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Evaluation of natural conditions for site selection of ground-mounted photovoltaic power plants in Serbia

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ABSTRACT

In recent decades, many countries tend to increase the use of renewable energy sources. Serbia has good natural conditions for the exploitation of solar energy. This paper integrates geographic information system and multi-criteria evaluation approach in order to select the best sites for development of ground-mounted photovoltaic power plants. The spatial suitability index was calculated for the whole territory of Serbia. It is shown that northern part, especially Banat region, possesses the largest potential for development of solar projects. Comparing obtained results with locations of existing photovoltaic power plants in Serbia, certain disagreements were noted. This is due to the application of exclusion criteria that except agricultural land even if the quality of the soil is poor. Beside the geographic distribution of suitable land, this study has shown that the largest electric power generation potentials have the City of Zrenjanin, Municipality of Novi Bečej, and Municipality of Čoka. Potentially, they can generate enough electricity to substitute whole yearly electricity production in Serbia. At the end, the subject of research was focused on the best ranked parcels, showing the potential electricity generation and the inter-annual variability in energy production based on module temperature.

1. Introduction

Sun is clean, free, and abundant energy source that could meet growing energy consumption in both developed and developing countries. Use of solar energy ensures the way for social and economic prosperity without environment pollution and impacts on climate change [1]. Many countries around the world are making significant efforts to evaluate their solar potential to formulate better strategic and planning documents, as well as, the incentives. It leads to expansion and sustainable development of the solar energy systems. In order to evaluate spatial suitability and selecting the most favorable areas for development of photovoltaic (PV) systems, it is necessary to collect and prepare certain data for selected criteria. Subsequently, the evaluation process is based on mathematical procedures, which usually require a lot of time and money, especially if they are carried out manually. With the development of multi-criteria evaluation (MCE) methods and Geographic Information System (GIS) it has become easier to obtain an optimal spatial allocation of photovoltaic power plants (PVPPs) [2]. GIS usually has many MCE methods [3]. It is able to handle, processing, and analyzing a large quantity of spatial data [4], and therefore it has become indispensable in many studies. Some authors, like Charabi and Gastli [5] considered the effect of temperature and dust when selecting the sites for large PVPPs using Fuzzy logic and GIS-based spatial MCE. Other authors [2–4,6] used Analytical Hierarchy Process (AHP) as common MCE method and more factors that have been classified into criteria groups (climate, location, orography, environment, etc.) to find the best sites for PVPPs. The AHP implemented in GIS environment was also used in this study.

The utilization of solar energy in the Republic of Serbia (hereinafter referred to as Serbia) is still at the beginning, although it is geographically positioned in southeastern Europe. Compared to Central Europe, where many solar plants already exist, the energy potential of solar radiation in Serbia is higher for 30% [7]. According to the International Renewable Energy Agency (IRENA), the estimation of the total installed PV capacity for the year 2015 in Serbia is 6 MW [8]. The northern part of Serbia has the highest values of annual average sunshine hours with ~2200 h per year [9]. It is not the case for average annual energy from global radiation with a peak of 1550 kWh/m^2/year in the south and southeastern parts of the country [10]. The lowest values of average annual energy from global solar radiation of 1240 kWh/m^2/year are in the northwestern

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part of Serbia [7]. It is equal to the highest one in Germany which is the second ranked country in the world according to total installed PV capacity of 37.9 GW [11]. So far, the economic situation in Serbia does not allow higher investments in such sophisticated technology. Based only on the currently available capacities of electric power system of Serbia for the provision of tertiary reserves, the maximum technically usable capacity of PVPP was estimated at 450 MW, i.e. their technically usable potential is 540 GWh/year [10]. This requires further research in order to better understand the potentials for development of PVPPs on the territory of Serbia. Pavlović et al. [12] used PVGIS program to calculate the annual sum of global radiation per square meter received by modules of different PV solar plants of 1 MW and their electric generation based on the geographical position for 23 locations in Serbia. In their study, Luković et al. [13] used Potential Incoming Solar Radiation module of SAGA (System for Automated Geoscientific Analyses) open source GIS software, and digital elevation model with the resolution of 90 m to get high resolution solar radiation maps for Serbia. Recent assessments of spatial suitability for development of PVPPs are usually performed for the single location or municipality, like in the study of Potić et al. [14], but never for the whole territory of Serbia.

Based on the aforementioned, the purpose of this paper is to indicate the most desirable sites for development of ground-mounted PVPPs in Serbia by taking into consideration natural factors which are classified into three groups: climate, orography, and vegetation. The aim of this paper is to find out the optimal spatial pattern for PVPP and to calculate the electric energy generation for the top ranked locations in Serbia using AHP and GIS. In addition, the intra-annual variations in the efficiency of PVPP based on module temperature were explored.

The paper is organized as follows: description of the study area, applied methods and used data is presented in Section 2 (Methods and materials); the obtained results with supporting explanations and case studies for selected areas are included in Section 3 (Results and discussion); and finally, conclusions are given in Section 4.

2. Methods and materials

2.1. Study area

Serbia is located in the southeastern Europe on Balkan Peninsula with mathematical coordinates 41.53°N–46.11°N and 18.49°E–23.00°E (see Fig. 1). The parallel of 45°N passing through the northern part of the country, administrative province Vojvodina, which means that Serbia is a middle latitude country with prevalent moderate continental climate. The total country area is 88361 square kilometers with a population of 7186862 inhabitants (without Autonomous Province Kosovo and Metohija) in 2011 [15]. The northern part of the country has an altitude less than 200 m

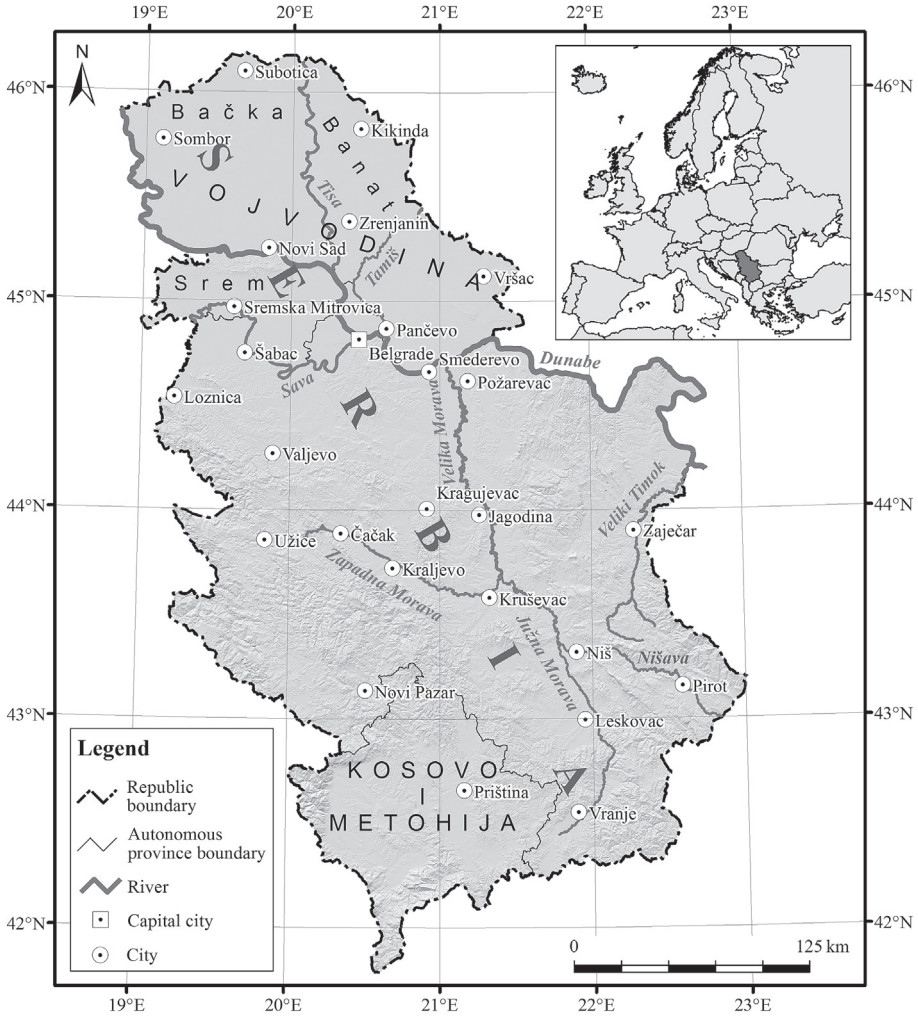

Fig. 1. Study area.