
MEGA
MONTENEGRO
ENERGY
GROWTH AND
ACCELERATION

Introduction

MEGA – Montenegro Energy Growth and Acceleration

Development of a tool (Study) for allocating medium and large renewable energy (RES) potentials

Consideration of existing constraints for land use for RES:

- Regulatory framework covering all areas relevant to spatial planning:
  - Environmental protection
  - Agriculture and forestry
  - Water management
  - Transport infrastructure
  - Cultural heritage
  - Areas of interest for tourism
  - Military zones
  - Communication infrastructure

Result – A maps with an indicative overview of the feasibility of RES projects

Work Methodology

Preparation of constraint maps

- Identification of legal and biophysical constraints
- Exclusion of unsuitable areas

Preparation of development potential maps

- Calculation of resource potential
- Assessment of site suitability based on resource potential values and feasibility criteria

Preparation of conflict maps

- Potential impacts of renewable energy use on biodiversity, natural resources, and society
- Assessment of the sensitivity level of the remaining areas

By overlaping data from steps 2–3, optimal locations for the development of solar and wind power plants are identified.

Presentation of constraint maps and development potential maps

Constraint maps

Areas not suitable for the construction of wind and solar power plants should be identified and excluded from further analysis. Constraints that may lead to the exclusion of certain zones may include the following:

•Legal – national legislation governing nature protection, infrastructure development, spatial planning, and other relevant sectors may restrict the construction of renewable energy facilities in certain areas (protected areas, tourism/recreation zones, military zones, areas with cultural, historical, or religious significance, etc.);

•Existing infrastructure – settlements (urban and rural) and corridors along and/or around existing infrastructure such as transmission lines, existing power plants, roads, and airports;

•Biophysical – terrain slope and orientation are also important for planning future renewable energy projects (steeper slopes increase the complexity of planned installations). In addition, water bodies (e.g., rivers and lakes) are not suitable for the construction of renewable energy facilities;

Constraint maps – Raster data

- **Topographic maps (scale 25K and 50k)**
- **Orthophotograph**
- **Web-based map layers**
- **Digital Elevation Model (DEM)**

Note: The data were processed in the QGIS software.

Constraint maps – Vector data

- Transmission power grid 110, 220 and 400 kV (CGES)
- Distribution power grid 35 kV (CEDIS)
- Substations
- Road infrastructure – existing and planned (Spatial Plan of Montenegro – PPCG)
- Railways (PPCG)
- Sanitary protection zones (Water Administration)
- Rivers (Water Administration)
- Lakes (Water Administration)

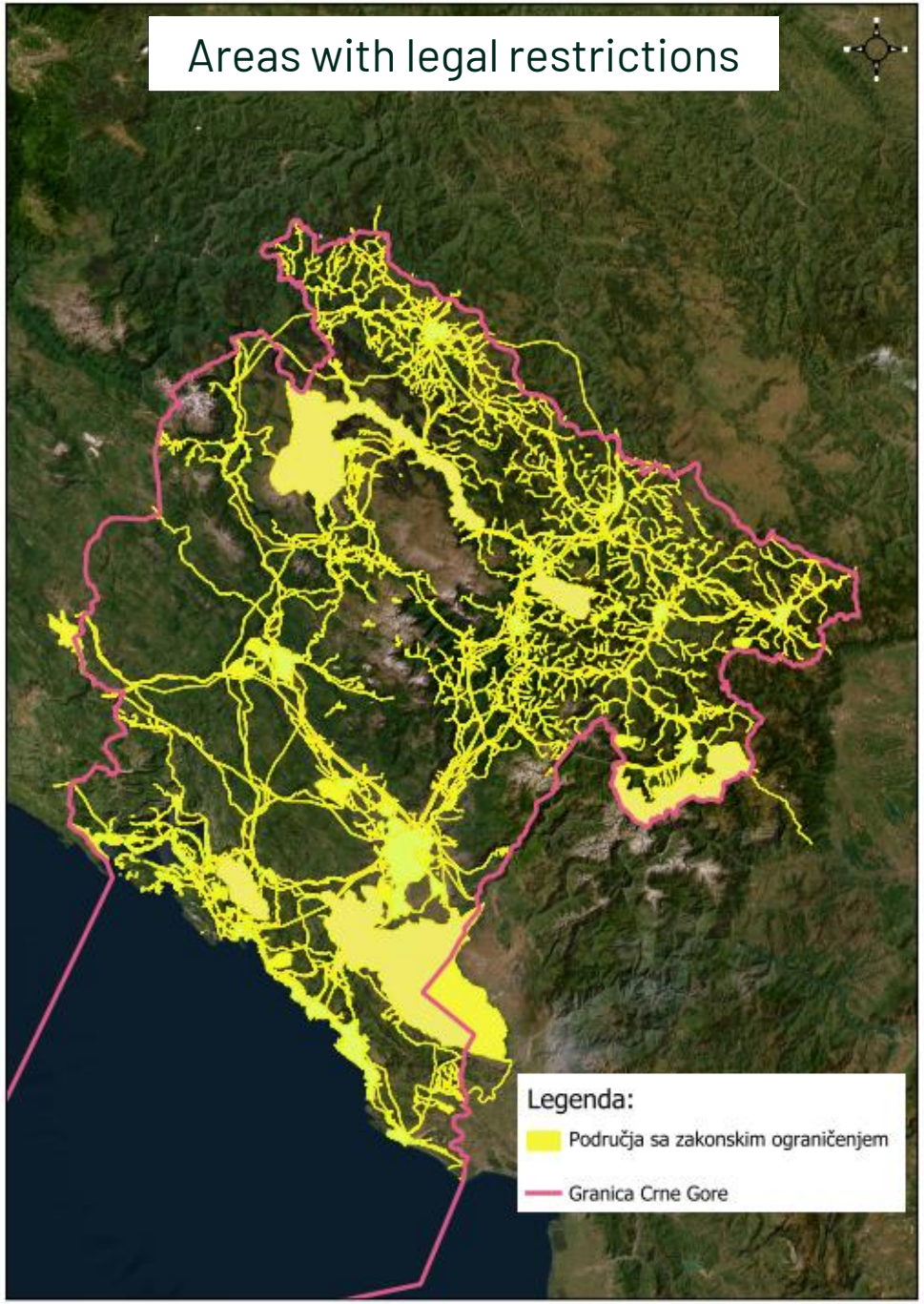
- State border (Administration for State Property and Cadastre)
- Protected areas (Environmental Protection Agency – EPA)
- Cultural and historical heritage sites (Administration for the Protection of Cultural Heritage)
- Radio relay stations
- Settlements (Spatial Plan of Montenegro – PPCG)
- Tourist zones
- Base stations (telecommunication towers)
- Airport (PPCG)
- Military zones

Legally defined buffer zones

Legal and biophysical constraints

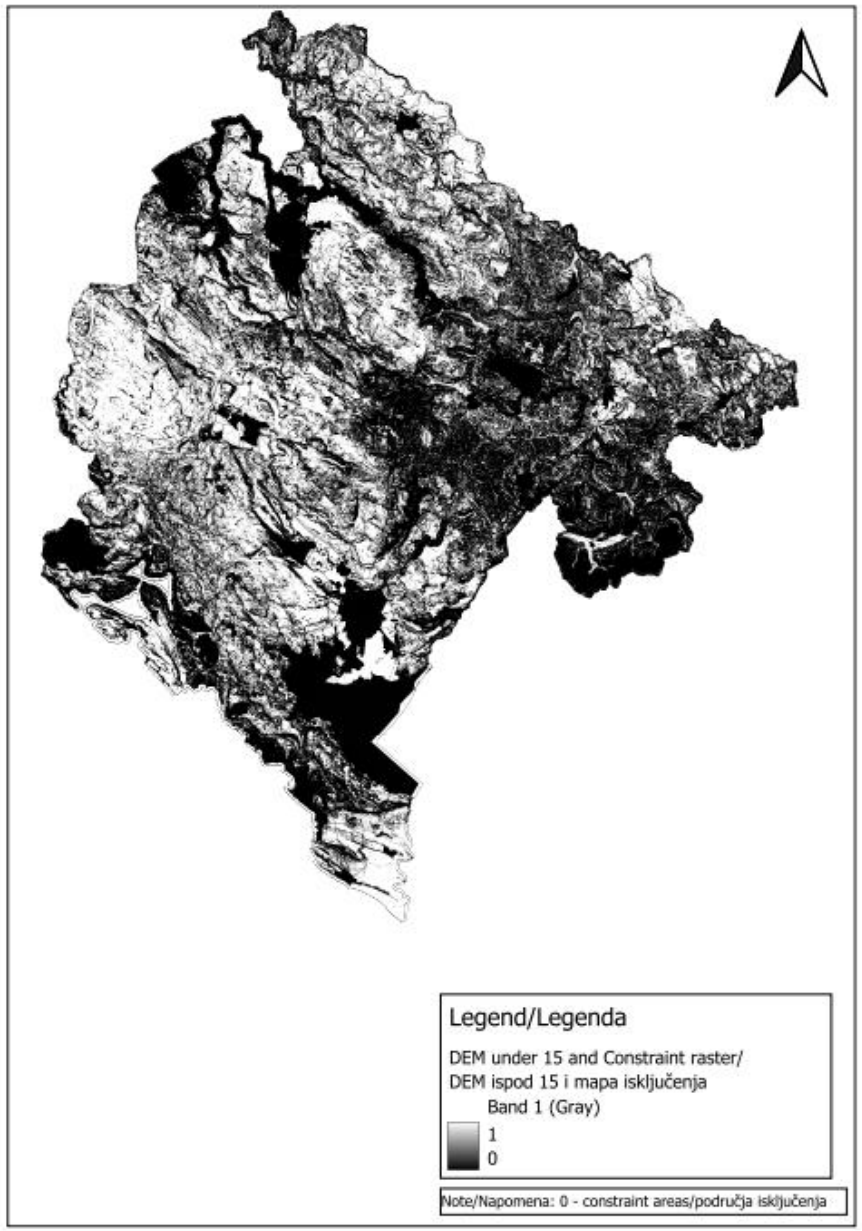
Constraints	Excludes	Size of the buffer	Unit	Legal basis	Explanation/Note
Transmission	feature + buffer	40 (400 kV) 30 (220 kV) 25 (110 kV)	m	Rules for construction of transmission and distribution powerlines	Transmission line 220-400 (110) kV – protection zone on both sides in relation to the vertical projections of the end conductors;
Distribution	feature + buffer	10 (35 kV)	m		Distribution line 35kV (10kV) - protection zone on both sides in relation to the vertical projections of the end conductors.
Power plants (wind, solar)	feature + buffer	0	m	Spatial plan	Location of WPPs and SPPs are given in form of zones (polygon).
Biophysical constraints *Slope of the terrain, elevation; River network, borders of basins and sub-basins, water springs and water sanitation zone; Land use;*					
Slope of the terrain	values above				
PV	values above	10	degrees		
Wind	values above	15	degrees		

Obtained result (area excluded due to legal/infrastructure constraints)



Note: Vector converted to raster

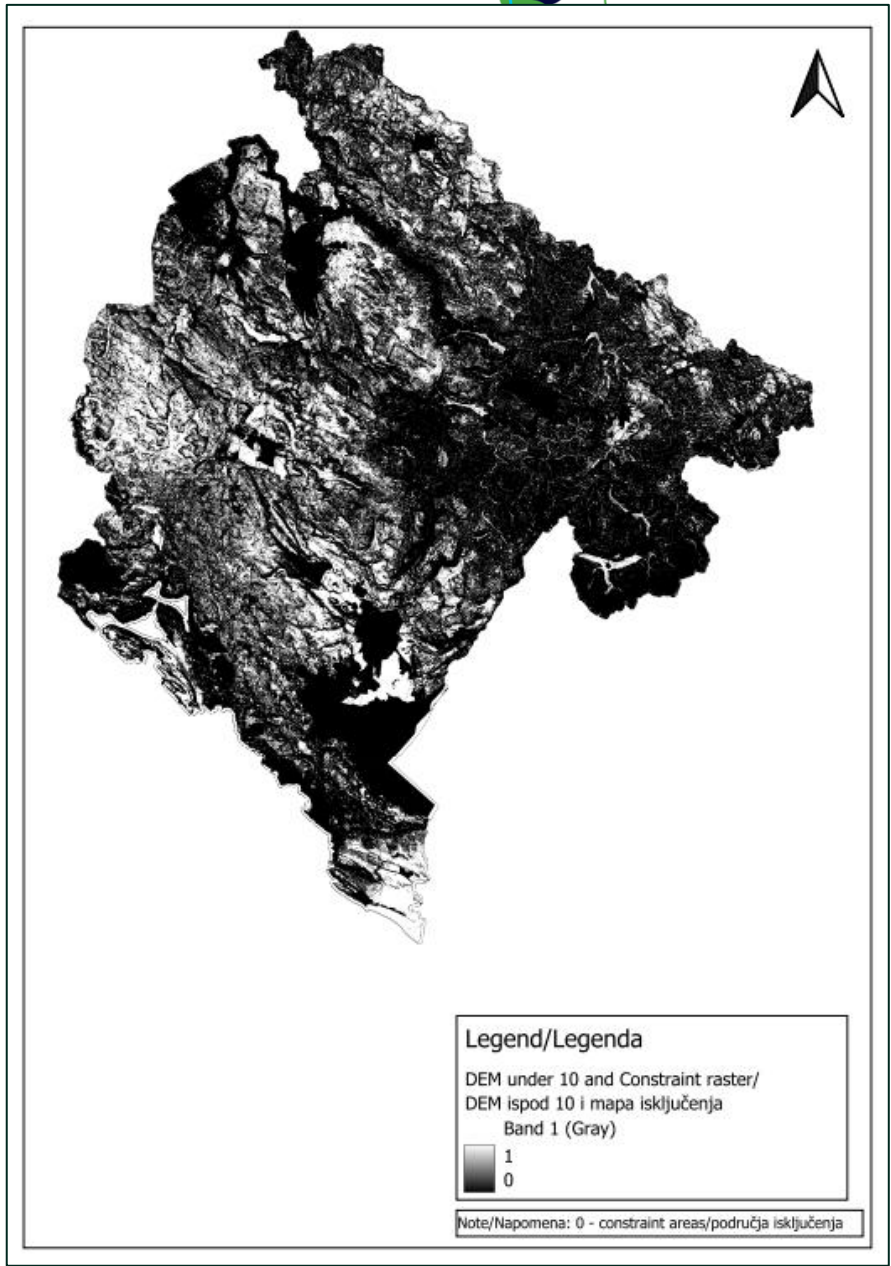
Constraint maps



In addition to zones excluded due to legal and infrastructure constraints, areas with terrain slope greater than **10° for solar** plants and **15° for wind** plants are **also excluded** from further analysis.

Wind

Solar



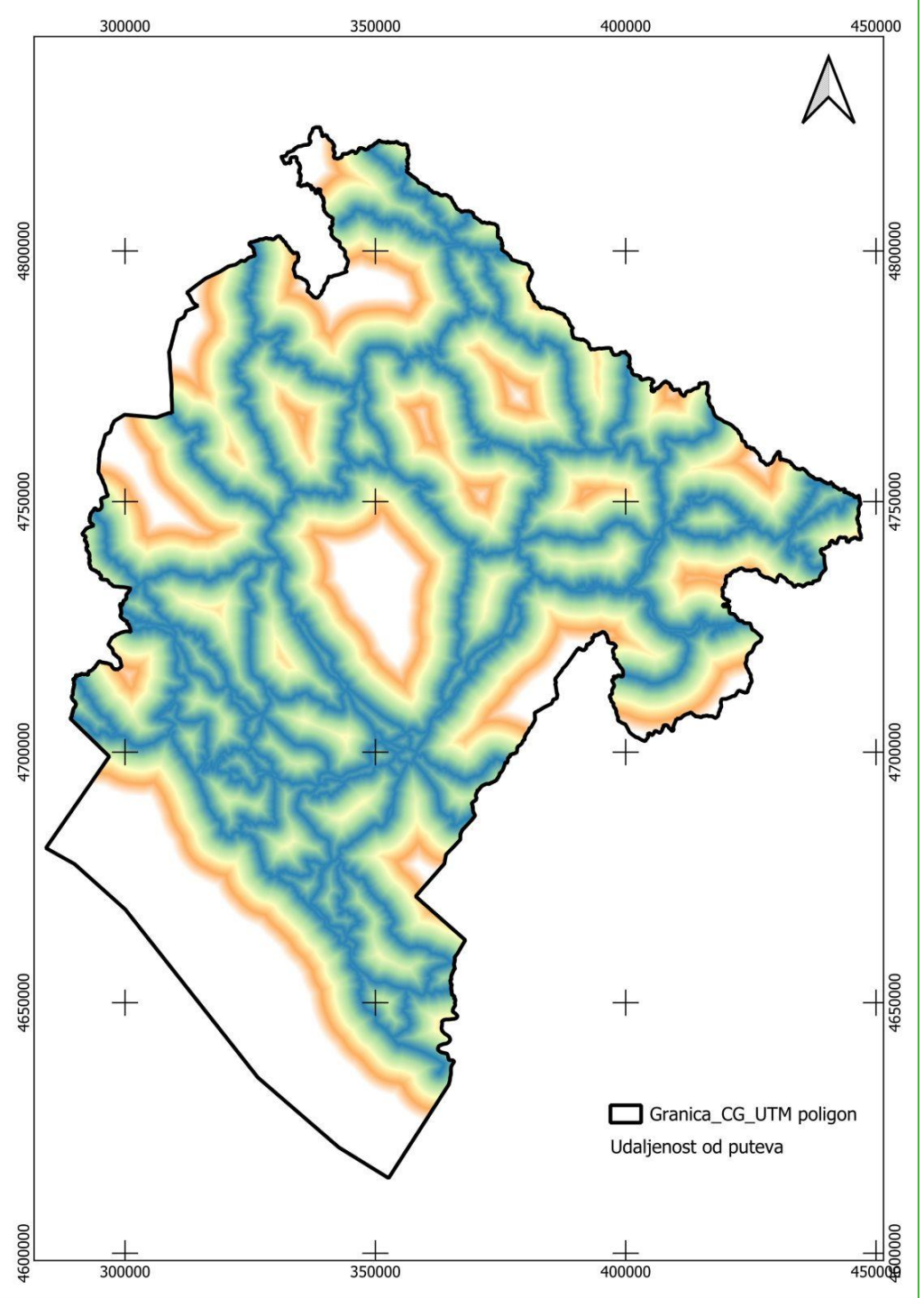
Development potential maps – data

- Reliable data on **solar radiation**, as well as **wind speed and consistency**, are required.
- Due to the lack of local datasets, globally available datasets were used for the territory of Montenegro:

Izvor	Relevantni skupovi podataka	Rezolucija
Global Wind Atlas	Wind speed (d) and wind consistency (K)	50 m
Global Solar Atlas	Global Horizontal Irradiance (GHI)	250 m

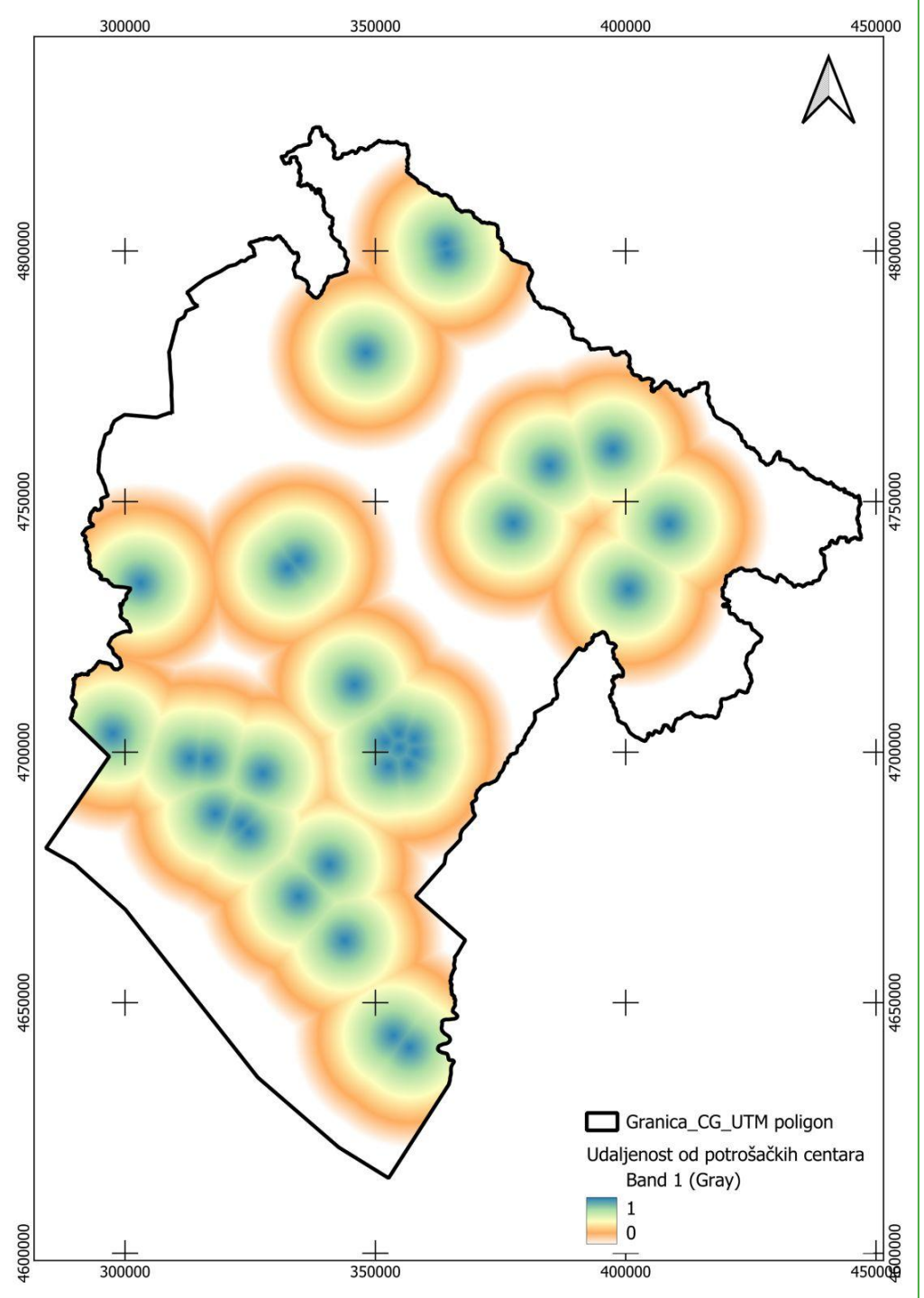
Selected values:

*From the **K** layer, values > 1.2 (**wind consistency below 1.2**) were taken, and from the **d** layer, **wind speed values above 4 m/s** were selected due to economic constraints.*



Development potential maps– distance from roads

The buffer zone around roads was set at 10 km. Everything beyond 10 km was assigned a value of **0**. The **white color** represents areas with no potential. The **blue color** represents the highest potential in relation to road infrastructure.



Development potential maps – distance from consumption centers (power substation)

The zone around the consumption centers was set to 20 km around each substation identified as a consumption center (31 locations-power substations).

Using the Raster Proximity tool, a graded evaluation of each pixel was obtained depending on its distance from the substation. All areas beyond 20 km were assigned a value of 0.

Development potential maps – grid capacity

- For **solar** energy, **two capacity layers** are developed (for the distribution and transmission grids). In this way, separate capacities are obtained for **small** and **large** power plants, which is also reflected in the final potential maps.

- For **wind** energy, **only the transmission grid** is considered in the capacity assessment.

- For the transmission network case, values are taken according to capacity:

  0–100 MW – value **0.2**,

  101–500 MW – value **0.6** and

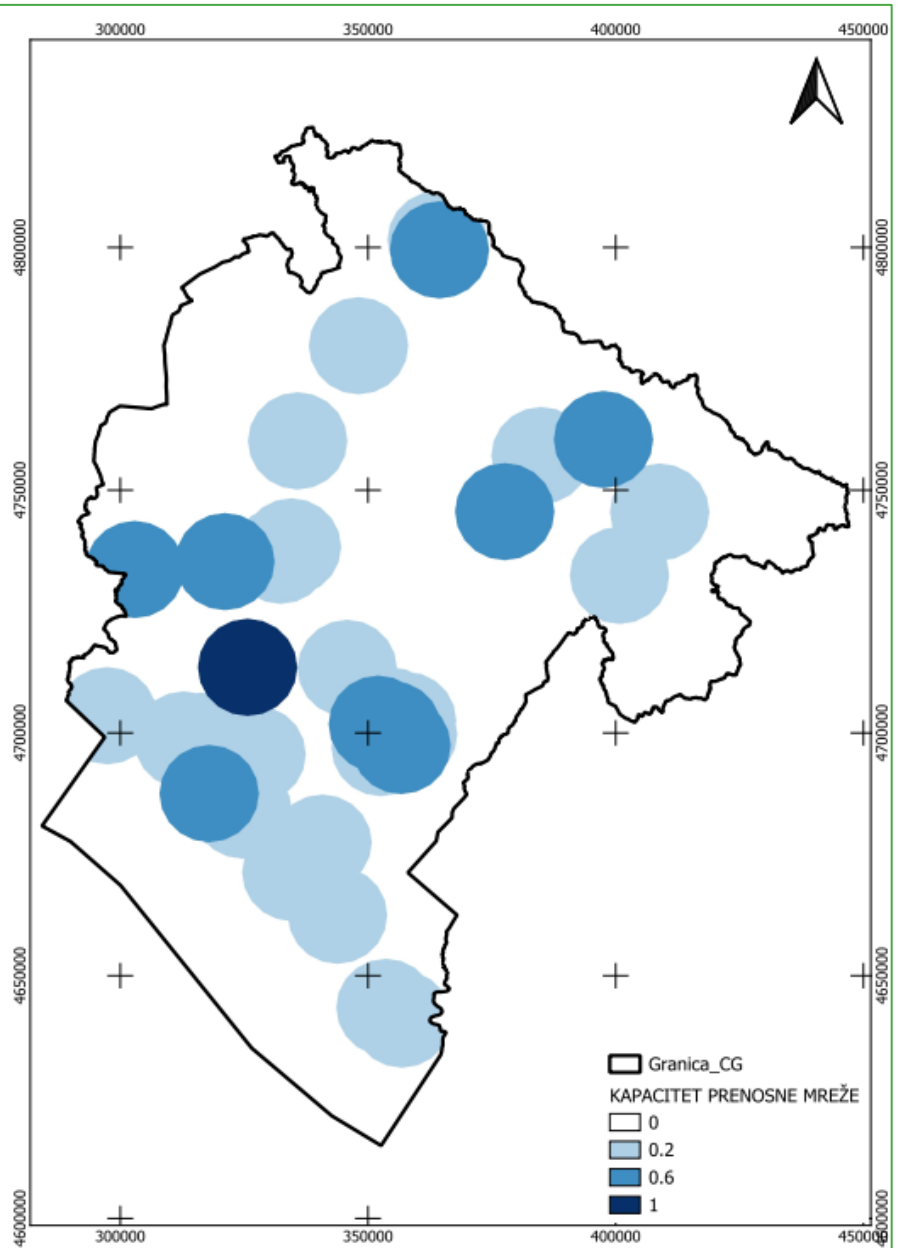
  above 500 MW – value **1**.

- Accordingly, **buffer zones of 10 km** were applied, and the above values were assigned depending on the capacity of the **transmission power substation.**

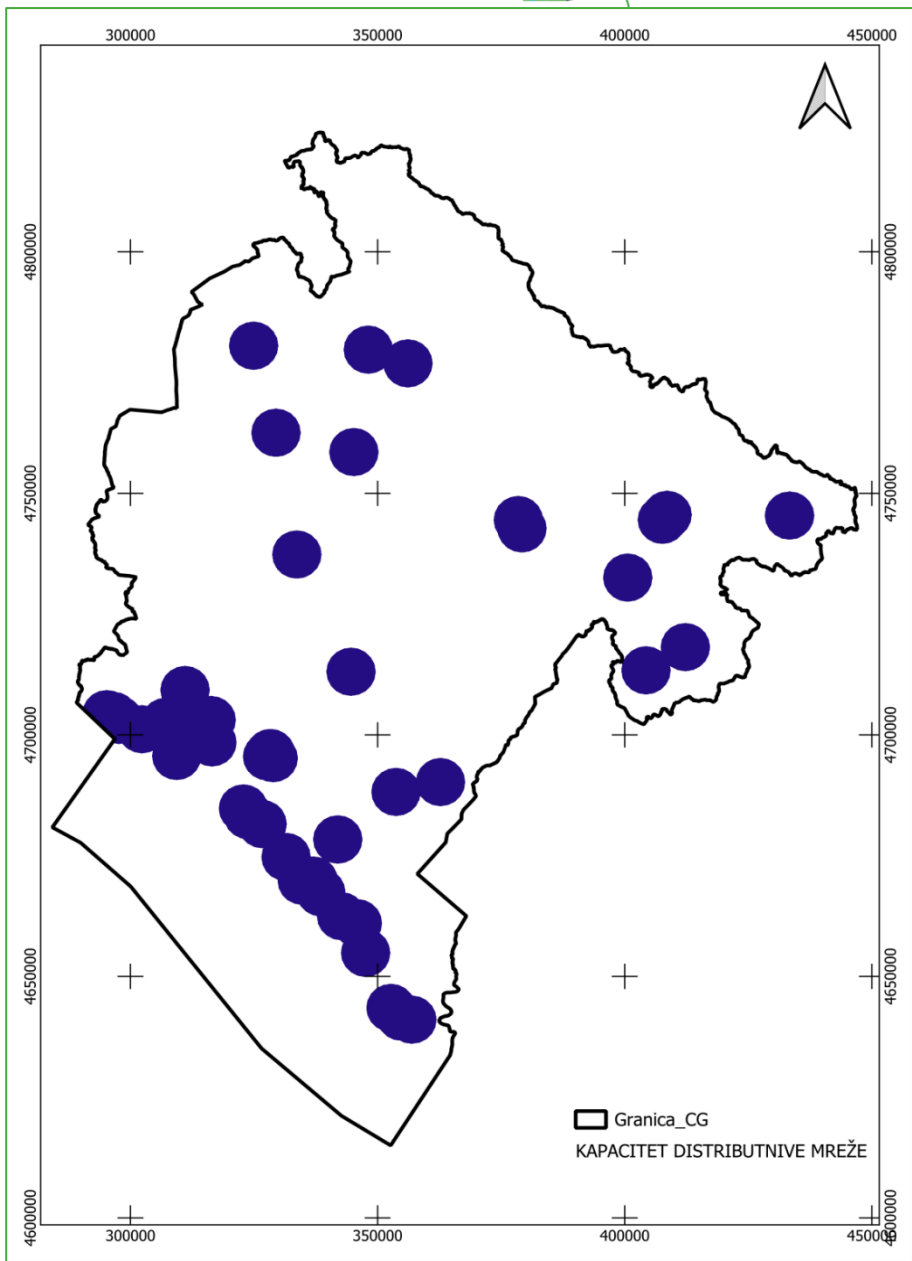
- For **distribution power substations**, two categories were considered: 0 MW and 5 MW. Using the same principle, **buffer zones of 5 km** were applied, and they were assigned values of 0 (for 0 capacity) and 1 (for 5 capacity).

Development potential maps

Grid capacity



Transmission power substations



Distribution power substations

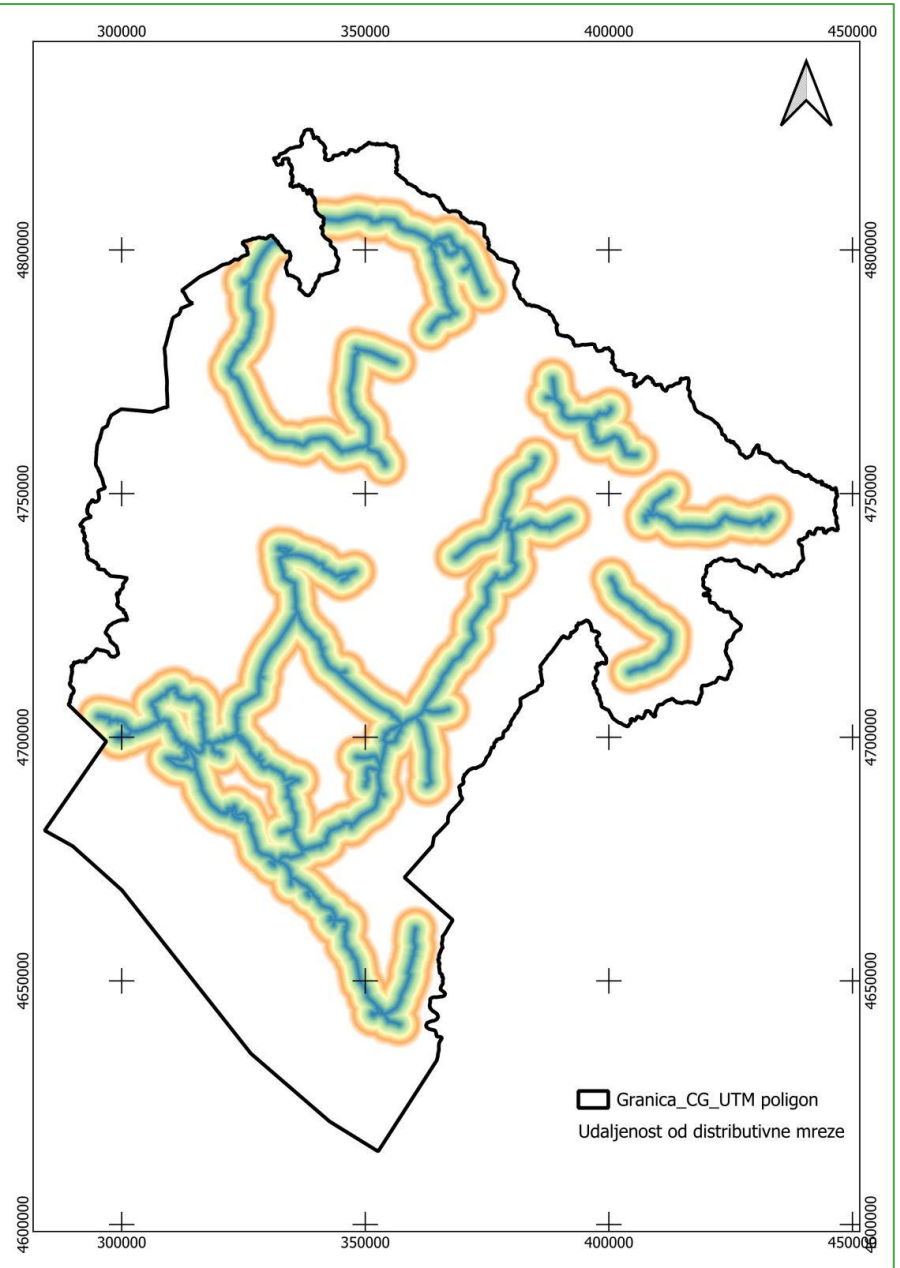
Development Potential Maps – distances from the grid

- For all voltage levels of the **transmission network**, the same values were used—a buffer zone with a radius of **10 km.** Using a raster proximity tool, a graded evaluation of each pixel was obtained depending on the distance from the network. Everything beyond 10 km was assigned a value of 0.

- For the **distribution network**, a buffer zone with a radius of **5 km** was proposed. Using the raster proximity tool, a graded evaluation of each pixel was obtained depending on the distance from the network. Everything beyond 5 km was assigned a value of 0.

- The result consists of two distance maps/layers: one for the transmission network and one for the distribution network.

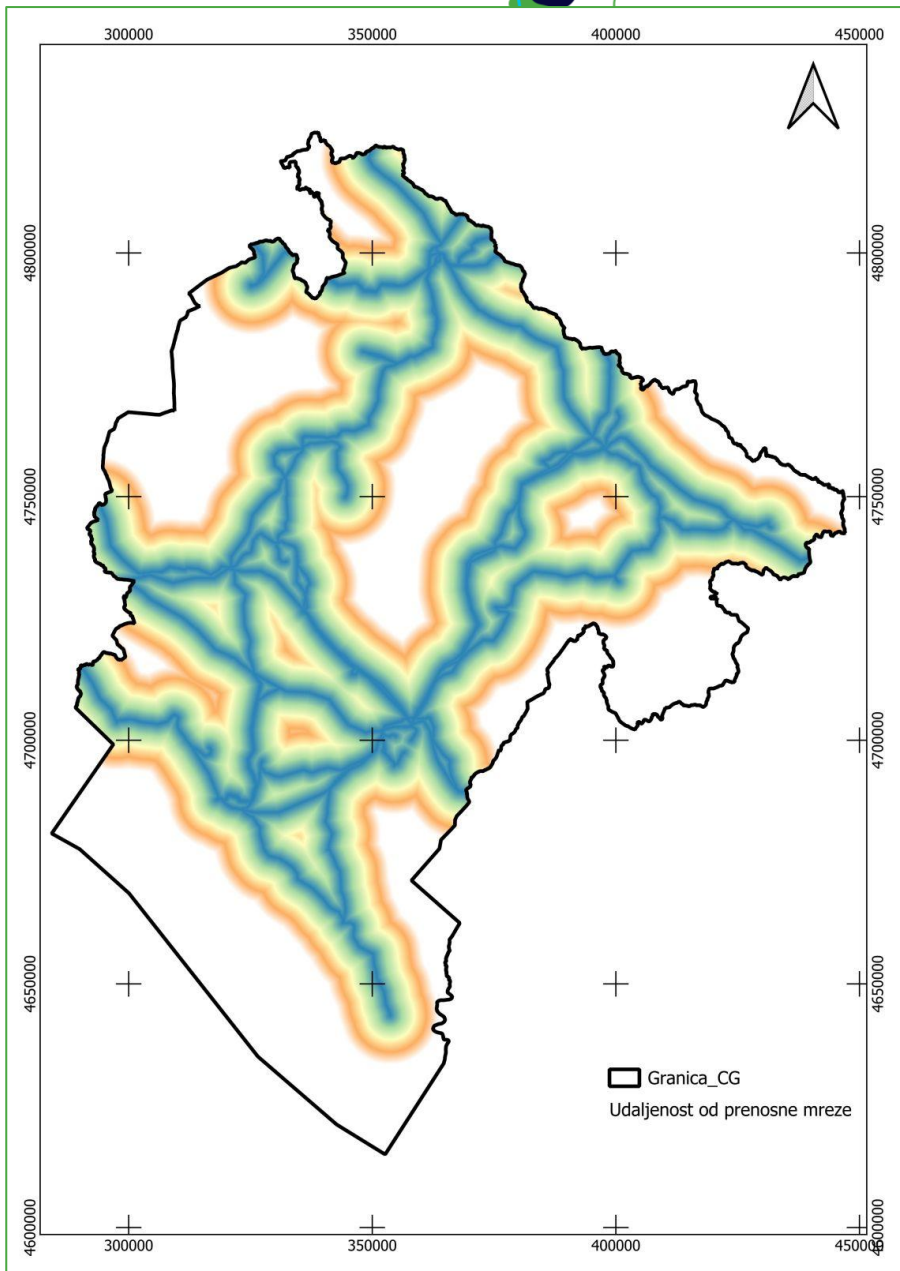
Development Potential Maps



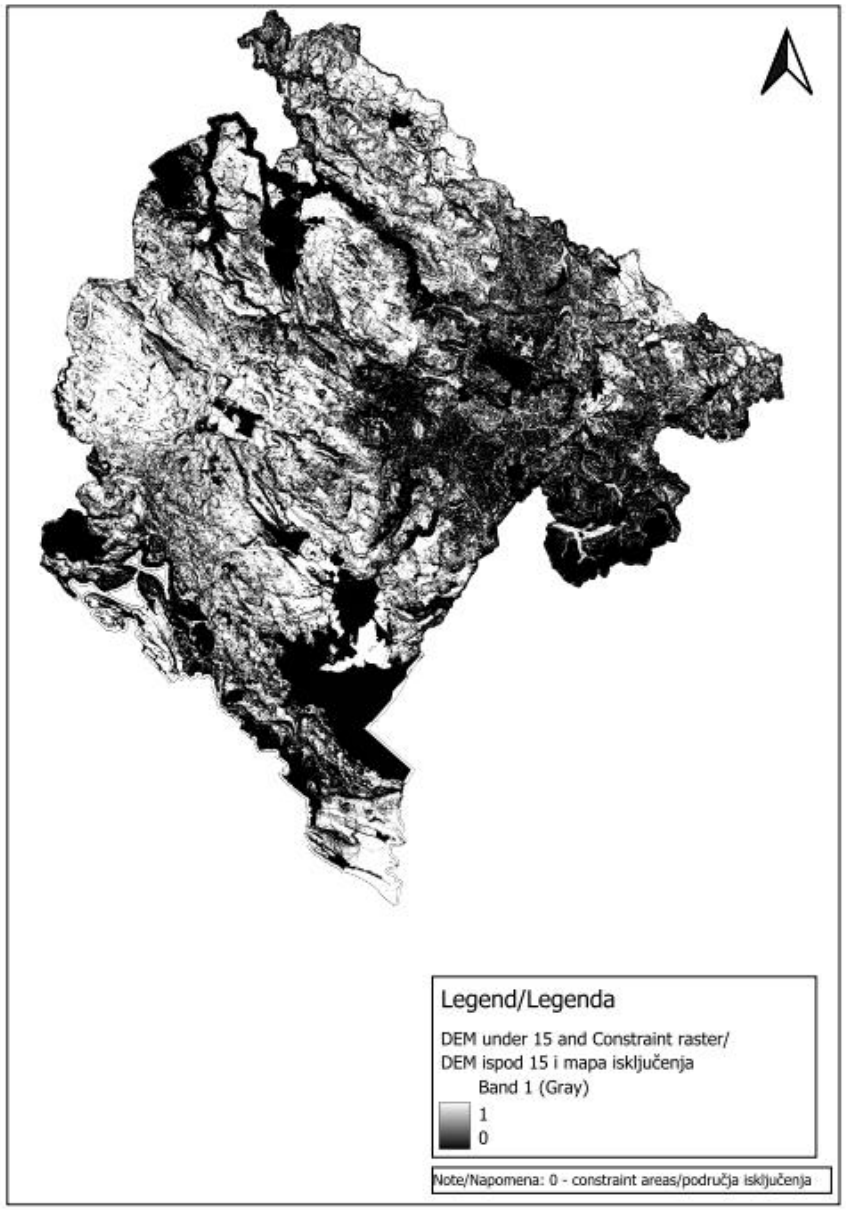
Distances from the grid

Distribution network

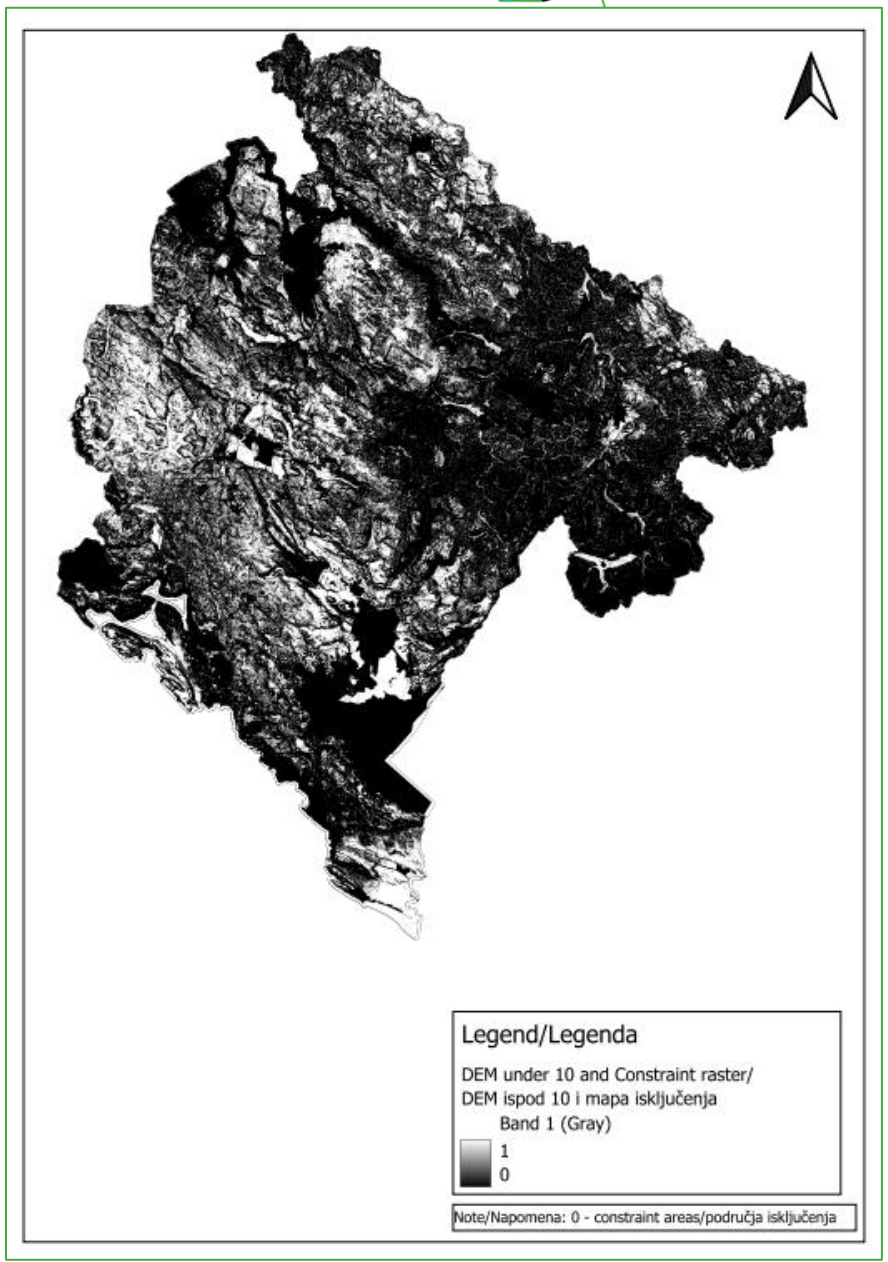
Transmission network



Development Potential Maps - constraint map

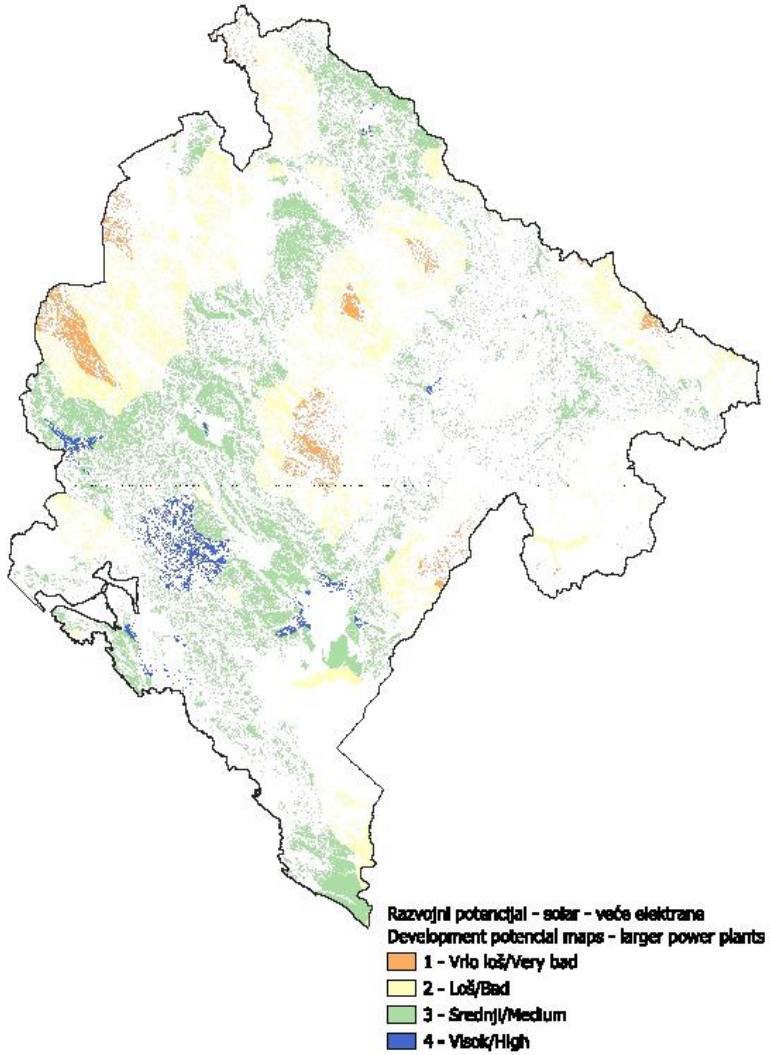


The result (obtained using the algorithm) was multiplied by the constraint map.

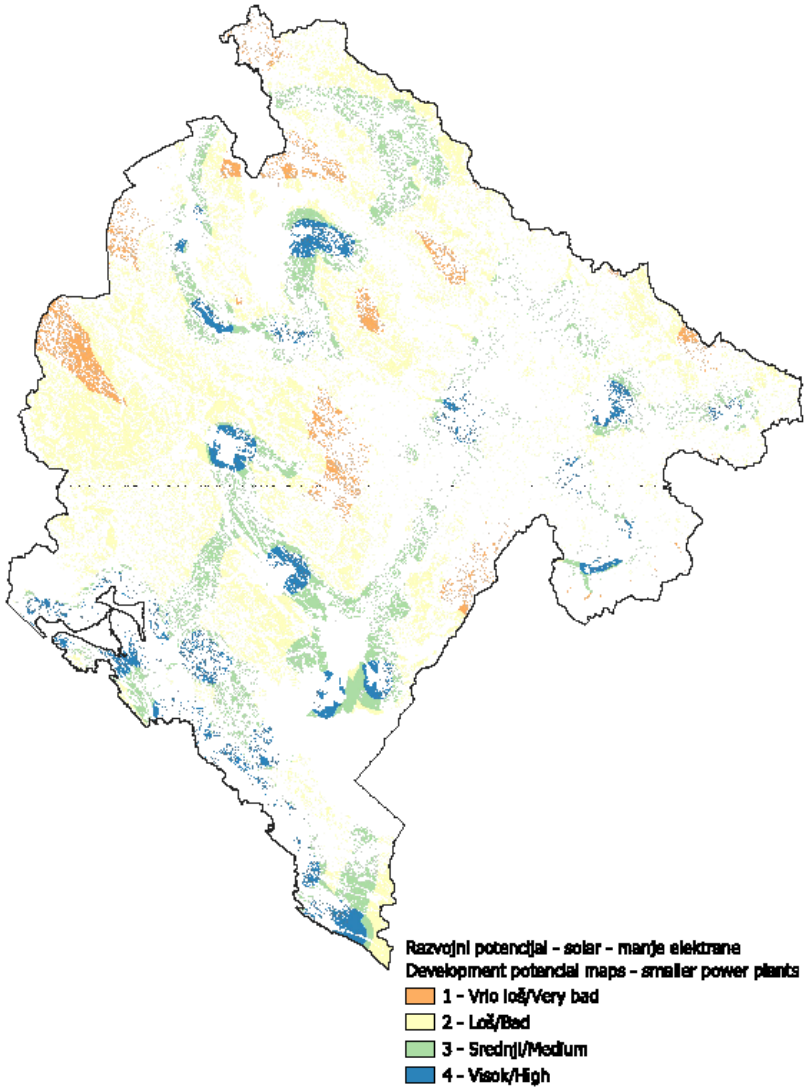


Development Potential Maps – Results

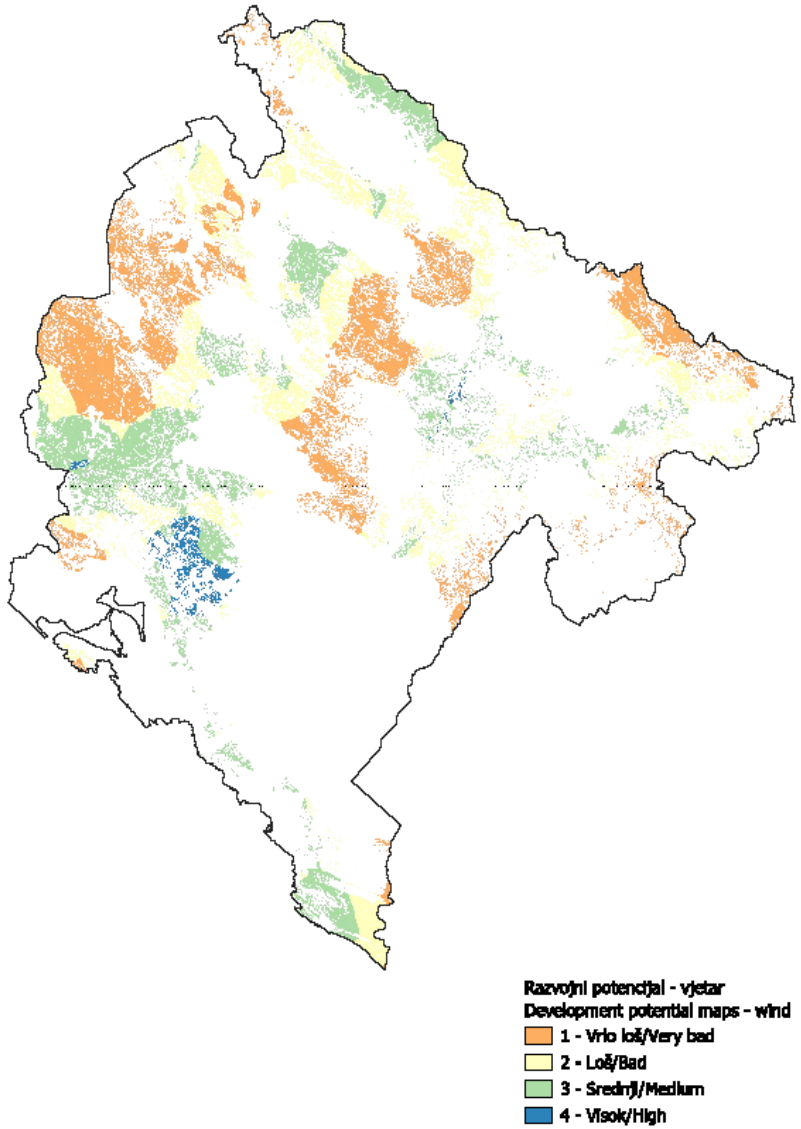
Large solar power plants



Small solar power plants



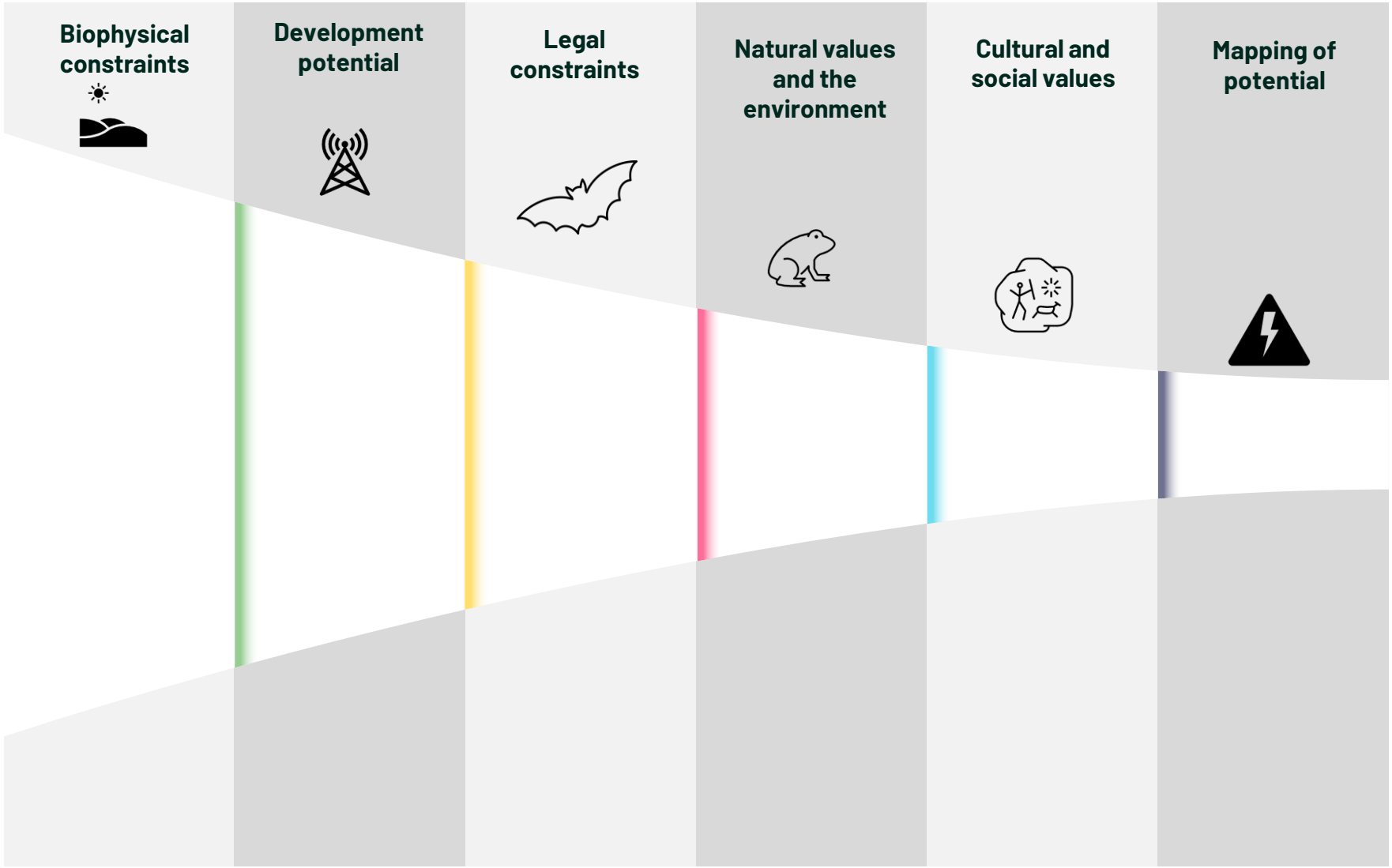
Wind



Process of creating conflict maps

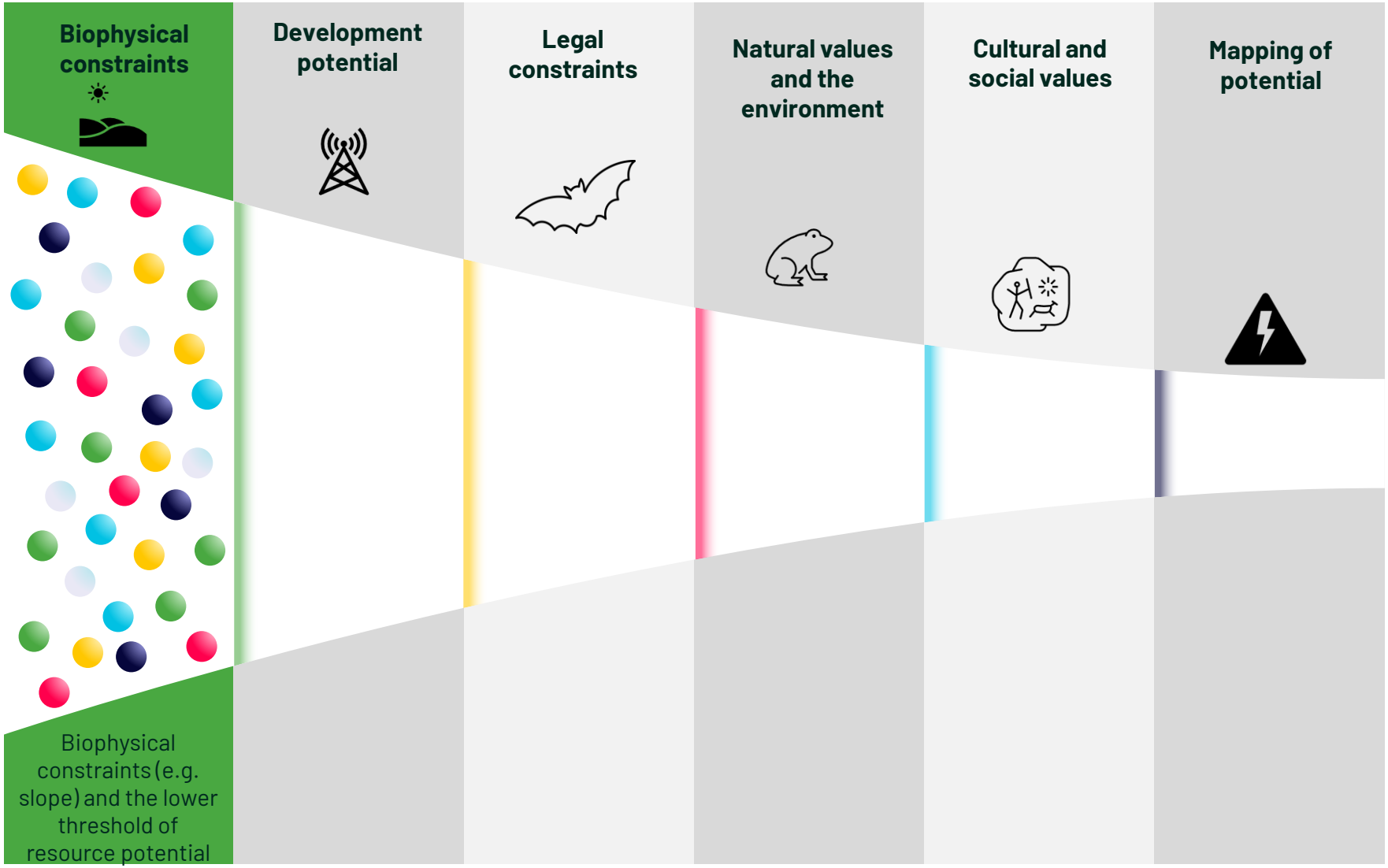
Criteria

Potential areas



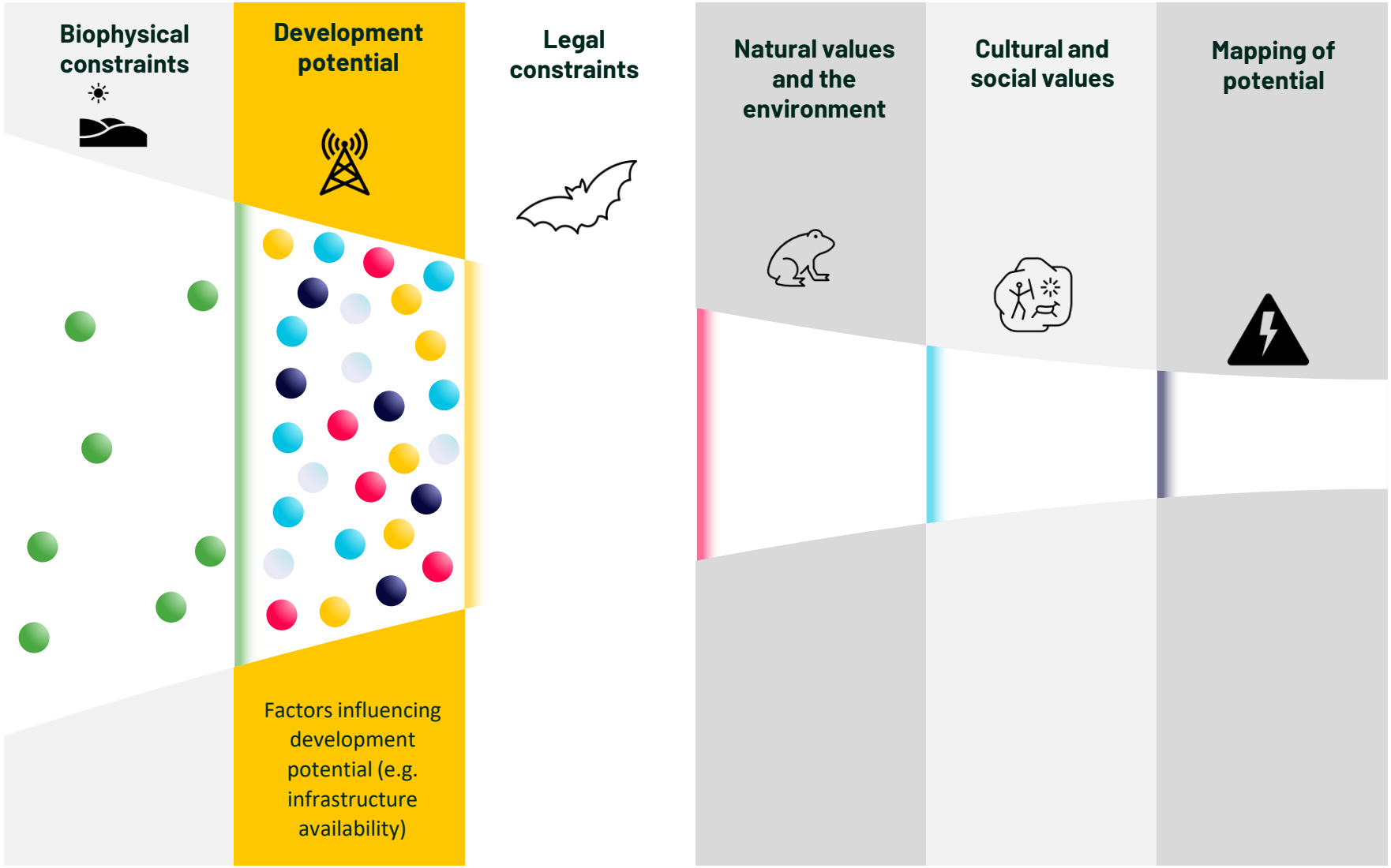
Criteria

Potential areas



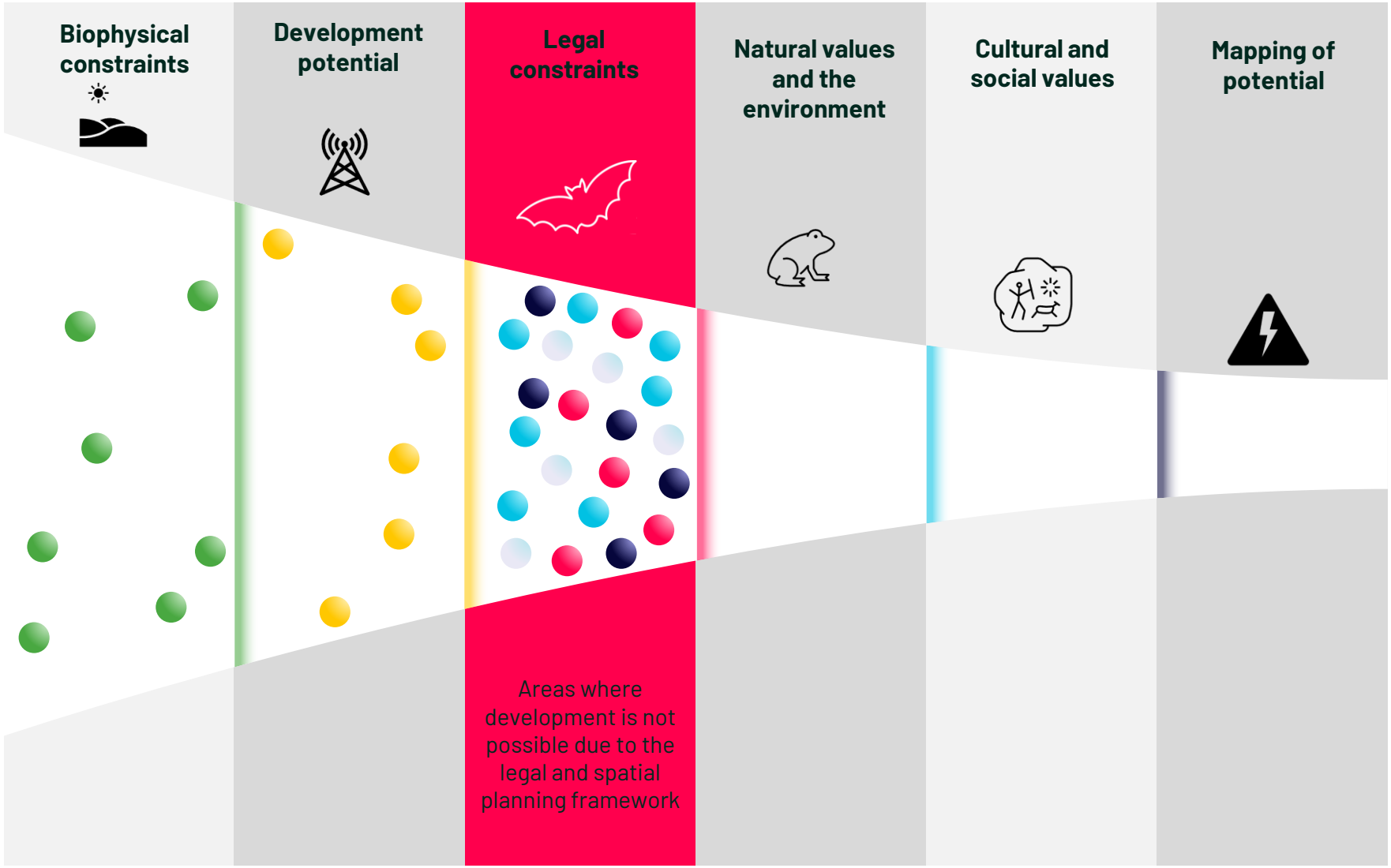
Criteria

Potential areas

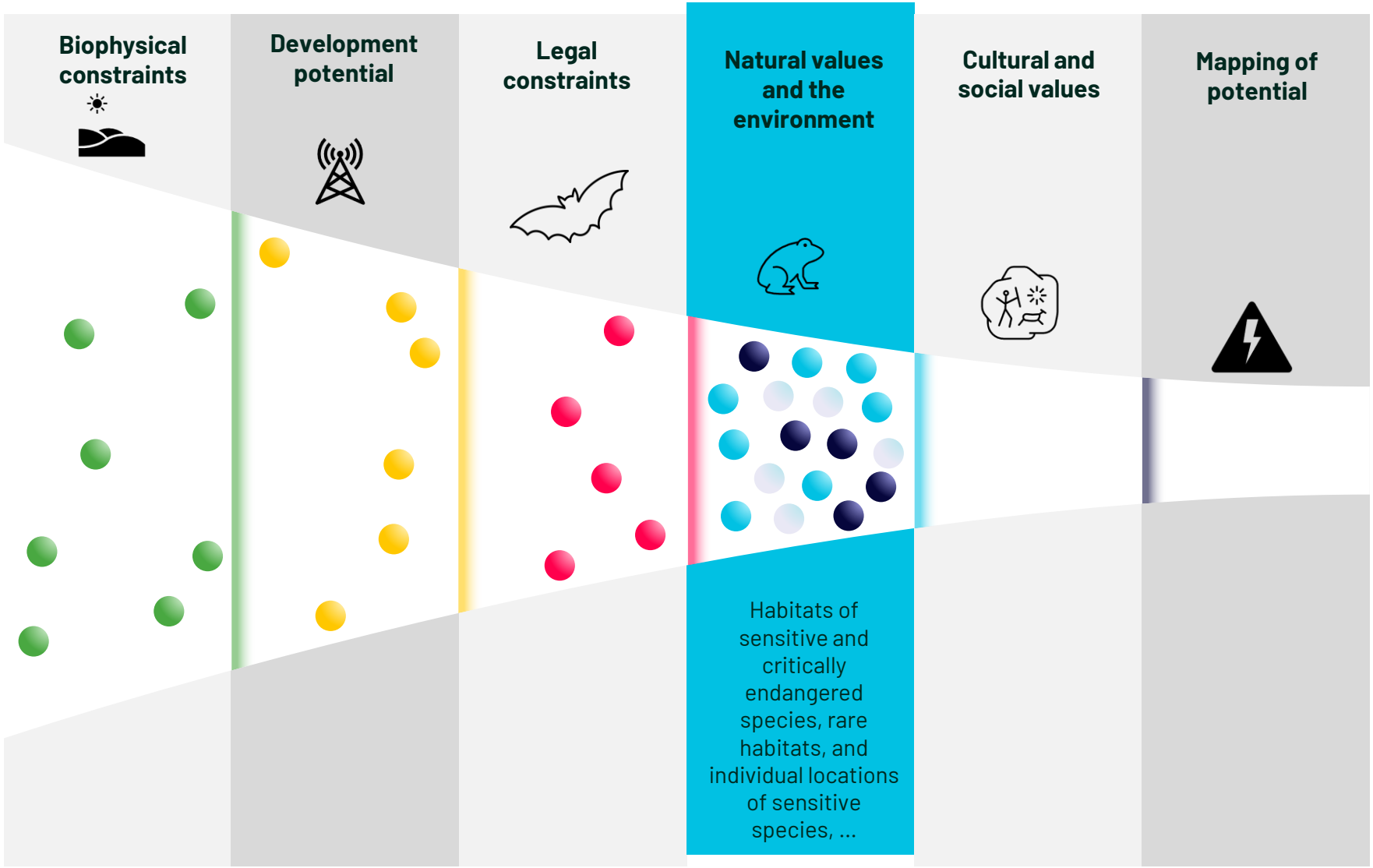


Criteria

Moguća područja

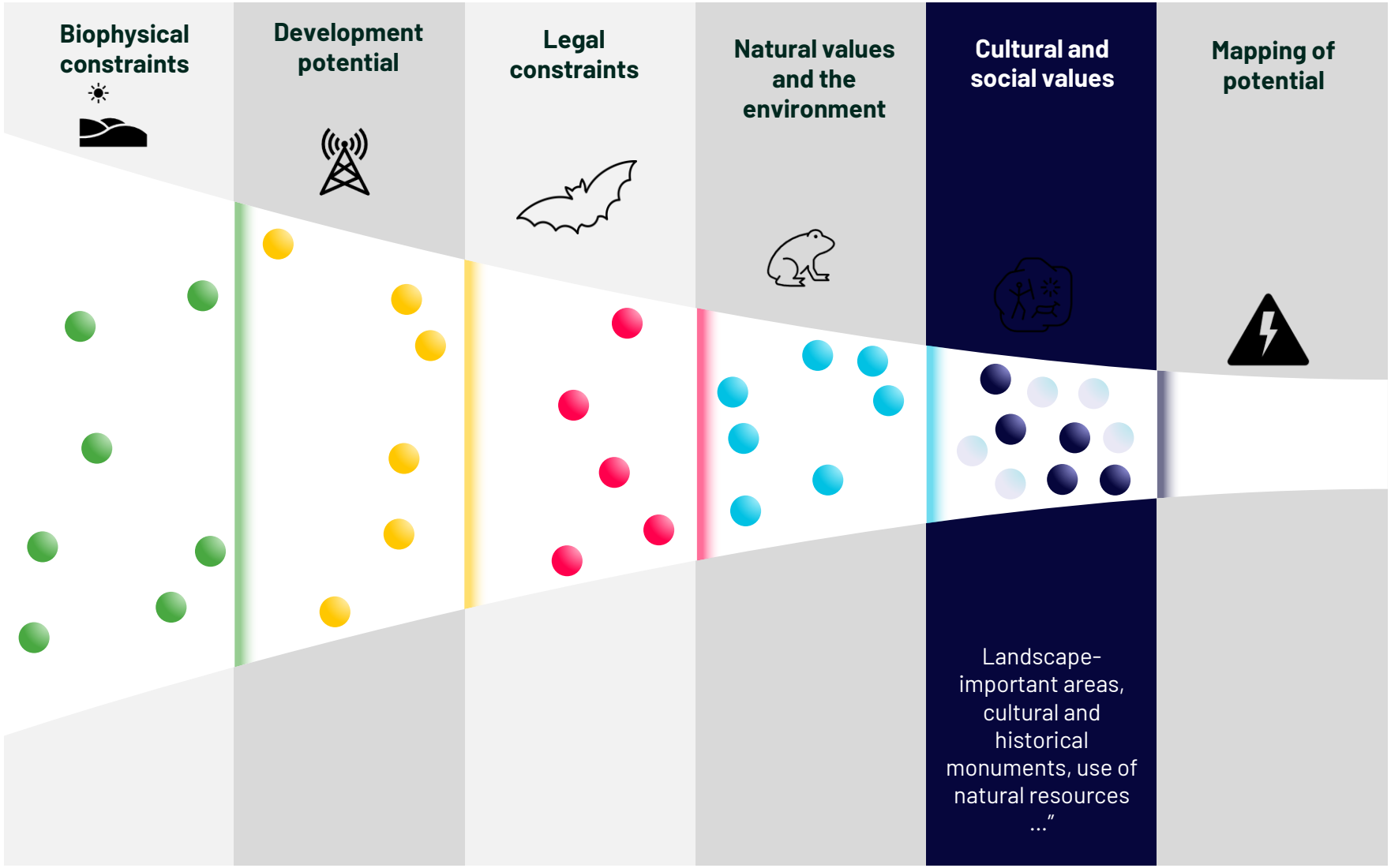


Criteria


Biophysical constraints
Development potential
Legal constraints
Natural values and the environment
Cultural and social values
Mapping of potential
Potential areas
Habitats of sensitive and critically endangered species, rare habitats, and individual locations of sensitive species, ...

Criteria

Potential areas



Criteria

Potential areas

Biophysical constraints

Development potential

Legal constraints

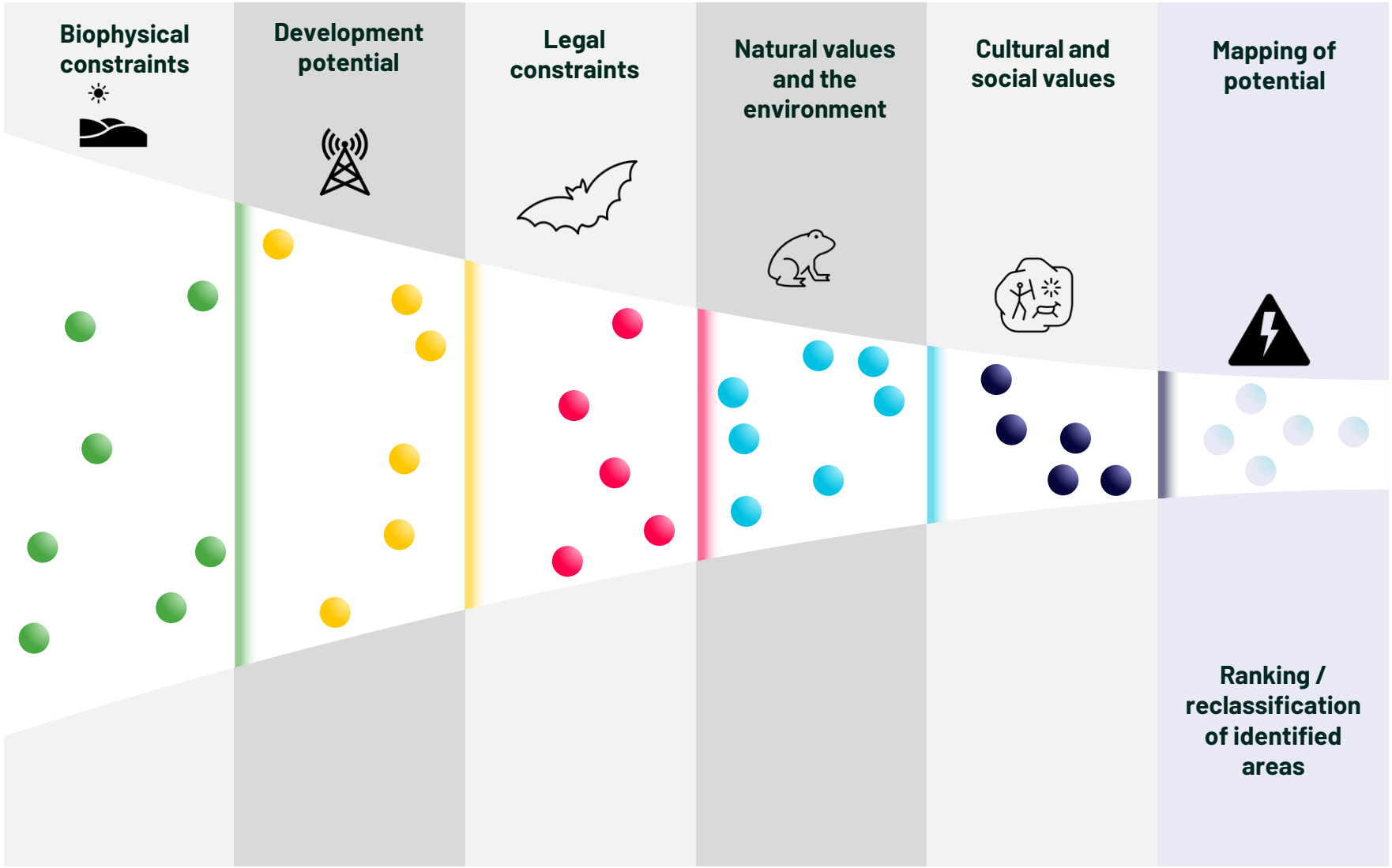
Natural values and the environment

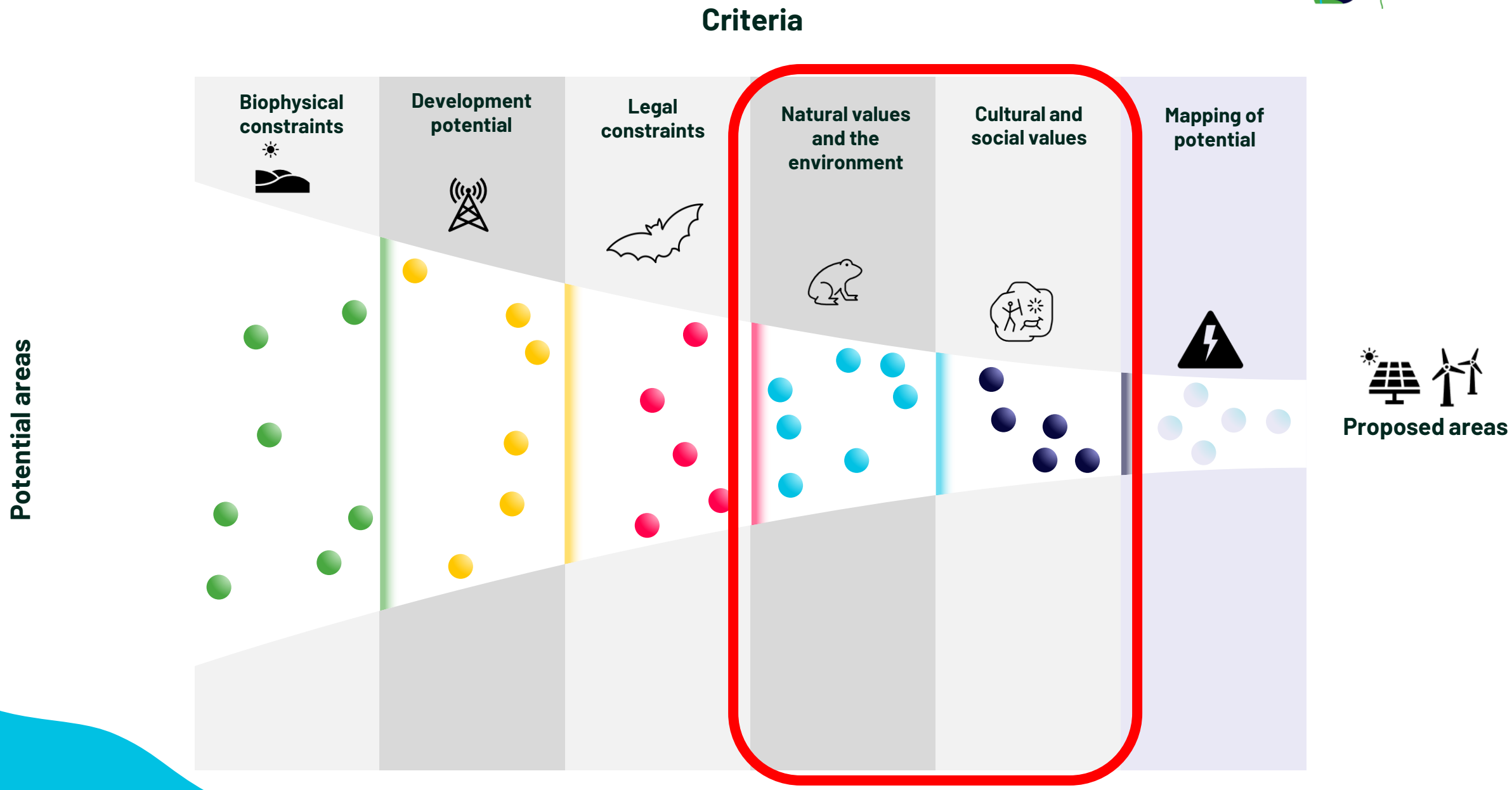
Cultural and social values

Mapping of potential

Ranking / reclassification of identified areas

Proposed areas




Criteria
Biophysical constraints
Development potential
Legal constraints
Natural values and the environment
Cultural and social values
Mapping of potential
Potential areas
Proposed areas

Conflict maps - Sensitivity criteria

1

NATURAL VALUES

- Protected areas (Zone III of protection)
- Areas proposed for protection
- International areas of ecological importance (Emerald network, IBA, SPA, Natura 2000, Ramsar)
  Important bat habitats

2

CULTURAL VALUES

- Distance from cultural and historical monuments

3

SOCIO-ECONOMIC VALUES

- Agricultural land
- Forests and forest land
- Distance from tourist and recreational areas
- Distance from settlements
- Landscape valuable areas

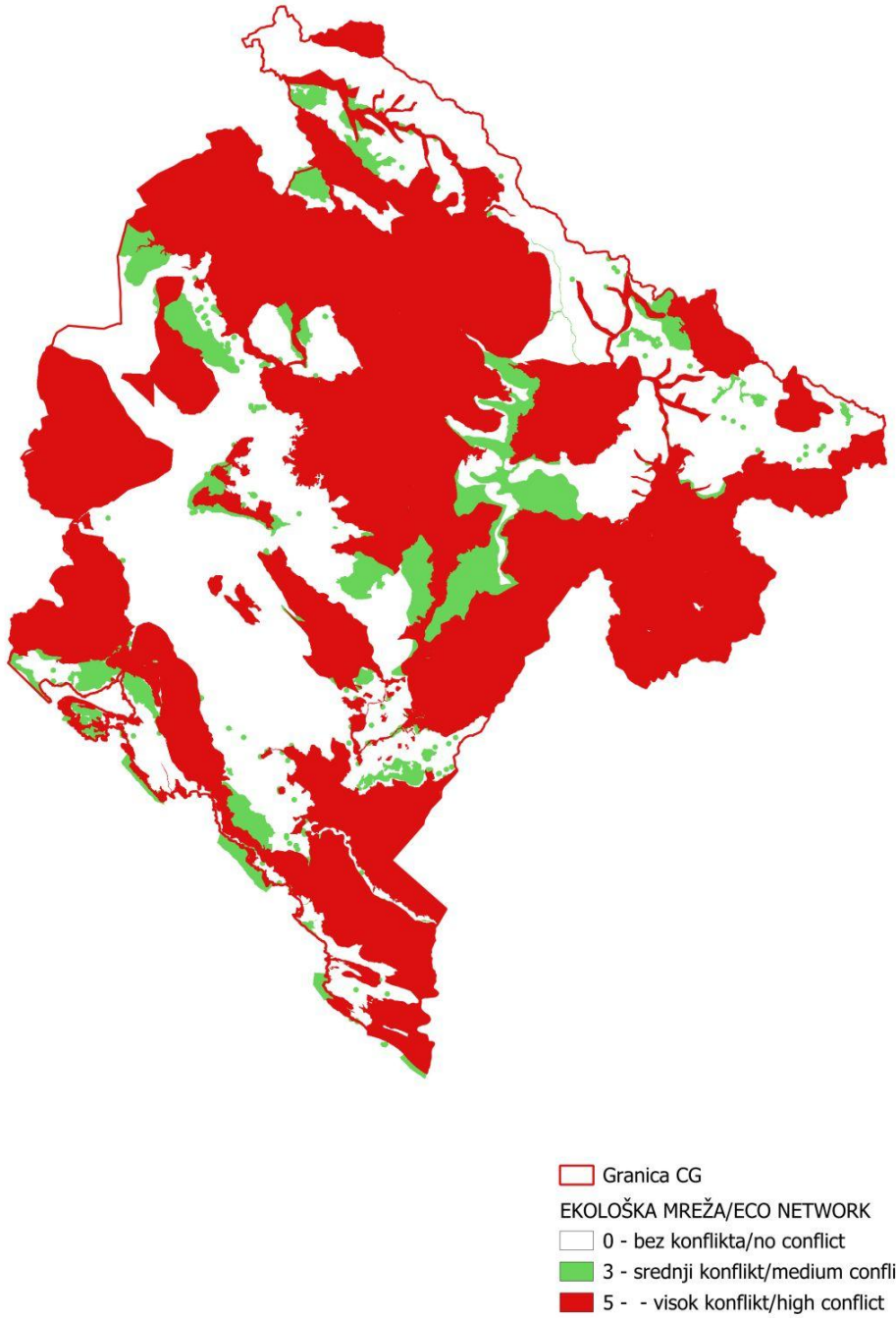
Conflict assessment methodology

Seven key criteria were selected for conflict evaluation:

- **Areas of ecological importance**
- **Agricultural land**
- **Forests**
- **Settlements**
- **Tourist and recreational areas**
- **Landscape valuable areas**
- **Cultural and historical assets**

GIS data were collected for all selected criteria.

Sensitivity levels were differentiated for each criterion—maps were created for each criterion with **3**, **4**, or **5** intensity levels.



Areas of ecological importance

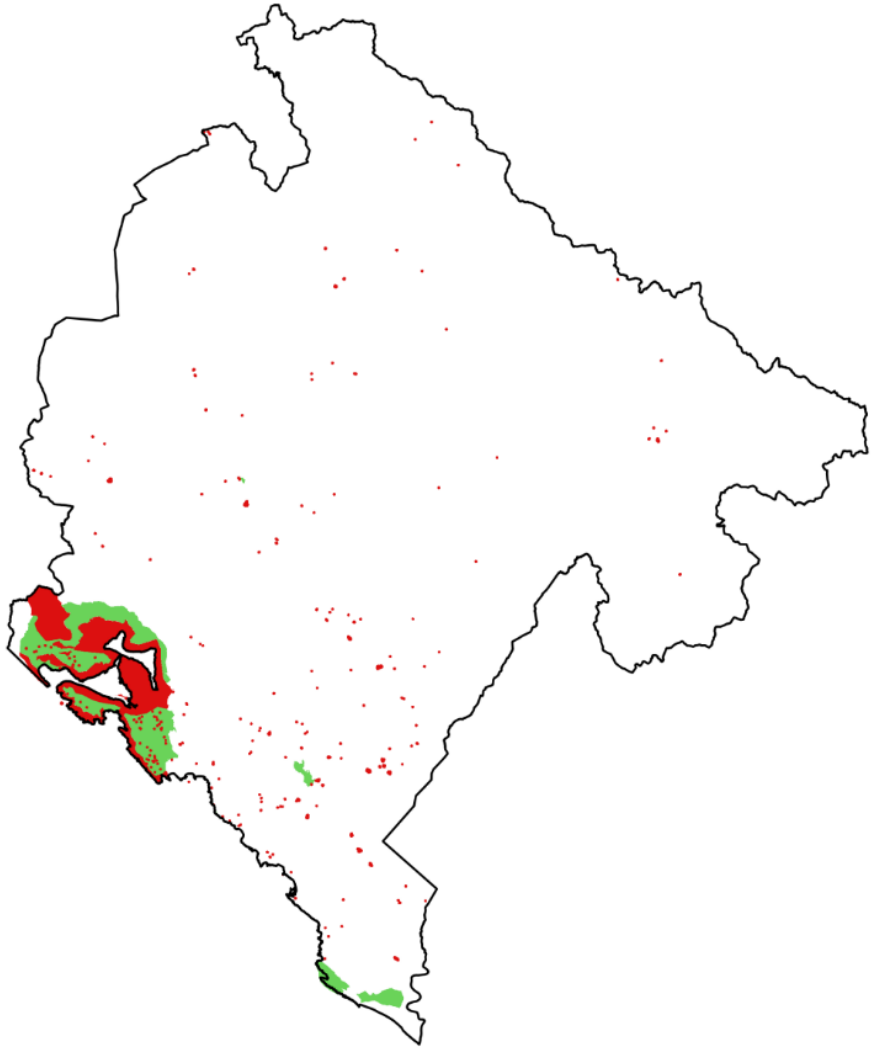
5 – high sensitivity

- Legally protected areas in the third protection zone (National Parks),
- Emerald sites,
- IBA, SPA,
- Ramsar sites,
- proposed Natura 2000 habitats of A representativity and Natura 2000 habitats of EU priority importance.

3 – medium sensitivity

- Legally protected areas in the third protection zone (Nature Parks, Natural Monuments, etc.),
- areas proposed for protection,
- proposed Natura 2000 sites of B representativity, important bat habitats (966 locations, 500 m buffer zone).

Cultural and historical assets



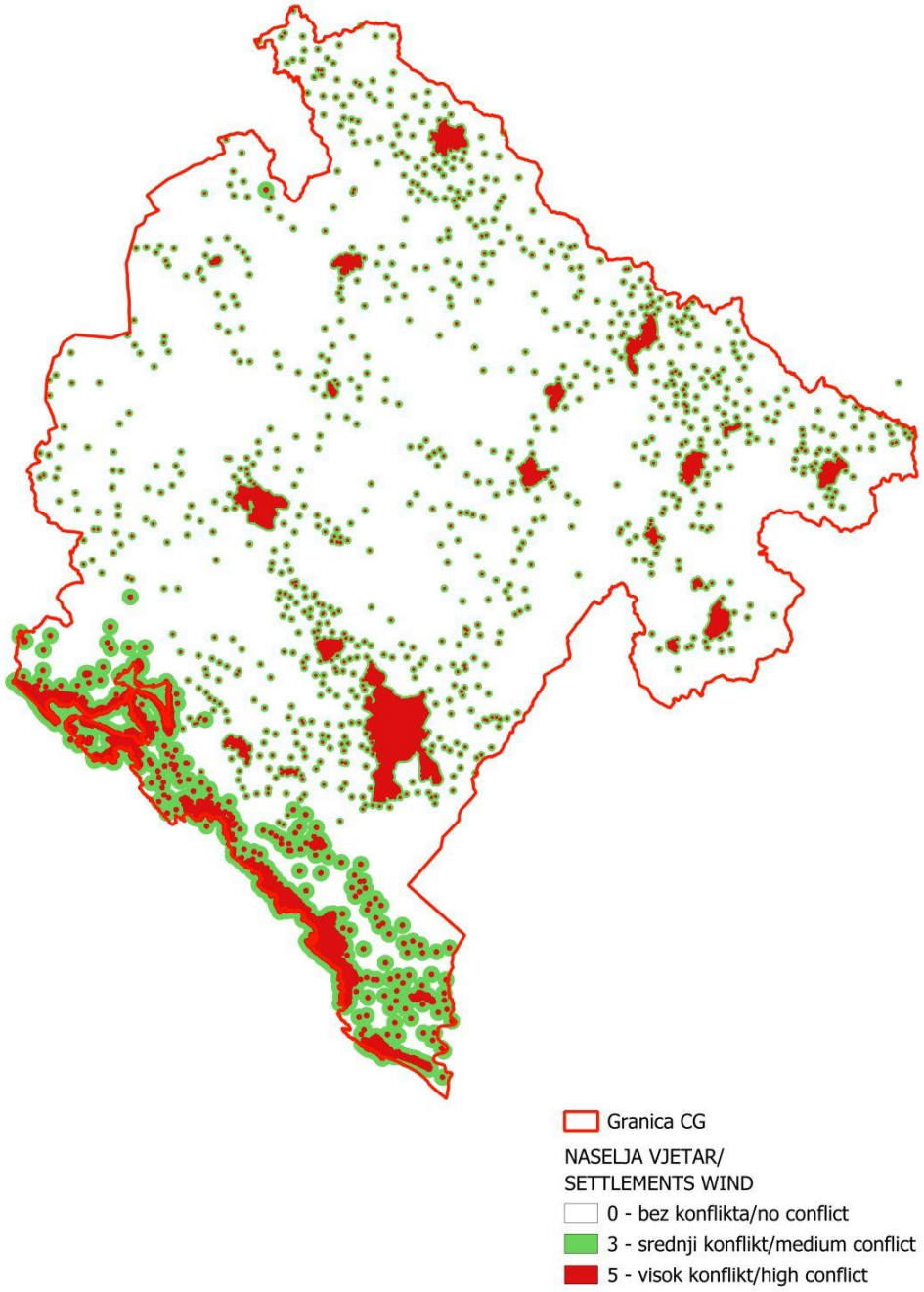
5 – high sensitivity

- Sacral architecture (250 m buffer zone),
- High-intensity conflict risk zones.

3 – medium sensitivity

- Potential cultural assets,
- Medium-intensity conflict risk zones.

Settlements – wind



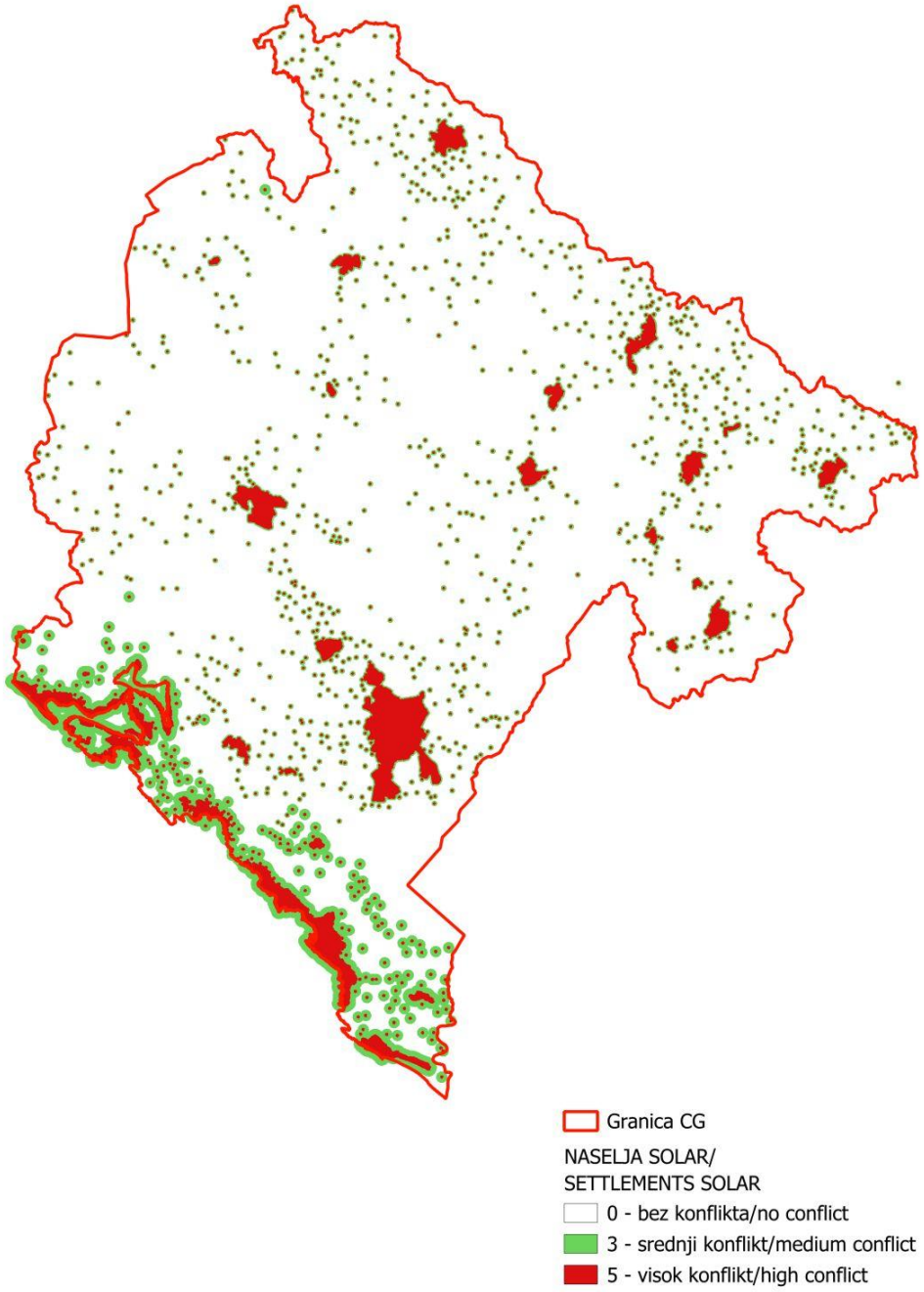
Settlements in special-purpose areas

- Urban and rural (distance < 500 m) – **5**
- Urban and rural (distance 500–1500 m) – **3**

Settlements outside special-purpose areas

- Urban and rural (distance < 300 m) – **5**
- Urban and rural (distance 300–700 m) – **3**

Settlements – solar



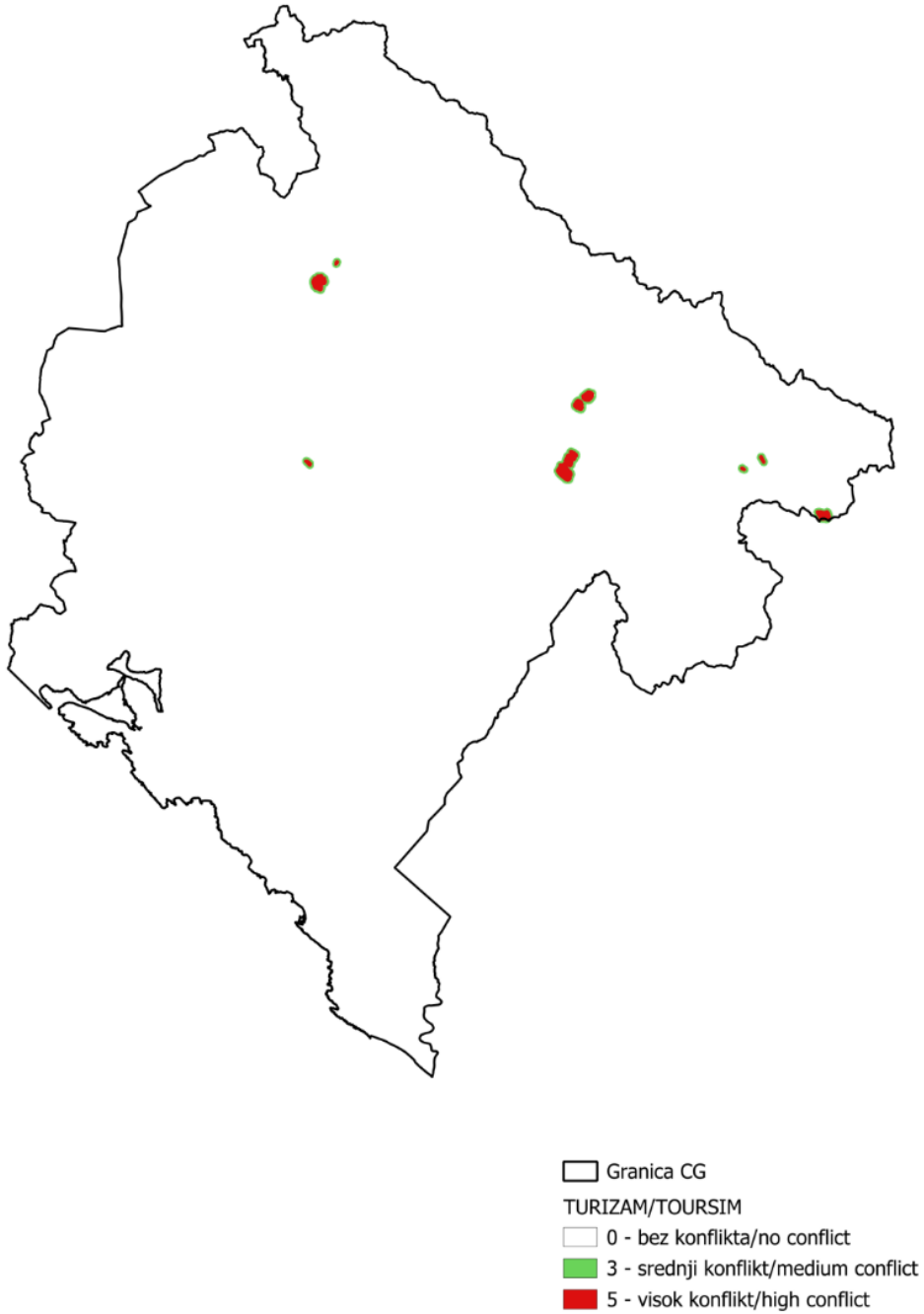
Settlements in special-purpose areas

- Urban and rural (distance < 300 m) – **5**
- Urban and rural (distance 300–1000 m) – **3**

Settlements outside special-purpose areas

- Urban and rural (distance < 250 m) – **5**
- Urban and rural (distance 250–500 m) – **3**

Tourist and recreational areas (ski resorts)



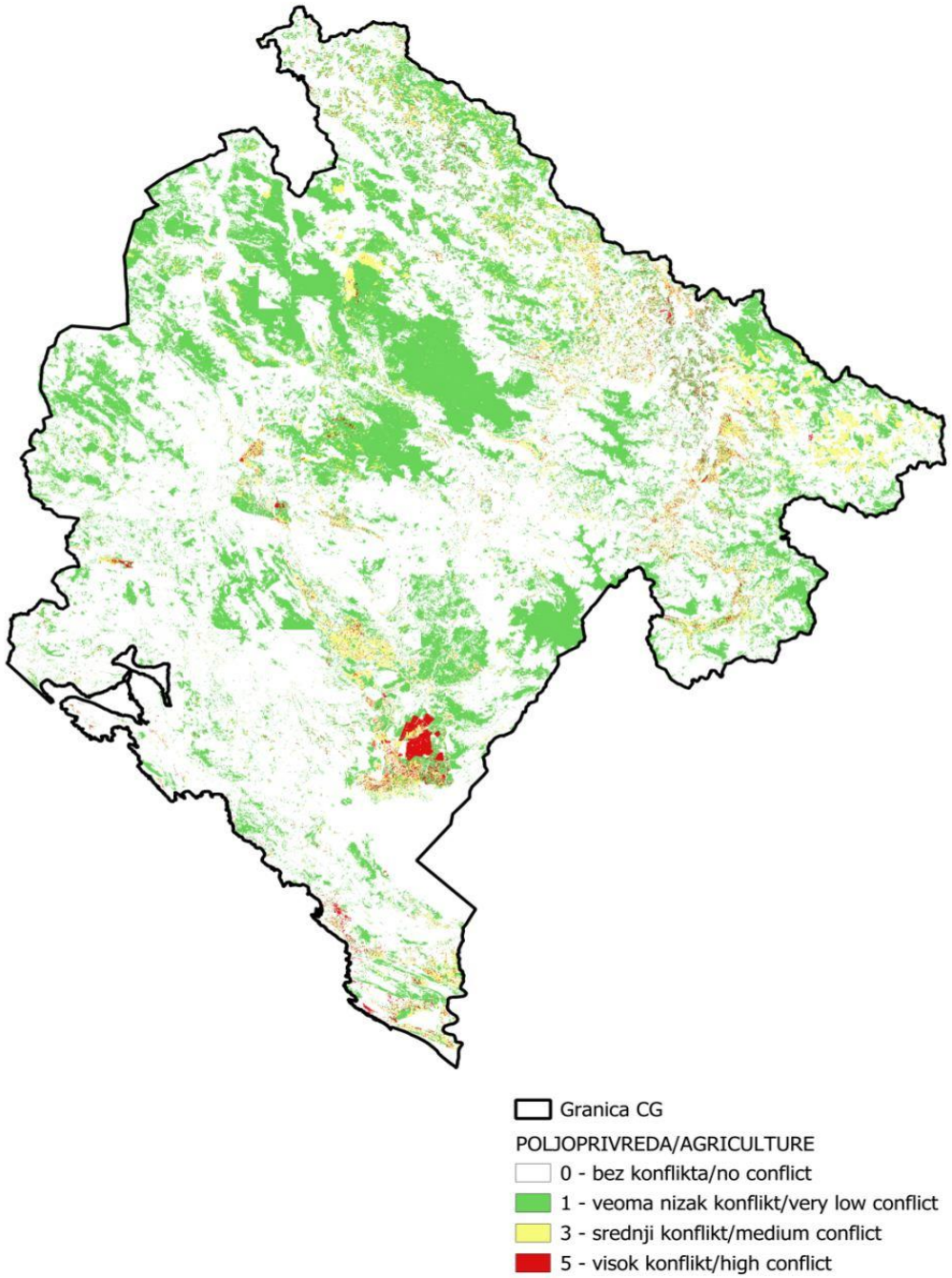
5 -high sensitivity

- distance < 300 m

3 -medium sensitivity

- distance 300 - 700 m

Agricultural land

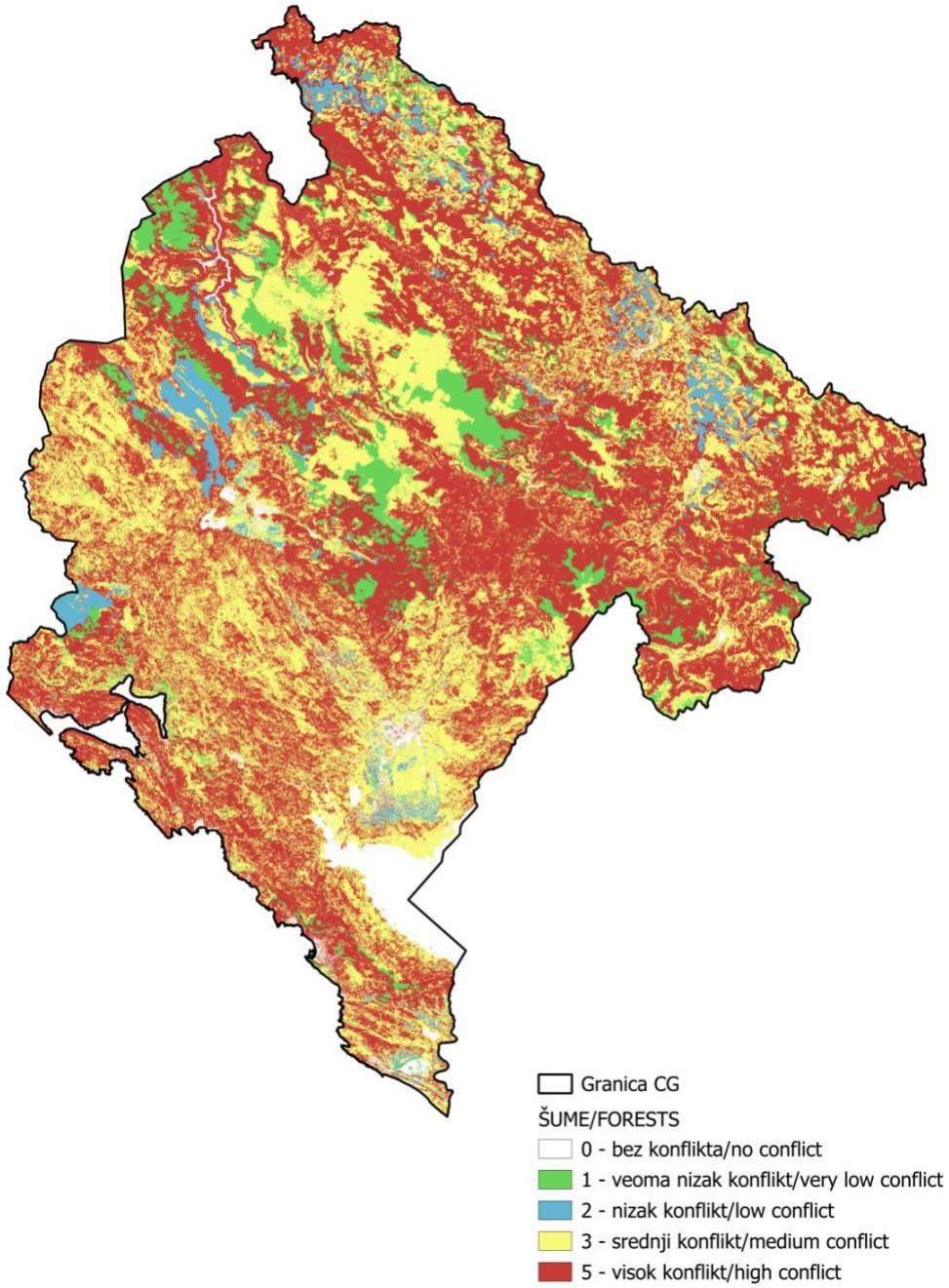


5
- Arable land

3
- Meadows

1
- Pastures

Forests



5
- High forests

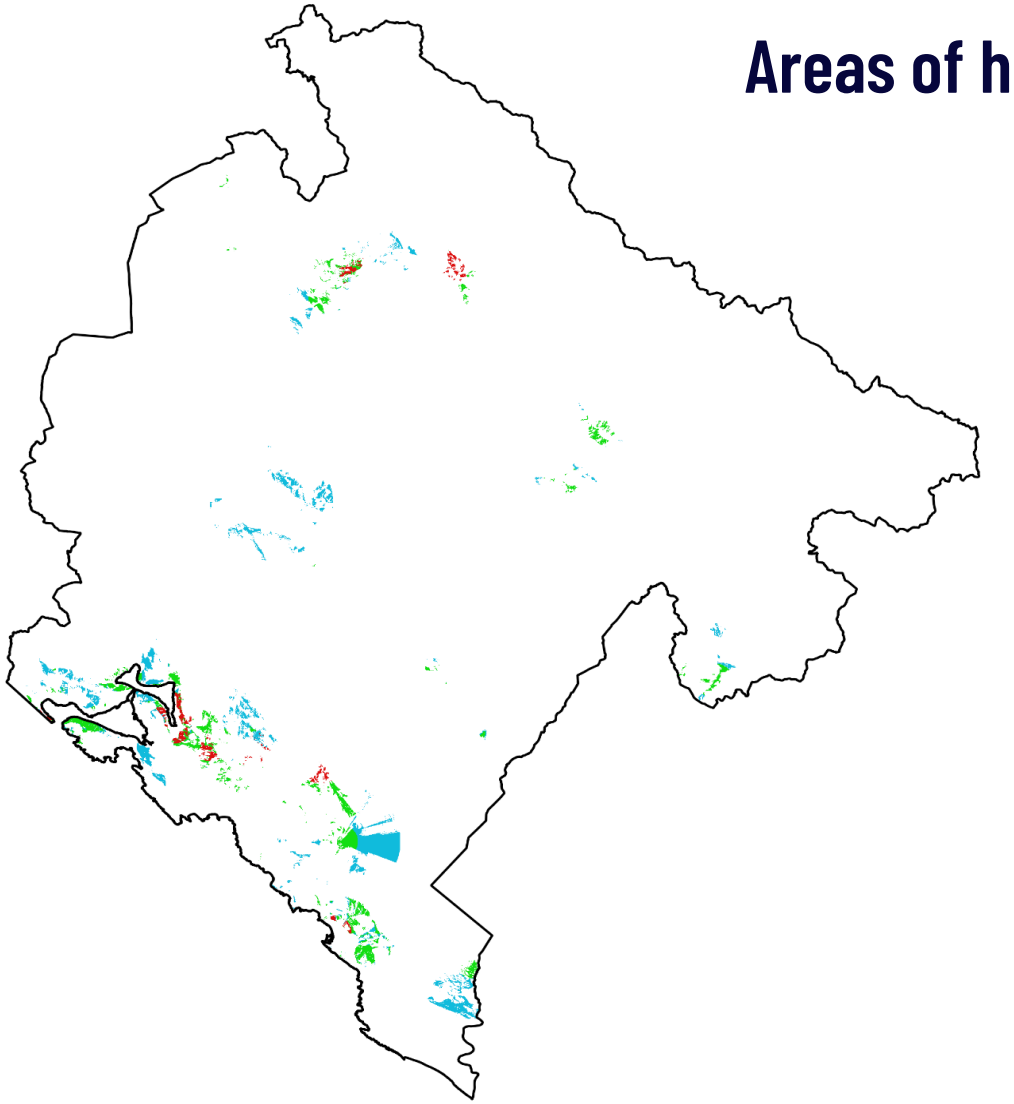
3
- Some types of coppice forests

2
- Some types of coppice forests and scrublands

1
Bare areas within forests

Copernicus Land Monitoring Service

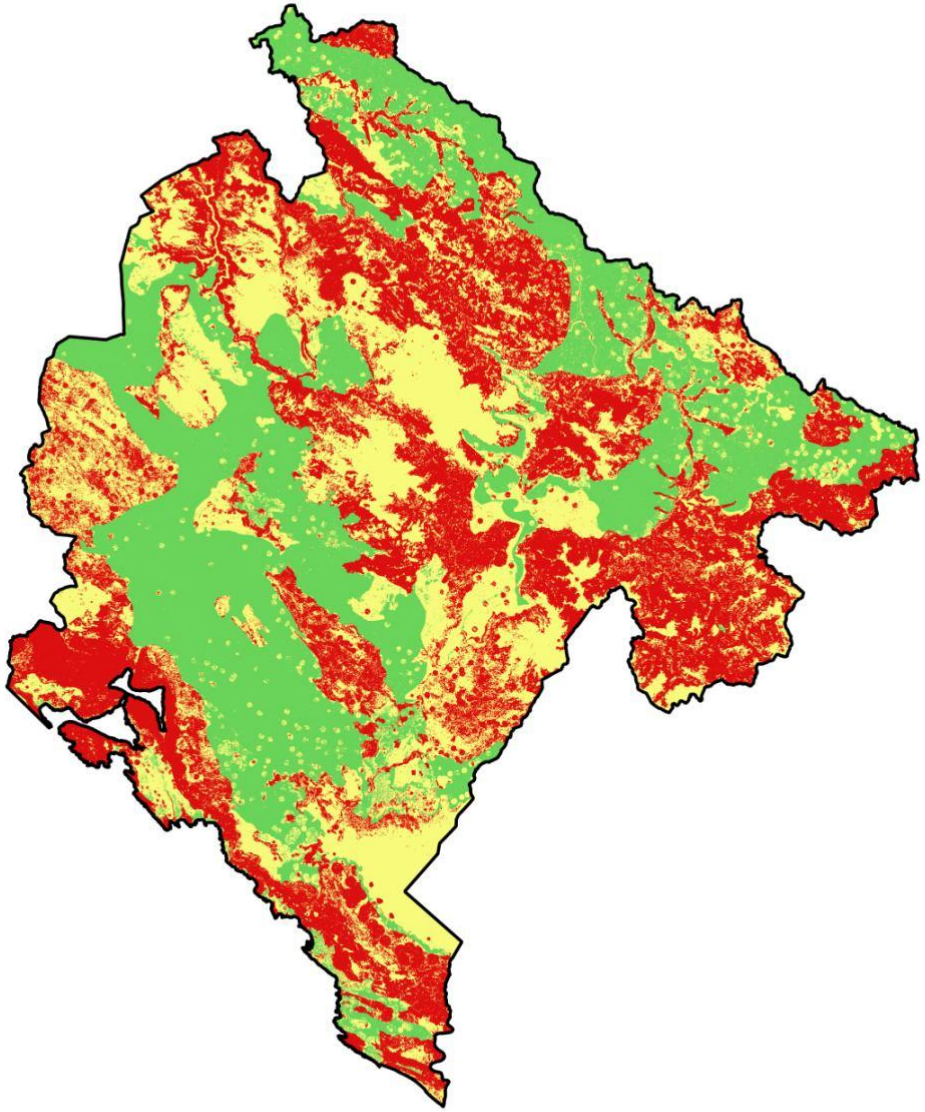
Areas of high landscape value



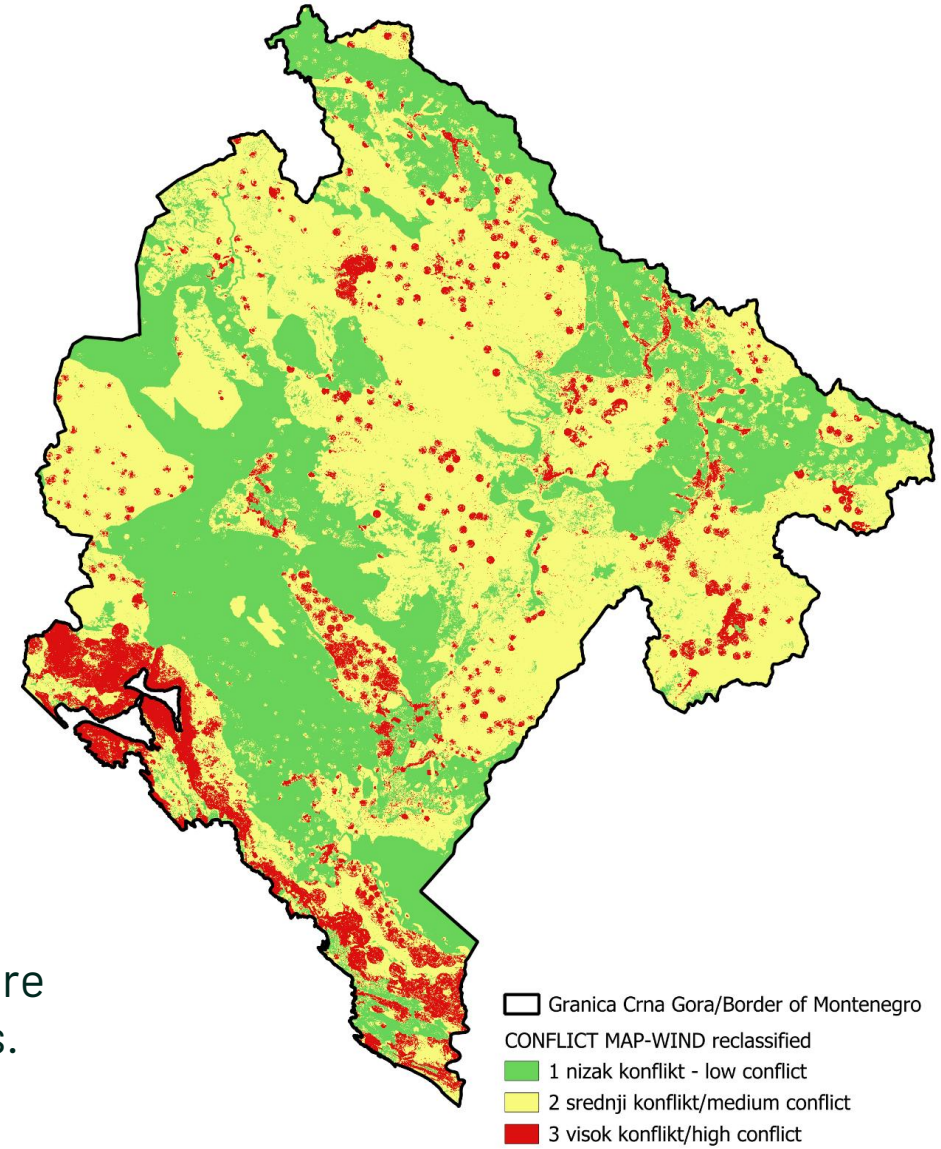
- Areas of **high** landscape value

- Areas of **moderate** landscape value

Conflict maps

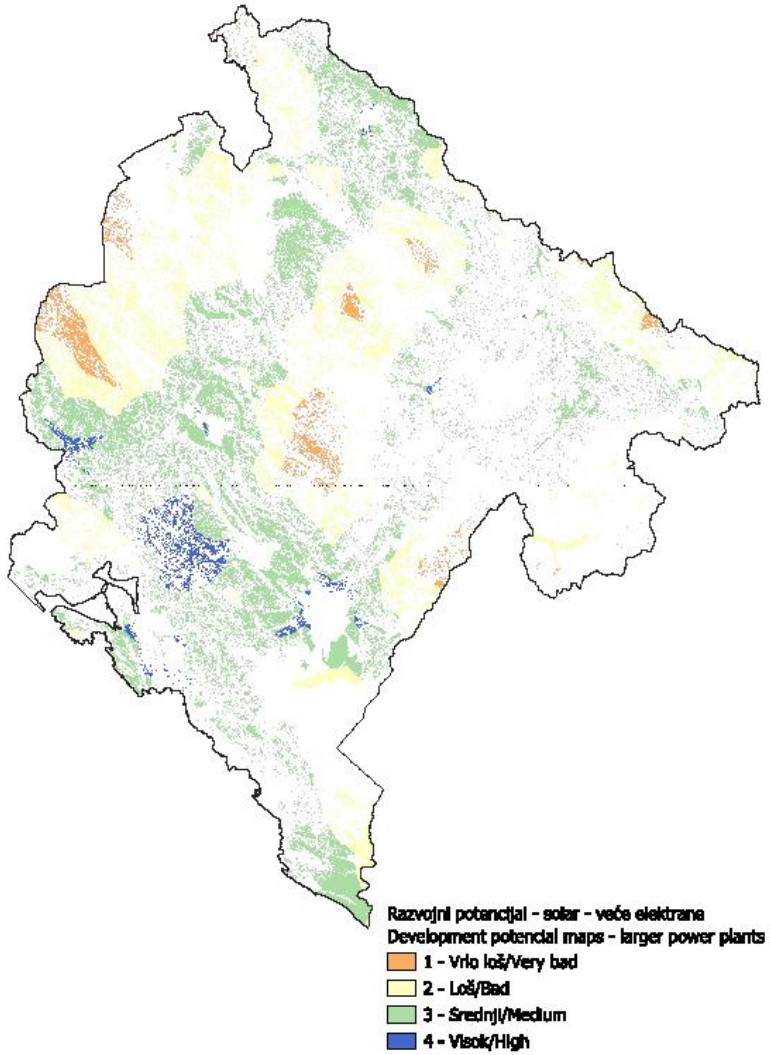


Only low conflict areas are used for further analysis.

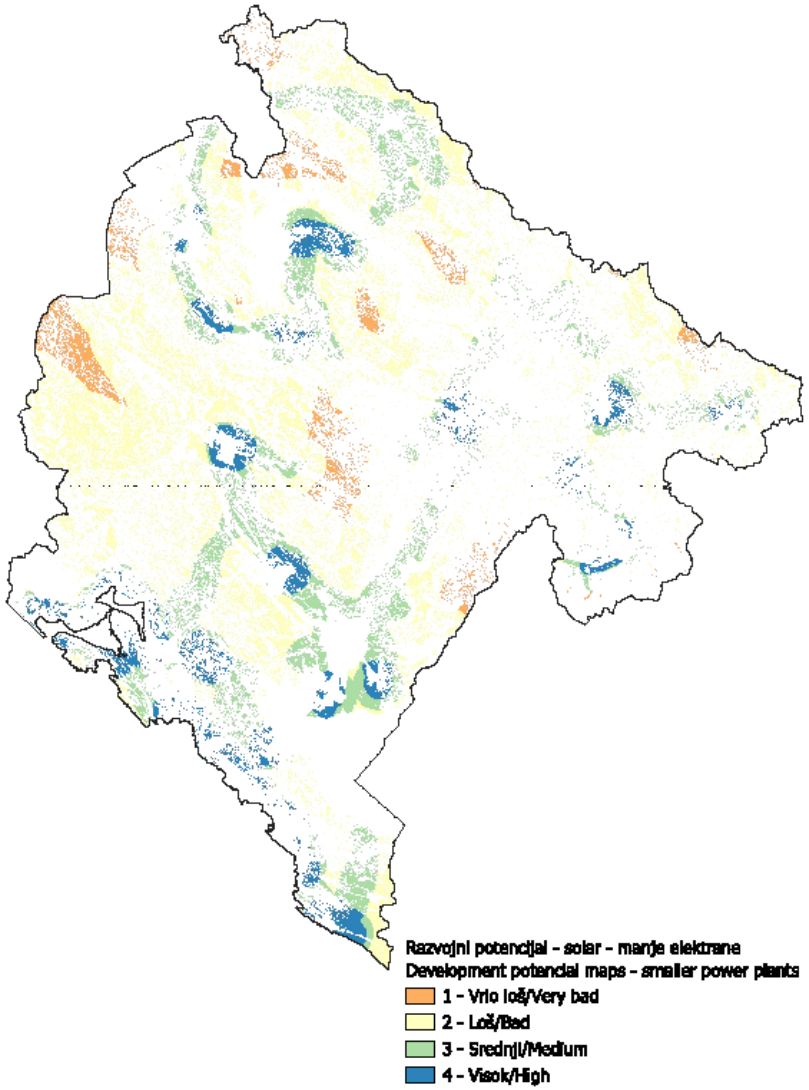


Development Potential Maps – Results

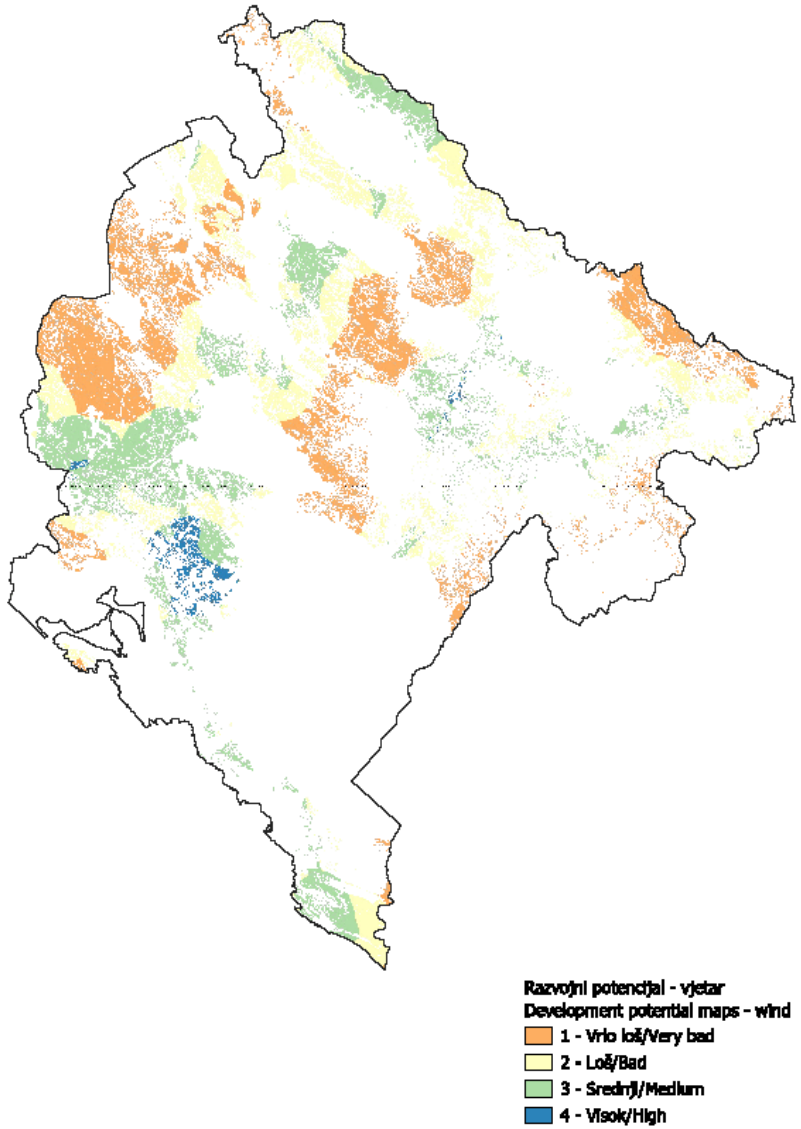
Large solar power plants



Small solar power plants

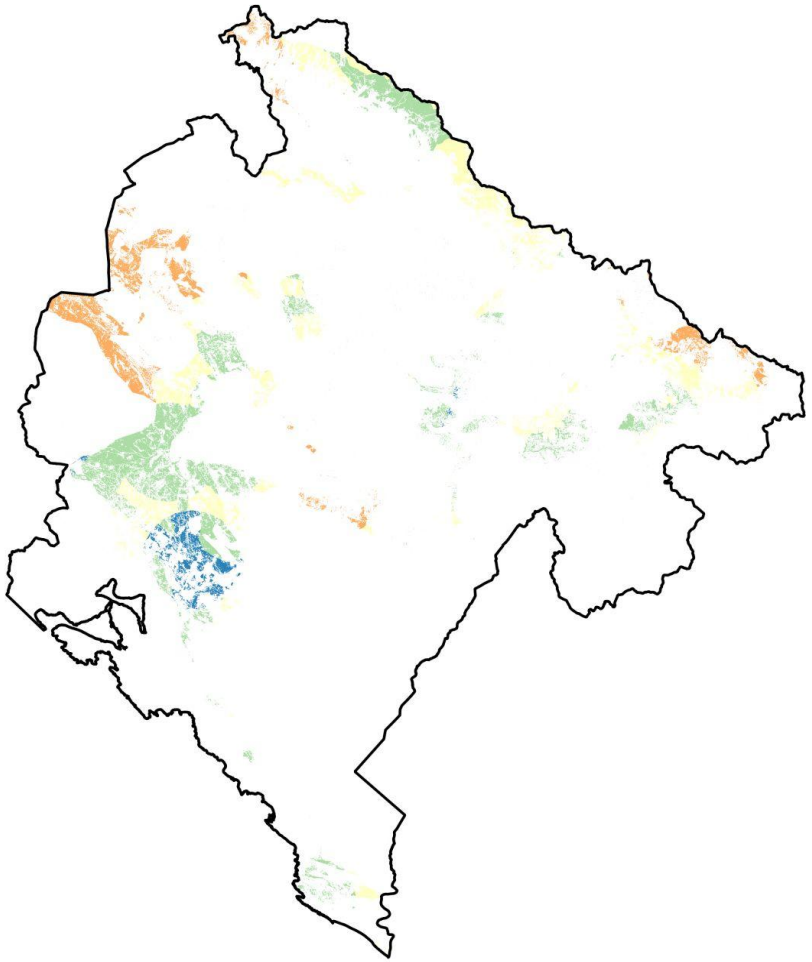


Wind



High development potential and low conflict maps

Wind

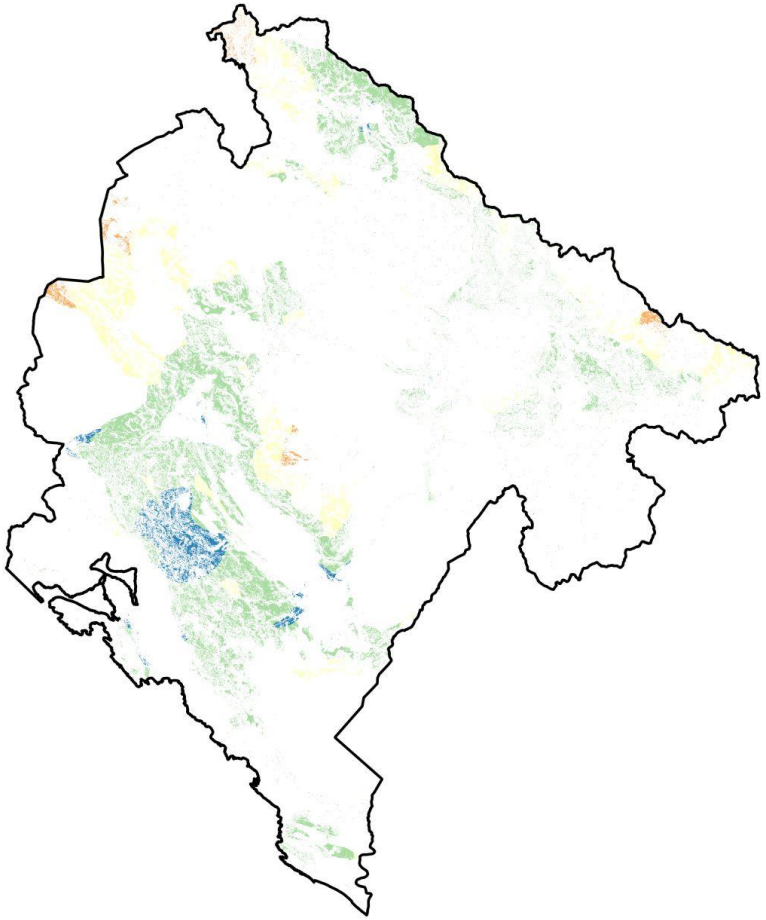


Granica CG

MAPA RAZVOJNOG POTENCIJALA NISKOG KONFLIKTA VJETAR
LOW-CONFLICT MAP FOR WPP DEVELOPMENT

- 1 - veoma niska pogodnost/very low suitaibility
- 2 - niska pogodnost/low suitaibility
- 3 - srednja pogodnost/medium suitaibility
- 4 - visoka pogodnost/high suitaibility

Large solar power plants

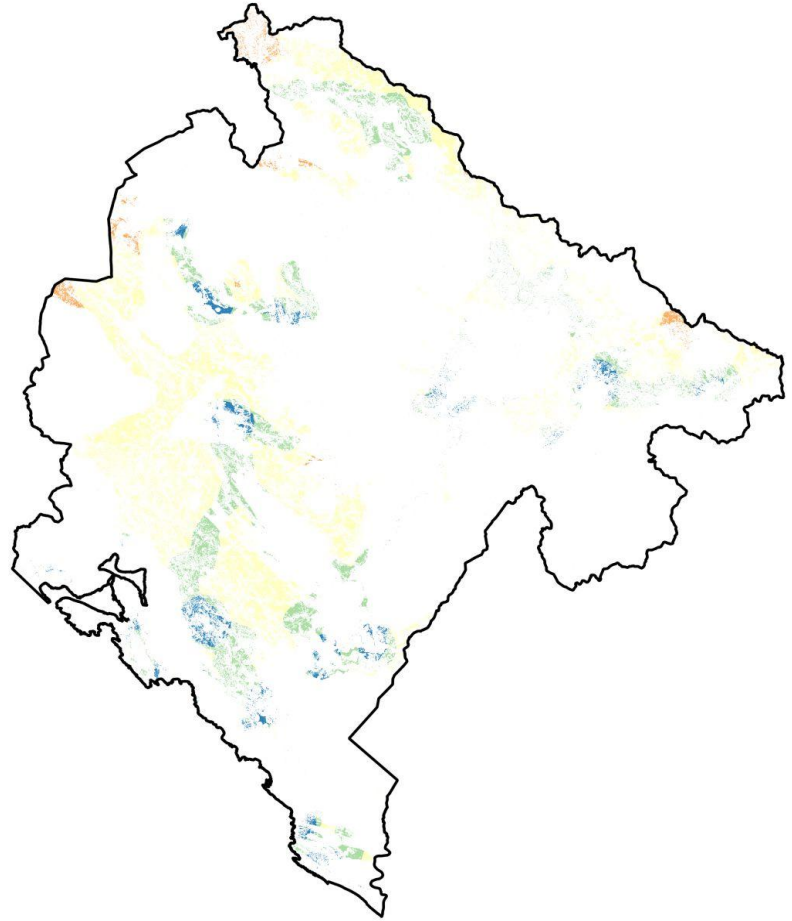


Granica CG

MAPA RAZVOJNOG POTENCIJALA NISKOG KONFLIKTA PRENOSNA MREŽA SOLAR
LOW-CONFLICT MAP FOR TRANSMISSION SPP DEVELOPMENT

- 1 - veoma niska pogodnost/very low suitaibility
- 2 - niska pogodnost/low suitaibility
- 3 - srednja pogodnost/medium suitaibility
- 4 - visoka pogodnost/high suitaibility

Small solar power plants



Granica CG

MAPA RAZVOJNOG POTENCIJALA NISKOG KONFLIKTA DISTRIBUTIVNA MREŽA SOLAR/
LOW-CONFLICT MAP FOR DISTRIBUTION SPP DEVELOPMENT

- 1 - veoma niska pogodnost/very low suitaibility
- 2 - niska pogodnost/low suitaibility
- 3 - srednja pogodnost/medium suitaibility
- 4 - visoka pogodnost/high suitaibility

Preliminary assessment of potential

- Overlay of development potential maps and low-conflict maps
- Result – areas with medium and large renewable energy potential
- Conversion of areas on the resulting maps into estimated potential
  - **Solar potentijal – 1 ha = 1 MW**
  - **Wind potential – 10 ha = 1 MW**
- Results :
  - **Solar**
    - High suitability (large solar power plants) – **7.352 MW**
    - High suitability **(small solar power plans) – 8.435 MW** – Infrastructure limits this potential to below 250 MW.

Wind

High suitability – 656 MW

Brownfields

- **Industrial areas that are not in use**
- **Landfills**
- **Quarries**
- A inventory of these locations needs to be prepared for the entire territory of Montenegro.
- **321 locations** with a total area of 2,607 ha
- Total potential – 346 MW (for large and small power plants)
- High potential – 51 MW

Micro-location analyses are required

Location-wise – the best choice from the perspective of land use

Thank you for your attention

Questions and discussion