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Investigating the Prospect of Small-Scale Wind Turbines Based on Regional Wind Velocities in Bangladesh

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Abstract

The wind turbine has the advantage of operating uninterruptedly, which ensures a constant source of electricity. This investigation includes a clear overview of the wind velocity, the flow direction; the amount of energy reserved, suitable regions for wind turbine installation, etc. The feasibility and possibility of installing a wind energy conversion system for several locations in Bangladesh are analyzed. A brief study of wind characteristics in different locations in Bangladesh is reported. Wind data obtained from the Bangladesh Meteorological Department (BMD) for Mongla, Patuakhali, Kutubdia, and Bhola stations are analyzed through wind rose, frequency distribution, and average wind velocity. The performance of suitable small-scale wind turbines will be assessed in order to confirm the prospect of wind turbines in Bangladesh.

Keywords

Wind Velocity, Flow Direction, Wind Turbine, Power

1. Introduction

Due to rapid urbanization and industrialization demand for energy is increasing abruptly. Producing energy from fossil fuels causes serious damage to the environment because burning fossil fuels results in the spread of toxic chemicals and gases. To reduce environmental pollution and meet the current energy demand, the implementation of alternative energy sources has obtained massive attention all over the world. Renewable energy resources are regarded as one of the most effective solutions for pollution, emission of greenhouse gases, and energy crises worldwide. Wind energy generation is considered a potential renewable energy resource for resolving the ongoing energy crisis because it provides clean energy at low power generation costs [1] [2] [3]; the reasons behind people having to search for energy from the available resources. On the other hand, renewable energy is eco-friendly as well as provides green energy.

With a total area of 147,570 sq. km, Bangladesh is geographically located between 20˚34 and 26˚38' north latitude and 88˚01 and 92˚41' east longitude. Along the Bay of Bengal, it has 724 km of coastline [4]. Currently, Bangladesh generates a minor part of its total electricity from renewable sources [5]. In order to maintain the development of Bangladesh, it has been estimated that 61 GW of electricity will be needed by 2041 [6]. Initially, we analyze the wind data (wind velocity and wind direction) collected from Bangladesh Metrological Department (BMD). The investigation is based on four wind stations namely Mongla, Patuakhali, Kutubdia and Bhola. Secondly, we will describe the working principle of wind turbines and finally evaluate some well-known wind turbines' performance.

2. Wind Velocity Profiles in Bangladesh

Wind turbines used to generate electricity are examples of clean and renewable energy technology. The present and future projections of the increasing worldwide trend of wind turbine installation address the issue of energy required for manufacture as well as the environmental impact due to energy consumption. Four Coastal areas where the wind is available in good amounts are our subject to investigate. The geographical positions of our selected regions are specified in Figure 1 and described below:

Mongla: situated in Bagerhat District of Khulna Division. Its geographical coordinates are 22˚28' North and 89˚36' East. The international Observatory number of the Mongla station is 41,958. For this station, the elevation in meters is 1.80 m.

Patuakhali: situated in Barisal Division. Its geographical coordinates are 22˚20' North and 90˚20' East. The international Observatory number of the Patuakhali station is 41,906. For this station, the elevation in meters is 1.50 m.

Kutubdia: situated in Cox's Bazar District of Chittagong Division. Its geographical coordinates are 21˚49' North and 91˚51' East. The international Observatory number of the Kutubdia station is 41,989. For this station, the elevation in meters is 2.74 m.

Bhola: situated in Barisal Division. Its geographical coordinates are 22˚41' North and 90˚39' East. The international Observatory number of the Bhola station is 41,951. For this station, the elevation in meters is 4.30 m.

The 3 hourly wind data is collected from the **Bangladesh Meteorological Department (BMD)** for the year from 2017 to 2021. We studied the average velocity and represented them graphically.

Graphical Representation of Average Monthly Velocities in Different Years (2017-2021):

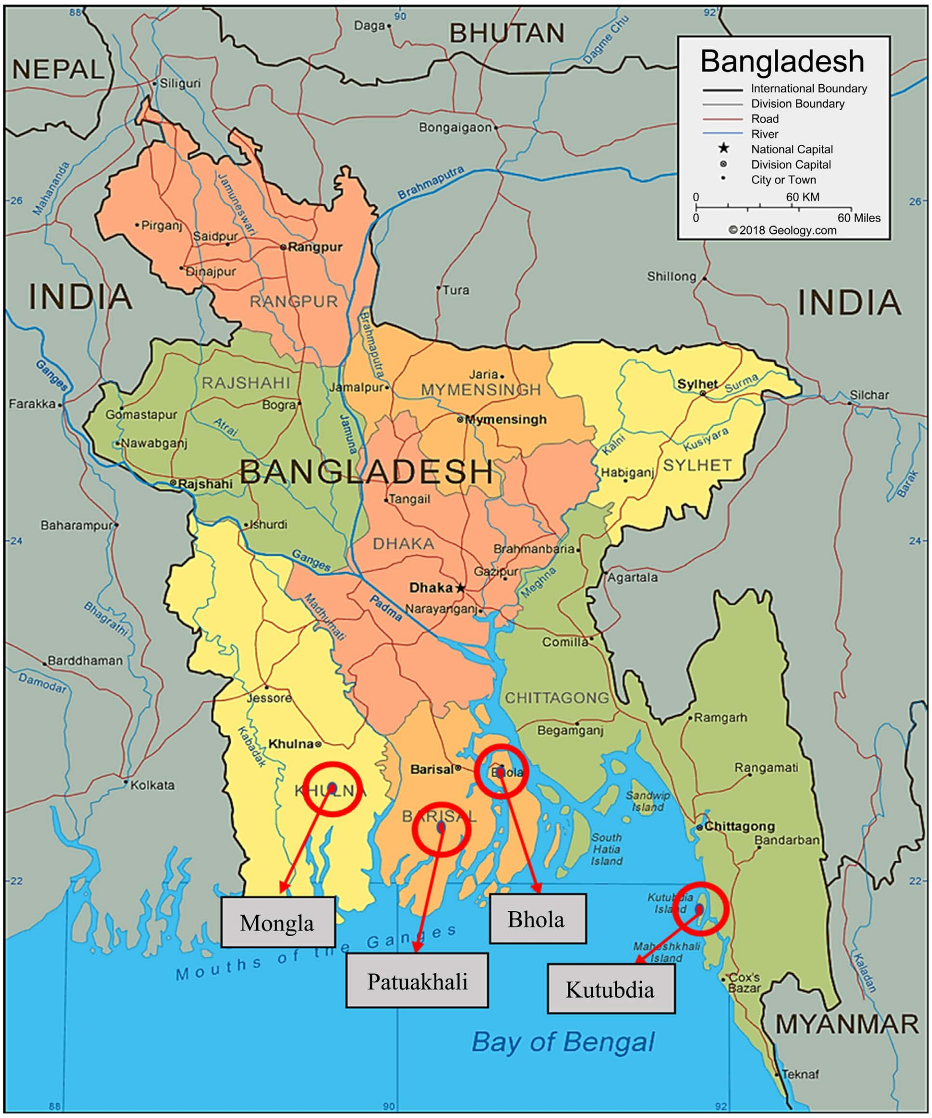


Figure 1. Geographical locations of Mongla, Patuakhali, Kutubdia, and Bhola.

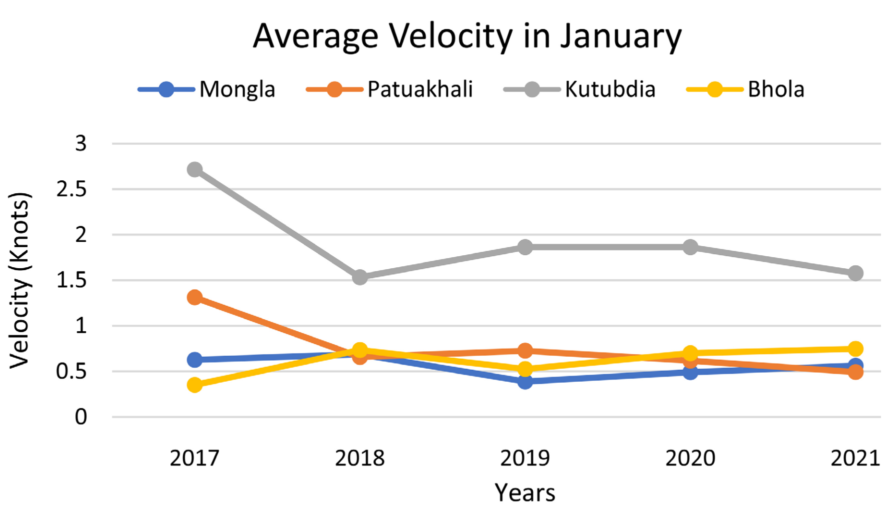


Figure 2. Average velocity in January.

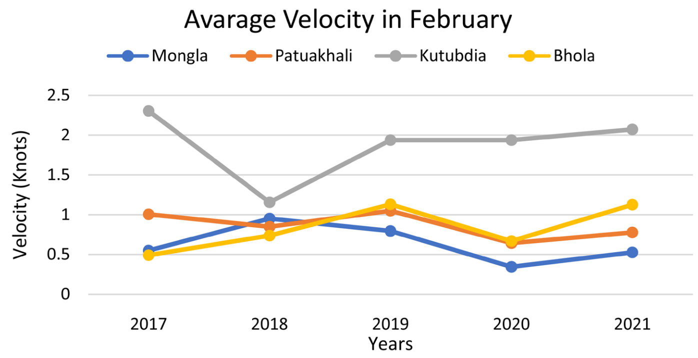


Figure 3. Average velocity in February.

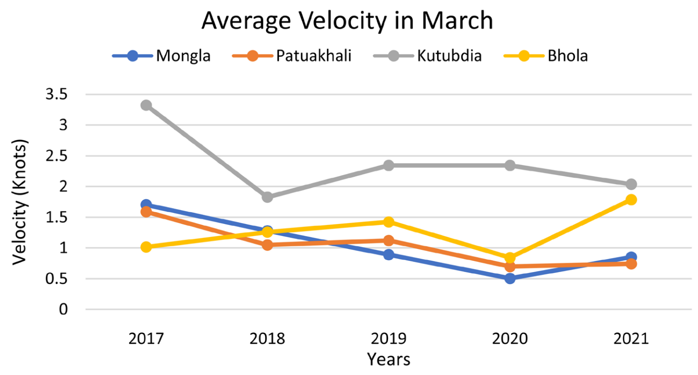


Figure 4. Average velocity in March.

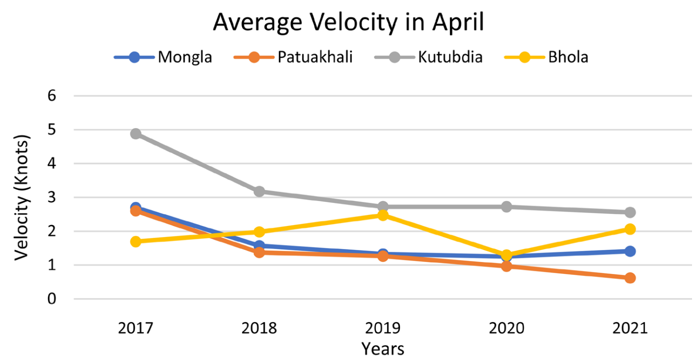


Figure 5. Average velocity in April.

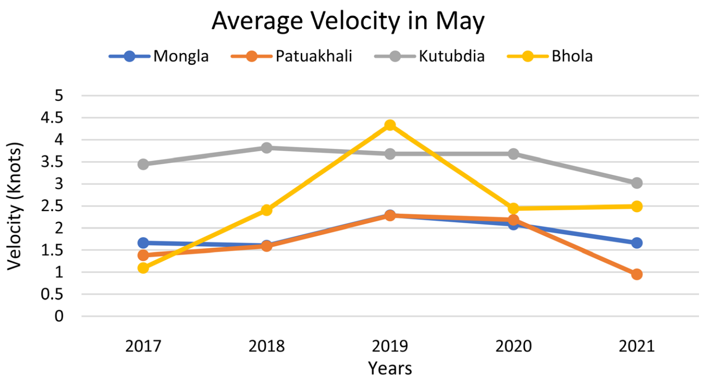


Figure 6. Average velocity in May.

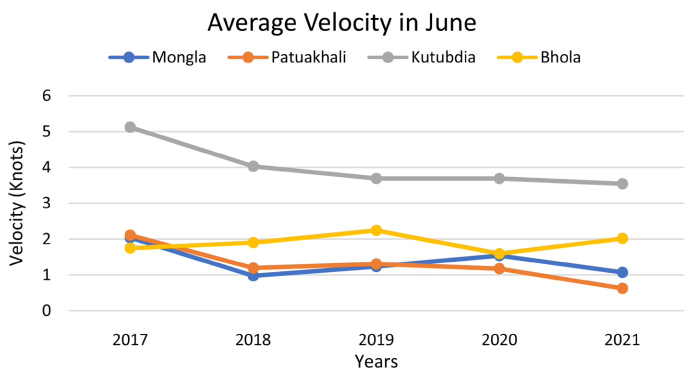


Figure 7. Average velocity in June.

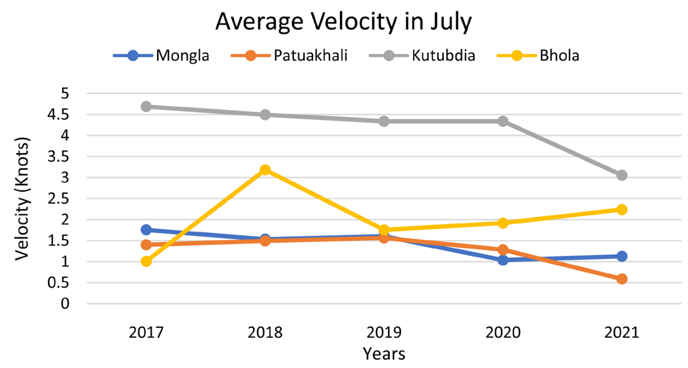


Figure 8. Average velocity in July.

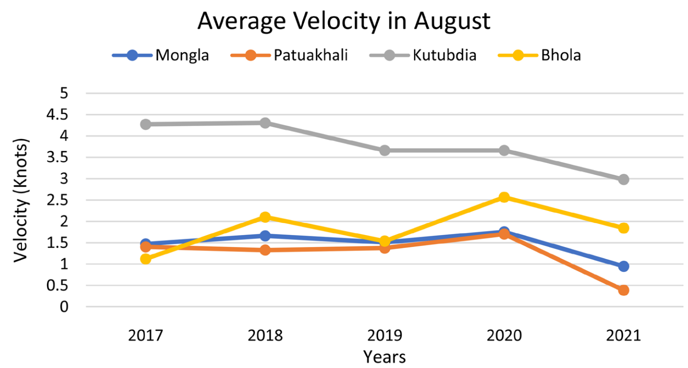


Figure 9. Average velocity in August.

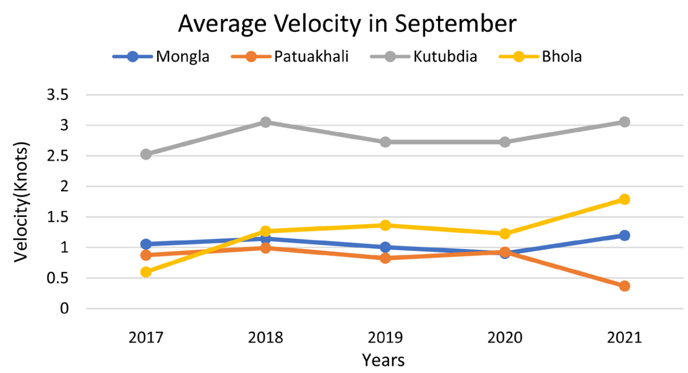


Figure 10. Average velocity in September.

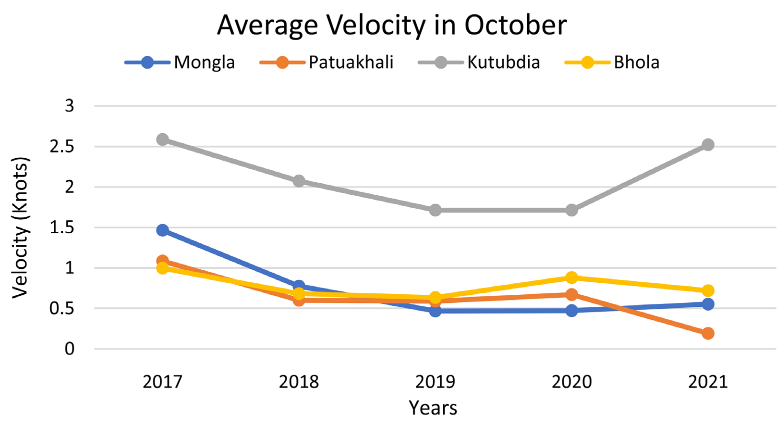


Figure 11. Average velocity in October.

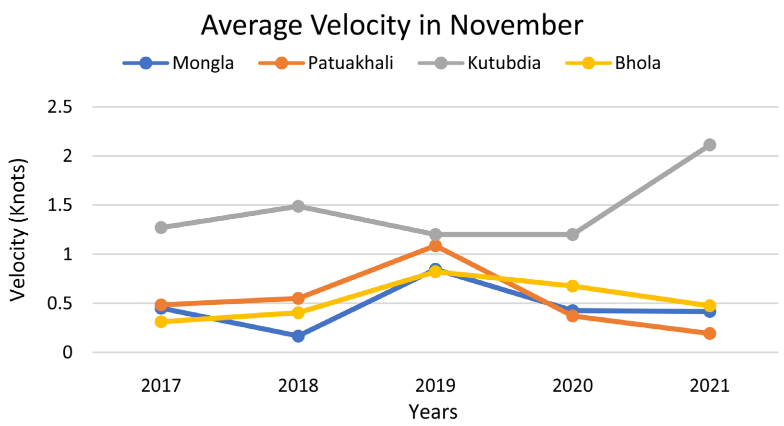


Figure 12. Average velocity in November.

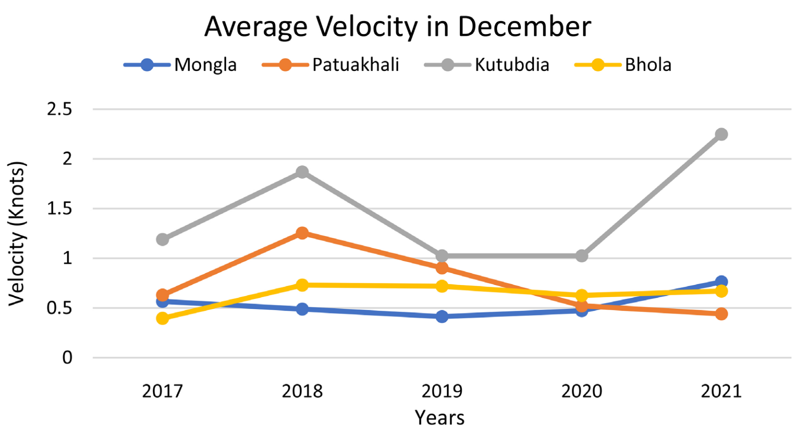


Figure 13. Average velocity in December.

The average velocity from the years 2017 to 2021 is depicted in Figures 2-13. These numbers demonstrate that the average velocity at Kutubdia Station was greater than that at Patuakhali, Bhola, and Mongla Stations. This suggests that Kutubdia Station is a more practical position for wind energy extraction.

Graphical Representation of Yearly (2017-2021) Average Velocities in Different Months:

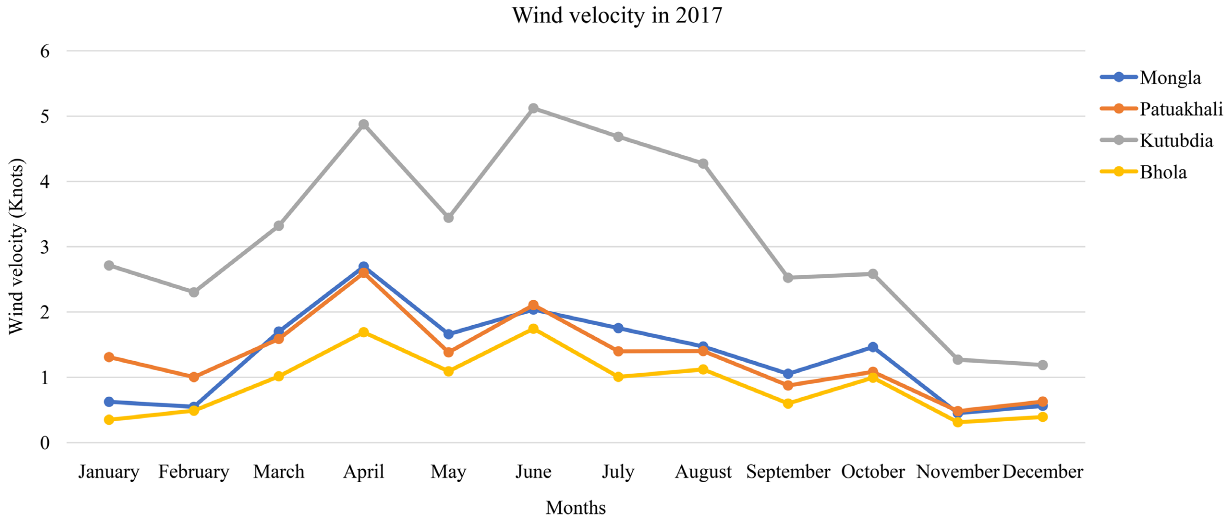


Figure 14. Average wind velocities in 2017 for four different regions in Bangladesh.

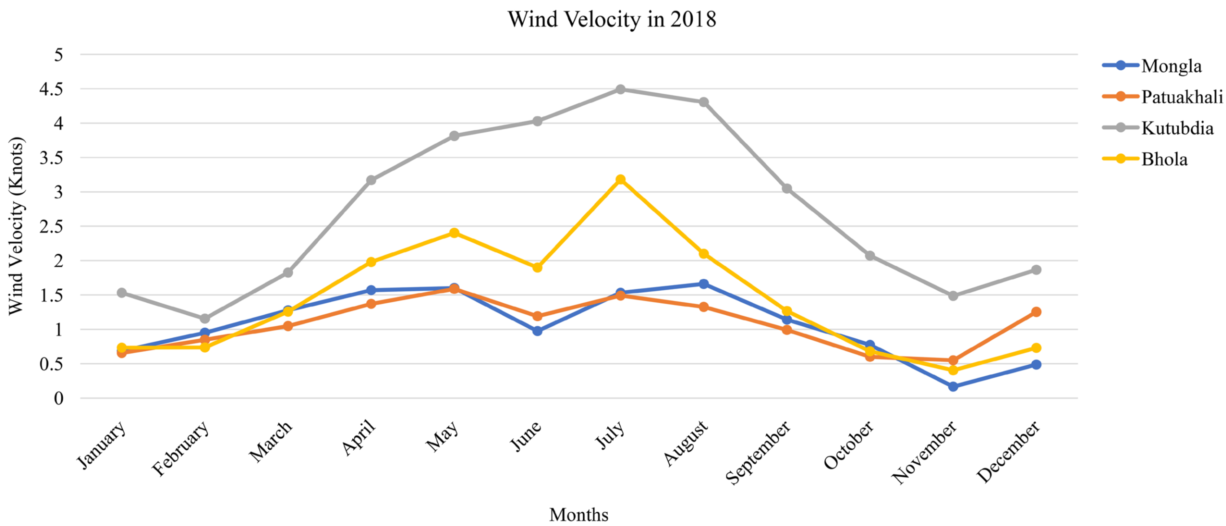


Figure 15. Average wind velocities in 2018 for four different regions in Bangladesh.

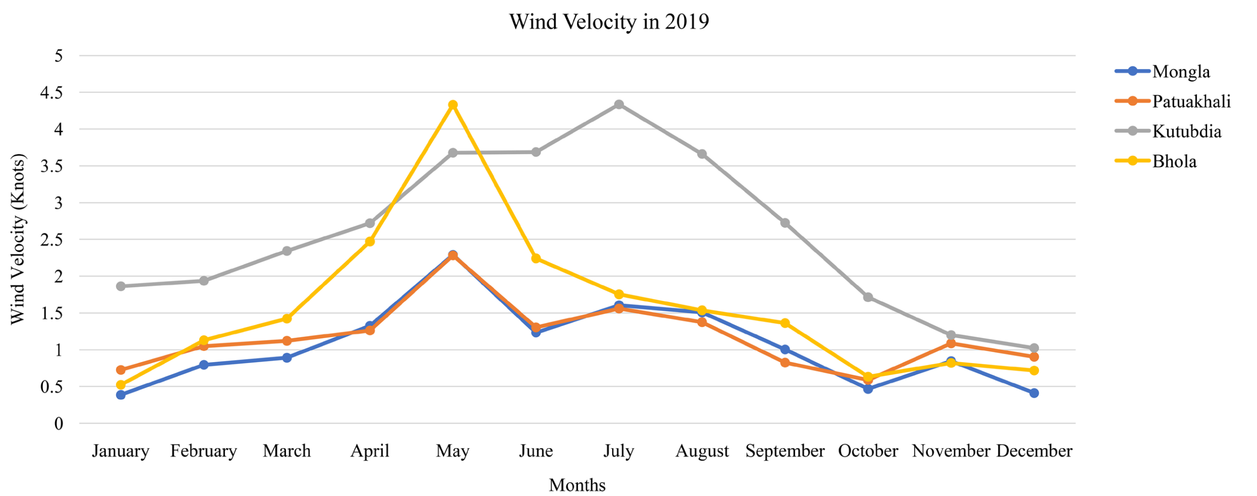


Figure 16. Average wind velocities in 2019 for four different regions in Bangladesh.

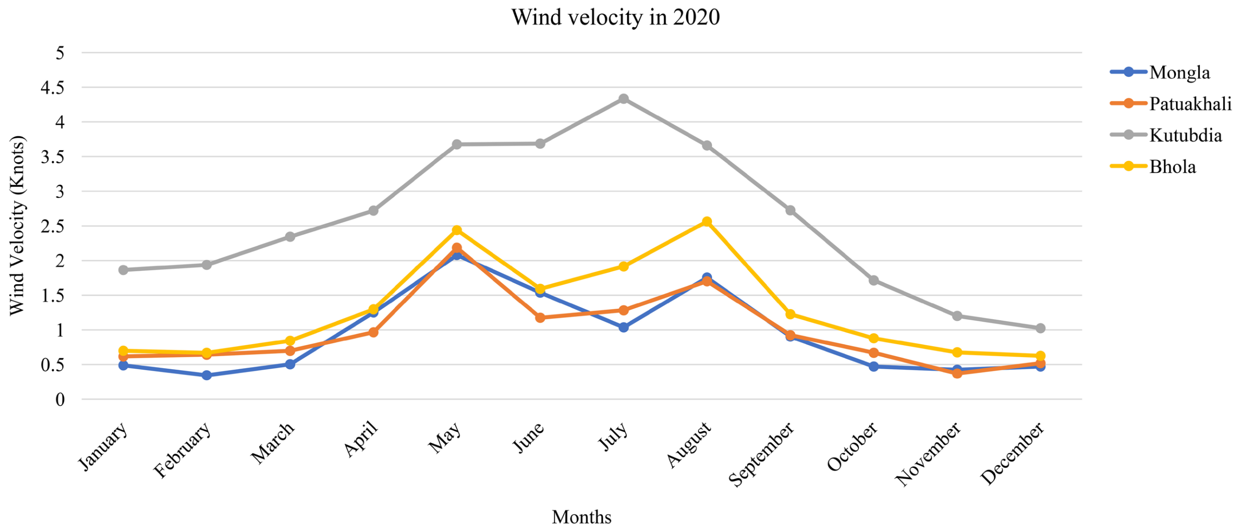


Figure 17. Average wind velocities in 2020 for four different regions in Bangladesh.

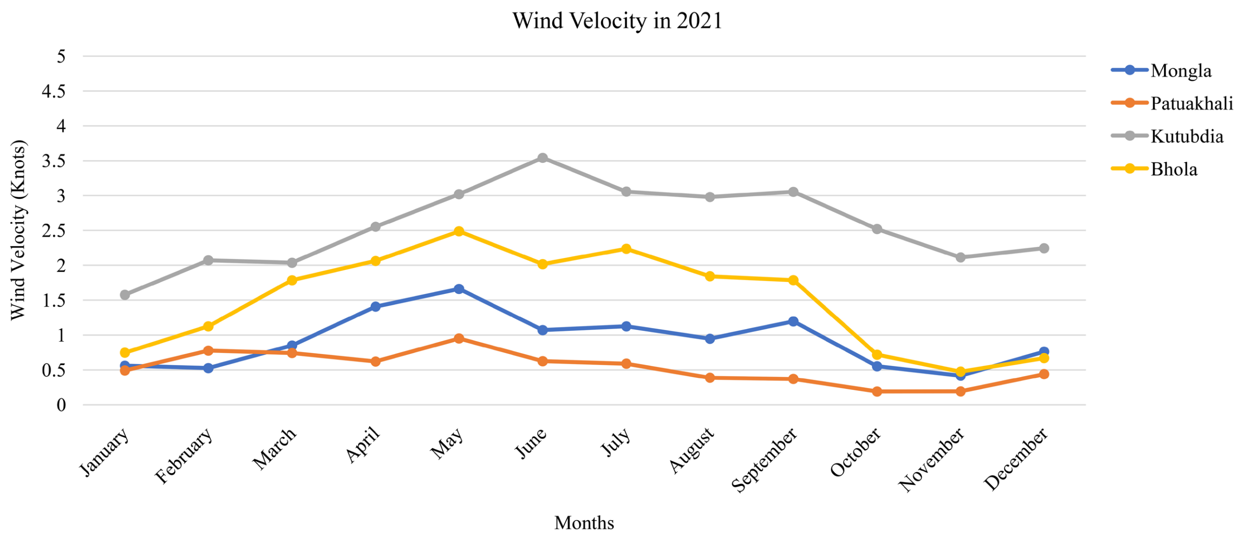


Figure 18. Average wind velocities in 2021 for four different regions in Bangladesh.

The average monthly velocity at the stations of Kutubdia, Mongla, Bhola, and Patuakhali from 2017 to 2021 is depicted in this article's Figures 14-18. These demonstrate the significant seasonal variance in the annual average wind speed at each location. The results show that the wind velocity is stronger from May to September and reaches its peak in July.

3. Wind Patterns for Different Seasons in Bangladesh

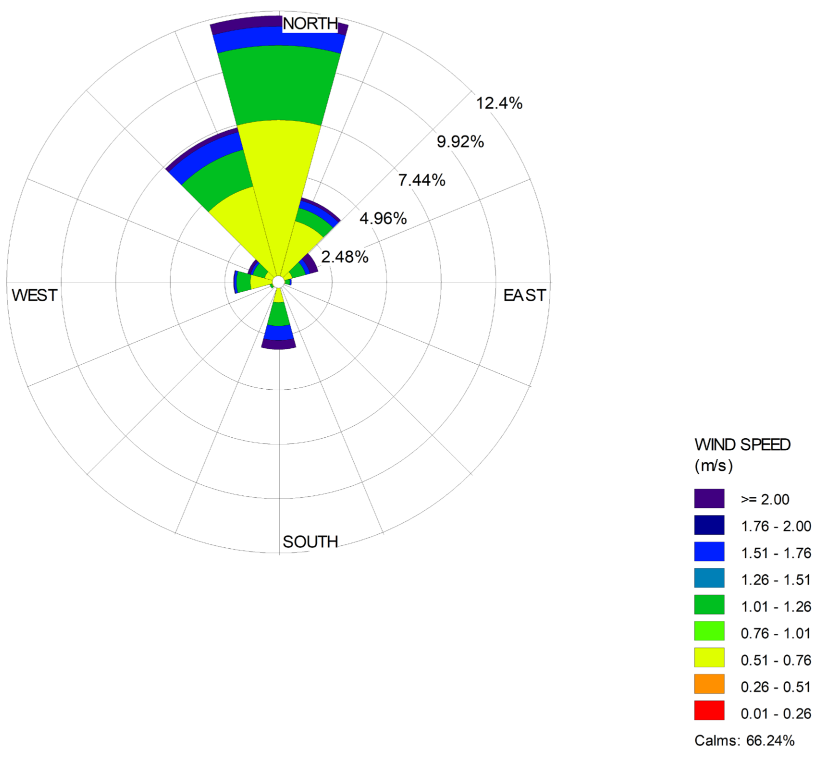
The wind is regarded as a crucial scale of atmospheric circulation. Whereas variations in wind direction and speed point to shifts in the position of the circulation brought on by either natural or man-made factors. In meteorology, wind direction is described as the direction from which the wind blows, given in degrees and measured counterclockwise from true north or in terms of the compass's points. One of the earliest metrological instruments, the wind vane, is commonly used to determine wind direction. Wind speed, which can be measured in kph, m/s, or knots, is the pace at which air moves in its immediate direction. Although there are many ways to measure wind speed, BMD typically uses a spinning cup anemometer.

The winter months in Bangladesh are December through January and February. Except for northern mountainous regions where easterly winds are more common during the winter months of December, January, and February, northeasterly winds often blow from land to sea. The heating belt moves northward from March to May during the summer due to the sun's apparent northward motion. In the summer, air pressure decreases, and temperatures rise throughout the nation. Early June is usually when Banitsgladesh's monsoon season starts, and it lasts until the end of September. The ongoing low pressure over northern India and Bangladesh increases during this time of year and draws trade winds from the southern hemisphere. The post-monsoon season in Bangladesh lasts from October through November. The low-pressure trough over Bangladesh progressively decreases during this time of year and is replaced by a high-pressure system [7].

A wind rose shows the distribution of winds (speed and direction) at a certain point graphically. The graphical representation of a large amount of data is really helpful and condensed. Four BMD stations' windroses—Mongla, Potuakhali, Kutubdia, and Bhola—are displayed for various seasons.

3.1. Mongla Station

Winter (December-February):



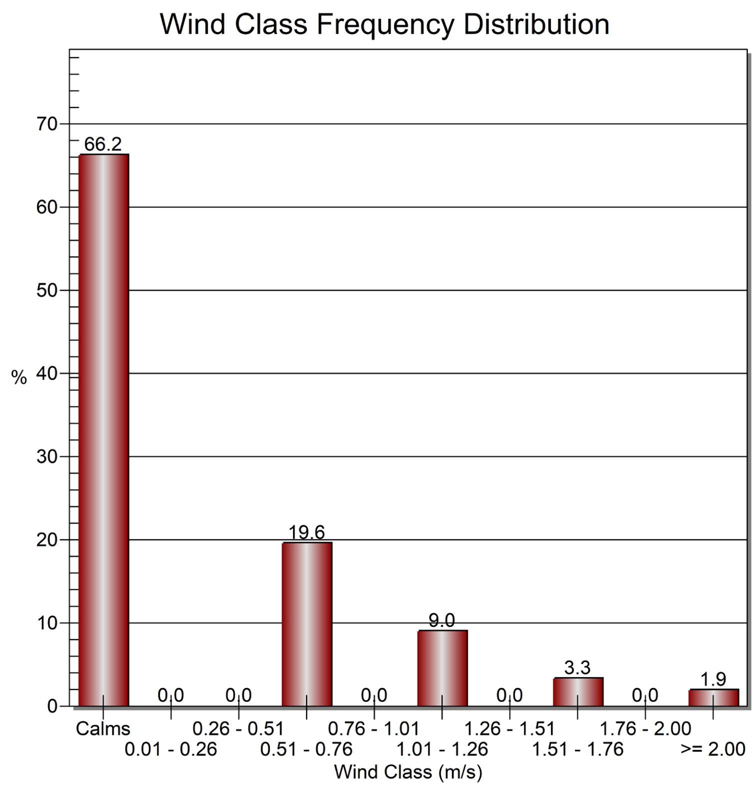
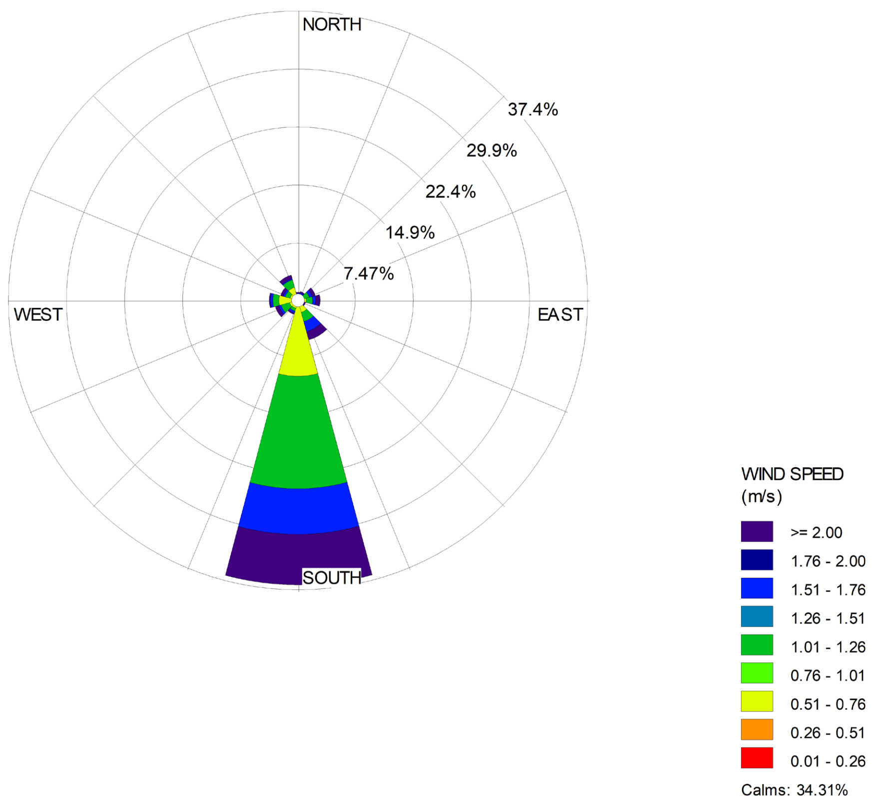


Figure 19. The distribution of wind direction and wind speed in Mongla during winter.

Summer (March-May):



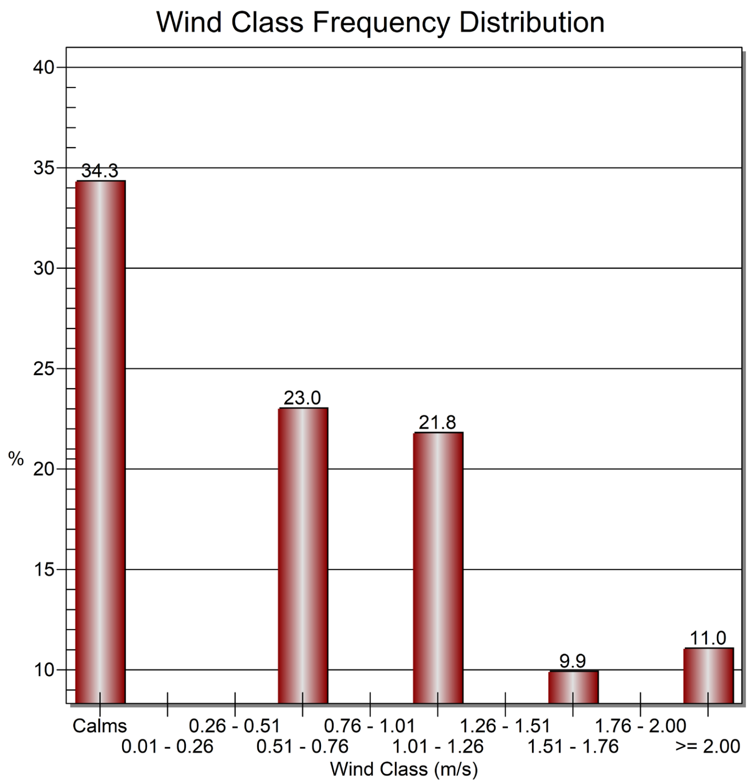
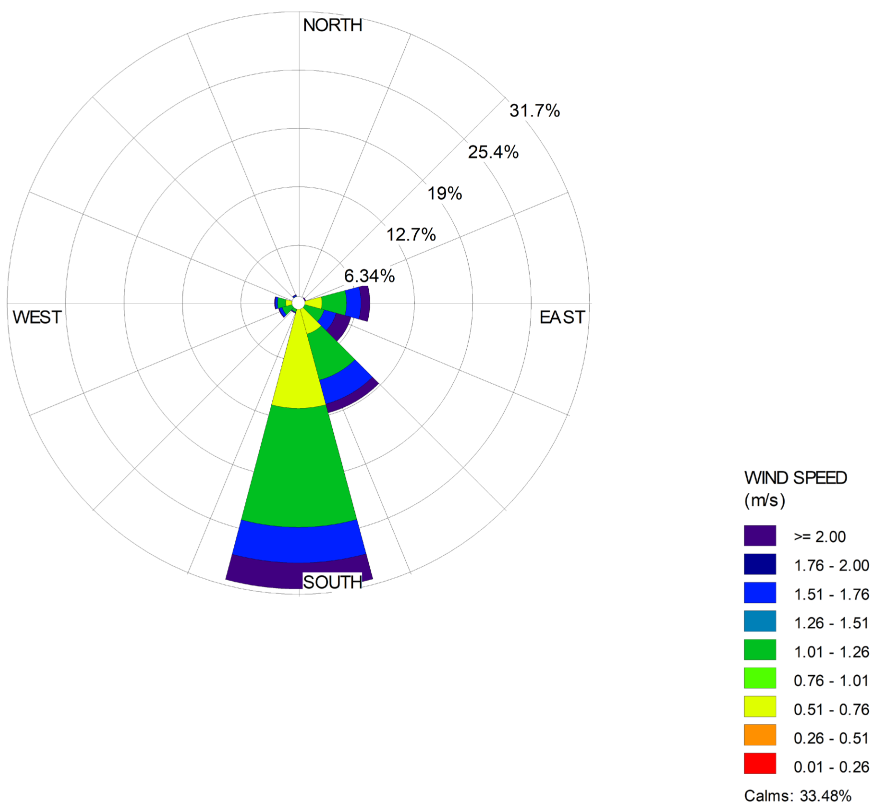


Figure 20. The distribution of wind direction and wind speed in Mongla during summer.

Monsoon (June-September):



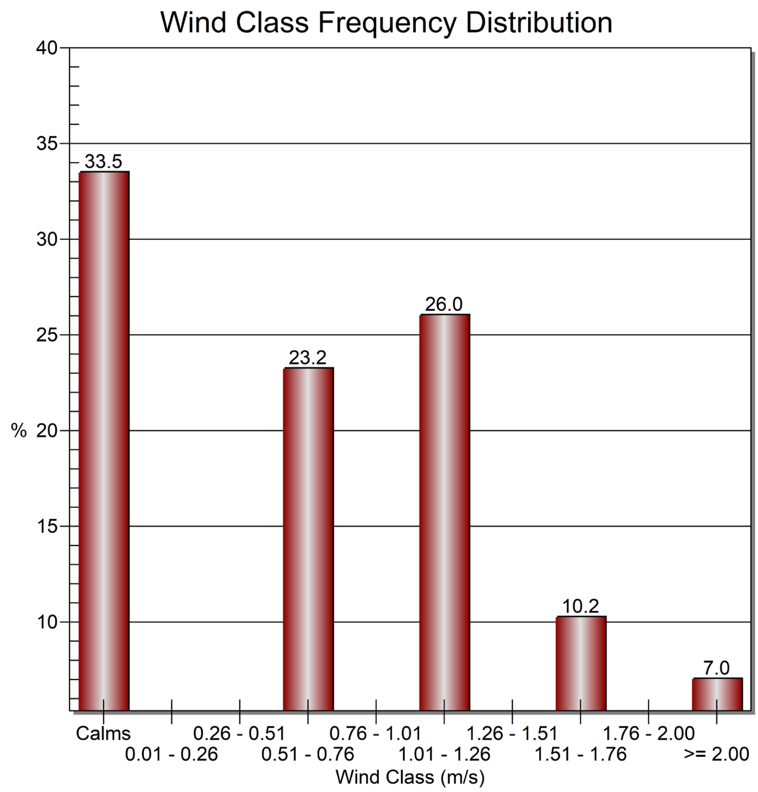
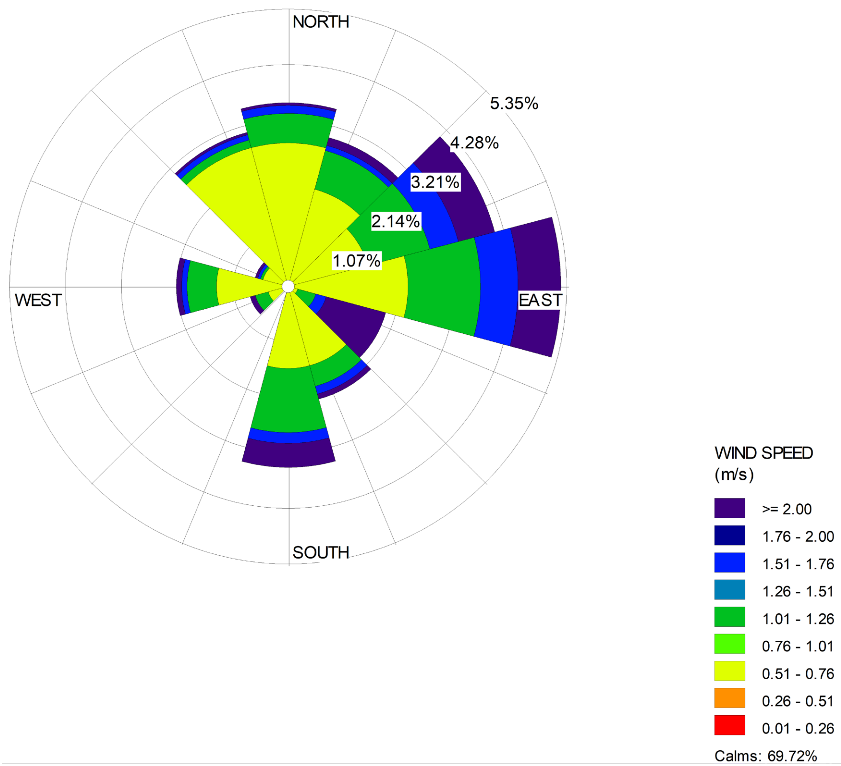


Figure 21. The distribution of wind direction and wind speed in Mongla during monsoon.

Post Monsoon (October-November):



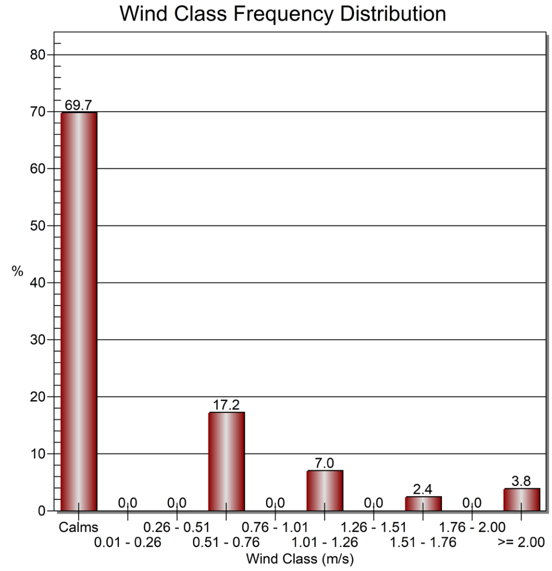
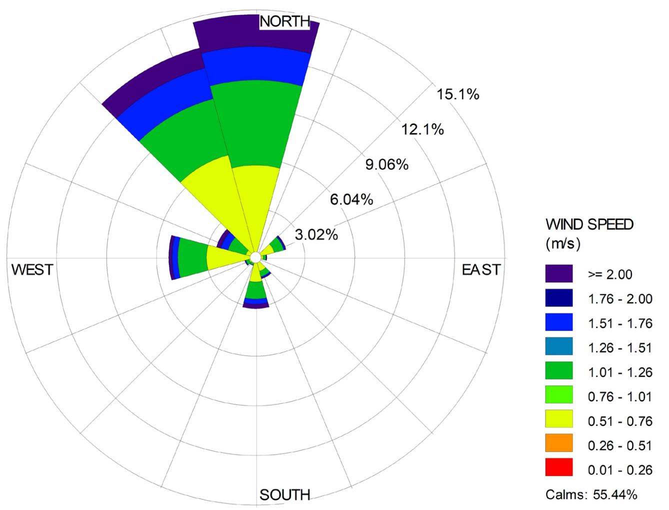


Figure 22. The distribution of wind direction and wind speed in Mongla during post-monsoon.

The distribution of wind direction and wind speed at Mongla during the winter, summer, monsoon, and post-monsoon is depicted in **Figures 19-22**, respectively. **Figure 19** demonstrates that the predominant wind directions during the winter are the north and the northwest, with 1.9 percent of all wind gusts exceeding 2 m/s. **Figure 20** demonstrates that throughout the summer, the wind normally blows from the south, with 11 percent of gusts over m/s. **Figure 21** demonstrates that the predominant wind directions during the monsoon are south and southeast, with a 7 percent prevalence of gusts over 2 m/s. Finally, **Figure 22** shows that wind blows in all directions throughout the post-monsoon season, with 3.8 percent of those gusts exceeding 2 m/s.

3.2. Patuakhali Station

Winter (December-February):



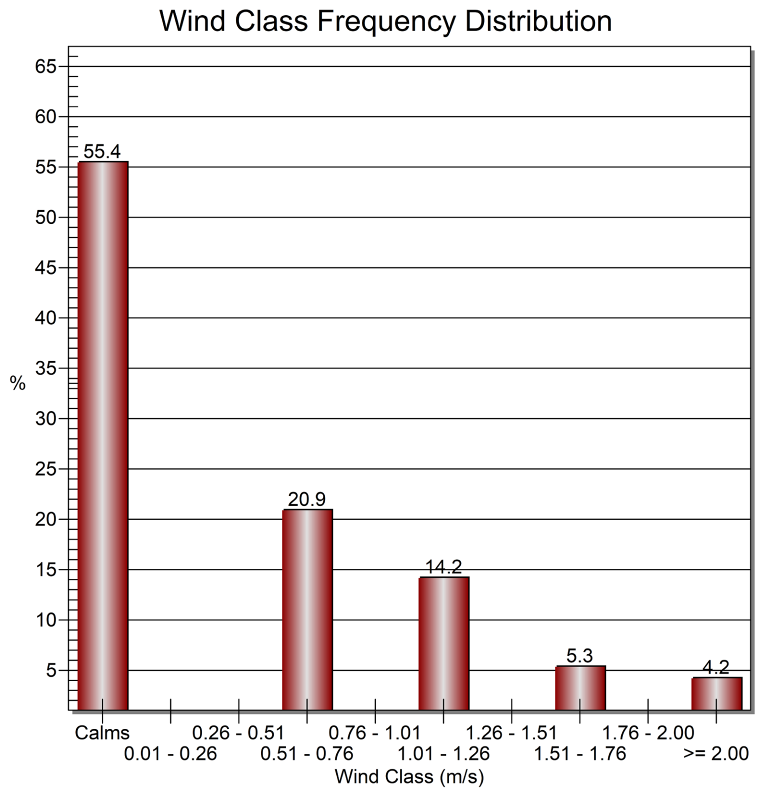
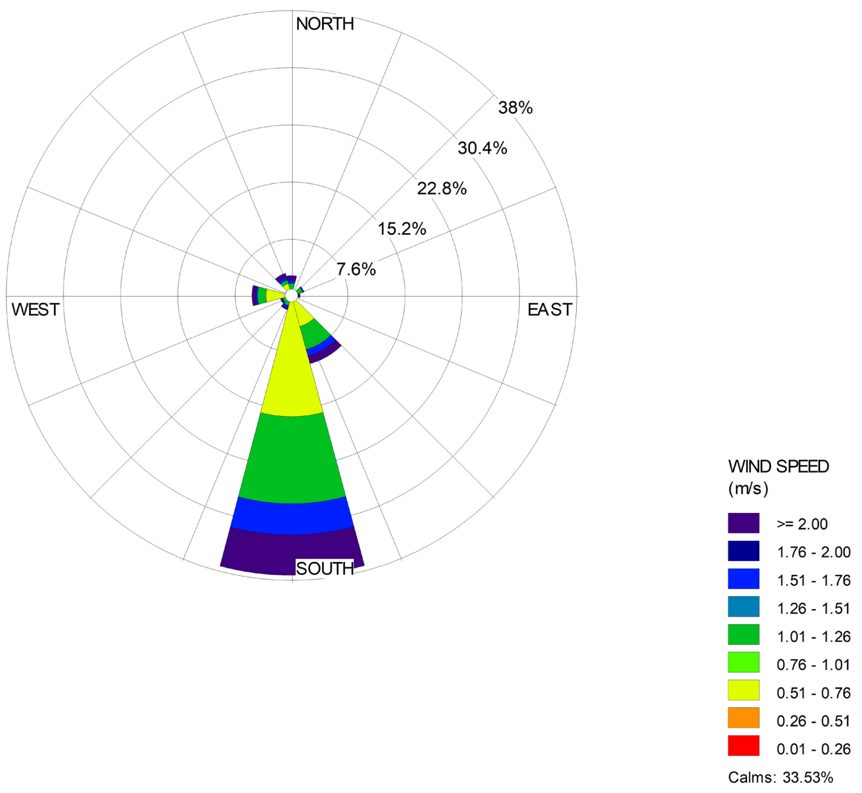


Figure 23. The distribution of wind direction and wind speed in Patuakhali during winter.

Summer (March-May):



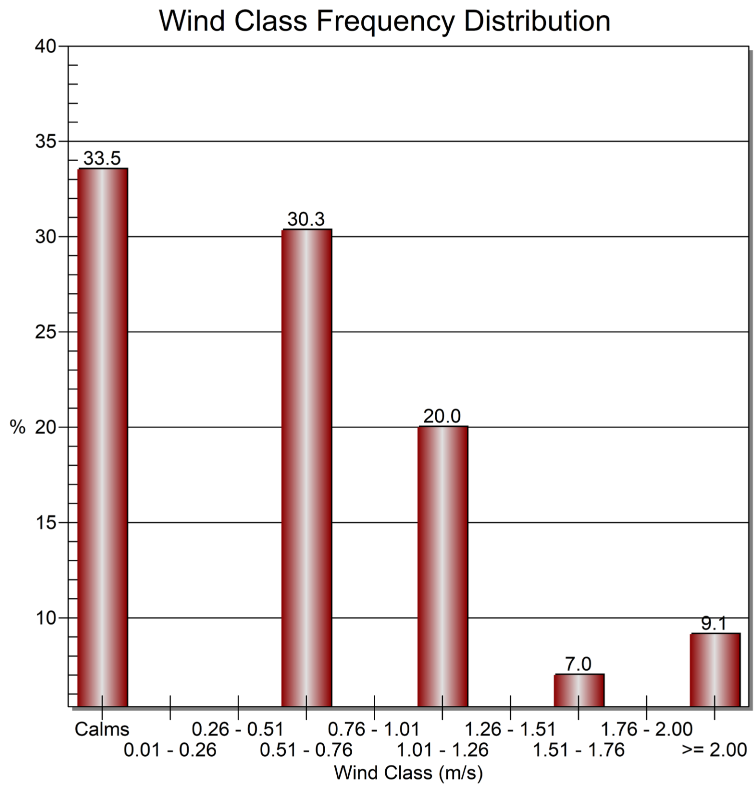
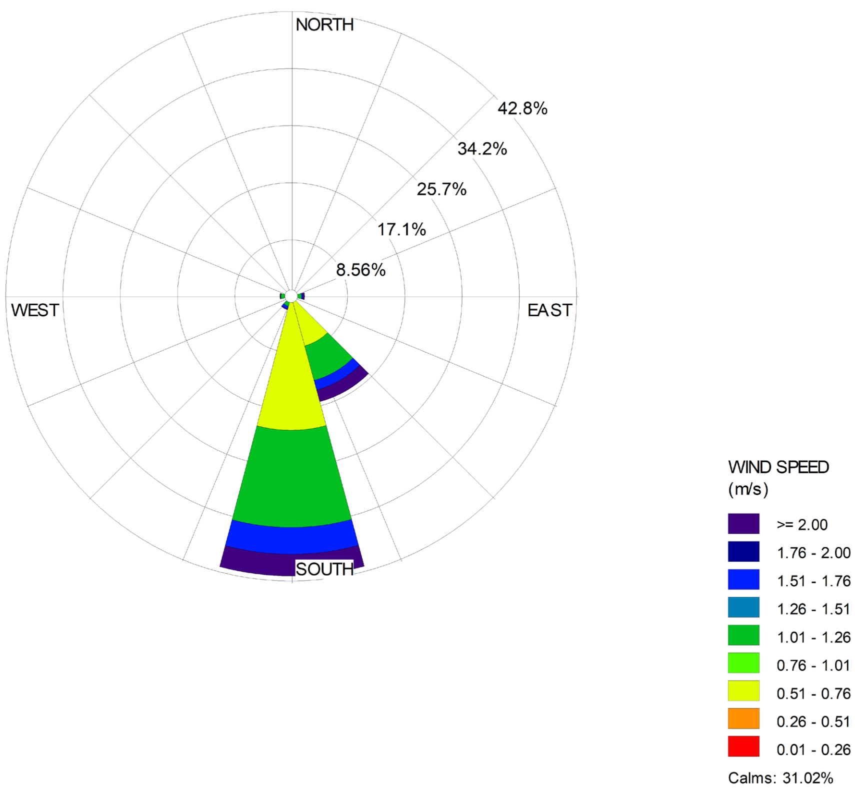


Figure 24. The distribution of wind direction and wind speed in Patuakhali during summer.

Monsoon (June-September):



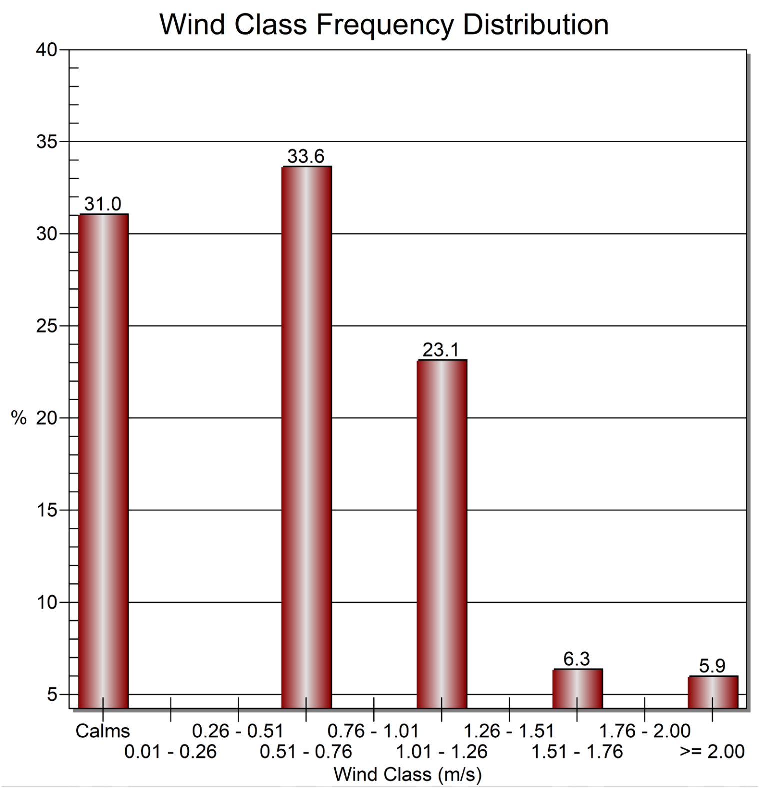
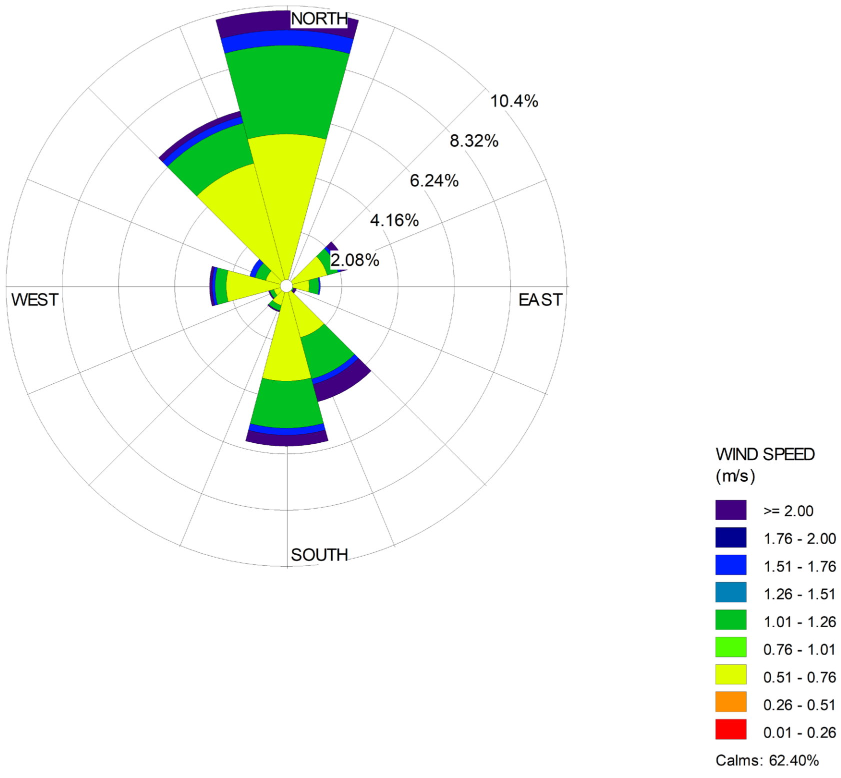


Figure 25. The distribution of wind direction and wind speed in Patuakhali during monsoon.

Post Monsoon (October-November):



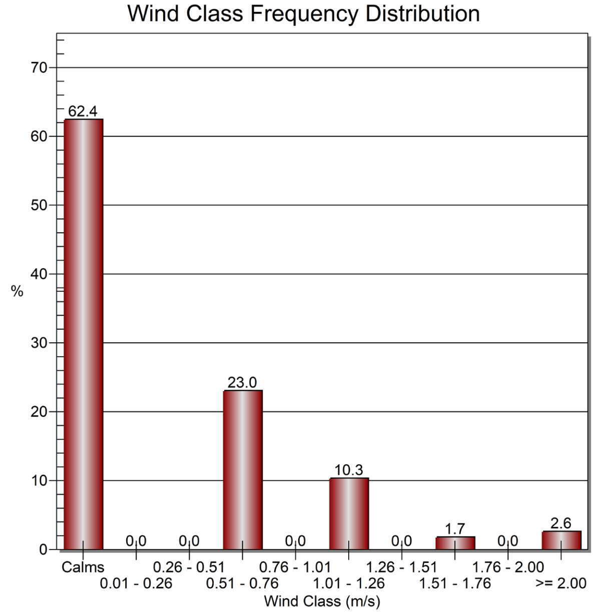
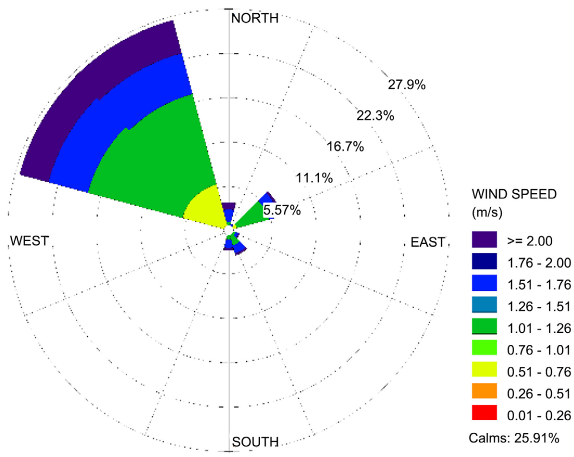


Figure 26. The distribution of wind direction and wind speed in Patuakhali during post-monsoon.

Figures 23-26 illustrate the distribution of wind speed and direction at Patuakhali station during the winter, summer, monsoon, and post-monsoon seasons, respectively. **Figure 23** shows that, with 4.2% of all wind gusts over 2 m/s, the major wind directions during the winter are north and northwest. **Figure 24** shows that the south is the most common wind direction during the summer, with a 9.1% incidence of gusts over 2 m/s. **Figure 25** shows that during the monsoon, the south and southeast are the most common wind directions, with a 5.9% incidence of gusts surpassing 2 m/s. Last but not least, **Figure 26** demonstrates that wind blows from both the north and the south during the post-monsoon season, with a percentage of 2.6 for wind speeds greater than 2 m/s.

3.3. Kutubdia Station

Winter (December-January):



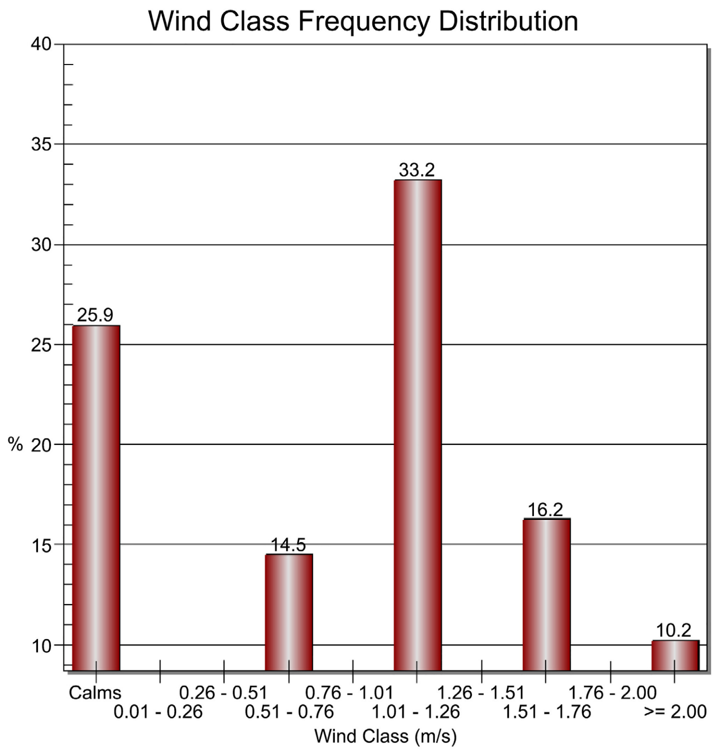
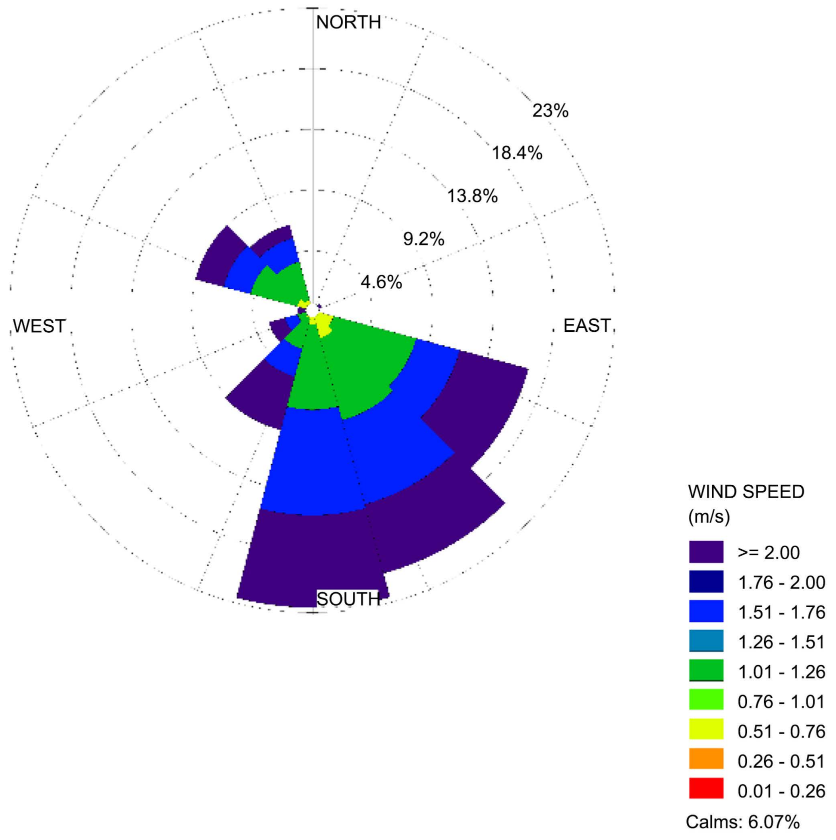


Figure 27. The distribution of wind direction and wind speed in Kutubdia during winter.

Summer (March-May):



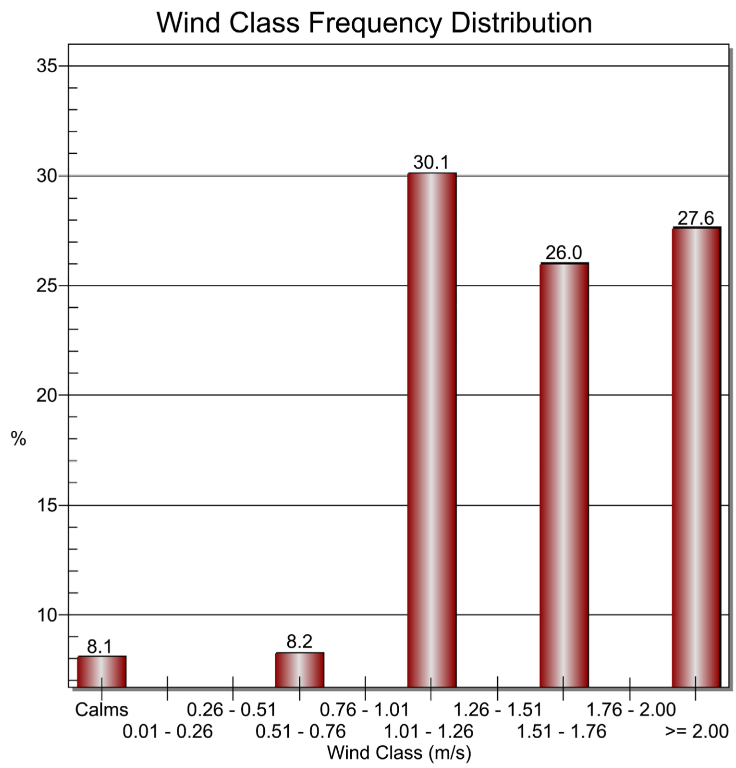
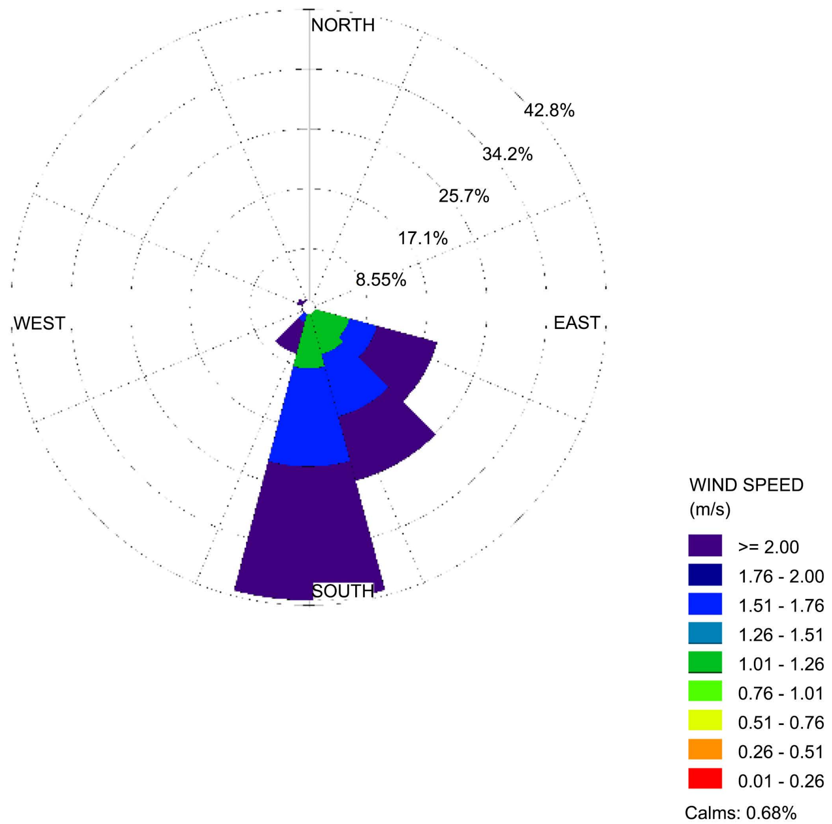


Figure 28. The distribution of wind direction and wind speed in Kutubdia during summer.

Monsoon (June-September):



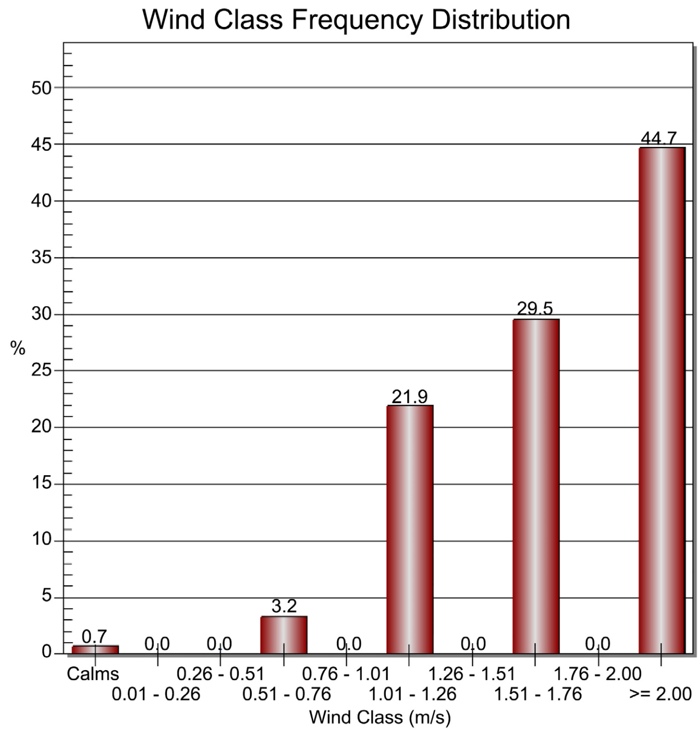
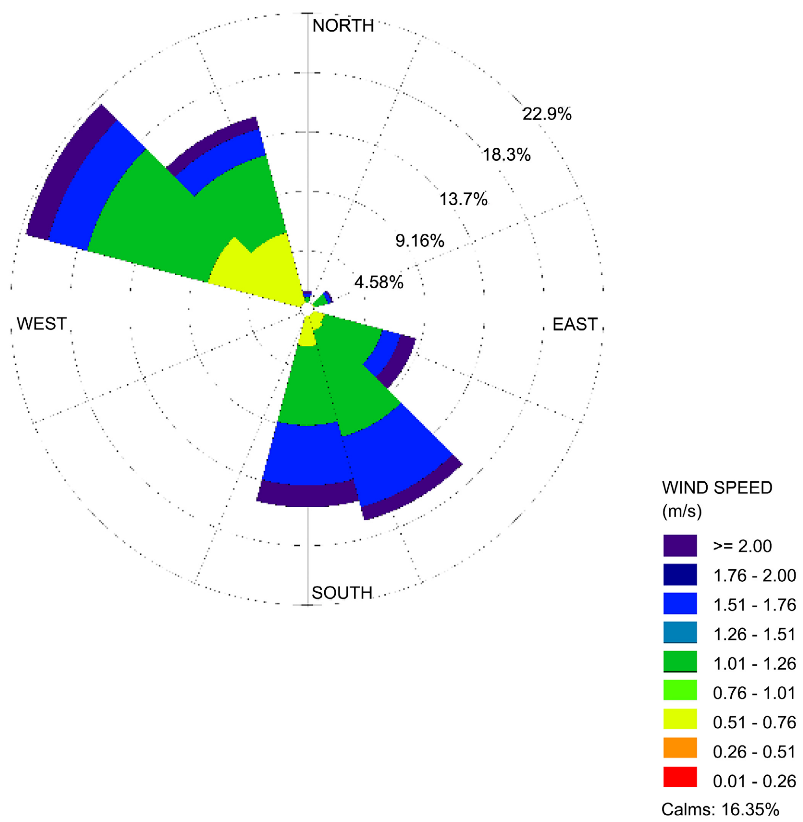


Figure 29. The distribution of wind direction and wind speed in Kutubdia during monsoon.

Post Monsoon (October-November):



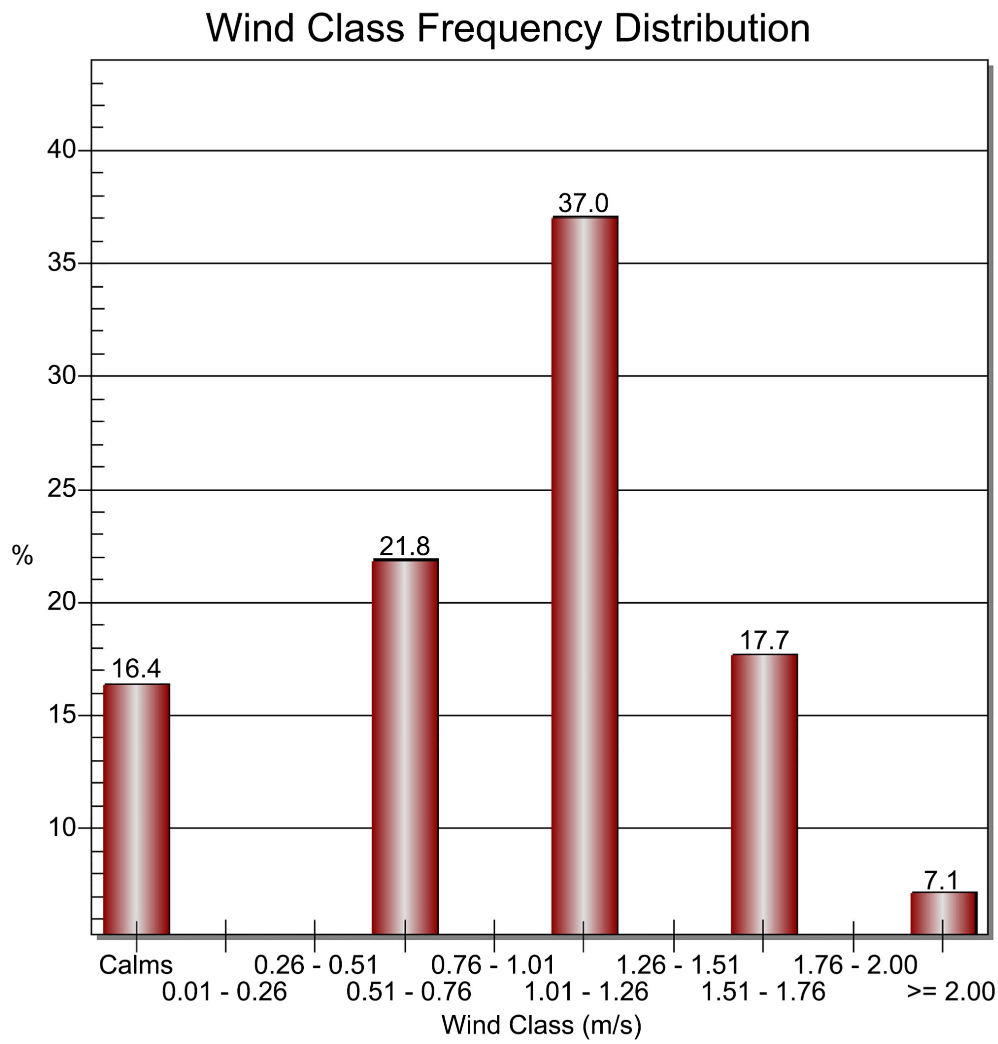


Figure 30. The distribution of wind direction and wind speed in Kutubdia during post-monsoon.

The distribution of wind direction and wind speed in Patuakhali station during the winter, summer, monsoon, and post-monsoon is depicted in Figures 27-30, respectively. Figure 27 reveals that the predominant wind directions throughout the winter are north and northwest, with a 10.2 percent prevalence of gusts over 2 m/s. Figure 28 demonstrates that the majority of the wind during the summer months originates in the southwest and northeast, with a 27.6 percent wind speed percentage of more than 2 m/s. Figure 29 demonstrates that during the monsoon, the predominant wind direction is from the southeast, with a 44.7 percent prevalence of gusts over 2 m/s. Figure 30 shows that during the post-monsoon season, both the northwest and southeast are the predominant directions for wind, with 7.1 percent of those winds being greater than 2 m/s.

3.4. Bhola Station

Winter (December-February):

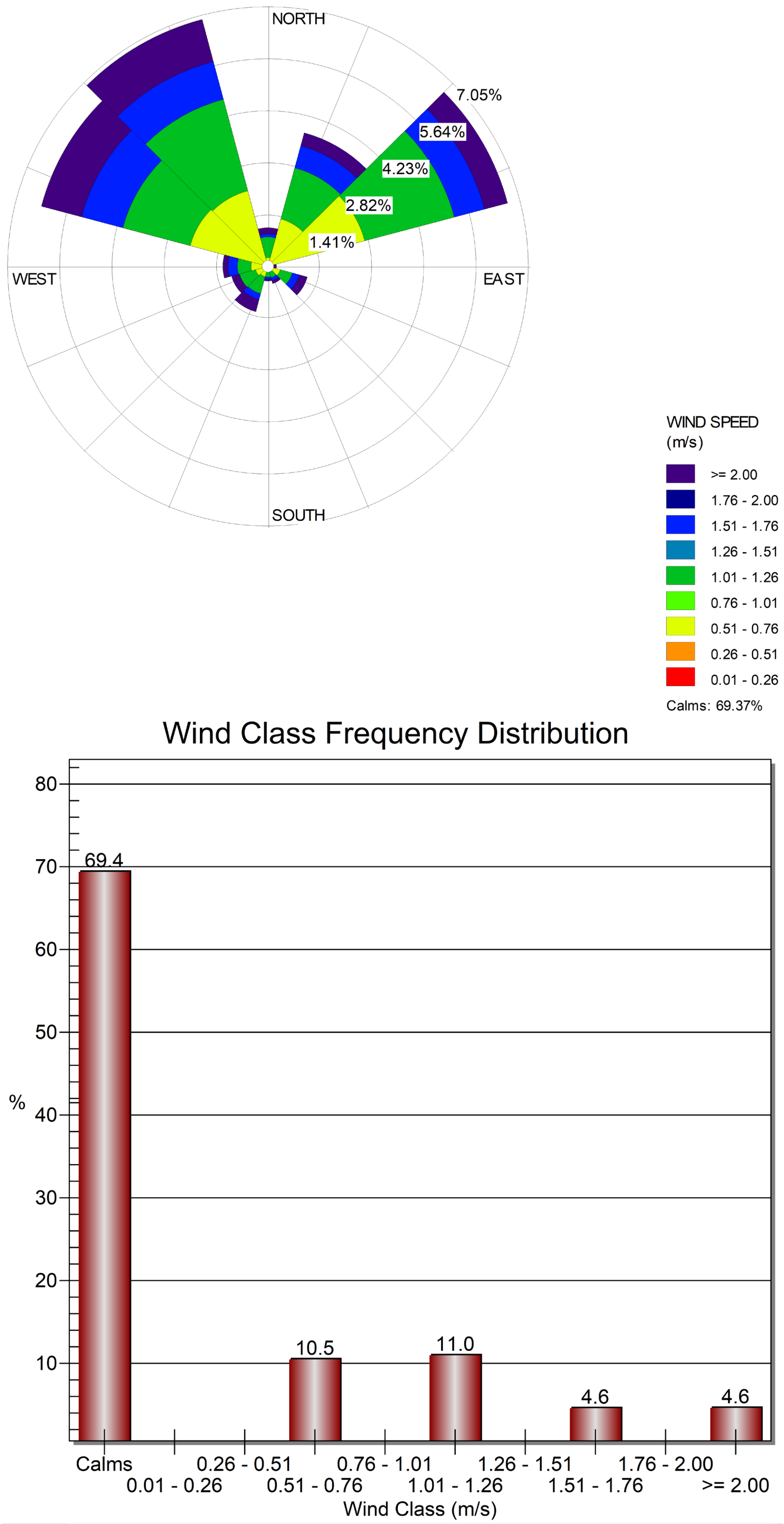
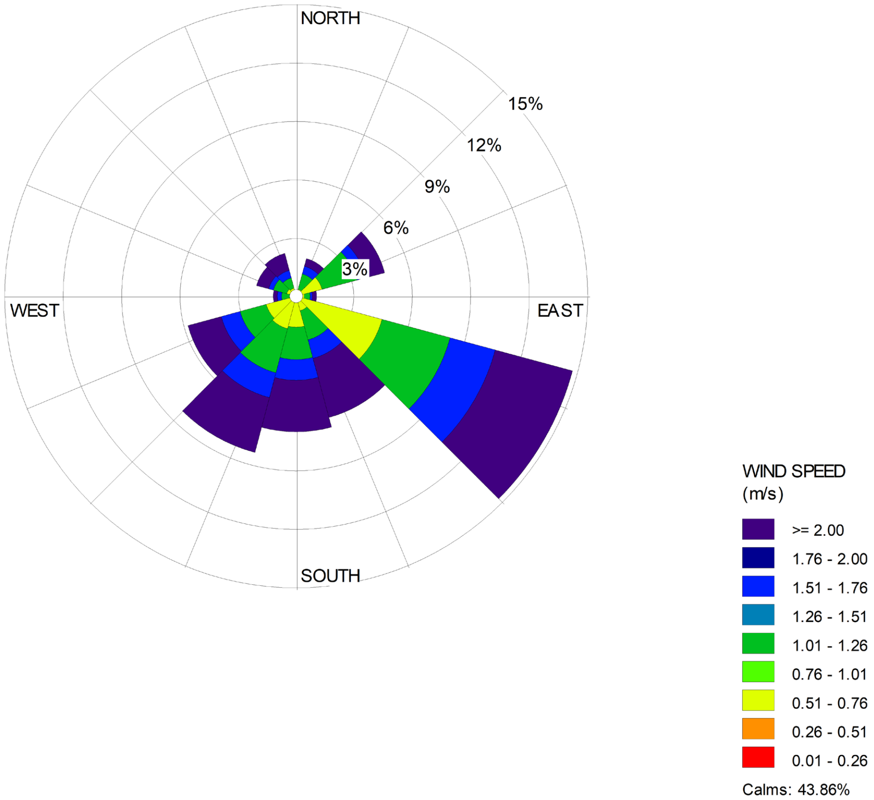


Figure 31. The distribution of wind direction and wind speed in Bhola during winter.

Summer (Mar-May):



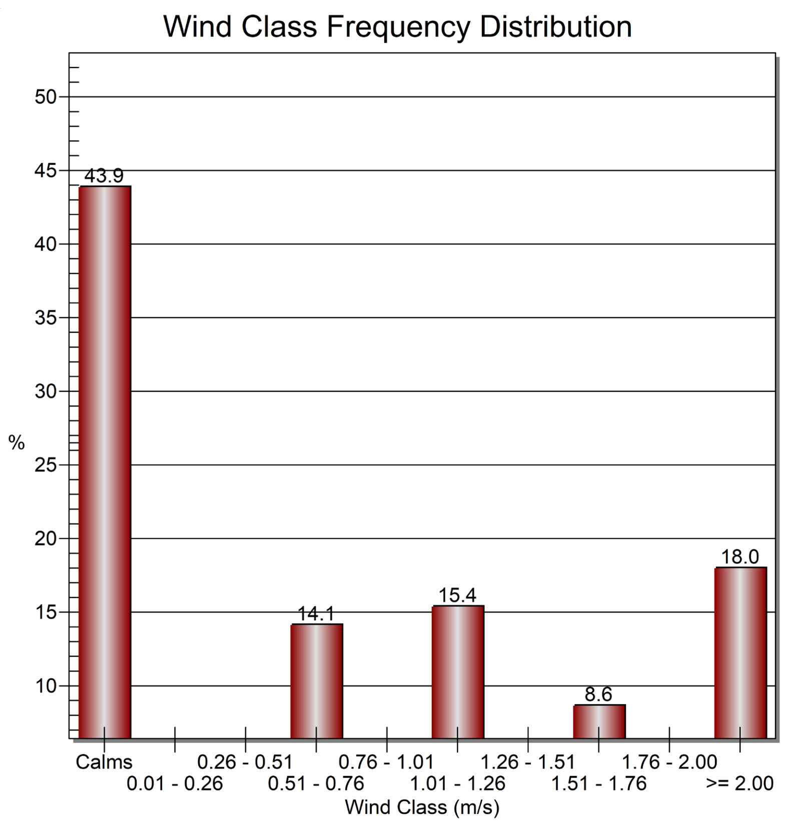


Figure 32. The distribution of wind direction and wind speed in Bhola during summer.

Monsoon (June-September):

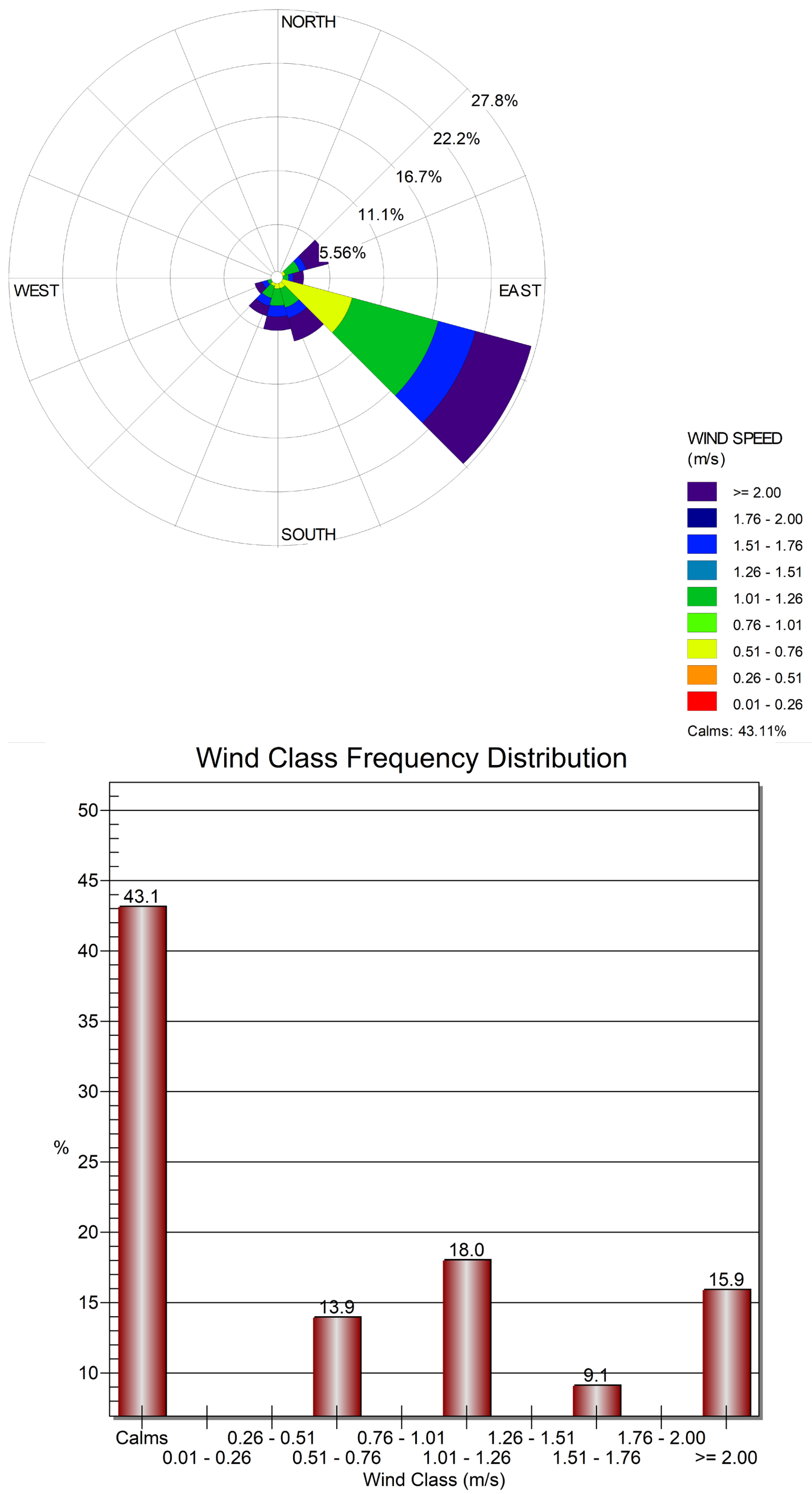
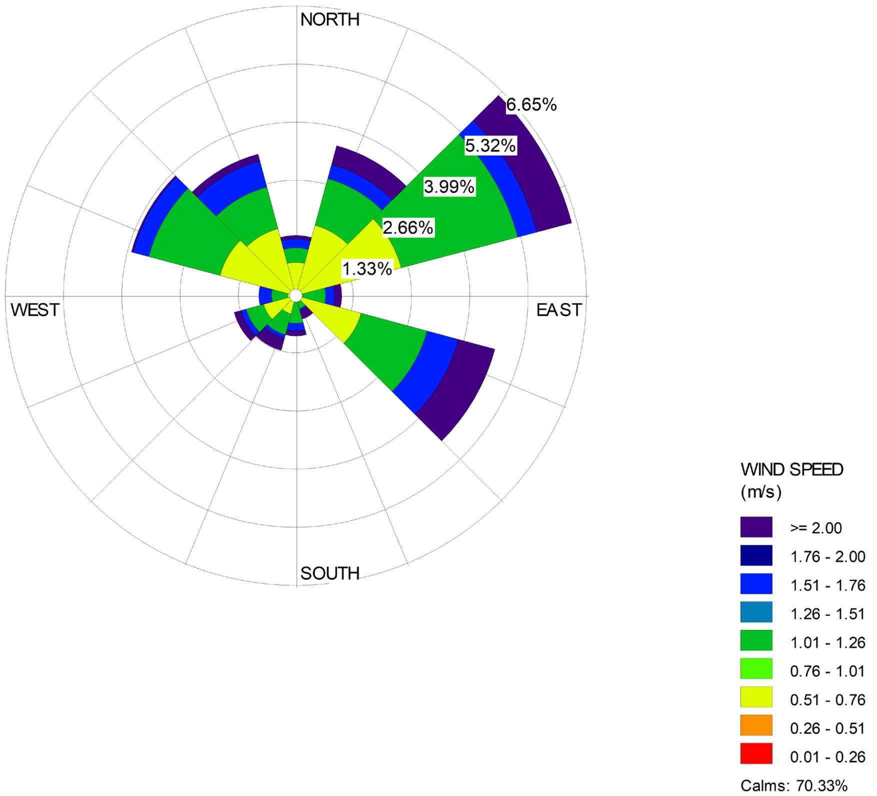


Figure 33. The distribution of wind direction and wind speed in Bhola during monsoon.

Post Monsoon (October-November):



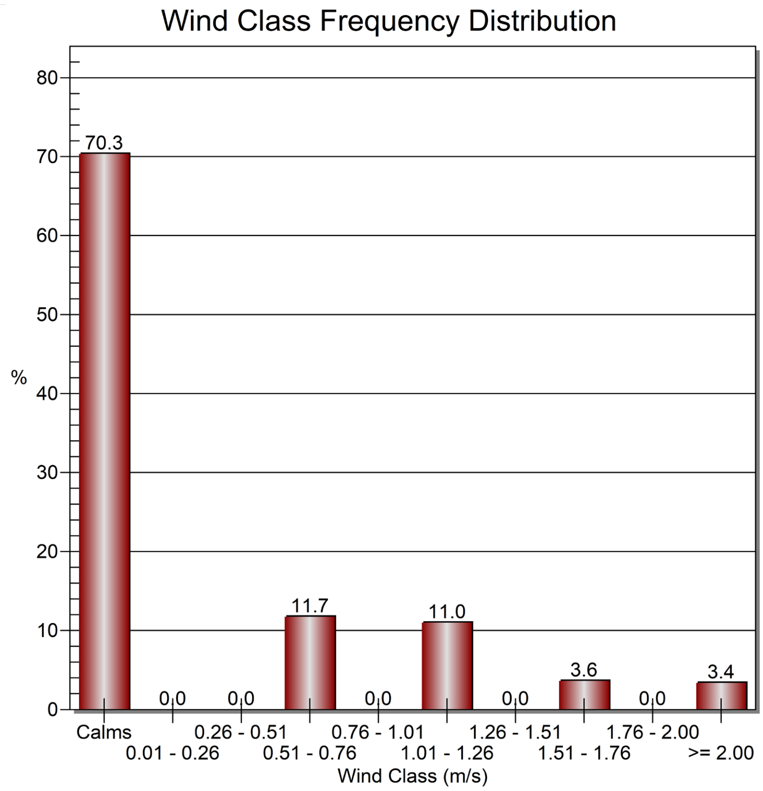


Figure 34. The distribution of wind direction and wind speed in Bhola during post-monsoon.

The distribution of wind direction and wind speed in Bhola station over the winter, summer, monsoon, and post-monsoon seasons is depicted in **Figures 31-34**, respectively. **Figure 31** demonstrates that the predominant wind directions throughout the winter, which are the northeast and northwest, are 4.6 percent of the time. **Figure 32** demonstrates that the predominant winds throughout the summer come from the southeast and southwest, with an 18% prevalence of gusts over 2 m/s. According to **Figure 33**, the wind during the monsoon normally comes from the southeast, and 15.9 percent of it has a speed more than 2 m/s. **Figure 34** shows that wind blows in all directions during the post-monsoon season and that its percentage for winds greater than 2 m/s is 3.4.

4. Power of Wind Turbine

Power of Wind turbine has been calculated by,

$$P = \frac{1}{2} C_p \rho A V^3$$

where,

Air density, $\rho = 1.223\ \text{kg/m}^3$,

Swept area = A,

Power Co-efficient (C_p) = 0.3 (Rated).

Velocities (V) are measured in m/s and Power (P) is measured in watt.

A number of commercial wind turbines developed by different researchers and companies are generating green energy from all over the world. In general, the design and size of a turbine vary with the installed area and the amount of wind available. We considered FX-3000/FX-8000 and D400 turbines due to their size, power efficiency, and working capacity under low wind velocity (**Table 1**, **Figure 35** & **Figure 36**).

Table 1. Fundamental specification of FX-3000/FX-8000 and D400 turbines.

FX-3000/FX-8000 Specifications	**D400** Specifications
Rotor Diameter of Blades (m): 0.6 m/1.1m	Rotor Diameter of Blades (m): 1.1 m
Swept Area (m^2): 0.48 m^2/1.452m^2	Swept Area (m^2): 0.95 m^2
Cut-in Speed: 3 ms^{-2}/3 ms^{-2}	Cut -in Speed: 2.5 ms^{-2}
Co-efficient of Power, C_p = 0.3 (Aprox.)	Co-efficient of Power, C_p = 0.3 (Aprox.)

Figure 35. Schematic of FX-3000/FX-8000 wind turbine [8].

Figure 36. Schematic of D400 wind turbine [9].

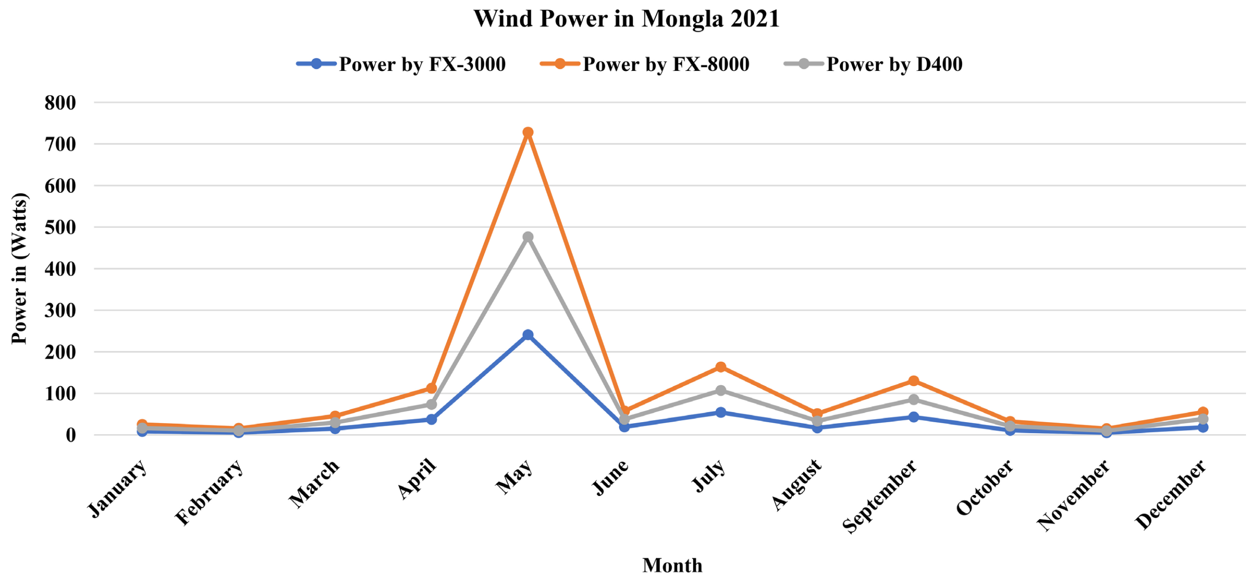


Figure 37. Wind power from three turbines in Mongla 2021.

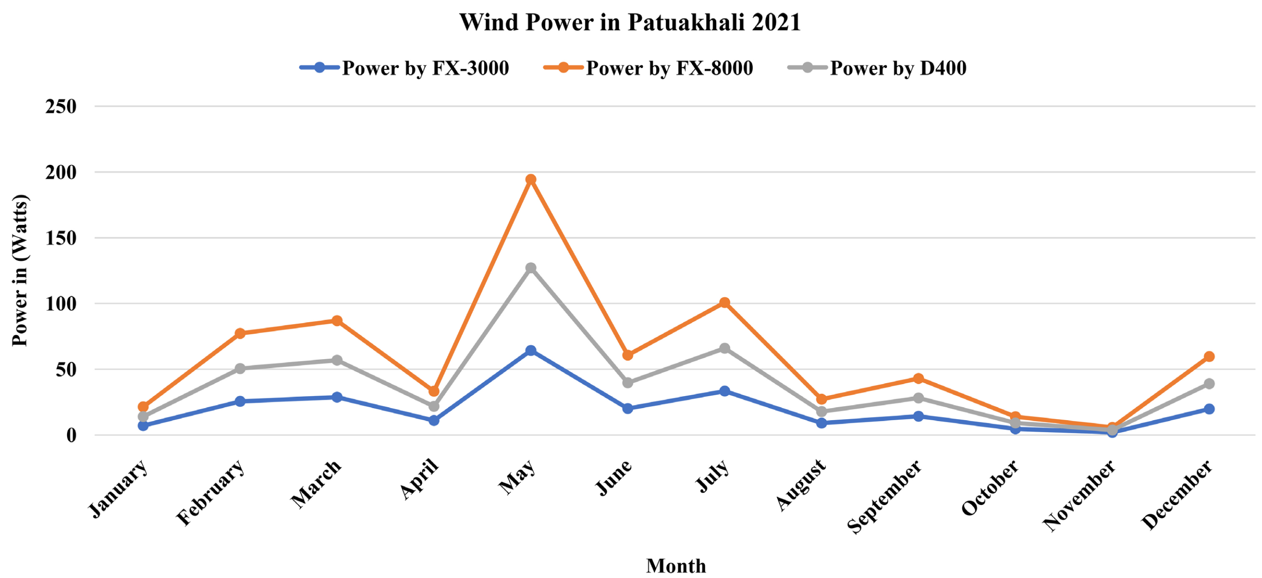


Figure 38. Wind power from three turbines in Patuakhali 2021.

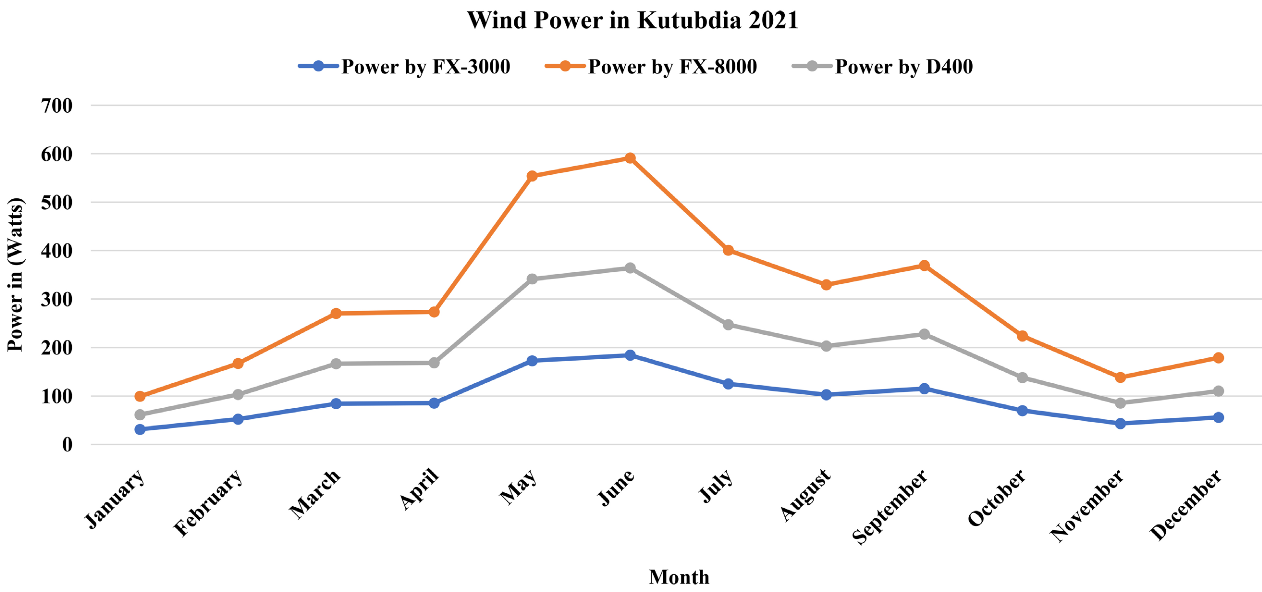


Figure 39. Wind power from three turbines in Kutubdia 2021.

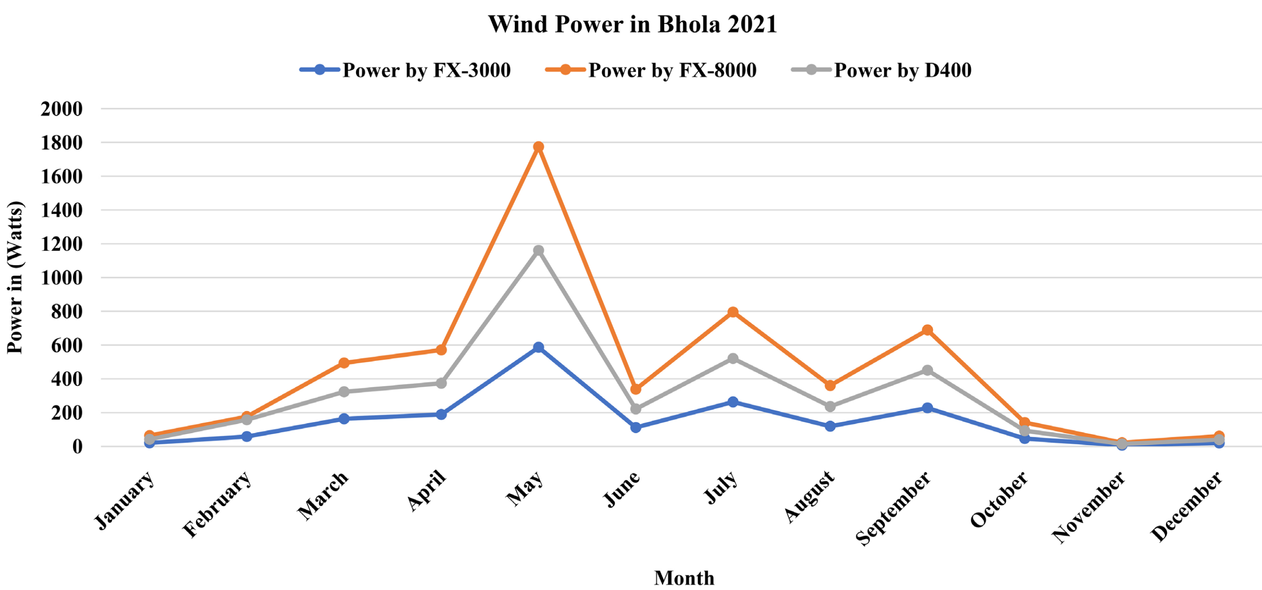


Figure 40. Wind power from three turbines in Bhola 2021.

Figures 37-40 reflect the power generated by the three wind turbines FX-300, FX-800, and D400 in each month of 2021 at Mongla, Patuakhali, Kutubdia, and Bhola. We may surmise from the statistics that the FX-800 is able to produce the most electricity at each station.

5. Conclusions

We briefly studied the wind velocities of Mongla, Patuakhali, Kutubdia, and Bhola stations for the years 2017-2021. An analysis of the local wind characteristics has been carried out with a wind rose, depicting the direction and intensity of local wind conditions over a seasonal period. In our observation, summer, specifically the months from April to July, is the best period for the energy harness due to the high wind velocity. Among the four stations, the maximum power generated stations are Bhola and Kutubdia, which can play a significant role in renewable energy for Bangladesh.

Some well-known wind turbines operated under low wind speeds have been studied and calculated the power that could extract from the available wind in the above four discussed regions in Bangladesh. The overview of the power obtained from these regions gives a preliminary idea about the prospect of wind turbines in Bangladesh. The discussed turbines have scale merits; this kind of turbine can be reassembled to install in a certain location in Bangladesh. In addition, the wind flow is not uniform. Hence, the selection of a suitable location as well as wind turbines is vital in this particular process to harness targeted wind energy. The performance of the turbines was assessed using historical wind data collected at three-hour intervals; however, uninterrupted wind data will provide a more accurate assessment of the turbine's performance. Experimental research can assist in overcoming this barrier; thus, that is what we will be emphasizing in the future.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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