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Faculty of Earth Science and Engineering
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CALCULATION OF THE USEFUL SOLAR ENERGY WITH THE HELP OF GIS METHODS ON GIVEN DIRECTED AND TILTED SURFACES

Theses of Ph.D. Dissertation

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I. INTRODUCTION, RESEARCH BACKGROUND

By the 21st century, the providing of energy supply continuously and sustainably (both from an environmental and economic point of view) has reached the level that it can not be limited to the utilization of „traditional" energy sources, and also environment protection considerations made necessary the increase of the rate of alternative, clean energy sources in energy production. Although the technologies applied for the use of renewable energy sources (RES) can only partly meet the current energy demand, their use can directly slow down the exploitation rate of traditional energy sources, and can help develop or establish energetically autonomous areas(Árpási et al. 2006, Büki 2004, EREC 2010). The necessity for the use of RES is further increased by the globally palpable political and economic instability and the need to decrease the energy dependency of countries poor in traditional energy sources. So it is a must to examine and assess on the national and local level the amount of usable alternative energy sources that are at the disposal of a given country. By the 21st century the nations of the Earth have gone through significant technological and economic development, thus making possible the increase in the rate of using RES (Wilkins 2002). Thanks to the developed and well-functioning technologies the renewable energy sources of nature can be utilized safely, cleanly, sustainably, locally (local production – local utilization) and last but not least economically. *The technologies utilizing RES (which are applicable by the people in settlements as well) are getting more and more widely available and affordable and their time of return has also significantly shortened compared to earlier decades, so providing the population with data and information in adequate quantity and quality on RES utilizable by them has become a primary concern. By turning such information into databases local government RES databases can be established and these can contribute to the working out of different settlement, district and regional RES-utilization plans.*

Out of the alternative energy sources, it is solar energy that is most easily utilizable by the population through solar cells and also it is the one that generates one of the most jobs in the sector of RES, plus it has extraordinary utilization potential due to the extent of roof surfaces (IRENA 2011, IRENA 2014).In the past 15 years it has had the biggest capacity extension among renewable energy sources. (Figure 1).

From the middle of the 20th century, the GIS (Geographical Information System – Földrajzi Információs Rendszer) environment has reached a level that by conducting the different geoinformatics and remote sensing processes and methods, quite exact RES-potential estimations can be carried out and published through web-based information service (Lang 1998, Pellegrino et al. 2008). In the United States and in some Western European countries (Germany, Great Britain, Austria) there have already been published so-called solar cadastres on the settlement level to define and present to the population the utilizable potential of solar energy. (Agugiaro et al. 2010). *A solar cadastre is basically a register database including the solar energy potential utilizable by the roof surfaces of a settlement, a district or a region and the radiation amount*(based on www.meteonorm.com). *However, in Central Eastern Europe no roof surface-radiation cadastres using geoinformatics* *methods have been published apart from two different researches(Czech Republic, Slovakia – Hofierka et al. 2009, Hungary – Munkácsy et al. 2008, DEnzero 2014).*

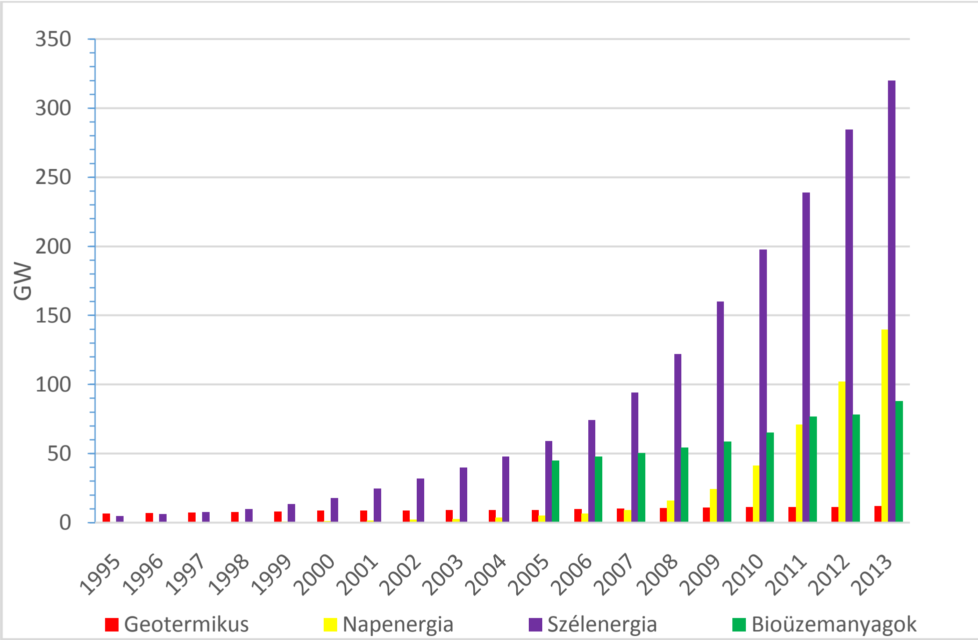

Figure 1 Globally used powerby RES
source: made by L. Szalontai on the basis of BP Statistical Yearbook 2014, Enerdata - Global Energy Statistical Yearbook 2014.

My research focuses on the most possibly exact calculation through geoinformatics methods of the utilizable potential of solar energy. Special attention is paid to the radiation-modifying effects of the inclination angles, exposures of roof surfaces providing space for devices utilizing solar energy, atmospheric parameters and land objects near buildings (greenery, higher buildings). These effects have not been researched thoroughly in Hungary so far.

II. Aims of the study

I have set as the main target of my research ***the working out of the methodology of a solar cadastre based on geoinfomatics conforming to the data of an authentic Hungarian global radiation measurement using data/databases available to local governments as well***.

To reach my set targets I have defined several sub-tasks to do as follows:

- examination and analysis of energy policy and energy utilization during the 20th and 21st centuries, paying special attention to solar energy utilization;
- examination of the investment rate in renewable energy sources;
- presentation of equipment and technologies utilizing solar energy;

- presentation of the process of solar energy formation, energy transmission and of factors determining radiation amount;
- presentation of types and methodologies of international radiation measurements and models;
- finding the common intersection of geoinformatics and remote sensing methodologies related to solar cadastres, through processing international and domestic research history
- searching for data and databases necessary for the working out of a Hungarian solar cadastre;
- parametering of atmospheric factors (dispersal – transparency factor) through using the data calculated and measured for the sample area;
- radiation modelling on the sample area, then comparing data to national and international measurement results
- searching for and naming of further domestic and international utilization opportunities of solar cadastres.

III. METHODS

To further substantiate my research I have also used secondary data sources. I have obtained the different energetics, social and other statistical data from the online and paper-based statistical yearbooks and databases of Központi Statisztikai Hivatal (KSH – www.ksh.hu) for Hungarian data and EUROSTAT (http://ec.europa.eu/eurostat), BP Statistical Yearbook 2014, 2015, CIA – The World Factbook 2014, Enerdata, Bloomberg Finance, Solarbuzz, OECD Statistical database (http://data.oecd.org), 2014 World Development Indicators - 2014 International Bank for Reconstruction and Development (http://data.worldbank.org/), Enerdata - Global Energy Statistical Yearbook 2014, Eu Energy Country Factsheets 2014 version 3.0, Eu Energy in Figures 2014: Statistical Pocketbook, GSR 2014: Renewables 2014 Global Status Report, U.S. Census Bureau, International Programs 2008, World Resources Institute – WRI Climate Analysis Indicators Tool (CAIT 2.0) – WRI's climate data explorer, (http://cait.wri.org) for international data.

To get authentic, measured meteorologoical data I have used one of OMSZ's (Országos Meteorológiai Szolgálat – Hungarian National Meteorology Service) services, as they provide limited data for research purposes free of charge, and this way I have obtained a daily breakdown of radiation data for the period between 2008 and 2012. A further source of information was the Hungarian Climate Atlas (series) issued by OMSZ, which include further important climatology data.

Further data sets and databases on global radiation (in case of horizontal and best inclination angles) and ratio of *direct/diffuse radiation*, are provided by the database of JRC PVGIS (http://re.jrc.ec.europa.eu/pvgis), and the database of CARPATCLIM (carpatclim-eu.org), which shows homogenized and interpolated results based on (up to 50 years) of measurements done by meteorological measuring stations in the Carpathian Basin. I have obtained authentic, calculated data regarding all and the potential radiation amount arriving on the outer boundary and the surface of the Earth from the database of Solar Radiation Data (www.soda-it.com). For the alternative determination of meteorological parameters I have used the method for parametering the diffuse radiation and transmissivity factors created by James Dyer, researcher of University of Ohio in the US, for the ArcGIS software (Dyer 2009, Dyer 2015).

I have processed the different digital geoinformatics files, hill models, surface models and the statistical calculations, radiation modelling on them through geoinformatics company ESRI's ArcGIS 10.x software and its accessories. For working out the methodology of the solar cadastre created by myself, an excellent basis was provided by the international, geoinformatics-based, settlement-level solar energy potential calculations and models (including, but not limited to) Sojer (1991), Wittmann – Bajons (1997), Winter (1994), Duffie – Luther (1991), Sandner (1993), Riecken (2012), Kassner et al. (2008), Redweik et al. (2011), Hofierka – Kanuk (2008), Izquierdo et al. (2007), Leitelt (2010), Wiginton et al. (2010), Rylatt et al (2001).

The basis of modelling, the point cloud from laser distance measurement (LiDAR) 2013-ban a was created within international project (number HUSK/1001/2.1.2/0009) realized by the Geography-Geoinformatics Institute of the University of Miskolc titled „Flood modelling and the building of the logistic system supporting flood relief - FLOODLOG". The LiDAR measurement was done bythe Remote Sensing and Rural Development Research Institute of Róbert Károly College, Gyöngyös.

During the research I visited the mayors of the 12 settlements involved in the LiDAR measurement, and I got data, maps, digital maps regarding their respective settlement from them (*Settlement Development Plans*, *cadastres*), and I interviewed them about investments related to renewable energy sources in their settlements being realized or to be realized later.

IV. NEW SCIENTIFIC RESULTS

From the point coud of a LiDAR measurement I created the 25 cm-resolution digital surface model of the city centre of Edelény, my sample area, for which I did the global radiation calculations. After working out the methodology of modelling I determined the calculation factors and did the radiation calculations. After comparing the results of these to the results of international researches and to the determining of factors and by using the 5 years of data sets measured by the OMSZ measuring station in Edelény every day, I have come to the following conclusions:

<u>Thesis 1.:</u> The specific monthly transmissivity and diffuse proportion factors could be determined with the help of the Dyer's parametrization method, which could be utilized as an imput parameter in the Solar Radiation – Point Solar module for calculating incoming solar radiation on horizontal surface (yearly, monthly, daily ammount) with high accuracy. Using the Dyer's method parameters the annual insolation value of the calculated global radiation is less than 1 % from many years average, as measured by the Hungarian Meterorological Service, while using parameters determined by the climate atlases and spatial analysis an 8 % difference arises between the measured and calculated values.

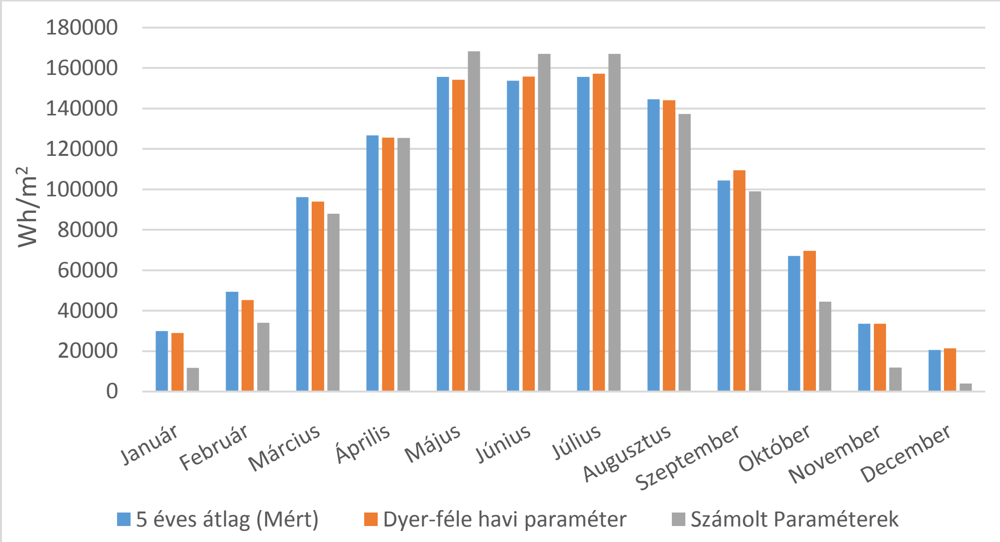

Figure 2: Radiation amounts measured on the coordinate of the Edelény measuring station and modelled with different climate parameters, source: OMSZ, prepared by: Szalontai L.

Table 1: Results of the radiation calculation done with different transmissivity and dispersal factors on the coordinate of the Edelény measuring station (horizontal point)

	OMSZ measurement	Dyer's parameter		Measured/calculated parameter	
	Global radiation (Wh/m2)	Global radiation (Wh/m2)	Difference (%)	Global radiation (Wh/m2)	Difference (%)
Jan	29847	29016	2,87	11776	153,47
Febr	49351	45200	9,18	34000	45,15
March	96194	93896	2,45	87989	9,32
Apr	126752	125512	0,99	125501	1,00
May	155647	154214	0,93	168287	7,51
June	153719	155821	1,35	167006	7,96
July	155607	157212	1,02	167066	6,86
Aug	144525	144083	0,31	137289	5,27
Sept	104385	109496	4,67	98937	5,51
Oct	67056	69539	3,57	44436	50,90
Nov	33456	33511	0,16	11797	183,59
Dec	20493	21279	3,69	3881	428,03
total	**1137031**	**1138778**	**0,15**	**1057964**	**7,47**

From the available data (measured and calculated transmissivity and diffuse proportion) the Dyer's parametrization process gives the best approximation of the HMS 5 year data series measured monthy and yearly average

As the factors received through Dyer's parametering provided the most exact calculation data regarding the amounts of radiation falling on horizontal surfaces , I used these for the area-based radiation modelling on high resolution digital surface model. (Figure 3). Then I compared the results to international and domestic low resolution, interpolated data regarding the sample area (Table 2).

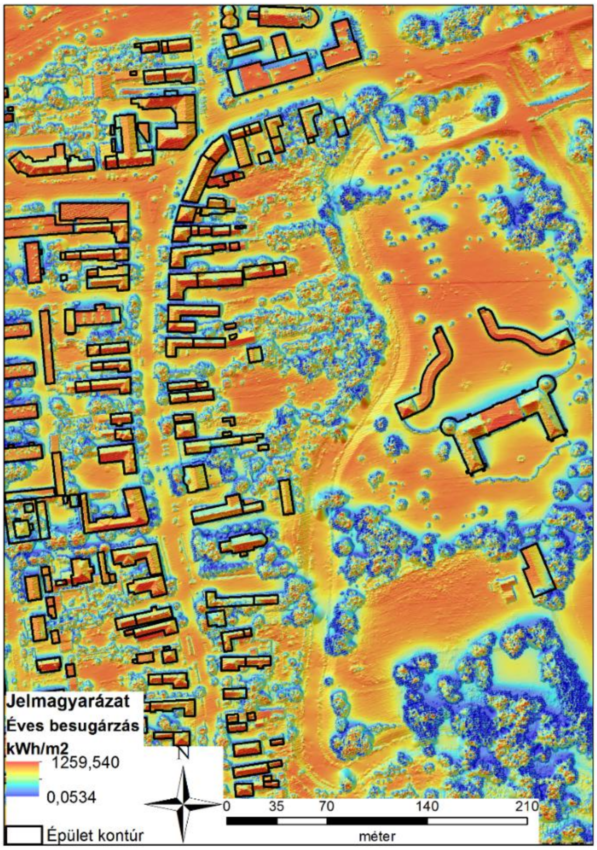

Figure 3: Total amount of yearlyglobal radiation on the sample area
prepared by: Szalontai L.

<u>*Thesis 2.:*</u> *The applied country-scale national and international global radiation estimation methods (nationwide global radiation estimates/calculations extended by interpolation) can be significantly refined using elevation model-based irradiation estimation methods. Besides using low resolution data derived from small number of calibration data (global radiation data sets measured by HMS measuring stations on flat surfaces), I significantly increased the spatial resolution by fitting high resolution environmental variables into the model (astronomic-, atmospheric-, topographic-, calculation- parameters), therefore I could further clarify the calculation parameters. This made it possible to characterize the radiaton-modification arising from the real, local environmental changes. Without these, fitting the natural and artificial surface objects into the model is not possible. Irradiation data generated this way keep the three-dimensional structure of the low-resolution data, but modifying them with atmospheric, astronomic (concerning specific coordinates) parameters derivated for the trial site, they provide data for variance within a small area.*

Table 2: Comparison of data interpolated and measured by international and domestic research institutes with radiation results generated by Solar Radiation

	Determining the amount of global radiation	Maximum amount of global radiation ($kWh/m^2/year$)
JRC - PV GIS (horizontal surface)	interpolation	1200-1250
JRC - PV GIS (on surface with optimal angle)	interpolation	1350-1400
OMSZ Éghajlati Atlasz (horizontal surface)	interpolation	1194-1222
OMSZ Edelény (horizontal surface)	measured figure	1137
Point Solar Radiation (horizontal surface – Dyer's parameters)	calculated figure	1138
Point Solar Radiation horizontal surface– with calculated parameters)	calculated figure	1057
Area Solar Radiation (Dyer's parametering)	calculated figure	1260
Area Solar Radiation (with calculated parameters)	calculated figure	1196

source: re.jrc.ec.europa.eu/pvgis, www.met.hu,prepared by: Szalontai L.

I analyzed the resulting daily, monthly, yearly radiation models - which also calculate with the radiation-modifying effects of the different field objects (greenery, building, chimneys, etc.). I also categorized them along different aspects (total radiation on a given roof surface, determining places with the most optimal value, potential place for equipment utilizing solar energy, etc.) (Figure 4).

<u>*Thesis 3.:*</u> *Applying the metodology I have developed, I have calculated the amount of energy of the incoming radiation, and have also delineated suitable areas and surfaces for solar panel installation, from wich such spatial statistics can be calculated that make solar cadastres suitable for carrying out regional examinations.*

According to the statistics calculated, various area-specific phenomena can be described. Therefore the global radiation calculated for settlements and geographical units can be classified and typified, which provides useful global radiation data for key actors (SMEs, policy makers, public, banking) interested in solar energy.

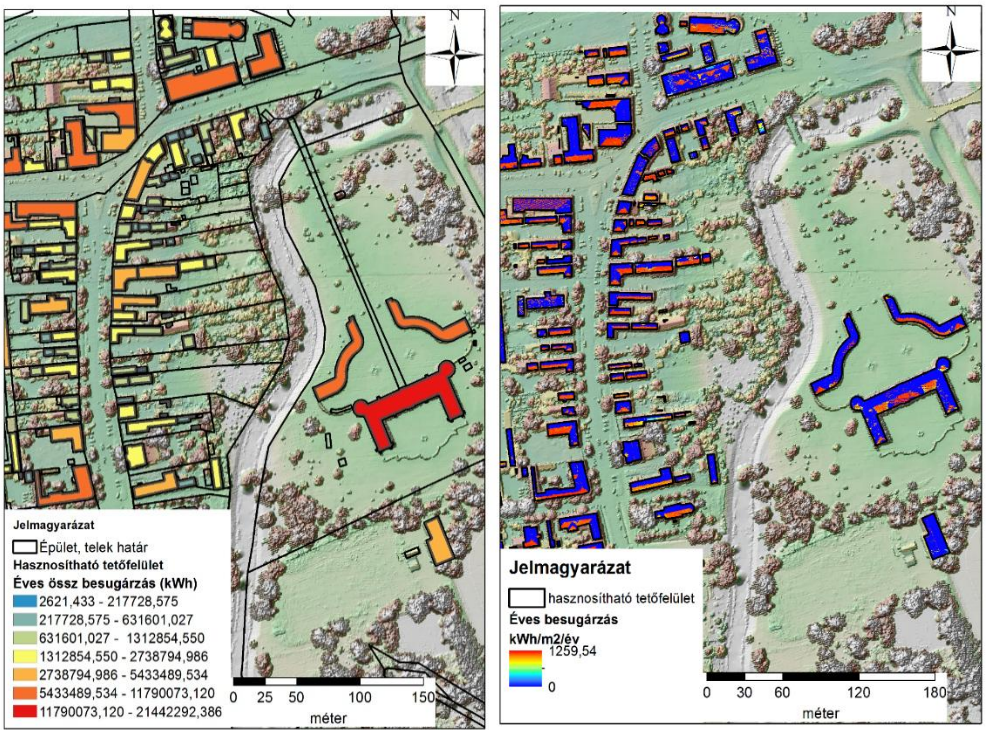

Figure 4: Showing yearly global radiation amount falling on roof surfaces (left) and global radiation amount falling on SE-SW exposed, flat and 35-43° roof surfaces (right), prepared by: Szalontai L.

In my dissertation I have also defined the circle of factors helping or inhibiting the creation of solar cadastres in the domestic data infrastructure environment. I have come up with suggestions for the prevention of error sources during digitization and modelling so that as exact and realistic as possible radiation modelling can be carried out. Thanks to these, by using the methodology I have defined, we can create databases characterized by exact territorial radiation amounts.(Figure 5).

<u>*Thesis 4.:*</u> *With the integration of the LiDAR point cloud (high resolution digital surface model), the land-resettlement plans, the five-year global radiation data series of HMS, and the Dyer's atmospheric factors parameterization methodology and the methodology of the international solar cadastres into GIS environment, I have adapted the creation of solar cadastre methodology applied in the international literature into the Hungarian data infrastructure environment. Due to all this, if there are specific databases available that are needed for the calculation of irradiation, high-precision settlement-level solar cadastres can be established for Hungary.*

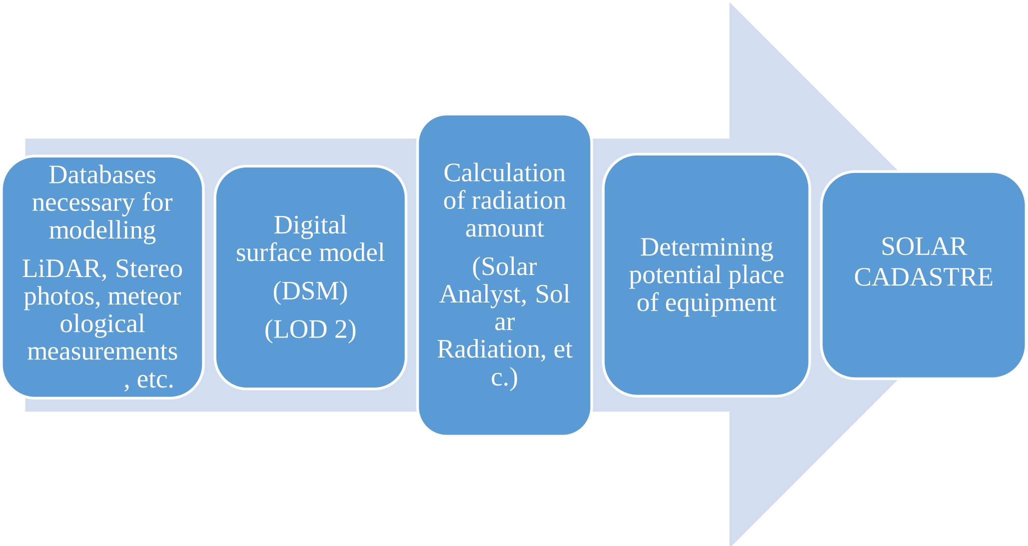

*Figure 5:*Main steps of creating solar cadastre, prepared by: Szalontai L.

V. Utilization opportunities of the results

A solar cadastre providing exact data is an incentive for society, molding and enhancing green consciousness, and also an excellent database, which can significantly contribute to the development of local/regional green economyand to increasing the rate of renewable energy sources. (Rylatt et al. 2001).

The solar cadastre base prepared for the sample area and the methodology describing its creation after running Solar Radiation (on the basis of received/calculated global radiation amounts) produced reliable results (the yearly radiation amount shows less than 1% deviation compared to measured values). Of course, the refinement of the different parameters is necessary in the future. By using the probably growing number of LiDAR and stereophoto shootings and surveys, further solar cadastres for the involved settlements can be created, which are even more exact and in line with local meteorological and environmental conditions.

Their importance apart from the radiation data they provide lies in the fact that individuals and state institutions alike can more easily and cheaply realize investments or make decisions on the design of a system related to solar energy. This makesposible the calculation of the amount of producable electric power, saved CO_2, investment costs and time of return of the planned system, etc. The existence of a solar cadastre and the database it provides can serve as a significant base for the decision-makers of settlements and regions to write their own energy utilization acton plan. (e.g.: SEAP (Sustainable Energy Action Plan – Fenntartható Energia Akcióterv)(Szalontai 2014 a, Szalontai 2014 b).The solar cadastre can function as a sort of „decision-supporting or decision-incentive"information service related to solar energy.

VI. REFERENCES

1. Agugiaro G – F Nex – F Remondino – R De Filippi – S Droghetti – C Furlanello 2012: Solar radiation estimation on building roofs and web-based solar cadastre, In. ISPRS Annuals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. 1-2. 2012. Melbourne, Australia, pp. 177-182.

2. Árpási M. - Barótfi I. - Ertsey A. - Gampel T. - Illyés Zs. – Kontra K. – Licskó B. – Medgyasszay P. – Orosz M. – Pálfy M. – Polgár A. – Varga G. – Varga P. 2006: Autonóm kisrégió az Európai Unióban, Esettanulmány az Alpokalja kistérség vizsgálatával, Független Ökológiai Központ Alapítvány, Budapest, 2006. 423 p

3. Büki G 2004: Erőművek, Műegyetemi Kiadó, Budapest, 2004., pp 463-520

4. DEnzero folyóirat2014/7. URL:http://denzero.unideb.hu/files/folyoiratok/denzero%20-%202014-07.pdfletöltésdátuma: 2015.02.02.

5. DEnzero folyóirat 2014/9. URL:http://denzero.unideb.hu/files/folyoiratok/denzero%20-%202014-09.pdfletöltés dátuma: 2015.02.02.

6. Dyer J 2009: Guidelines for Computing Monthly Radiation Grids Using the Solar Radiation Toolset in ArcGIS, Department of Geography, Ohio University, url: www.ohio.edu/people/dyer/Radiation_Grids.pdf

7. Dyer J 2015: User's Guide for Water Balance Toolbox (v.2.2) for ArcGIS, Department of Geography, Ohio University – url: www.ohio.edu/people/dyer/WB/water_balance_v2_user_manual.pdf 38 p

8. EREC 2008: Renewable energy in Europe: markets, trends, and technologies, European Renewable Energy Council (EREC), 2010., Earthscan Ltd. London, UK, 265 p
9. Hofierka J – Kanuk J 2009: Assessment of photovoltaic potential in urban areas using open-source solar radiation tools, Renewable Energy, 34 (10) (2009), pp. 2206–2214 URL: http://dx.doi.org/10.1016/j.renene.2009.02.021 letöltés dátuma: 2014.08.28.

10. IRENA 2011: Working Paper: Renewable Energy Jobs: Statuts, Prospects & Policies URL: http://www.irena.org/documentdownloads/publications/renewableenergyjobs.pdf letöltés dátuma: 2014.03.30.

11. IRENA 2014: Renewable Energy and Jobs – Annual Review 2014 URL: http://www.irena.org/publications/rejobs-annual-review-2014.pdf letöltés dátuma. 2015.03.05.

12. Izquierdo, S - Rodrigues, M - Fueyo, N 2008. A method for estimating the geographical distribution of the available roof surface area for large-scale photovoltaic energy-potential evaluations. Solar Energy 82 (10), pp 929–939

13. Lang L 1998.: Managing Natural Resources with GIS, ESRI, 380. New York Street, Redlands, CA, USA, 117 p

14. Leitelt R 2010: Developing a solar energy potential map for Chapel Hill, NC, Masters Project, University of North Carolina, 2010., 27 p, URL: https://cdr.lib.unc.edu/indexablecontent/uuid:6e5c0eac-e631-4741-b038-d7e9c3e4da41 letöltés dátuma: 2013.05.03.

15. Munkácsy B - Borzsák S - Egri Cs 2008: Projekt összefoglaló, Megújuló Energia Megújuló Határvidék, Esztergom 2008. pp 20-30

16. Pellegrino M – Caiaffa E – Grassi A – Pollino M 2008: GIS as a tool for solar urban planning, In: Proceedings of 3d Internationa Solar Energy Society Conference – Asia Pacific Region (ISES-AP 2008), Sydney, Australia, November 25-28. 2008. URL: https://www.academia.edu/353552/GIS_as_a_tool_for_solar_urban_planning letöltés dátuma: 2013.10.04.

17. Riecken J – Seifert M 2012: Challanges for the multi purpose cadastre, In: TS04A – Innovative Cadastre and Land Rights Management, FIG Working Week 2012. Rome, Italy

18. Rylatt M – Gadsden S – Lomas K 2001: GIS-based decision support for solar energy planning in urban environments, In. Computers, Environment and Urban Systems 25. (2001) pp 579-603

19. Szalontai L 2014a: Szolárkataszter – egy eszköz a kistérségi/járási napenergia hasznosítás arányának növelésére, In. Észak-magyarországi Stratégiai Füzetek, XI. évfolyam, 2. szám, 2014., pp 75-82

20. Szalontai L 2014b: The establishment and significance of district/regional roof cadastres in the utilization of solar energy, In. Agriculture and Environment, Acta Sapientia, Vol. 6/2014, Cluj, Romania, 2014., pp 45-51

21. Wiginton L.K. – Nguyen H.T. – Pearce J.M 2010: Quantifying rooftop solar photovoltaic potential for regional renewable energy policy, In Computers, Environment and Urban Systems 34 (2010) 345-357

22. Wilkins G 2002: Technology Transfer for Renewable Energy: Overcoming Barriers in Developing Countries. London: Earthscan, 2002. 256 p

23. Wittmann H – Bajons P 1997: Identification of roof areas suited for solar energy conversion systems, In. Renewable Energy, Vol. 11, No. 1., pp 25-36

<u>Statistical databases</u>

2014 World Development Indicators - 2014 International Bank for Reconstruction and Development / The World Bank URL: http://data.worldbank.org/

BP Statistical Review of World Energy 2014., BP Statistical Review of World Energy BP, 2014., London, URL: http://www.bp.com/content/dam/bp/pdf/Energy-economics/statistical-review-2014/BP-statistical-review-of-world-energy-2014-full-report.pdf letöltés dátuma: 2014.12.10.

BP Statistical Review of World Energy 2015., BP Statistical Review of World Energy BP, 2015., London

Enerdata - Global Energy Statistical Yearbook 2014 URL: http://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2014_en.htm letöltés dátuma: 2014.10.14.

Eu Energy Country Factsheets 2014 version 3.0 URL: http://ec.europa.eu/energy/sites/ener/files/documents/2014-country-factsheets.pdf letöltés dátuma 2015.01.12.

Eu Energy in Figures 2014: Statistical Pocketbook. Luxembourg: Office for Official Publications of the European Communities, 2014. Print.

GSR 2014: Renewables 2014 Global Status Report, REN21. 2014. (Paris: REN21 Secretariat) URL:http://www.ren21.net/portals/0/documents/resources/gsr/2014/gsr2014_full%20report_low%20res.pdf – Letöltés dátuma: 2014.12.05.

OECD 2015: OECD Statistical database, url: http://data.oecd.org

REN21. 2014. Renewables 2014 Global Status Report - (Paris: REN21 Secretariat). ISBN 978-3-9815934-2-6

The World Factbook 2013-14. Washington, DC: Central Intelligence Agency, 2013 . URL: https://www.cia.gov/library/publications/the-world-factbook/

U.S. Census Bureau, International Programs 2008, Historical Estimates of World Population, International Data Base (IDB), U.S. Census Bureau, Silver Hill Road, Washington, DC, letöltve 2014.10.06. U.S. CensusBureau, Silver Hill Road, Washington, DC, Centers of Population for Census

United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision, Key Findings and Advance Tables. Working Paper No. ESA/P/WP.241

World Resources Institute – WRI Climate Analysis Indicators Tool (CAIT 2.0) – WRI's climate data explorer, URL: http://cait.wri.org

www.carpatclim-eu.org

www.ksh.hu

www.meteonorm.com

www.polis-solar.eu/

www.soda-it.com

re.jrc.ec.europa.eu/pvgis

VII. PUBLICATIONS BY THE AUTHOR RELATING TO DISSERTATION

1. SZALONTAI L (2009): Borsod-Abaúj-Zemplén megye megújuló energiaforrásai, in: V. Kárpát-medencei Környezettudományi Konferencia, szerk.: Mócsy I. – Szacsvai K. – Urák I. – Zsigmond Andrea R., Kolozsvár, pp. 173-174 ISSN 1842-9815

2. SZALONTAI L (2009): Megújuló energiaforrások használata az Eperjes-Tokaji-hegység területén, in: Települési Környezet, szerk.:Szabó V. - Fazekas I., Debrecen, pp. 224-227 II. Települési Környezet Konferencia ISBN: 978-963-473-336-2

3. SZALONTAI L (2009): Megújuló energiaforrások Borsod-Abaúj-Zemplén megyében, in: Doktoranduszok fóruma Műszaki Földtudományi Kar Szekció kiadványa, pp. 129-134

4. SZALONTAI L (2009): A Tokaj-Eperjesi-hegység vizsgálata geotermikus energia szempontjából, Geográfus Doktoranduszok IX. Országos

Konferenciája Társadalomföldrajzi Előadások, Szeged, 2009. március 12-13., Konferencia CD, ISBN 978-963-306-012-4

5. SZALONTAI L (2010): Natural and renewable energy sources in the Eperjes-Tokaji-mountains, in: Proceedings of the 1st Knowbridge Conference on Renewables, editors: T. Madarász – R. Tóth, Miskolc, pp. 63-67 ISBN: 978-963-661-944-2

6. SZALONTAI L (2011): A globálsugárzás elméleti és gyakorlatilag hasznosítható potenciáljának meghatározása domborzatmodell alapján, zempléni mintaterületeken, in: HunDEM konferencia CD kiadvány, Miskolc, 2012., ISBN 978-963-358-006-6

7. SZALONTAI L (2011): Két zempléni kistérség megújuló energiaforrás potenciáljának vizsgálata, in: VII. Kárpát-medencei Környezettudományi Konferencia, szerk.: Mócsy I. – Szacsvai K. – Szikszai A. – Urák I. – Zsigmond Andrea R., Kolozsvár, pp. 190-194 ISSN:1842-9815

8. **SZALONTAI L** – SZAMOSI A (2011): Domborzatmodellek alkalmazása a természeti erőforrások és veszélyek területén, in: Az elmélet és a gyakorlat találkozása a térinformatikában II., szerk.: Lóki J., Debrecen, p 476. Térinformatikai konferencia és szakkiállítás ISBN: 978-963-318-116-4

9. SZALONTAI L (2011): Introduction of the Knowbridge project and its results, In: New results of cross-border co-operation, edit: G. Kozma, Debrecen, pp. 59-65 ISBN: 978-963-89167-3-0

10. SPÉDER F **- SZALONTAI L** – TÓTH T – VASS R (2012): A biomassza hasznosításának társadalmi megítélése a Hernád völgyében, In: A megújuló energiaforrások hasznosításának természeti, társadalmi és gazdasági lehetőségei a Hernád-völgyben, szerk.:Lázár I., Debrecen, 2012., pp 73-85.

11. B SISKÁNÉ SZILASI – Zs PISKÓTI KOVÁCS – **L SZALONTAI** – J VÁGÓ (2012): The analysis of the geotouristic potential by the help of a complex index in one sample area (Aggtelek-Rudabánya Mountains), In: GEOTOUR & IRSE 2012, Geoparks, Geoheritage and Geoconservation IRSE: History of Central European Mining (Conference Proceedings), 2012., Editor: L'ubomirStrba, pp. 80-87., ISBN 978-80-553-1270-5

12. SZALONTAI L (2013): Napenergia-hasznosítási tetőkataszter létrehozásának lehetőségei, In: Változó Föld, változó társadalom, változó ismeretszerzés 2013 – Megújuló erőforrások szerepe a regionális fejlesztésben, Eger, 2013. október 10-12., Eszterházy Károly Főiskola Földrajz Tanszék, Agria-Innorégió Tudáscentrum, szerk.: Pajókné Tari I – Tóth A; pp. 128-133.

13. SISKÁNÉ SZILASI B – **SZALONTAI L** – VÁGÓ J (2013): Észak-Magyarország felhagyott bányászati területeinek hasznosítási lehetőségei, In: Észak-magyarországi Stratégiai Füzetek, 2013. X. évfolyam 1. szám, Miskolc, szerk: G. Fekete É – Lipták K – Síposné Dr. Nándori E – Tóth G, pp. 26-36., ISSN 1786-1594

14. SZALONTAI L (2014): A Bódva-völgy szolárkataszterének létrehozása, jelentősége és hasznosításának lehetőségei – VII. Magyar Földrajzi Konferencia, Elektronikus Konferencia kiadvány

15. SZALONTAI L (2014): Járási/kistérségi tetőkataszterek létrehozása és jelentősége a napenergia hasznosításában, in: X. Kárpát-medencei Környezettudomány Konferencia, szerk.: Zsigmond Andrea R. – Szigyártó I – L. – Szikszai A., Kolozsvár, pp. 38-42 ISSN:1842-9815

16. SZALONTAI L (2014): Szolárkataszter – egy eszköz a kistérségi/járási napenergia hasznosítás arányának növelésére, In: Észak-magyarországi Stratégiai Füzetek – 2014. XI. évfolyam 2. szám, Miskolc, szerk: G. Fekete É – Lipták K – Síposné Dr. Nándori E – Tóth G, pp. 75-82., ISSN 1786-1594

17. L SZALONTAI (2014): The establishment and significance of district/regional roof cadastres in the utilization of solar energy, Acta Universitatis Sapientiae, Agriculture and Environment, 6 (2014) pp 45−51