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GIS MODELLING OF SOLAR POTENTIAL IN TOPLICA REGION

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ABSTRACT

In this paper we investigated possible potential solar area on Toplica region based on GIS (Geographical Information system) and using a special kriging method with the help of open sources GIS software Quantum GIS. This kriging method is very special to vectorized and calculated the small area. The statistical approach calculated between datasets of three meteorological stations (Niš, Prokuplje, Kuršumlija). Data using of insolation from that meteorological stations from the period of (1953-2013) is useful for a solution to calculating solar potential. The also used parameter is hypsometry of relief of the whole area of Toplica region. Area of Toplica region is 2.231 km² with a population of 90600 citizens. Divided into fourth municipalities (Prokuplje, Žitoradja, Black, Kuršumlija). The GIS modeling indicates that ideal areas for solar development are located the potential places in Toplica region. Only 13.6 km^2 of the head model scores that were in the 90-100% range. However, given the statewide high insolation values with minimal variance, solar projects may be better suited for small-scale residential or commercial projects.

Key words: Solar, potential, Toplica region, GIS, isolines, maps.

1. INTRODUCTION

The average intensity of solar radiation on the territory of the Republic of Serbia is 1.1 kWh/m^2/per day in the north and 1.7 kWh/m^2/per day in the south – in January and from 5.9 kWh/m^2/ per day to 6.6 kWh/m^2/per day – in July. On an annual basis, the average energy value of global radiation for the Republic of Serbia amounts to 1200 kWh/m^2/per year in northwestern Serbia, 1550 kWh/m^2/per year in southeastern Serbia, while in the central Serbia it amounts to 1400 kWh/m^2/per year (Pavlović & Čabrić, 1986). Today is the age of changes point about climate in the Earth. Greenhouse gases concentrations have risen over the last 200 years from greater fossil fuel and coal use (Radosavljević et al., 2010). That values today has incredible numbers. For that global warming has caused prediction for using new sources of energies in renewable oblique. One of them is solar energy (Lambić, 2010). The whole area of Toplica District is situated in the south-east part of Serbia (Pavlović, 2010). That would be a good reason for solar energy potential. Serbia has the average about 272 sunny days and probably more than 2300 sunny hours (Lambić et al., 2010). In Toplica District, the situation is very good, because more than 249 sunny days and more than 2115 sunny days. The slope of terrain in Toplica slightly positioned by Toplica valley in direction east-west (Malczewski, 2006). That is a lot of hills and mountains located in the south-west position. Multicriteria analysis in a vector data model (vector data, line, and polygon representation) is derived from a raster data model (Kuzevicova & Hurcikova, 2008). GIS data model selection and elimination can lead to different solutions (Ramachandra & Shruthi, 2007). Other geographical variables such as settlements schedule, settlements density, access to roads and location of slope grid area also play the main role (Yue & Wang, 2006). GIS is a very helpful tool for a variety of environmental, planning, waste management, water resources all applications have been undertaken using special GIS tool of multicriteria modeling techniques.2.

2. DATA AND METHODS

The Toplica region is situated in the south of Serbia, located in the south-east part between the mountains of Jastrebac in the north, Kopaonik in the west, Vidojevica ,Sokolovica, Radan and Prolom in the south (Rudić, 1978). More than 76% of this land area have a lot of sunny days. The climate of Toplica region is moderately continental, with cold winters and hot summers, with a wide range of extreme temperatures and an unequal distribution of rainy months which causes different values of semi- aridity classes (Prokuplje, strategic document). The average annual temperature is 12.1°C, and the annual amount of precipitation is 690 mm for the 1953-1999 periods. The data from the three meteorological stations have been used for the calculation of the number of sunny days in the 1953-1999 periods. These stations are operated by the Republic Hydrometeorological Service of Serbia (http://www.hidmet.gov.rs/). Data sets for each of the meteorological stations were downloaded and used for the calculations of the sunny days and intermediate value of the sunny days and intermediate value of isoline. The correlation coefficients for the data from these meteorological stations were above 0.6.

3. Methods

The variables used in this work have been obtained from the analogue database, and we have digitized them all. We observed the following variables: potential solar classes, relief slopes, population density, settlements distribution, grid location, slope direction models and the locations of the road networks in the Toplica region. The precision of the classes was determined by the superabundance and quality of data for solar potential, the complexity of the slopes terrain and the geographic variability of the situated location. The insolation values were derived from the Republic Hydrometeorological Service on maximum and minimum scales for the period presented (George & Maxwell, 1999). The Grid cells were put out at 100 m resolution and were validated with the ground measurement of shade tools with the help of GIS tools (Voivontas et al., 1998), (Joerin et al., 2001). Using open sources QGIS 2.6, the seven solar potential categories estimates were rescaled from 0 to 1 by dividing the maximum value in the grid. Each data set was resampled to 100 m using a special filter into GIS. Average isoline vector files were obtained from a digital shape when we derived data from DEM (Digital Elevation Model). The data from DEM were downloaded from the official website (http://earthexplorer.usgs.gov/) in a very high resolution. The grid was rescaled from 0 (least, welcome) to the value of 1 (ideal, close). Since all the data consisted of polygons, it was necessary to convert them into a grid like points in a 100 m resolution. Then, the data were standardized by 0 to 1 values. Ideal conditions exist where population density is the lowest. The distance of the roads is 560 m in the biggest places with solar potential. In order to exploit things easily, the locations which were closer to the existing roads were considered more suitable. The grid and slope directions were categorized according to their suitability for development. The three classes of the slope are given and also one class of grid valued in a 100 m resolution. The grid area which was not favorable for solar potential included the sparse, as well as the taller vegetation, lakes, valleys, streams an, etc. The non-ideal land cover grid contained pine and the deforested areas that would be difficult to develop. Other GIS data were derived from the distribution of settlements with precision coordinates which was given in WGS 84 system. The relief map of the Toplica region shows us that the it is Toplica river flows through the central part of the valley. In the north, Jastrebac Mountain is situated, but not good for potential solar area places, because the slopes have a greater value than 20 degrees. In the south-west area, close to the Kosovo border, the mountains of Radan, Prolom, Sokolica are the best places for solar potential. Other good potential places for solar energy in the Toplica region are in the south of the area, in the mountains Vidojevica and Rgajske. Based on the complete processing of GIS data in seven categories (relief, density, road networks, grid resolution, slope directions, settlements distributions and isoline mean distribution), inter mountains and hills basins (shrubs, plays, and grassland) have the greatest potential for solar development.

3.1. Special GIS tools

The view shed analysis is a very important tool in the GIS selection and data processing. For all GIS data, we used two software with open sources GIS Quantum and Global Mapper 17. The combination of both gave fantastic results. After downloading DEM from the official USGS website in the next step we transformed and resized the file. The DEM file of resolution 100 m was inputted into the GIS software Global Mapper and with the help of other software Quantum GIS, we marked the area of the Toplica region. With a special GIS tool (Viewshed tool), in Global Mapper 17. We selected the view shed analysis tool as the current tool. This tool allows us to perform a viewshed analysis using the loaded DEM elevation grid data with a specified user transmitter location, height and radius (Global Mapper Forum). We selected all areas within the places with solar potential. All areas within the radius selected are colored with a specified color. The option View Angle Selections gives us the complete radial area. When we performed the view shed analysis over the entire area, we found the potential solar place areas starting at 0 to 360 degrees. With the other special tool Fresnel Zone Specification, we found all points into the grid with slope <10°degree. Another special tool into the GIS software is the kriging method analysis. With the help of Quantum GIS 2.6 we give priority to this method which was employed through the QGIS extension Spatial Analyst. Although there are a few methods, an ordinary kriging method is given priority because it includes autocorrelation and the statistical relationship among the measured points. Thus, with this method the weights are based not only on the distance between the measured points and the predicted location, but also on the overall spatial arrangement of the measured points (Forum of QGIS; Hutchinson, 1994), and it minimizes the variance of the error estimation. Based on its input point features, it creates a surface raster with a spherical semivariogram model for each data of isolines.

3.2. Meteorological data

We used data from three meteorological stations (Nis,Kursumlija,Prokuplje, Table 1.) and calculated average isolines for the 1953-1999 periods (See Fig.1).

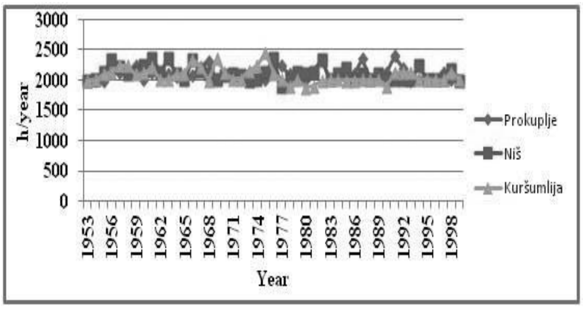

Fig. 1. Trends of average year insolation in the period (1953-1999).

The three meteorological stations have a relatively uninformed altitude which varies between 204 m and 383 m, while the last station Prokuplje has not always worked properly, and Nis meteorological station is very close to the Toplica region. These stations are operated by the Republic Hydrometeorological Service of Serbia (http://www.hidmet.gov.rs/). With all data sets of sunny days we created the average isolines data from those meteorological stations, and after that, we had them put into GIS (see Fig. 2). When we exported all data in the hours of sunny days.

Table 1. List of meteorological stations and their geographical coordinates and altitudes.

Meteorological Station	Longitude	Latitude	Altitude (m)
Niš	21°54′	43°20′	204
Kuršumlija	21°16′	43°08′	383
Prokuplje	21°36′	43°14′	266

4. Results

In order to understand the land cover characteristics, we determined all classes when we inserted the data (Johnston et al., 1994), (Meyer et al., 2009). According to the multi-criteria of the GIS solar model, larger solar potentials should be located in the south-west and the south part of the Toplica region. In the south of the town Kursumlija, there exists a cluster of high scores. The model scores near the mountain of Vidojevica, 25 km south from the town of Prokuplje are also high (Fig. 2). These areas are located in the sparsely populated urban area. Other isolated patches of good GIS model scores are located in the towns and that are not good area because of the high of slopes directions. Although GIS model scores vary significantly, the potential solar data indicate that there is only a slight difference between model classes since most of the Toplica region receives sufficient insolation (see Fig.2). The site in Kuršumija municipality is close to a good network connection line, so the potential to deliver solar power to the region is unlimited. The other parts of the Toplica region have medium or small results of GIS score. More than 12% of the area is not within the range and don't have a result. The results it's from 0.1 to 65%, on the 55% of the area, 65.1 to 80% is on the 11% of the area, 80.1 to 90% is on the 17.1% of the area, and only 4.9 % of the area has the highest score for the solar potential. The solar farms should be built if the model score is more than 70%. That is a score sufficient enough to use the solar potential.Road networks and densely populated settlements are not gods for explorations.

4. DISCUSSION

Place of a great solar potential. Some solar panels already exist in the Topolica region. Some of them are located near the Kosovo border (Merdare, for example). In the mountain of Jastrebac GIS, multi-criteria scores are >30%. The lowest scores are on the hills in the north-west of the mountain Jastrebac, with the medium altitude 200-350 m. On the south-west part of the region, all places receive high total direct insolation. Around 4.9% of the area belongs to the classes of the solar GIS model from 90.1-100%. This part of the area (109 km^2), in Serbia, is not small. The solar potential GIS model may be useful as a filter to find areas that are comparatively more suitable. This multi-criteria GIS analysis is a good pathway for the future discovering of places with a solar potential, because of the filtering potential the potential places and divided into classes ("see Fig. 2.").

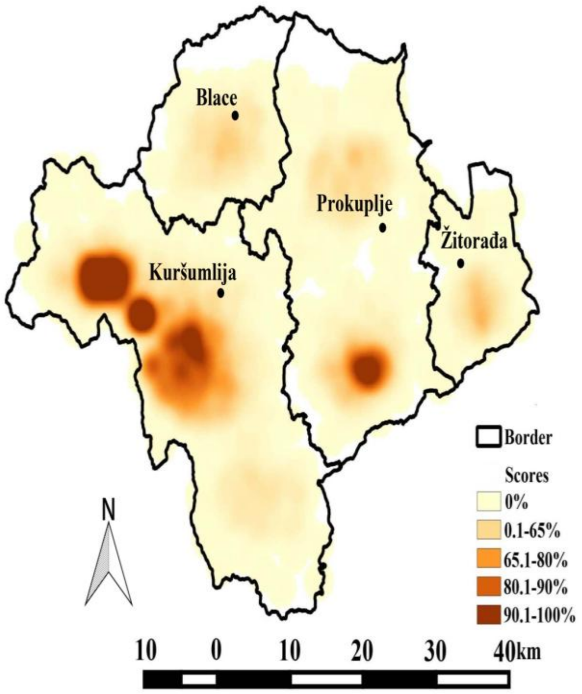

Fig. 2. Map of average solar potential in the Toplica region. Drawn by Aleksandar Valjarević.

5. CONCLUSION

The total area of the Toplica region is 2231km^2 divided into five classes. The first one has no scores, and they cover 12% of territory or 268 km^2. Other classes 0.1 to 65% cover 55 % of the territory or 1227 km^2. The result of 65.1% to 80% of area 245 km^2 or 11%. The result 80.1 to 90% has the total area of 382 km^2 or 17.1%. And the best scores 90.1% to 100% have 4.9% of the area or 109 km^2. Although GIS model scores vary significantly, potential solar data indicate that there is only a slight difference between the model classes. Since the Toplica region receives a large amount of total direct insolation, it is more advantageous to evaluate the solar potential on a local scale for homes than for businesses. The Toplica region gives a great opportunity for building new solar panels and solar farms. South-east Serbia and the Toplica region have a good chance for new renewable sources in the future.

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