HYDROLOGICAL ANALYSIS REPORT

Analysis of Rainfall Patterns at TIA (2015–2024)

A Comprehensive Study of Seasonal Distribution and Engineering Implications in the Kathmandu Valley.

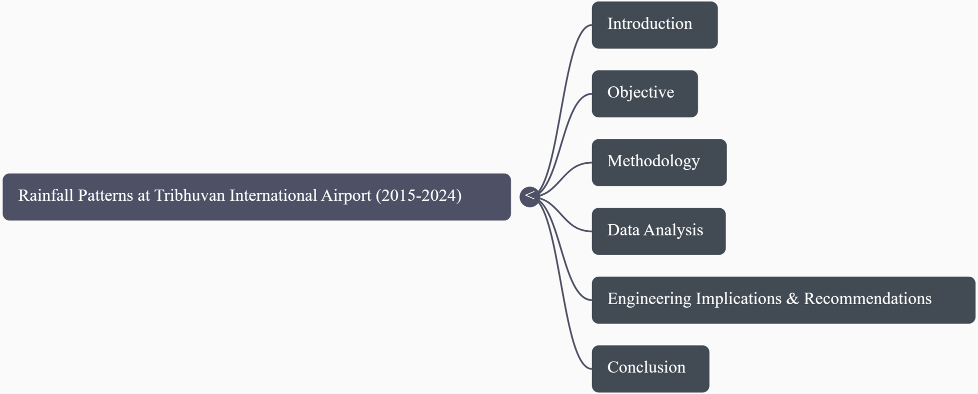


Figure 1: Rainfall Distribution at TIA (2015-2024)

Introduction: The Hydrological Context

- Rainfall analysis is an important part of civil and environmental engineering, especially in countries like Nepal where monsoon rainfall is dominant. Extreme rainfall events strongly affect urban drainage systems, flood risk, and infrastructure safety. Tribhuvan International Airport (TIA), located in the Kathmandu Valley, experiences irregular and high-intensity rainfall. These rainfall patterns create challenges for airport operations and nearby urban areas. This study analyzes daily rainfall data from 2015 to 2024 to understand rainfall intensity behavior and its implications for infrastructure design.

Study Scope

Location: Kathmandu Valley
Period: 2015–2024 [cite: 4]
Observations: 3,653 Days

Research Objectives

1. The main objective of this study is to analyze daily rainfall recorded at Tribhuvan International Airport using Indian Meteorological Department (IMD) rainfall classification standards. The study aims to evaluate the frequency and contribution of different rainfall intensity categories and to assess the importance of extreme rainfall events for drainage and infrastructure design.

   Data Description

   The dataset consists of daily rainfall measurements collected from the Tribhuvan International Airport meteorological station. The study covers a ten-year period from 2015 to 2024, including a total of 3,653 daily observations. The dataset includes both rainy days and dry days and was checked for completeness to ensure reliable analysis.

Data & Methodology

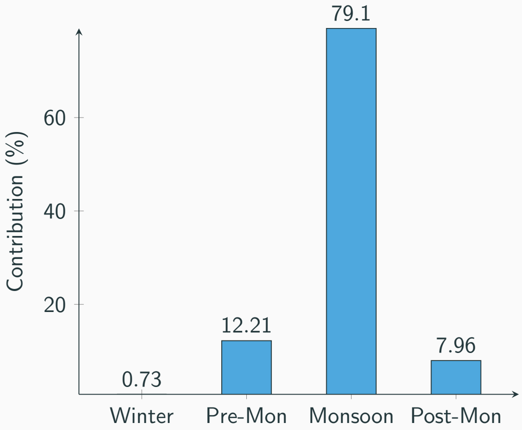
Daily rainfall data were classified into five intensity categories based on IMD standards: No Rain, Light Rain, Moderate Rain, Heavy Rain, and Very Heavy Rain. Statistical analysis was carried out using Python programming tools. The analysis included rainfall classification, frequency distribution, contribution analysis, percentile estimation, and wet and dry spell analysis. Statistical analysis was performed using Python (Pandas, NumPy, SciPy).

Metric	Value / Approach
Dataset Size	3,653 daily records spanning 10 years.
Quality Check	Zero missing values; Unit consistency verified.
Source	Tribhuvan International Airport station.
Reliability	Values within expected physical bounds.

Rainfall Intensity Classification

The IMD rainfall classification system helps identify hydrologically significant rainfall events. Light and moderate rainfall events occur more frequently, while heavy and very heavy rainfall events occur less often but have a much greater impact on total rainfall and drainage system performance.

(Results and Discussion)



Statistical Insight

The monsoon season dominates the hydrologic cycle, accounting for **79.10%** of total annual precipitation.

Engineering Implications & Recommendations

The dominance of extreme rainfall events has important implications for infrastructure design. Drainage systems should be designed based on high-intensity rainfall thresholds rather than mean rainfall values. Percentile-based design rainfall provides better safety and reliability. Sustainable drainage measures such as retention ponds and storage systems can help reduce peak runoff and flood risk.

Critical Implications

- **Drainage:** Peak loads during monsoon concentration[cite: 45].
- **Aviation:** Water-logging risks on airport infrastructure[cite: 44].

Recommendations

- **Urban Planning:** Design systems for high-intensity events[cite: 40].
- **Water Management:** Strategic planning for winter scarcity.

Conclusion

This study demonstrates that extreme rainfall events play a critical role in the hydrology of the Kathmandu Valley despite their low frequency. Heavy and very heavy rainfall events govern drainage design requirements and flood risk at Tribhuvan International Airport. The findings emphasize the importance of using historical extremes and percentile-based rainfall values to ensure resilient and safe infrastructure planning. The 10-year analysis confirms a highly uneven distribution. With **79.1%** rainfall in monsoon and only **0.73%** in winter, the Kathmandu Valley requires resilient infrastructure design and strategic water management.

THANK YOU

A Comprehensive Study of Seasonal Distribution and Engineering Implications in the Kathmandu Valley.

Latex code:

```
\documentclass[10pt, aspectratio=169]{beamer}


% --- Essential Packages ---
\usetheme{metropolis}
\usepackage{tcolorbox}
\usepackage{booktabs}
\usepackage{tikz}
\usepackage{pgfplots}
\pgfplotsset{compat=1.18}


% --- Custom Color Palette ---
\definecolor{DeepSea}{HTML}{003049}
\definecolor{TerraCotta}{HTML}{D62828}
\definecolor{OrangeSun}{HTML}{F77F00}
\definecolor{SkyBlue}{HTML}{4EA8DE}


% --- Footer Setup ---
\setbeamertemplate{footline}{

\begin{beamercolorbox}[wd=\paperwidth,ht=3ex,dp=1.5ex,leftskip=1cm,rightskip=1cm]{palette primary}
   \scriptsize A Comprehensive Study of Seasonal Distribution and Engineering Implications in the Kathmandu Valley. \hfill \insertframenumber / \inserttotalframenumber
  \end{beamercolorbox}
}
```

```
\begin{document}

% 1. ATTRACTIVE COVER PAGE
\begingroup
\setbeamercolor{background canvas}{bg=DeepSea}
\begin{frame}[plain]
  \begin{tikzpicture}[remember picture,overlay]
    % Graphic elements: stylized rainfall lines
    \foreach \i in {1,...,20} {
      \draw[SkyBlue, opacity=0.2, line width=1pt] ([xshift=\i*0.8cm]current page.north west) --
([xshift=\i*0.8cm-2cm]current page.south west);
    }
    % Title Box
    \node[fill=white, opacity=0.9, rounded corners, text width=10cm, inner sep=1cm] at
(current page.center) {
      \centering
      {\color{DeepSea}\Large\bfseries HYDROLOGICAL ANALYSIS REPORT}\\[0.4cm]
      {\color{TerraCotta}\large Analysis of Rainfall Patterns at TIA (2015--2024)}\\[0.8cm]
      {\color{gray}\small A Comprehensive Study of Seasonal Distribution and Engineering
Implications in the Kathmandu Valley.}
    };
  \end{tikzpicture}
\end{frame}
\endgroup
% 2. Content
\begin{figure}
  \centering
```

```
  \includegraphics[width=1.\textwidth, height=1\textheight, keepaspectratio]{1.png}
  \caption{Rainfall Distribution at TIA (2015-2024)}
\end{figure}


% 2. INTRODUCTION
\begin{frame}{Introduction: The Hydrological Context}
  \begin{columns}
    \begin{column}{0.6\textwidth}
      \begin{itemize}
      \item  Rainfall analysis is an important part of civil and environmental engineering, especially in countries like Nepal where monsoon rainfall is dominant. Extreme rainfall events strongly affect urban drainage systems, flood risk, and infrastructure safety.

Tribhuvan International Airport (TIA), located in the Kathmandu Valley, experiences irregular and high-intensity rainfall. These rainfall patterns create challenges for airport operations and nearby urban areas. This study analyzes daily rainfall data from 2015 to 2024 to understand rainfall intensity behavior and its implications for infrastructure design.
      \end{itemize}
    \end{column}
    \begin{column}{0.4\textwidth}
      \begin{tcolorbox}[colframe=OrangeSun, title=Study Scope]
        \small
        \textbf{Location:} Kathmandu Valley \\
        \textbf{Period:} 2015--2024 [cite: 4]\\
        \textbf{Observations:} 3,653 Days
      \end{tcolorbox}
    \end{column}
```

```
    \end{columns}
\end{frame}

% 3. OBJECTIVES
\begin{frame}{Research Objectives}
    \begin{enumerate}
        \item The main objective of this study is to analyze daily rainfall recorded at Tribhuvan International Airport using Indian Meteorological Department (IMD) rainfall classification standards. The study aims to evaluate the frequency and contribution of different rainfall intensity categories and to assess the importance of extreme rainfall events for drainage and infrastructure design.\\
        Data Description\\
The dataset consists of daily rainfall measurements collected from the Tribhuvan International Airport meteorological station. The study covers a ten-year period from 2015 to 2024, including a total of 3,653 daily observations. The dataset includes both rainy days and dry days and was checked for completeness to ensure reliable analysis.

    \end{enumerate}
    \begin{center}
        \tikz \draw[OrangeSun, ultra thick] (0,0) -- (10,0);
    \end{center}
\end{frame}

% 4. DATA & METHODOLOGY
\begin{frame}{Data \& Methodology}
\item Daily rainfall data were classified into five intensity categories based on IMD standards: No Rain, Light Rain, Moderate Rain, Heavy Rain, and Very Heavy Rain. Statistical analysis was carried out using Python programming tools. The analysis included rainfall classification,
```

frequency distribution, contribution analysis, percentile estimation, and wet and dry spell analysis.

\small

Statistical analysis was performed using Python (Pandas, NumPy, SciPy).

\vspace{0.3cm}

\begin{table}

\centering

\begin{tabular}{lp{8cm}}

\toprule

\textbf{Metric} & \textbf{Value / Approach} \\

\midrule

\textbf{Dataset Size} & 3,653 daily records spanning 10 years. \\

\textbf{Quality Check} & Zero missing values; Unit consistency verified. \\

\textbf{Source} & Tribhuvan International Airport station. \\

\textbf{Reliability} & Values within expected physical bounds. \\

\bottomrule

\end{tabular}

\end{table}

\end{frame}

Rainfall Intensity Classification\\

The IMD rainfall classification system helps identify hydrologically significant rainfall events. Light and moderate rainfall events occur more frequently, while heavy and very heavy rainfall events occur less often but have a much greater impact on total rainfall and drainage system performance.

% 5. VISUAL FINDINGS (BAR GRAPH)

```
\begin{frame}{(
Results and Discussion)}
  \begin{columns}
    \begin{column}{0.6\textwidth}
      \begin{tikzpicture}[scale=0.85]
        \begin{axis}[
          ybar,
          symbolic x coords={Winter, Pre-Mon, Monsoon, Post-Mon},
          xtick=data,
          nodes near coords,
          nodes near coords align={vertical},
          ylabel={Contribution (\%)},
          ylim={0,95},
          bar width=22pt,
          axis x line=bottom,
          axis y line=left,
          enlarge x limits=0.2,
        ]
          \addplot[fill=SkyBlue] coordinates {(Winter, 0.73) (Pre-Mon, 12.21) (Monsoon,
79.10) (Post-Mon, 7.96)};
        \end{axis}
      \end{tikzpicture}
    \end{column}
    \begin{column}{0.35\textwidth}
      \begin{tcolorbox}[colframe=DeepSea, title=Statistical Insight]
        \small
```

The monsoon season dominates the hydrologic cycle, accounting for \textbf{79.10\%} of total annual precipitation.

\end{tcolorbox}

\end{column}

\end{columns}

\end{frame}

% 6. ENGINEERING IMPLICATIONS & RECOMMENDATIONS

\begin{frame}{Engineering Implications \& Recommendations}

The dominance of extreme rainfall events has important implications for infrastructure design. Drainage systems should be designed based on high-intensity rainfall thresholds rather than mean rainfall values. Percentile-based design rainfall provides better safety and reliability. Sustainable drainage measures such as retention ponds and storage systems can help reduce peak runoff and flood risk.

\begin{columns}[T]

\begin{column}{0.48\textwidth}

\begin{tcolorbox}[colframe=TerraCotta, title=Critical Implications]

\footnotesize

\begin{itemize}

\item \textbf{Drainage:} Peak loads during monsoon concentration[cite: 45].

\item \textbf{Aviation:} Water-logging risks on airport infrastructure[cite: 44].

\end{itemize}

\end{tcolorbox}

\end{column}

\begin{column}{0.48\textwidth}

\begin{tcolorbox}[colframe=DeepSea, title=Recommendations]

\footnotesize

```
        \begin{itemize}
          \item \textbf{Urban Planning:} Design systems for high-intensity events[cite: 40].
          \item \textbf{Water Management:} Strategic planning for winter scarcity.
        \end{itemize}
      \end{tcolorbox}
    \end{column}
  \end{columns}
\end{frame}

% 7. CONCLUSION
\begin{frame}{Conclusion}
  \centering
  \begin{minipage}{0.8\textwidth}
    \begin{tcolorbox}[colback=DeepSea!5, colframe=DeepSea, arc=0mm]
    This study demonstrates that extreme rainfall events play a critical role in the hydrology of the Kathmandu Valley despite their low frequency. Heavy and very heavy rainfall events govern drainage design requirements and flood risk at Tribhuvan International Airport. The findings emphasize the importance of using historical extremes and percentile-based rainfall values to ensure resilient and safe infrastructure planning.
      The 10-year analysis confirms a highly uneven distribution. With \textbf{79.1\%} rainfall in monsoon and only \textbf{0.73\%} in winter, the Kathmandu Valley requires resilient infrastructure design and strategic water management.
    \end{tcolorbox}
  \end{minipage}
\end{frame}

% 8. HIGHLY GRAPHIC THANK YOU PAGE
\begingroup
```

```
\setbeamercolor{background canvas}{bg=DeepSea}

\begin{frame}[plain]

  \begin{tikzpicture}[remember picture,overlay]

    % Concentric circles

    \foreach \r in {1,2.5,4,6} {

      \draw[\textbf{black}, opacity=0.15, line width=0.5pt] (current page.center) circle (\r cm);

    }

    % Stylized Thank You

    \node[text=pink, font=\Huge\bfseries\sffamily] at (current page.center) {THANK YOU};


    % Mandatory Footer

    \node[text=white!40, font=\tiny, anchor=south, yshift=0.5cm] at (current page.south) {A Comprehensive Study of Seasonal Distribution and Engineering Implications in the Kathmandu Valley.};

  \end{tikzpicture}

\endgroup

\end{frame}


\end{document}
```