# Wind Power Potential Estimation by Using the Statistical Models-Adama, Ethiopia

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**Abstract.** This paper is aimed to statistically estimate wind power that can be converted to electrical power. It is important to have an inclusive fact of wind phenomena to efficiently plan the generation of power from the wind. To estimate wind power potential, this paper includes daily average wind speeds, monthly average wind speeds, and related wind power density, and frequency distribution based on wind speed probability frequency, Weibull and Rayleigh distributions. The two parameters for Weibull distribution were found out using data from the Adama wind farm site. The yearly average wind power densities for wind velocity frequency distribution, the Weibull distribution, and the Rayleigh distribution models 412 W/m$^2$, 370 W/m$^2$, and 532 W/m$^2$ respectively were estimated using wind speed statistics of the 2018 year at the ADAMA wind farm site. The value of estimated wind power density by Rayleigh distribution models is equivalent to maximum power density of the site. The result of this study shows that the selected site has utility-scale potential wind power.

**Keywords:** Rayleigh probability distribution · Weibull probability distribution · Wind power estimation

## 1 Introduction

The wind is a global recognized potential source of energy. It is important to have comprehensive facts of the wind phenomenon to efficiently plan the generation of power from the wind plants. This study is aimed to statistically evaluate wind power potential at the Adama wind farm site in Ethiopia. In Ethiopia due to a quick increment in the demand for energy utilization for development, there is a fast decline of natural energy sources like biomass. It needs to give attention to wind energy assessment and then capture utilizable energy from it. According to the statistics that were mentioned [1]; Ethiopia has a wind energy potential capacity of about 18.7 GW at the wind velocity of 7.5 to 8.8 m/s at 50 m height above the ground. Wind power potential capacity of


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Ethiopia is also indicated by [2]. That is the total national wind energy potential for grid connectable electricity from wind is about 100 GW. This can be captured from 20,000 square kilometers estimated land part of the country. Therefore, based on this information and energy needs, Ethiopia plans to generate 7 GW electricity from wind farms by 2030. Globally the wind energy contribution was reached 600 GW in 2018 [3].

Wind resources assessments are the basis for identifying and realizing the potential site of qualified wind energy and mitigating related risks. This was depicted by Premono B. S et al. [4] focusing on the recital of wind turbines. Power in the wind is related to the cube of the wind velocity. A 10% variation in wind velocity creates about 33% changes in wind power. Such fact is one of the main motivations to carry out wind resource appraisal. The other reason is variation in wind speed; wind shears causes great unpredictable loads that creating fatigue on the wind turbine blades since the blades run in regions of variant wind velocity. Turbulence causes dynamic loads on wind turbines. This paper focused to address the first point using resource assessments such as daily mean wind velocities, monthly average wind velocities, and related wind power density using wind pace frequency model, and Weibull and Rayleigh models. To evaluate a specific site's wind power capacity, wind speed occurrence has to be used as a scaling factor of an envoy wind turbine power curve. Wind class of the selected place is categorized using wind power density with average wind speed [2, 5] of a considered wind site. Theoretically expected wind power to be harvested from the selected site and related parameters were formulated by Altunkaynak et al. [6] considering variations in wind speed. More emphases have been carried on wind power estimation using mixture distribution [7–9].

The next parts of this paper are comprised of four sections; Theoretical Background of Statistical Models for Wind Data Analysis, method, Result and Discussion, and Conclusion.

## 2 Theoretical Background of Statistical Models for Wind Estimation

In the implementation of wind energy assessment and harvesting, the selected wind farm site is characterized by many statistical models. Wind energy resource potential site and estimation of its power generation capacity can be carried out using different statistical models. In the execution of the selected statistical model, the availability of varying measured wind velocity data at a specific height of that site is required. Using this data, the commonly accepted statistical models such as wind speed incidence distribution, the Weibull distribution, and the Rayleigh distribution were implemented and analyzed the data. The probability (likelihood) density and cumulative distribution functions of these models with their plots were employed. The wind power density at any wind speed in the selected site over the sampling period is stated by the expression [10]

$$\frac{\boldsymbol{p}}{A} = \boldsymbol{p}(\boldsymbol{v}) = \frac{I}{2}\boldsymbol{\rho}.\boldsymbol{v}^3.\boldsymbol{f}(\boldsymbol{v}) \tag{1}$$

For ρ is the density of air in kg/m$^3$, P/A is in W/m$^2$ for A is swept area; an average wind power density $\overline{P}$ in the selected site is

$$\overline{p} = \int_0^\infty p(v).dv \tag{2}$$

For f(v) in Eq. (1) describes frequency appearance of random wind velocity *(v)*, this can be wind speed frequency likelihood density, Weibull's probability density, or Rayleigh's probability density.

## 2.1 Weibull Distribution and Rayleigh Distribution Functions for Wind Power Estimation

To carry out wind energy resource capacity appraisal, two parameters Weibull probability density function which has been widely used in documents [7, 11] is described by (3) for *v,* b and α are wind velocity, scale factor in m/s and unit less shape factor respectively, and are greater than zero.

$$f(v) = \frac{a}{b}\left(\frac{v}{b}\right)^{a-1} \exp\left(-\left(\frac{v}{b}\right)^{a}\right) \tag{3}$$

The Weibull cumulative distribution function is also described in [11, 12] is

$$F(v) = \int_0^v f(v)dv = 1 - \exp\left(-\left(\frac{v}{b}\right)^{a}\right) \tag{4}$$

Based on a value of shape parameter, Weibull distribution is related to different other probability distribution functions; particularly for α = 2, it becomes Rayleigh distribution for the scale parameter can be set equal to average wind speed.

The Rayleigh distribution model is the easiest wind speed probability distribution function to represent the wind energy potential or possible resource. To describe this function the mean wind pace is considered as a scaling factor. Rayleigh probability density and its cumulative distribution functions are respectively described [11, 13] as shown below.

$$f(v) = \frac{\pi}{2}\left(\frac{v}{v_{mn}^2}\right) \exp\left(-\frac{\pi}{4}\left(\frac{v}{v_{mn}}\right)^2\right) \tag{5}$$

For $v_{mn}$ is a statistical mean wind speed of sample data.

$$F(v) = 1 - \exp\left(-\frac{\pi}{4}\left(\frac{v}{v_{mn}}\right)^2\right) \tag{6}$$

**Weibull Distribution Parameters Determination.** There are several techniques to evaluate the shape factor and scale factor in Weibull distribution using real-time wind data. The frequently used techniques are the graphical, moment, maximum likelihood, the least square regression, energy pattern factor, and the standard deviation methods [11, 13–16]. For this study, the energy pattern factor technique (EPF) was used in finding the Weibull distribution parameters. EPF is described as the average of the cube of each wind pace measured at considered height and site divided by the cube of the average speed of wind of the whole data [17, 18]. That is the division of power density exists in the wind to the power associated with the cube of average wind speed. EPF is formulated using per month mean wind power density (MMWPD) as follows. Per month mean power available in aerodynamic is

$$P = 0.5A\rho \sum_{i=0}^{n} \frac{v_i^3}{n} \tag{7}$$

$$MMWPD = \frac{P}{A} = 0.5\rho \sum_{i=0}^{n} \frac{v_i^3}{n} \tag{8}$$

For $v_{\mathrm{i}}$ is daily mean wind speed in the sample measured at instant i day, and n is total days in the month. The cube of statistical mean wind speed ($\mathrm{V_{mn}}$) is

$$v_{mn}^3 = \left[\sum_{i=1}^{n} v_{\frac{i}{n}}\right]^3 \tag{9}$$

Then the energy pattern factor is

$$EPF = \frac{\sum_1^n \frac{v_i^3}{n}}{\left[\sum_1^n v_{\frac{i}{n}}\right]^3} = \frac{MMWPD/0.5\rho}{v_{mn}^3} \tag{10}$$

According to [19, 20] the shape and scaling factors of Weibull distribution are described as

$$\alpha = 1 + \frac{3.69}{EPF^2} \tag{11}$$

$$b = \frac{v_{mn}}{\Gamma(1 + 1/a)} \tag{12}$$

Where the gamma function was expressed as

$$\Gamma(a) = \int_0^\infty x^{a-1}\, e^{-x} dx \tag{13a}$$

$$\Gamma(1 + a) = a\Gamma(a) \tag{13b}$$

The Weibull scale parameter can be calculated by applying the following relation [21].

$$b = \frac{v_{mn}.a^{2.6674}}{0.184 + 0.816.a^{2.78855}} \tag{14}$$

**Available Wind Power Density Estimation by Weibull and Rayleigh Models.** Using the Weibull parameters those were already found, meaningful powers available in the wind such as most likely wind power and highest wind power at the selected site and height are estimated. These two powers associated with the most likely wind speed and the wind speed that carrying maximum power respectively. The most likely wind speed ($V_{mps}$) is a most repeated wind speed used in selected the probability distribution and its expression [11, 21] was given as

$$V_{mps} = b\left(\frac{a-1}{a}\right)^{\frac{1}{a}} \tag{15}$$

The expression for wind speed that carries the highest power ($V_{maxp}$) is

$$V_{maxp} = b\left(\frac{a+2}{a}\right)^{\frac{1}{a}} \tag{16}$$

The unit of $V_{mps}$ and $V_{maxp}$ is m/s. The most frequent power density ($P_{fpd}$) and maximum power density ($P_{mpd}$) are good indications of the amount of power available on the site. These power densities can be manipulated by substituting Eq. (15) and Eq. (16) in to Eq. (17) for $v$ is $V_{mps}$ or $V_{maxp}$.

$$P_{fpd} = 0.5\rho V_{mps}^3 \tag{17}$$

$$P_{mpd} = 0.5\rho V_{maxp}^3 \tag{18}$$

Applying the Weibull and Rayleigh model, the average power density available at the selected site can be manipulated by substituting Eq. (12) in to Eq. (17) for $V_{mps}$ equal to $V_{mn}$ and in m/s. The mean power density for the Weibull model ($P_{we}/A$) is described as

$$\frac{P_{we}}{A} = 0.5\rho V_{mn}^3 = 0.5\rho b^3\Gamma\left(1+\frac{3}{a}\right) \tag{19}$$

In the case of Rayleigh model, the Weibull shape parameter was set to 2 with scale parameter is equal with $V_{mn}$, average power density in the wind ($P_R/A$) was described as

$$\frac{P_R}{A} = \frac{3}{\pi}\rho V_{mn}^3 = \frac{3}{\pi}\rho b^3 \tag{20}$$

## 2.2 Wind Power Density Estimation Based on the Wind Speed Frequency Distribution

The wind pace frequency distribution likelihood density function was derived as follows.

$$f(v_i) = \frac{freq_i}{\sum_{i=1}^{n} freq_i} \tag{21}$$

For $freq_i$ is the number of wind pace occurrences in each bin and i = 1, 2,…, n is bin number. Monthly mean wind speed is

$$V_{mn} = \sum_{i=1}^{n} v_{mni}.f(v_i) \tag{22}$$

$V_{mni}$ is the average wind speed of each bin. Monthly mean power density ($P_{fd}/A$) based on wind speed probability distribution is formulated by

$$\frac{P_{fd}}{A} = \sum_{i=1}^{n} [\frac{1}{2}\rho.(v_{mni})^3.f(v_i)] \tag{23}$$

## 3 Method

Real wind speed data measurement was gathered for a year at the ADAMA farm site. The real-time series data was obtained from Ethiopia Electric Power. This site is geographically located at the latitude of 8° 18′ 35.5″N, the longitude of the 38° 53′ 4.2″E and elevation of 1712 m above sea level in Ethiopia about 95 km far away to the south of Addis Ababa. Data were collected at 10 m above ground. At this site, a steady atmosphere density of 1.2 kg/m$^3$ was considered. Wind speed samples were collected using a WICOM-32 data logger (wind computer). Data is logged every 600 s or 10 min. In 24 h or a day WICOM-32 data logger stores 144 samples of average wind speed, highest wind speed, lowest wind, and standard deviance in m/s and wind direction in degree. One sample measurement is 7.2, 11.6, 3.5, 1.6, 85°. The statically daily mean wind speeds for twelvemonth were processed using Microsoft Excel and Matlab. All other wind speed statistics and statistical estimation of wind power were done using daily mean wind speeds.

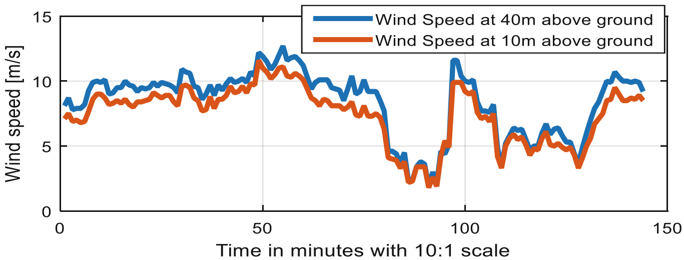


**Fig. 1.** Real-time wind speed profiles on January 1st, 2018 every 10-min wind pattern.

Real time-series wind speed data on the first day of January 2018 has been indicated in Fig. 1. The data was gathered at 10 m and 40 m height which fluctuates in the range of 6–14 m/s, and 12–17 m/s correspondingly. This indicates a variation of wind pace in space and time. Daily fluctuating wind speed in January, March, and September of the 2018 year was shown in Fig. 2. This gives information about daily wind patterns. In most of the durations in these months wind speed exceeds 4 m/s. From Fig. 2 it is clear that in January about 20–25% of the month, the wind velocity is varying between 7 and 10 m/s.

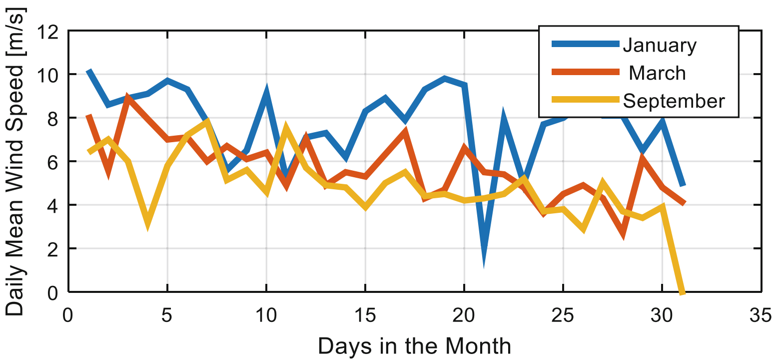


**Fig. 2.** Real-time wind speed profiles in January, March, and September of 2018 daily wind pattern

The wind pace direction was presented in Fig. 3 for wind incidence at a 10-m height above the ground at the Adama Wind Farm Station. In this Figure, WS, N, E, S, and W are represented wind speed (m/s), North (reference), East, South, and West directions respectively. Figure 3 indicated that yearly dominant wind was coming from ENE and West directions with a magnitude greater than 5 m/s.

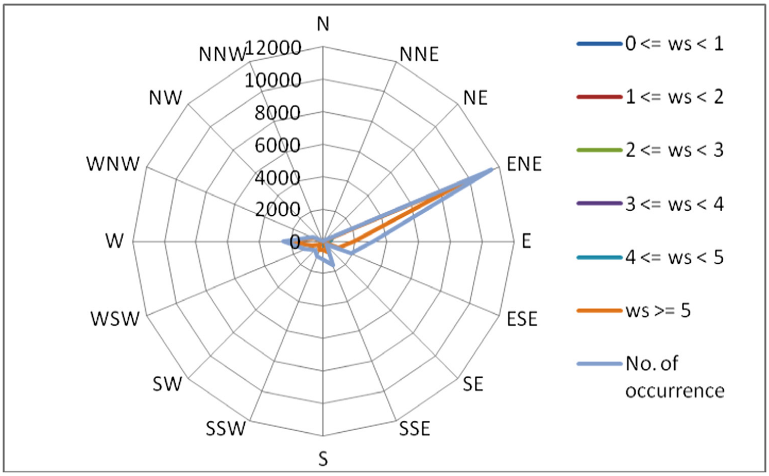


**Fig. 3.** Wind Speed Direction (wind Rose) in the year 2018 at Adama Wind Farm Site

## 4 Result and Discussion

The statistical mean wind speeds for twelvemonths and Weibull distribution parameters were calculated. Their values were tabulated in Table 1. In all cases mean speed exceeds 5.5 m/s. The standard wind turbine hub height is 50 m.

**Table 1.** Per month mean wind speed at 10-m height, two parameters of Weibull distribution function and gamma function value at Weibull distribution Shape factor for months in 2018

| Month | Parameters | | | | | | |
|---|---|---|---|---|---|---|---|
| | $V_{mn}$ | EPF | α | *b* | $V_{mps}$ | $V_{maxp}$ | $\Gamma(1 + 3/\alpha)$ |
| January | 7.7200 | 1.14 | 3.84 | 7.99 | 7.3900 | 8.9200 | 0.9300 |
| February | 7.2700 | 1.08 | 4.19 | 7.45 | 6.9800 | 8.1800 | 0.9100 |
| March | 5.7700 | 1.18 | 3.67 | 5.96 | 5.4700 | 6.7100 | 0.9400 |
| April | 5.5500 | 1.17 | 3.71 | 5.78 | 5.3100 | 6.4900 | 0.9300 |
| May | 5.7800 | 1.10 | 4.07 | 5.97 | 5.5700 | 6.5900 | 0.9200 |
| June | 6.8000 | 1.12 | 3.97 | 7.10 | 6.5300 | 7.7800 | 0.9200 |
| July | 7.1900 | 1.09 | 4.10 | 7.39 | 6.9000 | 8.1400 | 0.9100 |
| August | 6.8300 | 1.15 | 3.79 | 7.09 | 6.5400 | 7.9300 | 0.9300 |
| September | 5.0000 | 1.20 | 3.56 | 5.20 | 4.7400 | 5.9000 | 0.9400 |
| October | 5.7500 | 1.19 | 3.63 | 5.99 | 5.4800 | 6.7600 | 0.9400 |
| November | 7.8200 | 1.04 | 4.42 | 7.99 | 7.5300 | 8.6800 | 0.9100 |
| December | 7.6900 | 1.08 | 4.15 | 7.90 | 7.3900 | 8.6800 | 0.9200 |

The wind speed profile at this tallness can be approximately evaluated using the wind speed profile at 10 m height by applying power-law with a 0.2 shear factor. Because the ADAMA farm site is a terrain with small trees and crops. Hence, the mean wind speed will be 7.60 m/s. Other important results in Table 1 Weibull distribution parameters are manipulated by using the energy pattern factor method. In each month the size (scale) factor is greater than the shape (appearance) factor. Its value is near the value of average speed. The most likely wind speed, as well as the wind speed carrying the highest power, was found using the manipulated Weibull parameters. From Table 1 it was seen that most likely wind pace is less than mean wind pace whereas the wind pace that transports the highest power is greater than mean wind pace in all months. This indicates there is an opportunity to capture wind power greater than the mean value. These parameters in combination with the required gamma function value are used to find the power densities corresponding to most probable, maximum, Weibull, and Rayleigh models as the results are tabulated in Table 3.

For numerical examination of the selected site wind power capacity, real-time wind paces, which are presented in Fig. 1 and Fig. 2 were arranged in the frequency distribution as in Table 2. The January month wind speed ($v_i$) is clustered into bin classes as indicated

**Table 2.** January real-time wind pace in occurrence packet and probability density distributions based on wind speed probability density ($f(v_i)$), Weibull ($f_{we}(v_i)$), wind speed frequency distribution power density ($P_{fd}$ /A) and Rayleigh ($f_{Ra}(v_i)$) functions.

| Bin | Speed Range | $V_{mni}$ (m/s) | $freq_i$ | $f_{We}(v_i)$ | $f_{Ra}(v_i)$ | $f(v_i)$ | $V_{mn}$ (m/s) | $P_{fd}/A$ ($W/m^2$) |
|---|---|---|---|---|---|---|---|---|
| 1 | 0–1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 1–2 | 2 | 1 | 0.0108 | 0.0614 | 0.0323 | 0.0677 | 0.35849 |
| 3 | 2–3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 3–4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 4–5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 5–6 | 5.20 | 4 | 0.1170 | 0.1066 | 0.1290 | 0.6710 | 21.77156 |
| 7 | 6–7 | 6.40 | 3 | 0.1669 | 0.1055 | 0.0968 | 0.6194 | 30.44253 |
| 8 | 7–8 | 7.64 | 7 | 0.1822 | 0.0959 | 0.2258 | 1.7252 | 120.8364 |
| 9 | 8–9 | 8.45 | 8 | 0.1630 | 0.0865 | 0.2580 | 2.1807 | 186.8442 |
| 10 | 9–10 | 9.40 | 7 | 0.1180 | 0.0738 | 0.2258 | 2.1226 | 225.0615 |
| 11 | 10–11 | 10.2 | 1 | 0.0749 | 0.0627 | 0.0323 | 0.3290 | 41.07902 |
| Sum | | | 31 | 0.8328 | 0.5924 | 1 | 7.7155 | 626.40 |

in Table 2 second column. The average wind speed ($V_{mni}$) in each bin is in the third column. Observations or frequencies (freq) of each speed and corresponding probability distribution are listed in the fourth and seventh columns respectively. The fifth and sixth columns represent the values of Weibull and Rayleigh probability density at each speed. The highest monthly power density is found for the wind speed is flanked by 8 and 10 m/s. Considering the wind speed likelihood density ($f(v_i)$) function, the total monthly power density is 313.2 $W/m^2$. In this month, if a single unit wind turbine generator with a blade length of 37 m and 70 m hub height will be installed, 11.7 MW power can be obtained using the vertically extrapolated data which was measured at 10 m into the height of turbine hub applying power-law with the shear factor of 0.2. This is a good indication for Ethiopian to expand wind farm plants around the ADAMA wind farm site and hence conserve forest that is used for biomass to meet energy demand.

Figure 4 and Fig. 6 represent the likelihood density function of the Weibull model and the Rayleigh model respectively. From these statistical figures, it is clear that in all twelvemonths the means speed for the Weibull probability density distribution is shifted to the right side from statistical mean speed whereas in the case of the Rayleigh probability density distribution the means from the plot are around the statistical mean speed of each month wind speed. Figure 5 as well as Fig. 7, represents the cumulative distribution function of the Weibull model and the Rayleigh model respectively. In these figures, some of the plots were overlapped since the data in different months are closely the same. From the Weibull cumulative distribution plot and evaluating Eq. (4) with parameters in Table 1; it can be concluded that 60% of the data in the sample is more than the statistical mean wind speed for January month.

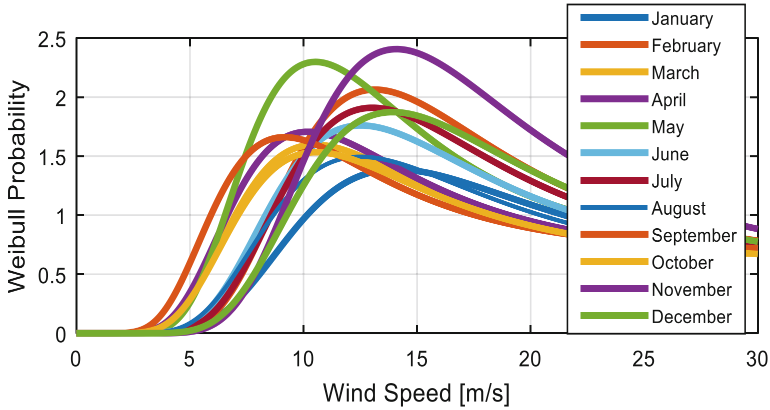


**Fig. 4.** ADAMA wind speed characteristic in 2018 by Weibull Probability Density function

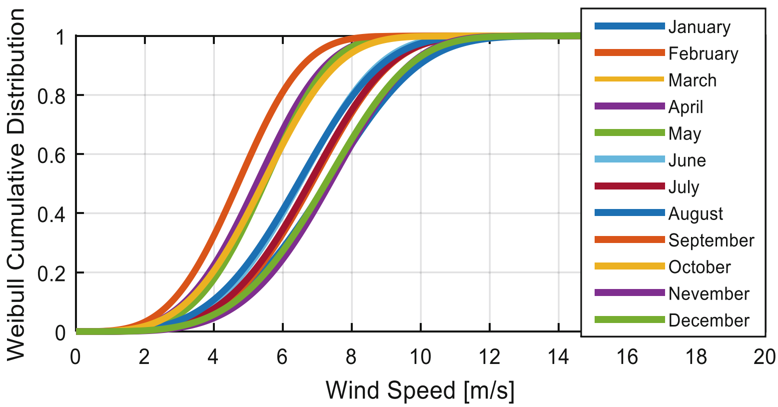


**Fig. 5.** Weibull Cumulative Distribution for the ADAMA site wind speed in 2018.

Similarly, from the Rayleigh cumulative distribution curve and evaluating Eq. (6) with parameters in the same Table, in January and February 54% of data is greater than the statistical mean wind speed. These hold for the whole data in the considered year.

Using available wind speed data with the implementation of the selected models, the values of mean wind power densities were evaluated. The results are tabulated in Table 3. These are the majority significant results that used in deciding whether the selected site wind power capacity is permissible or not. At this site in January, November, and December the power density was very large. In September, April, and October it was relatively lower than the power densities of other months. As indicated in Table 3, ADAMA wind farm site has 850 W/m$^2$, 814 W/m$^2$, 629 W/m$^2$, and 568 W/m$^2$ power densities for utmost extractable, by Rayleigh distribution model, wind pace frequency distribution model, and Weibull distribution model respectively in January 2018 at 10 m above the ground. The Rayleigh model provides relatively more power than the other models.

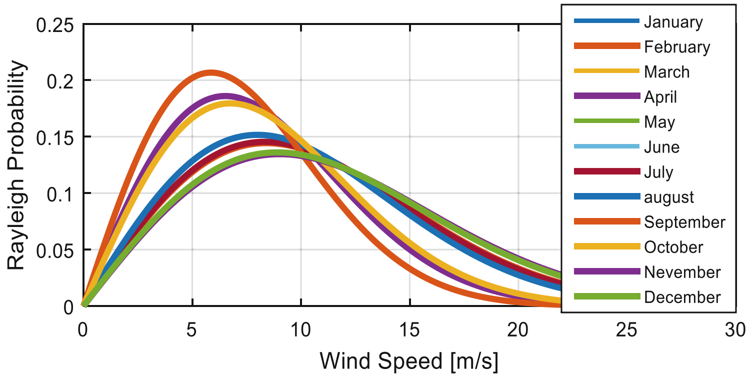


**Fig. 6.** ADAMA wind speed characteristic in 2018 by Rayleigh Probability Density function

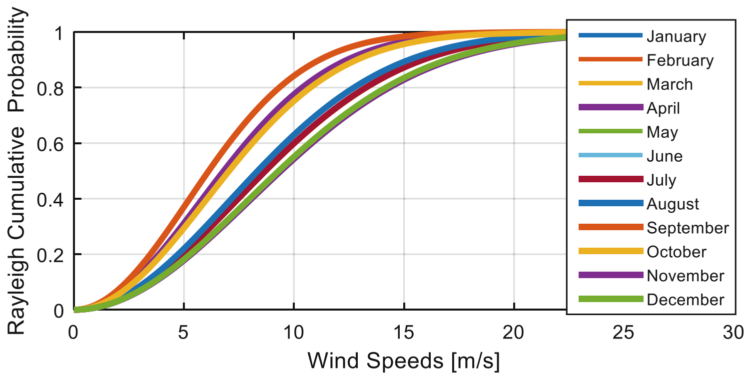


**Fig. 7.** Rayleigh Cumulative Distribution for ADAMA site wind speed in 2018.

For the results in Table 3, the annual average estimated power densities were calculated for most probable power density method, utmost power density approach, Rayleigh model, wind speed frequency distribution model, and Weibull model and the obtained values are 322 W/m$^2$, 545 W/m$^2$, 532 W/m$^2$, 412 W/m$^2$, and 370 W/m$^2$ correspondingly. The estimated mean wind power density using the Rayleigh model is almost equivalent to this maximum power density for the Adama wind farm. The application of the Weibull model and wind speed frequency distribution model to estimate power in the selected wind farm site gave good results. As it was seen in Table 3 the results obtained by these three statistical models were between most probable power density and maximum power density which confirms and validates the adequacy of the result. It needs to compare the mean wind speeds in Table 1 and the power densities in Table 3 with wind class data as it was documented in [2, 5]. Hence, the Adama wind farm site is in an excellent wind class and suitable for wind energy harvesting.

**Table 3.** The average wind power densities, wind speed probability, Weibull and Rayleigh distributions; and corresponding most probable and maximum power densities for the twelve month at Adama wind farm site at 10 m above the ground in the year of 2018.

| Month | Power densities (W/m$^2$) | | | | |
|---|---|---|---|---|---|
| | $P_{fd}$/A | $P_{we}$/A | $P_R$/A | $P_{fpd}$ | $P_{mpd}$ |
| January | 629.0000 | 568.0000 | 814.0000 | 484.0000 | 850.0000 |
| February | 494.4000 | 453.1000 | 660.4000 | 408.1000 | 656.6000 |
| March | 264.9000 | 238.1000 | 337.7600 | 195.9000 | 362.2000 |
| April | 240.5000 | 216.3000 | 304.1200 | 179.7000 | 328.1000 |
| May | 257.0000 | 234.0000 | 340.0000 | 207.0000 | 344.0000 |
| June | 420.0000 | 381.0000 | 552.0000 | 333.0000 | 564.0000 |
| July | 486.0000 | 442.0000 | 644.0000 | 394.0000 | 648.0000 |
| August | 438.8100 | 396.4100 | 568.1200 | 338.2100 | 598.4300 |
| September | 177.2600 | 159.2300 | 224.4300 | 128.5600 | 246.6600 |
| October | 268.0000 | 242.0000 | 342.0000 | 198.0000 | 370.0000 |
| November | 594.8100 | 551.4600 | 810.2100 | 512.3200 | 784.4000 |
| December | 584.54 | 546.3400 | 786.120 | 484.3000 | 784.760 |

## 5 Conclusion

The wind resource assessment includes daily average wind speeds, per month average wind speeds, wind power density, and frequency distribution based on wind speed probability frequency, Weibull and Rayleigh distributions. The wind paces were collected using the WICOM-32 data logger at the ADAMA wind farm site at 10 m above the ground. The two parameters for Weibull distribution were determined. The annual mean wind power densities, as a result, wind pace frequency distribution, Weibull distribution, and Rayleigh distribution models 412 W/m$^2$, 370 W/m$^2$, and 532 W/m$^2$ respectively were estimated in the year 2018. The estimated mean wind power density using the Rayleigh model is almost equivalent to this maximum power density for the Adama wind farm. For sthis site, the annual maximum harvestable power density is 545 W/m$^2$. Based on the collected data and its analysis the selected site is in the excellent wind class. It has utility-scale potential wind power. This is a good indication for Ethiopian to expand wind farm plants around the ADAMA wind farm site and hence conserve natural resources like biomass that most of the countryside communities use to meet energy demand.

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