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REGARDING THE CHARACTERISTICS OF THE WIND IN NORTHERN REGION DISTRICTS OF THE REPUBLIC OF MOLDOVA

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Abstract. The study is focused on three districts in the northern region of the Republic of Moldova - Briceni, Edinet and Ocnita. The maps were calculated and presented in terms of average annual wind speed and wind power density at a height of 100 m above ground level, wind rose and Weibull wind speed distribution. In the calculations performed for the three analyzed districts it was found that the average annual wind speed is between 6.84 and 7.35 m / s, and the wind power density - between 450 and 593 W / m^2. The highest annual average speed equal to 7.35 m / s was identified in Ocnita district. At the same time, having the maps of the wind speed and the power density, the convenient locations for the construction of the wind farms can be selected. For each district involved in the study, a location with a pronounced wind potential was identified, recommended for the location of any wind farms.

Keywords: *wind speed; power density, wind atlas method, software package WAsP 9.1.*

Rezumat. Studiul se concentrează pe trei raioane din regiunea de nord a Republicii Moldova - Briceni, Edineț și Ocnița. Au fost calculate şi prezentate hărțile în ceea ce privește viteza medie anuală a vântului și densitatea puterii eoliene la înălțimea de 100 m deasupra nivelului solului, roza vântului și distribuția Weibull a vitezei vântului. În calculelor effectuate pentru cele trei raioane analizate s-a constatat că viteza medie anuală a vântului este cuprinsă între 6,84 și 7,35 m/s, iar densitatea de putere eoliенă - între 450 și 593 W/m^2. Cea mai mare viteză medie anuală egală cu 7,35 m/s a fost identificată în raionul Ocnița. Totodată, având hărțile vitezei vântului și a densității de putere, se pot selecta locațiile convenabile pentru construirea parcurilor eoliene. Pentru fiecare raion implicat în studiul respectiv au fost identificate câte un amplasament cu potențial eolian pronunțat, recomandat pentru amplasarea eventualelor parcuri eoliene.

Cuvinte cheie: *viteza vântului; densitatea de putere; metoda atlasului vântului; pachetul software WAsP 9.1.*

Introduction

The need for studies on wind characteristics and wind potential was highlighted when the drafting of the legal framework for the capitalization of Renewable Energy Sources (RES) started. The Law on renewable energy no. 160 of 12.07.2007 sets (for the fi rst time in our country's history) the objectives of the state policy in the fi eld of renewable energy, which were then updated in the Law on the promotion of renewable energy sources no. 10 of 26.02.2016. Law no. 10 creates the necessary framework for the application of Directive 2009/28/EC of the European Parliament and
of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources, establishes the mechanism to support investors that will promote the use of RES and which will come into force in March 25, 2018 [1]. The roadmap in the fi eld of RES capitalization - National Plan of Action in the Field of Energy from Renewable Sources (NPERS) adopted by Government Decision no. 1073 of 27 December 2013 highlights the activities and objectives needed to be achieved for the years 2013-2020. Thus, in the list of Support mechanisms for promoting energy from renewable sources - electricity, heating and cooling and energy from renewable sources in transport, paragraph 58 provides for the Development of a study on the wind and solar potential resulting in the expected Atlas of the wind potential and Atlas of the solar potential.

Having said that, this study is focused on three districts - Briceni, Edineț and Ocnița, the main cause being the interest of local investors in capitalizing on the wind potential to produce electricity. According to the National Agency for Energy Regulation (NAER) [2] in 2019, the wind capacity installed in the respective districts constituted 43.3% of the total wind capacity of the country. Furthermore, due to the cubic relationship between wind velocity and output energy, sites with small percentage differences in average wind speeds can have substantial differences in available energy. Therefore, accurate and thorough monitoring of wind resource at potential site is a critical factor in the siting of wind turbines.

Methodology

In 1987 the Department of Meteorology and Wind Energy at Riso National Laboratory in Denmark has implemented Wind Atlas Method (WAM) as a powerful tool for wind data analyzing, wind energy resources mapping, power production calculation of a wind turbine or a wind farm. Over the years, WAM has become a standard method for assessing wind resources and wind turbine siting and has been used in over 100 countries worldwide. The first work at global level dedicated to assessing wind energy potential, should be considered European Wind Atlas published in 1989 [3]. The value of this Wind Atlas is more precious by attaching a set of programs called Wind Atlas Analysis and Application Program (WAsP) [4, 6], which can be used to process wind raw data, drawing meteorological station wind atlas and wind power potential estimation of a certain site. In this work was used the Wind Atlas Method and licensed software package WAsP 9.1.

WAM offers the possibility to transform wind data recorded over the years, called historical data, to describe the wind characteristics at one point or in a region where no measurements were made [14]. The length of the radius of the point where wind data are available, either historic or recent, to the point where we can predict the wind should not exceed 100 km [10].

Wind data collected by weather stations (normally, at height of 10 m above the ground) or through special campaigns of measurements at heights greater than 10 m, are representative only for points where anemometer and vane are mounted for measuring wind speed and direction. These data are influenced by the site characteristic (orography, terrain roughness, obstacles) around the measurement tower and cannot be used directly to characterize the wind in an another location with different characteristics from those in which the measurement tower is mounted. In order to use data from one site to calculate speed and wind power density into another site, measured data are converted into so-called wind atlas data for the specific meteorological station [9].

WAM consists of two distinct procedures: first - to analyze wind in the measurement point and the second - the application of climatology data to obtain wind speed maps and wind power density, energy production etc. in a point (region) where no measurements were performed. To obtain Wind Atlas data on the surroundings measurement tower are carried out studies like identifying roughness class of the terrain, obstacles (buildings, forests protective stripes etc.) existing at a distance not exceeding 50 heights of that obstacle and it porosity [12, 13].

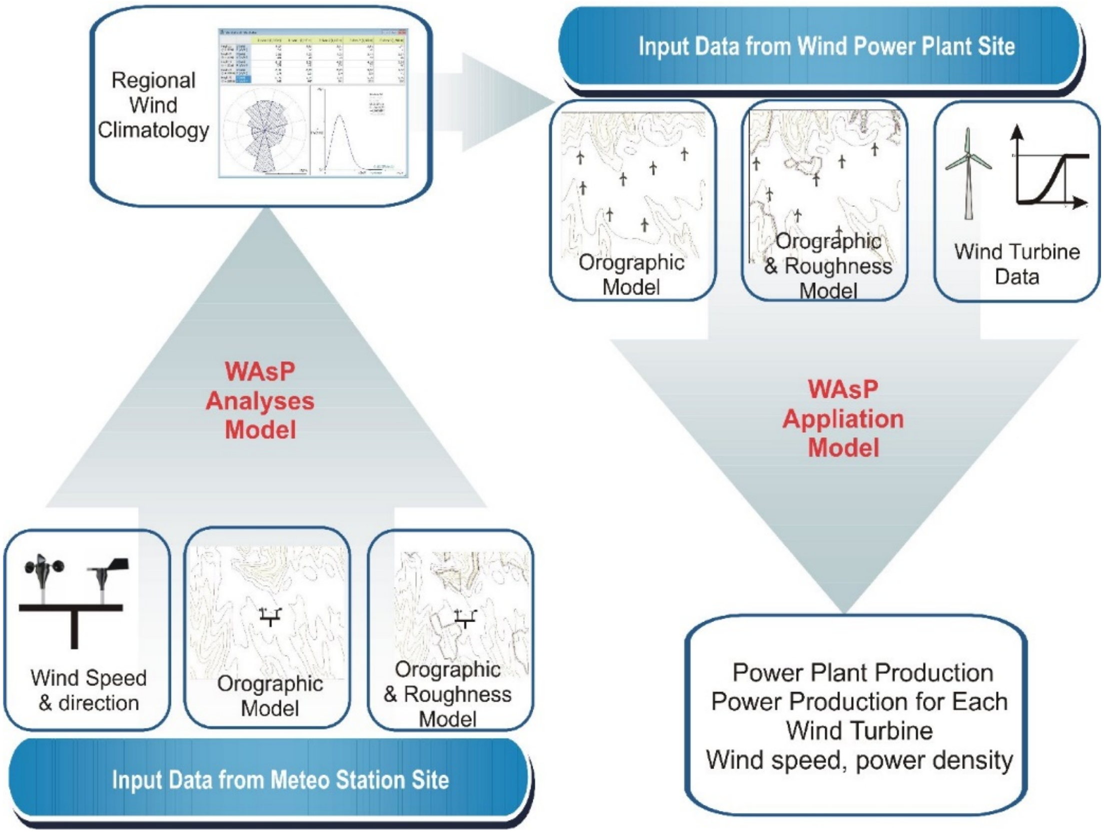

Figure 1. Wind Atlas methodology, done by authors.

Applying the analysis procedure of WAM, Figure 1 left, obtained wind atlas data, would have been recorded if the terrain roughness had been equal to 0 (water surface) and around measurement tower obstacles wouldn't exist. Wind atlas data are recalculated for 5 roughness classes, characterized by respective equivalent heights equal to 0,0; 0,03; 0,1; 0,4 and 1,5 m and 5 heights above the ground: 10, 25, 50, 100 and 200 m. With wind atlas data as input data, the reverse procedure is carried out, Figure 1 on the right, to yield the regional climatology of the wind in the region of interest.

At the applying phase of WAM, Figure 1 right, as the object of study can be: a wind turbine shown by the coordinates of the mounting point, a wind farm shown by the coordinates of all turbines or a rectangular region with specified borders. As an input data are:

- Observed Wind Climate (OWC) at Balti meteorological station. OWC for all Moldova's 14 meteorological station are presented in [5];
- Terrain orography and roughness, obstacles in the immediate vicinity of the points of location of turbines;
- Turbine wind power characteristic P(u) and the height of rotation turbine axis [17, 18].

Depending on what we need: regional wind climatology of interest region at the specified height above the ground, wind energy resources maps in terms of mean wind speed and wind power density at the specified height above ground and average annual electricity production will be obtained. For each wind turbine: gross and net annual energy production, average speed at shaft rotation height, wind power density, energy losses due to the effects of turbulence caused by other turbine (wake losses) will be obtained.

Results

Wind maps. For three districts from north Moldova's region were calculated wind maps in terms of wind speed and wind power density. The results are presented in Figures 2 - 7.

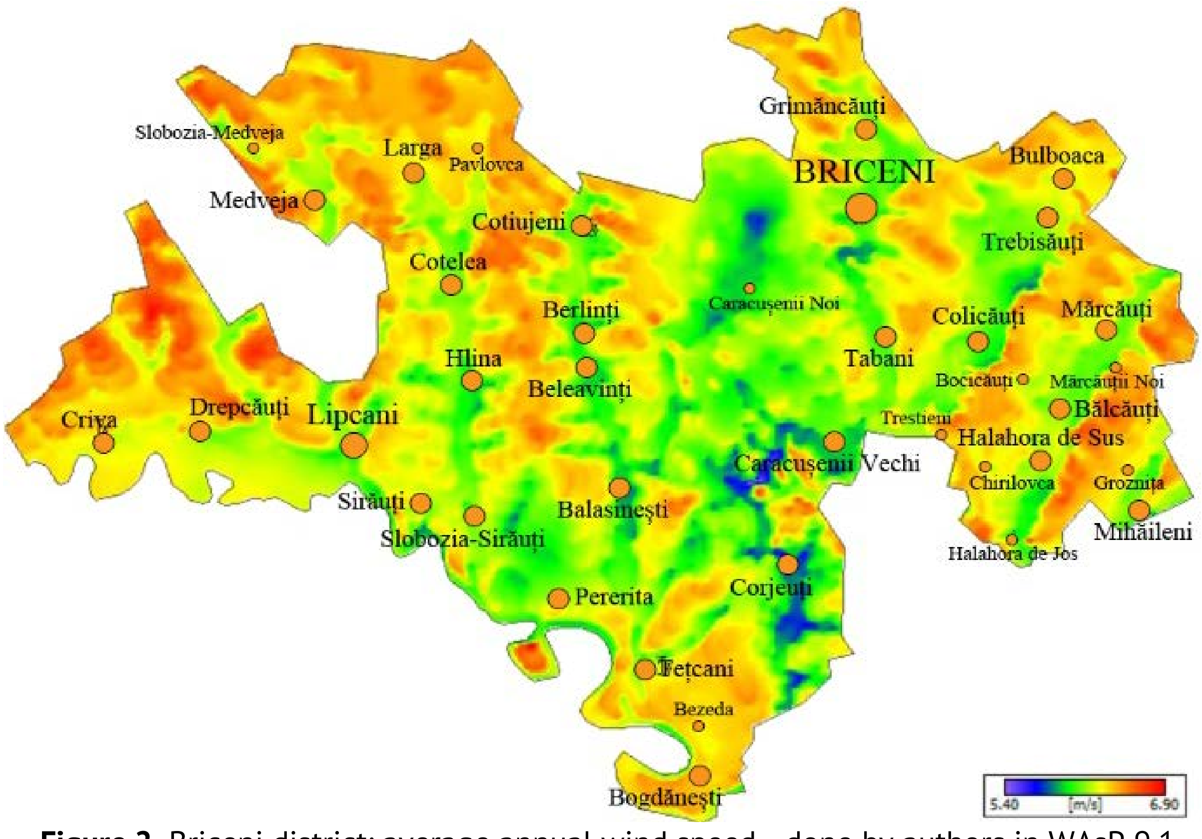

Figure 2. Briceni district: average annual wind speed - done by authors in WAsP 9.1 licensed software.

Having the maps of the wind speed and power density, we can do the next step: select a location for the construction of wind farms. For example, for the Briceni district, it was selected the hill located in southeast of the village of Balcauti. The advantage of this hill is the possibility of placing the wind turbines in a row perpendicular to the predominant wind direction.

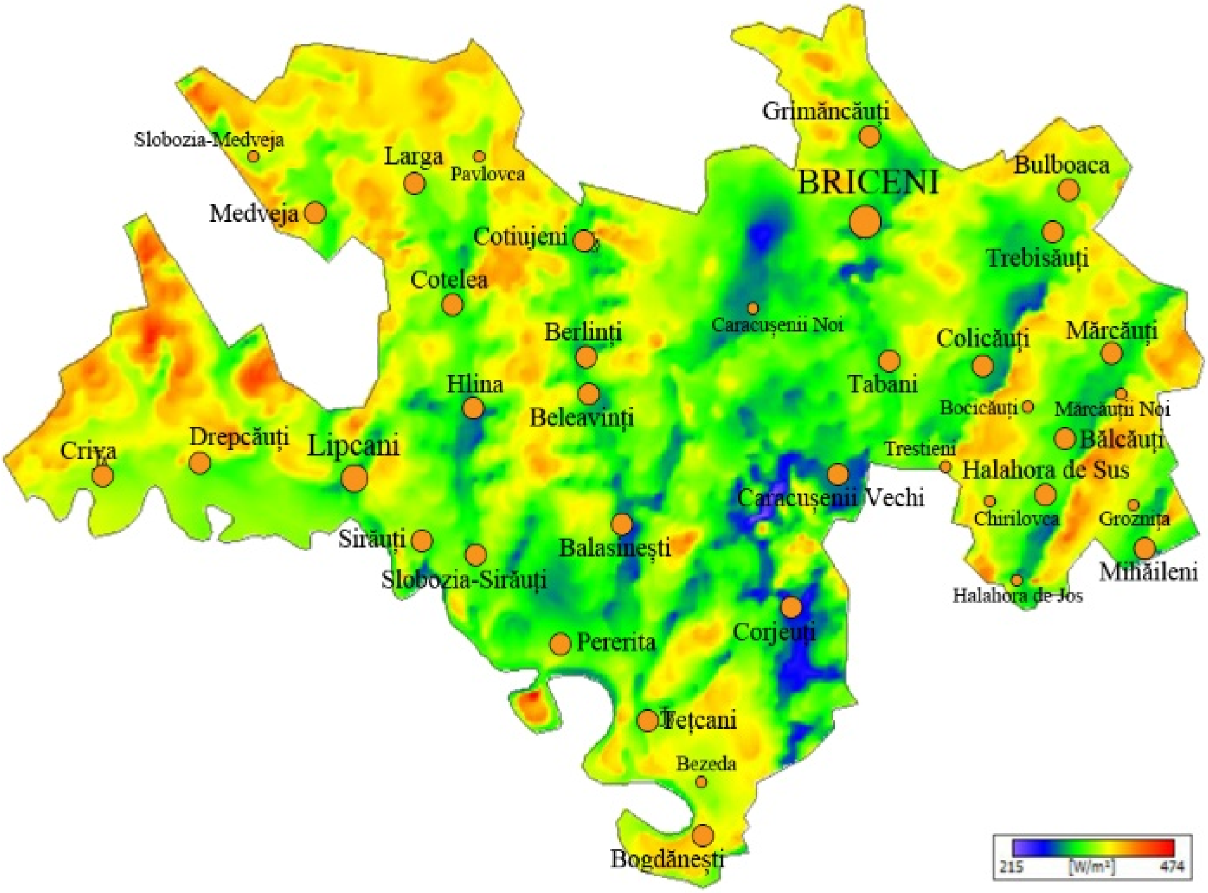

Figure 3. Briceni district: average annual wind power density - done by authors in WAsP 9.1 licensed software.

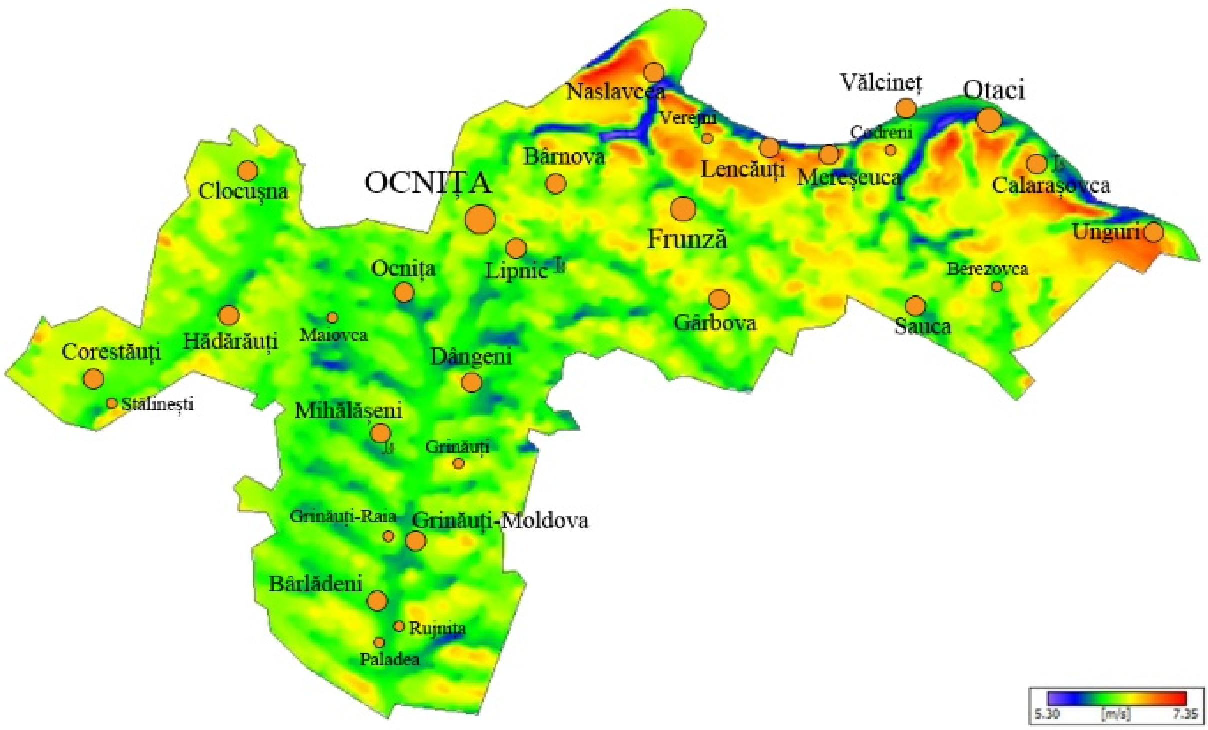

Figure 4. Ocniţa district: average annual wind speed - done by authors in WAsP 9.1 licensed software.

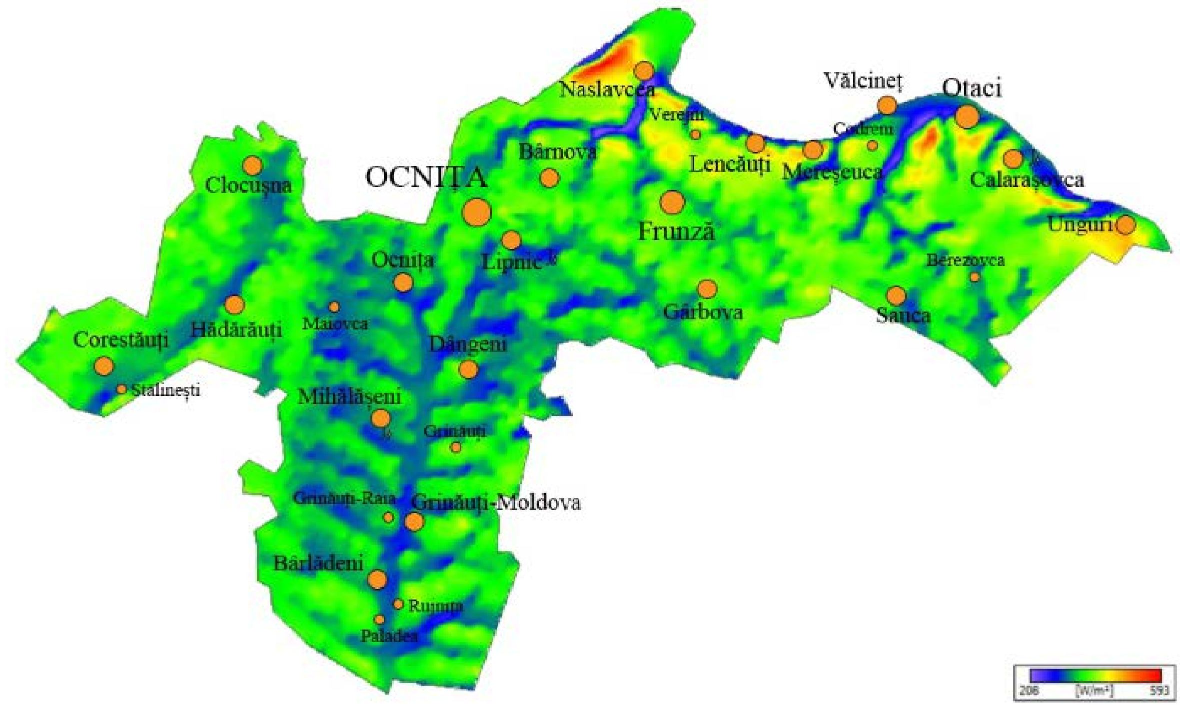

Figure 5. Ocnița district: average annual wind power density - done by authors in WAsP 9.1 licensed software.

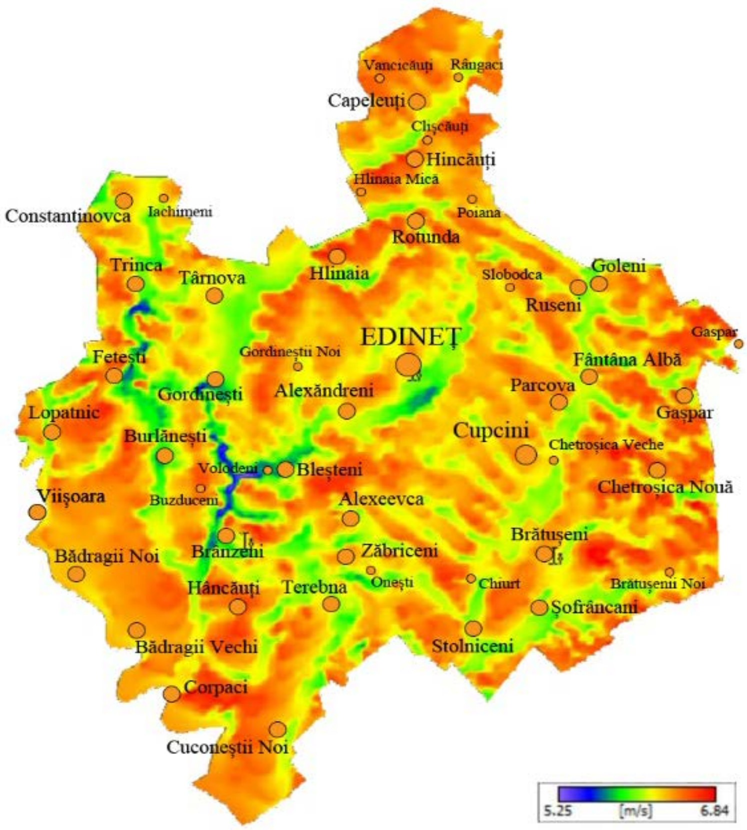

Figure 6. Edinet district: average annual wind speed - done by authors in WAsP 9.1 licensed software.

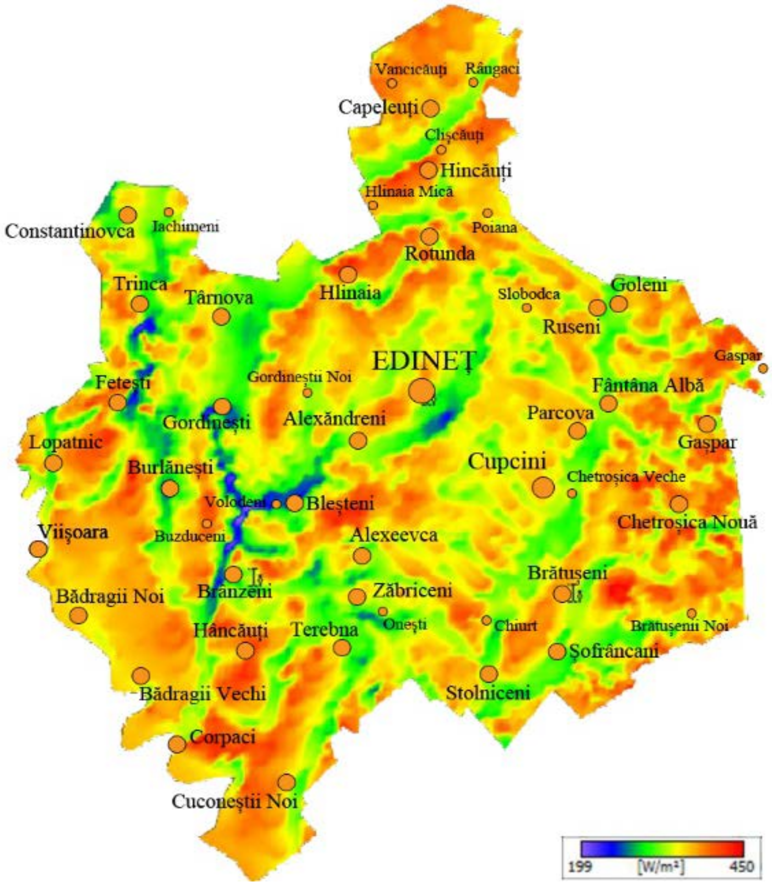

Figure 7. Edinet district: average annual wind power density - done by authors in WAsP 9.1 licensed software.

Applying the WAM, we also obtained wind rose & wind speed Weibull distribution, with the following results Figure 8:

1. Wind direction (wind rose) for 12 sectors.
2. Wind speed frequency distribution.
3. Weibull approximation of wind speed frequency distribution histogram.
4. The average wind speed in m/s and power density in W/m2.
5. Weibull approximation coefficients A and k.

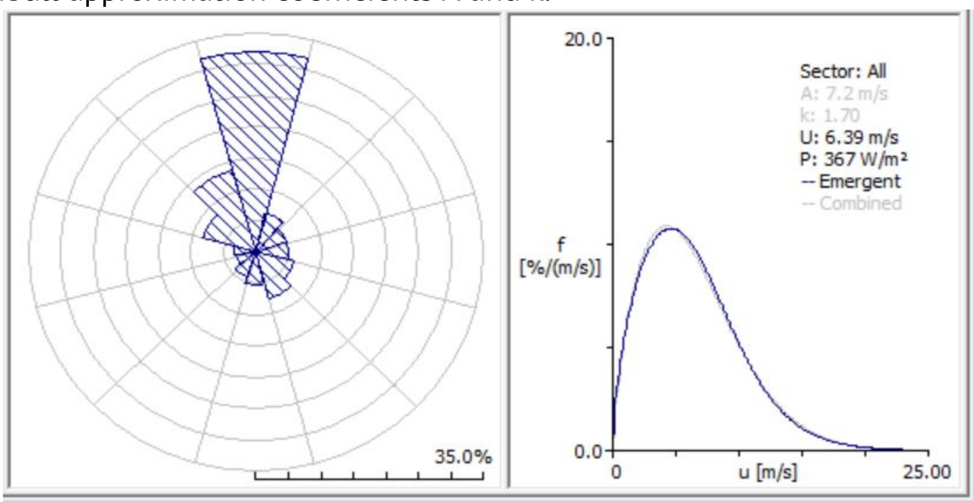

Figure 8a. Wind rose & wind speed Weibull distribution: Briceni district - done by authors in WAsP 9.1 licensed software.

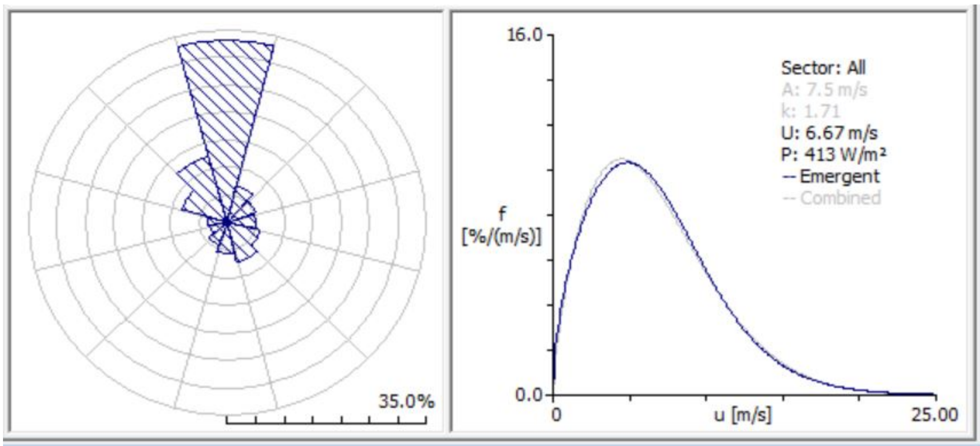

Figure 8b. Wind rose & wind speed Weibull distribution: Ocnița district - done by authors in WAsP 9.1 licensed software.

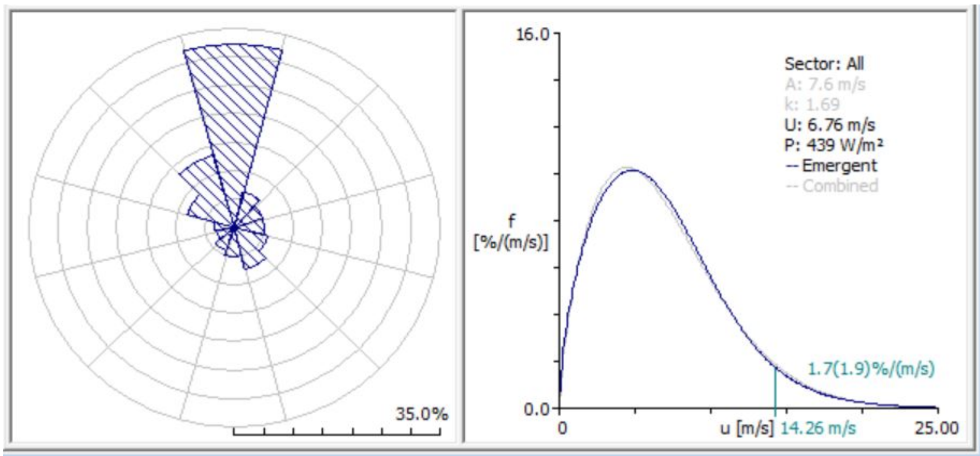

Figure 8c. Wind rose & wind speed Weibull distribution: Edinet district - done by authors in WAsP 9.1 licensed software.

For the analyzed districts, we have used historical wind data for a 10 years period from Balti weather station. The Balti weather station is situated near the Balti airport and is located about 2 km from the river Raut on its left bank, where the terrain is a relatively smooth meadow. To the south and southeast of the station, at distance of 4 - 10 km, the landscape is hilly, interspersed with valleys and ravines. The heights of the hills are 150 - 200 m. The width of the river valley in the station region varies between 4 - 5 km, and the river ranges from 3.5 to 5.5 m. Meteorological platform is on smooth area, covered with cover grassy and at about 70 m around it are located houses with solitary trees height of 4 - 5 m. At about 500 m in direction north is the route Balti - Floresti and the railway line. In the east of the station, about 100 m, extends the airport area and it is an open smooth field.

As a result of the calculations based on the obtained maps we performed the classification of the territory of each of the three districts according to the value of the power density and we determined the following:

- 48,62 % of the Briceni district surface has a power density between 350 - 400 W/m^2;
- 48,93 % of the Ocnita district surface has a power density between 350 - 400 W/m^2;
- 48,74 % of the Edinet district surface has a power density between 350 - 400 W/m^2.

According to the European Wind Atlas [3] and other publication, the areas, which has a power density, between 350 - 400 W/m^2, it is recommended to be used for possible wind farms.

Conclusions

1. In the three analyzed districts the average annual wind speed calculated at a height of 100 m above ground level is between 6,84 and 7,35 m/s and the wind power density - between 450 and 593 W/m^2. The highest average annual wind speed has been found in Ocnita district and is equal to 7,35 m/s.
2. For the development of wind farms, we recommend following sites:
   - Briceni district - the hill located southeast of the line connecting the villages of Halahora de Sus-Balcauți-Marcauți (See Figure 2);
   - Ocnița district - locations settled in the northeast at a distance of 5 - 8 km from the Dniester River (See figure 4);
   - Edinet district - in the northern and western areas, along the Prut river (See figure 6).
3. For all 3 districts about 48 % of the territory have a power density greater then 350 W/m^2, territory what can be used for possible wind farms.

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