Analysis of Precipitation and Wind Speed at Mundakkai and Chooralmala: A Python-based Investigation into the Conditions Leading to the Devastating Landslides in Kerala

By

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1. Introduction

Mundakkai and Chooralmala, picturesque villages in the Wayanad district of Kerala, India, are renowned for their lush greenery and hilly terrain. Located between latitudes 11°27'00" N and 11°58'35" N, and longitudes 75°47'50" E and 76°26'35" E, these areas boast significant biodiversity and scenic beauty. Despite their charm, they experienced severe landslides in July 2024, causing substantial loss of life and property. This disaster highlighted the region's vulnerability to natural calamities, exacerbated by its steep slopes and heavy rainfall.

This study investigates the primary factors contributing to these landslides, focusing on precipitation, soil type, and wind speed, and how these elements interacted to precipitate the catastrophic events. The study utilizes ERA5 data from 2014 to 2024 for the monsoon months(June, July and August), centered on the coordinates 11.5° N and 76.25° E, which are proximate to both Mundakkai and Chooralmala. By analyzing the correlation between extreme weather conditions and landslides, this research explores the climatic factors that triggered these devastating events, providing valuable insights into the role of extreme weather in landslide occurrences.

2. Data Analysis and Insights

2.1 Total Precipitation(mm)

Total precipitation (mm) is a measurement of the amount of water that falls to the ground over a specific period, expressed in millimeters (mm). This includes all forms of precipitation, such as rain, snow, sleet, and hail. Heavy or prolonged rainfall can lead to landslides. It can saturate the soil which in turn weakens it and results in soil erosion.

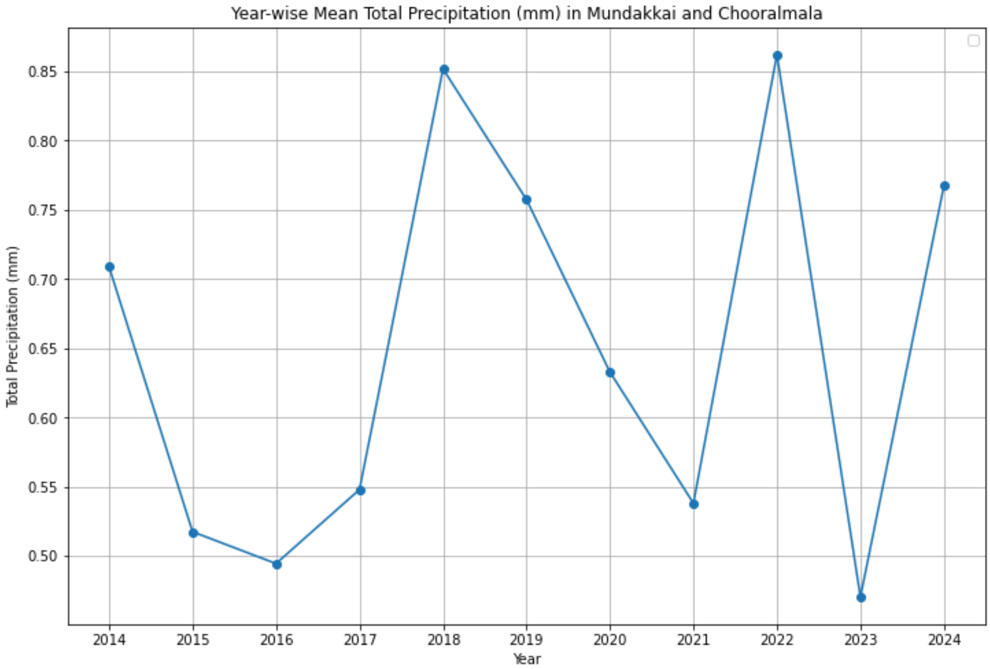

Figure 1. *Yearly mean total precipitation(mm) in Mundakkai and Chooralmala.*

The Yearly mean total precipitation graph(Figure 1) illustrates considerable variations in annual rainfall, indicating high inter-annual variability in the region's precipitation patterns. This variability suggests a susceptibility to both droughts and floods. Notably, the years 2018 and 2022 experienced exceptionally high precipitation levels, and the plot shows that 2024 is approaching these extreme values with similarly high rainfall.

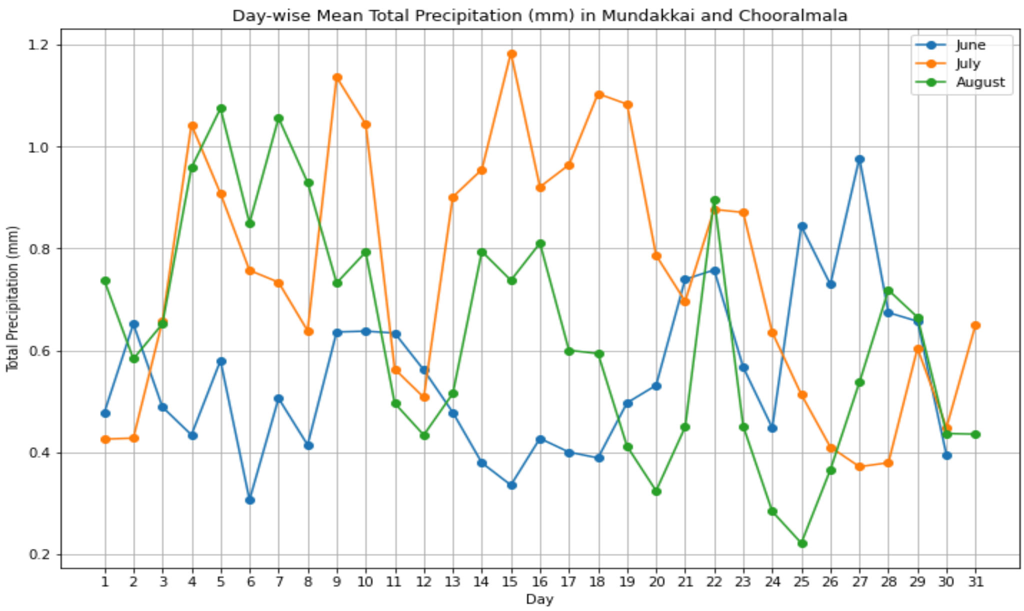

Figure 2. *Daily mean total precipitation(mm) in Mundakkai and Chooralmala during the monsoon months.*

From the plot in Figure 2, it is seen that in June, the region experiences lower overall precipitation, marking the onset of the monsoon season. By July, precipitation increases and reaches its peak, indicating the peak of the monsoon. August shows a gradual decline in rainfall compared to July, reflecting the end of the monsoon period. The most intense rainfall typically occurs in mid to late July, with some variations observed between years.

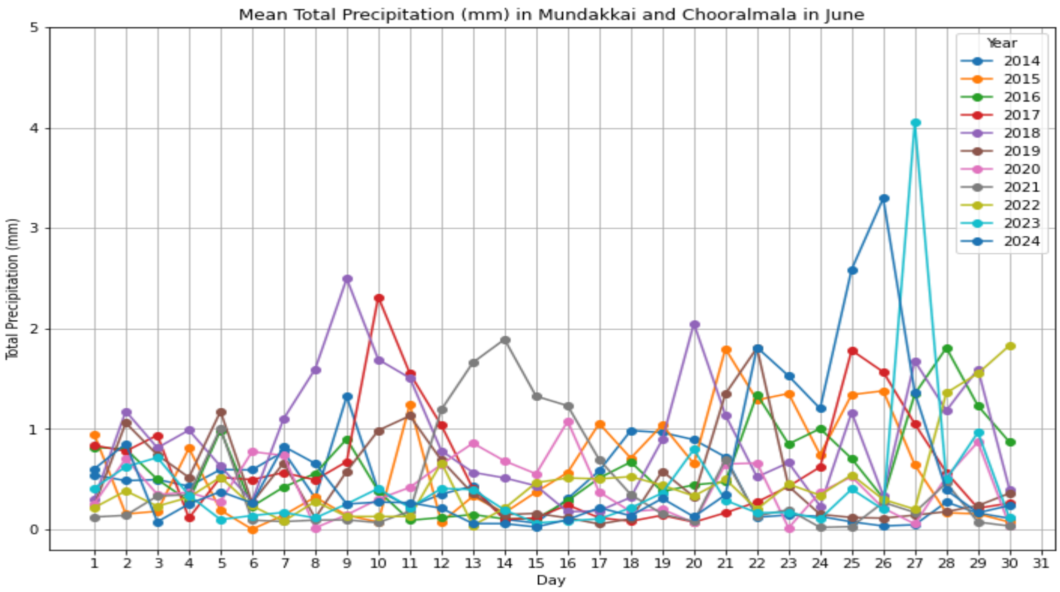

Figure 3a. *Daily mean total precipitation(mm) in Mundakkai and Chooralmala in June.*

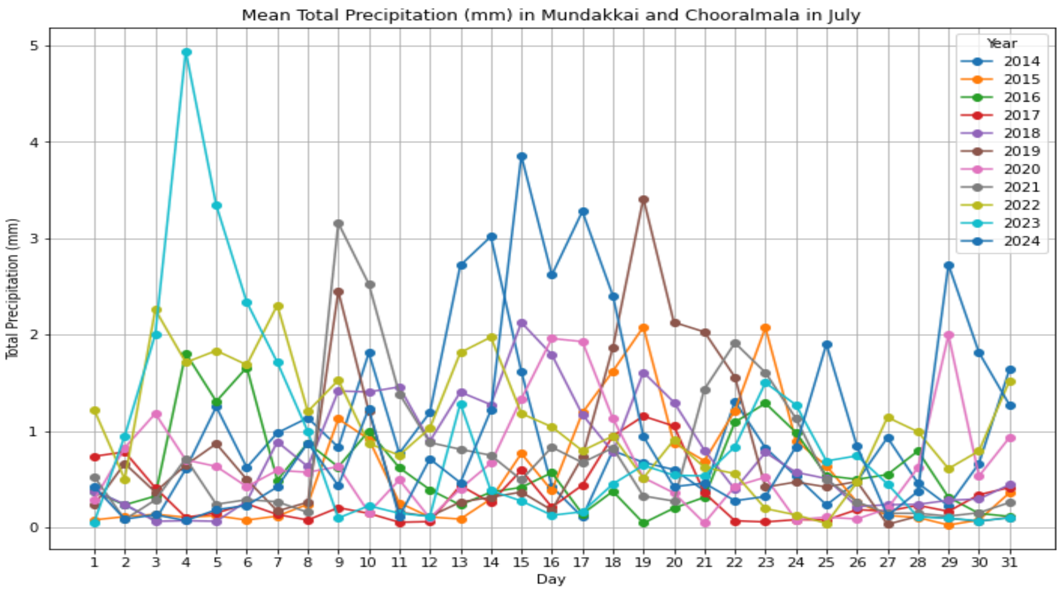

Figure 3b. *Daily meantotal precipitation(mm) in Mundakkai and Chooralmala in July.*

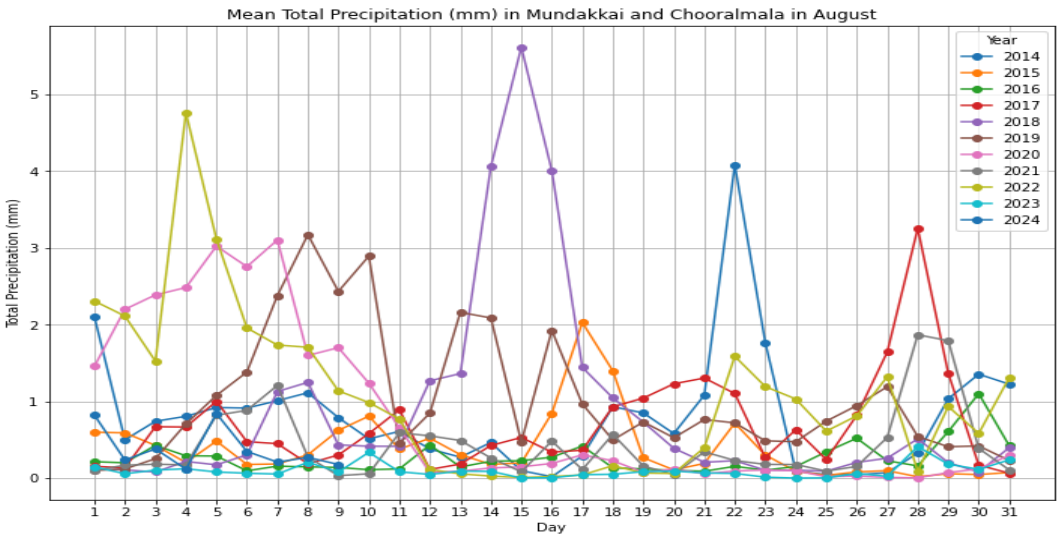

Figure 3c. *Daily mean total precipitation(mm) in Mundakkai and Chooralmala in August.*

Seasonal trends similar to that seen in Figure 2 can be understood from the graphs in Figure 3a,3b and 3c. It can be understood that June exhibits lower overall precipitation compared to July and August, marking the onset of the monsoon season. July experiences the highest precipitation levels, representing the peak of the monsoon. In August, there is a gradual decline in precipitation from July, indicating the tapering off of the monsoon season.

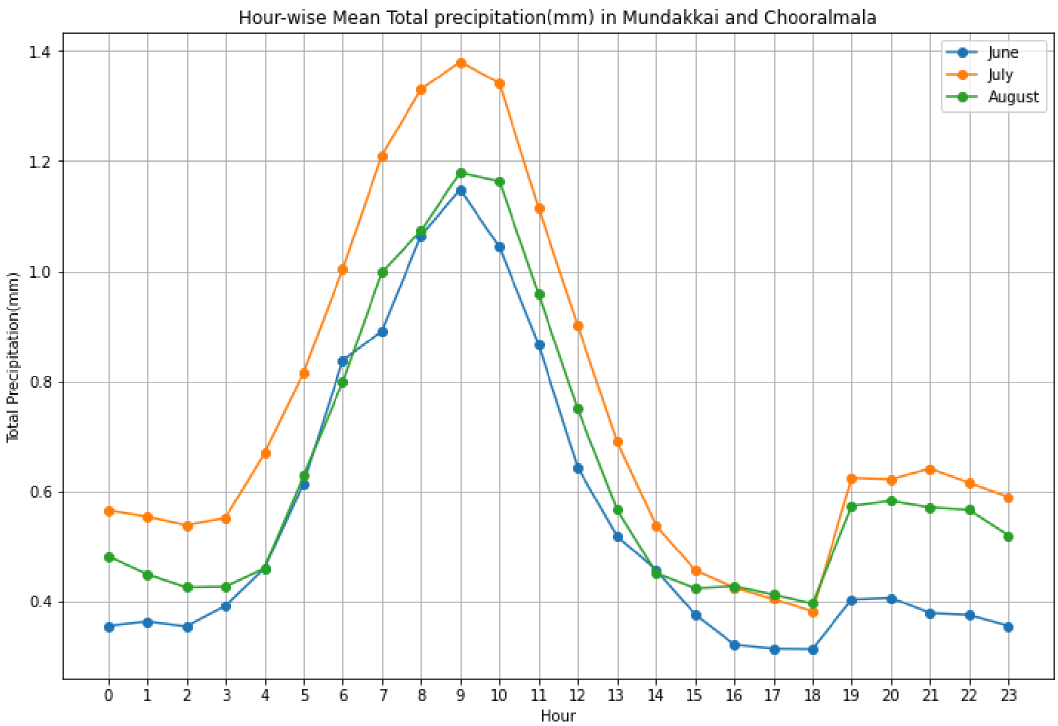

Figure 4. *Hourly mean total precipitation(mm) in Mundakkai and Chooralmala during the monsoon months.*

The analysis of Figure 4 reveals a distinct diurnal pattern in precipitation across all three months, with higher levels typically observed during the morning hours. Peak precipitation is seen between 7:00 AM UTC and 11:00 AM UTC, with July showing the most pronounced peak among the months. Once the peak value is obtained in the morning, the rainfall reduces until 18:00 PM UTC and remains almost constant throughout the night.

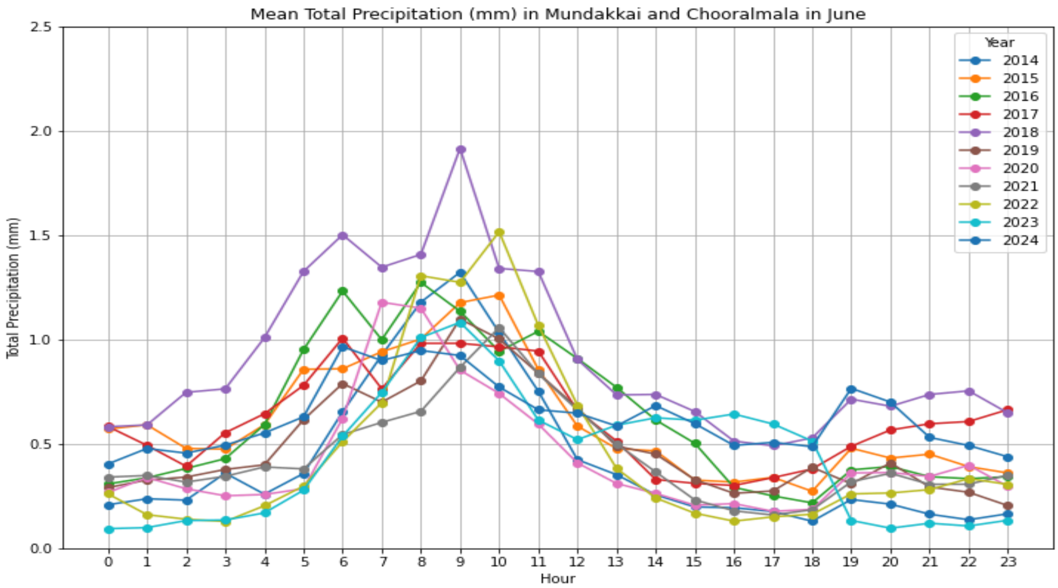

Figure 5a. *Hourly mean total precipitation(mm) in Mundakkai and Chooralmala in June.*

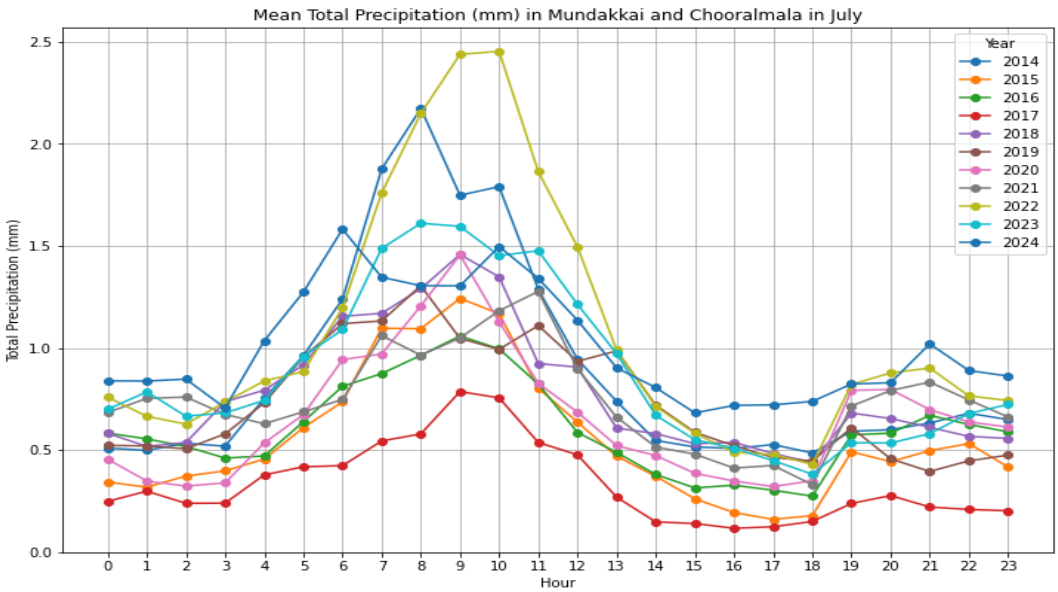

Figure 5b. *Hourly mean total precipitation(mm) in Mundakkai and Chooralmala in July.*

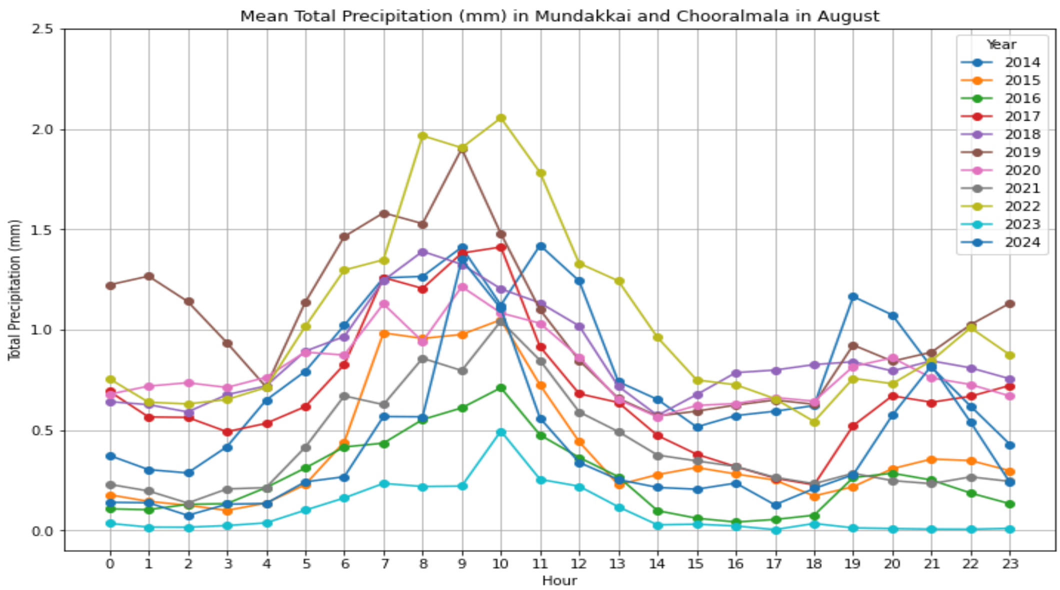

Figure 5c. *Hourly mean total precipitation(mm) in Mundakkai and Chooralmala in August.*

The Figures 5a, 5b and 5c reveal a similar diurnal pattern for all the years similar to that is seen in Figure 4. The precipitation across all three months, with higher levels typically observed during the morning hours.

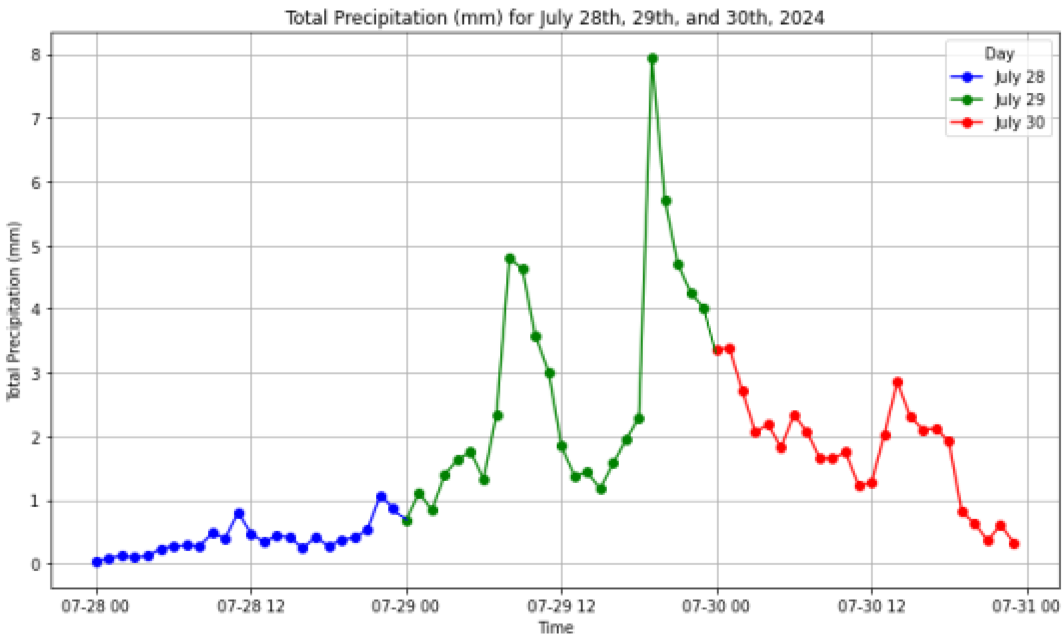

Figure 6. *Total precipitation in Mundakkai and Chooralmala on 28th, 29th and 30th of July 2024.*

The plot in Figure 6 shows the total precipitation (in millimetres) over three days: July 28th, 29th, and 30th, 2024. The most notable event occurred on July 29th, with a peak rainfall of approximately 8 mm (point A), indicating intense precipitation within a short period, where precipitation rapidly increased from about 2 mm to 8 mm. The rainfall intensity surged between 00:00 AM UTC on July 28th and 00:00 AM UTC on July 29th, likely saturating the soil quickly. The plot suggests a strong link between this intense rainfall on July 29th and the devastating landslides in Mundakkai and Chooralmala. The first landslide (point B) occurred soon after the peak rainfall, followed by a second landslide (point C), both happening between 01:00 AM and 04:30 AM IST. This helps us understand that the extreme precipitation likely destabilised the slopes, triggering the disasters.

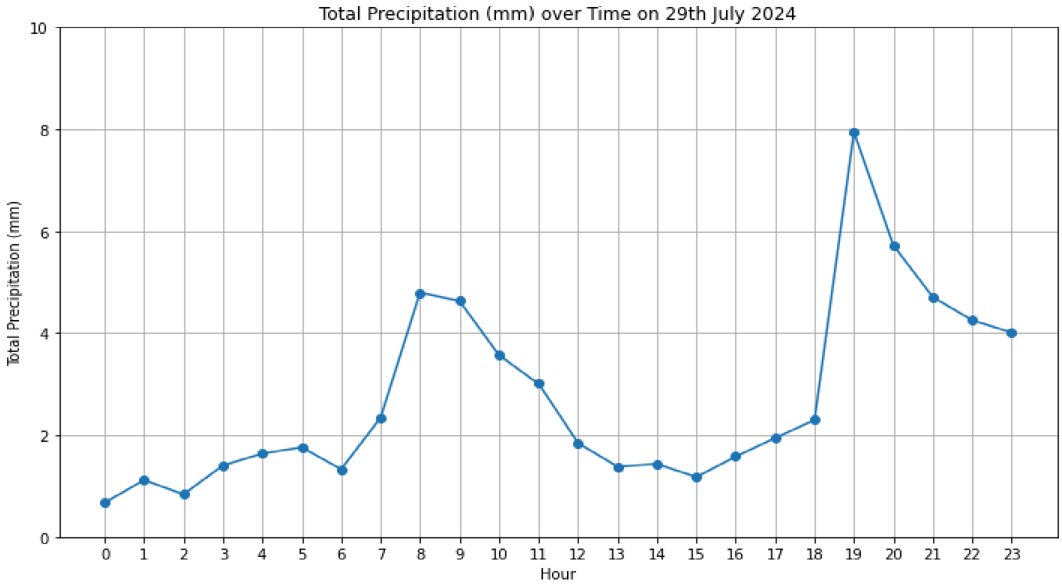

Figure 7a. *Total precipitation in Mundakkai and Chooralmala on 29th of July 2024.*

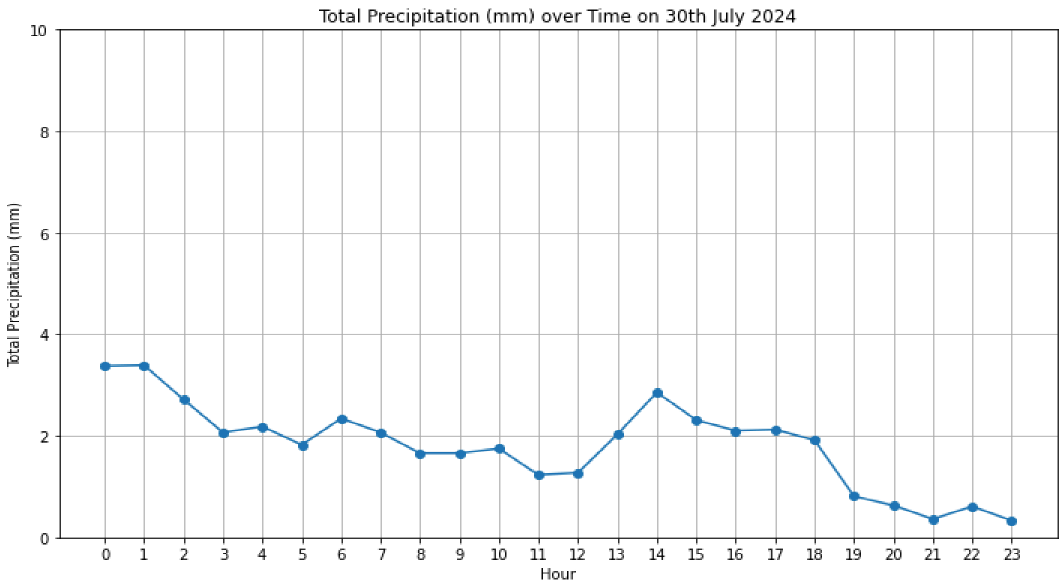

Figure 7b. *Total precipitation in Mundakkai and Chooralmala on 30th of July 2024.*

The plot in Figure 6 for 29th of July and 30th of July can be seen much more clearly in Figures 7a and 7b.

2.2 Wind speed

Wind speed measures how fast air is moving horizontally across the Earth's surface from a region of high pressure to a region of low pressure. It is typically reported in units like meters per second (m/s), kilometers per hour (km/h), or miles per hour (mph). Wind speed is an important meteorological parameter because it affects weather conditions, such as temperature and precipitation, and plays a role in various environmental processes, including the dispersion of pollutants and the erosion of soil.

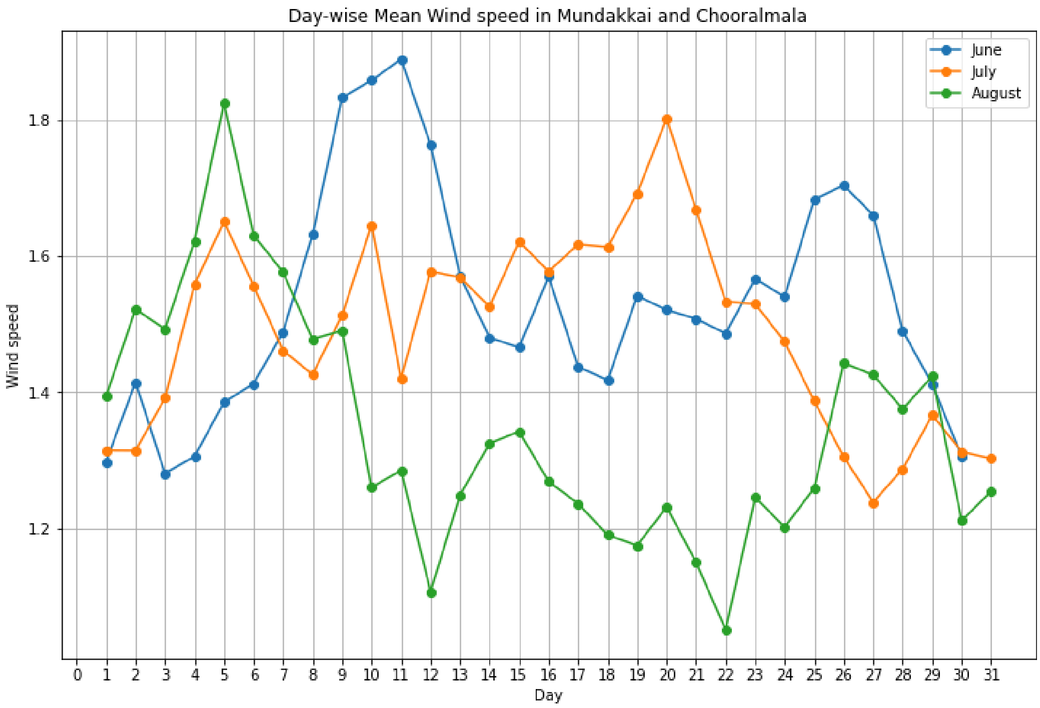

Figure 8. *Daily mean wind speed in Mundakkai and Chooralmala during the monsoon months.*

Figure 8 clearly shows that, when you look at wind speed averaged day wise there is no pattern even though a pattern was seen for precipitation.

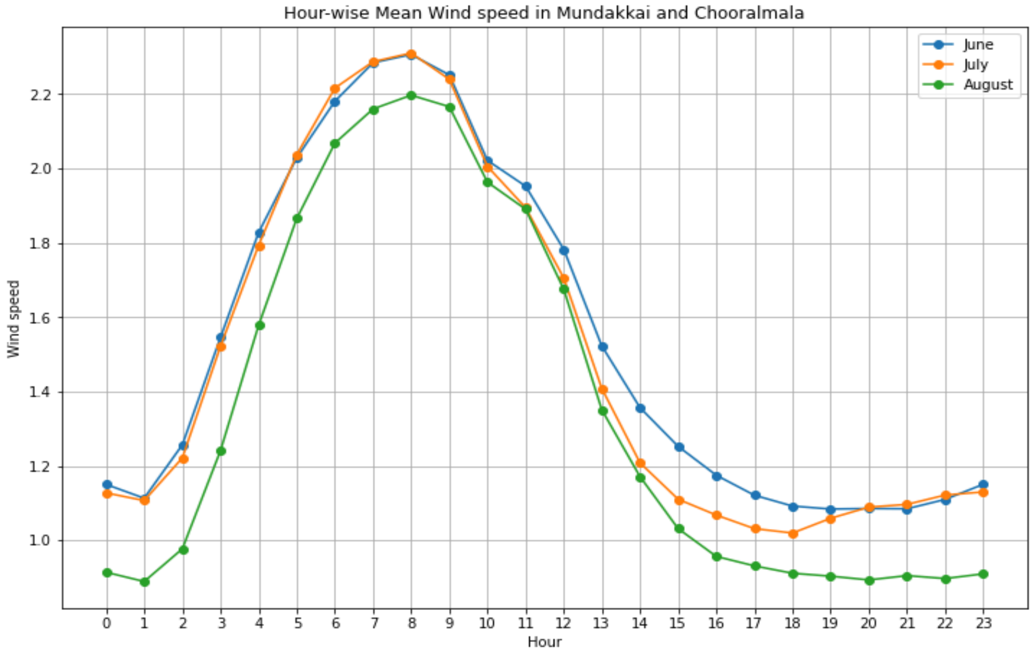

Figure 9. *Hourly mean wind speed in Mundakkai and Chooralmala during the monsoon months.*

According to figure 9, a diurnal pattern similar to that seen for precipitation can be seen for wind speed also, which clearly suggests that precipitation is accompanied with winds. The peak for precipitation was seen during the morning hours and a similar peak is observed for wind speed, which suggests that heavy rains are accompanied with strong winds in this place.

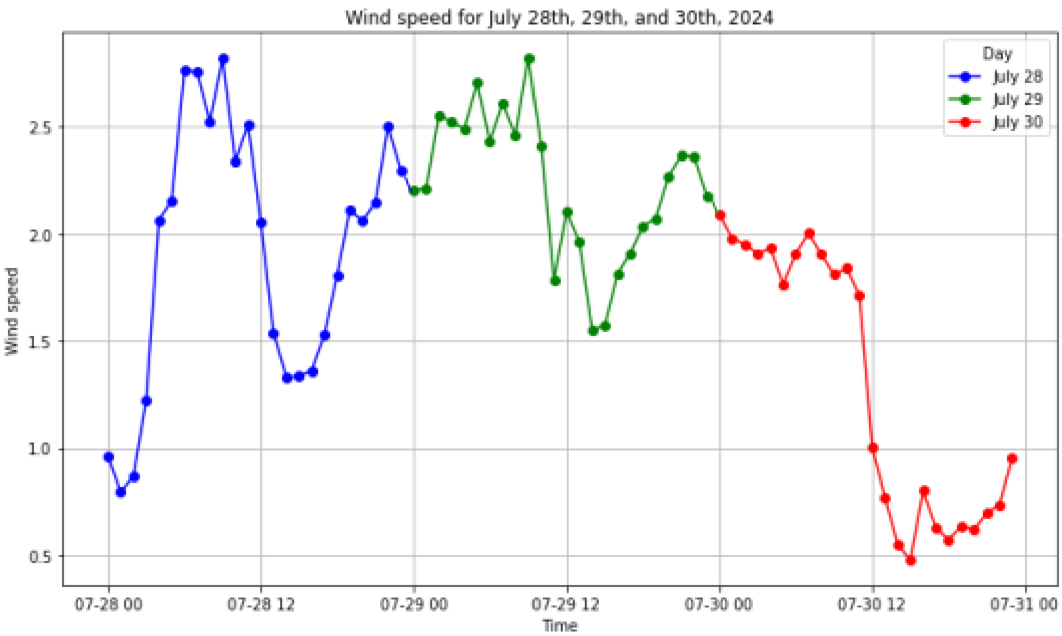

Figure 10. *Wind speed in Mundakkai and Chooralmala on 28th, 29th and 30th of July 2024.*

Figure 10 shows that strong winds were observed from 28th of July to 30th of July. The winds have reduced subsequently after 12:00 PM UTC.

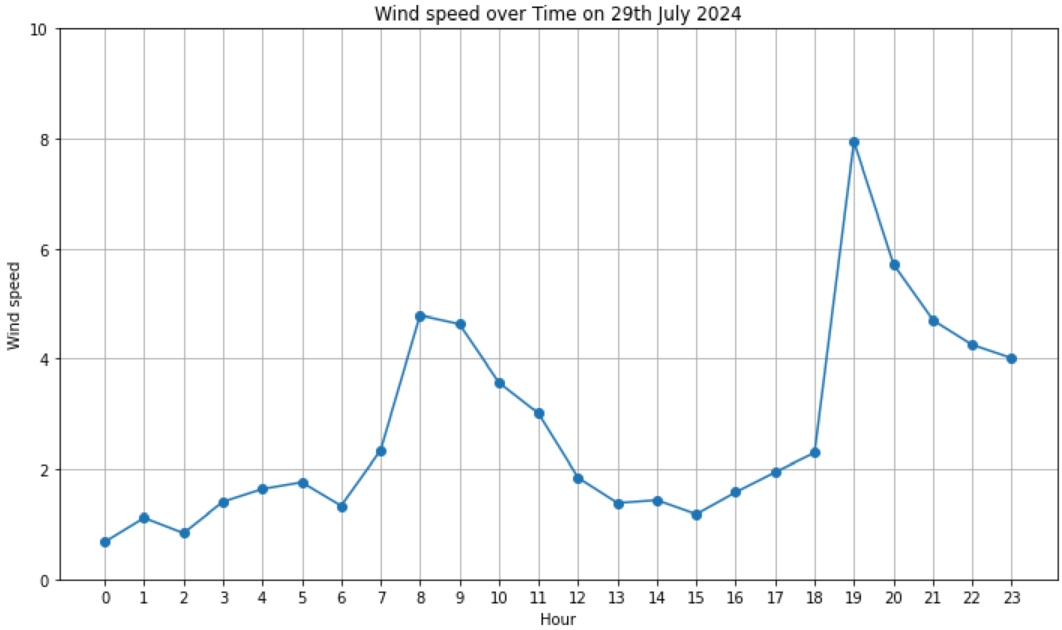

Figure 11a. *Wind speed in Mundakkai and Chooralmala on 29th of July 2024.*

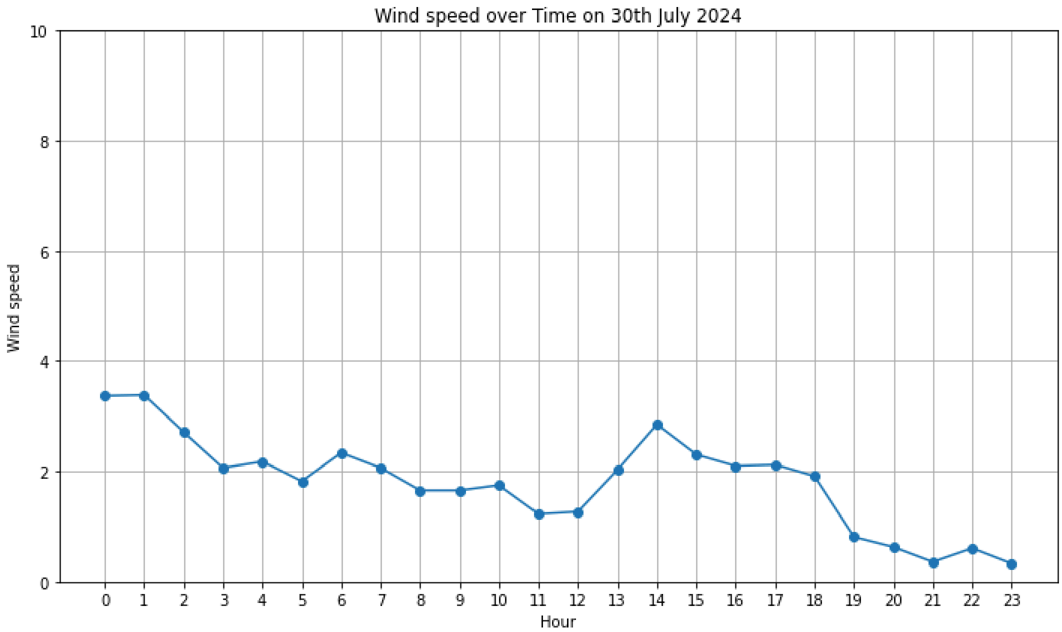

Figure 11b. *Wind speed in Mundakkai and Chooralmala on 30th of July 2024.*

Figures 11a and 11b show a much clearer version of wind speed on 29th and 30th of July.

2.3 Soil type

Soil type refers to the classification of soil based on its texture, composition, and particle size. According to ERA 5, there are 7 types of soils, and they are:

1. **Coarse:** Soil with large particles, allowing for quick water drainage and low water retention.
2. **Medium:** Soil with moderately sized particles, offering balanced water retention and drainage.
3. **Medium fine:** Soil with finer particles than medium soil, holding more water while still providing reasonable drainage.
4. **Fine:** Soil with small particles, characterized by high water retention and slower drainage.
5. **Very fine:** Soil with extremely small particles, holding a large amount of water but prone to waterlogging and poor drainage.
6. **Organic:** Soil rich in organic matter, generally having good water retention and fertility.
7. **Tropical organic:** Organic-rich soil typically found in tropical regions, characterized by high fertility and moisture retention.

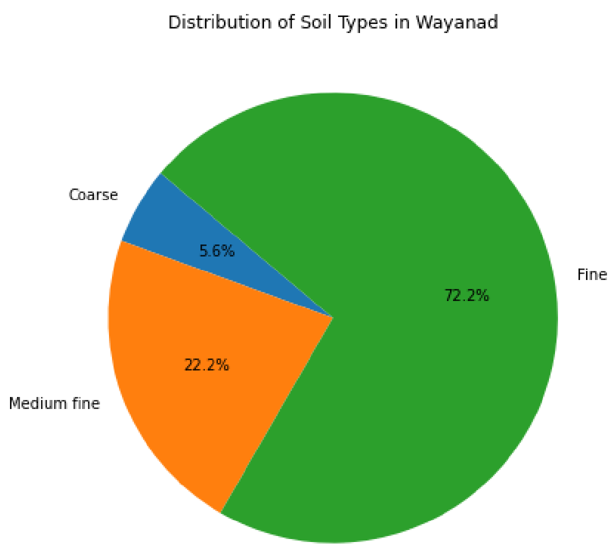

Figure 12. *Pie chart showing the distribution of soil in Wayanad.*

The pie chart (Figure 12) reveals that Wayanad's soil composition is predominantly fine soil (72.2%), followed by medium fine soil (22.2%) and coarse soil (5.6%). This distribution offers important insights into the region's water retention capabilities and landslide risks. Fine soil, with its smaller particle size, has a high water holding capacity, which benefits agriculture by retaining moisture. However, this also increases the risk of landslides, particularly during heavy rainfall when the soil can become saturated and unstable.

3. Conclusion

From this study, we can conclude that the combination of intense precipitation, elevated wind speeds, and the predominant fine soil in the region were key factors contributing to the landslides in Wayanad on July 30th, 2024. These natural conditions, when coupled with urbanization and the destruction of natural forests, created the perfect storm, ultimately leading to the disaster. This highlights the critical need for sustainable development and effective land management practices to mitigate the risks of such catastrophic events in the future.