CORRELATION BETWEEN SELECTED SOCIOECONOMIC VARIABLES AND THE NUMBER OF RENEWABLE ENERGY SOURCES IN ŚWIĘTOKRZYSKIE VOIVODESHIP (POLAND)

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Abstract. An improvement in the standard of living and a fast civilization progress in the 21st century result in a constantly growing demand for energy. The share of renewable energy sources (RES) in the total energy generation and consumption is increasing due to the limited nature of fossil fuels and their adverse impact on the environment. The paper examines the correlation between selected socioeconomic variables and the number of RES and evaluates the potential impact of these factors on introduction of RES in all districts (*powiat – second tier administrative unit*) of the Świętokrzyskie Voivodeship (Poland). The following socioeconomic variables were used: surface area of agricultural land, surface area of land under surface flowing water, surface area of wasteland, population density, unemployment rate, number of unemployed persons registered for over a year, total EU funds acquired, per capita income, and EU funds acquired per capita. Moreover, the paper presents the current use and methods of acquiring RES, split into types in the studied area. The research method was the Spearman's rank correlation. The study resulted in a determination of the strength and direction of correlation between the tested variables and in an attempt to answer the question: what variables, if any, affect the introduction of RES in the studied area?

Keywords: renewable energy, bioenergy, Spearman's rank correlation,socioeconomic factors, energy policy, energy market, statistical test.

Introduction

One of the most basic necessities that humans need in their every-day lives is energy. It is inseparable from the state economic growth due to its availability and price [1]. Today, the overwhelming majority of energy in Poland is produced using conventional energy sources, mainly hard and brown coal, which are not only limited but also harmful for the environment [2; 3]. Estimates of the environmental consequences of the use of energy crops as an alternative for coal are pending as well [4]. Simultaneously, people in many Central and Eastern European countries, including Poland, are increasingly more interested in producing and consuming renewable energy [2; 5]. It is mainly due to aspirations for energy self-sufficiency, increasing prices of fossil fuels, limited fuel resources, and the necessity to improve the state energy security [1; 3]. It is worth noting that Poland produced 8512 tonnes of oil equivalent (toe) from renewable energy in 2013, which is more than the EU mean of 6856 toe [6].

Use of renewable energy sources significantly contributes to the implementation of the Polish energy policy [7]. Moreover, it is in line with the EU policy and implements obligations imposed by it on individual member states. Increasing the share of RES in the EU final energy consumption to 27 % is the goal which the EU set in the negotiation process in 2014 [8]. Nevertheless, it will be hard for EU-28 to meet this goal due to developmental differences among the states. Only a few states managed to achieve their individual goals as regards renewable energy in 2010 (Germany, Denmark, Hungary, Ireland, Portugal, and Lithuania) [9]. At the time, the Polish government undertook to ensure increase of the share of renewable energy to 15 % in Poland's gross final consumption of energy by the end of 2020 [7; 9]. Despite the fact that in 2013 the share of RES in total energy production in Poland was 11.4 % (2011: 10.4 %, 2012: 11.0 %) [10], its energy import dependency was still significant and amounted to 31 % [6].

Power generated by hydropower plants is an important type of renewable energy produced in Poland. The second place is taken by biomass [6] but wind energy is also widely applicable, especially in the northern Poland [3]. Renewable energy sources are located primarily in rural areas [11] that constitute about 93 % of the Poland territory [12].

Studies by Szul have demonstrated that the primary sources of energy in the Świętokrzyskie Voivodeship (Poland) are hard coal and firewood. Their respective shares in the total balance of fuels are 56 % and 22.5 % [13]. Therefore, it is vital to increase the production of energy from renewable sources offered by nature in this area, particularly so as, according to Gutkowska et al., agricultural lands in the Świętokrzyskie Voivodeship are suitable to plant energy crops [14]. This trend is growing in the above-mentioned area, which undoubtedly has the potential to produce “green energy”.

Public acceptance is necessary for RES to grow further on the national, regional, and local level. According to a study carried out in Greece, awareness may depend not only on the country or region but also on selected socioeconomic variables [15]. It is also worth pondering upon what variables have the greatest impact on the number of RES and why. To answer this question, the authors conducted a study to determine the strength and direction of correlations between selected socioeconomic variables and the number of RES in all districts of the Świętokrzyskie Voivodeship.

Thus, the paper first presents the current state of the use of individual types of RES in the studied area and then proceeds to the main part that is an examination of relations between variables. The Spearman's rank correlation coefficient was used in the study. The hypothesis of the correlation coefficient significance was tested at $\alpha = 0.05$. The analysis resulted in determination of the strength and direction of correlation between the tested variables and answered the initial question: what variables, if any, affect occurrence of RES in a given area.

Materials and methods

The analysis was performed for the Świętokrzyskie Voivodeship, located in the south eastern Poland (Fig. 1). The area of the studied region is 11 711 km^2. It is inhabited by about 1.27 million people [16]. It is made up of 14 districts, including one city with district rights, Kielce.

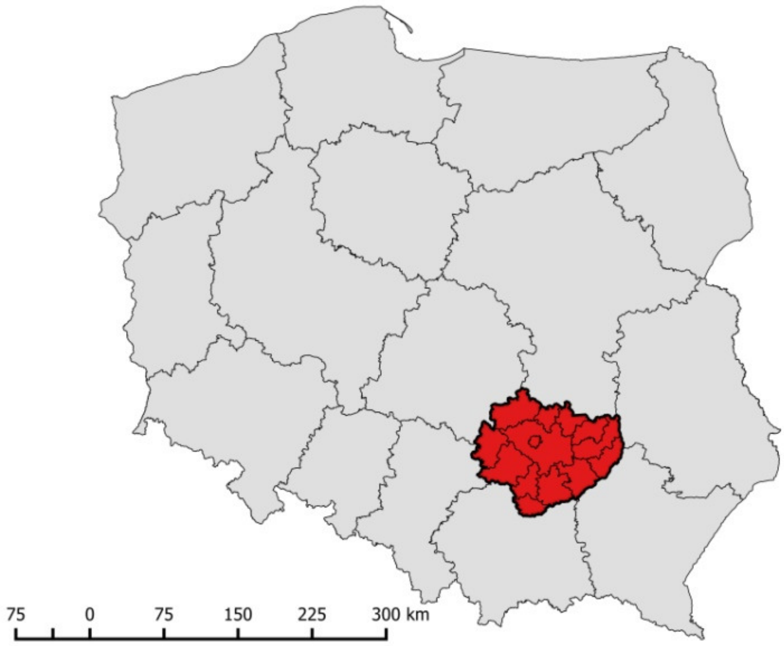

Fig. 1. **Location of Świętokrzyskie – the studied area**

The first step to determine the strength and direction of correlation between the variables was to select variables to be analysed and identify the existing renewable energy sources in each of the 14 districts.

The study takes into consideration the power and number of hydropower plants, wind turbines, biomass power plants, and biogas power plants in all districts of the Świętokrzyskie Voivodeship as of February 2014. The current state was assessed based on a July 2015 interview with an officer at the Marshall Office of the Świętokrzyskie Voivodeship who is directly responsible for RES in the area. The gathered data were then verified using an interactive map of renewable energy sources provided by the Energy Regulatory Office [17].

Data on socioeconomic variables and number of RES were gathered for each of the 14 districts individually. The following socioeconomic variables were used in the study: x_1 – surface area of the district, x_2 – surface area of agricultural lands, x_3 – surface area of land under surface flowing water, x_4 – surface area of wasteland, x_5 – population density, which is the number of residents per 1 km^2,

x_6 – unemployment rate, x_7 – number of unemployed persons registered for over a year, x_8 – total EU funds acquired, x_9 – per capita income, x_{10} – EU funds acquired per capita. The number of RES was considered as: y_1 – total number of RES andy_2 – number of hydropower plants. Values of x_i variables for 2014 were retrieved from the Local Data Bank (LDB), which is the largest systematic collection of the data on socioeconomic, demographic, social, and environmental situation in Poland [18]. The statistical characteristics of x_i and y_i were listed in Table 1.

Table 1

Selected statistical characteristics of the variables

Characteristics	**Variables**											
	x_1,ha	x_2,ha	x_3 , ha	x_4 , ha	x_5, people per km^2	x_6,%	x_7,people	x_8,PLN	x_9,PLN per capita	x_{10}, PLN per capita	y_1	y_2
Mean	83646	53578	558	615	224	15	2260	12390105	1351.1	7.8	4.5	3.4
Median	79188	48621	431	523	81	13	2352	3948443	1024.0	8.8	4.0	2.0
Standard deviation	51201	32775	405	446	460	5	1199	27228696	1156.5	5.5	3.8	2.5

For virtually every sample (except for variables x_7 and x_{10}), the mean value is greater than the median value, which indicates that the empirical distribution is asymmetric. Moreover, variables x_5 and x_8 have a particularly high dispersion, which is reflected in a high value of standard deviation. This is due to substantial difference between the sample values of variablesx_5 and x_8 for the city of Kielce district and the other districts. This is clearly visible in the histogram in Fig. 2-A where the sample values for $x_5$less than 500 (people per km^2) for the 13 districts of the Voivodeship and the value over three times larger for the city of Kielce, namely equal to 1814 (people per km^2), are shown. The shape of the histogram is similar for variable x_8 because its value is higher than 100 million (PLN) for the city of Kielce and a few times less for all the other districts (Fig. 2-B).

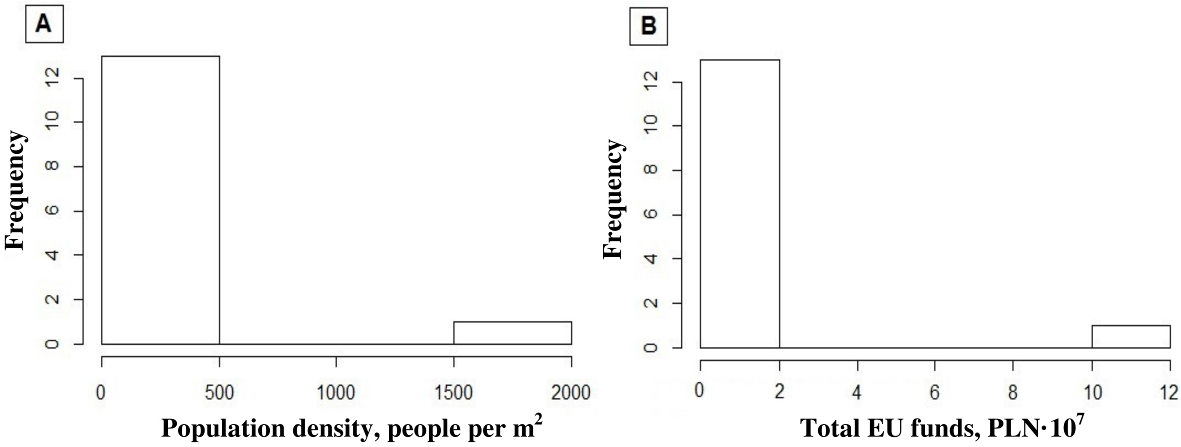

Fig. 2. **Variable histogram:** A – x_5, B – x_8

After the database with the total number of RES (y_1), number of hydropower plants (y_2), and individual socioeconomic variables (x_i) for the studied area was created, the next stage of the study was commenced where relations between variables y_1,$y_2$and every variable x_i were studied. For this purpose, statistical methods were applied. All the necessary calculations were carried out in *STATISTICA 10* (StatSoft, Inc., Tulsa, USA).

Strong asymmetries of empirical distributions were found for all the variables, hence distributions were not normal. Therefore, the nonparametric Spearman's rank correlation method was the basic method of the study. The Spearman's rank correlation coefficient for the sample is defined as [19; 20]:

$$r_s = 1 - \frac{6\sum_{i=1}^{n}\left(R_i - S_i\right)^2}{n\left(n^2 - 1\right)}, \tag{1}$$

where R_i – rank of variable y_i (number of RES);
S_i – rank of variable x_i (socioeconomic variables);
n – number of components.

The Spearman's rank correlation method does not require any assumption about the shape of the distribution function. Therefore, this is one of the oldest and most widely used nonparametric measures of statistical correlation between random variables [21]. It has become the standard nonparametric statistic used in environmental engineering [22], spatial management [23], biology, medicine, psychology and many other branches of academia [21; 24]. It also should be noted that r_s is, after a transformation, a Pearson correlation coefficient for ranks of observations [25].

The coefficient r_s satisfies the condition: $-1 \le r_s \le 1$. Additionally, the higher absolute value it assumes, the stronger the relation is between the tested variables. Positive (negative) values of r_s indicate that high values of one variable implicate high (low) values of the other [26].

The significance of the Spearman's rank correlation coefficient in the population (ρ_s) was tested using the following hypotheses:

$$H:\ \rho_s = 0,$$

$$H_A:\ \rho_s < 0 \quad \left(\text{lub } \rho_s > 0\right). \tag{2}$$

The test statistic is:

$$z_s = r_s\sqrt{n-1}, \tag{3}$$

where r_s – sample Spearman's rank correlation coefficient;
n – number of components.

The theoretical distribution of z_s is $N(0,1)$ thus for significance level of $\alpha = 0.05$ and for $n = 14$ components, the H hypothesis is rejected in favour of H_A: $\rho_s < 0$ when $r_s \le -0.46$ and in favour of H_A: $\rho_s > 0$ when $r_s \ge 0.46$.

Results and discussion

The studied area includes 37 hydropower plants, 17 wind turbines, 3 biomass power plants, and 6 biogas power plants. The total power of all the 63 renewable energy sources in the Voivodeship is 253.823 MW. Their share in the total number of renewable energy sources in each of the studied districts and the total power are shown in Fig. 3.

As shown in Figure 3, the total RES power is greater in the northern part of the Świętokrzyskie Voivodeship than in the remaining part of the area. The only exception is the Staszowski District with RES of 230 MW of total power due to the presence of the Połaniec power plant, which utilises biomass. When it comes to the share of individual types of renewable energy sources in the total number of RES, it is noticeable that biogas power plants are found only in the central and northern part of the Voivodeship, hydropower plants and wind turbines are located virtually all over the Voivodeship, and biomass power plants occur in only 3 districts: Staszowski, Włoszczowski, and the city of Kielce Districts. It should also be noted that there are no hydropower plants in three districts of the Świętokrzyskie Voivodeship (Buski, Opatowski, and the city of Kielce Districts).

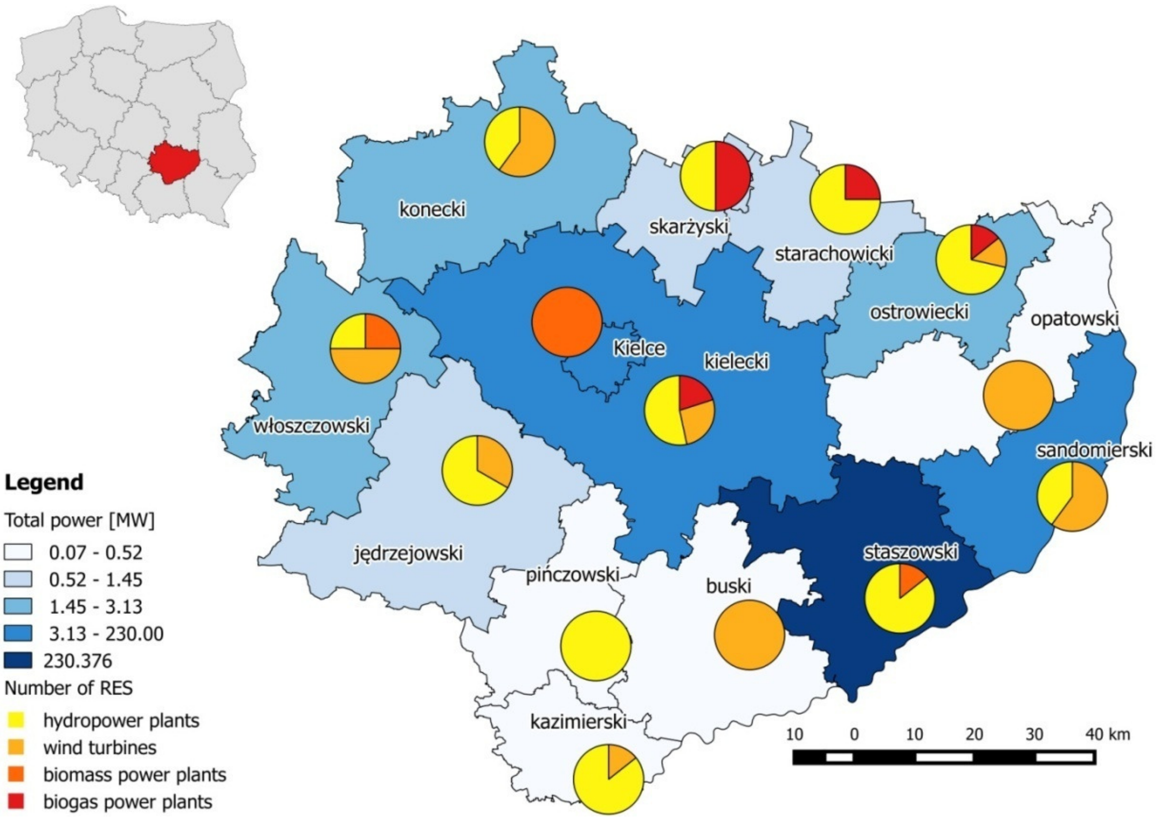

Fig. 3. **RES total power and share in the total number of renewable sources in the studied area**

In Table 2, the values of the Spearman's rank correlation coefficient (1) between every socioeconomic variable and the number of RES, are presented. Bold font is used for correlations significant at $\alpha = 0.05$ and for the one-tailed hypothesis H_A.

Table 2

Spearman's rank correlation matrix

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
y_1	0.27	0.16	0.30	0.17	0.21	0.24	0.09	–0.11	**–0.59**	–0.08
y_2	0.22	0.15	0.33	0.14	0.22	0.18	0.00	–0.16	**–0.60**	0.05

The results of the hypothesis testing (2) yield the following conclusions with the confidence level of 0.95:

- per capita income is negatively correlated with the number of RES;
- per capita income is negatively correlated with the number of hydropower plants.

This means that as the per capita income increases, both the total number or renewable energy sources and the number of hydropower plants decrease. It is, therefore, a valid conclusion that the richer a district is, the less inclined it is to invest in renewable energy sources in its area. A possible explanation of this fact is that rich districts are not interested in RES as they did not perceive it as a benefit but rather as an expense that may pay for itself in a few or more than a dozen years. Poorer districts are more likely to invest in renewable energy because they probably strive for substantial benefits or try to reduce costs of production of energy from conventional sources.

Other variables x do not correlate with any of the variables y because ρ_s is not significantly different to zero.

The analysis for the ŚwiętokrzyskieVoivodeship has demonstrated that one socioeconomic variable, namely, the per capita income, has a statistically significant impact on the total number of RES and the number of hydropower plants. This variable should not, however, be considered to be the only factor influencing the number of RES and hydropower plants in the studied area. According to the literature data, also other variables such as the location, natural conditions, level of economic growth, energy efficiency, national energy policy, and foreign policy may affect the number of RES [6]. An analysis of the influence of these factors on the number of RES could be tackled in future studies.

Conclusions

Results of this study allowed us to make the following conclusions.

1. The Spearman's rank correlation is a useful tool for testing the dependence of socioeconomic variables and the number of RES.
2. The total number of RES and the number of hydropower plants are negatively correlated with per capita income.
3. No correlations were found for the other tested variables.

It should be borne in mind that the result for the per capita income variable might not be the only factor influencing the number of renewable energy sources. Therefore, further studies of this issue, that could involve additional new variables, are justified. It is also vital that practical experience and statistical methods complement each other [27].

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