ENERGY AND ECO-ENERGY: THE ROMANIAN TERRITORY SEEN FROM THE GLOBAL CHANGE NEXUS VIEWPOINT

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Abstract. The energy – climate change – land cover and use nexus is easy to grasp from a theoretical perspective; nevertheless, field data cannot easily show the intrinsic connections due to the limitations of temporal extent. Within the nexus, the concept of primary eco-energy has an operational value, relating land cover and use to the alterations of energy flows using a causal relationship. The paper links primary eco-energy to actual energy using the national territory of Romania as a case study accounting for the appropriate spatial extent. The analysis of unconventional energy, seen from the perspective of its spatial distribution, does not provide significant results in order to elucidate the relationships, but suggest possible impact on biodiversity and has a practical relevance.

Key words: global change, eco-energy, kriging, unconventional energy, biodiversity

1. Introduction

Primary eco-energy is a concept introduced in the literature to assess the variability of environmental potential and defined as "initial energy of a system, before the conscious human intervention over its structure" (Ianoş, 2000:52). In territorial systems, primary eco-energy is inversely proportional to their level of anthropization. In more detail, natural systems are anthropisized and become anthropic at the end of the process; eco-energy is measured based on the environmental degradation of initial systems, and the level of anthropization, which is responsible for an increased complexity of systems, is proportional, but negatively (inversely) correlated with the level of primary eco-energy (Ianoş, 2000:52).

The dynamics of socio-economic systems includes alternating stages of spatial, structural, and economic growth, and structural and functional improvements (Vădineanu, 1998:123; Ianoş *et al.*, 2000). The underlying causes are external (cosmic, geological – same as for natural systems) and internal (dynamics of human population and needs, including social and institutional organization and development of better technological means to access and use natural goods (resources) and services (Vădineanu, 1998:135). Man-dominated systems are unable to carry out complete biogeochemical cycles and produce energy; resources (matter and energy) are 'parasitically' taken from natural systems (Vădineanu, 1998:65). The process results in adding several trophy levels to the natural ones: techno-trophy (technological processes) and noo-trophy (support activities, such as research and management) (Ianoş, 2000). Anthropization results in a series of processes leading to the simplification and fragmentation of natural systems, determining a loss of biodiversity (Vădineanu, 1998:133-134). However, urbanization produces new socio-economic structures (Sârbu, 1999), increasing the complexity of territorial systems (Ianoş, 2000:54), and their geo-diversity (Petrişor şi Sârbu, 2010).

The term "global change" encompasses all man-generated impact affecting our planet, *i.e.*, land use changes, climate change and energy use (Dale *et al.*, 2011). Given the fact that the three are related, some authors relate climate changes to land use changes (Feddema *et al.*, 2005; Cheval *et al.*, 2011), while others look at historical large-scale land modifications leading to climate change (Pielke, 2005). The causal path starting from land cover and use changes end ending with climate change includes the water cycle (Pielke, 2005), carbon cycle (Dale, 1997; Pielke *et al.*, 2002; Olofsson *et al.*, 2005; Dale *et al.*, 2011) or energy flows (Pielke *et al.*, 2002). Moreover, urbanization is the underlying cause of "heat islands" (Cheval *et al.*, 2009). Wise land management, called "landscape design" (Dale *et al.*, 2011) can be perceived as a means of adjustment to climate changes (Thomas *et al.*, 2004; Medina and Tarlock, 2010; Dale *et al.*, 2011).

The causal implications of this relation was analyzed by Dale *et al.* (2011), who pointed out toward three directions: climate modifications determines land cover and/or use changes; altered land cover and use modify the carbon cycle and lead to climate change; and finally land cover and/or use are changed in order to mitigate the effects of climate change. Moreover, changed land cover and/or use increases the emissions of greenhouse gasses, resulting into climate change (Mendelsohn and Dinar, 2009). Climate change influences directly the productivity of land and calls for mitigating land cover and/or use changes. Haim *et al.* (2011) show that the social effects of climate change include migrations, causing land cover and/or use changes given the limited space.

The studies looking at land cover and use changes determined by anthropization found out that land cover and use changes are due to the socioeconomic drivers of development (Petrişor *et al.*, 2010c), and can be tied to the anthropization process and evaluated through the consumption of primary eco-energies (Petrişor *et al.*, 2010; Ianoş *et al.*, 2011). For Romania, the most important changes are urbanization, two antagonistic phenomena affecting agriculture: development and abandonment of agricultural land, antagonistic phenomena affecting forests: deforestation and their regeneration due to natural causes (reforestation) or induced by man (afforestation), and, to a very little extent, floods, construction of dams, desertification, and drainage of waters (Petrişor *et al.*, 2010; Petrişor, 2012a, b; Petrişor and Ianoş, 2012).

A study attempting to analyze the relationship between the changes of land cover and use and climate changes yielded inconclusive overall results, but underlined the joint effects on agriculture, forests, and urbanization, pointing out the inability of spatial methods to prove causality (Petrişor, 2012c).

This paper attempts to analyze under the aforementioned theoretical framework the distribution of unconventional energy sources in Romania and predict its impact, in conjunction with the trends underlined by previous studies.

2. Methodology

The analysis consisted of several stages, increasing complexity and abstractness.

1. Geographical distribution of energy sources, attempting to identify spatial patterns. Values were grouped using the statistical method of natural limits, based on Jenk's optimization formula, minimizing the variability within each class (Petrişor, 2010).
2. Mapping all sources of energy based on their type, in order to identify the dominant ones
3. The analysis of energy potential started from previous results. Power was mapped using the ordinary kriging technique (Johnston *et al.*, 2001) based on the location and power of each power plant. To be able to increase the territorial relevance, an approach similar to the one described by Petrişor (2010) was developed: the surfaces corresponding to the five levels of power identified by kriging were intersected with administrative areas. The limits of resulting surfaces were dissolved within each county, computing a weighted average of power, using the areas of a given level as weights. The method of natural limits was used to find the five levels of the resulting distribution.
4. A final exploratory analysis overlaid the results of kriging and map of primary eco-energy (Ianoş, 2000:53) and urbanization in Romania (Ianoş, 2000:55) in an attempt to identify possible spatial patterns and connections.

3. Results and discussion

The analysis of spatial distribution for each type of energy source did not reveal conclusive results for each type of source taken separately. However, few of the resulting configurations can be explained by the natural potential: wind energy is found in the east and southwest (Fig. 1) and solar energy in the south (Fig. 2). A high density of wind farms is found in Dobrogea, including the Danube Delta and Black Sea coast, corresponding to the Steppic and Black Sea biogeographical regions. The Black Sea covers the shore over seven countries: Romania, Bulgaria, Moldova, Georgia, Russia, Ukraine and Turkey; only two are members of the EU – Romania and Bulgaria. Although the Romanian part of this region covers 340,981.72 ha (2.40% of its total), the share is 32.35% with respect to the EU total. The Steppic regions covers a very small portion of Bulgaria (less than 0.01% of the total); Romania includes 3,681,541.36 ha (2.91% of its total); the fast majority expands over former Soviet Union. Out of the EU total, Romania covers 99.99%. Biodiversity is part of the natural heritage, and the high share of the European total covered by Romania should imply an increased responsibility towards caring for these fragile ecological complexes (Petrişor, 2011).

Nevertheless, the important biodiversity is endangered by wind farms, with direct and indirect impacts on birds (especially songbirds) and bats (all bat species are a conservation priority in the EU), as shown by numerous studies summed up by National Wind Coordinating Collaborative (2010). Direct impacts include fatalities due to collisions; raptors are particularly attracted. Bats are affected in addition by sudden variations of air pressure around the windmill. Other studies documented impacts on the migration of birds (Hanowski şi Hawrot, 2000; Richardson, 2000), or loss of habitats, displacements and barrier effects (Drewill şi Langston, 2006). Moreover, the pressure on biodiversity in the southwest adds to already existing impacts due to anthropic activities related to the extractive industry associated with the generation of conventional energy (Braghină *et al.*, 2010, 2011; Peptenatu *et al.*, 2011).

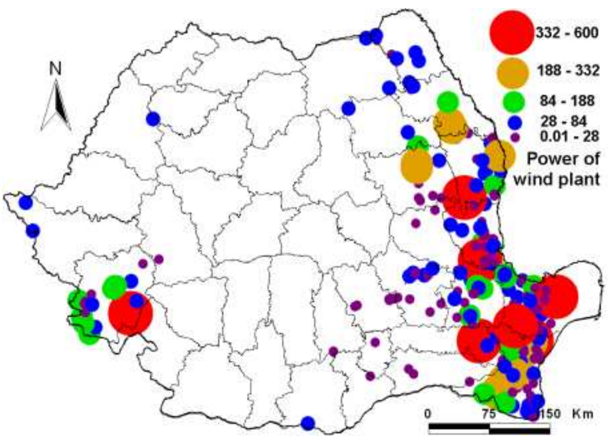

Fig. 1. Spatial distribution of wind plants. Color and size scale correspond to actual power.

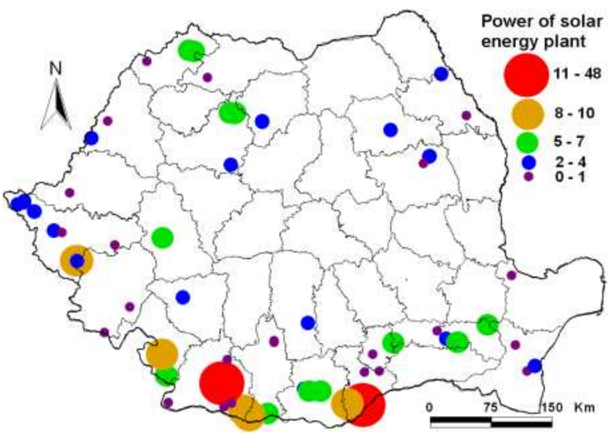

Fig. 2. Spatial distribution of solar plants. Color and size scale correspond to actual power.

The overlaid analysis of all types of energy (Fig. 3) showed that the most common form is wind energy. Moreover, the entire national territory has a potential for generating energy, except for the central area. If looking at the power of plants (Fig. 4), eastern and southwestern regions have the highest potential (the latest has the highest value). Values decrease towards the center to an average potential, wile the lowest values are found in the west and south of the central area. Nevertheless, the interpretation of the findings displayed in Fig. 4 must be done with caution, as the generalizing power of kriging is also its main limitation, provided that it reduces the possibility of interpreting the results in a specific territorial context (Petrişor *et al.*, 2010).

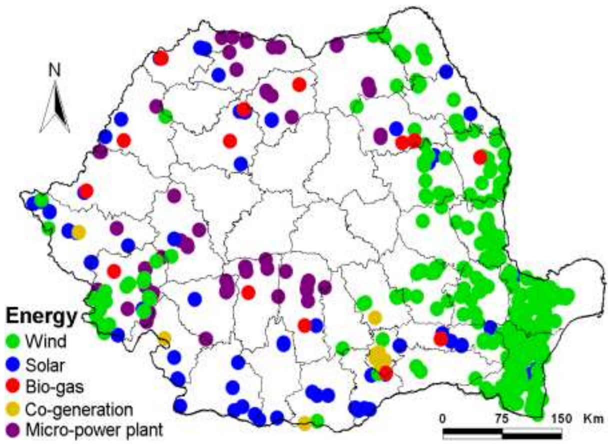

Fig. 3. Spatial distribution of unconventional energy. Color scale correspond to the type.

Fig. 5 displays the county distribution derived from Fig. 4. Some of the counties with a great potential for unconventional energy are situated within the least favored regions from an economic standpoint, such as the Northeast and Southwest regions of development. It can easily be inferred that, in a planning perspective, these regions should aim to explore their potential for greener energy as a start point for boosting their development. In a similar way, Bucharest has the highest level too; the capital city is known for its increasing need for energy, and needs to explore the possibilities for valorizing its potential for unconventional energy.

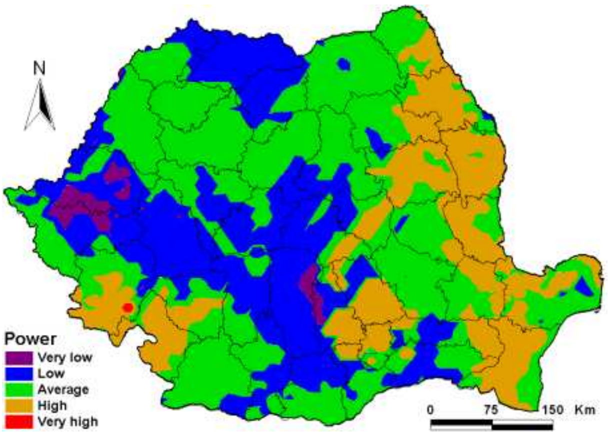

Fig. 4. Spatial distribution of unconventional power. Color scale corresponds to actual power.

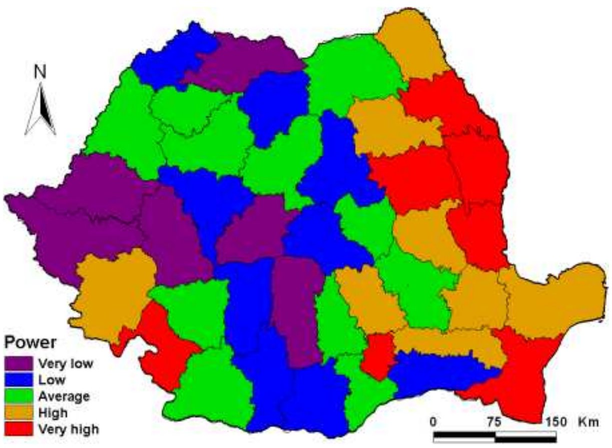

Fig. 5. Distribution of unconventional power by county. Color scale corresponds to actual power.

The exploratory analysis of the relationship between the average power resulted from unconventional sources and levels primary eco-energy (Fig. 6) and between the average power resulted from unconventional sources and urbanization (Fig. 7) did not reveal clear patterns; overlaps seem to be coincidental, with no correspondence between the levels of any two overlapped spatial distributions. Last but not least, the extreme southeastern counties should try to balance their natural potential (an important biogeographical area) and their high potential for unconventional energy. Therefore, the use of unconventional energy must be preceded by an in-depth analysis of its potential consequences against biodiversity; additional passive housing solutions could be explored, as they are less aggressive to the environment (Voica, 2011).

The present study aimed to cover a wide territory and connect spatial distributions. However, studies carried out at the local scale revealed different connections, which could not be pinpointed at the upper territorial level (Ianoş *et al.*, 2011). In addition to developing a multi-scale approach, starting from territorial distributions (such as Petrişor, 2010) and ending with in-house energy consumption and use, including alternative sources (see Voica, 2011; Petran and Radu, 2012), future research directions could include an environmental impact assessment of using unconventional energy, based on the experience of other countries. Moreover, it is important to investigate the political and economic means of stimulating its use, including an economic and risk assessment, particularly in the market conditions specific to Romania.

4. Conclusion

The study aimed to perform a spatial exploratory analysis of the distribution of unconventional energy sources in Romania in relationship to eco-energy and urbanization. Even though inconclusive with respect to the issue being addressed, the results have a particular practical significance, due to the potential effects of exploiting specific energies, such as the wind energy, on biodiversity, and consequent implications over the planning process.

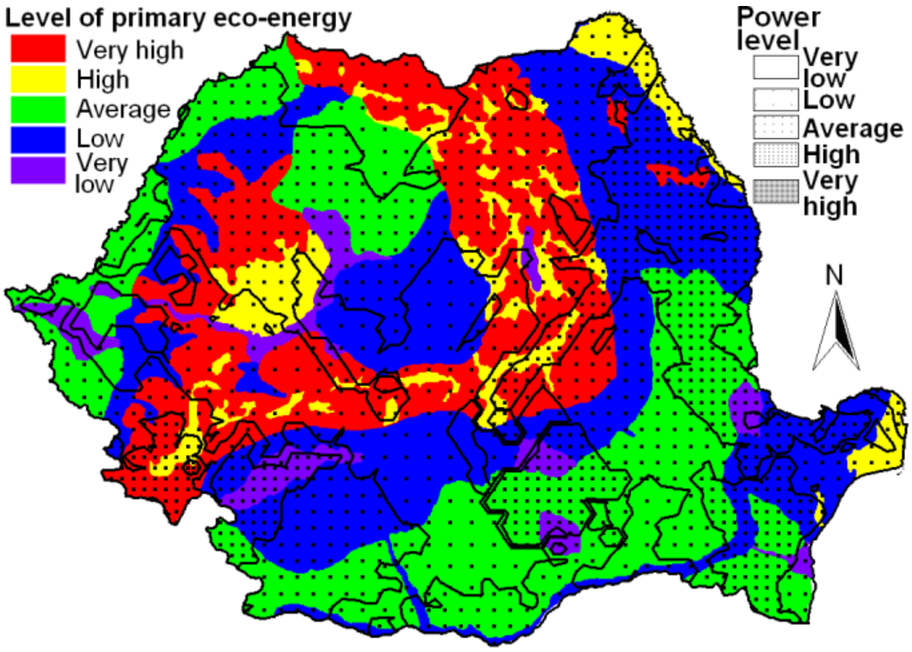

Fig. 6. Overlaid distribution of unconventional and primary eco-energies (Ianoş, 2000:53) in Romania

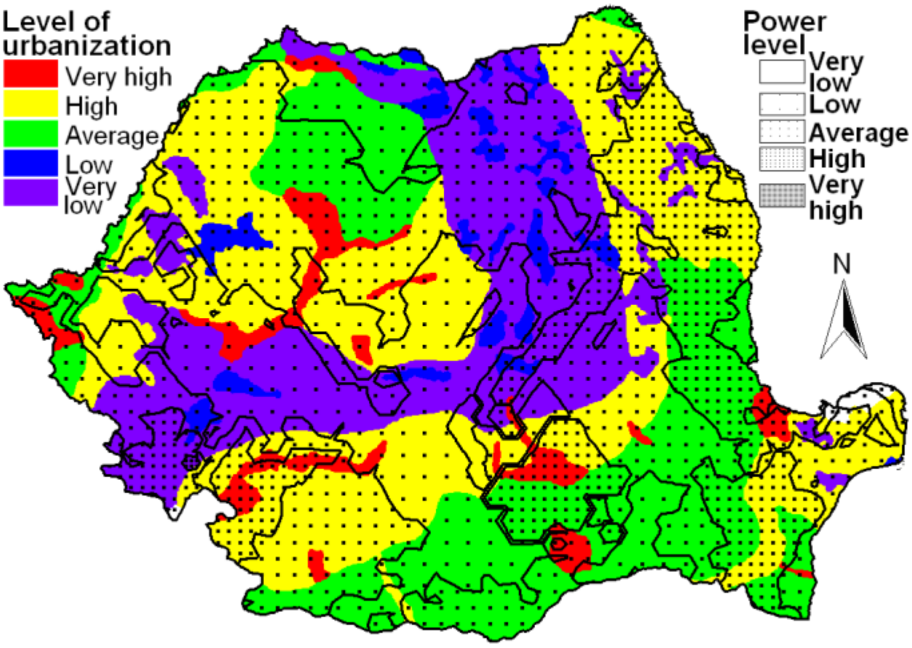

Fig. 7. Overlaid distribution of unconventional and level of urbanization (Ianoş, 2000:55) in Romania

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