ANALYSIS OF WIND CHARACTERISTIC PARAMETERS WITH A VIEW TO THE IMPLEMENTATION OF A 20MW WIND FARM in the DIANA Region

Mamy Nirina Rolland RANDRIANARIVELO[1], Richard Radiela RAMAROSON[2], Rijalalaina RAKOTOSAONA[3], Edouard Ravalison ANDRIANARISON[4]

[1] *Ecole Doctorale Ingénierie et Géosciences, Université d'Antananarivo, Madagascar*
[2] *Département de Météorologie de l'ESPA, Université d'Antananarivo, Madagascar*
[3] *Laboratoire de Chimie Physique de l'ESPA, Université d'Antananarivo, Madagascar*
[4] *Département de Génie des Procédés Chimiques et Industriels de l'ESPA, Madagascar*

ABSTRACT

The use of renewable energy is one of the best solutions to the challenge of climate change. Madagascar demonstrates remarkable wind potential, especially in the northern part of the country. The purpose of this research is to locate a site favorable to the establishment of a large-scale wind power plant. A clearly detailed comparative statistical analysis of the two windiest communes in the two regions, Sofia and Diana, was carried out. The results showed that the municipality of Andranovondronina is suitable for the installation of the power plant: the wind frequency roses, the power density roses as well as the analysis of the turbulence, of the wind shear profile, show that the energy production is much higher than that of Amparihy. The wind potential is exceptional there and deserves to be exploited. At a height of 80m, the power density rose of Andranovondronina displays a density of around 1300W / m2 in the SE direction, 1130W / m2 in the SSE, and 825W / m2 in the ESE, against a value almost zero in sector N. 54% of the total wind energy comes from the SE sector, 35% comes from the ESE wind. Thus, southerly winds (SSE to S) averaging 11.5m / s occur 69% of the time and would develop 89% of the predicted power. The occurrence of wind in the North axis is almost low, the turbines would be oriented so that they are facing the wind, to be able to capture the maximum kinetic energy.

Key words*:* *Wind energy – Climate change – Amparihy - Andranovondronina*

INTRODUCTION

The energy sector is very important. It is one of the basic needs for sustainable development based on three pillars: socio-economic development and environmental protection. The planet's energy consumption is advancing at an exceptional rate, endangering the future of the generations. For Madagascar, two-thirds of its electricity production is provided by the import of fossil fuels. Only 15% of the total population is connected to an electricity network, including 2% in rural areas while 70% of this population live in the countryside [1]. Despite its dependence on oil, local electricity production cannot meet its energy needs. This situation makes the national economy very vulnerable. For truly sustainable development, it is a duty to effectively integrate environmental and societal constraints [2] [3]. Man's energy manipulations lead to the depletion of precious natural resources as well as to violent pollution, including the release into the atmosphere of greenhouse gases causing global warming.

Madagascar has many renewable sources. Indeed, it enjoys a climate favorable to the wind and rich in solar radiation. It also has remarkable hydraulic potential. Wind climatology as well as existing scientific literature show that the northernmost section of the island is endowed with an enormous wind field [4]. The purpose of this research is to demonstrate how interesting it is to embark on the exploitation of the potential in renewable energies for electricity production, by highlighting the wind resources in the northern part of the Big Island. In this perspective, the comparative analysis of some climatic parameters will make it possible to identify the characteristics of the wind in the studied municipalities, namely Amparihy (AM locality) in the Sofia region, and Andranovondronina (AN locality) in the DIANA region as well as to propose the site favorable to a possible large-scale wind power operation in Madagascar. This study aims to be both a tool for promoting Madagascar's wind power potential and a decision-making support for the political decision-makers concerned by these questions, as urgent as they are strategic for this country.

I. MATERIALS AND METHODS :

1.1. Study locations :

Large-scale wind farm studies in Madagascar were carried out in the rural municipalities of Andranovondronina (AN) and Amparihy (AM) in the former province of Diego-Suarez in Madagascar. The AN municipality is located in the district of Antsiranana II, located in the region of DIANA. Its population is predominantly rural; rice paddies and corn cultivation fields mark its municipal territory. The AM municipality is located in the district of Port Bergé of the Sofia region of the same province.

1.2. Methodological approach

Windographer was used in this work. It is a powerful software for comprehensive statistical analysis and quality control, with several possibilities, with which high quality output is well suited to decision makers. The inputs are made up of the outputs of the WRF ARW [1]model; these data series are recorded at hourly intervals, on a grid of approximately 16km, adjusted and validated by in situ observation data [5]. These data come from the municipalities of Andranovondronina and Amparihy and are mainly composed of wind speed and direction, temperature, pressure, standard deviation of wind speed.

1.3. Periodic wind variations

1.3.1. Seasonal and daily variations

The speed and direction of the wind is constantly changing throughout the year. This phenomenon is mainly due to the displacement of high and low pressure areas on the earth's surface. The existence of more or less cyclical annual variation in wind intensity and direction has been observed [6]. Madagascar is not excluded from this seasonal variability. Thus, the determination of the monthly average speeds and the plotting of the frequency curves of the monthly averages make it possible to indicate the probability that the average speed has to exceed a given value [7]. The convective effects cause the daily fluctuations of the wind. Since the specific heat of the ground is much lower than that of water, the earth heats up faster than the sea under the influence of solar radiation. As a result, convective circulations are created: the “sea breeze” and the “land breeze” as well as mountain breezes and those of the valley [1]. Wind speed and direction are constantly changing throughout the year.

1.4. Wind frequency distribution

The distribution of Weibull is used to evaluate the energy available in places where data are missing. It models the probability that a wind blows at such speed on this site. She attributes to the wind speed, the probability density function of Weibull's law which is as follow:

$$f(U) = \frac{k}{A}\left(\frac{U}{A}\right)^{k-1}.exp\left[-\left(\frac{U}{A}\right)^{k}\right] \qquad (1.1)$$

This expression is valid for a Weibull shape parameter or shape factor $k > 1$ (Rayleigh distribution: k = 2, valid for most sites) (dimensionless) , an average of the wind speed $U \geq 0$ and a Weibull scale parameter or scale factor $A > 0$ (value of the mean speed therefore same unit as). Generally, the form factor is between 1 and 3. For a given average wind speed, a low form factor indicates that the distribution of wind speeds is relatively wide on either side of the average, whereas a high form factor indicates that the distribution of wind speeds is relatively narrow on either side of the mean.

1.5. Establishment of wind roses

The Windographer has permit to develop types of roses necessary for a determination of the site implantation’s specificity for wind turbines : roses illustrating the frequency of the wind, the total energy, power density, and the average speed, by sector of direction. Indeed, they make it possible to know the predominant wind direction sector and will facilitate the exact orientation of the wind turbines.

[1] Weather Research and Forcasting Advanced Research WRF

1.5.1. Air density

Air density (DA) is used in calculating the power efficiency of a wind turbine, as well as in wind power density. It is obtained by making the ratio between the mass of a quantity of air by its volume. Under the assumption of an ideal gas, the air pressure is defined by the ideal gas law:

$$p = d\frac{R}{M}T \qquad (1.2)$$

where is the air pressure expressed in [kPa] ; , the density of the air ; is the universal ideal gas constant = 8,314472 [$m^3.kPa.K^{-1}.kmol^{-1}$] ; M is the molar mass of air [kg/kmol] ; T is the air temperature [K].

Therefore, the air density is expressed:

$$d = \frac{M}{R}\frac{p}{T} \qquad (1.3)$$

For air which has a molar mass equal to 28.9664 kg/kmol, the following equation can be written:

$$d = 3{,}4837\frac{p}{T} \qquad (1.4)$$

1.5.2. Power density

The power density (PD), defined by the ratio $\frac{\mathcal{P}}{A}$, is also a necessary parameter to establish the wind roses :

$$\frac{\mathcal{P}}{A} = \frac{1}{2}dU^3 \qquad (1.5)$$

where, $\frac{\mathcal{P}}{A}$ is the average of the power density or average power per unit area, taking into account the time step, expressed in [W/m^2] ; d is the air density [kg/m^3] ; U the average wind speed [m/s].

1.5.3. Turbulence intensity - wind shear

Wind turbulence is a relative measure of the quality of wind as a resource, assessing the uniformity and variability of the wind. Turbulence Intensity (TI) is the most efficient way to measure wind turbulence. It is a dimensionless number which is obtained by making the ratio between the standard deviation of the turbulent fluctuations of the wind speed, at a given place, by the average speed at the same place in the same period.

$$I = \frac{\sigma_i}{U_i} \qquad (1.6)$$

where U_i is the average wind speed in a period i ; σ_i is the standard deviation of the wind speed in the same period i.

The i ntensité turbulence is great when the wind speeds are low, that is to say, dividing a standard deviation by an average low speed of the wind automatically generate greater turbulence intensity , that at higher average speed. Table 1 shows categories of turbulence based on the average turbulence intensity in an wind speed of 15m/s, defined in the 3rd edition of the CEI 61400-1 norm.

Tableau 1: **Classification of turbulence according to IEC 61400-1 standards**
(Source : WINERGY Study Office **[8]**)

Category	Average IT at 15 m/s
S	> 0.16
A	0.14 - 0.16
B	0.12 - 0.14
C	<0 .12

The reduction in wind speed near the ground is due to the friction exerted by vegetation, obstacles and buildings on the moving air. These obstacles generate in the vicinity of the ground, a zone of strong turbulence called the boundary layer extending to a certain height above the ground. Therefore, wind speed tends to increase with the height. The variation in wind speed with the height is called the wind shear profile. In the field of wind resource valuation, analysts typically use two mathematical models for quantifying the vertical profile of the wind in a region with homogeneous spatial characteristics: the logarithmic profile and the power law profile (power law).

1.5.3.1. The logarithmic profile

The logarithmic law assumes that the wind speed changes logarithmically with the height above the earth according to the following equation:

$$U(z) = \begin{cases} 0 & si\ z \leq z_o \\ \frac{U^*}{K}\ln\left(\frac{z}{z_o}\right) & si\ z > z_o \end{cases} \qquad (1.7)$$

Where : $U(z)$ designates the wind speed [m/s] at height z with respect to the ground, [m] ; U^* is the friction velocity [m/s] ; K is the Von Karman constant (= 0,4) ; z is the height in [m] ; z_o is the aerodynamic factor of the ground roughness in [m] ; ln is the natural logarithm.

Using ln (1/A) = - lnA:

$$U(z) = \frac{U^*}{K}\ln(z) - \frac{U^*}{K}\ln(z_o) \quad (1.8)$$

This equation is linear in form ***y = mx + b***. Therefore, if $ln(z)$ is the x-axis and $U(z)$ on the y-axis:

$$\text{Slope} = \frac{U^*}{K} \quad (1.9)$$

$$\text{Intersection} = -\frac{U^*}{K}\ln(z_o) \quad (1.10)$$

There is a variant of the logarithmic profile, where the logarithmic law involves the roughness of the ground in the form of a parameter z_0 having the dimensions of a length; given by the following relation:

$$\frac{U}{U_0} = ln\left(\frac{H}{z_0}\right)/ln\left(\frac{H_0}{z_0}\right) \quad (1.11)$$

Where, H is the height, H_0 is the height in the vicinity of 10m above the ground and U_0 denotes the wind speed [m/s] at the height H_0.

1.5.3.2. __The profile of the power law__

The vertical wind profile can also be approximated by a power law, expressed as follows:

$$U(z) = \beta z^{\alpha} \quad (1.12)$$

Where: $U(z)$ is the mean wind speed at height z ; β is a contant; α is the exponent of the power law and is typically equal to 0,14 (1/7) when sufficient information is not available on the measurement sites. The value of this exponent varies from 0.1 (corresponding to the tops of a hill) to 0.25 (for inhabited areas).

By introducing the natural logarithm, we have:

$$\ln\big(U(z)\big) = \alpha\ln(z) + \ln\beta \quad (1.13)$$

This equation is now of the form: $y = mx + b$. Consequently, if $ln(z)$ is on the x-axis and $\ln(U(z))$ on the y-axis, it can be deduced that:

$$\text{Slope} = \alpha \quad (1.14)$$

$$\text{Intersection} = \ln(\beta) \quad (1.15)$$

Several authors proposed to represent the law of change of velocity by the expression:

$$\frac{U}{U_0} = \left(\frac{H}{H_0}\right)^n \quad (1.16)$$

Where U_0, denotes the speed observed at height H_0; U, the speed at height H; n is the shear coefficient which varies from 0,10 à 0,40.

Table 2: Comparison of the value of z_0 and the shear coefficient n according to an underlying surface (Source: D. LE GOURIERES)

Underlying surface	z_0 **(in m)**	*shear coefficient n*
Smooth (sea, sand, snow)	0,001 – 0,02	0,10 – 0,11
Moderate roughness (meadows, cereals)	0,02 – 0,3	0,15 – 0,30
Rough (woods, villages)	0,3 - 2	0,20 – 0,27
Very rough (cities, buildings, high buildings)	2 - 10	0,27 – 0,40

II. RESULTS AND DISCUSSIONS

Our study aims to determine the viability of a wind power plants in Amparihy (AM) and/or Andranovondronina (AN). Thus, it focuses on statistical analysis of several parameters characteristic of the wind to deduce the potential available to permit a localization of the potential wind farm.

2.1. Wind Resources at both sites

The table below summarizes the input data used. With these inputs, the statistical methods deployed made it possible to identify the organization charts and graphs essential for the feasibility analyzes of establishing a wind power plant in the North of the Big Island.

Table 3: Properties of ser data ies of Site s AM and AN (Source: Author)

Variable	*Site AN*	*Site AM*
Latitude	12.05 S	15.667 S
Longitude	49.233 E	47.116 E
Elevation	62 m	16 m
Start of data recording	01/01/2010 00:00	01/01/2010 00:00
End of data recording	31/12/2010 18:00	31/12/2010 18:00
Duration of data storage	12 months	12 months
Calm Threshold	2 m/s	2 m/s
Mean temperature	27.4 °C	27.1 °C
Medium pressure	100.98 kPa	100.723 kPa
Average air density	1.162 kg/m³	1.223 kg/m³
Average power density at 50m	786,210 W/m²	325 W/m²
Wind power class	6 (Exceptional)	3 (Medium)
Surface roughness	0.05 m	0.075 m
Roughness class	0.06	0.06
Description of roughness	moderate	moderate

By referring to the map of wind resources of the two regions (Figure 1) where the two municipalities studied here were chosen, at 50m above the ground, Amparihy belongs to the 3rd class of wind resources while Andranovondronina is placed the 6 th, which is exceptional.

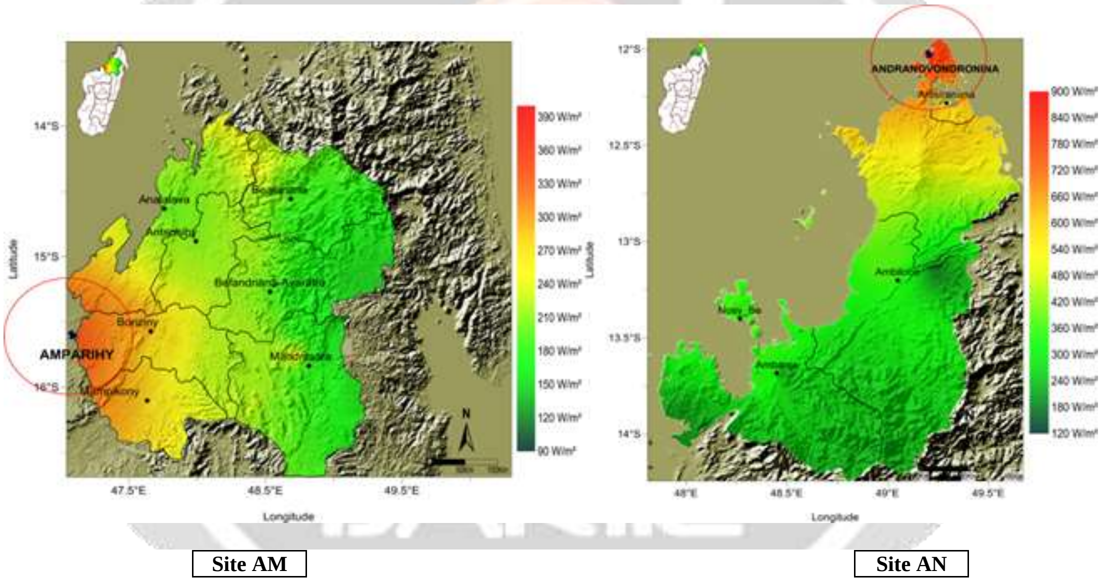


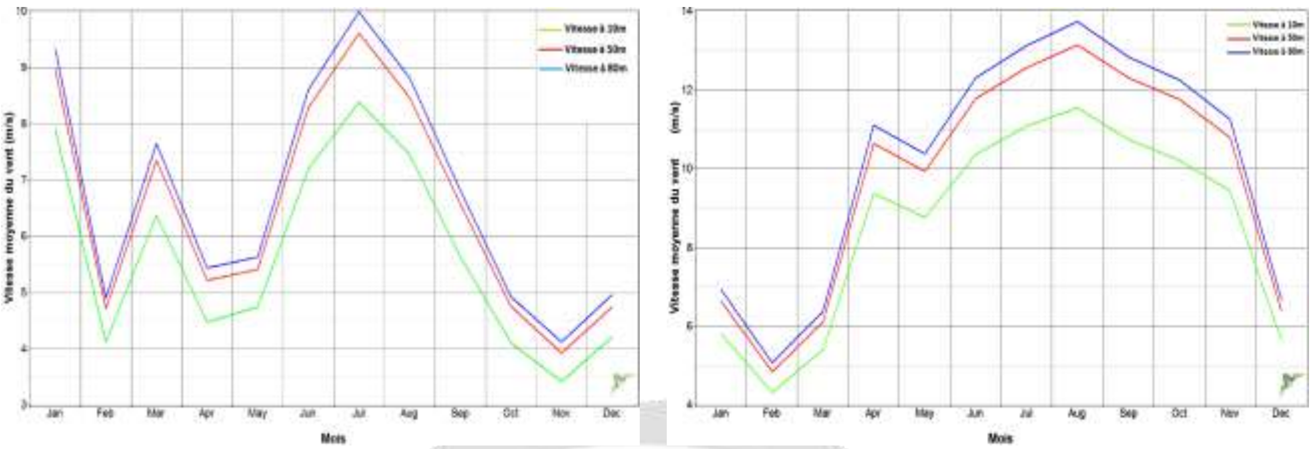
Figure 1: Densité de puissance moyenne à 50m au-dessus du sol des sites AM et AN (Source : auteur)

Table 4 : Wind resources

	Site AN	**Site AM**
Average annual speed at 50m	9,76 m/s	6,52 m/s
Average power density at 50m	786,210 W/m²	325 W/m²
Power density classification	6	3
Estimate	Exceptional	Medium
Dominant wind direction	127.2 °	135°

2.2. Seasonal and daily variations in wind speed

A key factor is the number of times strong winds of up to twice the average can be experienced, in a given period, because such a speed will provide more energy than that produced during periods of low wind speeds. Wind speed changes daily and on a seasonal basis.



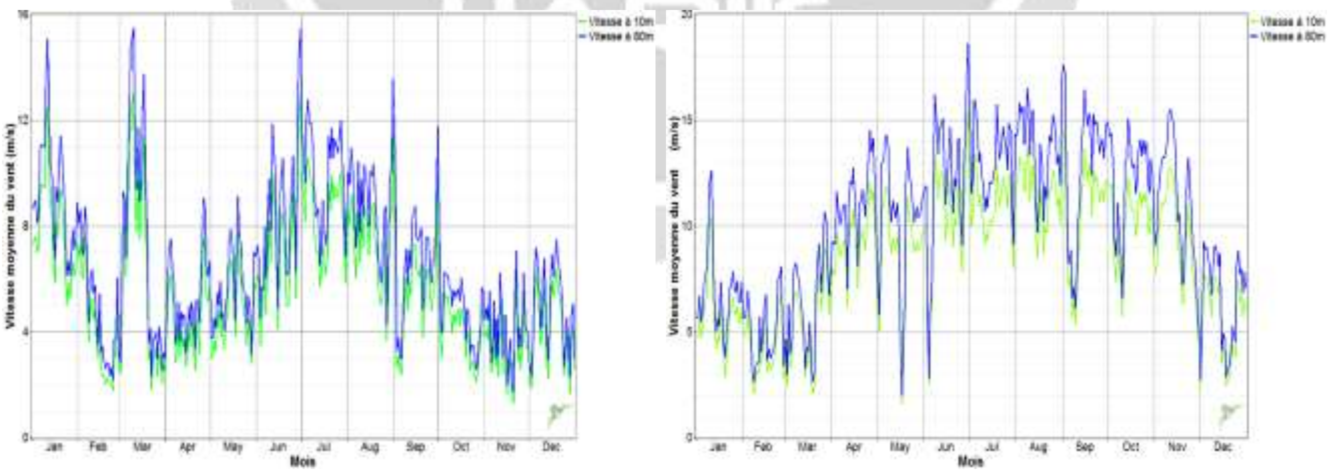
Site AM Site AN

Figure 2 : Variation saisonnière de la vitesse du vent aux sites AM et AN (source : auteur)

Figure 2, showing the seasonal variation in wind speed, indicates that strong winds occur mostly from May to October. During winter: for Amparihy , the wind begins to increase in intensity from May, and to decrease in August, the " varatraza " regime imposes its influence with a maximum in July. Thus, at Amparihy, the power produced is optimal in July while it is minimal in November. Wind turbine requires wind speed of 4m/s, and below this value, no appreciable power is produced.

In Andranovondronina , the wind begins to increase in intensity from the month of April, and retains its force until November, with a maximum in the middle of August. If the speed allowing a wind generator to start is 4m/s, it is noted that the wind turbines which will be installed there will not be subject to non-operation, unless there would be machine breakdowns. As a result, this municipality in Diana is among those most favorable in Madagascar.

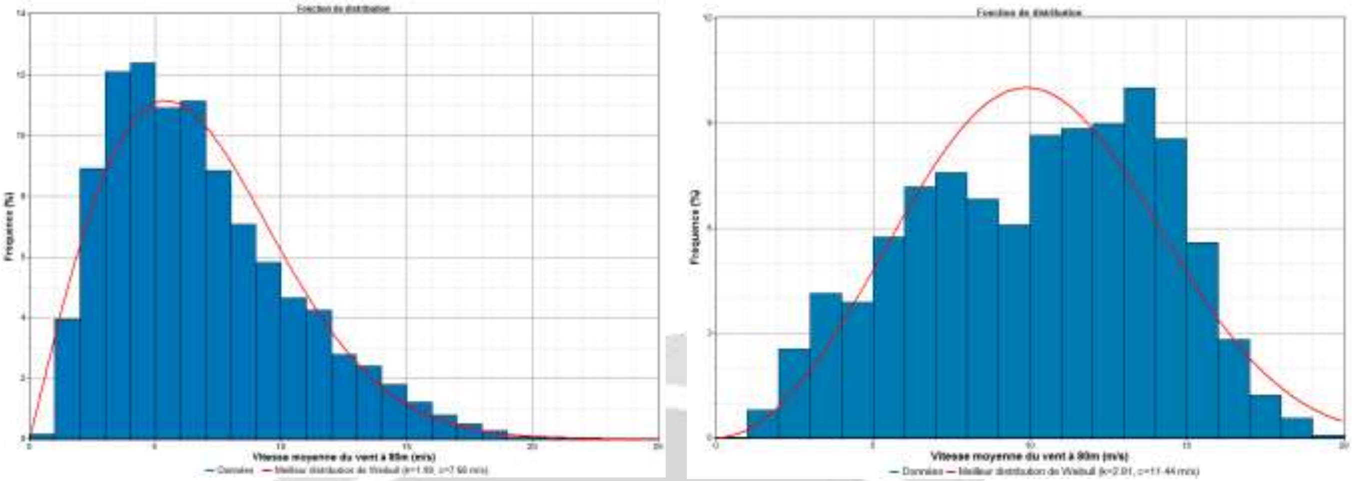
Generally, locations with a wind resource of class 4 or higher can be considered for the development of wind farms. Thus, in the first analysis and referring primarily to the wind resource and the seasonal variations in these two sites, the area of Andranovondronina class 6 wind power density appears more favorable to the implementation of installation of wind turbines than that of Amparihy of class is between 3 and 4 throughout the year [9].



Site AM Site AN

Figure 3 : Variation journalière de la vitesse du vent à 10 et 80m au-dessus du sol des sites AM et AN (source : auteur)

2.3. Wind frequency distribution



Site AM Site AN

Figure 4 : Fonction de distribution du vent à 80 m des sites AM et AN (source : auteur)

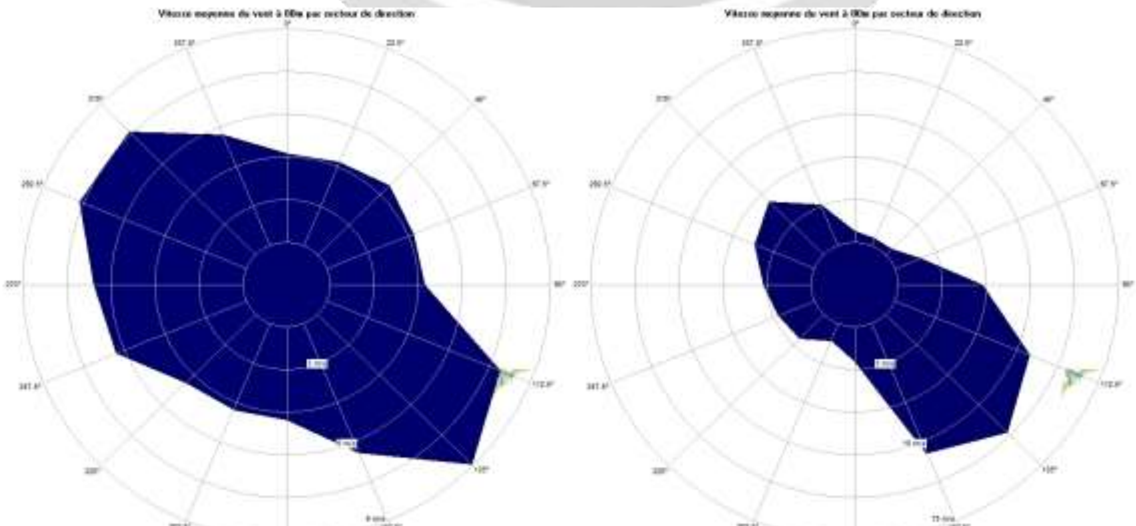
Power increases with the cube of the wind speed; also, in a probably favorable site, it is necessary to calculate the percentage of time the wind is blowing at a given speed in order to be able to determine the power in the wind. Figure 4 above shows that at Amparihy , it meets a speed of between 2 and 7 m/s, with a frequency of 8% to more than 12% of the time , while at Andranovondronina , winds 10 to 13m/s are more common at 6% to 9 % of the time , 80 meters from the ground..

Table 5: Comparison of frequency distribution (Source: Author)

	AN SITE			*AM SITE*		
Height **[m]**	**50**	**70**	**80**	**50**	**70**	**80**
Form factor k	2.898	2.903	2.906	1.969	1.986	1.993
c [m/s]	10.954	11.275	11.437	7.378	7.581	7.683
Average annual wind speed **[m/s]**	9.767	10.055	10.199	6.540	6.720	6.809
Annual average power density **[w/m^2]**	817.5	890.9	929.1	332.5	357.5	370.6

2.4. Wind direction and power

Knowing the direction of the wind is very important for the study of a wind farm project: to know the



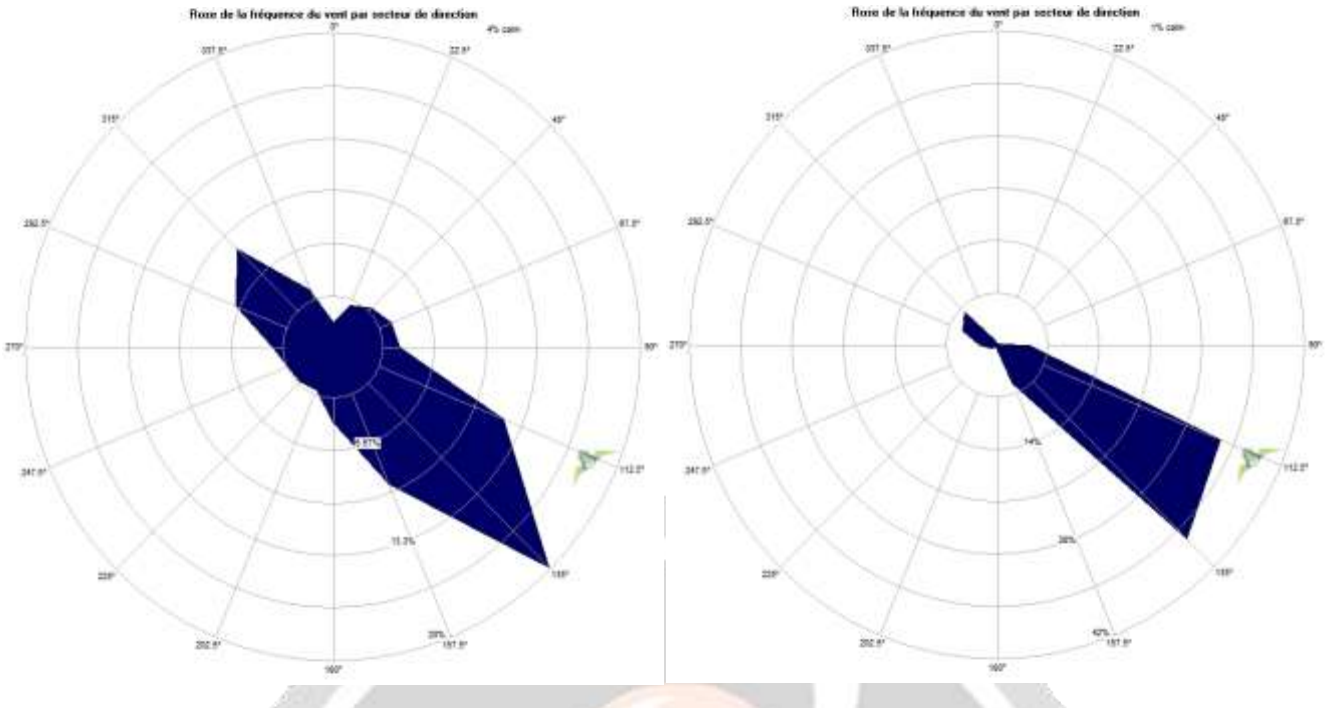
Site AM Site AN

Figure 5: Mean wind speed roses at 80m of AM and AN sites (source : author)

obstacles to the location of the possible wind farm, the precise orientation of the wind turbines is essential for their installation. While only a predominant direction exists, which is also our case, and for localized town in the Sofia region and one located to Diana, the spacing of the turbines can be relatively reduced the infrastructure costs [10]. According to observations, the wind direction varies constantly around an average direction.

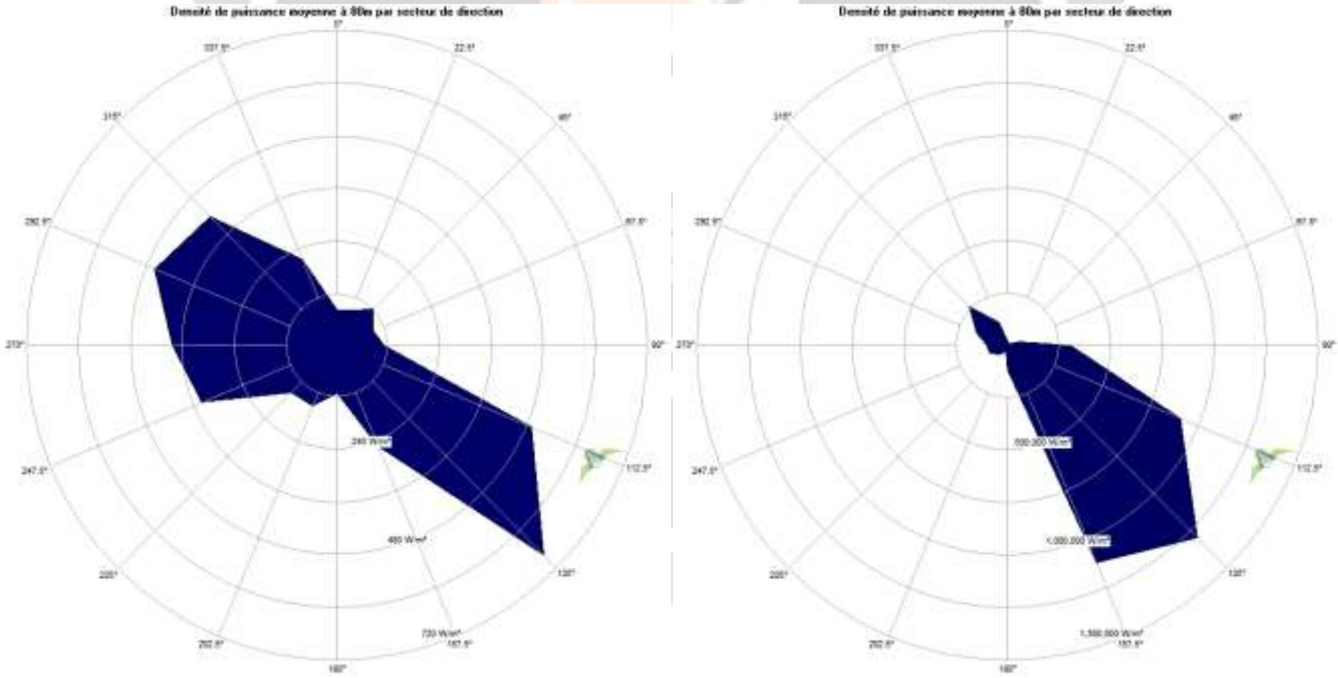
The Figure 5, left shows the average wind speed per direction sector in the municipality of Amparihy. It is remarkable that the speed is not uniform around the rose; an average of about 5 m/s invades a quarter of the rose from N to E, and 1/8 of a rose from S to SSW; the strongest average winds come from the SE (9.0 m/s), and from the ESE (7.9 m/s), from the SSE (6.1 m/s). The mean winds from the NW and the WNW reach the value of 7.7 m/s. The Figure 5, right asserts dominance flow E Andranovondronina , which is reinforced by the breezes in the dry season : in fact, the winds of great intensity, reaching more than 12m/s arrives from SE winds 11m/s mainly come from SSE and ESE; the NW sector is invaded by winds of 5 to 6m/s.

In the top right of Figure 6 , roses are respectively marked « 4% calm », « 1% calm » corresponding to the annual percentage of time during what wind speed has hte lower threshold calm value set at 2m/s. This is considered as a period of calm winds. Five inscribed circles are inside the rose indicating the frequency of the wind, their interval is proportional to the annual duration expressed as a percentage. According to the Figure 6, for the case of Amparihy (left), on about 20% of the time, the wind blast of the SE; winds from the SSE are observed 10.05% of the time , and the wind direction is from the SEE for 11.7% of the time. In the case of Andranovondronina , the figure 6 site AN shows that 'on average, 36% of the winds of the whole year come from the SE, 33% ESE winds and the frequency for other management areas is almost nothing.



Site AM Site AN

Figure 6: Wind frequency roses by sector of direction in AM and AN sites (source : author)



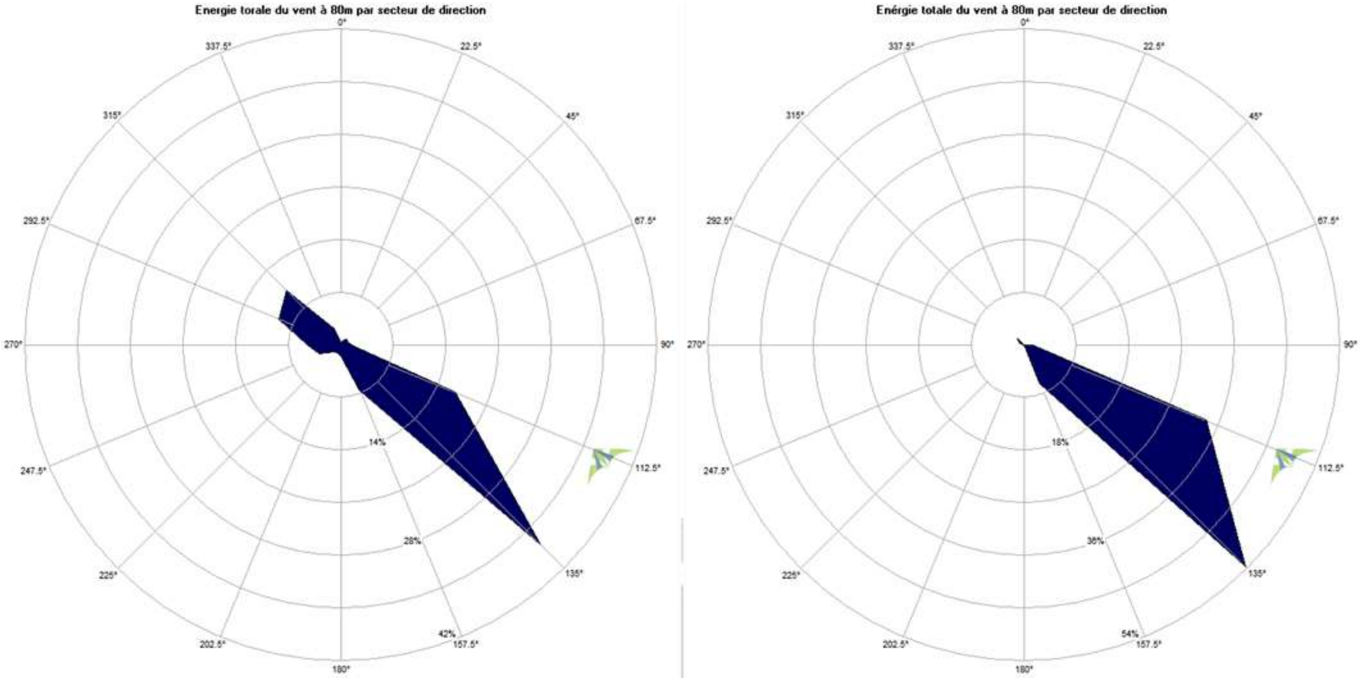
Site AM Site AN

Figure 7: Power density roses at 80m by sector of direction in AM and AN sites (source : author)

The rose of the power density of Andranovondronina shows a density of about 1300W / m2 in the SE direction, 1130W / m2 on SBS, and 825W / m2 to SEE, against an almost zero value in sector N. This d ' Amparihy shows that

Site AM Site AN

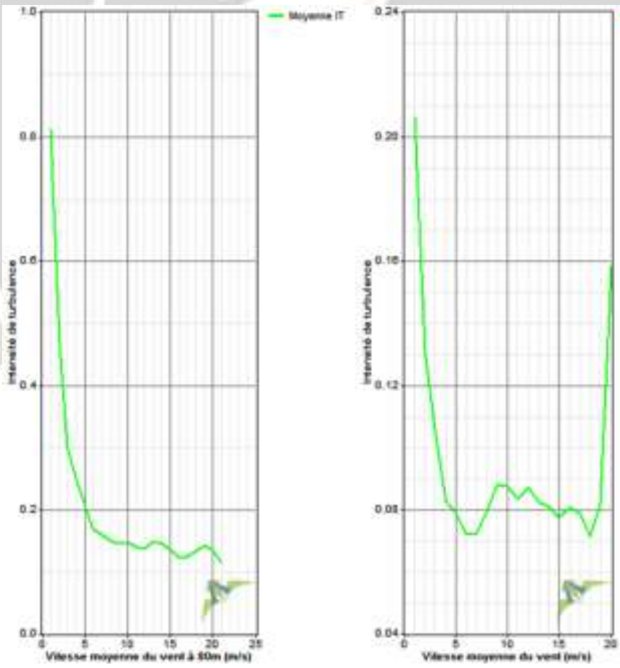
Figure 8: Total wind energy roses at 80 m by direction sector in AM and AN sites (source: author)



the winds coming from the SE have a power density of around 670 W/m2 while the power density in the W, WNW and NW sectors is around 450 W / m 2 . Figure 8 from the case of Andranovondronina shows that 54% of the total wind energy originates from the SE sector, 35% comes from the ESE wind while the total wind energy in the municipality of Amparihy is indicated by figure 8 on the left: 37% of the total energy produced comes from the SE sector.

2.5. Turbulence study

Turbulence has a very specific meaning in describing wind conditions. It is measured by the intensity of turbulence.

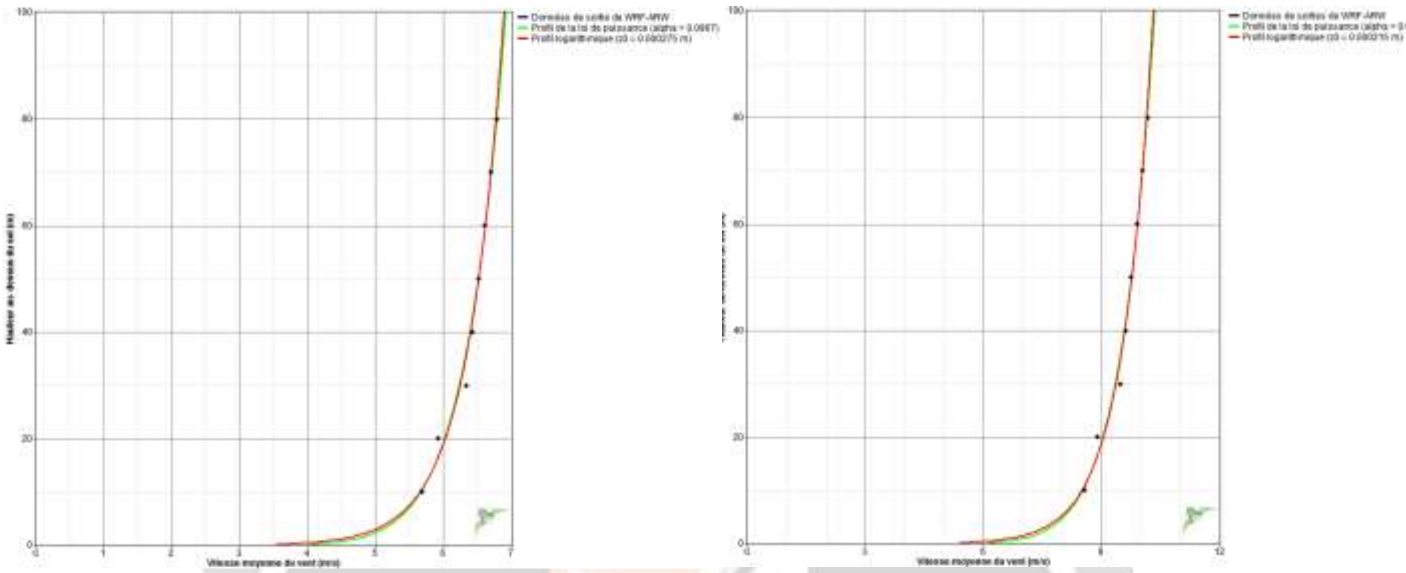


Site AM Site AN

Figure 9 : Intensity of wind turbulence in AM and AN sites (source : author)

According to the 61400-1 standards of the International Electrotechnical Commission (CEI) [11] , the mean IT of the data recorded at 15 m/s according to the results of figure 9 are 0.136 for the AM site and 0.077 for the site AN , classifying these respectively as sector B and C of turbulence, it is therefore a low turbulence sector. This is due to the fact that the predominant vegetation at the AM site is grassland, while that of the AN site is savannah. It should be noted that mangroves also exist in these places. Also, the data height is 80m, so local terrain effects no longer really affect air movement. Note that the IEC standard is defined at an average speed of 15m/s, possibly due to the relatively high mechanical loads applied to a turbine at this speed. In addition, seasonally, the highest IT contents occur during the months with the lowest average wind speeds (summer months). The months with apparently strong wind speeds (14 to 15m/s) are also the months with lower values of IT, implying more uniform winds.

2.6. Wind shear study



Site AM Site AN

Figure 10 : Profil vertical du cisaillement du vent des sites AM et AN (source : auteur)

The wind shear profile shown in figure 10 in the AM and AN sites where the wind speed was measured at eight different heights above ground: 10 - 20 - 30 - 40 - 50 - 60 - 70 - 80m. The corrected WRF ARW output data almost perfectly matches the power law profile and the log profile, except the data at 20 and 30m, with a small deviation. Therefore, the data used has a better fit. C A s the wind shear is the change in wind speed according to the distance to the surface of the earth (height above the ground), the account following is made in the construction of a wind: for rotor with a diameter of 54 m and a hub height of 70 m, the wind speed will be 6.93m/s at the highest point of the surface swept by the rotor, against 6.43m / s at the point the lowest. Thus, the forces working on the blades are stronger when they are in their highest position than when they are in their lowest position. From our one-year data, the power law coefficients of the sites AM and AN are respectively $\alpha = 0.0867$ and $\alpha = 0.0847$. The error between the power law curve and the input data is relatively small.

III. DISCUSSION - PERSPECTIVES

The analysis of all previous results showing the characteristics of the wind in the two study sites leads to the conclusion that the rural commune of Andranovondronina (Site AM) is more conducive to the installation of a wind farm. The results obtained here are more realistic simulations of what could really happen in reality. It should be noted that the input data used here are outputs of the WRF ARW mesoscale model, with a resolution of 16km, adjusted and validated by observation data on site. It is recommended to increase the spatial and temporal resolution of satellite data which will be spread over several years, or even over a clearly representative year, it is also necessary to use observation data on the ground. These recommendations are about the aimed of authenticating the preliminary studies carried out in this work and to ensure the efficiency of the future wind power plant.

3.1. Perspective on the choice of site :

To eliminate the effects of turbulence and obtain the maximum of available wind, the turbines should be placed in more high places possible. The relief of the AN site is mainly made up of plains, and the vegetation cover is mainly made up of savannas. Therefore, the height of the turbine will play a very big role in being able to acquire a strong, uniform and constant wind speed. The location should be chosen, considering some main technical parameters. By the fact that the field must be sufficiently windy, it must be able to receive more wind turbines , a minimum of obstacles, be close to the central power grid and sufficiently far away from residential areas. Finally, knowledge of environmental constraints is required.

3.2. Perspective on the orientation of turbines

By referring to the results particularly illustrated by figures 6 and 8 for the NA website, the winds from the south are (SSE/S) having an average of 11.5m / s occur in 69% of the time and develop 89% of the expected power. The occurrence of wind in the north axis is almost low, the turbines will be oriented so that they face the wind, in order to be able to capture the maximum kinetic energy. In fact, the orientation is such that the turbines are perpendicular to the axis of intended stronger winds. The prevailing wind therefore arrives in the southern sector and by applying the rule of perpendicularity, the optimal axis for the turbines must be between 225 ° - 45 ° and 202.5 ° - 22.5 °.

Tableau 5 : Consistent results (source: author)

	Wind direction	Mean wind speed	Total percentage of time	Percentage of total power
SE	**135.0**	12m/s	36%	54%
ESE	**112.5**	11m/s	33%	35%
South SSE and S		**11,5m/s**	**69%**	**89%**

Such study involves a great deal of investment in terms of time, human resources and financial resources. In addition, the hardware must be used. Computers, softwares, must have appropriate configurations. All steps in the methodology followed in this work, merit further analysis and investigation. The important thing not to neglect is the field study, and the purchase of an observation tower which will be used to measure the wind on the chosen site.

CONCLUSION

This study aims in evaluating wind power in the northern part of Madagascar. The statistical analysis carried out shows that the municipality of Andranovondronina (site AM) is suitable for the installation of wind power plant. The wind frequency roses and the power density roses show that the energy production is much higher than that of Amparihy (AM site). The different roses make it possible to specify the orientation of the wind turbines. The wind regime there is extraordinarily favorable for a large farm. In reality, wind regime of Andranovondronina (site AN) is similar to that of the wind farm in Texas, to power 780MW, consisting of 627 wind turbines spread over an area of 400km^2 and are among the largest plants in the world. Thus, the development of a wind power station in the locality of Andranovondronina is very possible according to our results.

The essence of the study lies in the consideration of the various statistical analyzes of the wind, necessary for a possible installation of large-scale wind power plant. It is advisable to do more in-depth research by making observations of wind parameters in the site, combined with results from models spanning several years, with very high spatial and temporal resolutions, so that the effects of the terrain are fully taken into account.

This work is of great use in wind research in Madagascar. Indeed, the use of renewable energies, such as wind energy, which is totally different from thermal energy, contributes to the protection of the environment and to fight against climate change,

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