# Exercise 1: To visualise wind power potential and aspects that relate to wind energy utilisation in a country of your choice.

## Objective:

To visualize wind power potential and aspects that relate to wind energy utilization in India.

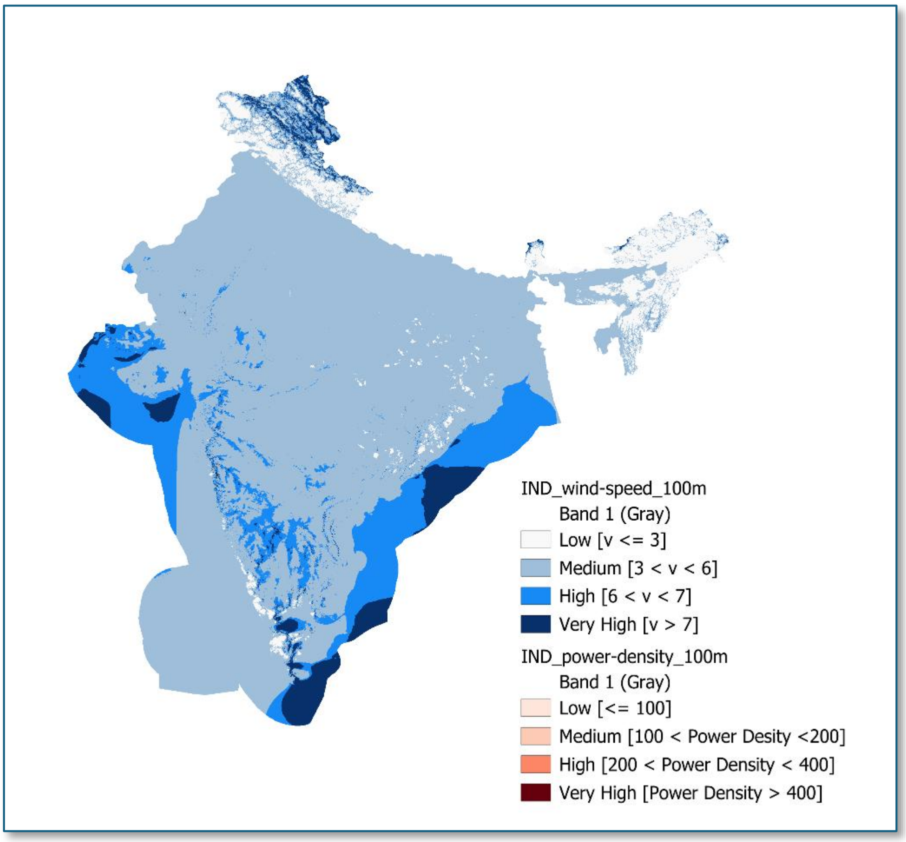



**Figure 1.1: Average wind speed and power density at a Hight of 100 m**

## Data Source:

**Download Wind Data**: Energy data Info
**Content of Data**: Wind speed and power density

## Method:

First step is to data importing. Second step is data analysis by using histograms to categorize wind speed. Next step is to categories to wind speed and power density [See Figure 1.1].

## Results:

The classification of wind speed and power density provided a clear representation of wind energy potential. The analysis successfully identified regions with varying suitability for wind energy projects, aiding in strategic planning and decision-making.

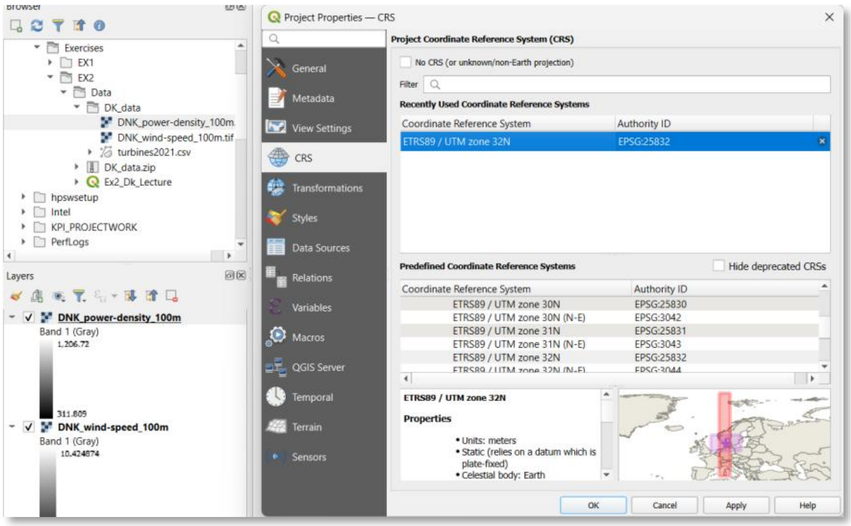
# Exercise 2: Download and visualise the wind speed and power density map for Denmark.

## Objective:

To download and visualize wind speed and power density maps for Denmark.

## Method:

First step is to load data (.TIF) files for wind speed and power density.



Second, set coordinate system which is **ETRS89 / UTM zone 32N** (See Figure 2.1). Next step is to analyse histogram and apply symbology for categorized wind speed and power density into classes.

**Figure 2.1: Set cooedinate system**

Then next step is to add wind turbines data, which is imported CSV file and reviewed its content (See Figure 2.2). Then next step is to visualize wind turbines to use graduated symbols and unique values to map for power capacity and manufacturers (See Figure 2.3 and 2.4).

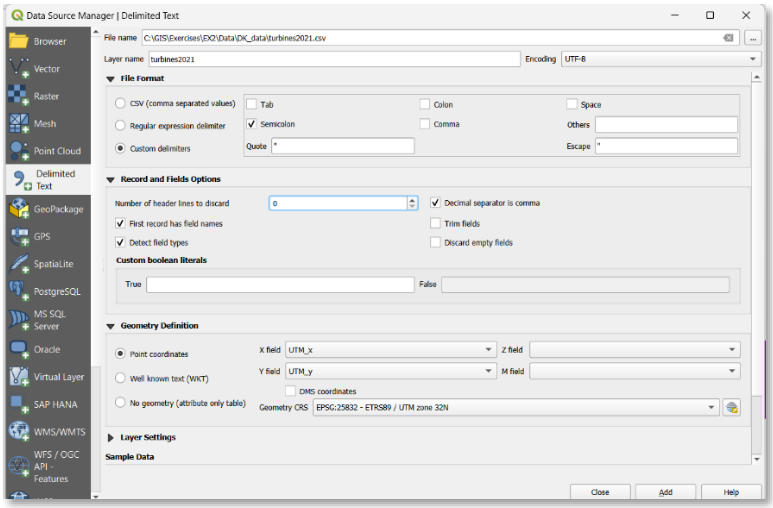


**Figure 2.2: Add wind turbines data**

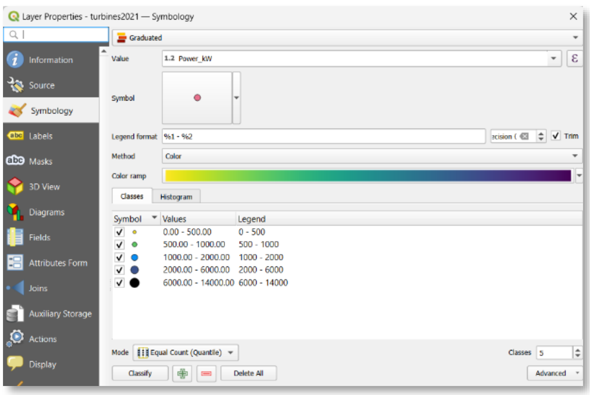


**Figure 2.3: Power capacity**

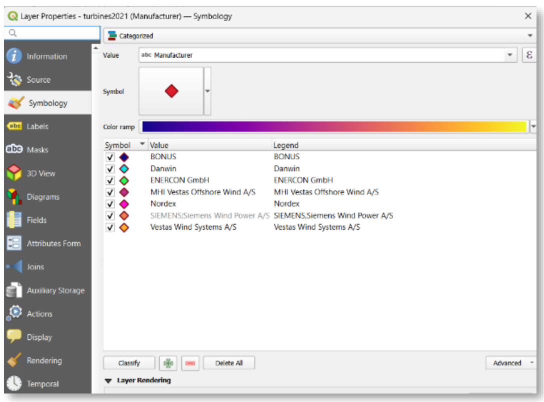


**Figure 2.4: Manufacturers**

Last but not least, enhance Map design to added grid, north arrow, and scale bar (See Figure 2.5).

## Results:

The analysis effectively visualized wind speed and power classifications, as represented in the legend. Wind turbine capacity and manufacturer distributions were mapped to provide insights into spatial patterns of wind energy infrastructure. The final outputs highlight key areas for wind energy potential while ensuring clear and informative data representation.

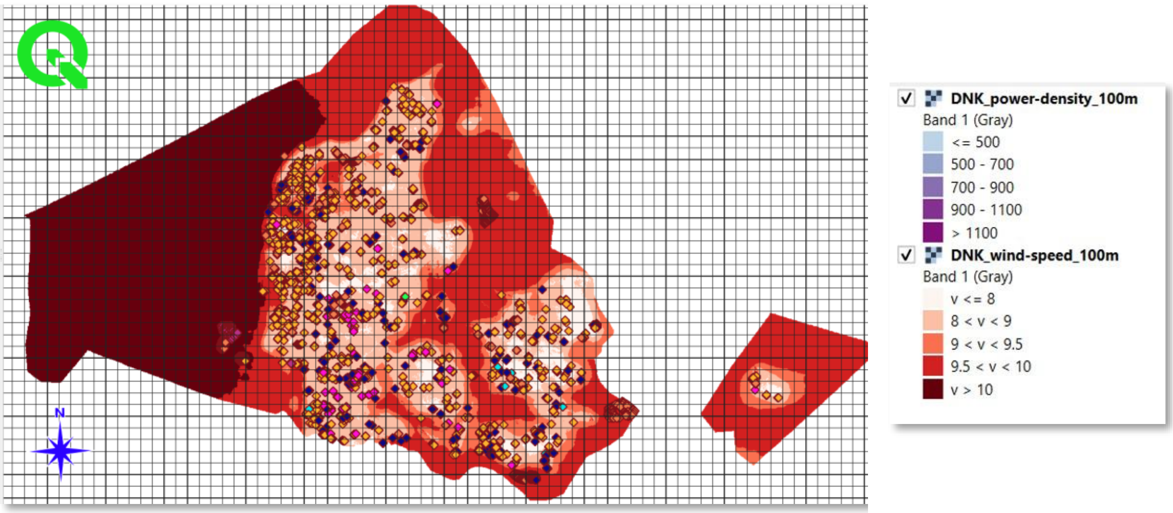



**Figure 2.5: Final output**

# Exercise 3: Find potential wind energy locations in County Galway, Ireland)

## Objective:

To find suitable locations for wind energy projects in County Galway, Ireland.

## Method:

First, we imported "County_Galway.shp" and other relevant shapefiles into QGIS, ensuring the projection from "County_Galway.shp" and adjusting symbology for clear visualization. Next, identified and saved specific land areas by selecting forests from "OSM_Landuse" using an attribute query (fclass = 'forest'), exporting them as a new shapefile (All_Forest), and identifying regions with wind power density **below 900 W/m²** which is See figure 3.1. To assess wind turbine placement, we used the "Select within Distance tool" to find turbines within **5 km** of natural heritage sites (See figure 3.2). For the final step, we created a "White Map" by conducting a buffer analysis: applying **1 km** buffers to forests, heritage sites, and residential areas, a **0.5 km** buffer to wind turbines, and a **0.2 km** buffer to main roads. These buffered areas, along with "OSM_Landuse" and "Power_Density_LessThan_900", were merged into a single layer to define no-go areas (See Figure 3.3). Finally, we applied the "Difference tool" to subtract restricted zones from "County_Galway", to find the suitable locations for wind energy projects (See Figure 3.4).

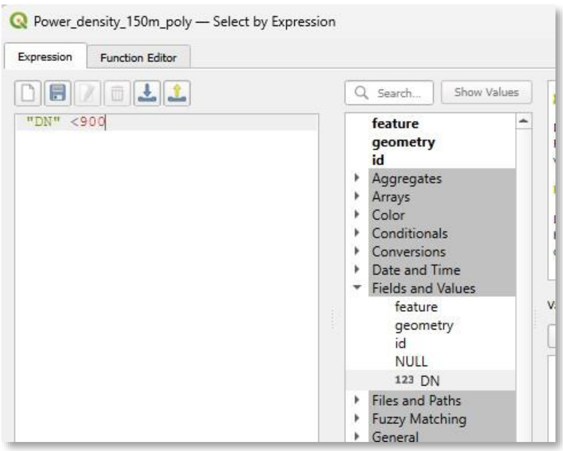



Figure 3.1: Power desity

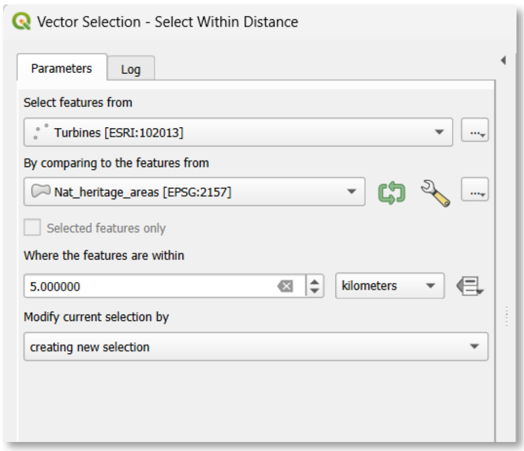



Figure 3.2: Find wind turbines within 5 km

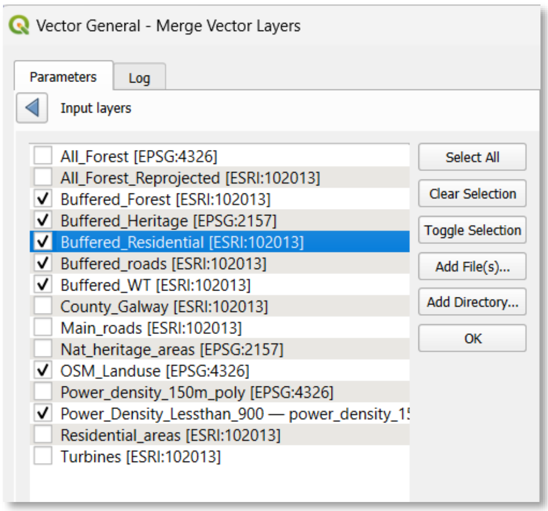



Figure 3.3: Merged into single layer

## Results:

The analysis successfully identified suitable wind energy locations by applying spatial queries, buffering constraints, and geoprocessing techniques. The final map highlights optimal areas while excluding environmentally and spatially restricted zones, ensuring an efficient and sustainable site selection process.

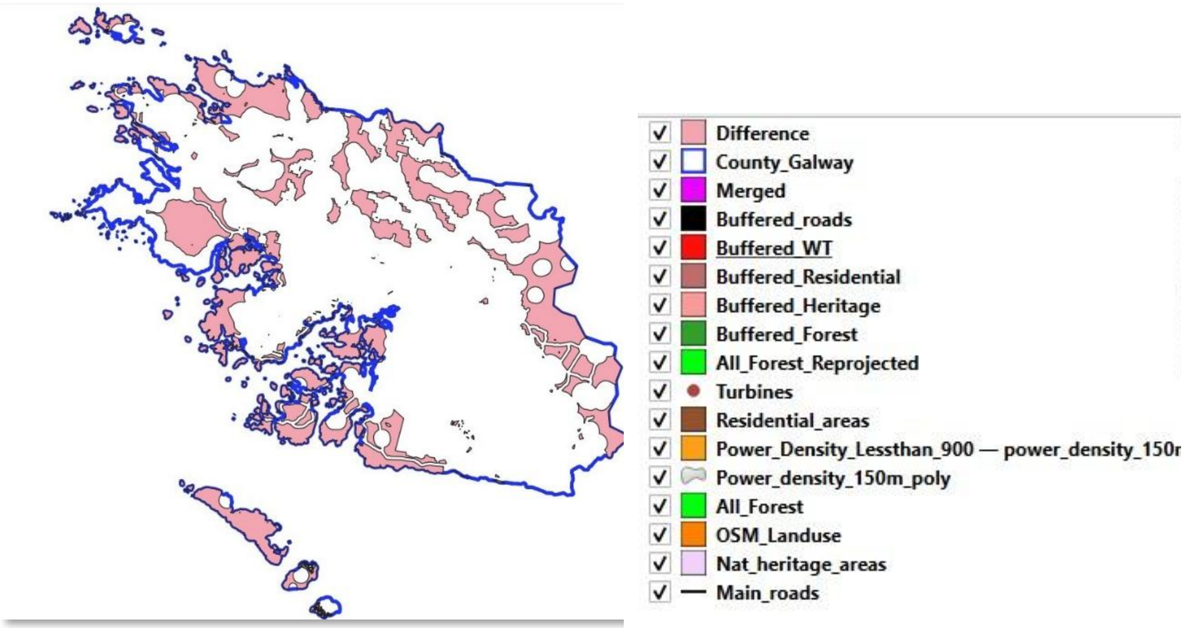


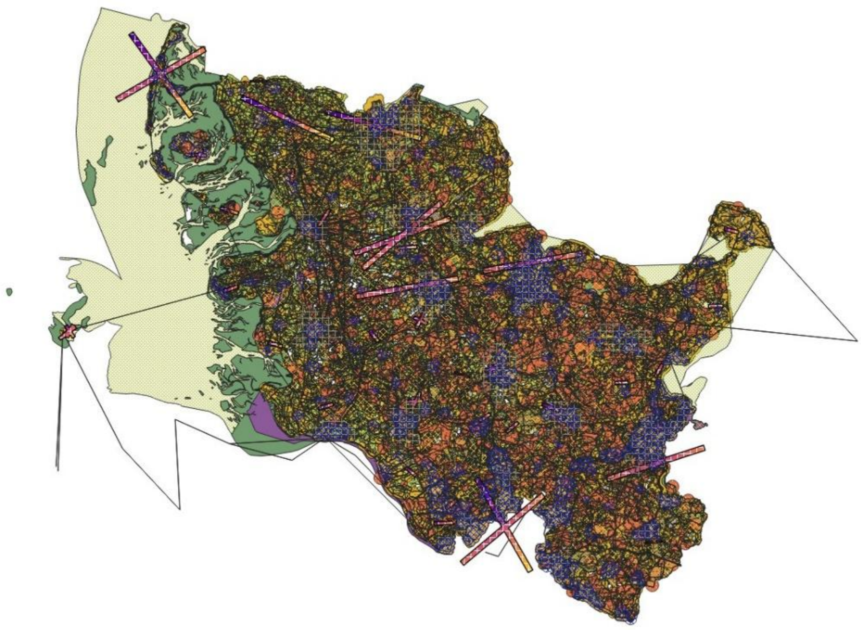

Figure 3.4: Suitable wind energy locations

# Exercise 4: Local Wind Farm Planning (Location: Lindewitt Municipality, Schleswig-Holstein).

## Objective:

To analyse wind energy potential in Schleswig-Holstein by categorizing goals and principles, integrating wind turbine data, and creating a wind farm development map.

## Method:



All relevant ".shp" files were imported into QGIS, and their colours and styles were adjusted for better visualization. The layers were categorized into two groups: Principles and Goals (See Figure 4.1).

**Figure 4.1: All layers with principles and goals**

Wind turbine data was downloaded from the official Schleswig-Holstein site (https://opendata.schleswig-holstein.de/dataset/windkraftanlagen-2023-07-13) and integrated into the project. To identify suitable wind farm development areas, an **800 m** buffer was created around existing wind turbines. A "difference tool" was attempted between the potential wind areas layer and the buffered turbine layer, but an invalid geometry error occurred. This was resolved by using *"Vector → Geometry Tools → Check Validity"* to fix the geometry before reattempting the operation. The final wind farm development map successfully highlights areas suitable for future wind energy development (See Figure 4.2).

**How Goals and Principles contribute to Potential wind areas around Lindewitt? Which goals and principles cut across potential wind areas?**

The analysis of Goals and Principles in relation to potential wind areas around Lindewitt reveals distinct contributions from each category. Goals represent non-negotiable constraints, including critical layers such as residential areas, federal inland waterways, legally protected biotopes, and forest areas, which strictly limit wind energy development. In contrast, Principles are more flexible, allowing for negotiation in certain areas. Through spatial analysis, it was determined that the G02a, G05, G08, G15, G16, G21, and G24 layers from the Principles category intersect with potential wind energy zones, whereas no Goal layers were found to overlap with these areas. This distinction helps refine the selection of viable wind energy locations while ensuring compliance with environmental and legal constraints.

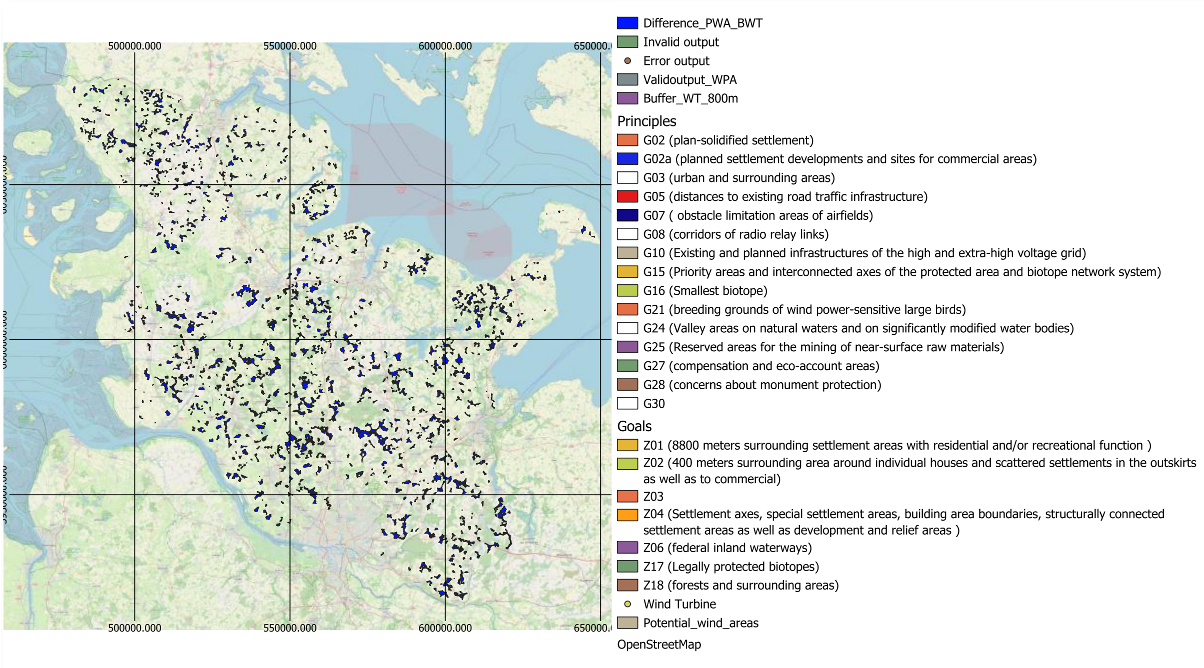



**Figure 4.2: Wind farm development map for an area without exiting wind turbines**

### Results:

The categorized principles and goals provided a structured approach to wind energy planning. The wind farm development map highlights suitable areas free from existing wind turbines while maintaining regulatory constraints.

## Exercise 5: Editing Points, Lines and Polygons

### Objective:

To identify and map the Wind Farm Priority Area "PR1_NFL_036", integrate high-resolution imagery, and digitize essential wind energy infrastructure elements, including wind turbines, access roads, and agricultural fields within the priority area.

### Method:

The "Wind Prio Area 2020" dataset was imported from Stud IP, and the attribute table was queried using "Select by Expression" to filter for the specified priority area ("PR1_NFL_036"). The selected feature was then exported as a new shapefile for further analysis.

To enhance visualization, ESRI World Imagery was added as a high-resolution backdrop using either ''QuickMapService'' in QGIS or an online site, which show in below.

(https:// server.arcgisonline.com/arcgis/rest/services/World_Imagery/MapServer).

Figure 5.1: Wind turbines and roads

For spatial mapping, a new shapefile layer was created to add wind turbine attributes. Using “Toggle Editing”, wind turbines were digitized by selecting Add point Feature and placing points near existing turbines (See Figure. 5.2: Blue point). Additionally, access roads were mapped using pre-existing road data (See Figure. 5.1: Yellow Lines).

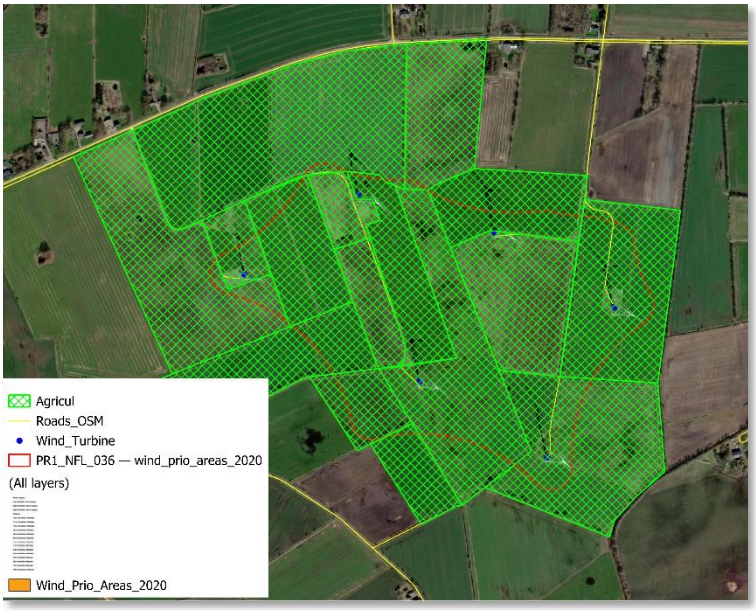



Figure 5.2: Agricultutal fields

Agricultural fields intersecting with the priority area (polygons). “Snapping tools” were utilized where necessary to ensure spatial accuracy, and attributes were added to the respective layers (See Figure 5.2).

## Results:

The final dataset provides an accurate representation of wind farm infrastructure within the designated priority area. The wind turbine locations were successfully digitized, with access roads mapped to illustrate connectivity. The agricultural fields intersecting the priority area were also identified, helping assess land use conflicts. The integration of high-resolution imagery provided a clear geographic reference, enhancing spatial analysis and decision-making for wind farm development.

# Exercise 6: Visualise the results with colours and transparency

## Objective:

To analyse the visibility of existing wind turbines in Schleswig-Holstein using a viewshed analysis and visualize the results with appropriate colours and transparency.

## Method:

Installed the "Visibility Analysis plug-in" to enable viewshed analysis in QGIS. Loaded the "SRTM3 elevation model (DSM)" and existing wind turbine locations for Schleswig-Holstein. Create viewpoints: Estimated observer height using the formula: **H [m] = hub height + 0.5 * rotor diameter.** Calculated the search radius as: **Radius = 150 x turbine height**. Added two new fields "tot_height" and "radius" to the attribute table and calculated their values. A binary viewshed analysis was performed using the "Processing Toolbox → Create Viewpoints", where wind turbines were set as observer locations, and the "Digital Elevation Model (DEM)" box select "DCM_ETRS_LAEA [EPSG:3035]", applied with a **5000 m** analysis radius and an observer height of **1.6 m**.

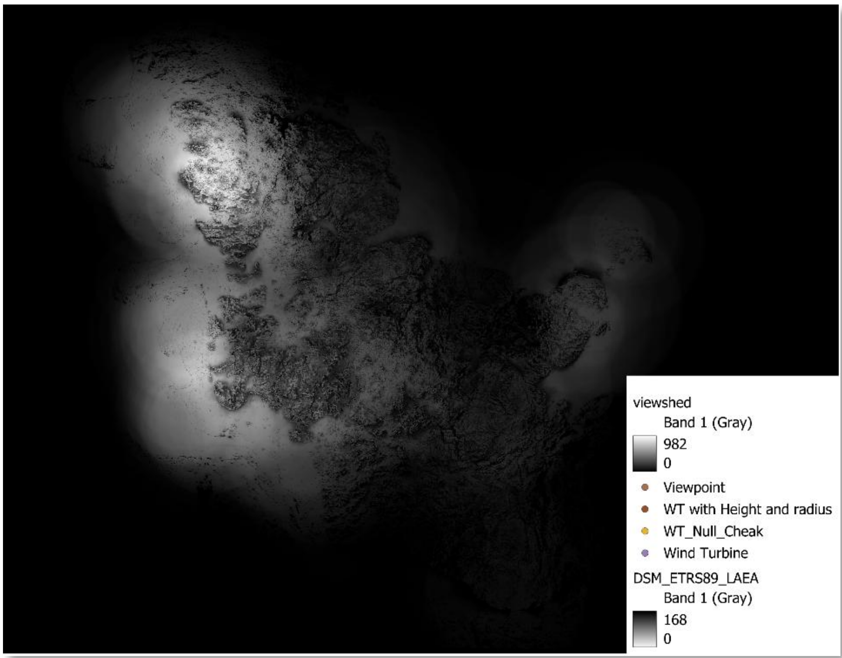



**Figure 6.1: Colours and transparency around wind turbines**

The final used the "Viewshed tool" to set the "binary viewshed" as the "Observer Location" and the "DEM" as the elevation reference. Saved and processed the output, then adjusted colours and transparency for better visualization (See Fig. 6.1).

## Results:

The viewshed analysis provided a binary representation of visible and non-visible areas around existing wind turbines. The visualization helped in understanding the impact of turbine height and terrain on visibility. Applying colours and transparency improved readability and provided insights into optimal locations for new wind turbines.

## Exercise 7: Convert (Rasterize Vector to Raster) the electric grid layer to an input raster for distance mapping. Calculate the distance from the grid in metres (r.grow.distance).

### Objective:

To convert the electric grid vector layer into a raster format and compute the distance from the grid in meters using “r.grow.distance”.

### Method:

The electric grid vector layer was rasterized using the “Vector to Raster tool”, with a burn value of **1**, a cell size of **100m**, and the same projection as the grid line vector layer. The “r.grow.distance” tool was then applied to compute the distance from the electric grid, ensuring accurate spatial analysis.

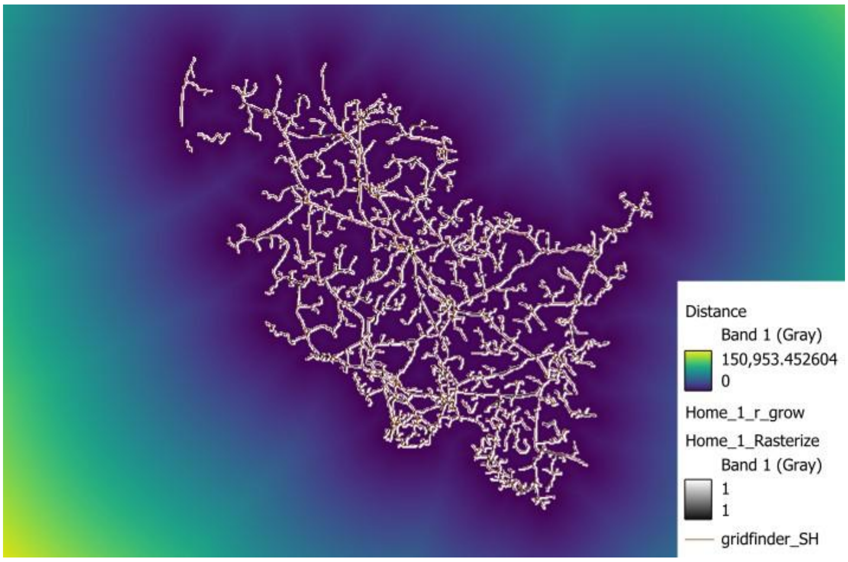



**Figure 7.1: Final raster output**

### Result:

The final raster output displays the computed distance from the electric grid in meters (See figure 7.1).

## Exercise 8: Make a simple noise map for a planned wind farm in priority area „PR1_NFL_036“

### Objective:

To create a simplified noise impact model for a planned wind farm in priority area "PR1_NFL_036" using hemi-spherical radiation. The analysis determines where the critical noise level of **45 dB(A)** is exceeded.

### Method:

The municipalities and wind priority area layers were imported, followed by selecting the ‘’PR1_NFL_036’’ priority area using the same method from Exercise 5.

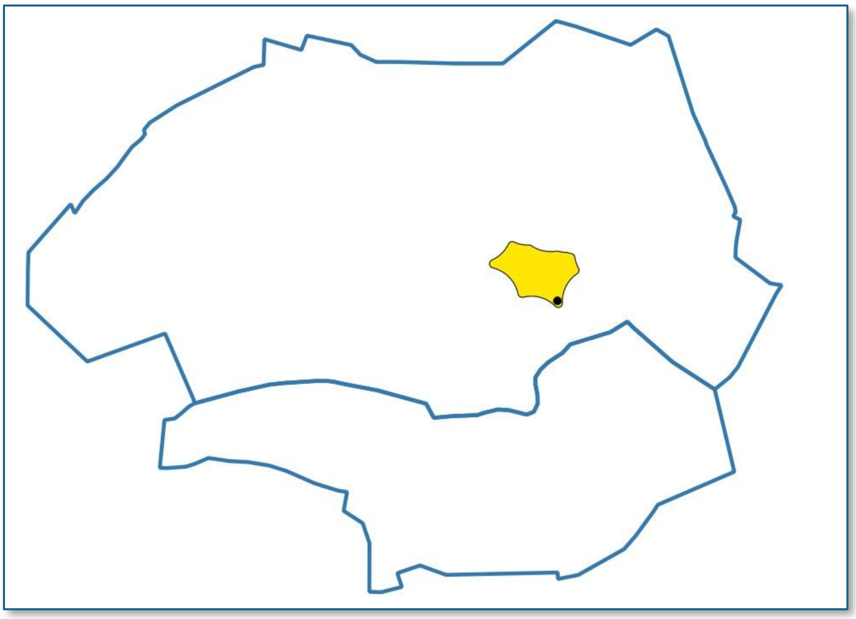


Figure 8.1: Priority area and selected wind turbine

Wind turbines were imported, and one turbine was selected (See Figure 8.1). Using the "Vector to Raster" tool and "r.grow.distance", the selected turbine was rasterized with a cell size of **1m**.

The noise level ($L_p$) was calculated using the formula:

$$L_p = L_w - 10 \cdot log_{10}(2\pi r^2) - a \cdot r$$

Where, Lw = **109 dB(A)** (source noise level), r = distance from turbine, a = atmospheric absorption (**0.005 dB/m**)

The "Raster Calculator" was used to apply this equation (See Figure 8.2), generating a noise propagation map. The results were visualized, with red areas indicating noise levels of **45 dB(A) or more**, marking the critical noise zone (See Figure 8.3).

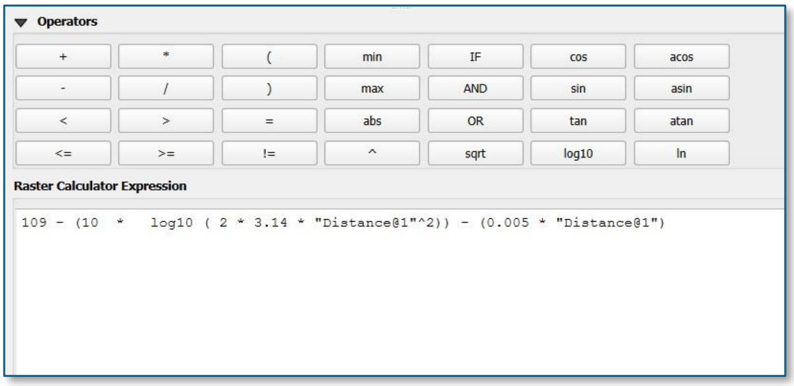



Figure 8.2: Noice level calculation by using raster calculator

## Result:

The final noise map identifies areas exceeding the **45 dB(A)** threshold, helping assess potential noise impact on surrounding regions.

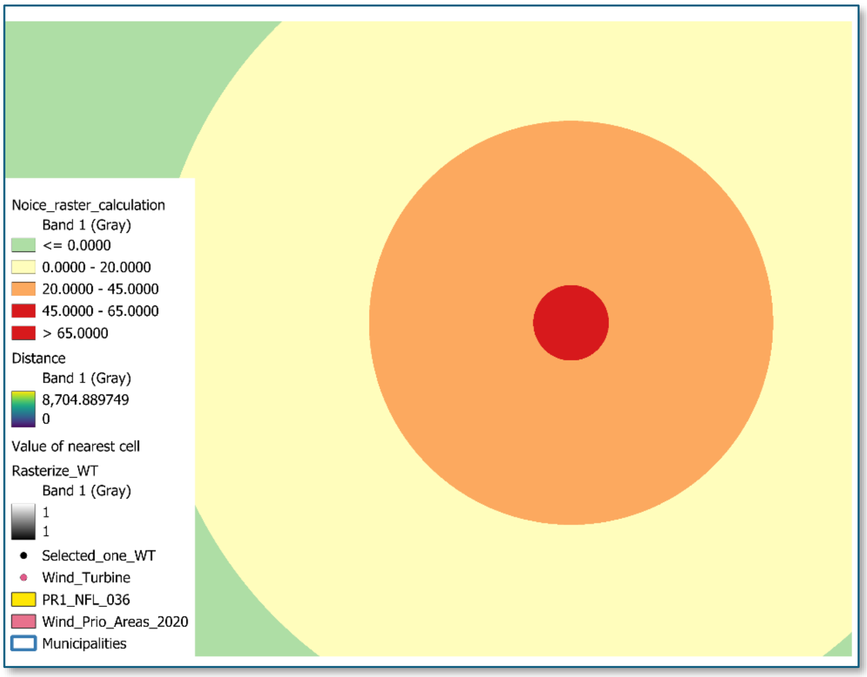



**Figure 8.3: Noice map output**

# Exercise 9: Offshore Wind Energy Planning in Sweden

## Objective:

To identify offshore areas in Sweden suitable for wind energy development by eliminating constrained regions and analysing wind power density and sea depth.

## Method:

A **500 m** buffer was created around power transmission lines, while additional buffers for shipping routes, recreational areas, protected nature sites, cultural heritage zones, and commercial fishing areas were already defined (See Figure 9.1). These six buffered layers were merged using the "Merge Vector Layers tool", forming a No-Go Area. To extract feasible regions, the "Difference tool" was applied, subtracting the No-Go Area from Swedish sea areas, generating a "White Map"—representing sea zones without constraints (See Figure 9.1).

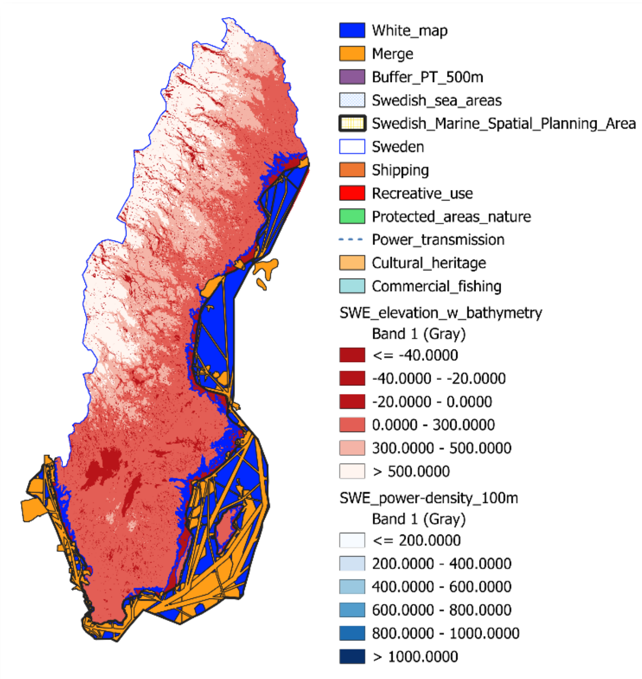



**Figure 9.1: All layes, No Go Area and White map**

To assess suitability for offshore wind energy, the “Clip Raster by Mask Layer tool” was used to overlay wind power density (see Figure 9.2) and sea depth (See Figure 9.3) onto the “White Map”. The resulting visualization highlights areas with high wind power density and optimal sea depth for offshore wind farms.

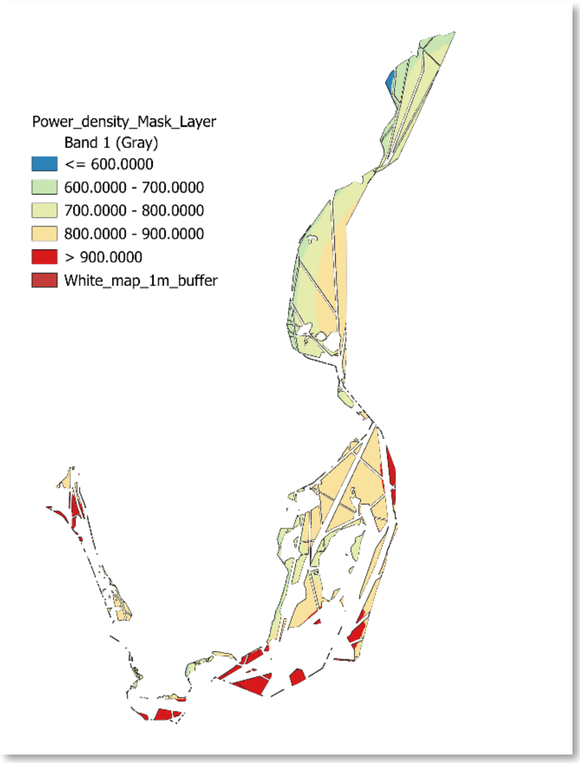



**Figure 9.2: Overlay wind power density**

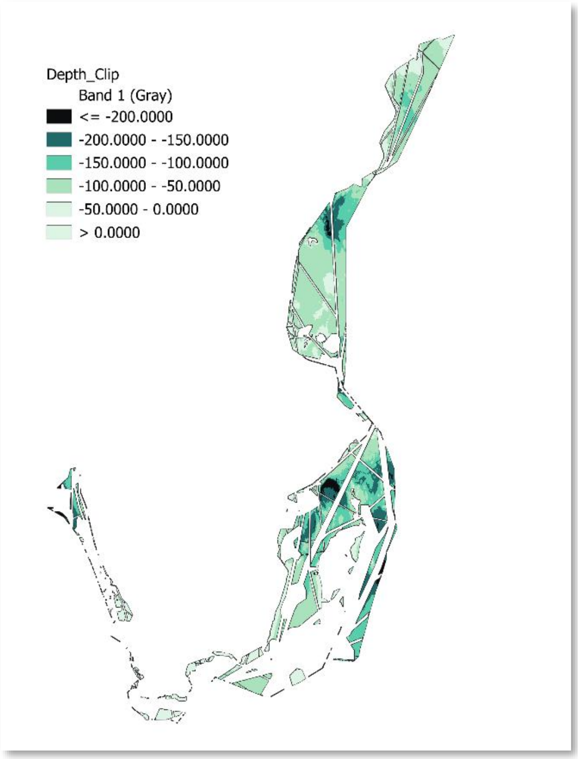



**Figure 9.3: Overlay sea depth**

## Result:

The final map identifies suitable offshore locations for wind energy development, considering areas with adequate sea depth and high wind power potential while avoiding restricted zones.

# Exercise 10: Calculate AEP Per Cell Offshore Wind Energy Planning in Sweden (Not Compulsory)

## Method:

In this exercise, the wind power density (See Figure 9.2) and sea depth (See Figure 9.3) were overlaid onto the White Map to identify suitable areas for offshore wind energy. The combined raster was then converted to a **1 km** cell size by “right-clicking” the layer, selecting "Save As", and setting the resolution to **1000 m**. After resampling, the “Raster Calculator” was used to compute the Annual Energy Production (AEP) [MWh/a] per cell using the formula (See figure 10.1):

$$AEP\ [MWh/a] = \frac{Power\ density\ [per\ cell\ size] \cdot 8760 \cdot \left(\frac{\pi}{4}\right) \cdot D^2 \cdot C_p}{1000000}$$

where **Cp = 0.4** and **Rotor Diameter = 178 m**. This resulted in a spatial distribution of energy potential across the study area (See figure 10.2).

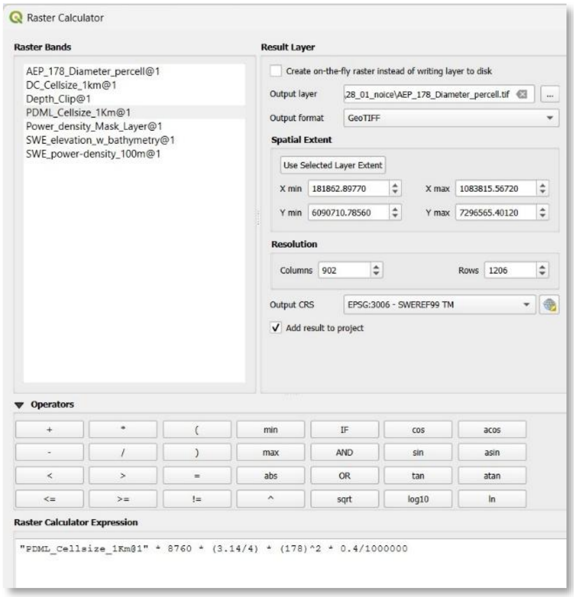



Figure 10.1: AEP calculation [MWh/a]

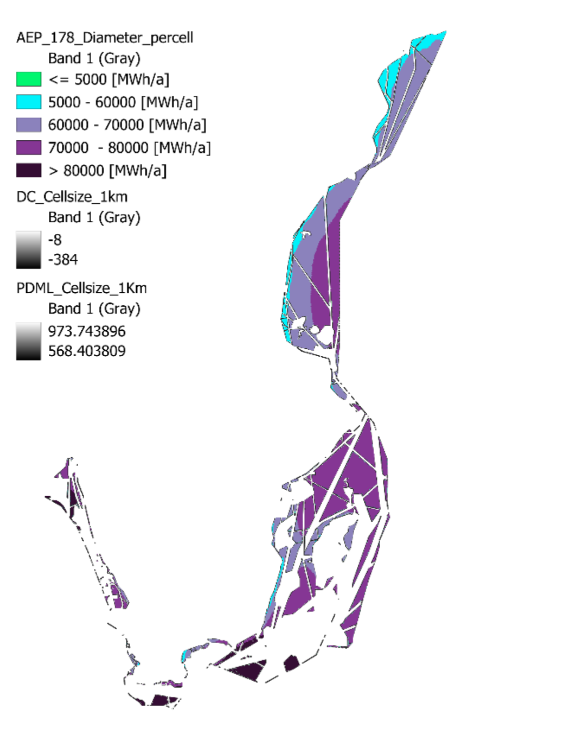



Figure 10.2: Spatial distribution of energy potential

# Exercise 11: Find good locations for wind turbine development in Sri Lanka.

## Objective:

The objective of this exercise was to identify suitable locations for wind turbine development in Sri Lanka based on multiple criteria, including wind resource availability, population density, proximity to infrastructure, land use suitability, and terrain characteristics.

## Methodology:

First, five key datasets were imported: Wind power density, Elevation, Population, Land use, and Grid connectivity. Each dataset was classified and reclassified based on suitability criteria.

For wind power density, classification was performed using “histograms” and “symbology”. The “Reclassify by Table tool” was used to assign values from **0 to 9**, where higher values represented better wind conditions.

Population density was reclassified inversely using the “Reclassify by Table tool”, assigning higher values to lower population densities to avoid noise and shadow effects.

Elevation followed a similar reclassification, where higher elevations received lower priority due to accessibility constraints.

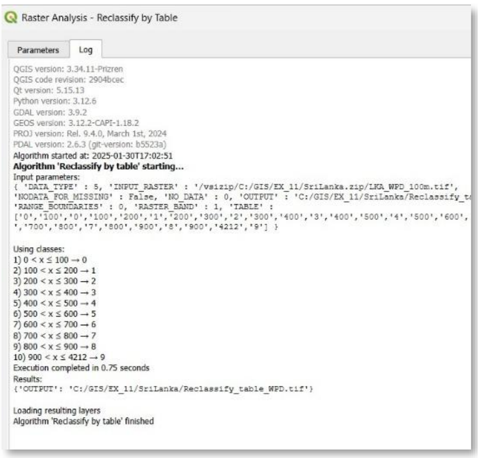



**Figure 11.1: Reclassify power density**

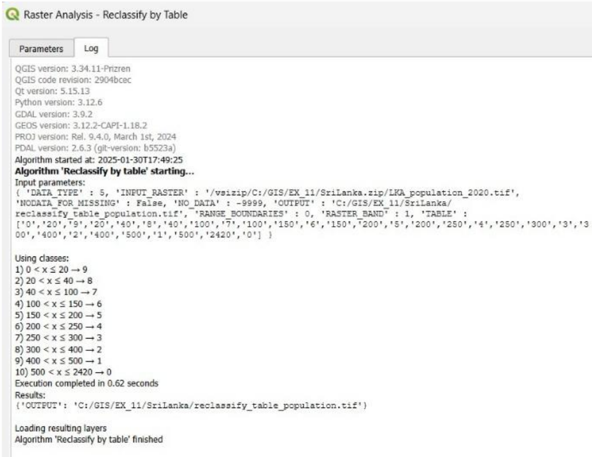



**Figure 11.2: Reclassify population**

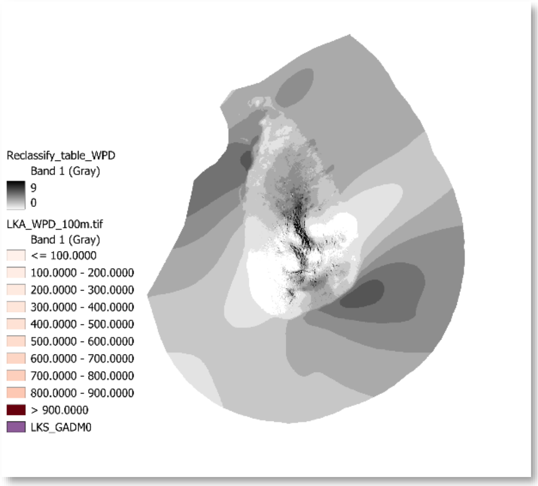



**Figure 11.3: Classification and reclassification of WPD**

Figures 11.1 and 11.2 illustrate the reclassification process using the reclassify by Table tool for Wind Power Density and Population, respectively. Figure 11.3 presents the classification and reclassification values for Wind Power Density, along with the corresponding map, highlighting areas with varying suitability levels for wind farm development.

For land use, a classification scheme was applied to determine areas most suitable for wind turbine development. The reclassify by Table tool was used to assign priority values based on land use type, following the table:

| Map code | Text | Reclassify |
|---|---|---|
| **20** | Shrubs | 9 |
| **30** | Herbaceous vegetation | 9 |
| **40** | Cropland | 8 |
| **50** | Urban / built up | 7 |
| **60** | Bare / sparse vegetation | 6 |
| **70** | Snow and Ice | 5 |
| **80** | Permanent water bodies | 4 |
| **90** | Herbaceous wetland | 3 |
| **100** | Moss and lichen | 2 |
| **110-130** | Various types of forest | 1 |
| **200** | Open sea | 0 |

Grid connectivity data was processed by selecting “Gridfinder” data using the Select by “Expression tool”. The data was then rasterized, and distance was calculated using the “r.grow.distance” tool (such as exercise 7). The “Reclassify by Table” tool was used to assign higher suitability to areas closer to the grid, with priority decreasing as distance increased. Figures 11.4 illustrates the reclassification process using the “Reclassify by Table tool” for grid. Figure 11.5 presents the classification and reclassification values for grid with map.

Finally, all reclassified datasets were combined using the “Raster Calculator”, applying weighted parameters based on their significance in determining site suitability. Wind power density was assigned the highest weight of **0.3** as it is the most critical factor for wind farm development. Elevation was given a weight of **0.25**, considering its influence on accessibility and construction feasibility. Land cover received a weight of **0.15**, accounting for terrain suitability. Population density was weighted at **0.2** to avoid areas with high human settlement, minimizing noise and shadow flicker issues. Lastly, proximity to the grid was assigned a weight of **0.1**, ensuring connectivity while prioritizing other critical factors (See Figure 11.6).

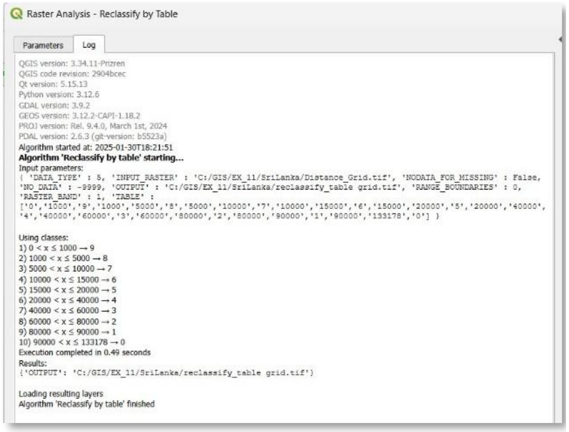



Figure 11.4: Reclassify distance of grid

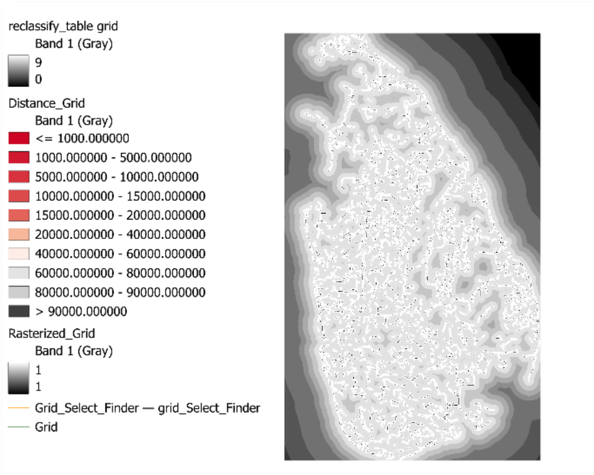



Figure 11.5: Classification and reclassification of grid

## Results:

The final suitability map (See Figure 11.7) identified optimal locations for wind turbine installation, highlighting areas with strong wind resources, low population density, suitable land use, and good infrastructure access. This analysis provides a data-driven approach for wind farm planning in Sri Lanka, ensuring energy potential is maximized while minimizing environmental and social conflicts.


Figure 11.6: Raster calculation

My GitHub homepage, I have attached more photos and process.

https://github.com/KSoni1505/Wind-Energy-Planning-and-Applied-Geoinformatics/settings

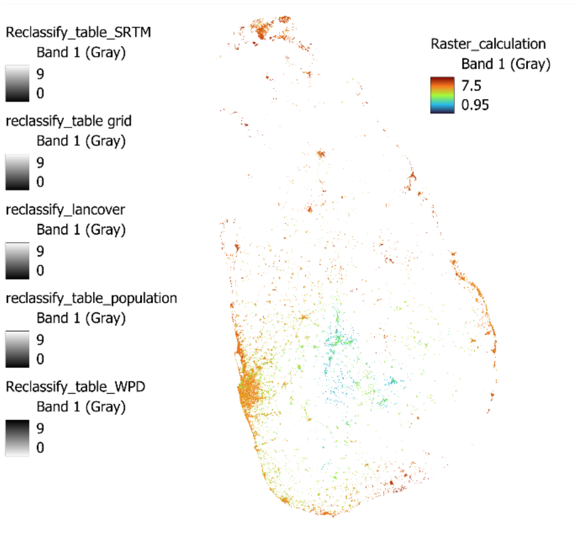



Figure 11.7: Final output