PRIRODNI I ENERGETSKI POTENCIJALI SOLARNE ENERGIJE NA TERITORIJI OPŠTINE VRANJE

NATURAL AND ENERGY POTENTIALS OF SOLAR ENERGY WITHIN THE VRANJE MUNICIPALITY

Vladimir ĆURIĆ*, Uroš DURLEVIĆ
University of Belgrade, Faculty of Geography, Belgrade, Serbia

U cilju sprovođenja održivog razvoja i smanjenja uticaja štetnih gasova na životnu sredinu, danas se u svetu sve više primenjuju obnovljivi izvori energije (OIE). Najveći potencijal od svih vidova OIE pripisuje se solarnoj energiji. Rad prikazuje analizu prirodnih i energetskih potencijala za izgradnju solarnih elektrana na teritoriji opštine Vranje. Primenom geografskih informacionih sistema (GIS), od prirodnih faktora obrađeni su i kartografski prikazani: nagib terena, ekspozicija reljefa, način korišćenja zemljišta i zaštićena područja. U analizi su uzeti i antropogeni faktori: blizina saobraćajnica i blizina naselja, od kojih zavisi pristupačnost potencijalne solarne elektrane, ali i mogući negativan uticaj na zdravlje ljudi usled prekomernog elektromagnetnog zračenja. Kabinetskim radom, metodom valorizacije i eliminacije dobijene su tematske karte. Obradom tematskih karata, dobija se finalna, sintezna karta pogodnosti primene solarne energije na teritoriji opštine Vranje. Analizom sintezne karte i dobijenih pogodnih lokacija, izvršeni su proračuni potencijalne instalisane snage solarnih elektrana za prostor Vranja, kako bi se dobio adekvatan prikaz količine električne enegije koja se može proizvesti fotonaponskim efektom u solarnim panelima.

Ključne reči: Solarna energija; Vranje; pogodne lokacije; energetika; GIS

Renewable energy sources (RES) have increasingly been used worldwide with the aim of implementing sustainable development and reducing the environmental impact of harmful gases. The most significant potential of all types of RES is attributed to solar energy. The paper presents the analysis of natural and energy potentials for the construction of solar power plants in the territory of the municipality of Vranje. The following natural factors were processed and mapped using geographic information systems (GIS): terrain slope, relief aspect, land use method, and protected areas. The analysis also allowed for the anthropogenic factors: the proximity of roads and settlements, affecting the accessibility of the potential solar power plant, but also the possible negative impact on people health due to excessive electromagnetic radiation. Thematic maps were produced by cabinet work, valorization and elimination methods. By processing thematic maps, the final, synthesis map of the benefits of using solar energy in the territory of the municipality of Vranje was obtained. By analyzing the synthesis map and suitable locations obtained, calculations of potential installed power of solar power plants for the Vranje area were made to get an adequate representation of the quantity of electric energy that can be generated by photovoltaic effect in solar panels.

Key words: Solar energy, Vranje; suitable locations; energetic; GIS

1 Introduction

The most considerable potential for the production of electricity from solar panels on the territory of Serbia is observed in municipalities located in the south and southeast of the country. Vranje is a municipality located in the south of Serbia, with an area of 857.3 km^2, which, according to the last 2011 census, counts 25839 households [1]. When it comes to renewable energy sources, the potential of this municipality is not negligible. It has long been known that Vranje and its surroundings have a large amount of high-temperature geothermal energy. The paper presents the analysis of locations suitable for the construction of solar power plants, which, together with geothermal ener-

* Corresponding author: vlado.curic@yahoo.com

gy, would supply the municipality with electricity. Almost all the renewable energy sources originate entirely from the sun [2].

It delivers more energy per hour than the earth uses in one year, it is free from pollutants, greenhouse gases and very secure from geo-political constraints and conflicts [3]. Solar photovoltaic panels play an extremely important role in electrical energy production in many countries [4]. Direct conversion of solar into electrical energy, the so-called photovoltaic effect, was observed almost two centuries ago, but only by the development of quantum theory in the early 20th century this phenomenon was explained and un-derstood [5]. Photovoltaic conversion of solar radiation takes place in PV solar cells made of semiconductor materials [6].

2 Materials and methods

GIS tools were used for the purpose of determining suitable locations for solar power plants. The method was cabinet work providing easily accessible data that could be largely used for the analy-sis of natural conditions and obtaining analytical and synthetic maps [7].

Five thematic maps were analyzed to obtain a synthesis map: terrain aspect, terrain slope, the method of land use, the proximity of roads, and the proximity of settlements.

The terrain aspect map (S_1) shows the solar exposure of the terrain, i.e. orientation of the terrain in relation to the Sun. Since Serbia is located on the northern hemisphere, the exposition in which the solar intensity is highest is southern, so the southern cardinal direction is most suitable for the con-struction of solar power plants in our country [7].

The terrain slope map (S_2) is a very important factor for solar energy potential. The most suita-ble terrains are those with an exceptionally gentle slope, for easier accessibility during construction of power plants and reduced risk of possible accidents whose chances increase with terrain slope [7].

The Corine Land Cover database [8], from which the classes of land use were taken, was used for the purposes of obtaining the land use map (S_3). Depending on the land use, valorisation was done based on the suitability for the construction of power plants [7].

The buffer zone around the roads (S_4) is a critical anthropogenic factor in determining the suitable locations and the subsequent realization of the construction of solar power plants. Accessibility to the construction of potential solar power plants depends on the proximity of the main roads.

Table 1: Buffer zone around roads

Buffer zone	Grade
0 – 300 m	5
300 – 600 m	4
600 – 900 m	3
900 – 1200 m	2
>1200 m	1

The buffer zone around the settlement (S_5) is an essential anthropogenic factor. Large areas under solar power plants operating on the principle of the photovoltaic effect in solar panels emit a large dose of electromagnetic radiation, adversely affecting human health.

In this paper, a 500 m buffer zone is set up around the settlement to protect the population from non-ionizing radiation. When it comes to protected areas, there are no protected green areas on the territory of the municipality of Vranje.

Based on the analysis of 5 maps, the final map of the advantages of the locations for the construction of solar power plants is obtained:

$$S_k = \frac{\sum_{i=1}^{5} S_i}{n} = \frac{S_1 + S_2 + S_3 + S_4 + S_5}{5}, \text{where}$$

S_k - synthesis map, S_i - individual maps, n - number of maps

By analyzing the synthesis map and locations most suitable for construction, a calculation was made to obtain the potential installed capacity of solar power plants. The processed factors include the area of solar panels, the area of the most suitable locations, the capacity of solar panels, and potential investment.

3 Results and discussion

On average, Serbia has more sunny hours than most European countries [9]. The lowest measured values in Serbia are similar to the highest ones measured in Austria and Germany, which are the leading countries in solar energy utilization [10]. The maps of terrain slope and aspect were obtained using the digital height model.

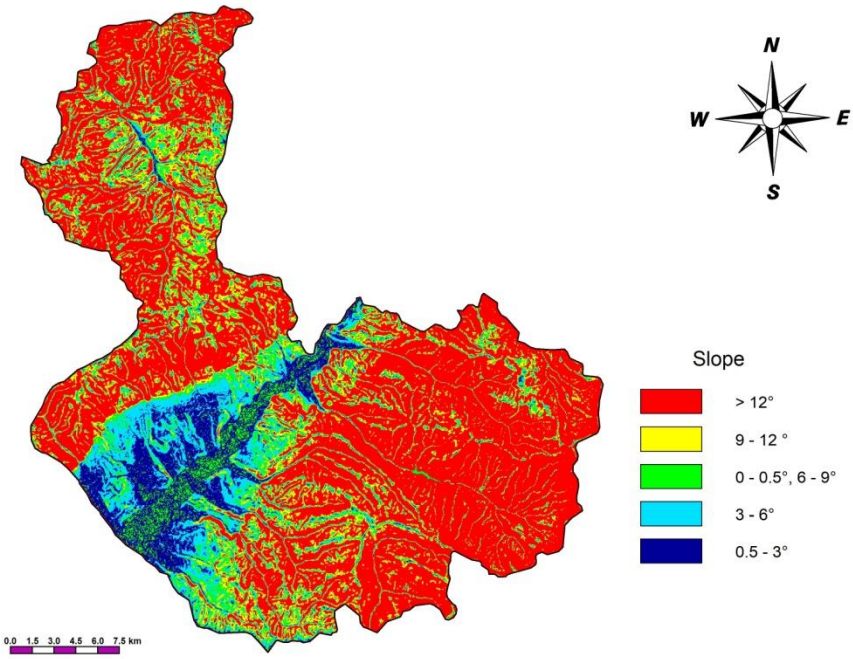

Figure 1: Terrain slope map

In the territory of the municipality of Vranje, a suitable slope of terrain is located in the valley of the South Morava. The most favorable terrain slope is 0.5 - 3°, which is best rated due to the availability of terrain for the construction of potential solar power plants, but also because of the stability of solar power plants. Flat terrains below 0.5° often impede normal water outflow, so water is often retained in this area after significant precipitations and due to the specific geological substrate. Due to inaccessibility during construction and difficult maintenance of power plants, high slopes are avoided [11].

Much of the southern, southwestern and south-eastern aspect is represented in the western part of the municipality. On sunny sides, the operation of solar panels is much more effective compared to the other directions.

The method of land use depends on natural and anthropogenic impact [12]. The most suitable areas for the construction of solar power plants are unirrigated agricultural areas that are mostly represented in the southwestern part of the municipality. A large part of the municipality is under deciduous forests, so it is necessary to protect forest ecosystems against anthropogenic impact.

The buffer zones around roads and settlements are fixed protection zones that play a role in the accessibility of the construction of solar panels, but also protection against non-ionizing radiation.

In the territory of the municipality of Vranje, about 16 km^2 of the area is estimated to be exceptionally favorable. However, this area should be combined with the locations rated 4 to more comprehensively observe the space for the application of solar energy.

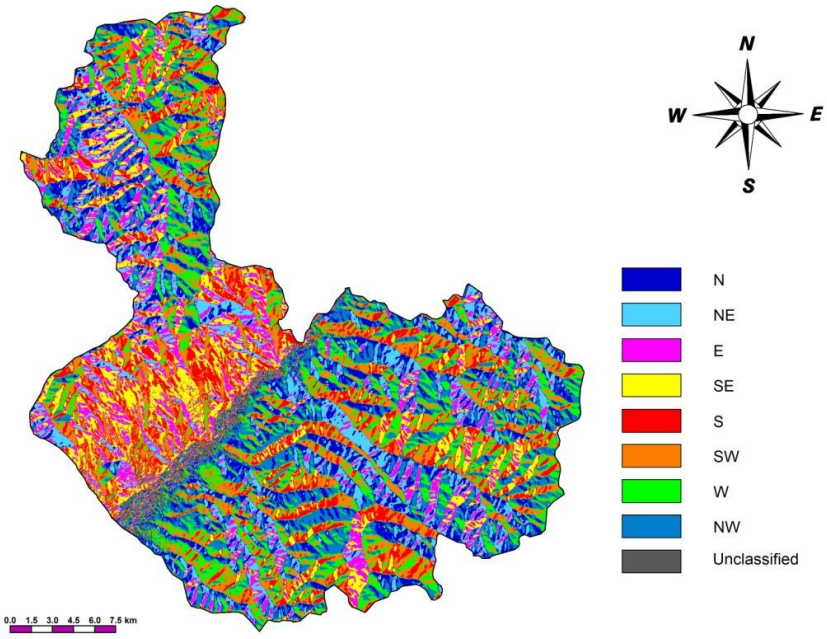

Figure 2: Terrain aspect map

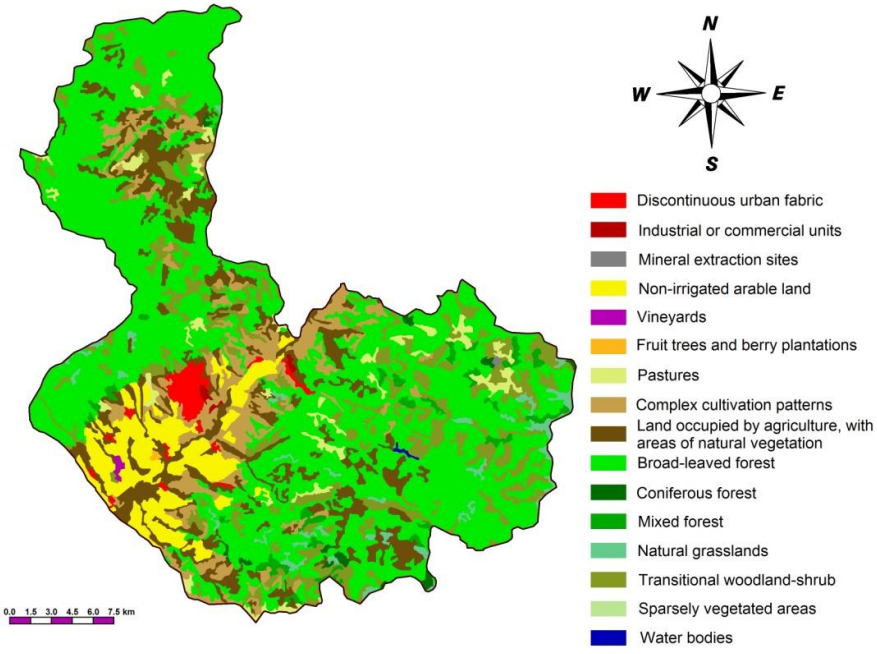

Figure 3: Land use map

Table 2: Evaluation of location benefits in the territory of the municipality of Vranje

Ratings	Area (km^2)	Share (%)
1	124.96	14.58
2	433.32	50.54
3	194.58	22.70
4	88.29	10.30
5	16.16	1.89
Total	857.31	100.00

According to the available data, 25839 households with an average of 3 family members settle the municipality of Vranje.

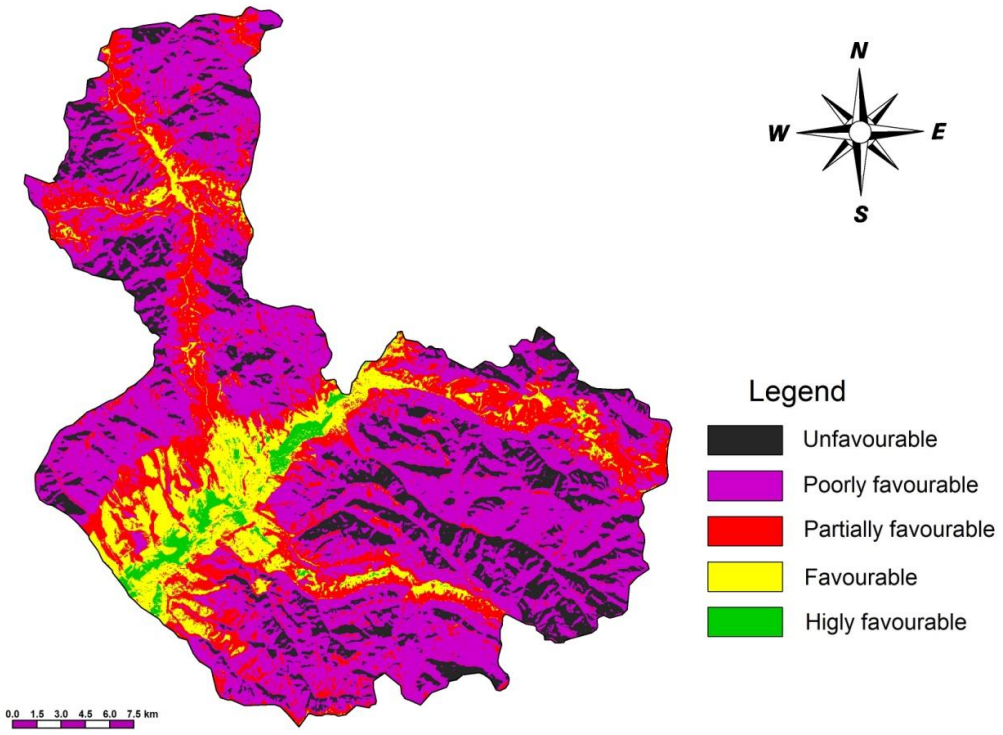

Figure 4: Sythetic map of sutability

After the model of the solar power plant in Kladovo and by additional calculations, it is possible to determine the amount of installed capacity of the solar power plant necessary to supply the municipality of Vranje with energy.

To obtain the required area, it is first necessary to calculate the potential installed capacity.

$$E_w = B \cdot P, \text{ where}$$

Ew - potential installed capacity in Watts (w), B – number of households, P - required installed capacity per household (in this case, it is 6000 W).

$$P\ (m^2) = \frac{Ew}{Pp\ (w)} \cdot Sp \cdot 3.5, \text{ where}$$

P - area required for solar power plant, E_w - potential installed capacity expressed in Watts, Pp - capacity of the solar panel expressed in Watts, Sp - the area of one panel in m^2, 3.5 is the space coefficient.

Following the principle of sustainable development, energy needs to be used rationally. That is why the calculation allows for the capacity of 6000W as sufficient for one household. The capacity of a panel is 275 W, and its area is 1.72 m^2.

Table 3: Capacity of the existing and potential solar power plant

Municipalities	Kladovo	Vranje
Installed capacity	2 MW	155.03 MW
Area of land	4,5 ha	339.38 ha (3.39 km^2)
Number of photovoltaic panels	Around 8400	563.760

Based on the calculation, it can be said that almost 3.4 km^2 is needed for the construction of a solar power plant. Due to the favorable latitude, a large number of sunny hours (in Vranje valley 2150 [13]), as well as the area of locations suitable for solar power plants, it is possible to build a solar power plant in this municipality that would supply the entire local population with electricity.

An investment in such an environmentally friendly venture would amount to 150-200 million euros. A large part of the costs could be covered by the organizations of the developed countries,

which at the conference held in Copenhagen in 2009 expressed their readiness to allocate significant resources (up to $ 100 billion annually) to assist developing countries and their transition to clean energy [14].

4 Conclusion

Suitable locations for the construction of a solar power plant in Vranje were identified using the GIS. The land area is sufficient for the application of solar energy to be environmentally justified and economically acceptable. An environmental impact assessment should be done to meet all the environmental criteria. In the future, the municipality of Vranje could be a "green municipality" in terms of renewable energy sources. Solar energy would be used for generating electricity, and geothermal energy could be deployed to obtain thermal energy, so the use of energy coming from coal combustion would be abandoned completely.

The transition from non-renewable to renewable energy sources will improve the quality of people's lives, but it is necessary to change consumer habits and rationally use electricity to make it accessible to everyone. The goal of sustainable development is to achieve economic and ecological balance. The whole project would be economically justified, environmentally acceptable, and would positively affect the quality of people's lives by reducing greenhouse gases and increasing the quality of air, water, and land.

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