12th International Scientific Conference on Energy and Climate Change
9-11 October 2019, Athens - Greece

The application of ArcGIS for assessing the potential of solar energy in urban area: The case of Vranje

Boban PAVLOVIĆ
Junior researcher, Faculty of Mining and Geology, University of Belgrade
Milica PEŠIĆ-GEORGIADIS
Teaching assistant, Faculty of Mining and Geology, University of Belgrade

Presentation Content

- Introduction
- Literature Review
- Methodology
- Solar Analyst Tool
- Land Cover Data
- Case of Vranje
- Results
- Conclusion

Introduction

- Methodology for the application of Solar Analyst Tool (Area Solar Radiation) for the estimation of solar energy potential in urban areas.
- The estimation of insolation/solar radiation energy – one of the most important factor for the optimal use of solar panels.
- Generally, solar energy potential depends on:
  - Latitude,
  - Terrain morphology,
  - Atmospheric conditions,
  - Solar irradiance,
  - etc..

➡ All the parameters above were used in the proposed methodology for assessing the solar energy potential in urban area.

Literature Review

- Various types of models for creating the solar maps. These models can be useful for predicting solar radiation in areas without measured data.
- The models are usually connected with computer software applications, with most using ESRI's ArcGIS as their base system.
- Many of the necessary capabilities, such as abilities:
  - to construct or import digital elevation models,
  - to integrate diverse databases for input and output,
  - to access viewshed analysis algorithms that permit assessment of sky obstruction and reflectance, etc.

  are now widely accessible from GIS platforms.
- **Solar Analyst Tool (SAT)** - extension module of ArcGIS, which derives a solar radiation map based on the input digital elevation model (DEM).

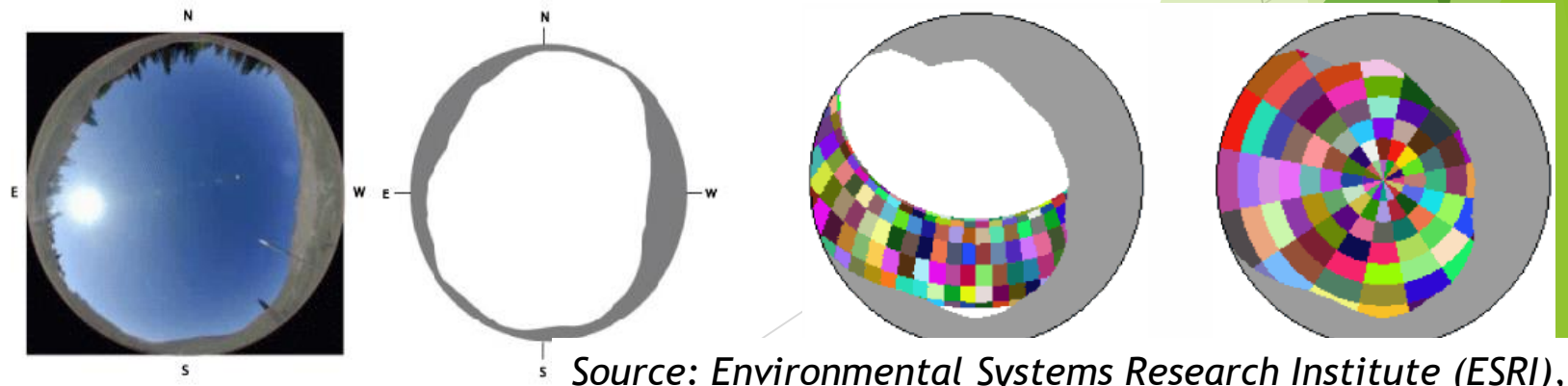
Methodology

1. For the calculation and mapping of solar energy it is used the methodology developed by Fu and Rich (1999, 2000, 2002).
   - DEM
   - Latitude for the site area - based on input DEM
   - Sky size - the resolution of the viewshed, sky map, and sun map rasters that are used in the radiation calculations (units: cells per side)
   - Time configuration - 4 options (winter and summer solstice, Calculation within one day, Multi-day, Within one year)
   - Day interval - data required to analyze the position of the Sun over time. The auto-set interval is 14 days (not recommended to be shorter than 3 days)
   - Hour interval - for calculation of sky sectors for sun maps. The recommended value is 0.5
   - Topography parameters: Z factor , Slope and aspect…
   - Solar radiation parameters: Zenith and Azimuth divisions, Diffuse model type, Diffuse proportion, Transmittivity
2. For the determination of the urban area it is used the CORINE Land Cover Open Data – the product of the visual interpretation of high-resolution satellite imagery

Solar Analyst Tool

- The SAT calculation involves four steps:
  1. The calculation of an upward-looking hemispherical viewshed based on topography;
  2. Overlay of the viewshed on a direct sun map to estimate direct radiation;
  3. Overlay of the viewshed on a diffuse sky map to estimate diffuse radiation;
  4. Repeating the process for every location of interest to produce an insolation map.
- The SAT generates an upward-looking hemispherical viewshed. A hemispherical viewshed is similar to upward-looking hemispherical (fisheye) photographs, which view the entire sky from the ground up, similar to the view in a planetarium.
- The hemispherical viewsheds are used to calculate the insolation for each location and produce an accurate insolation map.
- The total amount of solar radiation, entitled in the SAT as Global radiation ($Global_{tot}$), is calculated as:

$$Global_{tot} = Dir_{tot} + Dif_{tot}$$



Source: Environmental Systems Research Institute (ESRI), 2014

Solar Analyst Tool

Advantages:

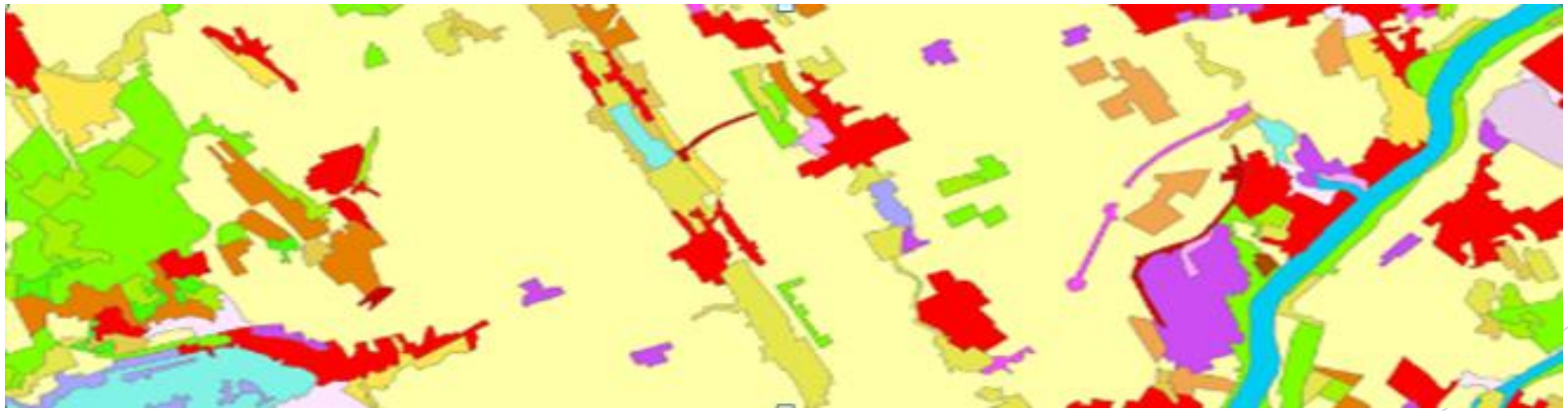
- Various outputs (direct, diffuse, global radiation, and direct radiation duration, sun maps and sky maps);
- Simple input
- Flexibility
- Fast and accurate calculation;
- User-friendly interface.

Disadvantages:

- Resolution limitation;
- Inaccuracy of the DEM;
- Simulation of clear sky can lead to overestimated solar energy potential.

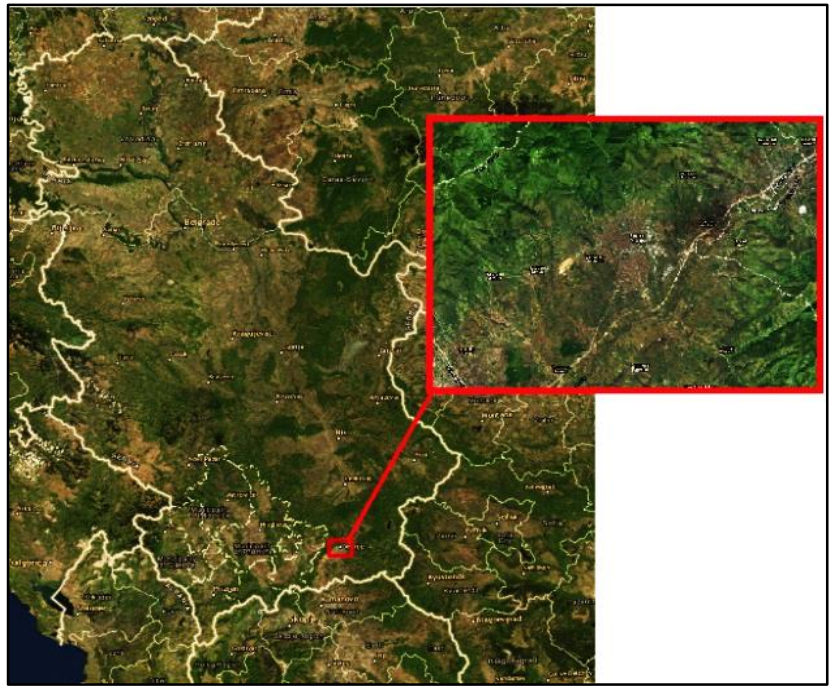
Land Cover Data

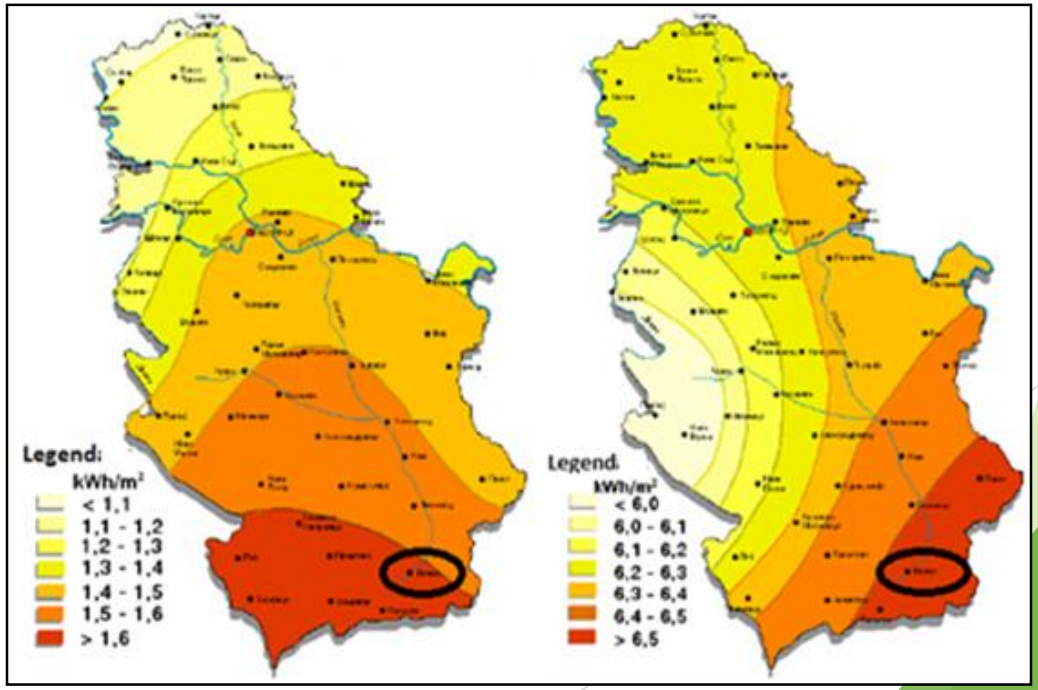
- Data from CORINE land cover (CLC) is generated by the processing of high-resolution satellite images and they provide information about land cover changes in the major part of Europe. Polygonal entities represent a state of land cover differentiated in 44 classes.
- Using the ArcGIS software (ArcMap) it is possible to extract the urban area from CLC data, originally defined as a class of Urban fabric, which is consisting of the next subclasses:
  - No. 111 - Continuous urban fabric, and
  - No. 112 - Discontinuous urban fabric.



Case of Vranje

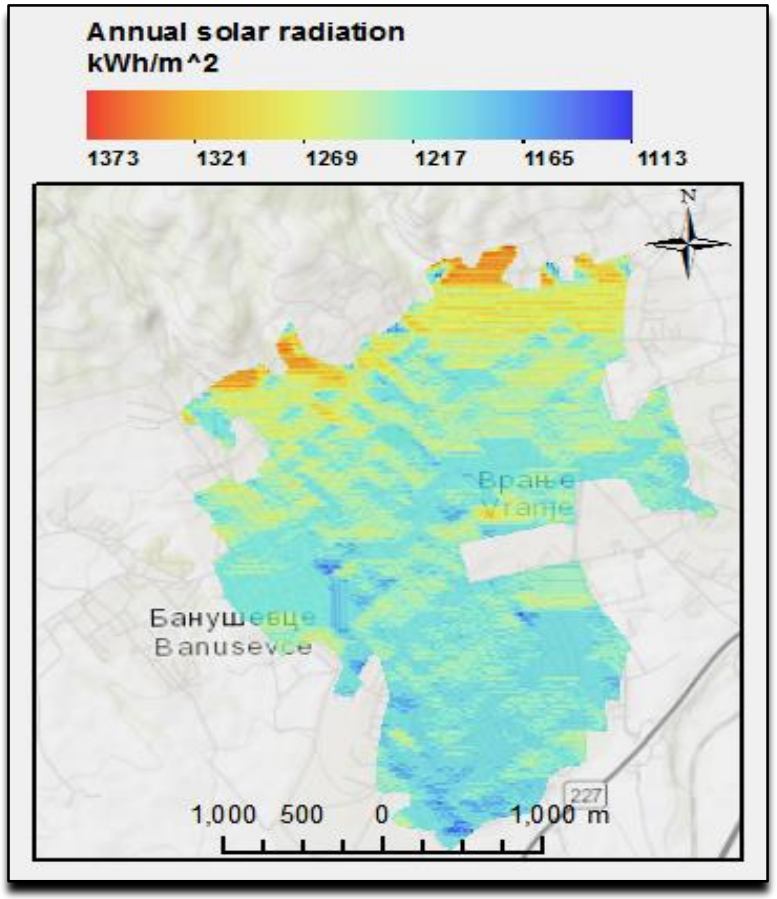
- Serbia has an average of about 272 sunny days and about 2,300 sunny hours, which is more than the European average.
- Annually, the average value of the overall solar radiation energy for the territory of the Republic of Serbia ranges from 1,200 kWh/m^2, in northwest Serbia, to 1,550 kWh/m^2, in the southeast Serbia. The average daily solar radiation energy in Southern Serbia for a flat surface during winter is 1.7 kWh/m^2, and in the summer 6.9 kWh/m^2.
- The City of Vranje is located in the southeastern part of Serbia. The DMS coordinates of Vranje are **42°33'5'' N 21°54'1'' E.**

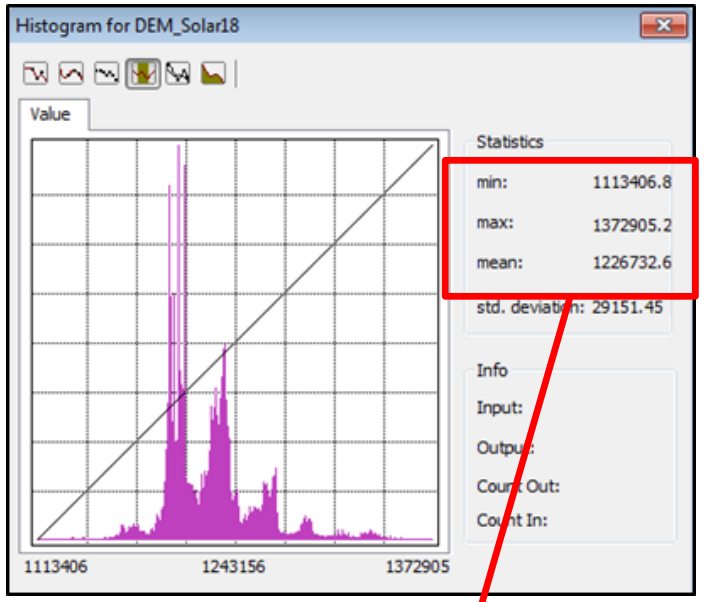


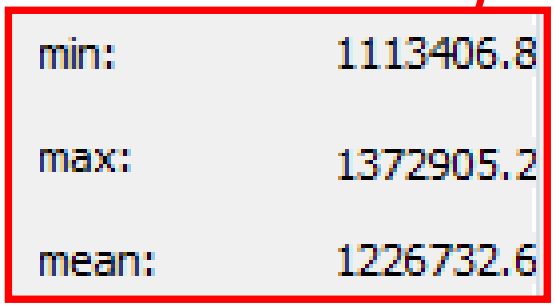


Results

- The amount of solar radiation energy/insolation during the year for the urban area of Vranje:



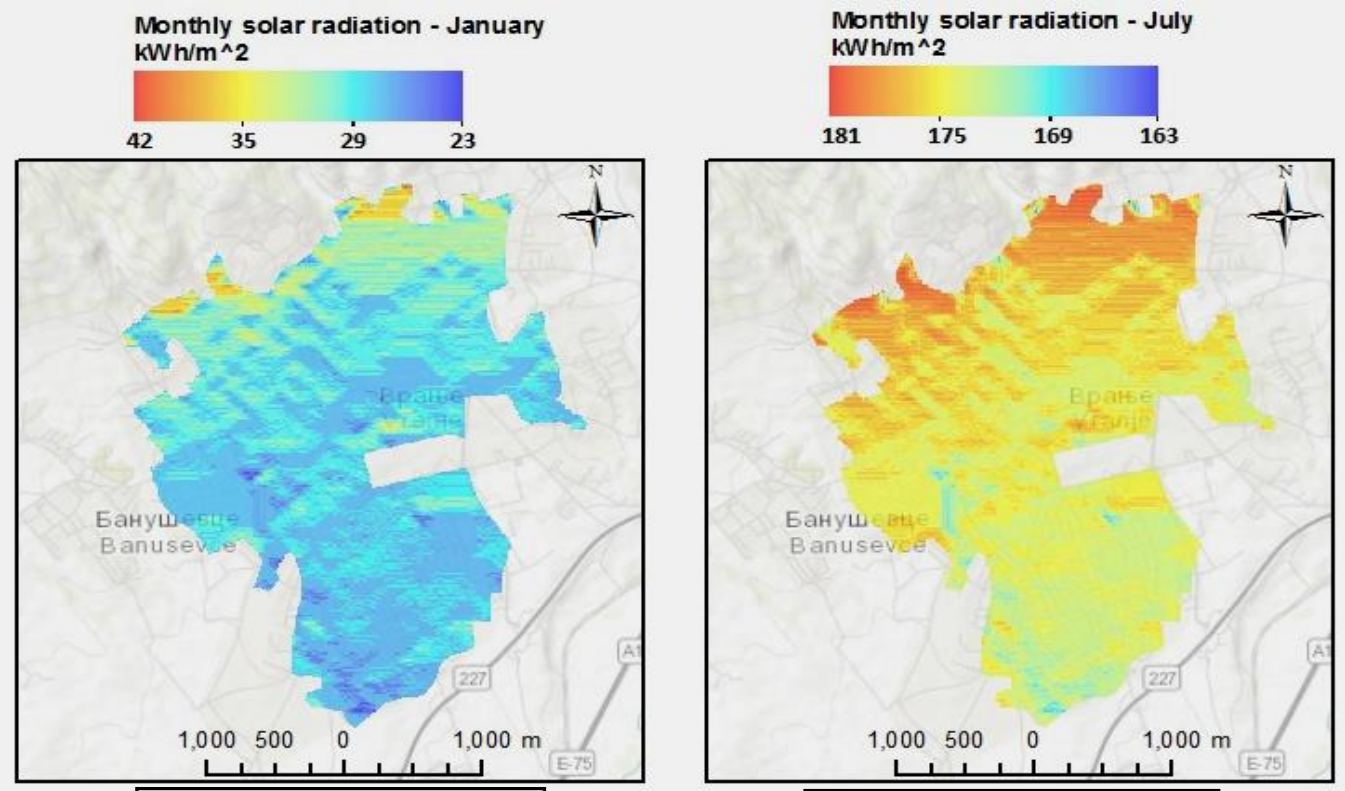




- The maximum amount of solar energy in certain parts of the area reaches a value of 1,373 kWh/m^2 annually (3.76 kWh/m^2 daily average).

Results

- Monthly values: January (left) and July (right)



- The maximum amount of solar energy in:
  - January - 42 kWh/m^2
  - July - 181 kWh/m^2

- The main advantage of this methodology is that it can give a quick estimation of solar energy potential for a specific space which there is no data about.
- The proposed methodology can be a good basis or a starting point for further technical and economic evaluations of the cost-effectiveness of using solar panels to generate electricity or for heating.
- A more detailed analysis would certainly include direct measurements of solar irradiation/insolation in the area, cost estimation, return on investment, analysis of land use and other factors affecting the use of solar energy.

Conclusion

THANK YOU!

Boban Pavlović

E-mail: boban.pavlovic@rgf.bg.ac.rs

Tel: +381654071990