IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 10, Issue 11, November 2020, ||Series -I|| PP 13-25

Application Of Wasp Model In Studying Wind-Power Potential In Tay Nguyen

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Received 20 October 2020; Accepted 04 November 2020

Abstract:
Tay Nguyen is one of the most well-potential windpower regions in Vietnam, wind energy utilization in this area however has been not deserved it potential due to lack of reliable assessments of wind-power. distribution of wind energy potential in the region.
The article presents the results using WAsP model (Wind Atlas Analysis and Application Program) in developing the distribution map of high wind speed elevation from 60m to 100m for the Tay Nguyen under the framework of the topic: “Research to establish a scientific foundation for rational exploitation and use of energy resources in the West Nguyen (Tay Nguyen program III) ”. Wind maps which have established the theoretical and technical wind potentials for the Tay Nguyen region will be used as scientific fundamental, suggesting rational and efficient solutions for exploitation of wind-power sources, contributing for locally socio-economic development.
Keywords: WAPs, theorical potential, technical potential, roughness, output

I. INTRODUCTION

The Central Highlands is a region rich in renewable energy potentials, in which solar energy and solar energy are outstanding. Up to now, there have been many studies, assessments and calculations on the energy energy potential in Vietnam in general and the Central Highlands in particular. The results from these studies are calculated mainly based on observed meteorological data collected from 17 wind measuring columns at the height of 10-12 m built in the Central Highlands provinces. In 2001, the World Bank (WB) also implemented a project to develop NLG maps for Southeast Asia, including wind Atlas maps for the Central Highlands. However, this map only shows the general potential of the natural energy of the Central Highlands without considering and taking into account the factors of topography and soil to identify specific areas where it is possible to build solar power plants.

WAsP is a computer program used for extrapolating wind climates characters. The WAsP consists of several models to describe the flow of wind through different terrain and close proximity to obstacles. The WAsP’s approach is simulated in Figure 1. Accordingly, wind data measured at nominated site is extrapolated to a regional representative wind data by omitting impacts including surface roughness, obscurity caused by objects such as buildings, and topographical effects. This regional wind data is used to compute wind data at another point using this procedure but in the opposite direction, i.e. taking into account the effects of the new site's topography over the regional wind parameters according to the altitude. By this method, wind atlas based on observed data were constructed. Normally, in uncomplicated terrain, data of a single wind monitoring station can be extrapolated to produce wind atlas for an area with a radius of approx. 20km.

The paper will present the results using WAsP model (Wind Atlas Analysis and Application Program) in developing the distribution map of high wind speed elevation from 60m to 100m for the Tay Nguyen. Wind maps which have established the theoretical and technical wind potentials for the Tay Nguyen region will be used as scientific fundamental, suggesting rational and efficient solutions for exploitation of wind-power sources, contributing for locally socio-economic development.

II. MATHEMATICAL MODELS

1.1. Modeling in WAsP

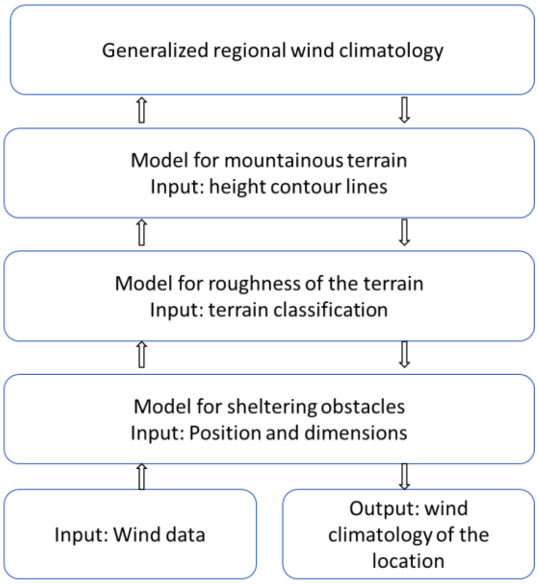


Figure 1: Approach of the WAsP model

Models of WAsP include: Roughness model, wind flow model, obstacle model and Windfarm model.
In general, accurate predictions using the WAsP program can be achieved by available data as below:
- The reference site (meteorological station) and the predicted location (wind turbine location) must be in the same climate zone.
- The common weather conditions are close to neutral steady state.
- Measured wind data is reliable
- The terrain in the calculation area is considerably smooth and does not cause flow separation.
- The input data is sufficient and reliable.

a) Wind data analysis:

Time series of wind data can be obtained from wind gauges, meteorological stations or other sources, but they shall satisfy the following conditions:
- Survey period is sufficient. At least a year, or several years if possible.
- The anemometer location should be located away from buildings and other obstacles.

Accurately describe the wind measurement conditions and the data should be measured every 10 minutes or every hour over the whole day.
Using raw data as a preliminary data source is good because it allows the user to detect errors in the data. The raw data needs to be processed by the OWC Wizard tool to obtain a usable statistical summary in the WAsP.
The WAsP models and the wind atlas methodology are described in detail in the European Wind Atlas. Figure 2 depicts the wind atlas methodology mechanism of WAsP.
In the analysis (upward arrow), meteorological models were used to calculate the wind climate from observed wind data or raw data.
In the opposite process - the application of the wind atlas data (downward arrow), the wind climate in any given location can be calculated from the regional wind climate.
In general, correct predictions using the WAsP program can be achieved by providing: The reference site (meteorological station) and the predicted site (wind turbine location or meteorological station) are said to be the same weather mechanism.
- The main weather conditions are close to neutral steady state.
- The referenced wind data is reliable.
- The surrounding terrain on both sides is smooth and does not cause flow separation and the input terrain model is sufficient and reliable.

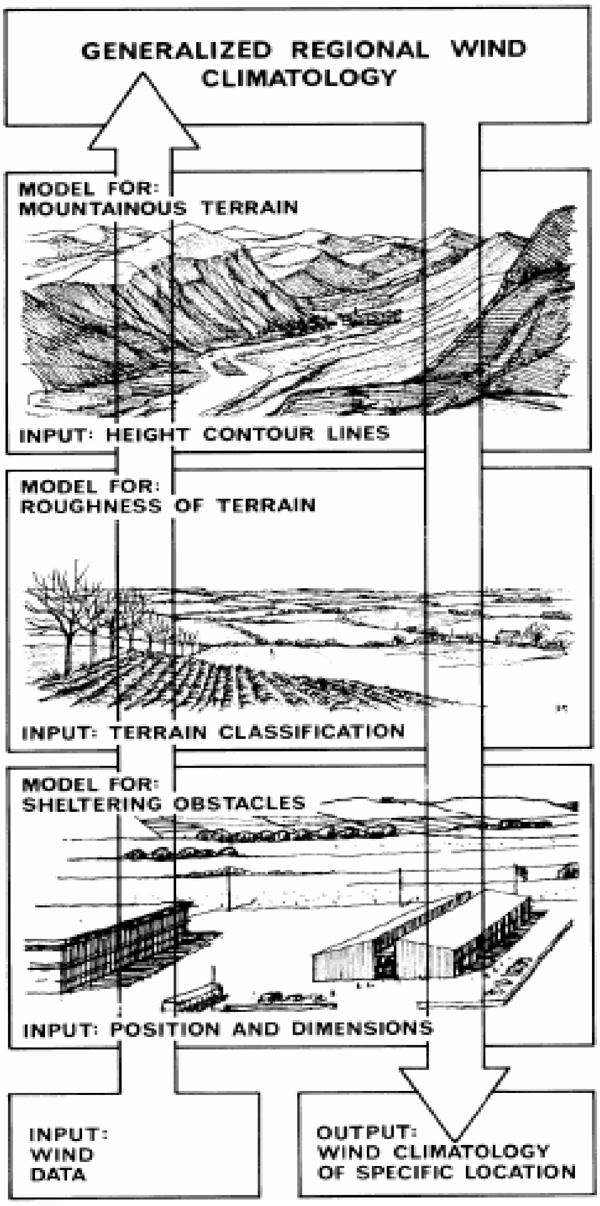


Figure 2: Wind atlas methodology of WAsP

1.2. Roughness model:

The roughness of a particular surface is determined by the size and distribution of the roughness it contains; in which land surfaces are usually vegetation, residential areas and land surfaces. In the European Wind Atlas the different terrains have been divided into four categories, each characterized by its roughness factors. Each type of terrain can be considered as a roughness layer. A description and illustration of these four roughness classes are given in the figures below showing the relationship between roughness length and roughness class.

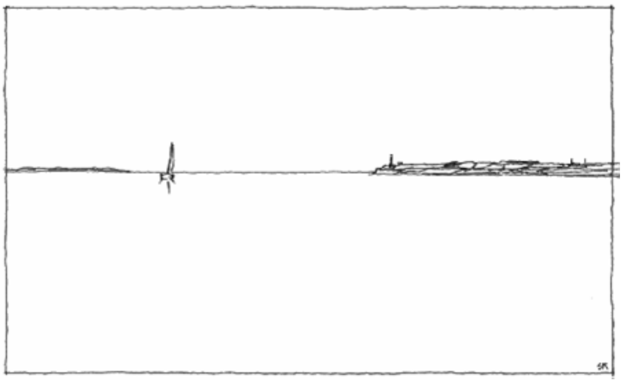


Figure 3. Examples of terrain equivalent to roughness class 0 are water surfaces. This class includes seas, bays, and lakes. The rough length $z_o = 0$ m

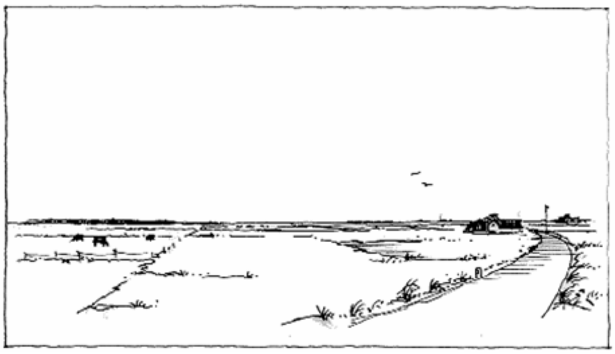


Figure 4. The terrain is equivalent to a roughness class 1, the areas are pretty flat, not causing wind flow separate. They are usually farms with small bushes. The length of roughness $z_o = 0.03$ m

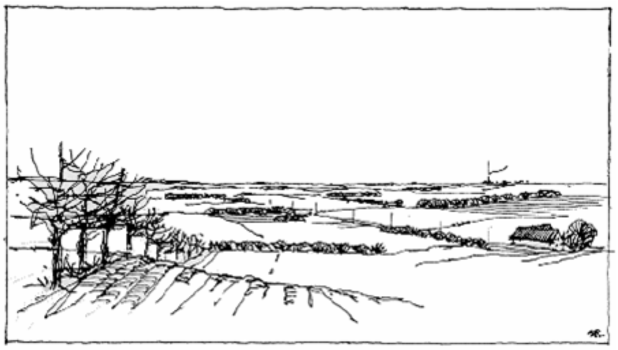


Figure 5. An example of a topography equivalent to roughness class 2: farmland, with a split in the wind flow from sparsely populated areas. The terrain can be either flat or undulating. There are many trees and houses. The rough length $z_o = 0.1$.

Figure 6. The terrain as the roughness class of 3: urban areas, forests, farmland with many separate wind flows. The length of roughness $z_0 = 0.40$ m.

The roughness of the topography is often characterized by the rough length, $z_{o.}$. The $z_{o.}$ usually is the altitude where the wind speed drops to 0, if the wind profile has a logarithmic change with elevation. This usually occurs in conditions of high or moderate wind speed.
The following table shows the relationship between roughness length, topographic surface characteristics and roughness class used in the European Wind Atlas. This table can serve as a guide for determining the roughness length values.

z_O (m)	Terrain specifications	Roughness layer
1,00	Urban	
0,80	Forest	
0,50	Suburb	
0,40		3 (0,4 m)
0,30	The tabernacle strips	
0,20	Many trees or shrubs	
0,10	Closed farm land	2 (0,1 m)
0,05	Opened farm land	
0,03	Farm land with very few houses and trees	1 (0,03 m)
0,02	Airport area with houses and trees	
0,01	The momentum zone for the aircraft	
0,008	Grass clippings	
0,005	Bare soil (smooth)	
0,001	Snow surface (smooth)	
0,0003	Sand	
0,0002		0 (0,002 m)
0,0001	Surface water	

The roughness length applied in WAsP must be considered as a climatic parameter in general because the roughness of an area varies with vegetation, snow cover, etc. The amount of a wind farm must be determined on the fundamental of climate, mainly due to weather changes. However, seasonal variation of topographic features also has a significant impact.
There are two different ways to describe the roughness of the terrain around a location.
- In the form of a digitized map of lines various roughness, for example lines dividing areas of equal roughness. The roughness map depicts the distribution of areas of equivalent roughness from which the WAsP can understand the roughness conditions at any point within the map.
- In the form of a specific roughness description at a site called roughness rose. In this case the roughness conditions at one site are described as bands when viewed from that position.
In the first case, the WAsP calculates its own roughness wind rose from the roughness map, while in the second case the WAsP will use the user-defined wind rose directly.

1.3. Wind flow model
WAsP utilizes Troen's (1990) BZ model to compute wind speed disturbances caused by topographic features such as single hills or more complex terrain. The BZ model belongs to a group of models related to Jackson and Hunt's theory of wind flow through hills. The model was developed with the specific purpose of determining wind energy and has the following overarching features:
- The model uses a high-resolution grid system, combined with map analysis to calculate various profiles of the potential wind flow at the model's center.
- The model merges roughness conditions of the topographic surface into the oscillation spectrum. The inner layer is calculated using an equilibrium condition between the surface pressure, the stratosphere flow and the pressure gradient.
It uses an atmospheric boundary layer thickness of approximately 1km to form a larger computational area (eg, a few kilometers) around high altitude areas.
The BZ traffic model can read digitized maps with approximately over 1,000,000 points. If the map contains much more point, number of points should be reduced.
In general, correct predictions using the WAsP BZ model can be achieved by providing:
- The reference location (meteorological station) and the predicted location (the position of the wind turbines on the anemometer) must be in the same climate area.
- The common weather conditions are close to neutral steady state.

- The terrain in the calculation area is relatively slippery and does not cause traffic separation. The final requirement has a relatively significant influence on the accuracy of WAsP's predictions in complex terrain.

1.4. Obstructive model

Obstruction is one component that causes the decrease in wind speed. An obstacle creates an obstruction at a specified location for the wind flow depends on the following factors:
- The distance from the obstacle to the point under consideration (x)
- The height of the obstacle (h)
- The height of the point of interest in the position under consideration (H)
- The length of the obstacle (L)
- The porosity of the obstacle.

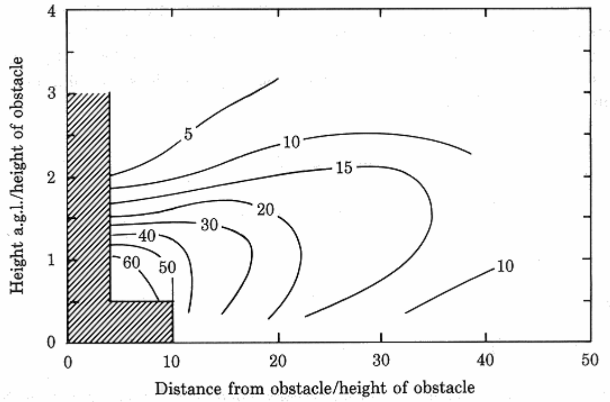


Figure 6. The decrease in wind speed due to obstruction from an obstacle with zero porosity

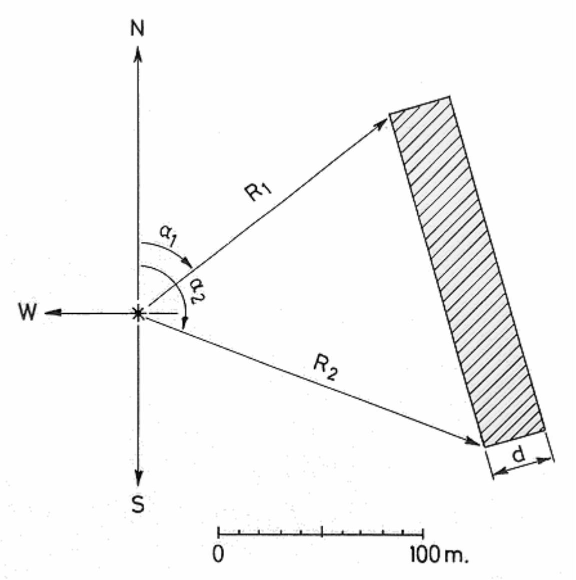
Obstruction will decrease as the length of the obstacle decreases and the porosity increases. In the affected area, obstructions highly depend on the detailed geometry of the obstacle. In addition, the wind speed is often increased near and above obstacles - similar to the acceleration effect of wind currents when blowing over hills.

Outer surface of obstructions	Porosity P
Solid (wall)	0
Very dense	< 0,35
Dense	0,35 - 0,50
Opened	> 0,50

As normal regulations, porosity can be set to zero for buildings and 0.5 for trees. A row of buildings with a distance between them equal to 1/3 of the length of a house will have a porosity of 0.33. For wind obstructions, the characteristics listed in the table below may apply.

Wind turbines in a wind farm can also interfere with each other, causing a decrease in overall energy production. Absolute obstacle modeling should not be used to model the effects between turbines or on wind farms.

In the WAsP, obstacles are referred to as cubic blocks with rectangular cross-sections. Each obstacle must be determined by its relative position to the calculated position, its size and the porosity are also assigned. The figure below shows the dimensions to be defined and to be imported into WAsP.



Where:

α_1	The angle is created by the North vector and of the first angle point of the obstruction [º]
R_1	Distance from the center to the first angle point[m]
α_2	The angle created by the North vector and the second angle point [º]
R_2	Distance from center to second angle point [m]
h	Obstacle height [m]
d	Obstacle thickness [m]
P	Estimated porosity
	The angles are measured from 0^o (north) to 360^o clockwise

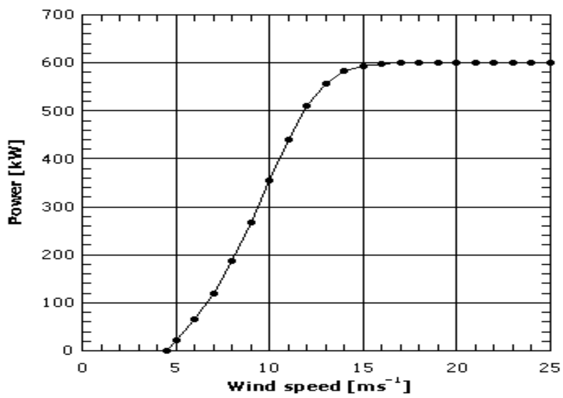
The WAsP obstacle model can handle up to 50 obstacles at the same time, a maximum number of 50 obstacles can be identified in an obstacle list.

1.5. Prediction of energy output

In order to calculate the energy production of a wind turbine or wind farm, it is neccesary wind climate at a a predicted location and turbine characteristics as follows:

- Wind turbine hub height (m)
- Power curve (m / s and kW)
- Thrust coefficient curve

Power curve: The energy production by a wind turbine varies with the speed of the wind reaching the turbine. Usually, the wind speed at turbine hub height is often used to construct a relationship between the wind speed and the corresponding generated power. The power produced as a function of the wind speed at the hub height is simply referred to as the power curve. The figure below shows an example of the power curve:



As the wind speed is less than lower limited wind speed, the turbine will not be able to generate while the wind speed exceeds the lower limited wind speed, the output power P(u) will increase following the wind speed. upto a maximum value is called rated power. The output power is almost constant afterwards. At the wind speed which is higher than the upper shear wind speed, the turbine will be stopped to avoid failure and destruction.

Predicting average capacity:

As a turbine power curve is available, the mean power production can be predicted by providing a probability density function of wind speed at hub height:

$$P = \int_0^\infty \Pr(u) P(u) du \tag{1}$$

If the probability density function has been specified, this function is usually given as a Weibull function. In this case, the average power function produced as:

$$P = \int_0^\infty \left(\frac{k}{A}\right)\left(\frac{u}{A}\right)^{k-1} \exp\left(-\left(\frac{u}{A}\right)^k\right) P(u) du \tag{2}$$

As a normal regulation, this merger cannot be calculated in detail and arithmetic methods need to be used.

The actual power curve is quite smooth and can be approximated by a linear function with a number of points.

$$P(u) = \frac{P_{i+1} - P_i}{u_{i+1} - u_i}(u - u_i) + P_i \tag{3}$$

This function allows an analytical solution of Eq (Petersen, 1981) as follows:

$$P = \sum_i \frac{P_{i+1} - P_i}{\alpha_{i+1} - \alpha_i}\left(G_k(\alpha_{i+1}) - G_k(\alpha_i)\right) \tag{4}$$

In which $\alpha_i = u_i/A$. In some cases, an interruption can be seen in the power curve. In the case of a power increase from P_i to P_{i+1} at $u_i = u_{i+1}$, the sum of this interval as belows:

$$\left(P_{i+1} - P_i\right) \exp\left(-\alpha_i^k\right) \tag{5}$$

By using formulas of (4) and (5), the mean power can be theoretically calculated for any power curve by dividing it into a reasonable number of linear parts. In practice, the method will only be useful if the power curve can be approximated by a number of linear segments.

The power curve for any given turbine is dependent on the air density, which varies with the air temperature and pressure (altitude). The power curve is usually defaulted to 1,225 kh / m3, which is equivalent to conditions of a standard sea surface pressure of 1013.25 hPa and an air temperature of 15 ° C. This is also the air density value fixed in WAsP while calculating the power density.

A power curve applied to a site where the mean air density is different from the standard value is normally assumed to be the corresponding value of the air density at that location relative to the standard value. with standard values. This is acceptable in some cases due to the rather limited range of air density values.

However, wind turbines which their output power is used for control, as for turbines with pitch control, the exact calculation of the output power is often complicated and complicated. than. The reliable solution in this case is using the power curve from the manufacturer that has been calculated for the specific air density at a particular location.

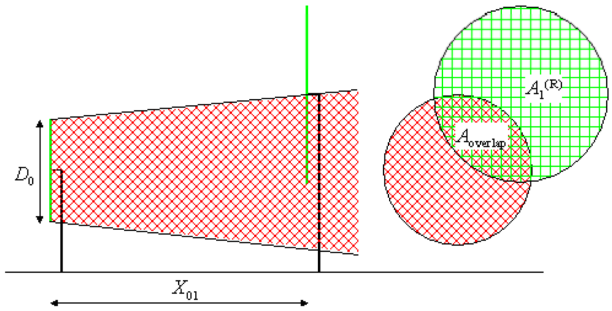
1.6. Wind farm energy production:

In order to calculate the energy production of a wind farm, taking into consideration the influence among the turbines, we can predict wind climates for the following wind turbine locations and characteristics:

- The hub height of wind turbine (m) and rotor diameter (m).
- Power curve (m / s and kW)
- Thrust coefficient curve (m / s and without units)

The wind farm model, in which wind farms with different turbine types, is based on the mathematical model of the Wake effect behind a wind turbine, developed by N.O. Jensen (1984) and later extended to practical wind farms by Katic in 1986. This model uses the torque deficit theory to predict the current field in a very simple way: the assumption is the linear expansion behind the rotor. Therefore, the only changes are the preliminary velocity deficit at the onset of the Wake phenomenon, as evaluated from the turbine coefficient Ct at the actual wind speed, and the effect attenuation constant. Wake, which is the ratio of the expansion (effect reduction) of the Wake effect.

The model assumes the centerline of the Wake effect expansion will follow the terrain, and the variable hub heights and rotor diameters are taken into consideration by superposition of a fraction of the Wake effect with a rotor plane at downstream. Due to the simplification of the model, the terrain must be pretty homogeneous to prevent large acceleration effects. The discharge field and wind farm geometry calculated by the turbine output model are shown below:



The effective wind velocity deficit at downstream is calculated as the following formula:

$$\delta V_{01} = U_0\left(1-\sqrt{1-C_t}\right)\left(\frac{D_0}{D_0+2kX_{01}}\right)^2\frac{A_{overlap}}{A_1^{(R)}}$$

Thrust coefficient: The thrust coefficient curve can be very difficult to determine according to technical standard data. However, all wind turbine data files provided by the WAsP also contain thrust coefficient data. It can be calculated by a rotor simulation program, predicted from data for the same turbines, or measured directly as the turbine tower bending moment. Thrust coefficient Ct is related to thrust Ft as follows:

$$C_t = \frac{2F_T}{\rho\frac{\pi}{4}D_0^2U_0^2}$$

The decrease of the preliminary wind speed from U0 to V, when passing through the rotor plane, is related to the coefficient Ct by the formula: $(1-C_t) = (V / U_0)^2$.

The distance between the turbines next to each other on a farm should be approximately four times greater than the rotor diameter. there will likely be a greater decrease in energy production than calculated with massive arrays (the model can handle up to several hundred turbines), due to the effect of the turbines on the roughness description. generalization for calculation position.

The model cannot reasonably handle the effects of acceleration or deceleration, which can be crucial for wind farms in mountainous and complex terrain. The Wake effects are expected to follow the topographic surface of the landscape.

III. RESULTS OF DEVELOPING WIND MAP FOR TAY NGUYEN BY WASP MODEL

2.1. Input

- Wind measurement data: using 06 wind measuring masts in the Tay Nguyen as follows:

+ Mast 1: Measuring mast in Kon Duong commune, Mang Yang district, Gia Lai province (Ministry of Industry and Trade)

+ Mast 2: Measuring mast in Ea Drang townlet, Ea Hl'eo district, Dak Lak province (Ministry of Industry and Trade)

+ Mast 3: Measuring mast in Ea Phe commune, Krong Buk district, Dak Lak province (Ministry of Industry and Trade)

+ Mast 4: Measuring mast in Ia Der commune, Ia Grai district, Gia Lai province (Ministry of Industry and Trade)

+ Mast 5: Measuring mast in Buon Ho town, Dak Lak province (Buon Ho 3 thermal power plant project)

+ Mast 6: Measuring mast in Nam Binh commune, Dak Song district, Dak Nong province (Nam Binh 1 thermal power plant project)

+ Mast 7: Measuring mast in Da Loan commune, Duc Trong district, Lam Dong province (Ministry of Industry and Trade)

Topography and geology: 1 / 10,000 topographic map of the entire Tay Nguyen region.

2.2. Results of wind map development for the Tay Nguyen region

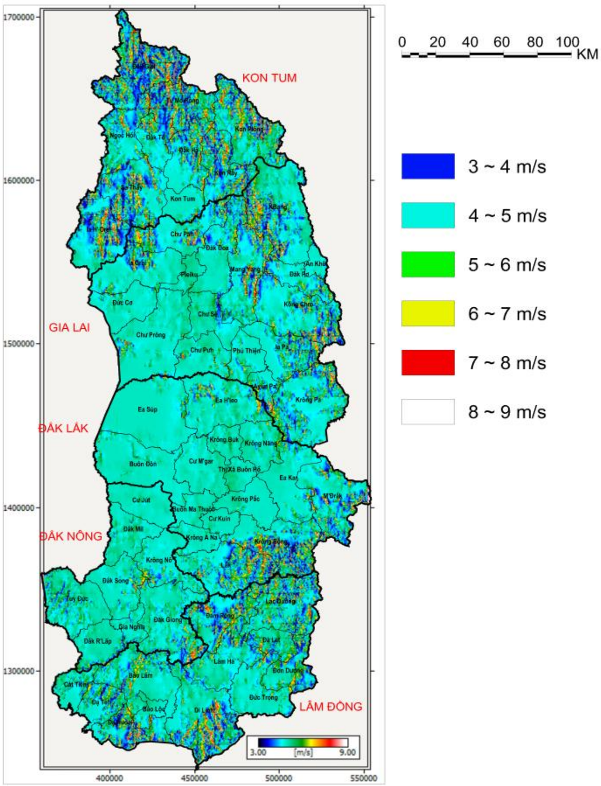


Figure 8: Map of wind speed distribution at altitude of 60m

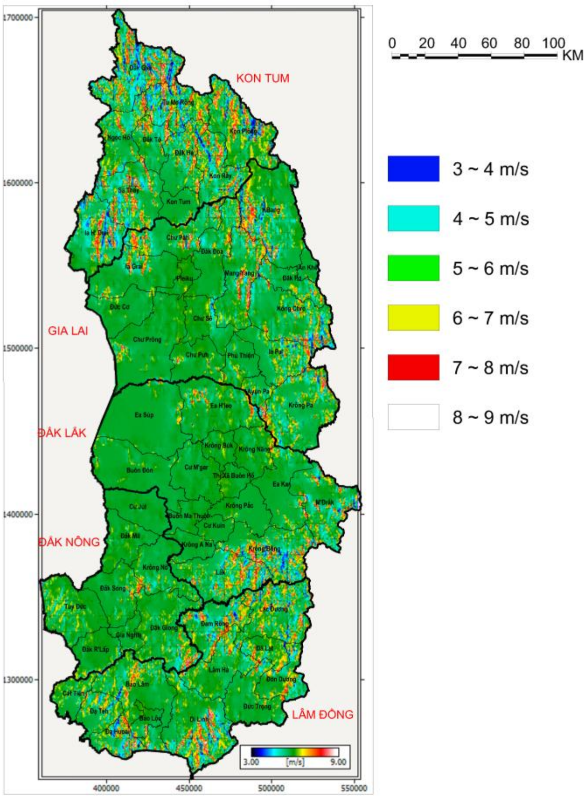


Figure 9: Map of wind speed distribution at altitude of 80m

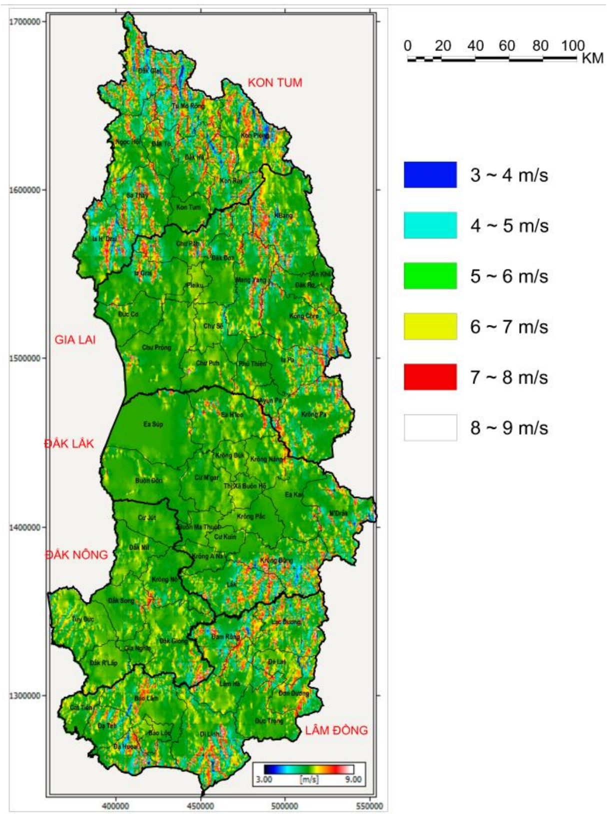


Figure 10: Map of wind speed distribution at altitude of 100m

Based on the wind speed distribution map, the following conclusions are shown on the distribution of potential regions in the Tay Nguyen provinces:

+ Kon Tum province: annual average wind speed from 6.0m / s or more at an altitude of 80m, distributed in districts of Dak Glei, Tu Morong, Kon Plong, Kon Ray, Dak Ha, Kon Tum province with a total area of about 12,952 ha, accounting for 1.34% of the total area of the province.

+ Gia Lai province: annual average wind speed from 6.0m / s or more at an altitude of 80m, distributed in districts of Dak Doa, Mang Yang, An Khe, Krong Chro, IA PA, Krong Pa, Chu Se, Chu Prong Gia Lai province with a total area of about 118,674 ha, accounting for 7.65% of the province's area.

+ Dak Lak province: Annual average wind speed from 6.0m / s or more at altitude of 80m, distributed in districts of Eah'leo, Krong Nang, Krong Buk, Buon Ho, Cu M'Gar, Krong Pac, Dak province. Lak with a total area of about 106,005 ha, accounting for 8.13% of the province's area.

+ Dak Nong province: annual average wind speed from 6.0m / s or more at the altitude of 80m, distributed in districts of Dak Song, Dak Glong, Dak Nong province with a total area of about 4,173ha, accounting for 0.64% of the area. area of the whole province.

+ Lam Dong province: annual average wind speed from 6.0m / s or more at the altitude of 80m, distributed in districts of Lac Duong, Da Lat, Lam Ha, Don Duong, Duc Trong, Di Linh, Lam Dong province with total an area of about 18,847 ha, accounting for 1.93% of the total area of the province.

Well-potential areas a on hilly areas, annual crops or perennial crops areas, or plan wet rice areas. However, because the permanently occupied land area of a wind-power project is small, these areas are able to accept wind-power projects.

IV. RESULTS OF THEORETICAL AND TECHNICAL POTENTIALS IN TAY NGUYEN AREAS

3.1. Theoretical potential

Circular No. 06/2013 / TT-BCT dated March 8, 2013 of the Ministry of Industry and Trade regulating the content, order, procedures for making, evaluating and approving wind-power development planning regulations on potential Theoretical wind potential is as follows: The theoretical wind-power potential is the wind-power potential determined with the wind speed of 6.0 m / s or more at the height of 80 m.

Table 1: Results of theoretical potential

Velocity (m/s)	Height from ground (m)	Distributed region	Distributed area (ha)	Theorical power (MW)
≥6,0	80	Dak Glei, Tu Morong, Kon Plong, Kon Ray, Dak Ha districts, Kon Tum province	11.915	596
≥6,0	80	Dak Doa, Mang Yang, An Khe, Krong Chro, IA PA districts, Krong Pa, Chu Se, Chu Prong, Gia Lai province	109.175	5.459
≥6,0	80	Ea h'leo, Krong Nang, Krong Buk, Buon Ho, Cu M'Gar, Krong Pac district, Dak Lak province	97.801	4.890
≥6,0	80	Dak Song district, Dak Glong, Dak Nong province	4.173	209
≥6,0	80	Lac Duong, Da Lat, Lam Ha, Don Duong, Duc Trong, Di Linh districts of Lam Dong province	17.140	857

The theoretical wind potential of the Tay Nguyen is approximately 12,010 MW, of which the provinces with great wind potential are Gia Lai and Dak Lak.

3.2. Technical potential

According to the Circular No. 06/2013 / TT-BCT dated March 8, 2013 of the Ministry of Industry and Trade regulating the content, sequence, making-procedures, evaluating and approving the wind-power development planning as follows : Technical wind-power potential is the wind-power potential to be able to construct and operate wind-power projects with current technical and technological conditions. From the above regulation, based on the location of possible land areas for wind-power development and the map of theoretical wind-power potential distribution, map overlapping to identify areas with technical potential. wind-power. The determination of technical capacity is done by stacking different layers: Using MapInfo software to stack theoretical wind potential map layers, land use planning maps, regulations on exclusion zones …. The final result is a distribution map of potential technical wind potentials.

Table 2: Result of technical potential

Velocity (m/s)	Height from ground (m)	Distributed region	Distributed area (ha)	Theorical power (MW)
≥6,0	80	Dak Glei, Tu Morong, Kon Plong, Kon Ray, Dak Ha districts, Kon Tum province	7.149	477
≥6,0	80	Dak Doa, Mang Yang, An Khe, Krong Chro, IA PA districts, Krong Pa, Chu Se, Chu Prong, Gia Lai province	65.505	4.367
≥6,0	80	Ea h'leo, Krong Nang, Krong Buk, Buon Ho, Cu M'Gar, Krong Pac district, Dak Lak province	58.681	3.912
≥6,0	80	Dak Song district, Dak Glong, Dak Nong province	2.504	167
≥6,0	80	Lac Duong, Da Lat, Lam Ha, Don Duong, Duc Trong, Di Linh districts of Lam Dong province	11.998	800

The wind energy potential of the Tay Nguyen is considered at approx. 9,722MW. However, depending on each specific location, there is necessary to locally measure as well as consider exploitation plans at various heights to point out the most technically and economically effective exploitation height.

V. CONCLUSION

The Tay Nguyen region is one of the regions with the best wind-power potential in Vietnam. The theoretical wind-power potential of the Tay Nguyen province concluded at approx. 12,010MW and the technical potential at approx. 9,722MW.

Dak Glei, Tu Morong, Kon Plong, Kon Ray and Dak Ha districts, Kon Tum province; the districts of Dak Doa, Mang Yang, An Khe, Krong Chro, Ia Pa, Krong Pa, Chu Se, Chu Prong, Gia Lai province; Eah'leo, Krong Nang, Krong Buk, Buon Ho, Cu M'Gar and Krong Pac districts, Dak Lak province; Dak Song district, Dak Glong district, Dak Nong province; Lac Duong, Da Lat, Lam Ha, Don Duong, Duc Trong, Di Linh districts of Lam Dong province are places with good wind-power potential, and can be effectively exploited.

Wind energy potential: It is necessary to conduct wind measurement in high potential areas (referenced to NEDO map). Wind measurement shall work out at an altitude of not lower 80m on a large-scale, with scientific and thorough observation.

In order to reduce wind measurement costs while achieving high accuracy, it is necessary to organize well international cooperation and cooperation with domestic wind-power project investors.

In order to effectively and sustainably develop grid-connected wind-power sources in the Tay Nguyen region, management units and investors are requested to strictly comply with State regulations in wind-power development. The current regulations and policies of the State are basically enough to encourage investment and development of wind-power.

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