in the scope of the method of determining the matrix of dependence or representation of initial data that can be used in cluster analysis. It should be noted that the final result will be most influenced by the numerical representation of the examined features of the clustered objects.

The interpretation of the diagram itself should be linked to additional information on the location of the village in the studied area and other relationships and relationships between the analyzed precincts, also in combination with economic factors. For example, it can be noted that the cluster Grążowice - Prymusowa Wola strongly interacts with the cluster Antoniówka - Kunice - Gawrony. In a similar way the relations between the clusters of Antoniówka - Kunice - Gawrony, Antoniów - Ludwinów - Ostrożna and Dąbrówka - Trojanów and village Kamięń can be described.

Considering the fact that it is possible and equally legitimate to use taxonomic ranking methods to develop a ranking of urgency of undertaking the land consolidation and exchanging works, what the authors have shown. Also, for the area cited in the example, an attempt was made to implement the results of the study to optimize the comprehensive programming of land consolidation and land exchanging works. The results of the study confirmed that the villages with the most unfavourable spatial structure are additionally characterized by faulty patchwork of land. Selecting these areas will enable to specify which villages should be consolidated at the same time as parts of consolidation and exchanging works (Art.2.1 of the Law on land consolidation and exchange says [19]: the consolidation covers land located in one or several villages or parts thereof; these lands form the consolidation area), what will result in better consolidation effects by elimination of the patchwork and thus, more efficient spending of funds for consolidations, what is at least equally important element of public spending planning.

References

[1] J. Czekanowski, “Zur Differentialdiagnose der Neandertalgruppe, Korrespondenz-Blatt,” der Deutschen Gesellschaft für Antropologie, 40, 1909.
[2] J. Czekanowski, “An outline of statistical methods for use in anthropology” (Polish), Works of the Warsaw Scientific Institute, nr 5, 1913.
[3] M. Dudzińska, „Patchwork of fields as a factor which affects rural space” (Polish), Infrastructure and Ecology of Rural Areas, Nr 2012/ 02 (3 (Sep 2012)), pp.45-56, 2012.
[4] J. Han, M. Kamber,J. Pei, “Data mining concepts and techniques, third edition”, Morgan Kaufmann, Waltham, USA, 2012.
[5] J.M. Juran, F.M. Gryna, “Quality - Design and Analysis” (Polish), Scientific and Technical Publishing House, Warsaw, 1974.
[6] R. Kolman, "Quantitative Quality Determination" (Polish), Polish Economic Publishing House, Warsaw, 1973.
[7] Ż. Król, P. Leń, “Individual Plot Patchwork: Determination of the Urgency in the Realization of
Consolidation and Exchange of Land", *Infrastructure and Ecology of Rural Areas*. vol. 2016/II, 2016, pp. 311-322, 2016.

[8] P. Len, G. Oleniacz, I. Skrzypczak, M. Mika, “The Hellwig’s and zero unitarisation methods in creating a ranking of the urgency of land consolidation and land exchange work”, *16th International Multidisciplinary Scientific GeoConference SGEM 2016*, ISBN 978-619-7105-59-9 / ISSN 1314-2704, Book2 Vol. 2, pp.617-624, 2016.

[9] P. Len, M. Mika, “Determination of the urgency of undertaking land consolidation works in the villages of the Sławno municipality”, *Journal of Ecological Engineering*, Volume 17, Issue 4, Sept. 2016, pp. 163–169, 2016.

[10] O. Maimon, L. Rokach, “Data mining and knowledge discovery handbook, second edition”, *Springer US*, 2005.

[11] K. Noga, “An analysis of an inter-village patchwork of farmland using the example of villages located in the upper basin of the River Soła” (Polish), *Scientific Papers of the Agricultural Academy in Cracow*, no 133, Scientific Session 7.

[12] K. Noga, “The problem of eliminating an inter-village patchwork of farmland” (Polish), *IUNG*, Puławy, t. I, pp.143-166, 1985.

[13] K. Noga, “Methodology for Programming Consolidation Activities and the Technology of Consolidating Land in mountainous areas. (The Example of the Beskid Catchment of the River Soła)” (Polish), *A habilitation dissertation no. 143*, Scientific Letters of the Agricultural Academy in Cracow.

[14] K. Noga, “Method of analysis, evaluation and elimination of a defective patchwork of privately-owned farmland” (Polish). *Biol. Reg. ZDR AR w Krakowie*, 304, pp. 110-114, 1992.

[15] K. Noga, „A comprehensive approach to methods of programming and implementing land consolidation and exchange interventions” (Polish). *School of Land Knowledge, Agricultural University of Cracow*, pp. 88, 2001.

[16] I. Rabczuk, “Problem a patchwork of land ownership in the proszowickim district, krakowskie voivodeship” (Polish), *Current issues of geodetic surveying, Polish Surveyors Association*, Warsaw, pp. 65–70, 1967.

[17] A. Sołtysiak, P. Jaskulski, “Czekanowski's Diagram. A Method of Multidimensional Clustering [in:] New Techniques for Old Times. CAA 98. Computer Applications and Quantitative Methods in Archaeology. Proceedings of the 26th Conference, Barcelona, March 1998", ed. J.A. Barceló - I. Briz - A. Vila, *BAR International Series* 757, Oxford, pp. 175-184, 1999.

[18] Ż. Stręk, “Analysis of demand for land consolidation in Milejów commune, Łęczna district”, *Engineering for rural development*, Jelgava, 2017, pp.593-599, DOI: 10.22616/ERDev2017.16.N119.

[19] Act of 26 March 1982 on Land Consolidation and Exchange (Official Journal of Laws 2003 No. 178, item 1749 with later amendments).