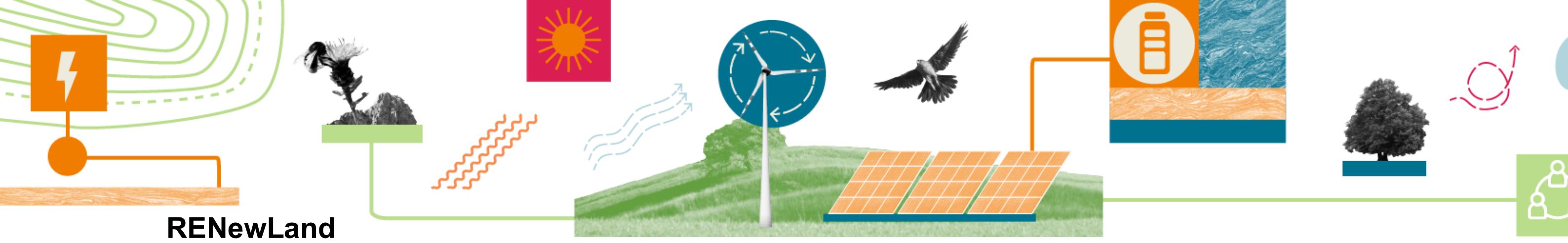

Overview of the Renewable Spatial Planning procedure and results in the RENewLand project

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Supported by: Federal Ministry for Economic Affairs and Climate Action on the basis of a decision by the German Bundestag

European Climate Initiative EUKI

Introduction

This report summarizes the results of the RENewLand project, which supports the identification of Renewable Acceleration Areas (RAAs) following a spatial planning exercise, in line with the EU Renewable Energy Directive (RED III). Using Geographic Information Systems (GIS) and Multi-Criteria Decision-Making (MCDM) methods, the project developed a harmonized approach to locate suitable areas for solar and wind energy deployment across Hungary, Romania, and Bulgaria.

It outlines the main methodological steps, including the selection and weighting of environmental, technical, and socio-economic factors, as well as the spatial analysis that guided RAA mapping. The findings highlight clear patterns across the pilot areas such as the fact that large portions of non-irrigated arable land proved consistently suitable for both wind and solar energy, raising further considerations. The analyses also identified substantial differences between regions, such as the high potential for solar in Prahova and Ruse, or the restricted wind potential in Kapuvár due to extensive conservation zones. Together, these results offer practical, location-specific insights that can guide national and regional authorities in targeting areas where renewable energy expansion is both feasible and sustainable.

The report further details lessons and recommendations to be considered in official RAAs designation processes based on local validation of results in pilot regions.

Summary

The aim of this analysis is to provide comprehensive guidance for delineating potential Renewable Acceleration Areas (RAAs) using scientific methods. The delineation process relies on a combined assessment of multiple spatial influencing factors, which together determine the location of suitable areas. Study areas must be defined so that they are sufficiently heterogeneous to allow complex investigations and have accessible spatial data describing both the objects within the area and the geographical phenomena occurring there.

A critical step is identifying the influencing factors to be considered in the study, which include technical, environmental, social, and economic aspects. Collecting the necessary data and GIS layers for these factors can be a significant challenge. Determining the extent of protective distances (buffer zones) and assigning weights to suitability factors should be carried out collaboratively by an expert group to ensure consistency. GIS layers from different sources must then be processed, transformed, and unified through a multi-step methodological process, with the analysis performed by a GIS expert using appropriate software. The results are presented cartographically, highlighting the areas most suitable for designation as RAAs.

However, due to limitations in accessing certain datasets and the need for a unified approach across the three implementation countries—Romania, Hungary, and Bulgaria—the methodology and resulting maps did not include several important criteria. These excluded factors are artificial surfaces such as urban areas, rooftops, warehouses, and industrial platforms; ecological corridors recognized by the scientific community but not officially designated; agricultural land categories (all were included as potential acceleration areas, although in some countries, such as Romania and Bulgaria, only unproductive or degraded land can legally be used for renewable energy purposes); property regimes distinguishing state-owned from private land; and surfaces already occupied by renewable infrastructure projects such as solar or wind installations. Furthermore, buffer zones applied for certain technologies or objectives may differ from those currently provided in national legislation, as they were harmonized at a regional level for all three countries.

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In conclusion, the Project Consortium recommends that the results of the RENewLand project be regarded as a strong starting point for the official process of mapping and designating acceleration areas for solar and onshore wind at the national level. From this foundation, further integration of all relevant country-specific criteria—including those mentioned above—will be necessary to ensure that RAAs are designated in a way that is legally compliant and contextually appropriate.

Selecting the study area

Selecting a study area begins with identifying the key factors that need to be assessed. In practice, however, the choice is often shaped by the availability and accessibility of relevant data, the social and environmental processes unfolding in the region, or the presence of characteristics that make the area particularly significant compared to others in the country.

In RENewLand, experts considered several elements when defining the study areas, including renewable energy potential, the distribution of protected and non-protected zones, the presence of electricity grid infrastructure, and other factors that could influence the quality of the analysis. The selected study areas therefore consist of municipal administrative units in Kapuvár (HU), Ruse (BG) and the counties of Brașov and Prahova (RO). In Romania, two sites were chosen to ensure that the methodology could be validated across a wider range of land use conditions.

Selecting suitability factors and collecting associated spatial data

Conducting a site suitability assessment begins with identifying the factors that influence either the success of an investment or its potential impact on the environment. These factors may describe specific objects (e.g., buildings), a broader area (such as species habitats), or a spatial phenomenon (like demographic patterns). When selecting them, it is important to determine the critical factors and the less important ones, without which the assessment can still lead to reliable results. At the same time, the number of factors must also be considered carefully, as each additional criterion increases the complexity and resource requirements of the analysis.

Once all the necessary factors have been selected, the experts must collect the data to describe them. Some datasets may already exist or be held by public authorities at the EU, national, or local level, while others may be managed by research institutions or NGOs. In some cases, data may need to be purchased from specialized providers or generated by the project team through field surveys or by processing proxy sources. The collection of spatial data can be a lengthy process that is worth dedicating sufficient time to adapt to gaps in data availability, either by identifying alternative datasets or by replacing certain factors with comparable ones.

In the RENewLand project, the experts who developed the methodology proposed 34 land suitability factors (criteria), which are detailed in the project methodology. However, due to project constraints, as well as the difficulties in collecting comparable data for all three countries, only a quarter of these factors were taken into consideration in the actual analysis. The factors incorporated were the following: electricity network accessibility, railway lines, distance from the road network and airports, average wind speed and global radiation, terrain slope, wild bird population density, surface waters and wetlands, valuable vegetation (forests and natural grasslands), protected natural areas, inhabited and other built-up areas, other land use categories (e.g., degraded lands), and a socio-economic factor (municipal tax revenue). Since no data was available for grid connection points in all three participating countries, the topology of the high-voltage power network was used as a substitute.

Determining safety distances and gradual distances

For some land suitability factors, protective distances had to be established, thus ensuring that the given geographical object or area would be adequately excluded from possible disturbance caused by the construction and operation of new solar or wind energy installations. These buffer zones usually protect natural wildlife and the human population. Any location falling within such a defined distance is therefore considered unsuitable for development.

In some cases, suitability was not just restricted but also graded: for example, areas became increasingly favorable as the distance from protected natural zones grew, encouraging developers to prioritize sites further away. In contrast, the areas closer to the electricity grid were valued more from an investment perspective. Similarly, areas characterized by higher wind speed or irradiation, as well as settlements in a less favorable economic situation, received an increasingly favorable evaluation. The protective distances and the gradual advantages were determined jointly by the project consortium partners (considering the methodological recommendations).

In the Bulgarian study area, the project team could not obtain consistent data on local economic performance. As a result, no socio-economic differentiation was applied in this region and all settlements received the same land suitability score.

Weighting suitability factors using a multi-criteria decision-making process

The individual suitability factors are awarded different weights in the methodology. The method allows for the overvaluation of certain aspects; for example, protected natural areas were given higher weighting. A multicriteria -decision making procedure was used to determine the relative importance of the aspects, which determines the weight of the individual factors in a consistent manner. The operation of the procedure is described in detail and with scientific rigor in the HUMEA methodological study[1]. It is important that these weights can only be interpreted and were prepared for those factors that can be characterized by gradual favorability based on distance or other values, since weighting is used to assess the degree of suitability. Factors that prohibit new investments only within their own area (e.g., railway lines) were not weighted due to their role. During the analysis, this methodological step provides- the most opportunities to shape and fine-tune the process according to needs. The more experts from different scientific fields the professional team consists of, the more careful the assessment can be made.

In the RENewLand project, these weighting factors were determined iteratively, with the help and agreement of a wide range of consortium partners (Appendix, Table 2). Experts from various fields provided the opportunity to establish rational weightings for the factors. In the project, two separate weightings and buffer zones were created for wind and sun, respectively, unlike the multiple scenarios proposed in the HUMEA study.

To determine the weighting factors in Table 2 (Appendix), an Analytic Hierarchy Process (AHP)

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1 https://www.epg-thinktank.org/wp-content/uploads/2025/10/Comprehensive-methodology-for-RAA-designation.pdf

was used. As described in the HUMEA report, AHP is a structured method that ranks multiple criteria through pairwise comparisons, using a scale of relative importance. A consistency ratio (CR < 0.1) ensures the reliability of these comparisons.

For uniformity, partners adopted a simplified scale: 1–5 for positive comparisons and 1 to 1/5 for negative ones. This reduced extreme variations while preserving meaningful differences. The weighting framework was designed to emphasize environmental criteria while maintaining stakeholder acceptance, and the criteria were grouped into environmental, technical, and socio-economic categories.

Environmental criteria received the highest weight due to their importance for Renewable Acceleration Areas (RAAs). Within technical criteria, RES potential ranked highest, followed by proximity to grid connection points and terrain slope, all essential for feasibility and timely deployment. Socioeconomic criteria reflected the role of RAAs in supporting -less developed- regions and improving public acceptance. These weightings were tailored specifically for RAAs, where simplified permitting procedures justify assigning greater importance to environmental considerations.

Spatial Data Preparation

Even GIS data initially thought to be uniform can differ significantly in their properties. This often affects the geographical accuracy of the data, the reliability or 'up-to--datedness' of the descriptive data in the attribute table, or—in the case of raster data—the resolution. For this reason, data from different sources- must be standardized before analyses can be performed. Such tasks include transforming all datasets to a common projection system, standardizing raster resolution, and homogenizing layers (e.g., treating different national protected area- categories as a single category).

The RENewLand project encountered numerous obstacles of this kind, and preparation was not always possible. For certain datasets, such as land use- and landcover layers, the project team was forced to give up the -high quality data of a study area and use a -panEuropean- database instead, in order to ensure consistency between study areas.

Defining Exclusion Criteria for Wind and Solar in Renewable Acceleration Areas

Once the GIS layers have been prepared, the protective zones and the distance or -locality based gradual suitability must be defined, and the previously developed weight values must be applied to the appropriate layers. These steps require specialized GIS expertise-, so a detailed description will not be presented here.

No -go areas are defined in such a way that if a given location is prohibited based on any suitability factor, it will remain excluded regardless of how favorable it might appear according to other criteria. In addition to the prohibited areas, the method also allows the evaluation of areas suitable for investment based on their overall suitability, taking into account all factors and their importance. A 0–10 point scale is used: low area suitability scores represent less favorable (but not prohibited) areas, while high scores represent- ideal areas for solar or wind energy.

It is important to highlight that all geographical elements within a **1 km radius** drawn around the study areas were also taken into account. This ensures that factors outside the study boundaries—such as the Brașov International Airport, located just outside the study area—still have an impact on the analysis and are considered accordingly.

Determining the Suitable Area and Evaluating the Results

The first results have been prepared in both map and graph form, presented below for each study area. The map display shows excluded areas by omitting pixels, so only areas that are somewhat suitable are displayed with a red-yellow---green gradient corresponding to the suitability score associated with the given locations.

For the designation of accelerated areas (RAA), project participants recommend selecting areas with a value of 5 and above.

Suggestions for replication of similar site suitability and site selection studies

The collection of data describing the factors is lengthy and not always effective. In many cases, data owners are reluctant to provide data, or the competent authorities are slow to process it. Some data do not exist at all (or the project team has not obtained a source for them) but is available in other countries. We therefore recommend that the competent authorities and decision-makers, especially the European Commission, make access to the data possible, because without this, the designation of facilitated areas cannot be carried out properly and uniformly throughout Europe.

The quality of data is of utmost importance. It should be surveyed and produced for all areas and kept up -to -date and in a form accessible to experts.

In many cases, the project team has experienced situations where similar geographical areas (e.g., forest patches) or processes (bird migrations) and phenomena (settlement social indicators) are stored in different data formats in different countries, and their resolution, content, and topicality may differ significantly. The application of a uniform methodology also requires a uniform dataset, which must be converted to comparable formats. The quality of the data may be damaged during such conversion operations.

It is recommended to employ GIS experts who are qualified to perform such tasks related to spatial planning, environmental protection, and renewable energy sources, not only in projects like RENewLand, but also within the authorities competent to perform the task.

Brasov County study area (RO)

The Brașov County sample area covers 100,973 hectares. Regarding land cover, approximately 50% of the area is covered by broadleaved forests, while non--irrigated- arable land (25%) and pastures (18%) are also present in significant proportions (*Figure 1*). Other landcover categories include complex cultivation patterns and predominantly agricultural areas, though these constitute a smaller proportion of the overall area. The forest areas are concentrated along the central north–south axis of the sample area, corresponding to higher elevation zones. In contrast, the northwestern and eastern boundaries of the area are characterized by lower elevations and are mainly composed- of arable land and grasslands (typically between forests and arable land).

Based on the analysis, the potentially suitable areas for RAA designation encompass 7,430 hectares for wind energy development, representing approximately 7.4% of the total area (*Table 1*). These areas have the potential of around 1,486 MW installed capacity of wind energy, assuming the entire surface was used for electricity generation. The primary locations are situated along the northwestern border of the study area (*Figure 2a*), including the municipalities of Parau and Comana; near the eastern border, in the municipalities of Apata, Crizbav, Codlea, and Vulcan; and centrally, within the municipality of Dumbravita.

Figure 3a illustrates the designated nature conservation areas within the study area, as well as the locations of the settlements. These areas, along with other relevant considerations not detailed here, serve as exclusion criteria for investment activities, for which buffer zones have also been established. The most suitable RAAs (suitability score higher than 5) are located outside these zones and consist of non-irrigated- arable land (4.03% of the study area) and pastures (3.22%), as these regions do not present limiting factors that would hinder the implementation of investments (*Figure 4a*). Additionally, only 0.1% of other landcover types fall within the most suitable categories. The most suitable areas in the eastern part of the study area consist mainly of- arable land, while the central and northwestern regions are primarily pastures.

Based on the analysis results concerning solar energy development, approximately 14,742 hectares are suitable for RAA designation, accounting for 14.6% of the study area (*Table 1*). The identified sites have a solar energy installed capacity potential of 7,371 MW, assuming the entire surface was used for electricity generation. Most of these suitable areas received a score of 8 (*Figure 2b*), indicating a more favorable assessment compared to the typical score of 7 observed for wind energy projects. The location of suitable areas is similar to wind energy developments, but covers larger areas, including the northwestern and eastern borders of the study area, as well as its central part. Areas designated for nature conservation are also avoided by suitable areas for solar energy developments (*Figure 3b*), although to a lesser extent than in the case of wind energy projects. Regarding land use, the most suitable regions are non-irrigated- arable lands (9.2% of the study area), followed by pastures (4.6%), and to a minimal degree, other land types (0.2%) (*Figure 4b*).

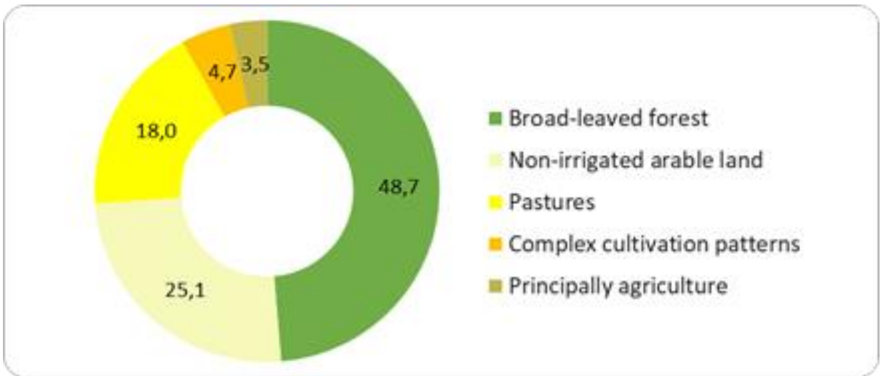
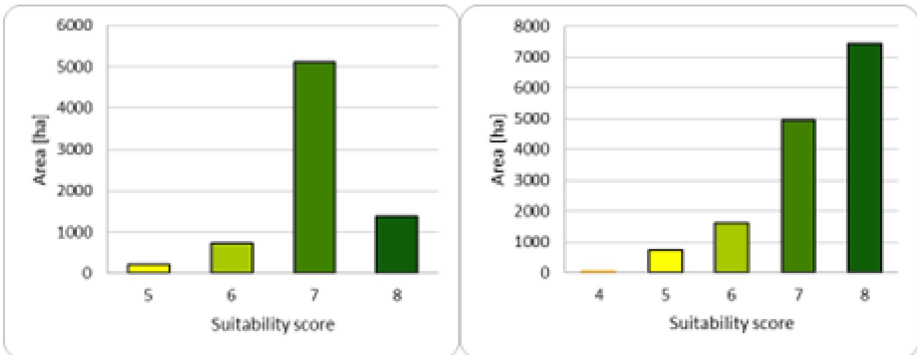


Figure 1: Land use types of Brasov study area, Romania (%)



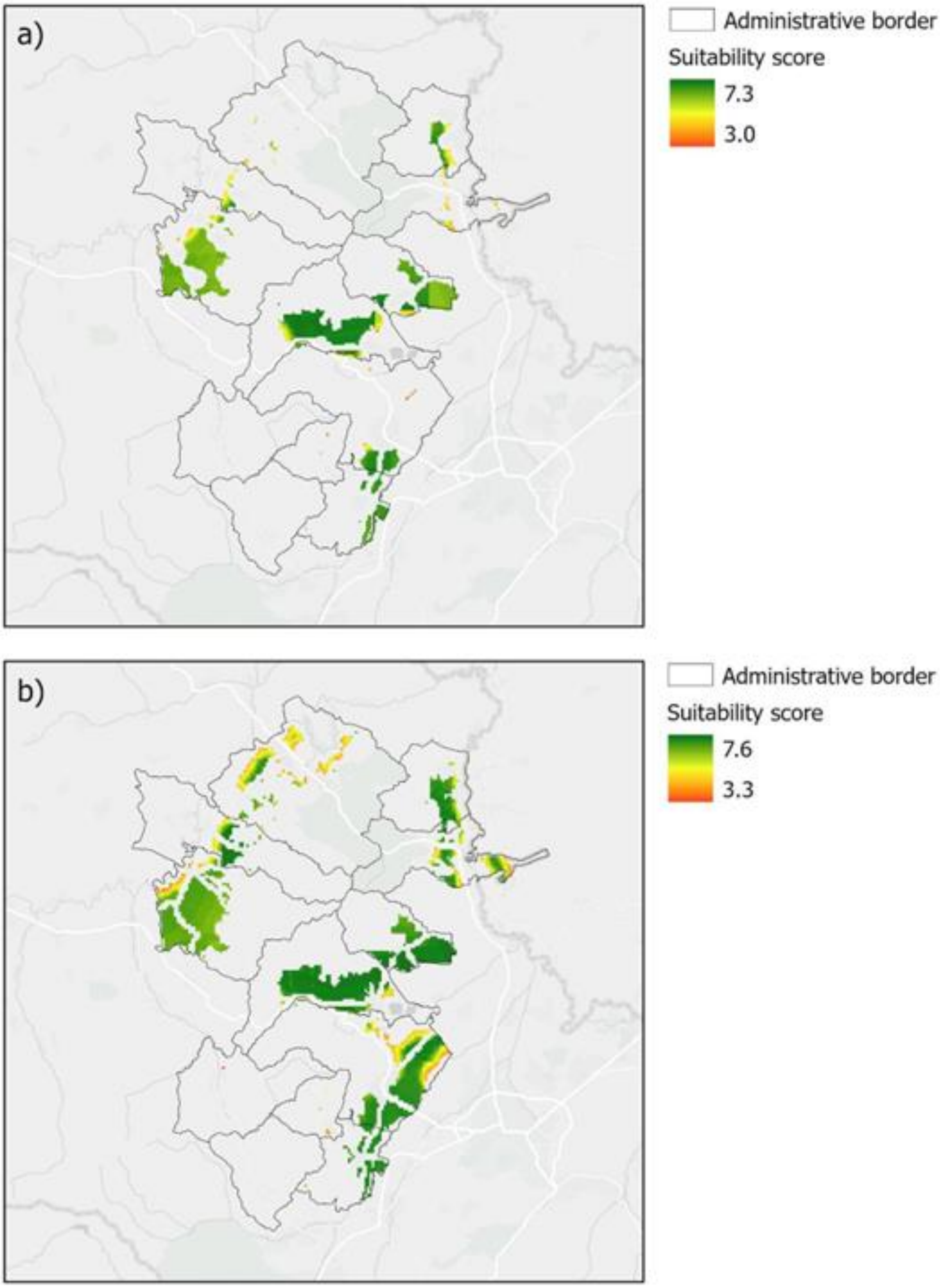


Figure 2: Site suitability for wind turbine (a) and solar PV (b) investments in the region of Brasov, Romania

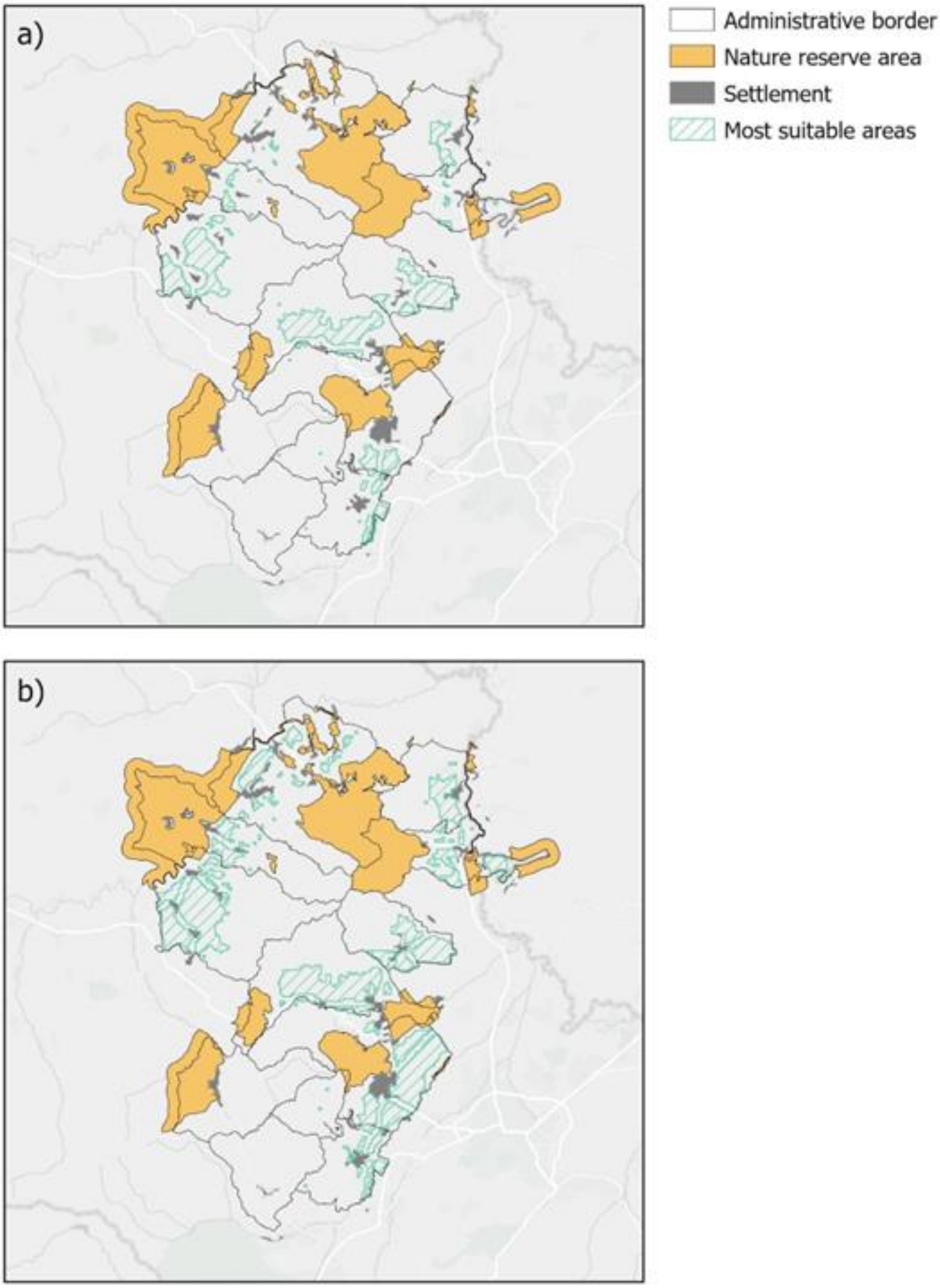


Figure 3: Most suitable areas for wind turbine (a) and solar PV (b) investments in the region of Brasov, Romania

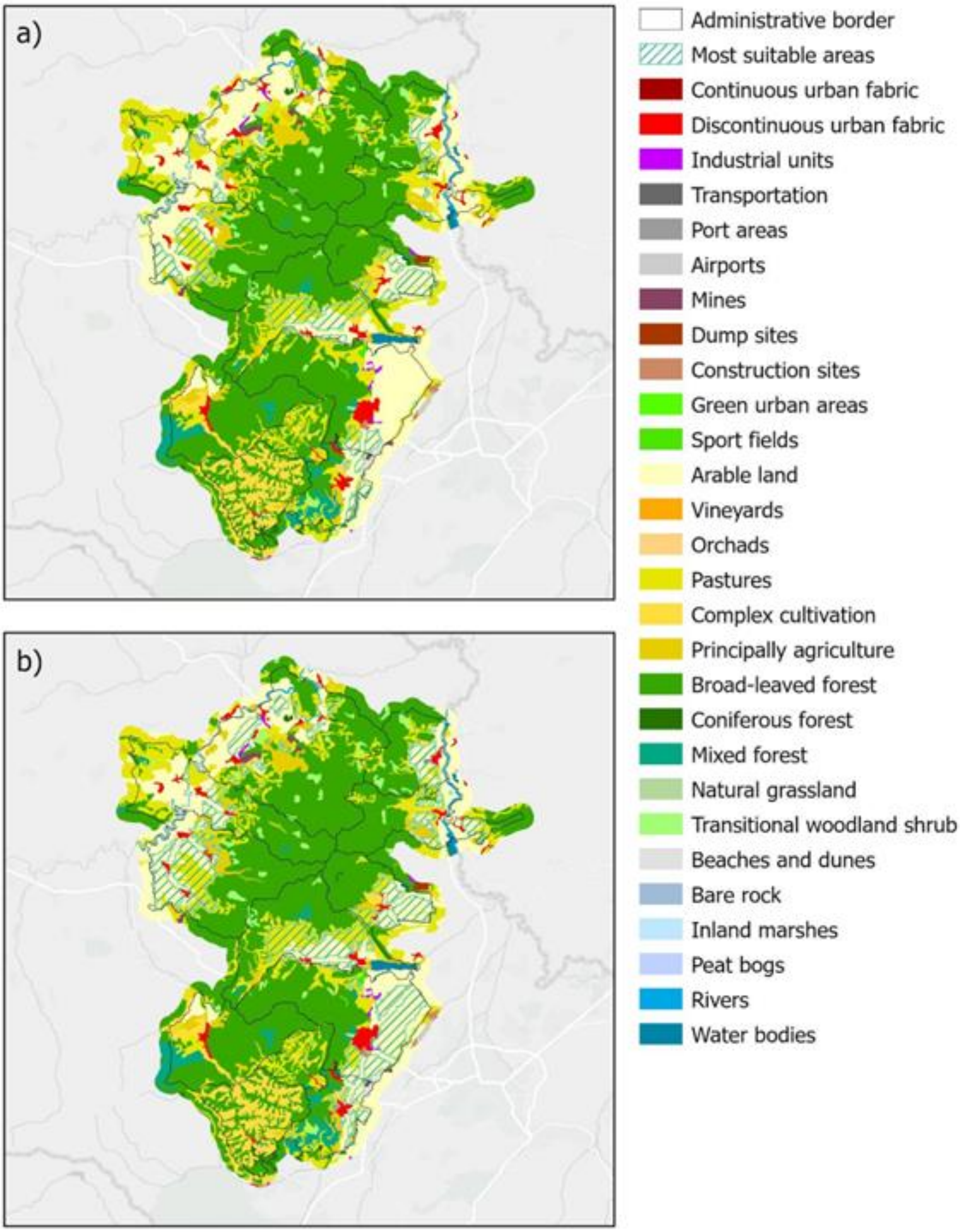


Figure 4: Most suitable areas for wind turbine (a) and solar PV (b) investments and land use in the region of Brasov, Romania

Table 1: Statistical data on suitable areas and the estimated wind and solar PV installed capacity potential in the Brasov study area, Romania

Wind	Suitability score	area [ha]	area [%]	MW
	5	205	0.20	41
	6	725	0.72	145
	7	5124	5.07	1025
	8	1376	1.36	275
		7430	7.4	1486
Solar	Suitability score	area [ha]	area [%]	MW
	4	5	0.01	3
	5	733	0.73	366
	6	1617	1.60	808
	7	4943	4.90	2472
	8	7444	7.37	3722
		14742	14.6	7371

Study Area of Prahova County (RO)

The Prahova County study area covers 76,378 hectares. Approximately 64% of the area is covered by non-irrigated- arable land, with broadleaved forest and pastures each covering 12%. Discontinuous urban fabric (settlements) accounts for 6%, while other land uses, principally agricultural, constitute 5%. The southern part of the region is characterized by flatlands abundant in surface waters. Land use varies according to natural conditions, with arable lands predominating in the flatter areas. As elevation increases moving northward, land use- transitions to vineyards, followed by grasslands and forests.

Based on the assessment, the regions suitable for wind energy development encompass approximately 24,608 hectares (*Table 2*). This represents a significant portion of the area (32%). The predominant suitability rating within the study area is a score of 7 on a scale of 10. This designated area has an estimated installed capacity potential of 4,921.7 MW, assuming the entire surface was used for electricity generation. The suitable areas are located in the southern flat part of the region, where they form large contiguous areas, mostly in the settlements of Ciorani, Drăgănești, Colceag, Fulga, and Baba Ana (*Figure 6a*).

Nature conservation areas in the study area are in the southern region, mainly associated with lowland wetlands (*Figure 7a*). During the assessment, we determined suitable areas while maintaining a protective distance from these areas for nature conservation reasons. Regarding the most suitable areas, 21,331 hectares, representing 28% of the study area, are designated on non-irrigated arable lands. Based on our study findings, arable land appears to be- the most suitable terrain for installing wind turbines in Prahova County. Pastures constitute an additional 2.8%, while other land use types comprise- a minimal share of the most suitable areas (*Figure 8a*).

In the Prahova study area, 47.1% of the region, equivalent to 35,944 hectares, is identified as suitable for solar energy development (*Table 2*). These areas have a combined installed capacity potential of 17,972 MW, assuming the entire surface was used for electricity generation. The designated areas are predominantly located in the southern portion of the region (*Figure 6b*). Areas with a score of 8 are most frequently identified as suitable (in the case of wind energy, a score of 7 is more commonly observed).

Nature protection areas are also avoided by the most suitable areas for solar energy developments (*Figure 7b*), although to a lesser extent than in the case of wind energy. The most suitable land use is 27.9% non--irrigated arable land (compared to the total study area), 2.8% pastures, and 0.2% other land (*Figure 8b*).

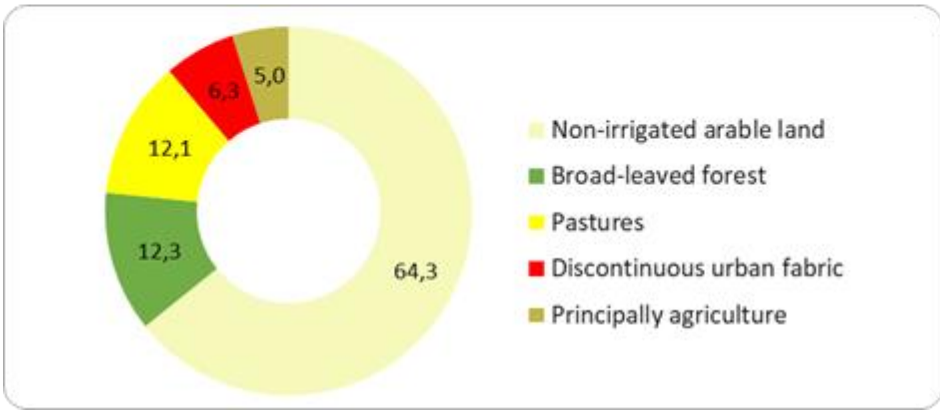
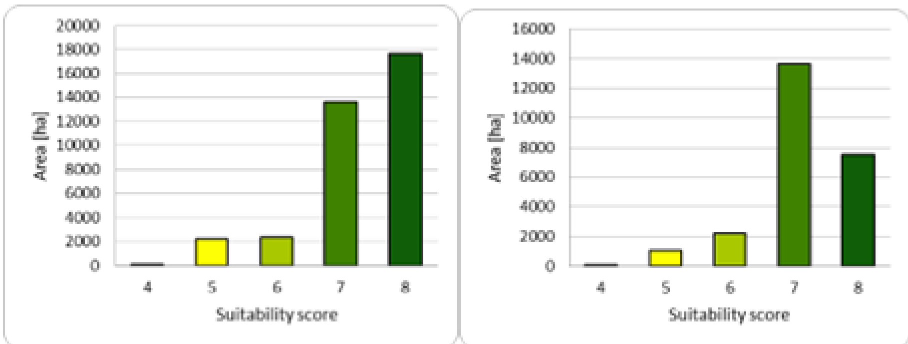


Figure 5: Land use types of Prahova study area, Romania (%)



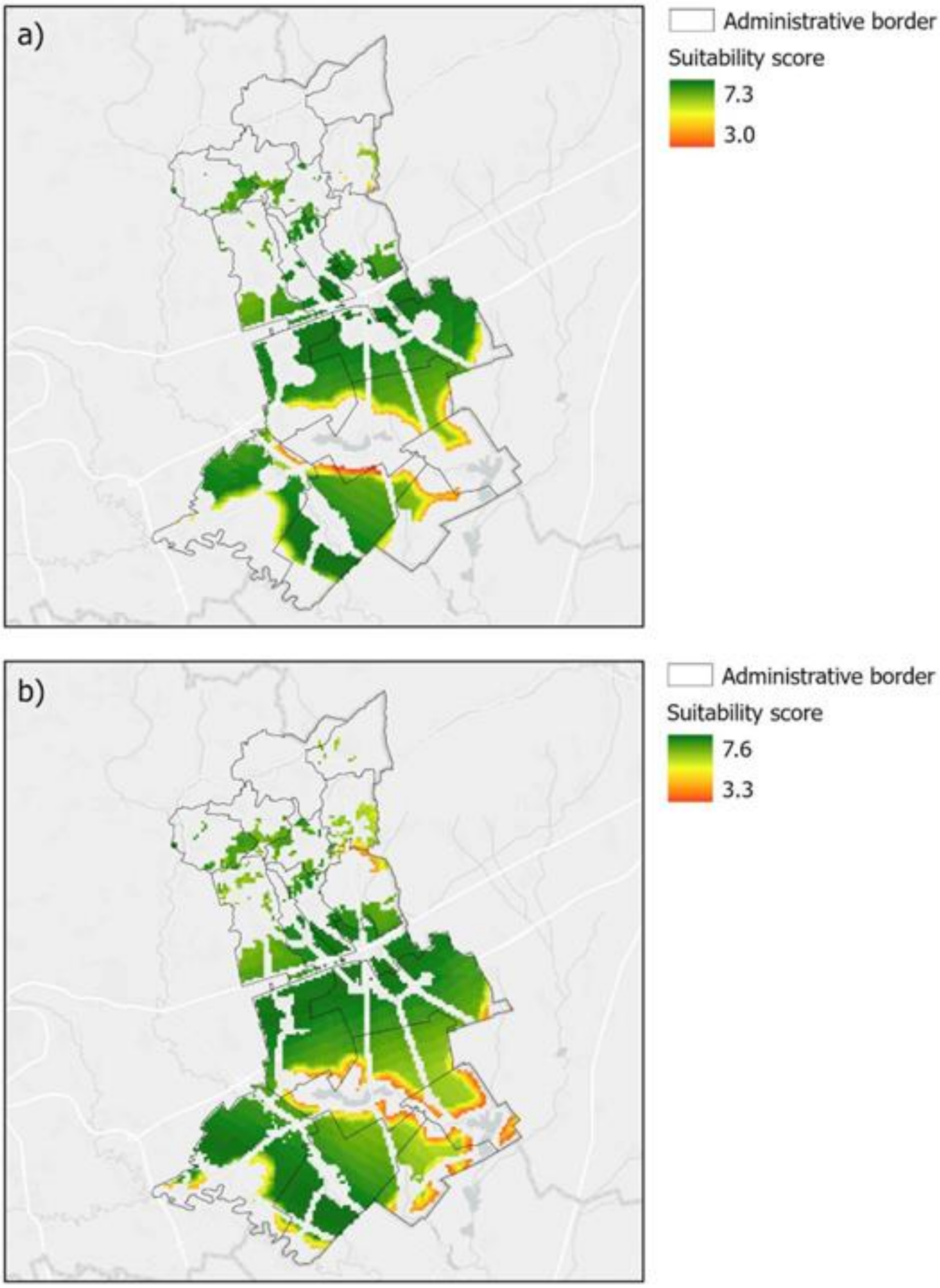


Figure 6: Site suitability for wind turbine (a) and solar PV (b) investments in the region of Prahova, Romania

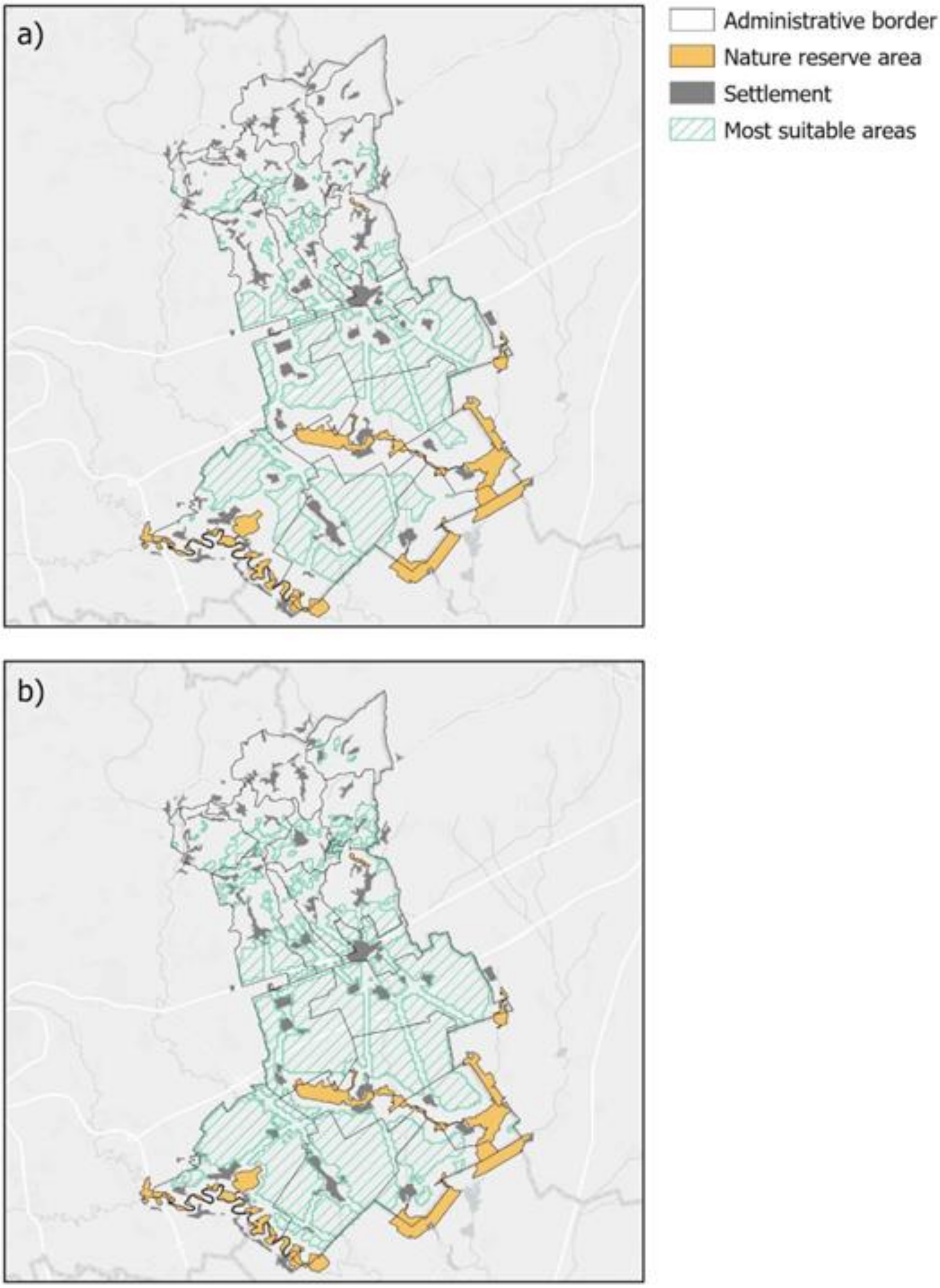


Figure 7: Most suitable areas for wind turbine (a) and solar PV (b) investments in the region of Prahova, Romania

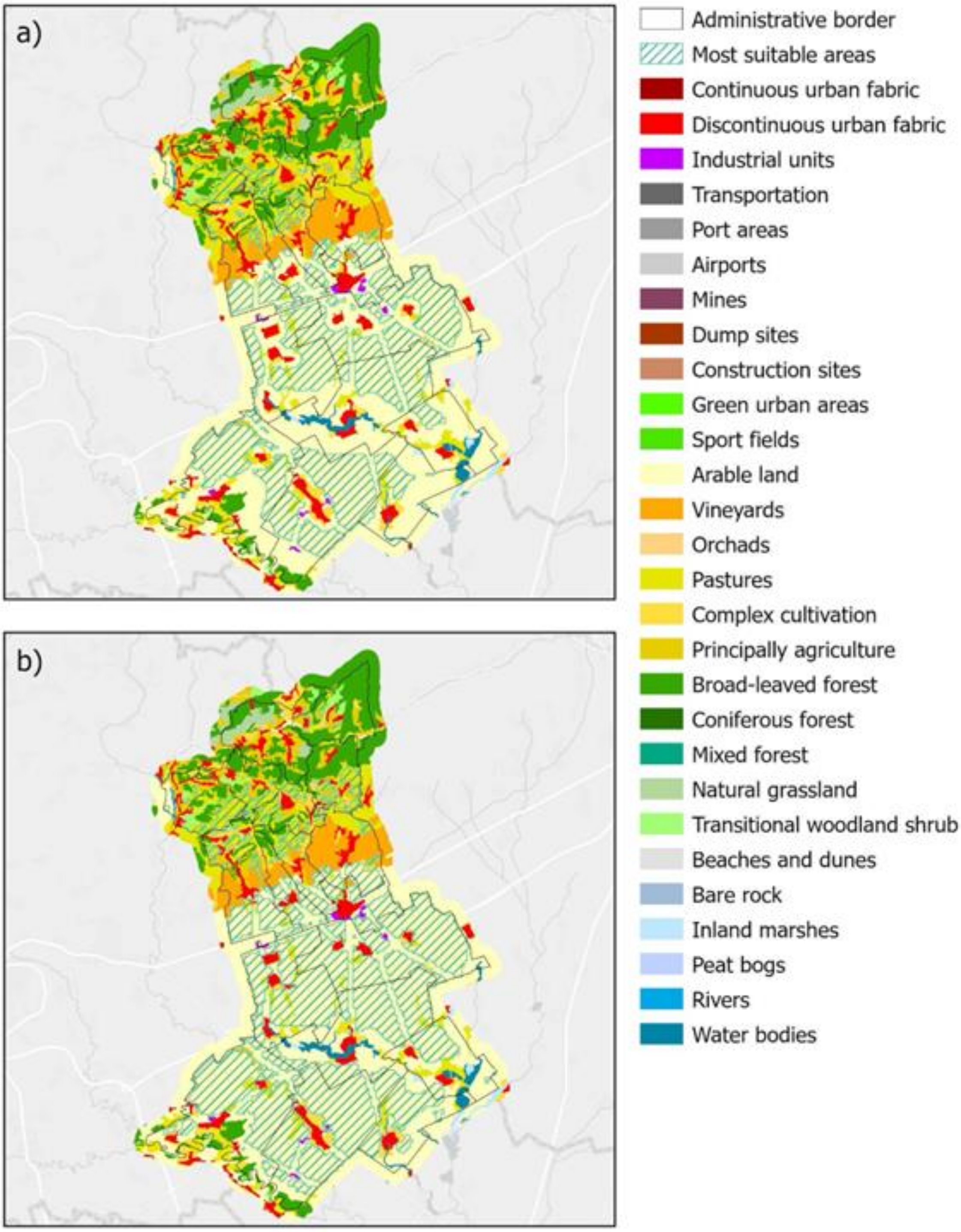


Figure 8: Most suitable areas for wind turbine (a) and solar PV (b) investments and land use in the region of Prahova, Romania

Table 2: Statistical data on suitable areas and the estimated wind and solar PV installed capacity potential in the Prahova study area, Romania

Wind	Suitability score	area [ha]	area [%]	MW
	4	95	0.12	19
	5	1046	1.37	209
	6	2217	2.90	443
	7	13704	17.94	2741
	8	7546	9.88	1509
		24608	32.2	4922
Solar	**Suitability score**	**area [ha]**	**area [%]**	**MW**
	4	88	0.12	44
	5	2214	2.90	1107
	6	2355	3.08	1177
	7	13619	17.83	6809
	8	17668	23.13	8834
		35944	47.1	17972

Results from local validation

The local validation suggests Romania should differentiate agricultural land categories (prioritizing degraded/low fertility parcels and using agrivoltaics as a -dual-use safeguard on better farmland for family farms under 30 ha), integrate ALS to unlock -low conflict potential near settlements and logistics hubs, and link site suitability to grid realities (hosting capacity, reinforcements, flexibility and storage), especially salient given stakeholder feedback on outdated/saturated networks in Prahova. It also points to the need for heritage and landscape buffers, benefit- sharing- in disadvantaged localities, and alignment with municipal PUG/PUZ and regional plans to reduce downstream conflicts.

As Romania moves to the official national RAA mapping and designation, the RENewLand results provide a robust starting point, to be completed with the missing layers and country specific rulebooks (buffers, -micrositing, excluding fertile and high nature value (HNV) agricultural land or ecological corridors still to be designated, agronomic monitoring, community benefits, circularity at -end-oflife), ensuring RAAs are legally compliant, environmentally and socially accepted, and -gridready-.

Study Area of Kapuvár Micro-Region (HU)

Non-irrigated- arable land is the predominant land use within the study area situated in the Kapuvár micro-region, accounting for 82.4% of the study area. The area covers 59,164 hectares. Broadleaved forest represents- the second largest land cover, covering 13% of the area. Pastures and discontinuous urban fabric (settlements) constitute around 5–6% of the total land area. Additionally, there is a noteworthy proportion of transitional woodland–shrub within the study area. The largest contiguous forest, shrub, and pasture areas are located on the western border of the study area. The remaining region primarily comprises large arable lands, which are interspersed with settlements and small patches of forest or pastures.

Regarding wind energy, the proportion of suitable areas is limited, primarily due to the extensive presence of nature conservation areas. These most suitable zones are dispersed in small patches throughout the area, mainly within the settlements of Mihályi, Vadosfa, Beled, Páli, Rábapordány, and Egyed (*Figure 10a*). Overall, suitable areas constitute 4.6% of the study area, with an estimated installed capacity potential of 541 MW, assuming the entire surface was used for electricity generation (*Table 3*). The average suitability score within these areas is lower compared to other study areas, with the highest concentration of areas receiving a score of 5 out of 10.

Nature conservation areas are primarily situated along the western and northern borders; however, they are distributed throughout the region in smaller, mosaic like- patches (*Figure 11a*). In our analysis, we included a buffer zone around these areas, which significantly limited the number of suitable locations available for wind turbine installation. In terms of land use, suitable areas include non-irrigated arable lands and pastures. Specifically, approximately 1,396 hectares (2.4%) of arable land have been identified as suitable, along with an additional- 12 hectares of suitable pastures (*Figure 12a*).

Based on the results of the assessment, the Kapuvár study area demonstrates a significantly higher proportion of suitable land for solar energy development compared to wind energy. Specifically, 26.5% of the area, equating to 15,656 hectares, is deemed suitable for solar projects, with an estimated installed capacity potential of 7,828 MW, assuming the entire surface was used for electricity generation (*Table 3*). Additionally, areas with suitability scores of 6, 7, and 8 are more prevalent for solar energy development than for wind energy (*Figure 10b*). Suitable areas are scattered in small patches throughout the region, with higher suitability scores observed in the southern part of the study area.

Due to the smaller buffer zone designated for nature protection areas, the availability of suitable sites for solar energy installation is greater than for wind energy (*Figure 11b*). The most suitable areas are mostly arable land (17.7% of the study area), with a smaller portion (0.2%) of pastures (*Figure 12b*).

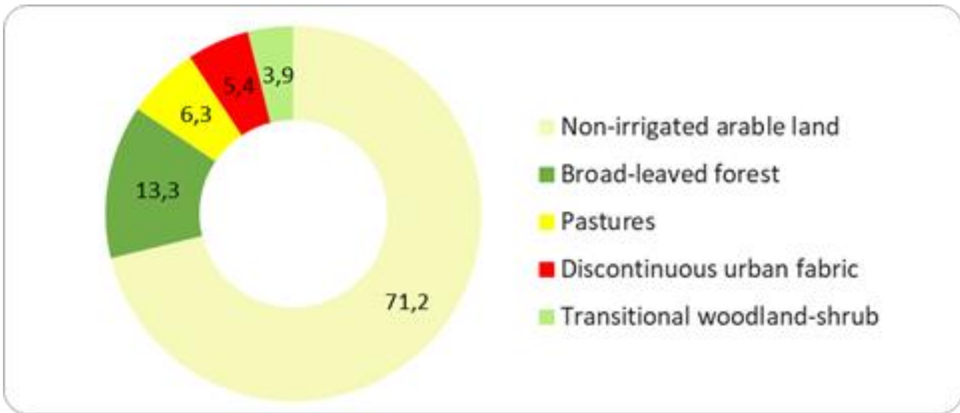
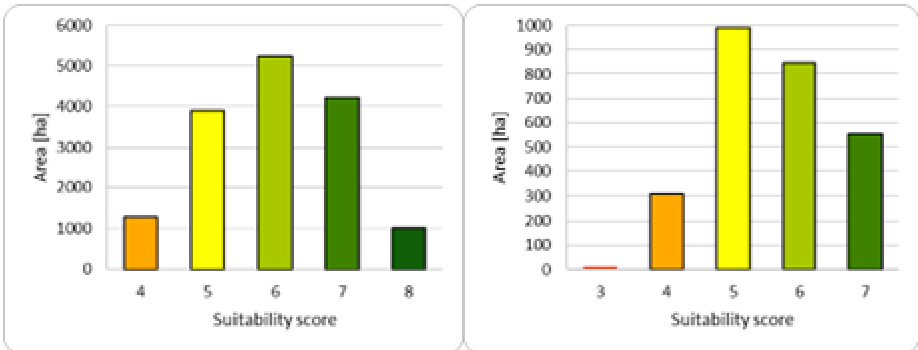


Figure 9: Land use types of Kapuvár study area, Hungary (%)



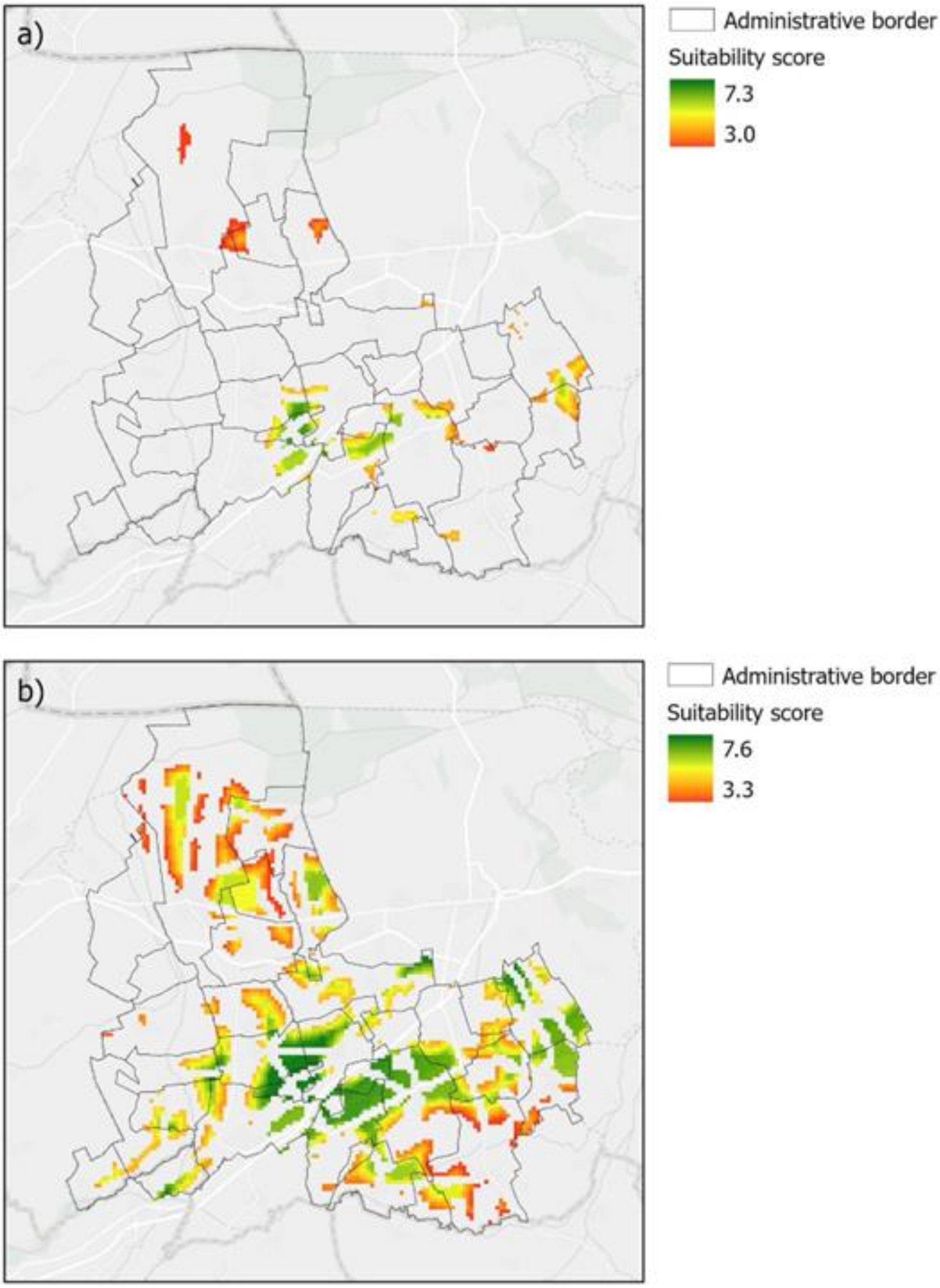


Figure 10: Site suitability for wind turbine (a) and solar PV (b) investments in the region of Kapuvár, Hungary

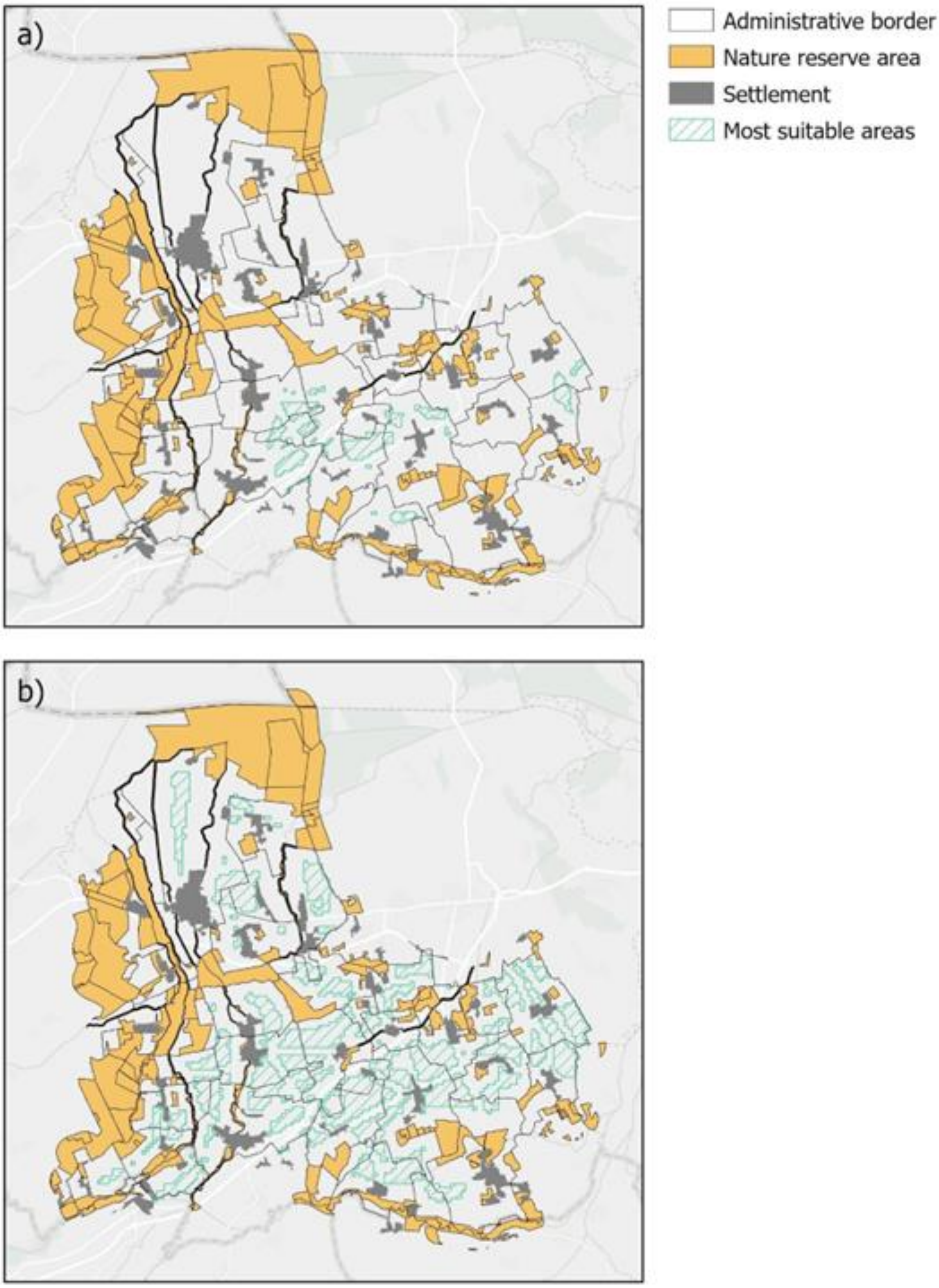


Figure 11: Most suitable areas for wind turbine (a) and solar PV (b) investments in the region of Kapuvár, Hungary

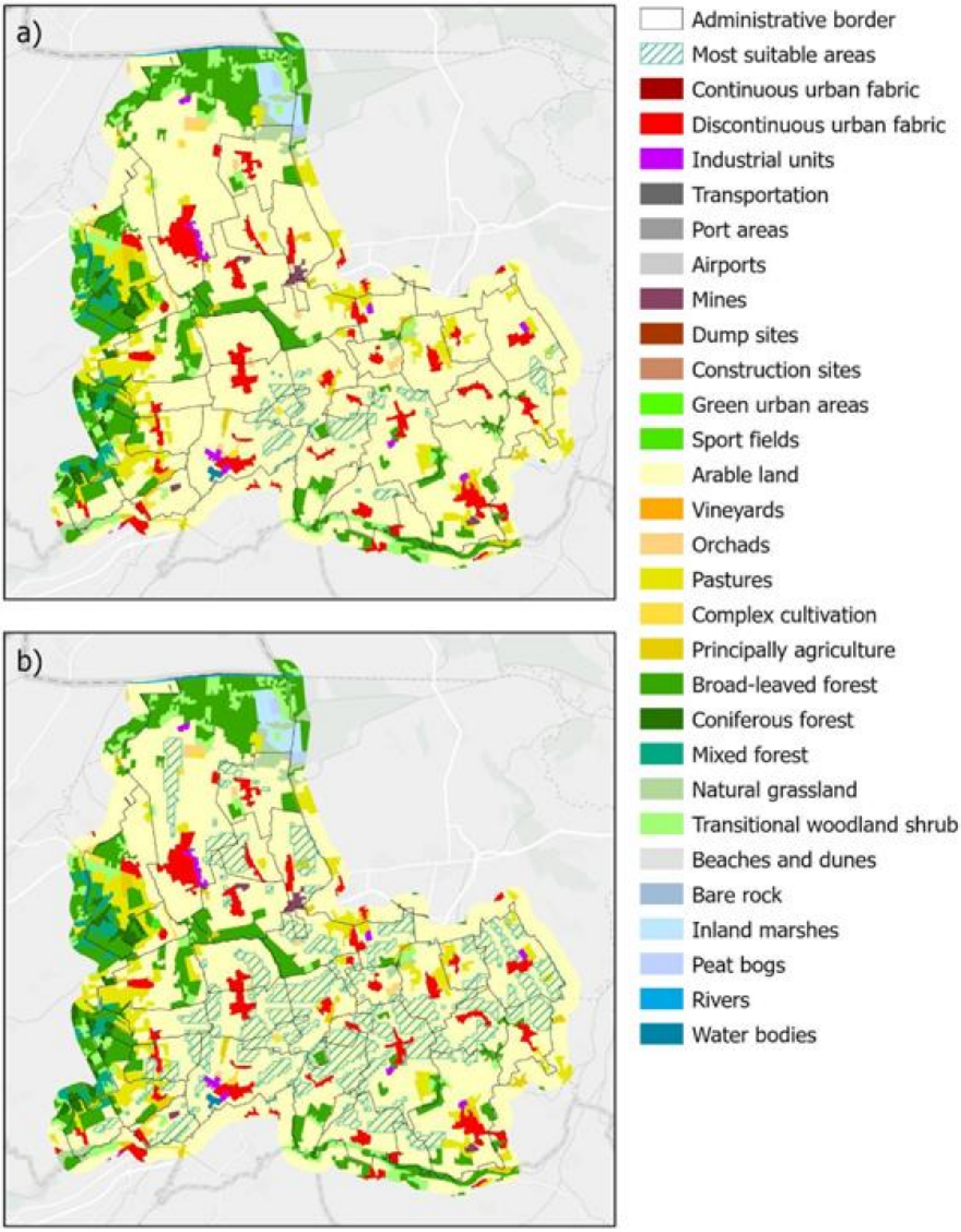


Figure 12: Most suitable areas for wind turbine (a) and solar PV (b) investments and land use in the region of Kapuvár, Hungary

Table 3: Statistical data on suitable areas and the estimated wind and solar PV installed capacity potential in the Kapuvár study area, Hungary

Wind	Suitability score	area [ha]	area [%]	MW
	3	12	0.02	2
	4	309	0.52	62
	5	988	1.67	198
	6	844	1.43	169
	7	552	0.93	110
		2705	4.6	541
Solar	**Suitability score**	**area [ha]**	**area [%]**	**MW**
	4	1263	2.13	632
	5	3919	6.62	1960
	6	5229	8.84	2615
	7	4231	7.15	2116
	8	1014	1.71	507
		15656	26.46	7828

Results from local stakeholders' discussions and validation in Hungary:

Permitting and land use safeguards emerged as the binding- constraints. National stakeholders converged on the view that the land protection regime, combined with a highly detailed, multilayered licensing process, can delay or even derail otherwise viable projects. The prevailing legal framework for wind development was widely regarded as outdated and burdensome relative to current technology and planning standards, indicating- a need for modernisation to align procedures with today’s project scales and risk controls.

Logistics and grid interconnection are also decisive. The large dimensions of modern turbines introduce nontrivial haulage and route limitations that must be planned well in advance, while connection timing and hosting capacity on the electrical grid require tight coordination to avoid bottlenecks. Together, these factors shape which sites identified in the GIS analysis are genuinely viable on a realistic timeline. Social acceptance proved conditional and -location specific: while support for wind energy is strong in principle, NIMBY dynamics surfaced around particular localities in the Hungarian study are, heightening the importance of transparent communication and visible local -cobenefits-.

A core operational lesson was that RAAs designation must be followed by careful local validation processes. Parcel level validation, covering access, tenure, -micrositing constraints, and permitting prerequisites, will be essential to translate mapped suitability into implementable projects and to smooth subsequent- licensing steps. Overall, the Hungarian pilot reinforced that modernised permitting, early logistics and grid planning, desentralized and community centered engagement, and -post designation- local validation are essential to an effective designation of RAAs.

Study Area of Ruse County (BG)

The Ruse study area encompasses 56,779 hectares. Non-irrigated arable land constitutes- much of this area, representing over 78%. Broadleaved forest areas account for approximately 8.5%, while water bodies, primarily due to the presence of the Danube River along the northern boundary, make up nearly 6.6%. Settlements (discontinuous urban fabric) occupy about 3.4%, with approximately 3% designated as principally agricultural areas. Built--up areas are concentrated near the Danube (Ruse settlement). The -land use pattern within the landscape is mosaic -like-: forests are most prevalent along the banks of the Danube and on the eastern border of the area, and the landscape is predominantly agricultural, interspersed with settlements and small forested patches.

Areas suitable for wind energy development cover 17,828 ha, which is 31.4% of the total area. The majority of these areas have received suitability scores of 7 and 8 (*Table 4*). The estimated overall installed capacity potential within these suitable areas is approximately 3,566 MW, assuming the entire surface was used for electricity generation. According to the study, the most appropriate locations are situated in parts of the landscape that are farther from the Danube River. Large contiguous patches can be found, for example, in the settlements of Bazan, Semerdzhievo, Novo Selo, Tetovo, and Nikolovo (*Figure 14a*).

The nature conservation areas are situated along the northern border near the Danube and within the forested regions on the eastern boundary. The central part of the area does not contain any designated protected zones (*Figure 15a*). Similar to the other study areas examined, non-irrigated- arable land accounts for the largest proportion of suitable areas in Ruse County. Pastures and other land uses are present only to minimal extents (*Figure 16a*).

Suitable areas for solar energy installation within the Ruse study area encompass approximately 22,902 hectares, representing 40.3% of the total area (*Table 4*). The identified suitable areas have an estimated installed capacity potential of 11,451 MW, assuming the entire surface was used for electricity generation. Additionally, a considerable portion of these suitable regions are rated at suitability score 8 (in the case of wind energy, ratings of 7 and 8 are similarly common). The distribution of suitable areas is similar to that observed for wind energy, but larger contiguous areas are typical (*Figure 14b*).

Protected areas limit development along the north-western and eastern boundaries of the study area; however, they do not affect development in the central part of the area (*Figure 15b*). In terms of land use, the most suitable areas are predominantly non-irrigated arable land. A smaller proportion consists of pastures, while other -land use- categories are minimal (*Figure 16b*).

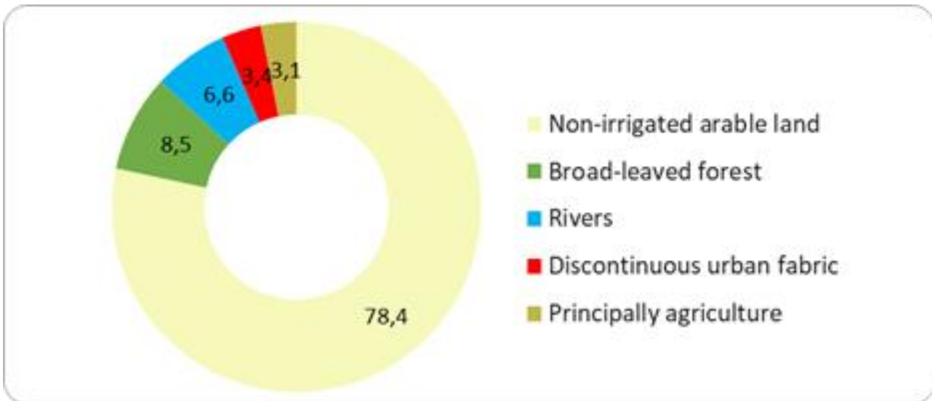
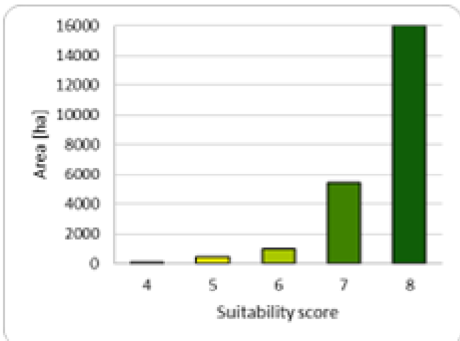
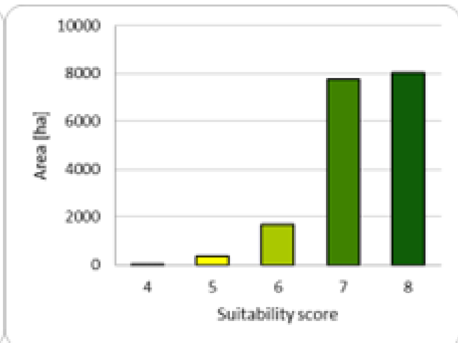


Figure 13: Land use types of Ruse study area, Bulgaria (%)





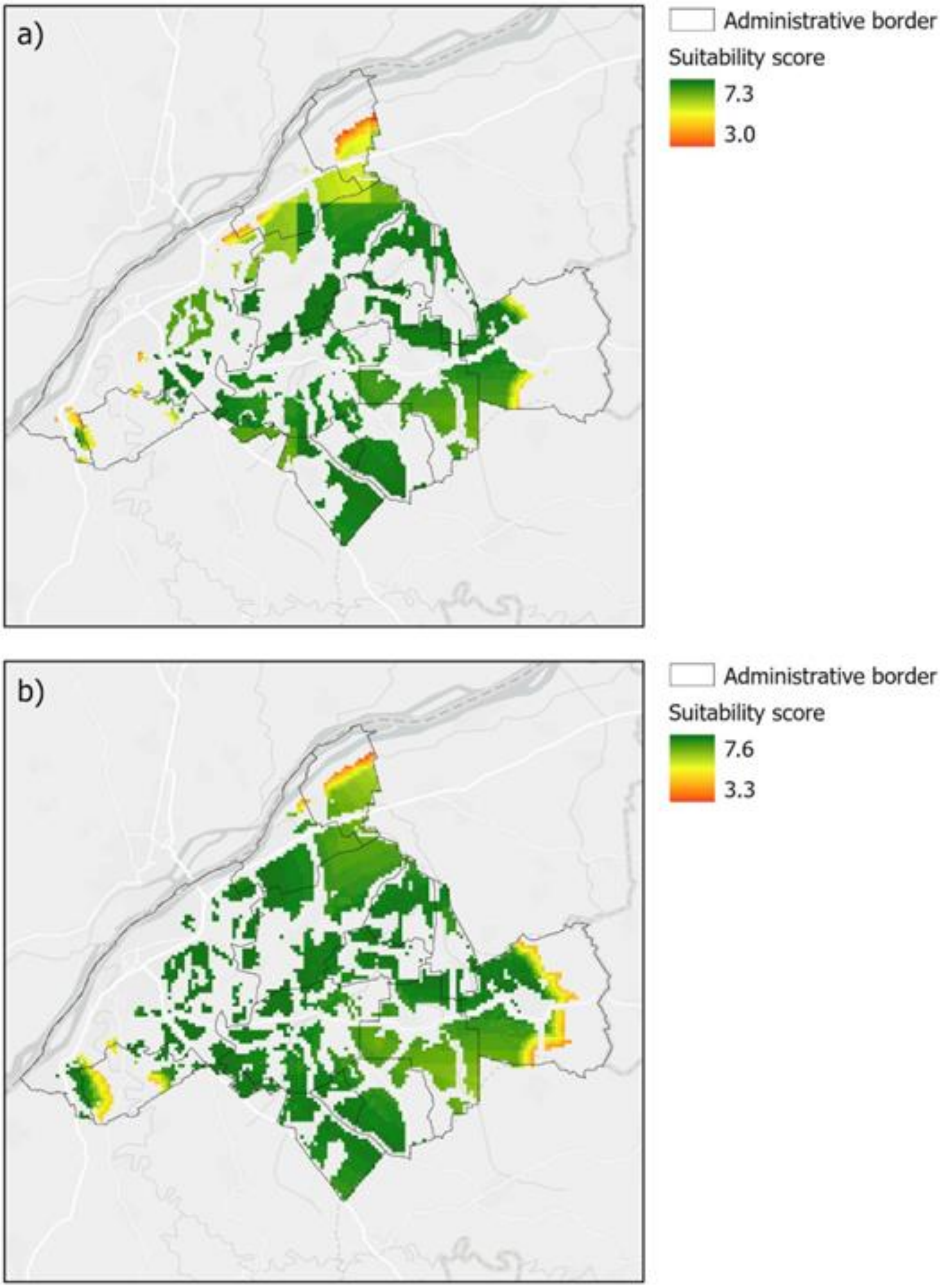


Figure 14: Site suitability for wind turbine (a) and solar PV (b) investments in the region of Ruse, Bulgaria

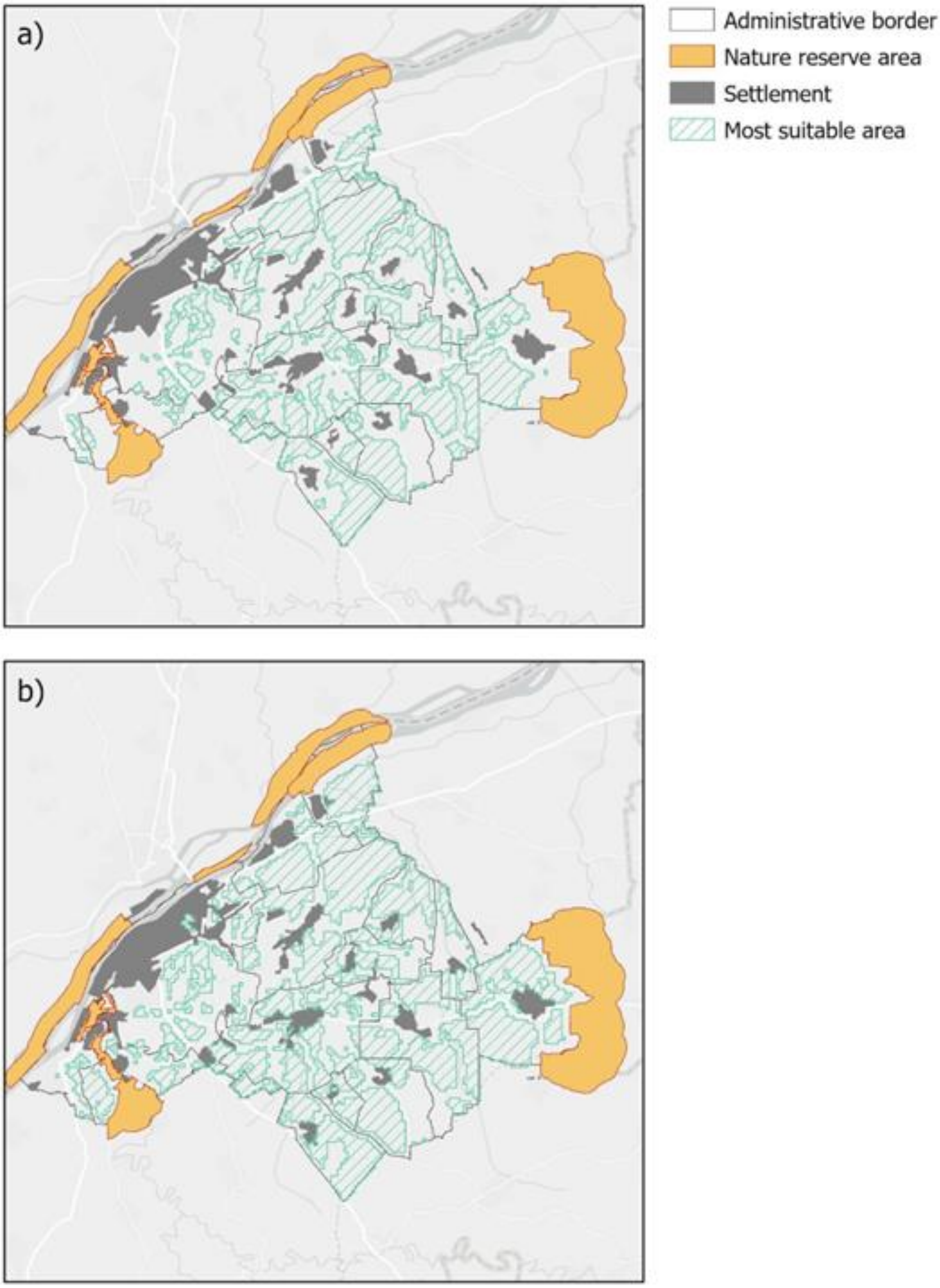


Figure 15: Most suitable areas for wind turbine (a) and solar PV (b) investments in the region of Ruse, Bulgaria

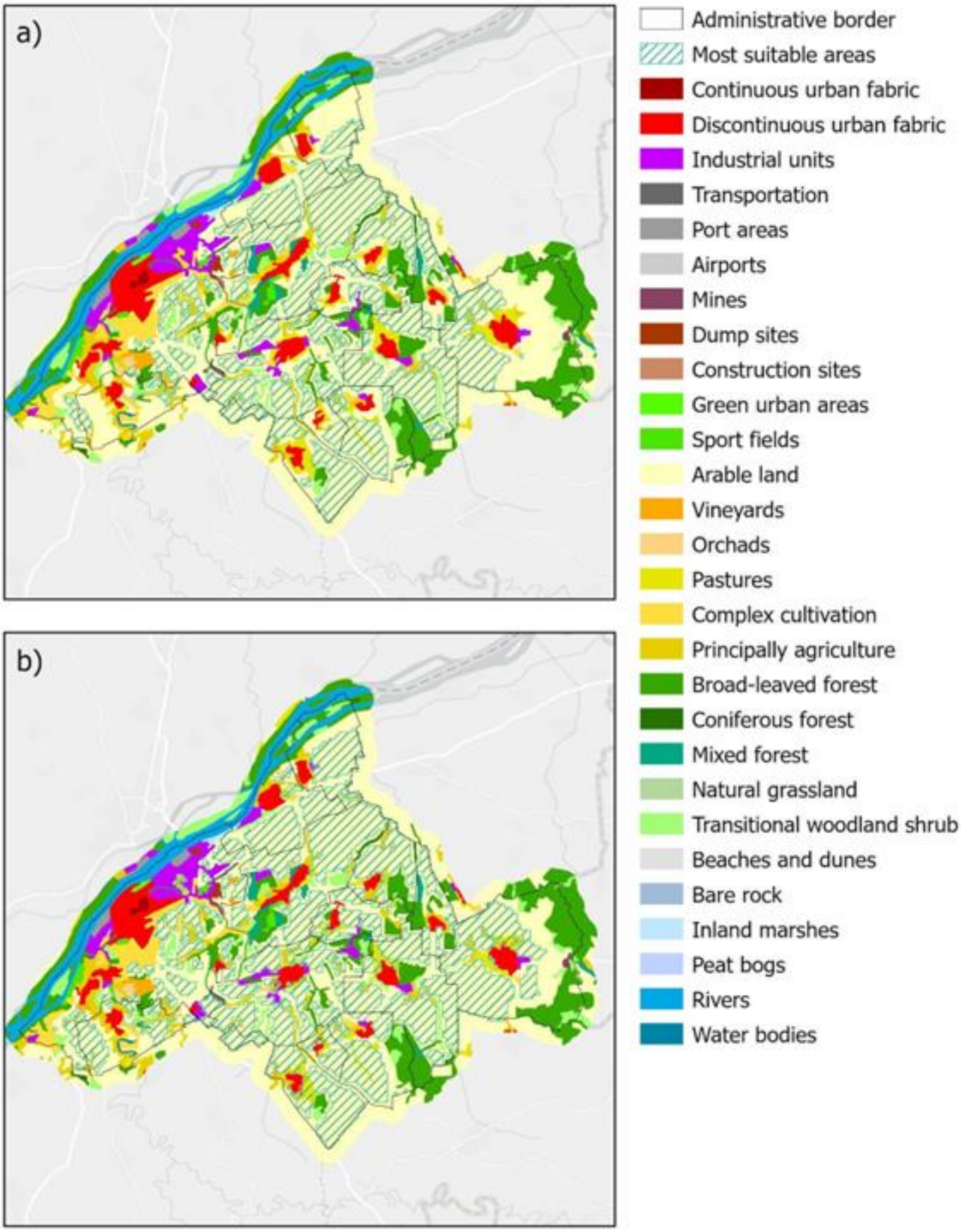


Figure 16: Most suitable areas for wind turbine (a) and solar PV (b) investments and land use in the region of Ruse, Bulgaria

Table 4: Statistical data on suitable areas and the estimated wind and solar PV installed capacity potential in the Ruse study area, Bulgaria

Wind	Suitability score	area [ha]	area [%]	MW
	4	23	0.04	5
	5	370	0.65	74
	6	1682	2.96	336
	7	7748	13.65	1550
	8	8005	14.10	1601
		17828	31.40	3566
Solar	**Suitability score**	**area [ha]**	**area [%]**	**MW**
	4	16	0.03	8
	5	437	0.77	218
	6	993	1.75	496
	7	5422	9.55	2711
	8	16036	28.24	8018
		22902	40.3	11451

Ruse- stakeholder validation and methodological adaptations

Local engagement in Ruse confirmed the value of prioritising disturbed and artificial land surfaces (ALS) and testing them early for solar and wind siting, consistent with the broader lesson to unlock low conflict options. Following the initial technical assessment, the team further refined the results to the Bulgarian context by applying a -land use filter from the National Cadastral Map to exclude forests, marshes and other ecologically valuable territories, and by removing -high-quality- arable categories (1–6). Frequent cadastral inconsistencies surfaced during this step, reinforcing the report's emphasis on data harmonisation and the need to document provenance and use reliable proxies.

To mitigate these data gaps, satellite layers from the European Soil Data Centre were used to identify genuinely degraded soils based on multiple degradation parameters. Comparing these layers with the cadastral checks and then intersecting them with the regional suitability outputs produced the final proposal for RAAs in Ruse, which were validated in follow-up discussions with the Municipality's spatial planning- experts.

The national stakeholder discussion in Bulgaria aligned with cross-cutting safeguards: participants warned that rapid solar buildout has encroached on sensitive areas with incomplete or bypassed EIAs, underlining the need for robust SEA rulebooks, -micrositing standards, and heritage/ecology buffers in RAAs. They also noted that "-low-quality-" arable (categories 7–10) can include valuable grasslands, which supports the agricultural tiering lesson to avoid blanket assumptions and to require agronomic/ecological validation before dual use. With wind projects increasingly proposing turbines above 150 m, stakeholders called for larger buffers and technologyspecific- design standards, fully in line with treating wind and solar separately.

Resistance from local communities, administrative hurdles, and grid connection constraints remained key risks, echoing the report's findings on acceptance and grid readiness. Overall, Ruse's process demonstrated that early ALS screening, cautious agricultural tiering, stricter safeguards, and iterative, -data improving workflows, combined with municipal validation, are essential to designate- risk--reduced RAAs that can withstand permitting scrutiny and public review.

Conclusions and recommendations

The following recommendations and insights aim to strengthen Renewable Energy Area (RAA) spatial planning by addressing cross-cutting challenges, mitigating risks, and leveraging lessons learned from recent analyses across the four study areas. They focus on ensuring that renewable energy deployment aligns with agricultural priorities, biodiversity safeguards, grid realities, and socio-economic fairness, while maintaining coherence with broader spatial and climate resilience objectives. By integrating these measures into coordinating spatial planning efforts as well as part of SEA processes for the RAAs designation, planners and decision-makers can reduce conflicts, accelerate permitting, and deliver projects that are technically and financially viable, while at the same time ensuring biodiversity conservation and support from local communities.

Joint conclusions from the four study areas

Data harmonization and filling data gaps: Standardising projections and resolutions, substituting HV topology for missing grid point data, and using pan-European land cover to equalise inputs across countries were effective interim measures. However, the next iteration should restore higher-quality national layers and incorporate currently omitted Artificial Land Surfaces, data on ecological corridors, on future planned protected areas, on property, and existing RES layers. As such, a dedicated data improvement workstream is recognized as critical for future iterations.

Technology-specific analysis: Separate buffers and weights for wind and solar reflected real-world siting differences. Solar proved far more abundant in Kapuvár (26.5% suitable vs. 4.6% for wind) and also outperformed wind in Ruse (40.3% vs. 31.4%). Keeping technology-specific layers avoided over- or under-screening.

Buffers and mosaic landscapes strongly shape wind outcomes: In Kapuvár, nature protection buffers fragmented wind suitability into small patches and lowered average scores (peaking at 5/10). Similar effects are expected wherever mosaic protected areas or wetlands are prevalent, such as along the Danube in Ruse.

Arable-dominant flatlands deliver scale and require a tailored planning approach: Prahova showed very large suitable extents for both wind (32%) and solar (47.1%), clustering in southern flatlands. The Ruse analysis displayed similar patterns. These findings underscore the need for agricultural tiering, multiple land use and land saving solutions including agrivoltaics, and strong grid coordination.

Methodological choices matter: Exclusion zones, the buffer zones, the 0–10 suitability scale with a ≥5 cut-off, and AHP weighting with CR < 0.1 were sound foundations that made constraints visible, decisions communicable, and trade-offs transparent. To keep such an analysis robust as conditions evolve, the methodology factors can be applied iteratively: starting from considering sensitivity factors (e.g., buffer sizes, alternative thresholds), exploring scenario variants based on local conditions and comparing weight sets tailored to technology and local ecological contexts.

Recommendations for coordinated spatial planning and RAAs designation

Agricultural land differentiation and dual use are critical: Across all areas, much of the “most suitable” land fell into non-irrigated arable classes. A tiered approach that prioritises lower fertility or degraded parcels proved essential to minimise food production trade-offs. Where higher-quality arable land is unavoidable, agrivoltaic solutions should be considered. Country-specific legal frameworks (e.g., Romania’s allowance on Classes III–V outside city limits) requires tailored exclusion and priority rules, and agronomic monitoring as a safeguard for soil health over time.

Artificial Land Surfaces (ALS) remain an untapped opportunity: The initial analysis did not include factors and data on ALS such as industrial parks, car parks, and brownfields. These are essential as they offer low-conflict, quick-deployment options.

Heritage and landscape safeguards influence siting outcomes: Exclusion buffers around archaeological sites, cultural landscapes, and protected areas, combined with micro-siting are essential to minimize impacts, especially in conservation-heavy areas like Kapuvár and along river corridors in Ruse.

Cumulative effects with existing RES assets should be considered: Overlaying operational and permitted wind and solar projects with sensitivity layers can help avoid ecological pressures. This is particularly relevant in areas where suitable zones might cluster or might be in proximity to areas with a high presence of operational RES projects.

Alignment with municipal and regional plans reduces conflict: Cross-checking RAA maps against urban and regional plans can help avoid clashes with settlement growth, logistics corridors, and future grid lines, ensuring coherence across different development sectors.

Prospective protected areas need precautionary treatment: Adding temporary constraints for areas under consideration for protection to meet the EU Biodiversity Strategy 30% protection target would allow planners to anticipate legal changes and avoid future conflicts. Such data on possible future protected areas can be obtained from national environmental authorities and from scientists currently researching the topic eg. The Natura

Connect Horizon project[2].

As currently site suitability is often tied to grid hosting capacity, connection queues, and reinforcement timelines, sequencing development with grid upgrades and steering projects toward grid-ready areas can prove decisive. At the same time, recommendations for future grid developments can be made where areas with high suitability are identified far from the existing network.

Embedding socio-economic factors into coordinating spatial planning exercises can ensure fairness but require careful design. Suitable areas often concentrate in less advantaged localities. Benefit-sharing mechanisms, such as local ownership tranches and energy poverty measures, can help prevent negative perceptions of major RES projects and support local development. At the same time, early engagement of municipalities and local communities can help tailor RAAs plans and improve the quality and process of SEAs.

[2] https://naturaconnect.eu/

Appendix

Table 1: Suitability factors, buffer zones and gradual suitability values for Wind turbine and solar PV developments

Wind turbines	Distance (m) from / other threshold															
Suitability score	**Electricity grid**	**Main roads**	**Railways**	**Airports**	**Average wind speed (m/s)**	**Terrain slope (°)**	**Spatial density of bird population (%)**	**Water bodies**	**Wetlands**	**Valuable vegetation**	**Protected natural areas**	**Inhabited areas**	**Other built-up areas**	**Arable lands**	**Vineyard and orchads**	**Economy (€/capita, %)**
Excluded areas (0)		0-250	0-250	0-3500		> 15		0-500	0-500	0-250	0-1500	0-700	0-250		X	
1	10000 <	10000 <			< 3		80 <				1500-1600					80 <
2	8000-10000	8000-10000			3-4	13-15				250-300	1600-1700					
3	7000-8000	7000-8000			4-5						1700-1800					
4	6000-7000	6000-7000			5-6	11-13	79-60			300-350	1800-1900					50-80
5	5000-6000	5000-6000			6-7						1900-2000					
6	4000-5000	4000-5000			7-8	9-11				350-400	2000-2100					
7	3000-4000	3000-4000			8-9		59-40				2100-2200			X		25-50
8	2000-3000	2000-3000			9-10	5-9				400-450	2200-2300					
9	1000-2000	1000-2000			10-11						2300-2400					
10	0-1000	250-1000			11 <	0-5	0-39			450 <	2400 <					0-25
Solar PV																
Excluded areas (0)		0-50	< 50			> 15		0-500	0-500	0-250	0-500	X	X			
1	10000 <	10000 <		not relevant	< 1100		not relevant				500-600				X	80 <
2	8000-10000	8000-10000			1100-1150	13-15				250-300	600-700					
3	7000-8000	7000-8000			1150-1200						700-800					
4	6000-7000	6000-7000			1200-1250	11-13				300-350	800-900					50-80
5	5000-6000	5000-6000			1250-1300						900-1000					
6	4000-5000	4000-5000			1300-1350	9-11				350-400	1000-1100					
7	3000-4000	3000-4000			1350-1400						1100-1200					25-50
8	2000-3000	2000-3000			1400-1450	5-9				400-450	1200-1300					
9	1000-2000	1000-2000			1450-1500						1300-1400					
10	0-1000	50-1000			1500 <	0-5				450 <	1400 <			X		0-25

X: Within its own total area

Table 2: Importance weights of the suitability factors

Wind turbines	
Grid connection point	***0,096***
Proximity to roads	***0,038***
Average wind speed	***0,130***
Terrain slope	***0,047***
Spatial density of bird population	***0,193***
Valuable vegetation	***0,168***
Protected natural areas	***0,195***
Preferable land-use areas	***0,072***
Economic indicator	***0,060***

Solar PV	
Grid connection point	***0,135***
Proximity to roads	***0,048***
Global horizontal irradiation	***0,104***
Terrain slope	***0,073***
Valuable vegetation	***0,210***
Protected natural areas	***0,249***
Preferable land-use areas	***0,117***
Economic indicator	***0,065***