Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. XI, 2022
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

OPEN-SOURCE GIS FOR TERRITORIAL PLANNING - SOLAR MAP OF TIMIȘ COUNTY, ROMANIA

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Abstract

The space regarded as land, as the primary support of mankind has undergone continuous evaluations as the source of raw materials, means of agricultural production, forestry source to the location of social and urban activities being thus an invaluable asset. The land's potential is invaluable, so that its efficient, correct, accurate management is a sine qua non condition for keeping it with all its benefits. In modern times, its management can best be done through the Geographical Information System. The territorial arrangement combines the balanced development of the exhaustible geophysical elements, respecting the cultural, social, traditional (historical) elements of the environment and helps to harmonize them and to avoid the negative evolutions. Territorial planning is the basis of sustainable development policies. The theoretical notions that support the realization of the case study - creating the solar map of Timiș county, Romania using open source GIS programs - are thoroughly documented, including aspects regarding solar energy mapping and the methodology of solar irradiation calculation as well as the current global context in which emphasis is put on the use of renewable energy.

Key words*: Open-source GIS, planning, solar map, sustainable development.*

INTRODUCTION

The major problem of space today, more precisely in relation to its lack, its affectation, its exhaustion, is that it is necessary to maintain a balance in its use and identify the benefits of urban planning and controlled and sustainable urban development.

Urban planning is a complex process of effective use of greenfield and urban land, involving urban design, transport infrastructure and the harmonious integration of existing and future buildings (https://www.britannica.com/topic/urban-planning). Urban planning, although by name seems to refer only to urban localities (municipalities, cities and fairs) is much more comprehensive covering any human settlement, regardless of size.

Sophisticated phenomenon, urban planning involves fields such as architecture, construction engineering, research, analysis, financing, strategic planning, public consultation, neighbourhood planning, strategic thinking, recommendations and limitations, historical preservation, implementation, management and, finally, buildings, roads and structures construction.

The actual changes of a territory are the result of the decisions adopted by real estate developers, corporations, traders, bankers, politicians, urban planners, civil servants, roads, architects, nongovernmental organizations, prospective home builders, of the economic development, ecological balance, social balance etc.

In order to overcome this chaos, a single general oversight, accepted by all these actors, must be established to produce integrity at all levels.

In this context, nowadays, there is a constant preoccupation for finding directions of action in order to improve the cities competitiveness.

We can consider the following action strategies as being of fundamental importance in order to improve the cities competitiveness:

- Creating and providing good quality public spaces;
- Modernization of infrastructure networks and increasing energy efficiency;
- Pro-active innovation and educational policies;
- Paying special attention to the disadvantaged areas in the context of the city as a unitary whole;

- Strengthening the local economy and local politics related to the labour market;
- Proactive education and education policies for children and young people;
- Promoting efficient and cheap urban transport (A report of the Global Agenda Council on Competitiveness. The Competitiveness of Cities. World Economic Forum, 2014).

The present paper aims at presenting a cheap solution which implies using open-source GIS software for mapping the solar potential of Timis County, Romania. This preoccupation falls under the action strategies mentioned above, namely increasing energy efficiency and can represent a solution for local authorities in order to increase Romanian cities competitiveness. By implementing such an approach it also brings added value to the urban planning process, as optimal decisions can be adopted with regard to the most suitable areas for placing solar panels.

MATERIALS AND METHODS

Renewable energy can bring a number of benefits to humanity and the natural environment. These are reflected in:

1) social: health improvement, consumer choice, greater self-confidence, job opportunities and technological advances;
2) environment: reducing air pollution, reducing greenhouse gas emissions, lower impact on reception basins, reduced transport of energy resources and maintaining long-term natural resources;
3) economic: job creation, cost reduction and economic diversification.

Thus, countries generally tend to increase the exploitation of renewable energy sources. For example, according to the energy sector development strategy for the coming period, a short-term objective is to increase the existing share of renewable energy sources (Pereec, 2004) to reach the highest gross consumption in 2020. Recent cost reduction of solar technology has generated an increased interest in solar energy exploitation, in particular. It is the largest energy resource on Earth and the International Energy Agency estimates that the sun could also be the largest source of electricity in the world by 2050 (International Energy Agency, 2021). The potential of solar energy is very high. Every half hour, the Earth receives from the Sun an amount of energy equivalent to the energy consumption of mankind for a whole year. That is why solar energy represents the energy alternative of the future (Moscovici et al., 2020).

This approach has led to a series of studies on solar potential of certain special geographical areas (Pereec, 2010) and the mapping of suitable locations for the installation of solar panels. Of particular interest is obtaining information regarding solar potential in urban environments, due to the advantages of producing energy closer to consumers. Moreover, a number of research studies dealing with models and methodologies for estimating the solar potential of buildings and the degree of roofs adequacy for the installation of photovoltaic systems have been carried out (Pinker et al., 2005).

Solar radiation is a key driving force for many natural processes. At the Earth's surface, solar radiation is the result of the complex interaction between the atmosphere and the Earth's surface. Solar radiation is a major driving force for physical, biological, hydrological and agricultural processes. The study of solar radiation is particularly important recently in the context of climate change. An overall decrease in solar radiation of -0.51 ± 0.0 W/m^2 per year was recorded between 1950 and 1980, which is 2.7% per decade (Wilde, 2009). This decrease phenomenon is known as global blur. In contrast, the opposite trend has been observed since 1980, and is known as the worldwide brightness, which is characterized by an increase in overall solar radiation (Pons, Ninyerola, 2008).

It has been documented that anthropogenic activities have been the basis of the increase in atmospheric concentrations of aerosols which could be the reason for the decrease of solar radiation (Protic et al., 2012). On the other hand, specialists in the field have shown that the reduction of aerosol emissions from anthropogenic activities in recent decades has contributed to an increase in solar radiation (Raaflaub, Collins, 2006). Suggesting a degree of uncertainty in previous conclusions, experts have emphasized the importance of anthropogenic aerosols in relation to local and regional solar radiation.

The analysis of the spatial model of solar radiation and/or irradiation is also of great significance. The spatial variability of solar radiation can be a key tool in ecological and economic planning, as well as for the development of renewable energy strategies. The spatial heterogeneity of the received solar radiation is determined by many factors besides atmospheric vapours and clouds, including topography, the coefficient of water reflection and the crowning of trees in green areas. Topography, and in particular altitude, slope and environmental conditions are major factors that determine the amount of incident solar radiation on the Earth's surface (Ramanathan, 2001).

In recent years there have been a number of initiatives to bring solar power closer to citizens, business and public local communities, and many are using solar maps as a tool to achieve this goal. In this context, the term "solar map" refers to an interactive cartographic web tool that provides various information related to the solar potential of buildings or greenfield, as well as the benefits related to this potential exploitation. The information helps potential users plan their investments in solar technology or include solar energy in their future projects and plans (Ruiz-Arias et al., 2001).

There are a number of recently developed and published urban solar maps. They have been produced using different methods and are intended to provide different levels of information, from very basic (for example, irradiation levels) to advanced (for example, the production of solar systems, financial considerations, installers etc.). It is expected that many cities will develop their solar maps in the near future.

Solar irradiation calculation methodology

In this study, SAGA GIS - open source software was used, (Vilceanu, 2017) in particular the module called “Potential Incoming Solar Radiation” (Unkasevic, 1997). The detailed description of the implemented methodology has been previously published (Bohner, Antonic, 2009). The authors recognized three main factors that have an effect on the spatial variation of solar radiation:

1) the relative orientation of the Earth in relation to the sun;
2) clouds and other atmospheric inhomogeneities;
3) topography.

SAGA GIS offers the possibility to enter many input parameters to model the received solar radiation potential; however the best option is to use Digital Elevation Model instead of individual terrain features such as slope, appearance, clear sky factor, shadow or geographical coordinates (latitude and longitude).

These input parameters cover the influence of the first and third main factors that have an effect on the spatial variation of solar radiation, that is, the relative orientation of the Earth in relation to the sun and topography. In order to take into account the impact of the second group of factors, represented by clouds and other atmospheric in homogeneities, information such as cloud cover is required.

Direct irradiation is a function of the solar zenith angle, solar flux at the top of the atmosphere, atmospheric transmittance, the angle of solar illumination on the slope, and the elements obstructing the sky.

The zenith angle and the solar flux depend on the calendar date, while the atmospheric transmittance is a function of altitude since the substances that absorb the energy decrease in proportion to the altitude. The angle of solar illumination (the angle between an orthogonal plane to the sun's rays and the ground) is a function of surface altitude (slope and aspect of the ground) and the relative position of the sun in the sky (sun orientation and azimuth) (Watson et al., 2003).

Daily direct irradiation $S^*_{S(d)}$ can be calculated by using the following formula:

$$S^*_{S(d)} = \sum_{i=1}^{n} S^*_{S(h)i} = \sum_{i=1}^{n} z_i \frac{S_{S(h)i}}{\sin\theta_i} \cos\gamma_i \quad (1)$$

where:

- $S^*_{S(h)i}$ represent direct topographic radiation per hour;
- z is the binary mask of shadow (0 = shadow, 1 = non-shadow);

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- θ - sun's orientation of the over the horizon;
- γ - sunlight's angle;
- n is the number of hours used to calculate daily radiation amounts.

In this study for n we have used 24 hours (time frame between 0a.m. to 24p.m.).

Diffuse irradiation $S(h)$ is the part of the total irradiation received from the sky hemisphere (Watson et al., 2003). It is a function of the solar geometry, the pressure (elevation) and the scattering and absorption properties of the atmosphere. It is necessary to calculate the sky view factor ψ_s to describe the portion of the sky that can be obstructed by the terrain topography for each individual location when modeling this solar irradiation partition:

$$\psi s = \frac{1}{2\pi}\int_0^{2\pi}[\cos\beta cos^2\pi + \sin\beta\cos(\Phi - \alpha)(90 - \varphi - \sin\varphi\cos\varphi)]df \qquad (2)$$

where:

- φ represents the zenith angle at the local horizon for the azimuthal direction Φ;
- β and α represent the slope, respectively the terrain's aspect.

ψs the sky view factor is a measure that quantifies the diffuse irradiation ratio at a certain point from that on an unobstructed horizontal surface. This parameter ranges from 1 (for the completely unobstructed terrain surface, such as the landscape of the plane horizon or peaks or ridges) to 0 for the completely obstructed terrain surface.

Topographic diffuse solar radiation S_h^* is calculated as:

$$S_h^* = S_h \, \psi s \qquad (3)$$

❖ Description of the study area

The geographical location of Timiş County gives it a privileged location, being the westernmost county in Romania.

It is bordered on the west by Csongrad County - Hungary and on the southwest by the province of Vojvodina - Serbia, the connection between the two counties being ensured by the border crossing points from Cenad, respectively those from Stamora Moravița and Jimbolia. The neighbouring Romanian counties with Timiş County are Arad to the North, Hunedoara to the East and Caras-Severin to the South-East.

Timiş, the largest county in the country ($8697 km^2$), benefits from a very varied relief: plain in the western and central part, hilly area continued with mountainous relief, in the eastern part.

The territory of the county is crossed by Timiş and Bega rivers, and the climate is pleasant, temperate-continental with Mediterranean influences.

Figure 1. Localization of Timiș County

From the point of view of urbanism and territorial planning, at present the entire territory of Timiş County is managed through the specialized GIS software, MapSys Internet Map Server, implemented within the County Council.

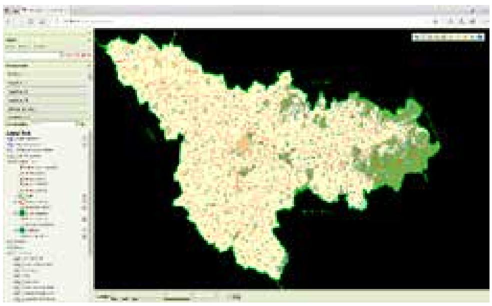

Figure 2. Overview of the Timiș County managed with MapSys software

The most important layers defined in the application include area town planning, detailed urban plan, electric wires network, territorial administrative boundaries, vegetation, roads, green spaces, ortophotoplans etc. which can be subject to geospatial analysis. The final product of the geospatial analysis consists of thematic maps.

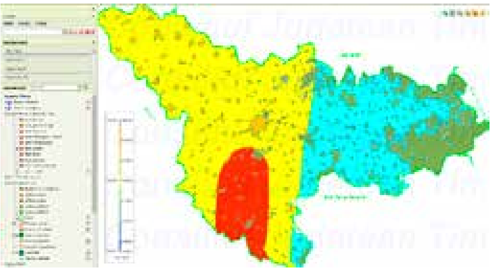

Figure 3. Thematic map with Timiș county seismic susceptibility

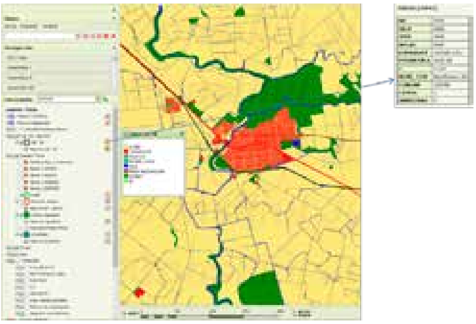

Figure 4. Thematic map with Timiș County land use

Sources of data

Creating the solar map for Timiș County, Romania using open-source GIS involved procuring, as initial geospatial data, the Digital Elevation Model - D.E.M., the administrative limits of the study area and the "sky clearness".

D.E.M. was downloaded from http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp, being part of the Shuttle Radar Topography Mission, 90m resolution. The file that covers Timiș county and was used for the study is srtm_41_03.zip.

Timiș county map was downloaded from http://www.gadm.org/country, a site which contains a database with the administrative boundaries of the countries.

The file is structured on 3 levels of administrative boundaries: for country - (0), administrative territorial units - (1) and municipalities - (2). For this study, ROU_adm1.shp has been used.

D.E.M. and the digital map were imported into the specialized QGIS program. The Clip raster with polygon function from the toolbar was used to crop the "tiff" image of the Digital Elevation Model from SRTM by overlapping it with the digital map.

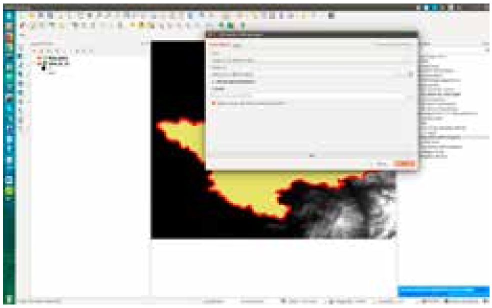

Figure 5. D.E.M. overlapped with administrative boundaries of Timiș County

But before executing the function it is necessary to select only the polygon that contains the region of Timiș County. When using the function, the user can choose to perform the processing including only the selected polygon, a possibility offered by the version QGIS 3.0. The goal is to get this D.E.M. which only covers the study area, then is saved for later use.

To download the "sky clearness index" we need to know the coordinates of the cell in the grid. These coordinates are in the WGS84 system and are found in the properties of the layer cut in the previous step, in the section "Metadata Properties". "Sky clearness index" is downloaded from the specialized site https://eosweb.larc.nasa.gov/cgi-bin/sse/subset.cgi based on the grid coordinates determined for D.E.M. cut only for Timiș County (Tables 1 and 2).

Table 1. The grid limits needed to be determined to download the "sky clearness index"

Limits	20.2637505219999987, 45.1937503549999988 22.5529170970000017, 46.1904169820000021

Limits	19,44 : 24,48

Table 2. "Sky clearness index" values for Timiș County

	44	45	46	47	48
24	0.68	0.68	0.68	0.68	0.69
23	0.67	0.68	0.68	0.69	0.70
22	0.69	0.69	0.69	0.70	0.70
21	0.69	0.70	0.70	0.71	0.70
20	0.69	0.71	0.71	0.71	0.71
19	0.68	0.72	0.72	0.72	0.72

RESULTS AND DISCUSSIONS

Solar radiation calculation involves having the data in a 2D projection system, so it is necessary to reproject the D.E.M. cut for Timiș County before the actual processing of the solar radiation. In this sense, the “warp (reproject)” function is used. Regarding the projection systems, we will select EPSG:4326 for the source and EPSG:31700 (equivalent of the Stereographic projection system 1970) as the target. Also during this stage, the user can select the type of interpolation to be bilinear or if the user types “0” the software does not use interpolation data in processing. The result of the reprojection is saved for use in subsequent stages.
In order to be able to create the solar map for Timiș County based on the geospatial data downloaded from the online environment, after the D.E.M. reprojection in the 2D system, it is necessary to create in QGIS a new layer in which to import the “sky clearness index” values. For this purpose, we used the Add Layer - Add Delimited Text Layer command.

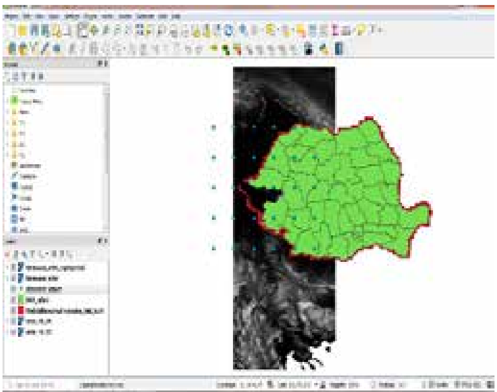

Figure 6. The result obtained after creating the layer with the “sky clearness index” values

After all the geospatial data has been introduced in the SAGA GIS software, the “Potential Incoming Solar Radiation” function is used (The European Solar Radiation Atlas, 2000). In the dialog box of this command, the user chooses the option “Total Insolation” and the time period for which we need to calculate the solar radiation.

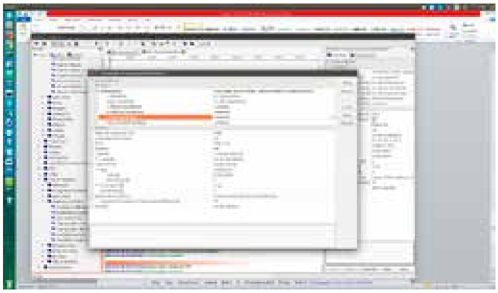

Figure 7. “Total Insolation” for a longer period of time

The actual calculation of the solar radiation is done from the menu Tools - Lighting Visibility - Potential Incoming Solar Radiation.
After the realization of the digital thematic solar map, through the open layers or qgis2web plugins available in GIS specialized programs such as QGIS and SAGA GIS (https://sagatutorials.wordpress.com/about-saga-gis/), we can position the solar map on Google Maps.

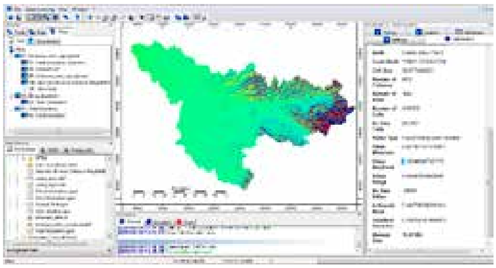

Figure 8. Solar map for Timis County, Romania

As it can be seen from the mapping of the Global Photovoltaic Power Potential (https://globalsolaratlas.info/global-pv-potential-study), Romania is suitable for developing strategies of implementing solutions based on green energy, in particular solar energy.
Being situated in a mostly plain area, Timis County has high solar potential high both for installing solar panels on residential houses and for developing projects for photovoltaic parks.
The map realized shows variability of the solar potential on the Timis County’s territory, as follows: the eastern part of the county is less populated as the relief is hilly in contrast to the western part where the solar potential is at a high value (being represented with light green).

The solar map of Timis County is a high scale precision map which can be further used to be uploaded into a platform that should represent a pillar of the national strategy for energy. This platform would benefit from adding small producers of green energy, geospatial information regarding wind energy and heat pumps energy produced in Romania. Implementing such a GIS platform can be extended in the future with more capabilities in order to answer to the needs of different users: both energy companies and residential users.

CONCLUSIONS

The economic and demographic evolution have led to the current situation where we are facing the shortage of spaces that ensure - at the same time - all the necessary uses without creating a conflict situation between them (for example, housing - green spaces - traffic areas).
Adopting strategies such as creating and ensuring good quality public spaces, modernizing infrastructure networks and increasing energy efficiency, pro-active innovation and educational policies, paying special attention to disadvantaged areas in the context of the city as a whole, strengthening the local economy and of local politics related to the labour market, the promotion of pro-active education and education policies for children and young people and of an efficient and cheap urban transport lead to an efficient territorial arrangement.
The actual estimation of solar radiation is of considerable interest in the sustainable planning of the environment and resources. Increased greenhouse gas concentration has led many governments to explore renewable energy sources. By the Kyoto Protocol signed in 2007, 175 countries have approved the implementation of the protocol, thus assuming responsibility for increasing the amount of energy produced from renewable energy, which includes biomass, geothermal, solar and wind energy sources. So far, the use of renewable energy in Romania is mainly based on hydro-power plants, biomass and wind farms to a small extent. Although in the first years the scope of the use of solar panels in Romania has been quite limited, in recent years this phenomenon has taken hold, energy production being subsidized through different projects and initiatives, considering the country's potential for using solar energy.
The "Green House" program started timidly with the support of the installation of solar panels in 2012 and continues today with the "Green House 2019" - regarding the financing by the Romanian State of the citizens who install their photovoltaic panels at home, approved by Order number 1287/2018 and "Green House 2021". In order for the citizens to make the most of this program, the authorities should implement a webGIS, freely available, with maps like the one created by the authors in order to find out if the region they live in is suitable for installing solar panels.
The methodology presented in this paper consists of a cheap solution which implies using open-source GIS software for mapping the solar potential, in particular for Timis County, Romania. The topicality of this research is given by the fact that it contributes in real time to increasing energy efficiency and can represent a solution for Romanian local authorities in order to increase cities competitiveness. By implementing such an approach it also brings added value to the urban planning process, as optimal decisions can be adopted with regard to the most suitable areas for placing solar panels.

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