# A GIS BASED ASSESSMENT OF RENEWABLE ENERGY SOURCES IN ROMANIA AND ITS IMPACT ON ISOLATED AREAS

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***Abstract:*** *Taking into account the significant potential of renewable energy sources in Romania, it is reasonable to use it in order to develop Romanian cities and rural regions. There are some current technologies that may be applied to rural sustainable development, such as new-generation photovoltaic panels and systems of passive heating of water.*

*This paper presents an application of Analytic Hierarchy Process for selection of renewable energy sources and technology in context of Central Region of Romania. The option – solar energy have been evaluated based on selected criteria. The objective of our working paper is to analyze the renewable energy development policy in isolated areas of Romania. Renewable sources of energy play an important part in the sustainable supply of energy and in the sustainable economic and social development.*

*Using a GIS model, the aim is to demonstrate which of the analyzed sources of energy is the most convenient to be used in a sustainable system, solar or electric network.*

***Keywords:*** *renewable energy, analytic hierarchy process, site selection, geographical information system.*

## 1. Introduction

Many countries have designed incentive structures to induce private investment in renewables, especially those that involve higher or incremental costs.

This paper consists into a scientific approach of the potential of the renewable energy sources in the central area of Romania and analyzes the occupational and skill needs in domain of renewable energy.

In this perspective, Romania has to intensify its efforts to use and implement renewable energy resources and technologies. The renewable energy resources will be used both in the sector of electricity production and in the heating sector; in the latter both building of new power plants for high efficiency cogeneration (especially based on biomass use) and building of new power plants based on solar and geothermal energy are envisaged, thus leading to an increase of RES-based heat production. (Miron, D., Preda, M., 2009).

The total number of non-electrified households in rural Romania was 2,025 localities and 41,376 households. Based on this information's, this paper will approach and analyse the main energy resources for isolated areas and compares this. Households without electricity we encounter both in mountain areas and of hills and plains. This enables solutions addressing one type of renewable energy - solar.

The renewable energy represents the energy produced from a wide variety of resources, having the ability to renew. Virtually all regions of the world have renewable resources of one type or another.

In the second stage, considering various factor criteria, will be obtained a map of suitability, based on Analytical Hierarchy Process and the weight setting.

In the last step, will be decided the optimal sites for renewable source of energy and compare the cost of implementation with electric network.

Geographic information system (GIS) based decision support systems (DSS), often known as spatial decision support systems (SDSS), are a class of computer systems in which the technologies of both GIS and DSS are applied to aid decision makers with problems that have a spatial dimension (Walsh, 1992).

GIS offer a level of functionality that is difficult to achieve with other software packages; they have powerful analytic capabilities, exceptional spatial data management, storage, and retrieval functionality, and an array of visualization tools that make them an invaluable tool for site suitability analysis (Malczewski, 2004; Marinoni, 2004).

## 2. Material and method

### 2.1 Methodologies based on Multi-Criteria Analysis

Multi-criteria decision making means defining each criterion using attributes, based on which chooses a suitable alternative for achieving objectives. Multi-criteria analysis (MCA) also referred as multi-criteria evaluation (MCE) methods allow analysis of complex, multi-dimensional trade-offs between choice alternatives for example locations or suitability analysis of an area (Meng et al. 2011).

Analytical Hierarchy Process (AHP) is one of the most commonly used methods of multi-criteria analysis. The analytic hierarchy process (AHP), which was developed by Saaty, has been an effective tool in structuring and modelling multi-objective problems. AHP can assist decision makers to evaluate a problem in the form of a hierarchy of references through a series of pairwise comparisons of relative criteria. To create the pairwise comparison matrix in the PCM, Saaty (1980) has employed a system of numbers to indicate how much one criterion is more important than the other. These numerical scale values and their corresponding intensities are stated in Table 1.**1.**

**Table 1.1. - The scale of relative priorities**

| Intensity of importance | Value | Definition |
|---|---|---|
| 1 | Equally important | I and j are equally important |
| 3 | Moderately more important | I is moderatly more important than j |
| 5 | Strongly more important | I is strongly more important than j |
| 7 | Very strongly more important | I is very strongly more important than j |
| 9 | Extremely more important | I is extremely more important than j |
| 2,4,6,8 | Intermediate values | Used when compromised is needed |

The comparison matrix is an nxn dimensional square matrix A=[aij] . Elements of this matrix are pairwise or mutual importance ratios between the criteria which are decided on the basis that how well every criterion serves and how important it is in reaching the final goal.

A – comparison pairwaise matrix,

$w_1$ - wheight of element 1,

$w_2$ - wheight of element 2,

$w_n$ - wheight of element n.

$$A = \begin{bmatrix} 1 & \frac{w_1}{w_2} \cdots & \frac{w_1}{w_n} \\ \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} \cdots & 1 \end{bmatrix}$$

The relative weights (W) of matrix A is obtained from following equation: ( A- $\lambda_{max}$I ) × W = 0 (1)
$\lambda_{max}$ – the biggest eigenvalue of matrix A,
I = unit matrix.

The consistency property of matrices is checked to ensure that the judgments of decision makers are consistent. Consistency Index (CI) is calculated as: CI = $\frac{\lambda_{max} - n}{n-1}$ (2)
Generally, if CR is less than 0.1, the judgments are consistent, so the derived weights can be used. The formulation of CR is: CR = $\frac{CI}{RI}$ (3)

The last step the relative weights of decision elements are aggregated to obtain an overall rating for the alternatives as follows:

$W_i^S = \sum_{j=1}^{j=m} w_{ij}^S \, w_j^a$ , i = 1,…n (4)
$w_{ij}^S$ - weight of alternative i associated to attribute j,
$w_j^a$ - weight of attribute j,
m = number of attribute,
n= number of site.

The consistency ratio (CR) is designed in such a way that if CR < 0.10, the ratio indicates a reasonable level of consistency in the pairwise comparisons; if, however, CR > 0.10, then the values of the ratio are indicative of inconsistent judgments. In such cases one should reconsider and revise the original values in the pairwise comparison matrix.

## 2.2 Additions

Covering 34.100 square kilometres, approximately 14.3 % of Romania, Center Region is the fifth largest of the eight Romanian regions. Its geographical position connects it to six of the other seven regions, the distances between its central area and the country borders being almost equal. The Central Region is situated in the central part of Romania at the interior of the Carpathian Mountains, on the course of Mures and Olt rivers. The region includes 6 counties: Alba, Brașov, Covasna, Harghita, Mureș and Sibiu.
Carpathian Mountains of Transylvania have a potential for exploitation of energy resources especially wind energy, and biomass micro-hydropower (of wood) and the Transylvanian Depression has a high potential of solar energy recovery and biomass (Muntean, 2012).

**Data acquisition**

This project was created using ArcGIS 10.2 (ESRI®). ArcGIS includes Spatial Analyst and 3D Analyst extensions.
The data used for this project are widely used in renewable energy sources application in oreder to collect data regarding evaluation purpose and downloaded from an open source site study area boundaries, settlement areas, roads, water bodies, slope, natural reserves, and airports (earth.unibuc.ro) (Vasile Craciunescu et. al, 2006).

The solar data was accessed from Photovoltaic Geographical Information System (PVGIS). The file contains a table with solar radiation for each month of the year (Wh/m$^2$/day) and it creates an excel file with the average for the whole year. Using this table, it creates a shapefile and an interpolation. Factor criteria found throughout the literature consist in proximity to roads, proximity to urban areas, solar radiation, slope, aspect, and land use, proximity to the electric grid, bird migration path, impact of noise and others. (Harrison, 2012)

The constraints were implemented using the Buffer Tool in ArcGIS. To create the constraint map, a model was built using Model Builder. Based on this, we have created a map of the constraints available for solar energy. The model for Constraint can be seen in Figure 2.1 and the constraint map can be seen in Figure 2.2.

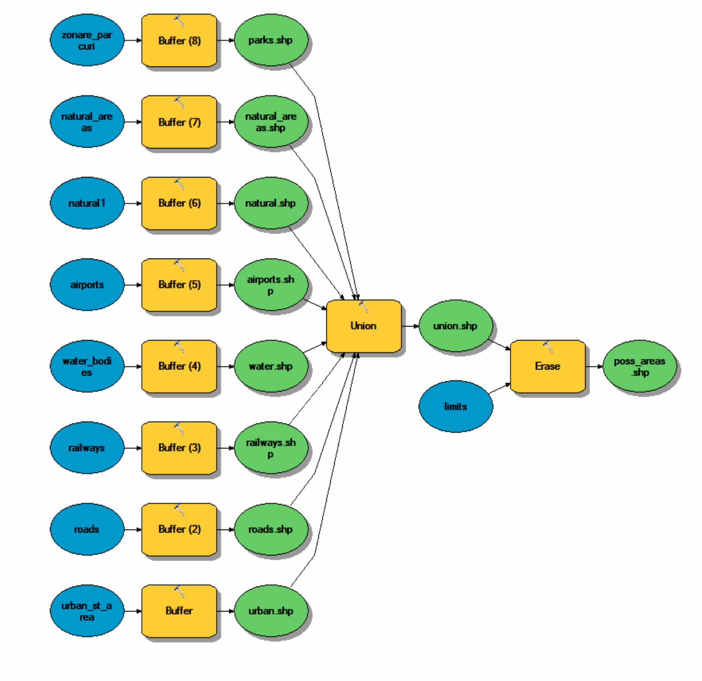


Fig. 2.1. Model for Constraint map

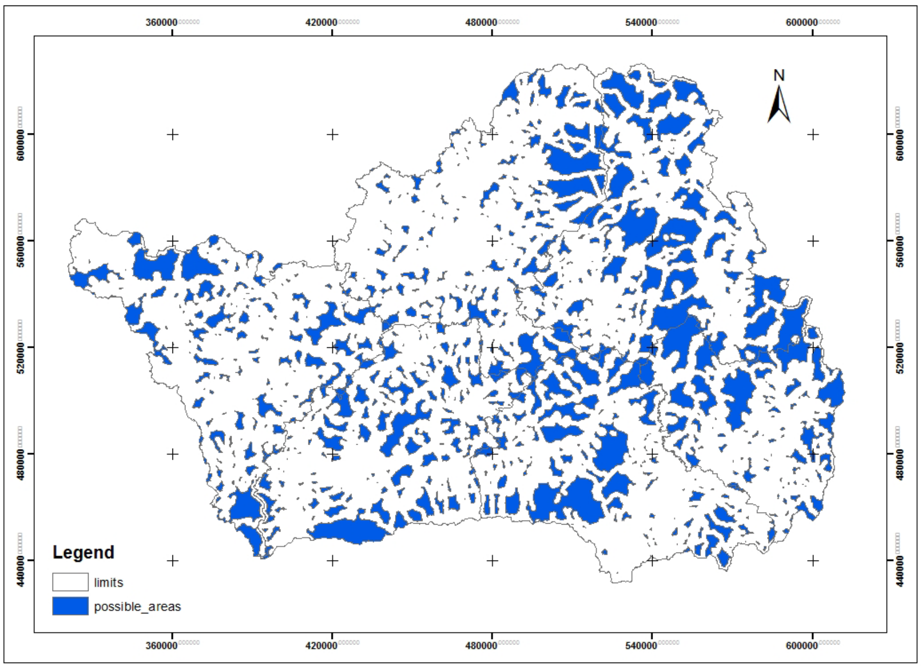


Fig 2.2. Constraint map

**Standardization of Criteria** - In this step all the layers were reclassified to a common scale of 0 to 4, called scale values, using equal intervals into five classes with intervals between the maximum and minimum values. These scale values were used as the suitability scores. After scoring each factor, the datasets will be reclassified using the Reclassify Tool in ArcGIS. The Factor criteria and constraints shown below in Table 2.1.

*Table 2.1. Factor criteria and constraints*

| Criteria | Constraint |
|---|---|
| Solar radiation | 3000 (kWh/m$^2$/year) |
| Slope | Must be < 20% rise |
| Land cover | Some classes are excluded |
| Proximity to Roads | Greater than 500 m |
| Proximity to Urban | Greater than 2000 m |

Arithmetic average of each row of the normalized matrix gives the weight of the corresponding criterion or alternative. Weights of the corresponding criteria are shown into the following Table 2.2.

*Table 2.2. Weights of the corresponding criteria*

| Criteria | Weight (Priority vector) |
|---|---|
| Solar radiation | 0.47 |
| Slope | 0.24 |
| Land cover | 0.12 |
| Roads | 0.09 |
| Urban | 0.08 |

From the suitability index were selected the optimum locations for solar farms over 300 h and shown in the Figure 2.3.

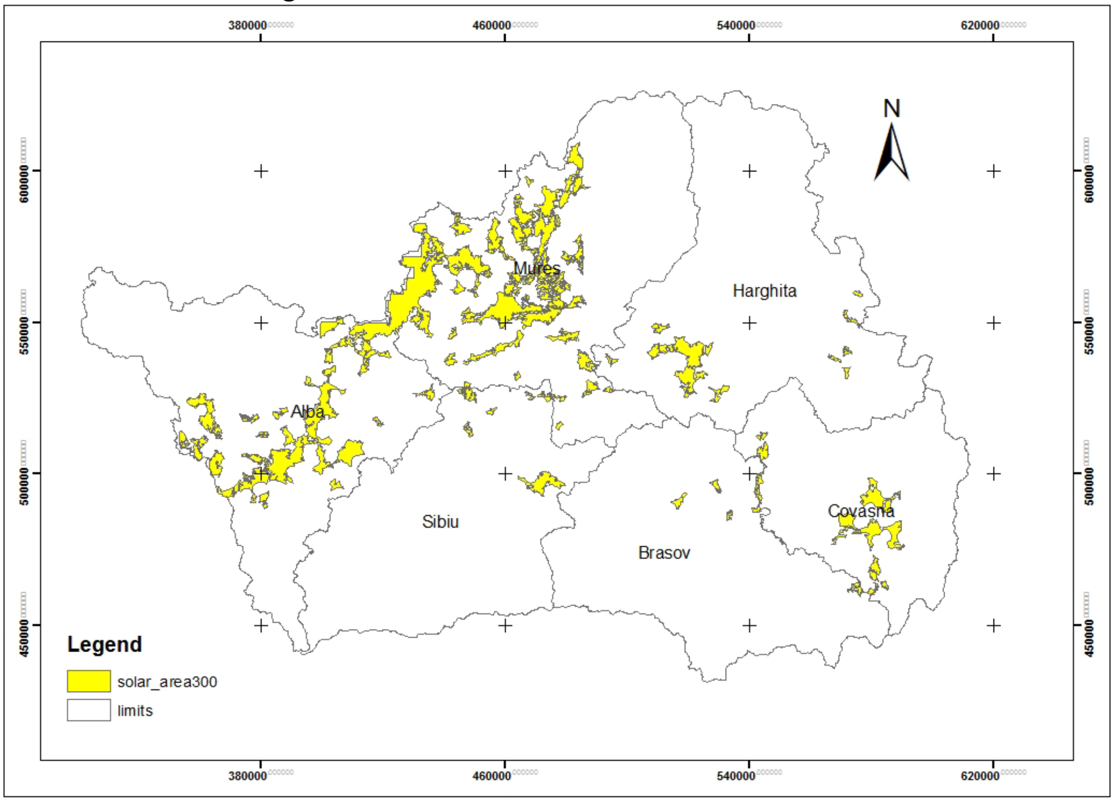


Fig. 2.3. Areas larger than 300 ha map

Using the raster data and the weighted overlay as inputs, the cost distance tool generated an output raster, showing for each cell the cumulative cost of travel away from the nearest source of renewable energy cell. The algorithm for computing the direction raster assigns a code to each cell that identifies which one of its neighbouring cells is on the least-cost path back to the nearest source. In the direction coding diagram above, 0 represents each processing cell in the accumulative cost raster. Each cell is assigned a value representing the direction of the nearest, cheapest cell on the route of the least costly path to the nearest source.

The Cost Path tool produces an output raster that records the least-cost path or paths from selected locations to the closest source cell defined within the accumulative cost surface, in terms of cost distance. Based on the inventory presented by Ministry of Economy, about rural villages without electricity, we establish non-electrified areas in our study area: Râmeț, Întregalde, Ceru-Băcăinți, Lueta and Zetea. Based on this, were chosen the most suitable area for installing solar panels. This area has a surface of 16866 ha. The results are shown in to into the Figure 2.4.

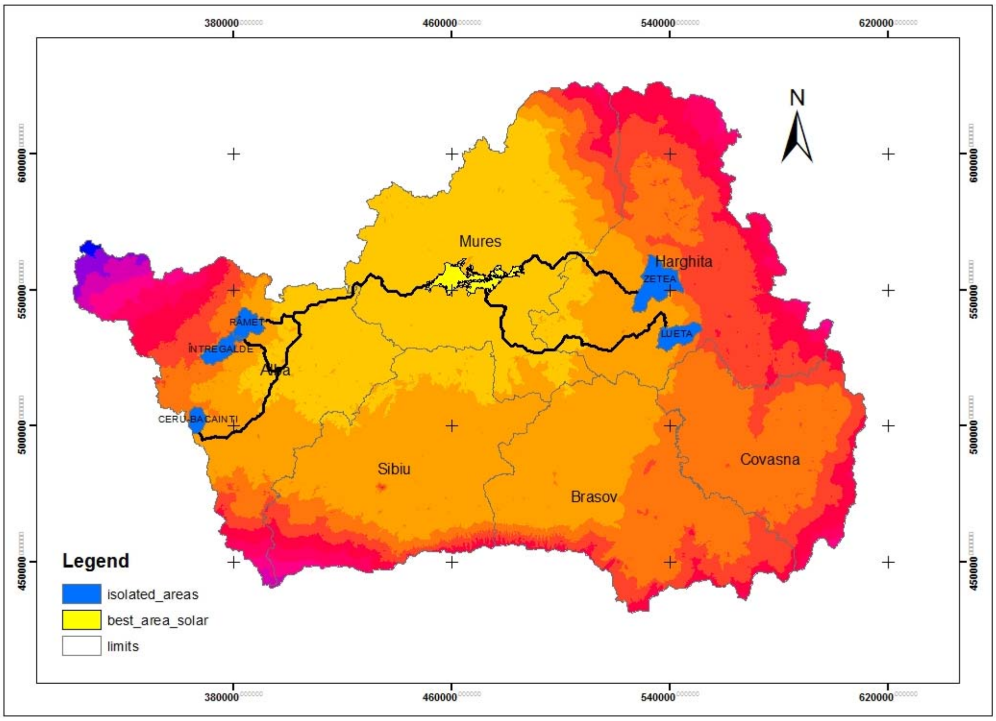


Fig. 2.4. Cost path for solar map

**Electric Network**

The cost to connect to the electricity network depends on a range of factors, including distance from the grid, underground or over ground cabling, crossing neighboring properties, easements, transformer requirements, and many more things. The result of the cost distance for Electric Network are shown in the next Figure 2.5.

Renewable energies, driven by climate change, fuel security and other motives, will be providing more and more of our electricity in the future.
Fortunately the outlook for cost reductions is good, particularly for the average cost of new projects. The technologies with the largest cost reduction potential are CSP, solar PV and wind. Hydropower technologies are mature and their cost reduction potentials are not as large.

The hydropower, solar and wind are all competitive with or cheaper than coal, oil and gas-fired power stations, even without financial support and despite falling oil prices. (IRENA, "Renewable Power Generation Costs in 2014"). The advantages of using alternative energies: improving quality of life: creating optimal conditions for living in isolated areas by adopting alternative energy solutions, increase their attractiveness to the area, increase the birth rate is reduce the phenomena of exodus, depopulation, unemployment rate decreases by attracting investors.

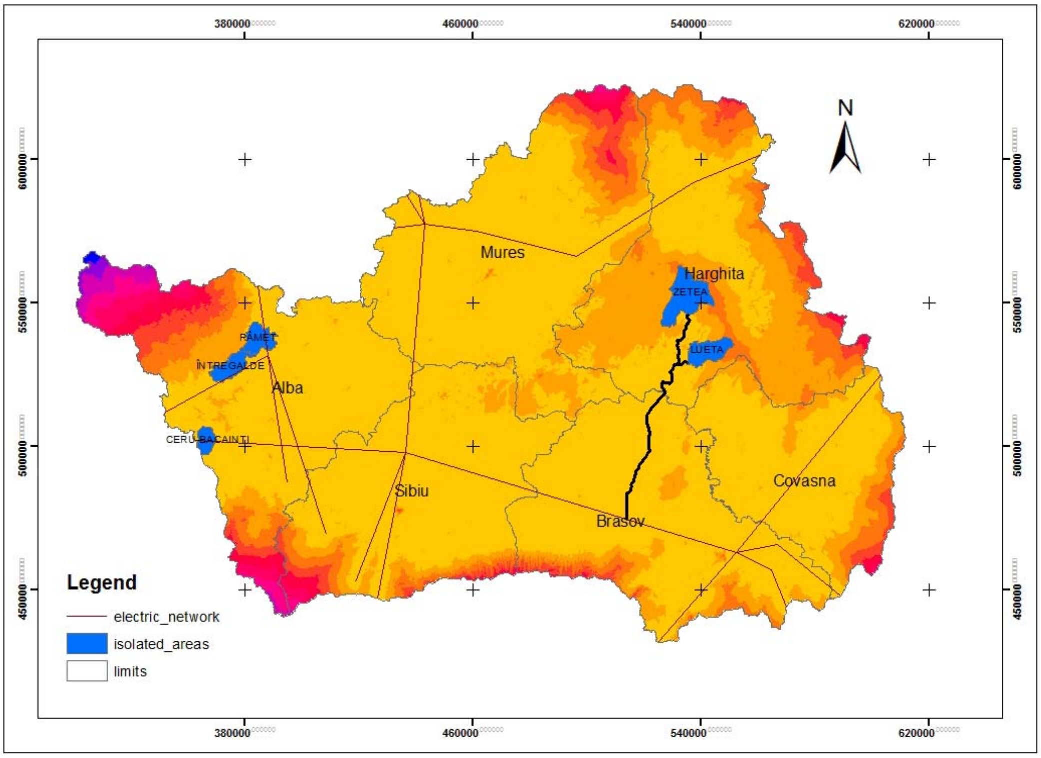


Fig. 2.5. Cost path for electric network map

## 3. Conclusions

This paper analyzed and produced a suitability index maps with plenty of suitable zones to construct grid-connected photovoltaic power plants and defined a set of future research avenues for GIS-based energy infrastructure planning with a focus on the use of renewable energy.

The cost of generating power from renewable energy sources has reached parity or dropped below the cost of fossil fuels in many parts of the world, according to a new report from the International Renewable Energy Agency (IRENA).

Solar photovoltaic (PV) power generation is leading the cost decline, with solar PV module costs falling 75% since the end of 2009 and the cost of electricity from utility-scale solar PV falling 50% since 2010.

This requires public acknowledgement of the low price of renewables, an end to subsidies for fossil fuels, and regulations and infrastructure to support the global energy transition.

Based on this, we could choose for our study area as a source of renewable energy, the solar energy. It is expected that in the future, PV projects will attain viable capital costs comparable with other renewable projects.

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