The method of assessment of solar potential for selected area with use Geographical Information Systems

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1. Introduction

The main goal of this study is to analyse the spatial distribution of solar radiation, which is determined by numerous elements, such as: terrain, atmosphere, pollutants, water and aerosol in atmosphere, clouds.

The key problem is the solar radiation incident on a regional scale, i.e. the Lower Silesia region. In such a case, the major factor modifying the distributions of the radiation is the terrain (e.g. slopes and aspects). Apart from it, the local shadowing effects of the terrain are of no less importance.

Anther crucial element of the solar analysis is the cloud cover. As the clouds constitute a barrier for the sun radiation, the solar radiation models should include the cloud cover. This problem was examined in numerous studies and some authors used data from the local ground stations to determine the range of the clouds. However, such data is reliable exclusively for a region surrounding the station.

Summing up, all the above elements should be included to properly assess the spatial and temporal variation of the solar radiation. It is GRASS that gives such a possibility.

2. About r.sun

The r.sun is one of the GRASS commands, used to analyze the spatial distributor of solar radiation (Hofierka, Suri 2002). The parameters of the r.sun has already been described by Pietras (Pietras 2011).

R.sun model computes direct, diffuse and reflected solar irradiation raster maps for given day, latitude, surface and atmospheric conditions. Solar parameters (e.g. sunrise, sunset times, declination, extraterrestrial irradiation, daylight length) are saved in the map history file. The shadowing effect of the topography is optionally incorporated [-s option].

The user can use a superscript with variable day to compute radiation for some time interval within the year (e.g. vegetation or winter period, months).

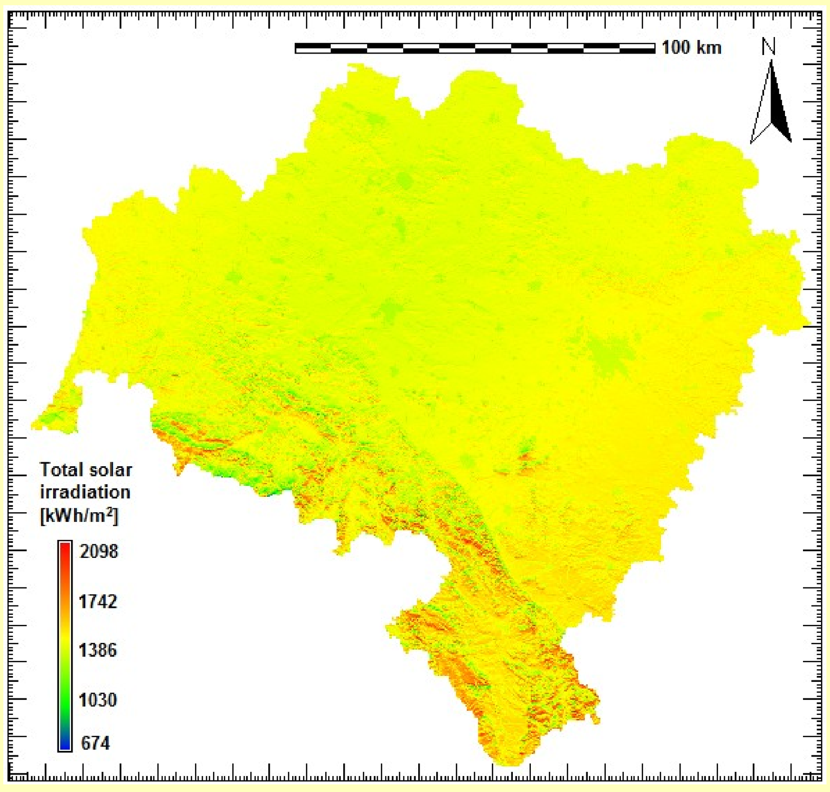

Fig. 1 Spatial distribution of solar radiation on Lower Silesia

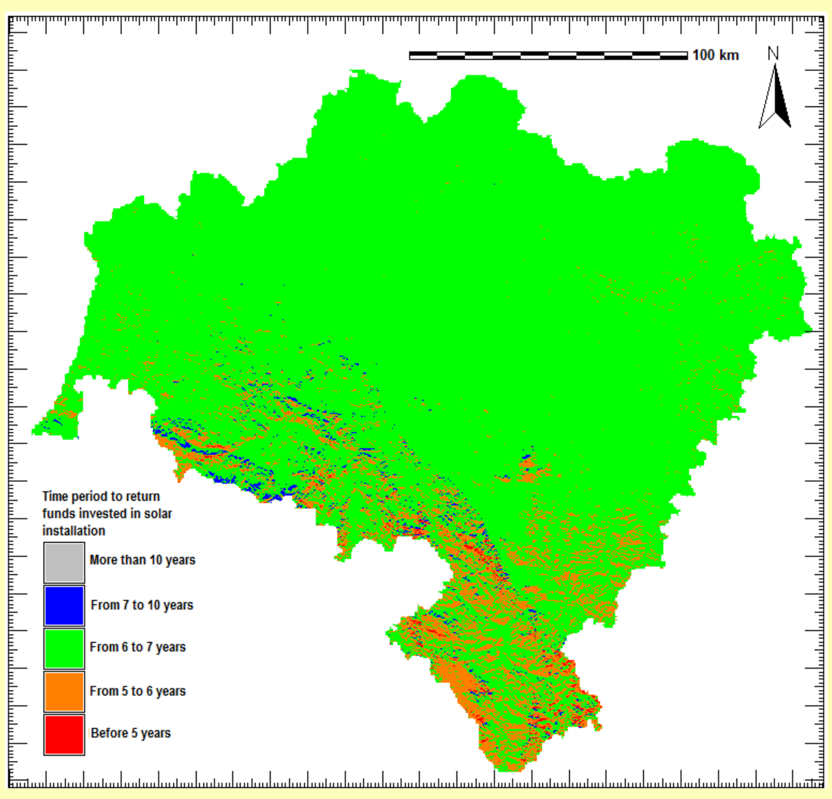

Fig. 2 Classification of the Lower Silesia region in terms of work efficiency solar installations

Tab. 1 Summary of r.sun model performance

Month	HelioClim[1] [kWh/m²]				r.sun [kWh/m²]			
	Wrocław	Kłodzko	Legnica	Jelenia Góra	Wrocław	Kłodzko	Legnica	Jelenia Góra
I	24,77	26,64	24,45	19,00	29,81	32,59	27,94	31,58
II	45,73	45,32	46,55	29,82	48,18	49,38	45,73	49,28
III	76,15	74,53	79,18	56,10	99,05	103,70	91,73	96,13
IV	127,43	123,87	135,97	96,96	153,89	159,36	145,20	150,70
V	164,80	167,93	159,16	125,47	189,57	195,00	179,03	183,45
VI	150,59	146,76	150,63	124,23	199,17	203,68	190,92	195,47
VII	138,39	136,16	137,44	115,60	201,10	205,43	192,78	194,13
VIII	158,24	152,03	156,64	118,13	171,09	176,44	162,52	166,01
IX	103,97	100,72	107,56	74,61	124,20	125,83	119,04	118,61
X	61,30	59,98	62,52	43,64	74,60	76,10	69,46	72,39
XI	31,68	33,24	32,09	23,33	34,53	37,10	31,37	34,93
XII	28,90	30,29	26,69	17,77	23,17	25,42	20,98	24,47
Year	1111,92	1097,47	1118,86	844,67	1348,36	1390,03	1276,70	1317,15

[1] HelioClim is a family of databases which comprise solar irradiance and irradiation values available at ground level. HelioClim cover Europe, Africa, the Mediterranean Basin, the Atlantic Ocean and part of the Indian Ocean. In this study HelioClim data was used as a reliable source for verification of results obtained through r.sun model.

3. Input data

Input data for solar analyses was the numerical model of a terrain for a selected area, the maps of the slopes and aspects, the atmospheric turbidity data, in this case a Linke Turbidity Factor (LTF) and cloud cover parameters Cc.

The model of the terrain used in this work had the resolution of 100 meters and covers the area of the Lower Silesia. The maps of the slopes and aspects were created with the use of the r.slope.aspect command in GRASS.

As for the atmospheric turbidity data, in this study it was gathered by the use of the Link Turbidity Factor (LTF). The size of this factor depends on the solar elevation angle, the water vapour and the contents of the aerosols in the atmosphere. The LTE coefficient medium value in temperate latitudes is 3.0, but in the cities where atmosphere is polluted its value may exceed 3.5.

Cloud cover parameters was calculated from the empirical formula proposed by Kasten and Czeplak (Kasten, Czeplak 1979).

$$Kc = 1 - 0.75(N/8)^{3.4}$$

4. Results

The use of the r.sun model to calculate the total solar radiation for the large area, covering the Lower Silesia region, gives good results, they prove to be compatible with the values obtained using HelioClim (Tab.1) and with measurement values (Tab.2). Results obtained with r.sun perfectly reflect annual course of solar radiation. The biggest difference between measurement and modeled value appear during the summer months and they are about a dozen kWh/m2 bigger then measurement value of irradiation in case of Wroclaw. In winter months it is difference only a few kWh/m2. (Tab.2).

The Pearson's correlation coefficient of the value measured and modeled with by r.sun is equal 0,98, which also proves the reliability of the results obtained by the r.sun model.

The map of the solar potential on the Lower Silesia region generated with use of r.sun module (Fig.1) would allow everyone to check the solar potential of their region.

Map of spatial distribution of solar radiation on Lower Silesia will broaden people's knowledge about the opportunity of use solar energy. This elaboration is dedicated to local communities, as well as for businesses concerning at the environment protection and the climatic change problems. This map is also a base to classify the Lower Silesia region in terms of work efficiency solar installation (Fig.2). It will gives people information about the date of the return of the funds invested in the purchase of the solar collectors.

Tab. 2 Model verification

Month	Wroclaw [kWh/m²]		
	Average 2001-2005	Model r.sun	Difference between modeled by r.sun and measured value
I	36,30	29,81	-6,49
II	49,74	48,18	-1,56
III	92,22	99,05	6,83
IV	132,84	153,89	21,05
V	180,80	189,57	8,77
VI	180,68	199,17	18,49
VII	154,52	201,10	46,58
VIII	155,24	171,09	15,85
IX	105,76	124,20	18,44
X	71,32	74,60	3,28
XI	40,06	34,53	-5,53
XII	30,52	23,17	-7,35

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