INDICATOR-BASED APPROACH TO ASSESSING THE ENVIRONMENTAL AND SOCIO-ECONOMIC IMPACTS OF PHOTOVOLTAIC PARKS IN ROMANIA. NORTH-WEST DEVELOPMENT REGION

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ABSTRACT

In Romania, the energy sector still largely relies on conventional sources (coal, oil, natural gas) whose extensive use pose significant threats to the environment and population. To avoid that, a process of capitalizing the renewable energy resources has been set in motion. Following Romania's EU accession, support schemes were granted to investors in the field of renewable energies and deadlines were also imposed to convert a percentage of conventional energy sources into renewable (32% by 2030, compared to 1990). In Romania, investments can be made in several types of renewable energies (wind, solar, geothermal, hydropower, biomass), depending on the regional particularities. This study is aimed at examining the environmental and socio-economic impacts of photovoltaic (PV) energy in the North-West Development Region (NWDR) using and indicator-based approach. NWDR has high values of sunshine duration sufficient for the development of 54 PV parks, spread over an area of 471 ha. The PV parks were mapped and analyzed spatially and statistically. Several indictors were selected and computed to pinpoint their environmental (distribution on main soil types; distance to forests, waters, natural protected areas) and socio-economic (e.g. distribution on land use/cover, distance to settlements, roads) impacts.

Keywords: photovoltaic (PV) parks, environmental impact, socio-economic impact, North-West Development Region (NWDR), Romania

INTRODUCTION

In recent decades, people have relied on conventional and unsustainable energy sources for all their activities and the result of burning fossil fuels has been the release of greenhouse gases into the atmosphere. The direct negative impacts associated with greenhouse gases is that of rising temperatures, but also the changes in the conditions of some wild habitats, rising sea levels, floods [1], and the occurrence of extreme weather events. The increasingly debated issue of climate change includes energy security and the methods used to prevent the effects of rising temperatures among its main topics. Renewable energy responds to the concept of sustainable development, thus to the need for safe, inexhaustible energy sources [2] and reduced environmental impacts. Over time, technologies that use various environmental resources to generate energy, i.e. water, sun, wind, biomass or the Earth's internal heat, have been developed. In Europe, the energy

obtained from renewable sources is an important component of the EU Sustainable Development Strategy, renewable energy and energy efficiency becoming the two key elements that support the sustainable energy systems [3].
In Romania, important sources of renewable energy (wind, solar, geothermal, hydropower, biomass) are found and exploited, but conventional energies still hold the majority in total energy production (65.9%). However, the legislative measures introduced after the EU accession, but also following the signing of the Paris Agreement on climate change [4], were meant to change the hierarchy of the types of energy used, so that the dependence on fossil fuels to acquire a smaller role compared to renewable energies. This is reflected in the targets imposed and assumed by Romania for the 2030 and 2050 horizons [5,6,7]. Although in the recent years the production of renewable energy has increased significantly, the provisions of the European Green Pact, recently adopted by the EU, require a rethinking of policies on clean energy supply in all economic sectors. It envisages the development of an electricity sector that relies heavily on renewable sources followed by the rapid decarbonisation [8].
Decarbonisation is one of the key transitions of Europe's commitment to reducing CO2 emissions to be achieved mainly through the integration of more renewable energy sources into the power system [9]. Within this context, the photovoltaic sector can make a significant contribution to the transition towards Low-Carbon Economy, while still enjoying a number of technical, economic or political advantages. However, one must have in mind that, besides the solar radiation, which is free and available anywhere on Earth, the development potential of solar energy is determined by the electricity demand, the policies of different states in terms of support or restriction, implementation costs and investment payback times, the climate change-related risks, the interconnection of transmission and distribution networks, as well as other technical, environmental, social and economic factors [10].
Nationwide, the solar energy registered the highest increase, over 900%, in the period 2013-2020 compared to other energy sources, even if in 2020 has the last but one position in the hierarchical structure, with only 2.4% of total energy, followed by from biomass with 0.86%. The benefits of the use of renewable energy have already been acknowledged and addressed in the literature, i.e. minimizing pollution, increasing economy, energy security, job opportunities etc., without overlooking some of its negatives [11,12,13,1]. Regional-level studies have been developed to quantify the spatial differences of environmental and socio-economic impact of photovoltaic (PV) parks/farms at various spatial levels: Romanian Plain [6], Southern Romania [5], Centre Development Region [7] and West Development Region [14]. The present study aims to complete and expand the series of regional case studies in order to provide a more detailed picture of the PV parks impacts in Romania.

STUDY AREA

The North-West Development Region (NWDR) occupies 14.3% of the country's surface and concentrates 12.7% of its population. The natural conditions, with the existence of relatively flat relief forms (parts of the Western Plain and Hills, Transylvanian Depression) and the sunshine duration values (2,100 hours/year) are sufficient for the development of 54 PV parks with areas varying between 0.26 and 96.7 ha. The PV parks were built in the 2013-2018 period and are spread over an area of 471 ha, having a total installed capacity of 197 MW. The uneven spatial distribution of the sunshine duration values (compared with the western and southern parts of the country) can be explained by the presence of Carpathian Mountains that makes this type of energy difficult to exploit in areas with high fragmentation and slope declivity (Fig. 1A). This aspect determined the investors to direct the capital into the plain region (Western Plain), an area that accounts for over 50% of the power plants in the NWDR. However, the level of economic development involving a better quality of roads, a more developed energy network and a lower degree of bureaucracy (necessary in the development of photovoltaic parks), allowed Cluj County, despite lower climate parameters compared to Bihor County, to concentrate over 25% of the units built in the NWDR. Generally, the installed power have less than 6 MW with two exceptions: the largest PV park, built with an investment of approximately 105 million Euros, located in Satu Mare County and Lechința Solar Park (Bistrița-Năsăud County), which develops a capacity of 14.5 MW (Fig. 1B).

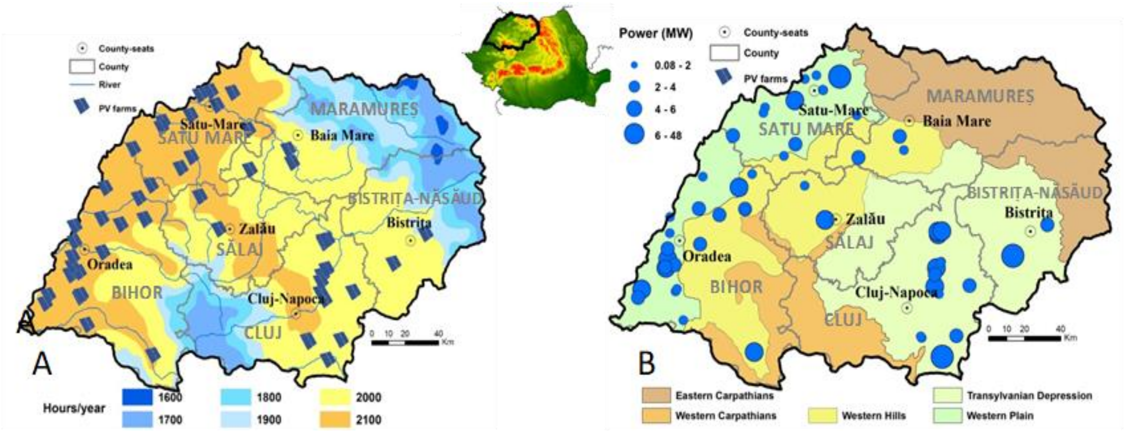

Figure 1. Sunshine duration (A) and PV parks distribution on relief units and at county level (B)

METHODOLOGY

The largest body of literature on renewable energy consider solar energy technologies as the cleanest, cost effective, accessible and environmentally friendly, yet taking into account some adverse consequences to safety, health and environment (e.g. [15,16,11,12,13,1]).

The dimension and intensity depending on the development phase: construction, installation, use, management etc. The resulted spatial and functional effects (positive and/or negative) apply to almost all environmental and socio-economic components: e.g. landscape, land use/cover, vegetation, soil, hydrology, investments, jobs [16,5,6,11,12,13,7,1].

For the current study, the authors computed several indicators to assess the PV parks impacts grouped into two main categories: environmental (distribution on main soil types, distance to hydrological network, protected natural areas, forests) and socio-economic (distribution on main land use/cover categories, distance to settlements, roads, and the solar electric footprint). Both quantitative and qualitative approaches were used to obtain an accurate assessment. Several stages were completed to perform this research: (1) mapping all PV parks in NWDR using the satellite images (Landsat 7 ETM and Landsat 8 OLI, 2018) and the records provided by the Romanian Transmission and System Operator (TSO) Transelectrica (e.g. installed power of PV parks, type of PV); (2) gathering information from field investigations (questionnaire surveys and interviews) in order to fill in the missing or incomplete information; (3) performing the impact assessment based on the calculation of the selected environmental and socio-economic indicators (Fig. 2).

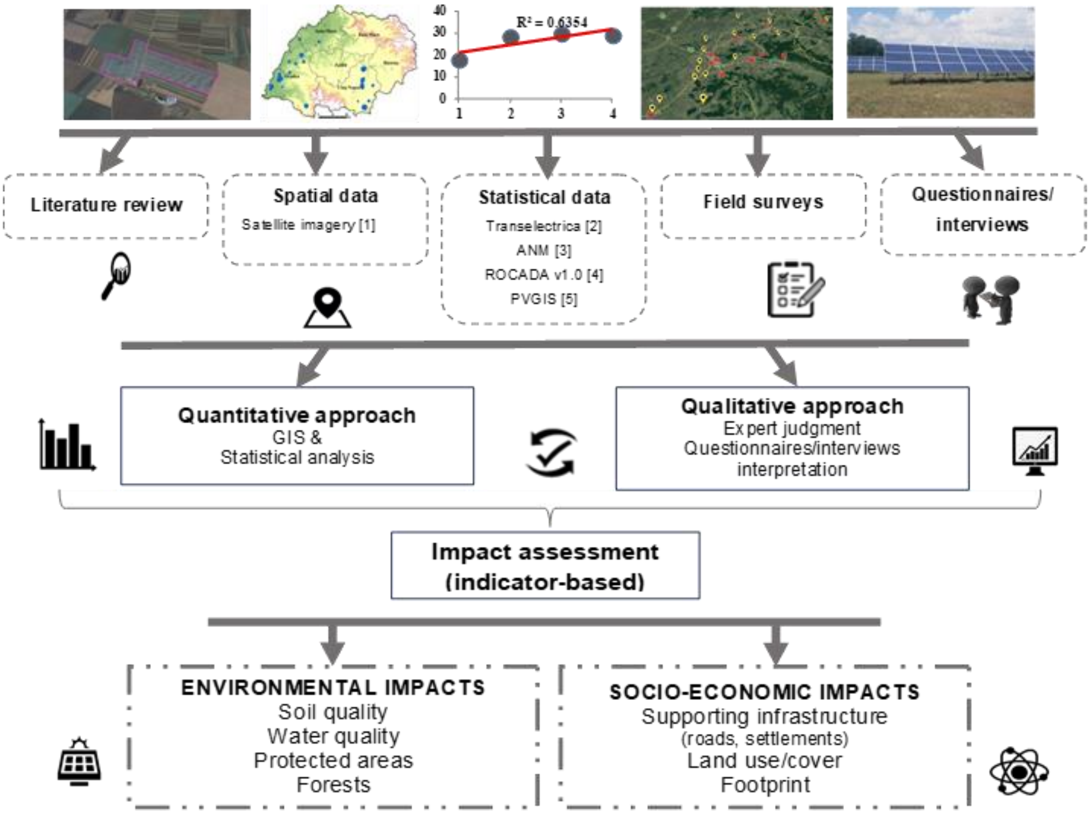

Figure 2. The methodological flow[12]

RESULTS AND DISCUSSION

PV parks have significant positive environmental impacts such as the reduction of GHG emissions and climate change mitigation [17,11,1], but also several negative impacts felt at the level of all components of the biotic and abiotic environment, i.e. air, water, soil, vegetation, fauna [17,18,19,15,11,20,12].

Soil is significantly degraded, especially during the construction phase in relation to the changes in land use/cover [1] and to the movement of the equipment and transportation [19,11]. Even if in the NWDR more than 50% of the total lands are poorly fertile or non-fertile, approximately 52% of the photovoltaic parks occupy lands with molisols or alluvial soils, recognized for the high degree of fertility/productivity. Moreover, only 13% of the total PV parks investments represent the reintroduction of uncultivated land into the economic circuit.

[12] Landsat 7 ETM and Landsat 8 OLI, 2018;
Romanian Transmission and System Operator (TSO) Transelectrica (website);
National Meteorological Administration (website);
doi.pangaea.de/10.1594/PANGAEA.833627
https://ec.europa.eu/jrc/en/pvgis;
https://www.minind.ro/domenii_sectoare/energie/studii/potential_energetic.pdf

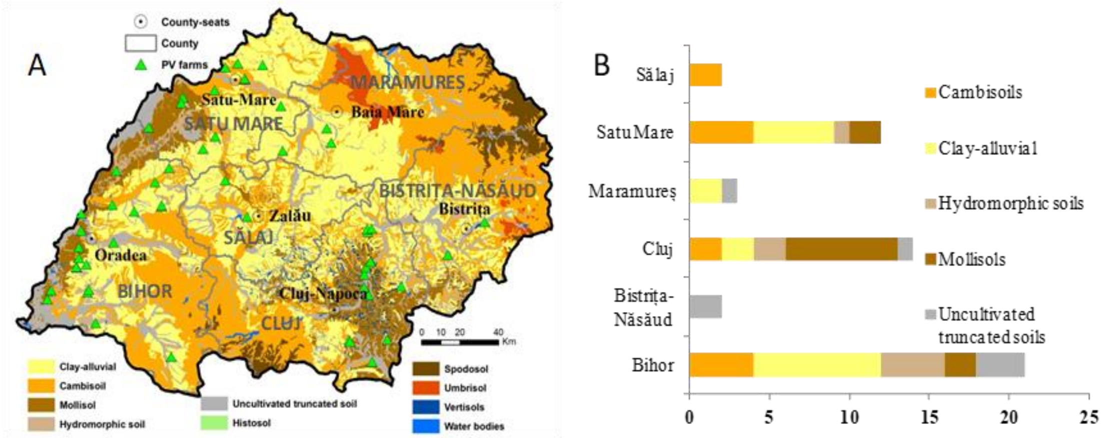

Figure 3. PV parks distribution on main soil types in NWDR (A) and at county level (B)

Dust is a drawback in the proper functioning of PV parks, reducing the productivity by 5-7%/year, even up to 10% in the droughty years, as the interviewed persons in charge with the maintenance of PV panels clamed. This requires periodic cleaning of panels and the large amounts of water, up to 60–99% of the total water used during the maintenance period [18]. In this respect, the proximity to the hydrographical network could be an advantage for the maintenance of solar panels. Over 60% of the PV parks are located at distances of less than 1km from the watercourses (Fig. 4). On the other hand, washing the solar panels with chemical detergents has other effects on the environmental quality such as damaging the structure and quality of the soil, biodiversity loss etc.

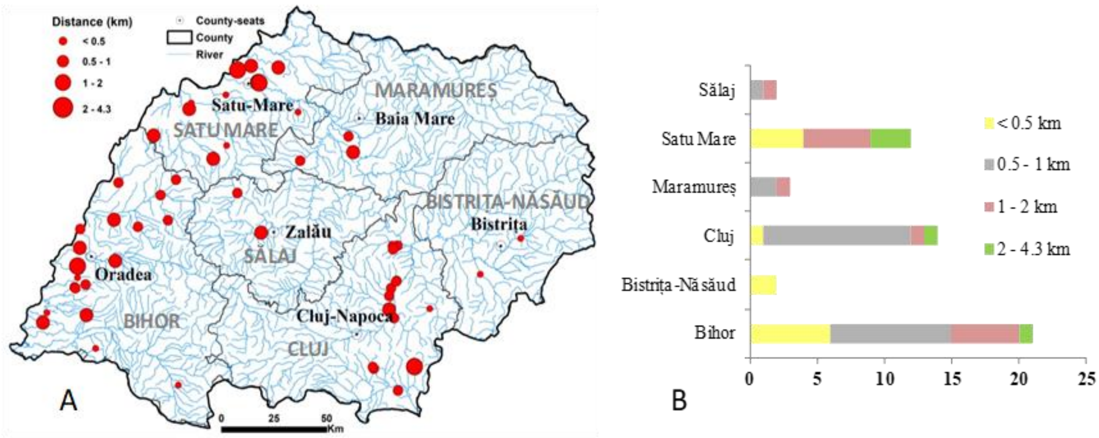

Figure 4. Distance of PV parks to water bodies in NWDR (A) and at county level (B)

Ecosystems are among the most affected by the activities related to PV farms construction, operation or decommission, studies generally indicating habitat and biodiversity loss, especially wildlife and birds among the key negative impacts [17,18,21,22,20]. In the study area there are 88 protected natural areas included in the Natura 2000 network, to which 170 protected natural areas of national interest are added. In relation to Natura 2000 sites, by positioning the PV parks in their vicinity, several impacts to local fauna and flora are expected, i.e. habitat degradation and loss, which are caused by fragmentation and edge effects, changing the ways of feeding and moving of animals, biodiversity loss. Within the NWDR there is only one case of overlapping a photovoltaic park over a protected natural area (ROSC0021-Ierului Plain); however over 50% of PV parks are located less than 5 km from natural protected areas (Fig. 5).

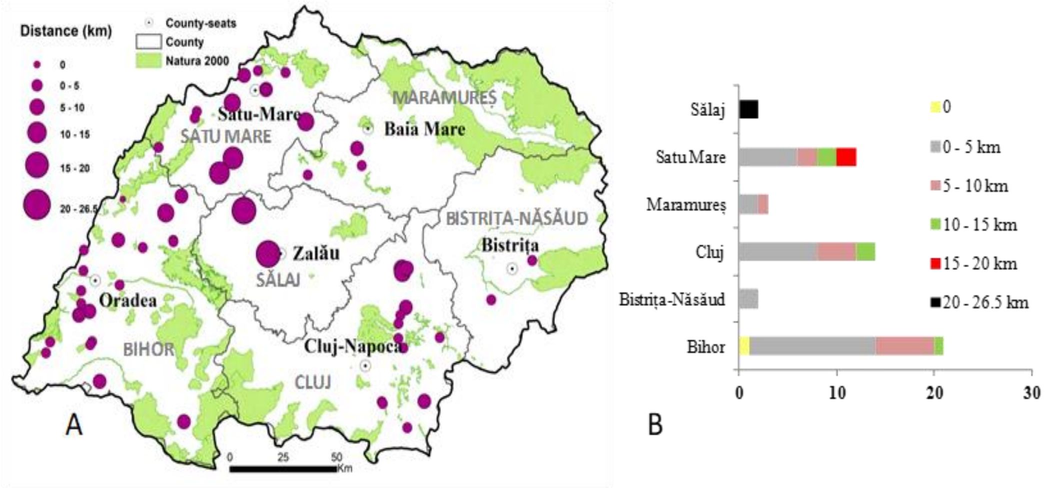

Figure 5. Distance of PV parks to Natura 2000 sites in NWDR (A) and at county level (B)

Unlike the proximity to Natura 2000 sites, in the case of forests, all PV parks are positioned at a distance of less than 5 km (Fig. 6). However, our analysis revealed that 80% were installed at least 500 m from the trees to avoid shading and, consequently, decrease the return on the investment.

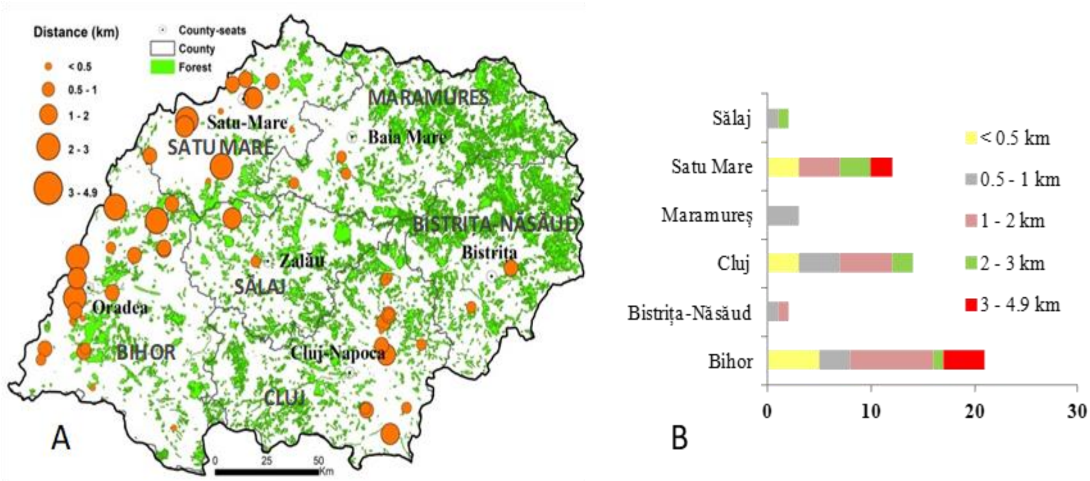

Figure 6. Distance of PV parks to forests in NWDR (A) and at county level (B)

The main socio-economic impacts of the PV parks that could be assessed using the indicator-based analysis are: distance to roads and settlements, hitherto considered as environmental impacts [5,6,7,14], here considered as supporting infrastructure for the economic investment; land/cover changes and the loss of farmland; and solar electric footprint.

The network of national and county roads facilitates the access to areas suitable for the construction of photovoltaic parks; most of investments were built so as to benefit from the existing access roads [5,11,6,7]. For this reason, over 66% of investments in the NWDR are located less than 1 km from roads, which reduces the costs (fast transportation, easy access of the equipment, less and/or no additional investments related to roads). As a result, all PV parks are positioned at a distance of less than 6 km from a main road, the road network of the region being very well developed (Fig. 7).

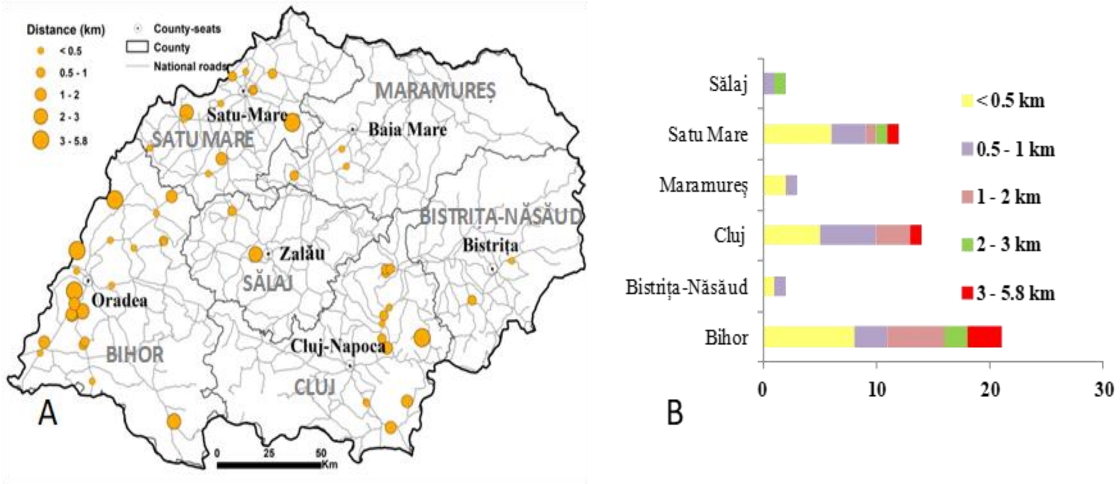

Figure 7. Distance of PV parks to national roads in NWDR (A) and at county level (B)

Considering the high cost for the construction of a photovoltaic park with a capacity of 1 MW (approx. 1.5 million Euros), the proximity to settlements and, implicitly, to the electricity network, was generally one of the conditions of the investment. For this reason, all solar power plants in the NWDR are located less than 2 km from inhabited areas (Fig. 8). Coupled with the high level of unemployment, especially in rural areas, investments in green energy can provide new jobs, for construction, security or maintenance. Our field investigations revealed that, in general, 1 MW installed requires, on average, between 5 and 7 employees to cover all stages of the entire life of the installation.

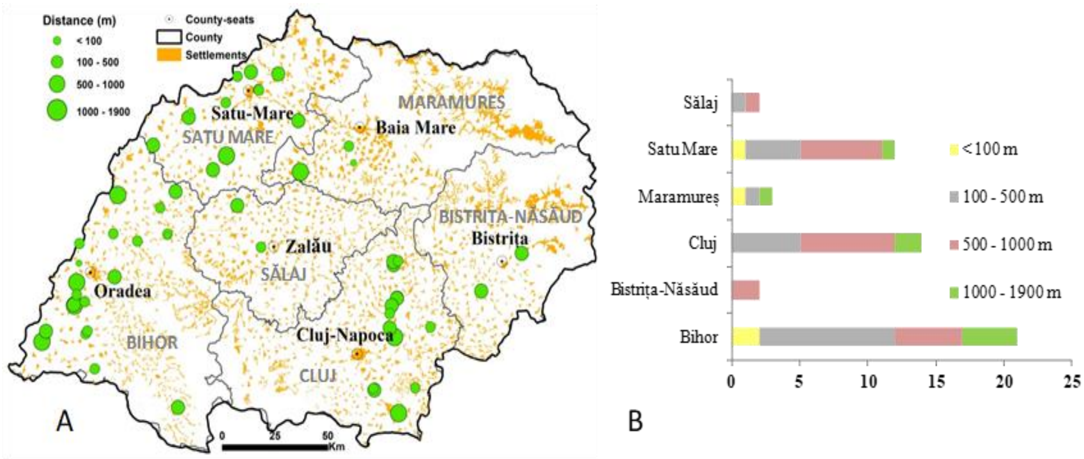

Figure 8. Distance of PV parks to settlements in NWDR (A) and at county level (B)

There are a number of factors that generally dictate the dimension of PV farms impact on land use/cover, i.e. topography, land use/cover type, distance from areas of natural beauty, size of the solar plant [17,19,16,18]. PV parks are usually known as being built on high value agricultural land [17,23,5,14,6,7], but also shrubs and grasslands [18,24]. In the study area, over 90% of the investments covered productive lands from an agricultural point of view, either covered with cereal or vegetable plantations, or intended for grazing (Fig. 9). Also, photovoltaic parks built on artificial land have replaced urban land, although there are many derelict industrial areas in the NWDR.

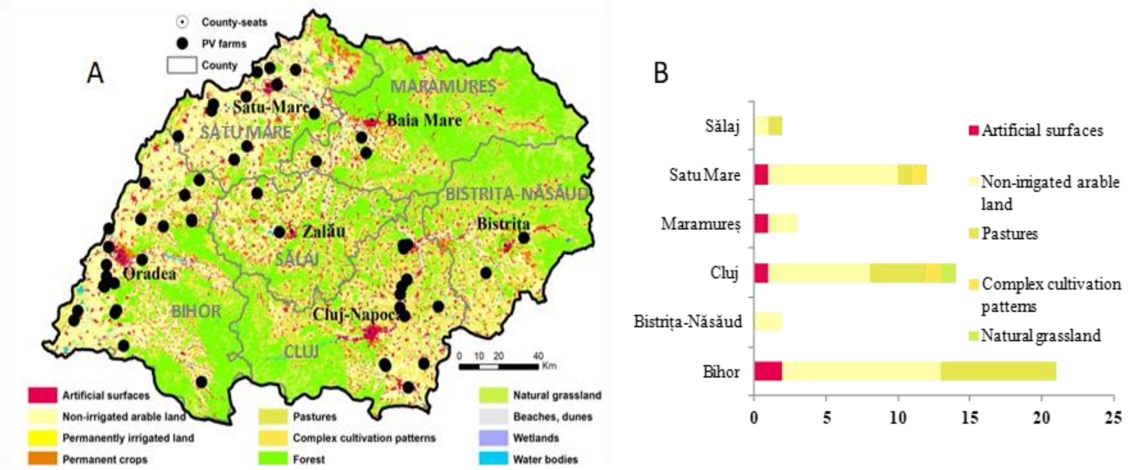

Figure 9. PV parks distribution on LUC categories in NWDR (A) and at county level (B)

The surface of photovoltaic parks and, implicitly, the amount of energy generated and introduced into the network, is a very important element for the quality of life by bringing added value for the local community, i.e. additional green energy, job opportunities for locals, decreasing the degree of pollution, increasing the attractiveness for investors, etc. The solar electric footprint explains the relationship between (1) the local communities, the first beneficiary of the solar energy produced by the PV parks located in a certain rural or urban settlement, and (2) the land cover category necessary to supply electricity from a PV park [7]. In the NWDR, there are no created patterns of the footprint of photovoltaic power plants, but there are large discrepancies between localities, being an unfair development in terms of the positive aspects mentioned above (Fig. 10).

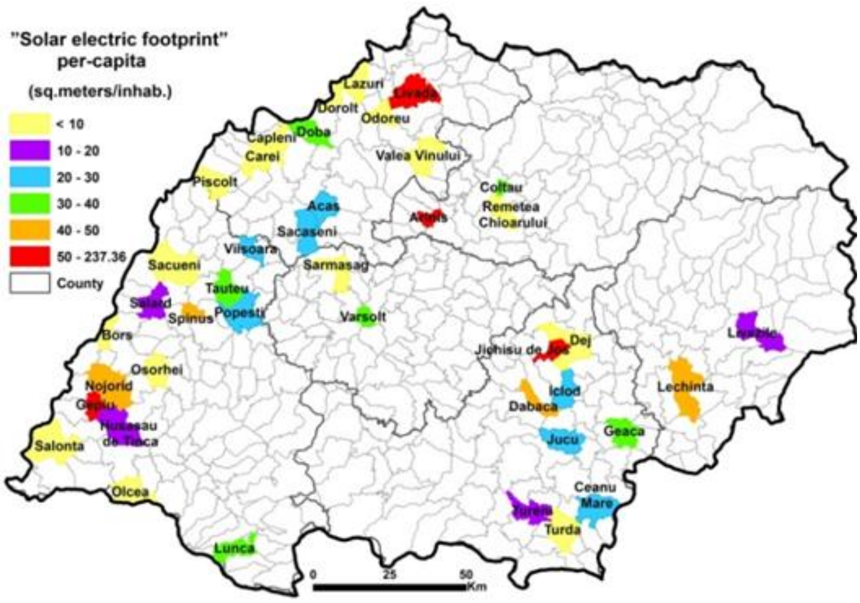

Figure 10. Distribution of solar electric footprint values in NWDR

For example, while at a population of about 7,000 inhabitants, Livada locality amounts to almost 1 million square meters of photovoltaic panels, Turda Municipality, with over 57,000 inhabitants, concentrates about 10% of this area. Such situations highlight an uneven development in the region, representing a low standard of quality of life for part of the population.

CONCLUSION

The favourable natural conditions (relief, sunshine duration) and the economic context (ability to attract investments) have made the North-West Development Region rank second in terms of capitalizing the solar potential after the South Development Region.

In terms of the positives and negatives of PV farms impacts, the findings of the current study pinpoint some key aspects of the relationship between PV farms and the environmental and socio-economic factors. Over 50% of PV parks are built on arable land with a high fertility degree which indicates a substantial loss of valuable land resource. Over 50% of the PV parks are positioned at distances less than 5 km from protected natural areas, which represents a potential negative impact through the harmful effects of overheating of the panels for bird and insect species, the transit of protected areas during construction phases, but also during use, for maintenance actions etc. On the other hand, the proximity to the supporting infrastructure (settlements and roads) has a special importance because it can have a defining role from the beginning of the solar PV installation and can reduce the construction and transportation costs; 66% of PV parks are located less than 1 km from roads. Moreover, PV parks bring about significant socio-economic benefits to the local communities, e.g. taxes generated by the PV parks, (green) jobs created during the construction/operation, investments and general impacts on the local economy etc. However, such evaluations require timely evaluations based on in-depth investigations to compensate for the lack of available statistical data.

The Regional Development Plan for the North-West Development Region (2021-2027) [13] has many references to the energy factor, but only in terms of increasing of the energy efficiency of dwellings, conventional resources (oil, coal, natural gas) or energy consumption per capita, without clear references to the renewable energy potential and valorisation. As a result, the outcomes of this study will bring necessary and useful information for the decision makers at local and regional level to consider renewable energy sources as alternative energy sources, but also as a way to protect the environment and provide socio-economic support for local communities.

Acknowledgement

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