




# Statistical Analysis of Ethiopian Wind Power Potential at Selected Sites

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**Abstract.** The intent of the study reported in this paper is to make analysis of the wind speed data and annual wind energy potential at Abomsa Metehara and Ziway in Ethiopia. The wind speed data was collected from National Metrology Agency of Ethiopia, and then monthly and annual mean wind speed, wind power potential, wind energy potential and Weibull distribution parameters for these three sites have been analyzed and assessed. In the results, the monthly mean wind speeds, the measured and Weibull estimated of most probable monthly wind velocity, wind velocity carrying maximum energy, monthly wind power and wind energy density for these three sites at site locations have been estimated. Based on monthly and annually mean wind speeds at stations, annually and monthly mean wind velocities at 40 m, 60 m, 80 m, 100 m and 120 m heights via wind shear law have been extrapolated. At these heights, annual mean wind velocity carrying maximum energy, annual most probable wind velocity, annual mean wind power and annual wind energy density for these sites have been estimated. Additionally, the annual cumulative distribution function and probability density function of wind speed for the selected sites have been obtained using the Weibull distribution functions.

**Keywords:** Mean wind speed · Wind power density · Weibull parameters · Wind-driven water pump

## Abbreviations

$ED_{ci}$	Individual corrected measured energy density
$ED_{cw}$	Weibull corrected estimation of wind energy density
$f(v)$	Probability of observing wind speed ( $v$ )
$F(v)$	Cumulative of observing wind speed ( $v$ )
$h_1; h_2$	Height of data measured; the selected height
$N$	Number of collected data
$n$	Exponent of Weibull scale parameter at $h_2$
$P_{Dci}$	Individual corrected measured wind power density
$P_{Dcw}$	Weibull corrected estimation of wind power density
$T$	Period or time
$v$	Wind speed

$V_1; V_2$	Wind velocity at stations ( $h_1$ ); corrected wind velocity ( $h_2$ )
$v_m$	Mean wind speed
$V_{mE}$	Wind speed carrying maximum energy
$V_{mP}$	Most probable wind speed
$Z$	Is the roughness height of terrain

## Symbols

$\alpha$	Weibull shape parameter
$\alpha_{h2}$	Weibull shape parameter at $h_2$
$\beta$	Weibull scale parameter
$\beta_{h1}$	Weibull scale parameter at $h_1$
$\beta_{h2}$	Weibull scale parameter at $h_2$
$\rho$	Air density
$\mu$	Weibull location parameters
$\gamma$	Wind shear exponent
$\sigma$	Standard deviation
$\Gamma(x)$	Gamma function

## 1 Introduction

Fossil fuels, as resources energy, are important for power generation which plays significant role in global economic development [1]. Contrary to the important role fossil fuels play, this source of energy has certain key limitations such as limited amount of available reserves and carbon emissions. The last mentioned one of the known unwanted environmental effects of use of fossil fuels as source of energy. As a result, recent focus is directed towards use of renewable energy sources and improving the efficiency and the management of energy sources [1, 2]. Among the available renewable energy sources, wind energy is the forefront energy resource for remote rural areas, for example for power generation and for water pumping purposes. Nowadays, many countries see wind energy as an alternative source of energy in order to mitigate the negative effects of fossil fuels. The operation of wind energy system is influenced by several factors such as size of generated power, wind shaft position and the wind regime [3]. Furthermore, wind speed potential analysis of a region is crucial to choose the proper wind energy conversion system. In order to map the existing potentials, wind speed frequency distribution is used and displayed using diverse distribution functions such as Gamma, lognormal, Rayleigh and Weibull. From these distribution functions, two parameter of Weibull distribution are used to model the wind speed in many regions of the world in recent years. This is because this method provides very good fit wind distribution [3].

Ethiopia is a country benefitting from wind energy resources in every region [4]. Wind energy potential in Ethiopia is estimated to be enormous due to local peculiar landscape. However, the country started to utilize the potential only very recently. One of the reasons for low utilization of wind energy in Ethiopia is the absence of reliable and accurate wind energy resource data. Development of reliable and accurate wind atlas helps to

identify candidate sites for wind energy applications and facilitates the planning and implementation of wind energy projects [5]. However, the whole land area of the country practically falls under various wind resource categories without excluding land areas that could possibly be eliminated for reasons of accessibility, economics or environmental parameters [6]. In this work, the analysis of wind speed data and assessment of their wind energy potential for three selected sites was conducted. For 1-year (October 2018 to September 2019), every three hours a day, the wind data valid for a height of 10 m were collected from the National Meteorological Agency (NMA) of Ethiopia and daily mean wind speed were determined which was used as input parameter. The geographical location of the selected sites are Metehara (longitude  $39^{\circ}55'8.4''$ E, Latitude  $8^{\circ}51'31.2''$ N and altitude 944 m a.s.l), Abomsa (Longitude  $39^{\circ}49'58.8''$ E, Latitude  $8^{\circ}28'0.12''$ N and altitude 1630 m a.s.l) and Ziway (Longitude  $38^{\circ}56'51''$ E, Latitude  $7^{\circ}58'57.9''$ N and altitude 1705 m a.s.l).

Based on these collected data, the monthly and annual average wind velocities and their predicting wind power and energy output have been estimated at stations height and at extrapolated heights of 40 m, 60 m, 80 m, 100 m and 120 for the three selected sites. Weibull parameters, probability density and cumulative distributions function and most probable monthly wind velocity, wind velocity carrying maximum energy were considered.

## 2 Review of Previous Studies in Ethiopia

Some of previous reports that contributed to analysis of wind speed data and energy potential assessing at different sites in Ethiopia are Getachew et al. [7] who investigated the wind energy potential at four different sites in Ethiopia, i.e. (1) Addis Ababa ( $09:02$ N,  $38:42$ E), (2) Adama ( $08:32$ N,  $39:22$ E), (3) Bishoftu ( $8:44$ N,  $39:02$ E) and (4) Mekele ( $13:33$ N,  $39:30$ E). The data are compiled from various sources to make analysis using a software tool for data measured at the specified height (i.e. 10 m). The result showed a reasonable wind energy potential with average wind speed of about 4 m/s and mean wind speed of less than 3 m/s. Benti et al. [4] investigated the wind power potential of Ambo area in West Ethiopia using real wind speed data. A 6-year wind speed data (2010–2015) at 10 m height was obtained from the NMA of Ethiopia and statistically analyzed. According to the result, Ambo has an average wind speed of 3.2 m/s at the targeted height, where the wind gets maximum value of 4.5 m/s in February and minimum speed of 2.0 m/s in June and July. Wind data at 30 m and 50 m was extrapolated. Kumar et al. [8] analyzed wind speed data for energy production in Adama area. To design a small scale energy production from wind turbines, it is essential to get the probability density function, the cumulative density function and the cut-in wind speed of the targeted location. Bayray et al. [5] reported that wind data collected at 10 m over a period of one year from measuring masts in six different sites in Tigray, Ethiopia.

The data was analyzed and evaluated for the wind energy potential of the area by using different statistical software. Gaddada et al. [9] studied the wind resource assessment in the selected locations in Tigray, Ethiopia. Based on the wind assessed, three commercial wind turbines were chosen for technical assessment of electric power generation in eight selected locations. Girma [10] studied the wind speed distribution and estimated

and comparative study of Weibull to Rayleigh distribution function has been analyzed for Dire Dawa and Hawasa in Ethiopia. Dulla et al. [11] examined wind energy potential of six sites i.e. Hawassa, Dilla, Wolayita sodd, Hossana, Wolkite and Butajira in southern Ethiopia. Weibull distribution function was used to analyze daily wind speed in five years, as well as the daily temperature and pressure of the areas. All sites have more than 50% chances that the wind speeds are greater than 4 m/s.

As the above review of literature shows, previous studies were based on wind speed data collected at a specified height, i.e. 10 m, and extrapolated the values in order to determine the wind speed for multiple numbers of heights to get more wind speeds and assess their wind power potential. If actual rotors of the wind turbines are placed more than 10 m height, it can be possible to estimate the variations of wind speed extracted at any different heights. Unlike the previous studies, this study focuses on specifically three selected location sites in Ethiopia i.e. Abomsa, Metehara and Ziway to analyze the wind speed potential and assesses their wind power and wind energy potential of these three selected sites at different heights.

### 3 Mathematical Formulation

The Weibull distribution approximates the probability laws of many natural phenomena. It has been used to represent wind speed distributions for application in wind loads studies. This method has greater flexibility and simplicity. Furthermore, it also gives a good fit to experimental data for wind energy applications. Weibull probability density function for three parameters is expressed as [12]:

$$f(v) = \left(\frac{\alpha}{\beta}\right) \left(\frac{v - \mu}{\beta}\right)^{\alpha-1} \exp\left[-\left(\frac{v - \mu}{\beta}\right)^\alpha\right] \tag{1}$$

Where,  $v$  is the wind speed,  $\alpha$ ,  $\beta$  and  $\mu$  are the shape, scale and location parameters respectively. As  $v \geq 0$ , then  $\mu = 0$  and Eq. (1) becomes [1–4]:

$$f(v) = \left(\frac{\alpha}{\beta}\right) \left(\frac{v}{\beta}\right)^{\alpha-1} \exp\left[-\left(\frac{v}{\beta}\right)^\alpha\right] \quad v \geq 0, \alpha, \beta > 0 \tag{2}$$

Where  $f(v)$  is the probability function of observing the wind speed  $v$  whose descriptive parameters can be obtained. Then, the cumulative distribution function  $F(v)$  is given as [12, 13]:

$$F(v) = \int_0^v f(v)dv = 1 - \exp\left[-\left(\frac{v}{\beta}\right)^\alpha\right] \tag{3}$$

The mean value  $v_m$  and standard deviation  $\sigma$  of the wind speed, shape  $\alpha$  and scale parameter  $\beta$  of the Weibull distribution can be expressed as [1, 4, 13]

$$v_m = \beta \Gamma\left(1 + \frac{1}{\alpha}\right) \tag{4a}$$

$$\sigma = \beta \left[ \left\{ \Gamma\left(1 + \frac{2}{\alpha}\right) - \left[ \Gamma\left(1 + \frac{1}{\alpha}\right) \right]^2 \right\} \right]^{\frac{1}{2}} \tag{4b}$$

$$\alpha = \left( \frac{\sigma}{V_m} \right)^{-1.0860} \tag{4c}$$

$$\beta = \frac{\bar{v}}{\Gamma(1 + \frac{1}{\alpha})} \tag{4d}$$

The measured standard deviation can be estimated from

$$\sigma = \left\{ \left( \sum_{i=1}^N v_i - v_m \right) / N \right\}^{0.5} \tag{5}$$

### 3.1 Wind Speed Extrapolation

In most locations, wind speed varies with height, a phenomenon known as wind shear. The variation of wind speed as a function of height can be obtained using wind shear power law given as Eq. (6a) and the wind shear exponent as Eq. (6b) [12–14]:

$$V_2 = V_1 \left( \frac{h_2}{h_1} \right)^\gamma \tag{6a}$$

$$\gamma = \left[ 0.096 \left( \log_{10}^{(Z)} \right) + 0.016 \left( \log_{10}^{(Z)} \right)^2 + 0.24 \right] \tag{6b}$$

Where  $h_1$  is 10 m,  $h_2$  is the selected height,  $V_1$  is the wind velocity at stations (10 m),  $V_2$  is the corrected wind velocity ( $h_2$ ),  $\gamma$  is the wind shear exponent and  $Z$  is the roughness height of terrain, which is 1.5 m for the selected sites. The corresponding shape and scale parameters are expressed as [2]:

$$\alpha_{h_2} = \frac{\alpha_{h_1}}{1 - 0.0881 \ln(h_2/h_1)} \tag{7a}$$

$$n = 0.37 - 0.0881 \ln \beta_{h_1} \tag{7b}$$

$$\beta_{h_2} = \beta_{h_1} \left( h_2/h_1 \right)^n \tag{7c}$$

### 3.2 Wind Energy Potential Assessment

The individually corrected measured wind power density and energy density at any height can be considered as [13, 14]

$$PD_{Ci} = \frac{1}{2} \rho v_m^3 \tag{8a}$$

$$ED_{Ci} = \frac{1}{2} \rho v_m^3 \times T \tag{8b}$$

Where T is the time duration. The corrected estimation of wind power density and wind energy density at any height for the selected sites with Weibull distribution can be expressed as given in Eq. (9a, 9b) [4, 14]:

$$PD_{CW} = \frac{1}{2} \rho \beta^3 \Gamma(1 + 3/\alpha) \tag{9a}$$

$$PD_{CW} = \frac{1}{2} \rho \beta^3 \Gamma(1 + 3/\alpha) T \tag{9b}$$

The most probable wind velocity  $V_{mP}$  and wind velocity carrying maximum energy  $V_{mE}$  with Weibull distribution can be expressed as [14]:

$$V_{mP} = \beta \left( \frac{\alpha - 1}{\alpha} \right)^{\frac{1}{\alpha}} \tag{10a}$$

$$V_{mE} = \beta \left( \frac{\alpha + 2}{\alpha} \right)^{\frac{1}{\alpha}} \tag{10b}$$

### 4 Discussion of Numerical Results

The collected wind speed data for Abomsa, Metehara, and Ziway at 10 m height over whole 1-year (October 2018 to September 2019) has been investigated. The wind data was collected during the daytime (06:00 – 18:00) within 3 h interval. The daily average of wind speed data were determined and monthly and annual average of wind velocities, standard deviation, wind power densities, and wind energy densities were estimated based on the measured wind velocities. From numerical results, the monthly mean wind speeds for the three selected sites at a height of 10 m are compared and illustrated in Fig. 1. As seen from Fig. 1, the average monthly distribution of wind speed values fluctuate between the lowest value of 2.01 m/s at Abomsa to the highest value of 4.14 m/s at the Ziway site. And also Fig. 2 demonstrates the daily average wind speed variations for the three sites at 10 m height. It can be seen that the daily average wind speed fluctuations are different in 1-year.

Tables 1, 2, 3 and 4 show the monthly variation of the mean wind speed characteristics ( $V_m$ ,  $V_{mp}$  and  $V_{maxE}$ ), the mean power density and mean energy density as well as the annual values of these parameters at 10 m height. As given in Table 2, the monthly mean wind speed of the selected sites varies from 2.01 m/s in August to 3.82 m/s in January (for Abomsa), from 2.53 m/s in March to 3.37 m/s in June (for Metahara) and from 2.66 m/s in April to 4.14 m/s in June (for Ziway). And also, annual mean wind speed for these sites is 2.80, 2.88 and 3.36 m/s respectively.

The least monthly value most probable wind speed is (1.84 m/s in August) and the wind speed carrying maximum energy is (2.86 m/s in September) in Abomsa and the highest value of most probable wind speed is 4.10 m/s in June and the wind speed carrying maximum energy is 5.54 m/s in November in Ziway site. The measured and estimated monthly mean power density varies between (7.95–37.52 W/m<sup>2</sup> and 7.81–37.63 W/m<sup>2</sup>)

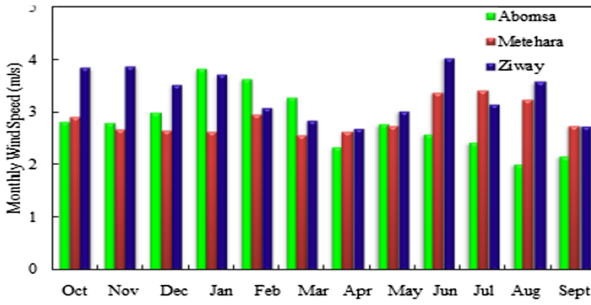


Fig. 1. Plot of monthly variations in mean wind speeds for the three sites at 10 m height.

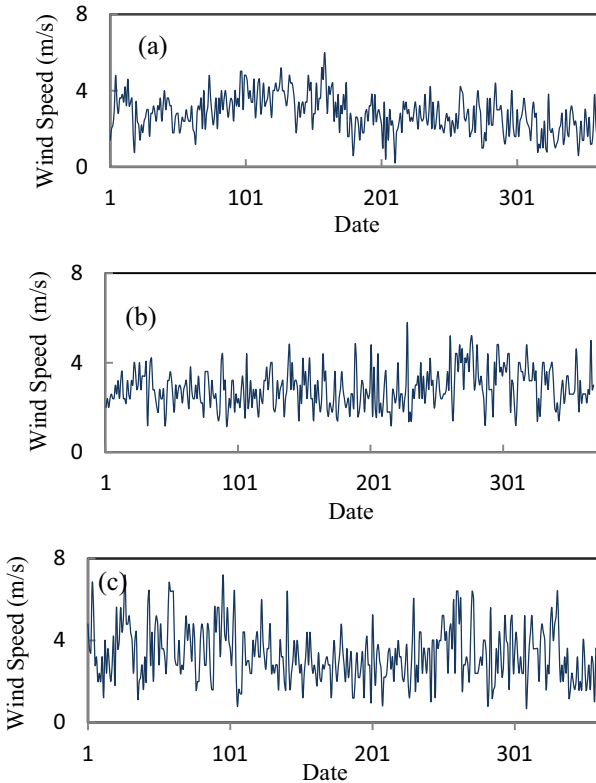


Fig. 2. Daily average wind speeds variation for (a) Abomsa, (b) Metehara and (c) Ziway at 10 m height

in Abomsa, (12.80–29.29 and 12.72–29.49) in Metehara and (16.46–58.87 W/m<sup>2</sup> and 16.72–59.50 W/m<sup>2</sup>) in Ziway respectively as shown in Table 2 and 3.

The smallest monthly value of the Weibull shape factor ( $\alpha$ ) for Abomsa is 2.50 and the highest value is 6.32 in January. The annual shape factors for Abomsa, Metehara and

**Table 1.** The monthly mean wind speed ( $V_m$ ,  $V_{mp}$  and  $V_{mE}$ ) for three selected sites

Year	Month	Abomsa			Metehara			Ziway		
		$V_m$ (m/s)	$V_{mp}$ (m/s)	$V_{mE}$ (m/s)	$V_m$ (m/s)	$V_{mp}$ (m/s)	$V_{mE}$ (m/s)	$V_m$ (m/s)	$V_{mp}$ (m/s)	$V_{mE}$ (m/s)
2018	Oct	2.82	2.80	3.66	2.93	3.07	3.32	3.82	3.63	5.26
	Nov	2.81	2.94	3.18	2.72	2.82	3.20	3.92	3.64	5.54
	Dec	2.99	3.09	3.61	2.63	2.68	3.32	3.56	3.52	4.65
2019	Jan	3.82	4.00	4.29	2.63	2.73	3.14	3.67	3.42	5.15
	Feb	3.63	3.78	4.24	2.92	2.99	3.57	3.05	3.02	3.96
	Mar	3.27	3.18	4.38	2.53	2.56	3.17	2.91	2.99	3.55
	Apr	2.33	2.25	3.13	2.65	2.58	3.53	2.66	2.554	3.61
	May	2.76	2.88	3.17	2.75	2.73	3.58	3.01	2.95	3.99
	Jun	2.58	2.64	3.17	3.39	3.47	4.15	4.14	4.10	5.41
	July	2.42	2.36	3.22	3.36	3.45	4.11	3.20	3.07	4.36
	Aug	2.01	1.84	2.86	3.23	3.34	3.89	3.64	3.53	4.89
	Sept	2.16	2.12	2.86	2.75	2.83	3.35	2.72	2.49	3.89
Annual average		2.80	2.77	3.67	2.88	2.86	3.73	3.36	3.43	4.15

**Table 2.** Monthly measured wind powers and energy densities for three selected sites

Year	Month	Abomsa		Metehara		Ziway	
		$PD_{ct}$ ( $W/m^2$ )	$ED_{ct}$ ( $kWh/m^2$ )	$PD_{ct}$ ( $W/m^2$ )	$ED_{ct}$ ( $kWh/m^2$ )	$PD_{ct}$ ( $W/m^2$ )	$ED_{ct}$ ( $kWh/m^2$ )
2018	Oct	18.35	13.65	17.16	12.76	50.52	37.59
	Nov	15.00	10.80	14.34	10.32	56.47	40.66
	Dec	19.71	14.66	14.51	10.80	37.18	27.66
2019	Jan	37.52	27.92	13.35	9.93	45.95	34.18
	Feb	33.58	22.56	18.78	12.62	23.98	16.12
	Mar	29.94	22.27	12.80	9.52	18.58	13.82
	Apr	10.65	7.67	16.28	11.72	16.46	11.85
	May	14.60	10.86	17.64	13.13	23.37	17.39
	Jun	13.16	9.48	29.29	21.09	58.87	42.39
	July	12.15	9.04	28.35	21.09	28.86	21.47
	Aug	7.95	5.915	24.58	18.29	41.34	30.76
	Sept	8.51	6.124	15.85	11.41	19.74	14.21
Annual average		18.43	161.40	18.58	162.73	35.11	307.57

Ziway are 3.13, 3.22 and 3.81, respectively. The value of the least monthly scale factor ( $\beta$ ) is obtained as 2.26 m/s in Abomsa (August), and the highest value of 4.63 m/s in

Ziway (June). The annual scale factors are 3.13 m/s, 3.21 m/s and 3.72 m/s for Abomsa, Metehara and Ziway respectively (Table 4).

**Table 3.** Estimated Monthly wind powers and wind energy densities for three sites

Year	Month	Abomsa		Metehara		Ziway	
		PD <sub>ct</sub> (W/m <sup>2</sup> )	ED <sub>ct</sub> (kWh/m <sup>2</sup> )	PD <sub>ct</sub> (W/m <sup>2</sup> )	ED <sub>ct</sub> (kWh/m <sup>2</sup> )	PD <sub>cw</sub> (W/m <sup>2</sup> )	Ed <sub>cw</sub> (kWh/m <sup>2</sup> )
2018	Oct	18.60	13.84	17.18	12.780	50.89	37.86
	Nov	15.05	10.83	14.42	10.380	57.41	41.33
	Dec	19.87	14.79	14.58	10.848	37.82	28.14
2019	Jan	37.63	28.00	13.33	9.920	46.49	34.59
	Feb	33.87	22.76	18.86	12.671	23.51	15.80
	Mar	30.46	22.67	12.72	9.467	18.60	13.84
	Apr	11.07	7.973	16.08	11.578	16.72	12.04
	May	14.61	10.87	17.37	12.921	23.46	17.45
	Jun	13.11	9.439	29.49	21.231	59.60	42.92
	July	12.23	9.101	28.74	21.384	29.38	21.86
	Aug	7.81	58.08	25.05	18.639	42.26	31.44
	Sept	8.607	61.97	15.68	11.291	19.57	14.09
Annual average		18.45	161.65	19.70	172.613	29.15	255.367

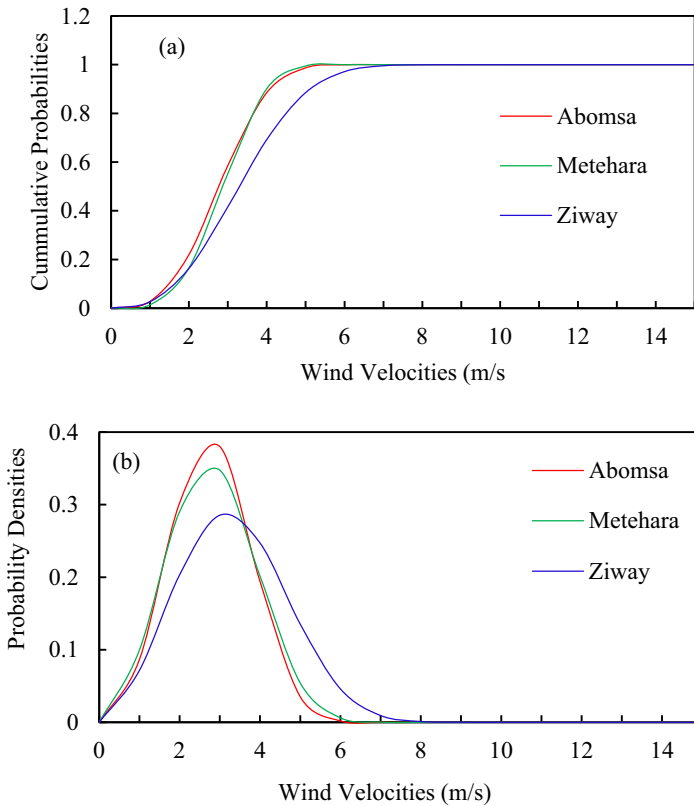
**Table 4.** Monthly standard deviation, shape and scale parameters for three sites

Year	Month	Abomsa			Metehara			Ziway		
		$\alpha$ (-)	$\beta$ (m/s)	$\sigma$ (m/s)	$\alpha$ (-)	$\beta$ (m/s)	$\sigma$ (m/s)	$\alpha$ (-)	$\beta$ (m/s)	$\sigma$ (m/s)
2018	Oct	3.21	3.15	0.97	5.97	3.16	0.57	2.718	4.30	1.52
	Nov	5.97	3.03	0.55	4.70	2.97	0.66	2.55	4.42	1.64
	Dec	4.25	3.29	0.80	3.61	2.94	0.81	3.14	3.98	1.24
2019	Jan	6.32	4.11	0.71	4.45	2.89	0.67	2.59	4.13	1.52
	Feb	4.95	3.95	0.84	3.96	3.22	0.83	3.20	3.40	1.05
	Mar	2.94	3.67	1.21	3.58	2.81	0.78	4.02	3.21	0.81
	Apr	2.89	2.61	0.87	2.97	2.97	0.97	2.82	2.98	1.02
	May	5.42	2.99	0.59	3.19	3.07	0.95	3.02	3.37	1.09
	Jun	3.89	2.85	0.74	3.95	3.74	0.96	3.15	4.63	1.44
	July	2.98	2.71	0.89	3.97	3.71	0.95	2.80	3.59	1.24
	Aug	2.50	2.26	0.84	4.24	3.56	0.86	2.91	4.08	1.36
	Sept	3.04	2.42	0.78	4.05	3.03	0.76	2.48	3.07	1.17
Annual average		3.13	3.19	0.98	3.22	3.21	0.98	3.81	3.72	0.98

Figure 3(a) and (b) show the annual cumulative distribution function (CDF) and probability density function (PDF) of wind speed for three sites respectively. The CDF is used to estimate the time when the wind speed is within a certain speed interval. As Fig. 3(b) shows, the most frequent expected wind speed in Ziway, Abomsa and Metehara are about 3.5, 2.8 and 2.8 m/s respectively.

The measured wind speed is extrapolated, because data was collected at a limited number of heights (10 m), for determining the wind speed for multiple numbers of heights to get more wind speeds and assess their wind power potential. And also by considering, if actual rotors of the wind turbines are placed more than 10 m height, we estimated the variations of wind speed extracted at any different heights such as 40 m, 60 m, 80 m, 100 m and 120 m.

The estimated values of extrapolation of annual average wind speed, the wind powers, energy densities, mean wind speed characteristics ( $V_{mp}$  and  $V_{mE}$ ) and scale and shape parameters at different selected heights for three selected sites presented in Table 5. Generally, the three site's wind speeds are suitable for lifting water, or for battery charging purposes. And also the wind speed for Ziway is suitable for small wind farms.



**Fig. 3.** Annual wind speed distribution (a) CDF and (b) PDF for three selected sites

**Table 5.** Extrapolated value of annual parameters for three sites at selected heights

Sites	H (m)	$V_m$ (m/s)	$\alpha$ (-)	$\beta$ (m/s)	$PD_{cw}$ ( $W/m^2$ )	$Ed_{cw}$ ( $kWh/m^2$ )	$V_{mp}$ (m/s)	$V_{mE}$ (m/s)
Abomsa	40	3.41	3.56	4.55	54.29	475.58	4.15	5.15
	60	3.62	3.72	5.07	74.57	653.26	4.66	5.69
	80	3.77	3.83	5.48	93.46	818.71	5.06	6.12
	100	3.89	3.92	5.82	111.38	975.68	5.40	6.46
	120	3.99	4.01	6.11	128.57	1126.25	5.69	6.76
Metehara	40	3.51	3.67	4.65	57.62	504.76	4.26	5.23
	60	3.72	3.83	5.18	79.00	692.06	4.79	5.78
	80	3.87	3.94	5.59	98.88	866.17	5.20	6.21
	100	4.00	4.04	5.94	117.71	1031.16	5.54	6.56
	120	4.10	4.12	6.24	135.76	1189.27	5.83	6.86
Ziway	40	4.09	4.34	5.29	82.06	718.85	4.98	5.77
	60	4.34	4.53	5.86	111.22	974.32	5.55	6.35
	80	4.52	4.67	6.31	138.06	1209.39	5.99	6.81
	100	4.68	4.78	6.67	163.29	1430.45	6.35	7.18
	120	4.79	4.88	6.99	187.33	1641.00	6.67	7.50

## 5 Conclusion

In this article, the wind speed and wind energy potential over a period of one year (October 2018 to September 2019) has been analyzed and discussed. The annual mean wind speeds are observed to be 2.80 m/s, 2.88 m/s and 3.34 m/s and wind speeds carrying maximum energy are 3.67 m/s, 3.73 m/s and 4.15 m/s for the selected site in Abomsa, Metehara and Ziway respectively, while the annual value of most probable wind velocities are 2.77 m/s, 2.86 m/s and 3.43 m/s at the three sites respectively. The mean annual values of Weibull shape and Scale for Abomsa, Metehara and Ziway are (3.13, 3.22 and 3.81) and (3.13 m/s, 3.21 m/s and 3.72 m/s) respectively.

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