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Spatial Analysis of Water Infrastructure Development On Example of Eastern Europe Rural Regions

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Abstract. In the paper the assessment of water supply in rural areas in Poland was performed in aspect of future problems and the necessity of investments. The analysis proposed in this work is a helpful tool in making the ranking of the level of infrastructure development in different regions of the country. The assessment of the water supply network functioning is a very important issue that requires the use of operational experience with the practice of water supply. The analysis was based on data associated with the exploitation of water supply systems. Among others, to illustrate this diversity, the multidimensional comparative analysis was used. The developed analysis will enable decision support in the process of evaluating the economic efficiency of the operation of water supply infrastructure, through established indicators including the water network length development.

1. Introduction

The situation of water supply in rural areas in Poland has rapidly changed since the nineties after a period of economic and political transformation. The degree of equipment in the water supply system increased, but in many areas it stays at not satisfactory level. At present the water supply system is under public supervision.

The act on collective water supply and sewage disposal controls several issues connected with quality of services provided by the waterworks companies but does not introduce the concept of availability of water services quality level, that is characterised by quantitative reliability and safety of water supply [1]. Worldwide there is a trend to improve the quality of services rendered by the waterworks company. In many countries a significant interest in this subject is seen, [2]. In the United Kingdom the Water Services Regulation Authority OFWAT exists, which regulates the relationship between the recipient and the supplier of water, using the precise criteria for, among others, the required degree of reliability, the procedures of dealing with consumer complaints.

A legitimately working water supply framework must ensure a consistent water supply to the consumers, with a suitable quality and satisfactory quantity, required pressure, at a particular time, [3]. One of the reasons of not maintaining parameters at the required level is a continuous development of water supply infrastructure, caused mainly by the connection of the new customers or changes in water consumption by the users already connected [4]. For that reason, in order to know the present condition of water supply infrastructure it is necessary to conduct the periodic analyses that were proposed in this work. Due to the importance of the discussed issue, the analysis of the differentiation of the Polish regions regarding the level of water supply infrastructure development was conducted.

2. Data and method

The data used in the article concern the characteristics of water supply in different regions in Poland and was gathered from water companies and based on the exploitation data, as well as from Central Statistical Office. The following regions involving the biggest territorial unit as Masovia and Łódź voivodeship (central region), Lesser Poland and Silesia Voivodeship (south region) and Lublin,

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Subcarpathian, Świętokrzyskie and Podlaskie Voivodeship (east region) were characterised. The analysis regards the following factors: the length of water supply system, the number of waterworks connections to residential buildings, the numbers of waterworks connections falling per 1 km of the distribution pipe, water consumption for production and population purposes, individual daily water consumption, intensity of loading the network, indicators of the degree of equipping individual's settlement with water supply systems. The analysis was performed using the application contained in a Statsoft computer program Statistica.pl 10.0. After the preliminary analysis the regions where aggregated with application of the correspondence analysis, which presents structure between rows and columns, allowing its graphical presentation by illustrating points on two or three-dimensional coordinate system [6, 7]. Stages of analysis are as follows: the first step in the analysis is the construction of inputs matrix, then the matrix is converted into a matrix of frequency, which is formed as a result of dividing the elements of the matrix by each observation. Then division of the individual frequencies in rows/columns in the matrix by the sum of all frequencies in rows/columns the matrix of rows and columns profiles is obtained, the distance between the profiles of rows/columns are calculated using the Euclidean taking into account the importance of the frequency of rows/columns. Designated inertia (distance chi-square) informs about the degree of differentiation of elements regarding to the average profile.

3. Results of the waterworks infrastructure research

3.1. Preliminary analysis

The preliminary analysis indicates that access to water networks has increased on average of 15% in comparison to 2002, which was presented on the map (Figure 1). The result of such situation is that in the past decade, many programmes were being implemented in order to improve the situation of water supply system. The largest change occurred in Masovian of about 24.5%, and the smallest in Silesia, which might be caused by the fact that in Silesia already in 2002 a lot of people used public water supply. The lowest access to the water network in Subcarpathian and Lesser Poland voivodships occurred in the south, it is due to the considerable dispersion of households and differentiation of the height location and the construction of water supply network in these areas.

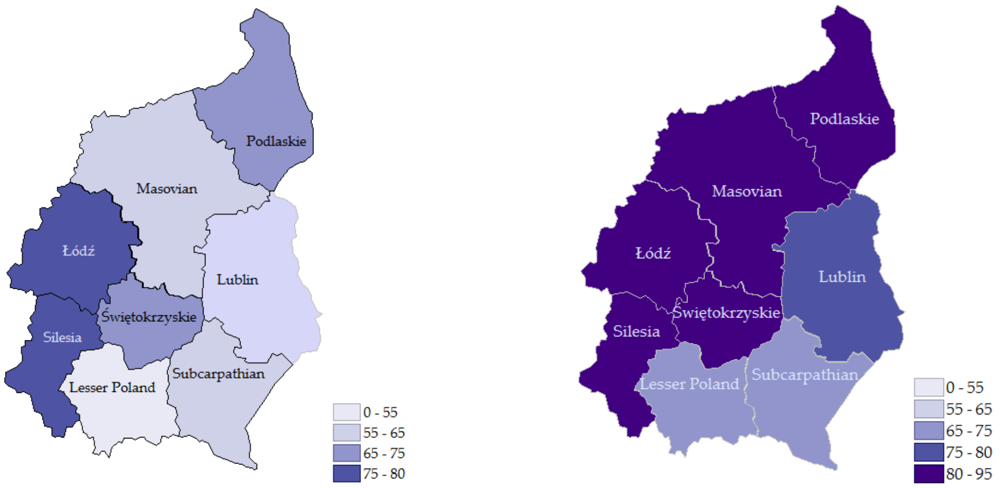

Figure 1. People having the access to water networks in % in rural areas in 2014 in provinces of: a) Subcarpathian; b) Lesser Poland

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Such situation is also caused by the high unemployment rate and a small number of businesses with low capital investment, that provides small using of water supply on the level of 18%. The primary source of water to such households are individual wells. Unfortunately, often the quality of water in wells deviates from the accepted standards and its consumption is frequently a cause of many illnesses.

The increase of distributional pipes length was presented in Figure 2. From 1995 in all regions a dynamic growth of distributional pipes length is observed. Particularly the great increase of the network length was observed in the Masovian voivodeship (ca. 300%). The greatest increase in the country appeared in the 90s and amounted on the average in the considered region over the 59% in 2000. Consecutive years were also characterized by a high development of water supply systems, but in the little smaller degree - ca. 41%.

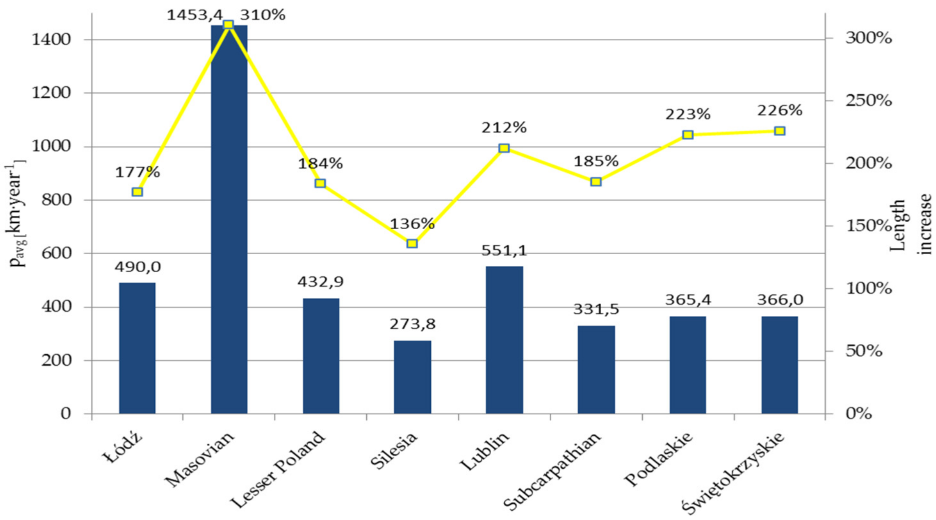


Figure 2. Increase of the water system length in the examined region in the years 1995÷2014, as a point of reference it was assumed that in 1995 the length of distribution pipes was 100%

After 1995 a development of waterworks infrastructure took place in the country, which was the result of building water supply systems almost parallel in most of the villages.

Another indicator describing the development of infrastructure waterworks is the indicator of the equipping degree with water supply systems. The length of water supply system falling per unit area is bigger in more developed regions, characterized by a bigger population density compared with the areas with the smaller density (Figure 3). Such analysis can be very helpful in the assessment of the water network condition. Next, it can be implemented to compare the level of water losses in different water supply systems, as well as in prediction of water supply network development. The correlation between the intensity of water system loading and water price indicates, e.g. for Lublin, strong correlation R^2 = 0.73 and for Silesia the less strong R^2 = 0.53. Changes in the water prices remained at relatively similar levels, with the exception of Silesia, which is characterized by the mining industry existing in this area (Figure 4).

3.2. Analysis concerning correspondence dependence

As to perform the corresponding analysis the following variables were taking into account, which are not correlated to each other (A - water network per 100 km^2, B - people having the access to water networks in %, C - investment in water supply infrastructure, D - water price, E - individual average daily water consumption). Before attempting the analysis, the average synthetic indicator was determined from considered variables. The first place in terms of the best development in water supply in the conducted ranking occupied Silesia (76.91%), followed Masovian (67.61%) and Łódź (57.87%).

In contrast, the worst regions presented Podlaskie, Lublin and Subcarpathian. Applied corresponding analysis and its results was presented on the Figure 5, taking into account the considered three-dimensional and two-dimensional space.

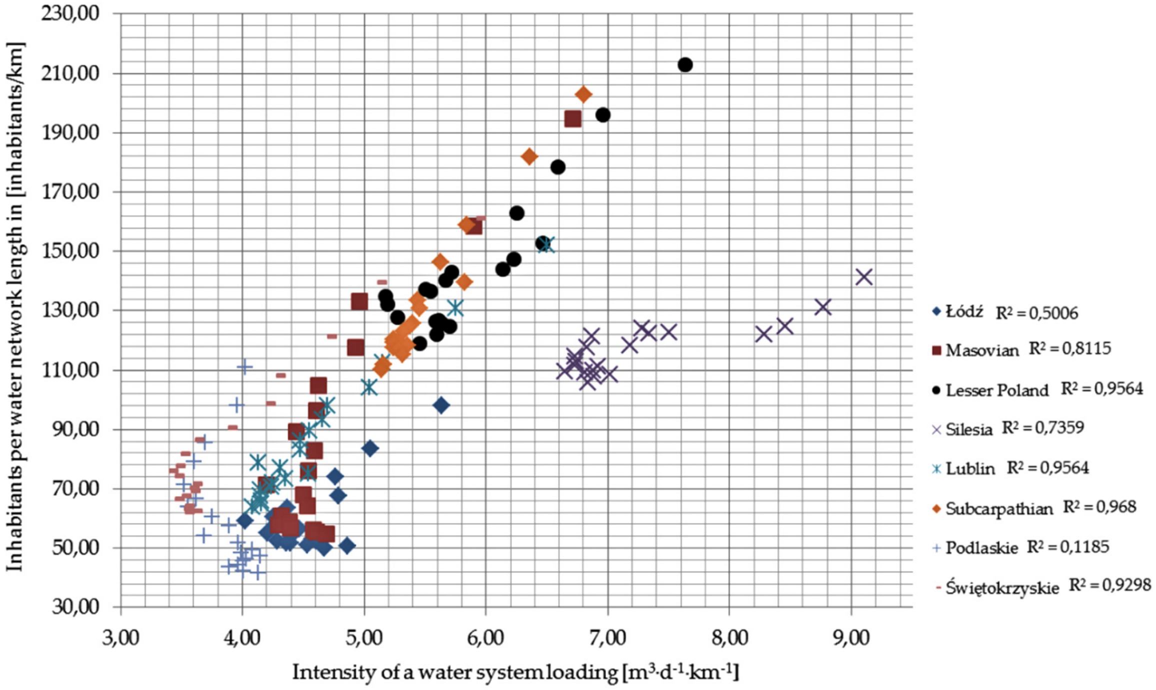
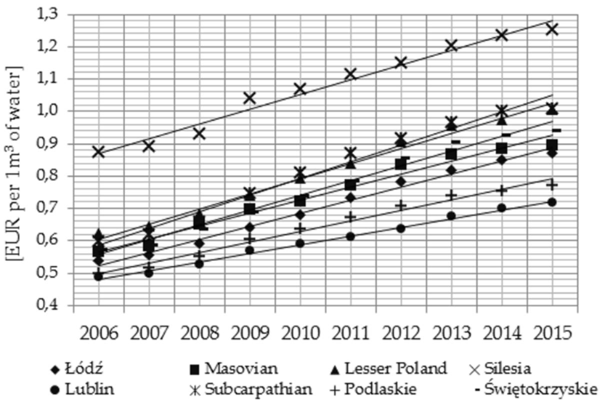


Figure 3. Length of a water system falling to the unit of the surface area [m/ha]



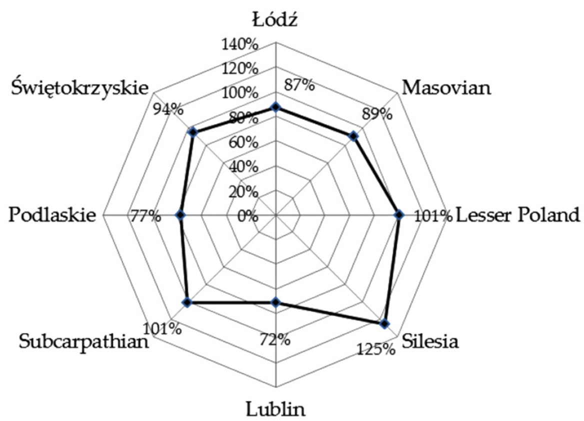
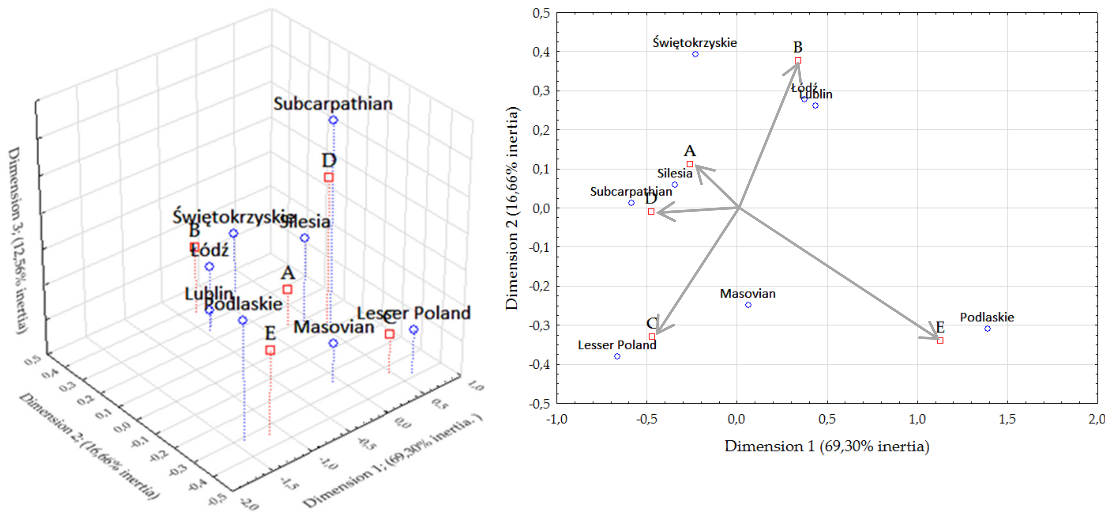


Figure 4. Price per 1 m^3 of water: a) in distinguished years in [EUR/1 m^3], b) as a point of reference it was assumed that in 2006 the water price of was 100%



a) b)

Figure 5. Coordinate diagrams: (a) three-dimensional and (b) two-dimensional

Adopted three dimensions in the correspondence analysis explain 98.52% of inertia, where 69.30% of inertia is explained on the first axis, 16.66% (dimension 2) and 12.56% (dimension 3). While the other two dimensions allow reproduction of 85.96% of inertia. The smallest differentiating parameter of development of water supply infrastructure is a parameter that describes the length of the water network per 100 km^2 (A). Other parameters are scattered throughout the system, which shows a large contribution to the diversification of regions.

Parameters lying relatively close to the origin affect the smallest variation of investigated regions. Such parameters include water network falling per 100 km^2 and a water price, according to the most distinguished regions of Silesia and Subcarpathian. Only Masovian province is not correlated with any parameter, which results from spreading characteristics in all parameters. In contrast, Podlaskie province and Lesser Poland are the most diverse in comparison to other regions. Their distribution in the structure deviates most from the average.

4. Conclusions

Since the nineties the significant development of the waterworks infrastructure occurred in rural areas, but still many problems with water supply take place. An important issue not discussed in this work is the poor quality water supplied to customers, that does not meet the current standards, which often occurs as a result of oversizing the network, secondary pollution, poor technical condition and high failure rate of pipes. Along with the development of the water supply system infrastructure, the water consumption reduction occurred, which undoubtedly was caused, among others, by metering water supply through the installation of water meters. High investment costs as well as reducing water consumption affect the increase of water service price, including cost of used water. Municipalities often subsidize costs of investments because the costs incurred for investments do not generate high profits and the reimbursement of expenses takes many years. Conducting analyses of the current state of the water supply network can be helpful to identify the need of repair, modernization and investment.

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