Government of Nepal
Ministry of Agriculture, Forests and Environment
Department of Environment
Babarmahal, Kathmandu

Status of Air Quality in Nepal
Annual Report, 2025

June, 2026

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Foreword

Clean air is fundamental to human health, environmental sustainability, and the overall quality of life. In recent years, concerns related to air pollution have continued to grow across Nepal, highlighting the need for systematic monitoring, scientific assessment, and informed policy interventions. In this context, the **Status of Air Quality in Nepal: Annual Report 2025** presents an overview of the air quality conditions observed throughout the year using data collected from fourteen continuous monitoring stations located in six provinces of the country.

This report reflects the continued efforts of the Department of Environment to strengthen the national air quality monitoring network and promote evidence-based environmental management. By analyzing trends and patterns of major air pollutants recorded between January 1 and December 31, 2025, the report provides important information for understanding the state of ambient air quality in Nepal. The findings presented here are expected to support government agencies, researchers, development partners, and the general public in addressing air pollution challenges more effectively.

The Department is committed to further improving the coverage and quality of air quality assessment in the coming years. Expansion of monitoring stations, enhancement of data analysis techniques, and stronger collaboration with concerned stakeholders remain among our key priorities. We believe that reliable scientific information is essential for developing practical solutions and safeguarding public health and the environment.

I would like to express sincere appreciation to all members of report preparation technical committee whose contributed to the preparation of this report is incrediable. I extend special thanks to Dr. Govinda Prasad Sharma, Secretary of the Ministry of Agriculture, Forests and Environment, for his continuous guidance and encouragement. I am also grateful to the experts from various organizations, and all technical and administrative staff of the Department of Environment for their valuable support, suggestions, and dedicated efforts throughout the preparation of this publication.

The Department of Environment welcomes constructive feedback and recommendations for further improvement of future reports and ongoing air quality management initiatives. Through collective commitment and coordinated action, we can work toward cleaner air and a healthier environment for all.

Gyanraj Subedi
Director General
June, 2026

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Message

The quality of the air we breathe has become an increasingly important concern for Nepal as rapid urbanization, growing transportation demands, industrial expansion, and changing climatic conditions continue to place pressure on the environment. In many parts of the country, especially densely populated urban areas and valleys, air pollution remains a serious challenge affecting public health, ecosystems, and overall quality of life. Addressing this issue requires reliable scientific information, continuous monitoring, and collective action from all levels of society.

In this regard, the ***Status of Air Quality in Nepal: Annual Report 2025*** provides a comprehensive assessment of ambient air quality conditions observed throughout the year. The report is based on data generated from fourteen continuous air quality monitoring stations operating across six provinces between January and December 2025. Through detailed analysis of pollutant concentrations and seasonal variations, the report offers valuable insights into current trends and emerging concerns related to air pollution in Nepal.

The Ministry of Agriculture, Forests and Environment and the Department of Environment remain committed in strengthening national air quality management systems and promoting evidence-based decision-making. Expansion of monitoring infrastructure, improvement of data quality, and enhancement of technical capacity are essential steps toward developing effective policies and mitigation measures. The findings presented in this report are expected to support government agencies, researchers, development partners, and local authorities in designing targeted interventions for cleaner air and healthier communities.

Although several initiatives have been undertaken in recent years, the report indicates that sustained efforts and stronger coordination among concerned sectors are still necessary. Effective implementation of environmental regulations, adoption of cleaner technologies, improved urban planning, and increased public awareness will play a crucial role in reducing pollution levels and minimizing associated health risks.

I would like to extend my sincere appreciation to all experts, institutions, and technical teams involved in the preparation of this report. Their continuous support, technical expertise, and commitment have been instrumental in ensuring the quality and reliability of this publication. I also acknowledge the valuable contribution of partner organizations and stakeholders who have supported Nepal's air quality monitoring and management efforts.

I believe this report will serve as an important reference document for future planning, policy formulation, and environmental research. Let us continue working together with shared responsibility and stronger commitment toward achieving cleaner air, protecting public health, and ensuring a sustainable future for Nepal.

Saroj Kumar Chaudhary
Deputy Director General
June, 2026

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We would like to express our profound gratitude to all the individuals and experts whose invaluable support, guidance, and expertise have been instrumental in the preparation of this report.

We are deeply indebted to Dr. Govinda Prasad Sharma, Secretary of the Ministry of Agriculture, Forests and Environment; Mr. Gyanraj Subedi, Director General; Mr. Saroj Kumar Chaudhary, Deputy Director General; Mr. Sailesh Kumar Jha, former Deputy Director General and all Section Heads of the Department of Environment for their support throughout this endeavor.

We extend our sincere appreciation to the distinguished experts from various organizations, including Ms. Bina Ghimire, Dr. Rajesh Poudyal, Mr. Niroj Timalsina, Dr. Amrit Sharma, and Dr. Nosan Bhattarai, for their insightful comments, constructive recommendations, and valuable technical guidance. Their expertise greatly enhanced the quality, accuracy, and scientific rigor of this report.

We are equally grateful to the members of the Air Quality Data Analysis Committee: Dr. Kundan Lal Shrestha, Professor, Kathmandu University; Dr. Ramesh Prasad Sapkota, Professor, Central Department of Environmental Science, Tribhuvan University; Mr. Keshab Raj Joshi, Environment Inspector, Ministry of Agriculture, Forests and Environment; Mr. Sudarsan Humagain, Meteorologist, Department of Hydrology and Meteorology; and Mr. Suresh Pokhrel, Air Pollution (Observation) Analyst, ICIMOD. Their continuous guidance, technical expertise, critical insights, and thoughtful suggestions were invaluable throughout the preparation of this report.

We would also like to acknowledge with gratitude the significant contribution of Mr. Sabit Desar, Environment Inspector, for his dedicated support in GIS data analysis and mapping. Our heartfelt thanks are further extended to Ms. Arati Shrestha, Ms. Manisha Ghimire, Ms. Sadikshya Wosti, Ms. Swasti Shrestha, Ms. Hasana Shrestha, and Ms. Pradipika Acharya, as well as all staff members of the Department of Environment, whose dedication, commitment, and collaborative efforts greatly contributed to the successful completion of this report.

Finally, we extend our sincere thanks to all individuals and institutions who contributed, directly or indirectly, through their time, expertise, cooperation, and encouragement. Their generous support has been indispensable to this undertaking, and we remain deeply appreciative of their contributions toward the successful completion of this report.

EXECUTIVE SUMMARY

Air pollution remains one of the most significant environmental challenges facing Nepal, with adverse implications for public health, ecosystems, visibility, and sustainable development. The "**Status of Air Quality in Nepal, Annual Report, 2025"** presents a comprehensive assessment of ambient air quality across Nepal based on data collected from Air Quality Monitoring Stations (AQMSs) operated by the Department of Environment. The assessment was further complemented by satellite observations and atmospheric transport modeling to provide a broader understanding of spatial and temporal air quality patterns.

By 2025, Nepal's air quality monitoring network had expanded to 31 stations distributed across all seven provinces. These stations primarily monitor particulate matter, including PM_1, $PM_{2.5}$, PM_{10}, and Total Suspended Particulates (TSP). Fourteen stations with adequate data completeness were included for detailed analysis. Those stations were grouped according to Nepal's major physiographic zones: high mountain and Himalayan region, the middle mountain region, and the Tarai and Dun Valley region. Given distinct emission characteristics, the middle mountain region was further divided into Kathmandu Valley and outside the Kathmandu Valley cluster.

Air quality data were processed following quality control procedures. Hourly, daily, monthly, quarterly, and annual averages were calculated using a hierarchical approach with a minimum data completeness threshold of 75% at each level according to the provision of National Ambient Air Quality Standards (NAAQS). The analysis integrated ground-based monitoring data, satellite observations, and atmospheric transport modeling.

Clear seasonal variations in air quality were observed across the country. Generally, pollution levels were at the highest level during winter and pre-monsoon seasons. In winter, stable atmospheric conditions and low mixing heights contributed to pollutant accumulation, while in the pre-monsoon season, biomass burning, forest fires, and regional transport significantly influenced air quality. In contrast, the monsoon season recorded the lowest pollution levels due to enhanced wet deposition and improved atmospheric dispersion. Monthly $PM_{2.5}$ and PM_{10} concentrations typically peaked during January-April and declined substantially during July-September.

Spatial analysis revealed that Kathmandu Valley and the Tarai belt were the most polluted regions in Nepal, driven by high population density, vehicular emissions, industrial activities, construction dust etc. In contrast, the western hills and Himalayan regions generally exhibited lower pollution levels due to lower emissions and favorable dispersion conditions, although episodic pollution events were observed due to regional transport and biomass burning period.

Satellite observations and model analyses further supported these findings. Elevated aerosol loading and CO hotspots were consistently observed in the Kathmandu Valley and eastern Tarai. Higher tropospheric NO_2 levels over Kathmandu Valley indicated strong vehicular emission sources compared to other regions. HYSPLIT back-trajectory analysis of selected station during high

pollution episodes confirmed the influence of transboundary pollution during high pollution episodes.

It highlights the need for coordinated and time sensitive regional interventions. Analysis of satellite-derived AOD and CO data suggested an overall improvement in air quality across Nepal in 2025 relative to 2024. Reductions in aerosol loading and carbon monoxide concentrations were observed over most regions, particularly in urban, valley, and southern part of country.

The findings of this study have important implications for air quality management in Nepal. Persistently high concentrations of $PM_{2.5}$, PM_{10}, CO, and aerosol loading in the Kathmandu Valley and the Tarai and Dun Valleys both densely populated regions indicate strong anthropogenic influences, mainly from vehicular emissions, industrial activities, and other urban sources. $PM_{2.5}$ remains a critical air quality concern nationwide, with four out of five stations exceeding the national annual standard of 25 µg m^{-3} for $PM_{2.5}$, and the highest levels consistently observed in the Kathmandu Valley. PM_{10} also showed mixed compliance with NAAQS, with exceedances observed in Shankhapark and Bhaktapur within the Kathmandu Valley, while other stations remain within the annual standard of 70 µg m^{-3} for PM_{10}.

Overall, the results highlighted that air pollution in Nepal is driven by a combination of local emissions, seasonal meteorological conditions, biomass burning, forest fires, and transboundary movement. Therefore, effective air quality management should prioritize major urban and industrial corridors, strengthen emission control measures, address seasonal pollution episodes, enhance regional cooperation etc. Integration of ground based monitoring, satellite observations, and atmospheric modeling is essential to support evidence based policy making and long term air quality improvement.

कार्यकारी सारांश

नेपालले सामना गरिरहेको प्रमुख वातावरणीय समस्याहरु मध्ये वायु प्रदूषण महत्वपूर्ण सवाल रही आएको छ। यसले जनस्वास्थ्य, पारिस्थितिक प्रणाली, दृश्यता (Visibility) तथा दिगो विकासमा नकारात्मक प्रभाव पारिरहेको छ । यस **"Status of Air Quality in Nepal, Annual Report, 2025"** प्रतिवेदनमा वातावरण विभागद्वारा स्थापना तथा सञ्चालन गरिएका वायु गुणस्तर मापन केन्द्रहरुबाट सङ्कलित तथ्याङ्कको विश्लेषणका आधारमा नेपालभरको वायु गुणस्तरको विस्तृत मूल्याङ्कन गर्ने प्रयास गरिएको छ । साथै, यस अध्ययनलाई भू-उपग्रहहरूबाट प्राप्त तथ्याङ्कहरू तथा वायुमण्डलीय मोडेलिङमार्फत थप सुदृढ बनाउने प्रयास गरिएको छ ।

सन् २०२५ सम्म नेपालमा वायु गुणस्तर मापन केन्द्रहरुको संख्या ३१ वटा पुगेको छ । यी मापनकेन्द्रहरूले मुख्यतया कणजन्य पदार्थहरु (PM_1, $PM_{2.5}$, PM_{10} र TSP) को मापन गर्दछन् । यस प्रतिवेदन तयारीका लागि पर्याप्त तथ्याङ्क उपलब्ध भएका जम्मा १४ वटा मापन केन्द्रहरु लिइएको थियो । यी मापन केन्द्रहरूलाई नेपालको प्रमुख भौगोलिक क्षेत्रहरूका आधारमा उच्च पहाडी तथा हिमाली क्षेत्र, मध्यपहाडी क्षेत्र र तराई तथा दुन उपत्यका क्षेत्रमा वर्गीकरण गरिएको थियो । फरक विशेषताका कारण मध्यपहाडी क्षेत्रलाई काठमाडौं उपत्यका भित्रका मापन केन्द्रहरू र काठमाडौं उपत्यका बाहिरका मापन केन्द्रहरूमा थप विभाजन गरिएको थियो ।

वायु गुणस्तर तथ्याङ्कलाई गुणस्तर नियन्त्रण विधि अवलम्बन गर्दै प्रशोधन गरिएको थियो । वायु गूणस्तर सम्बन्धी राष्ट्रिय मापदण्ड, २०८२ ले निर्देशित गरे अनुसार कम्तीमा ७५% तथ्याङ्क उपलब्धताको मापदण्ड कायम राख्दै घण्टागत, दैनिक, मासिक, त्रैमासिक र वार्षिक औसतहरू गणना गरिएको थियो । यस विश्लेषणमा वायु गूणस्तर मापन केन्द्रबाट प्राप्त तथ्याङ्क, भू-उपग्रहहरूबाट प्राप्त तथ्याङ्क तथा वायुमण्डलीय मोडेलिङलाई समेत एकीकृत गरिएको थियो ।

उक्त विश्लेषण अनुसार देशभर वायु गुणस्तरमा स्पष्ट मौसमी उतारचढावका प्रभावहरु देखिएका छन् । सामान्यतः प्रदूषणको स्तर जाडो र प्रि-मनसुन याममा सबैभन्दा उच्च देखिएको छ । जाडो याममा स्थिर वायुमण्डलीय अवस्था र वायुमण्डलीय प्रतिलोमका कारण प्रदूषकहरू जमिनको सतहनजिक थुप्रिएर रहने अवस्था सिर्जना हुन्छ भने प्रि-मनसुन याममा जैविक पदार्थको दहन, वन डढेलो जस्ता कारणले वायु प्रदूषण उच्च हुन पुग्दछ । यसका अतिरिक्त सिमापार वायु प्रदूषणले पनि यहाँको वायु गुणस्तरमा महत्वपूर्ण प्रभाव पार्दछ । मनसुन याममा वर्षाले वायुमण्डलबाट प्रदूषकहरु हटाउने तथा वायुमण्डलमा उत्सर्जन भएका प्रदूषकहरु सजिलैसँग फैलिने भएकोले प्रदूषण स्तर सबैभन्दा कम देखिएको छ । सामान्यतः $PM_{2.5}$ र PM_{10} को मासिक औसत जनवरी देखि अप्रिलमा महिना सम्म उच्च र जुलाई देखि सेप्टेम्बर महिनामा उल्लेखनीय रूपमा कम देखिएको छ ।

स्थान विशेषतः काठमाडौं उपत्यका र तराई क्षेत्र नेपालका सबैभन्दा प्रदूषित क्षेत्रहरू रहेको देखिएको छ । यसको प्रमुख कारणमा उक्त क्षेत्रमा रहेको उच्च जनघनत्व, सवारी साधनबाट हुने उत्सर्जन, औद्योगिक गतिविधि तथा निर्माणजन्य गतिविधिबाट हुने उत्सर्जन आदि रहेका छन । यस विपरीत पश्चिमी पहाडी तथा हिमाली क्षेत्रहरू सामान्यतया कम प्रदूषित देखिएका छन्, यद्यपि सिमापार वायु प्रदूषण ओसार पसार तथा वन डढेलो जस्ता कारण उक्त क्षेत्रमा पनि बेला बेलामा उच्च वायु प्रदूषणका घटनाहरू देखिन्छन् ।

भु-उपग्रहहरूबाट प्राप्त तथ्याङ्क तथा वायुमण्डलीय मोडेलले पनि यी नतिजाहरूलाई थप पुष्टि गरेको छ । काठमाडौं उपत्यका र पूर्वी तराई क्षेत्रमा भू-उपग्रहहरूबाट प्राप्त एरोसोलको भार (AOD) तथा कार्बन मनोक्साइड (CO) को मात्रा उच्च देखिएको थियो । यस्तै काठमाडौं उपत्यकामा भु-उपग्रबाट प्राप्त NO_2 को उच्च मात्राले उपत्यकामा अन्य क्षेत्रहरूको तुलनामा सवारी साधन उत्सर्जनको प्रभाव अधिक रहेको देखाउँछ । केही वायु गूणस्तर मापन केन्द्रहरुमा उच्च वायु प्रदूषण भएको समयमा गरिएका HYSPLIT ब्याक ट्राजेक्टोरी विश्लेषणले सीमापार वायु प्रदूषणको प्रभाव थप पुष्टि गरेको छ । यसले समयमै र समन्वयात्मक रुपमा क्षेत्रीय तहमा सहकार्यको आवश्यकता उजागर गरेको छ । भू-उपग्रहहरूबाट प्राप्त AOD र CO को तथ्याङ्क विश्लेषणले सन् २०२५ मा नेपालभर समग्र वायु गुणस्तर २०२४ को तुलनामा केही सुधार भएको संकेत गर्दछ । विशेषगरी शहरी क्षेत्र, उपत्यका तथा देशको दक्षिणी क्षेत्रमा एरोसोल र कार्बन मोनोअक्साइडको मात्रा घटेको देखिएको छ ।

यस प्रतिवेदनका नतिजाहरूले नेपालमा वायु गुणस्तर व्यवस्थापन तथा नीतिगत निर्णयका लागि उपयोगी आधारहरू प्रदान गरेका छन् । काठमाडौं उपत्यका तथा तराई र दुन उपत्यकाजस्ता घना जनसंख्या भएका क्षेत्रमा $PM_{2.5}$,PM_{10} र CO को उच्च मात्राले मुख्यतया मानवीय गतिविधिबाट हुने उत्सर्जनहरू :विशेष गरी सवारी साधन, उद्योग तथा अन्य शहरी उत्सर्जनका स्रोतहरूको प्रभाव बढी रहेको स्पष्ट हुन्छ । तथ्याङ्कको उपलब्धताका आधारमा कुल पाँचवटा मात्र मापन केन्द्रहरूबाट प्राप्त $PM_{2.5}$ र PM_{10} को बार्षिक औसत गणना गरिएकोमा चारवटा मापन केन्द्रहरूमा $PM_{2.5}$ को मात्रा वायु गुणस्तर सम्बन्धी राष्ट्रिय मापदण्डले तोकेको वार्षिक सिमा २५ $\mu g\, m^{-3}$ भन्दा बढी रहेको छ भने सबैभन्दा उच्च मात्रा काठमाडौं उपत्यकामा रहेका मापन केन्द्रहरूमा देखिएको छ । यसले $PM_{2.5}$ राष्ट्रिय स्तरमा वायु प्रदूषणका लागि प्रमुख चिन्ताको विषय रहेको उजागर गरेको छ । यसै गरी PM_{10} को हकमा पनि राष्ट्रिय गुणस्तरको वार्षिक मापदण्डको आंशिक अनुपालन भएको देखिन्छ । जसमा काठमाडौं उपत्यकामा रहेका दुईवटा मापन केन्द्रहरू शङ्खपार्क र भक्तपुरमा PM_{10} को वार्षिक औसत राष्ट्रिय मापदण्डको सिमाभन्दा बढी रहेको देखिएको छ भने अन्य मापन केन्द्रहरूमा बार्षिक औसत राष्ट्रिय मापदण्डको सीमा भित्रनै रहेको पाइएको छ ।

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ACRONYMS AND ABBREVIATIONS

µm	:	Micrometer
µg m^{-3}	:	Microgram per Cubic Meter
AOD	:	Aerosol Optical Depth
AQI	:	Air Quality Index
AQMS	:	Air Quality Monitoring Station
CO	:	Carbon-monoxide
CSV	:	Comma-separated Values
EDM	:	Environmental Dust Monitor
ESA	:	European Space Agency
FIRMS	:	Fire Information for Resource Management System
GEE	:	Google Earth Engine
GFS	:	Global Forecast System
GIBS	:	Global Imagery Browse Services
GoN	:	Government of Nepal
hr	:	Hour
HYSPLIT	:	Hybrid Single-Particle Lagrangian Integrated Trajectory
ICIMOD	:	International Centre for Integrated Mountain Development
km	:	Kilometer
L/min	:	Liter per Minute
masl	:	Meter above Sea Level
MAIAC	:	Multi-Angle Implementation of Atmospheric Correction
MODIS	:	Moderate Resolution Imaging Spectroradiometer
MoAFE	:	Ministry of Agriculture, Forests and Environment
MoFE	:	Ministry of Forests and Environment
NAAQS	:	National Ambient Air Quality Standards
NASA	:	National Aeronautics and Space Administration
NITC	:	National Information Technology Centre
NO_2	:	Nitrogendioxide

NOAA	:	National Oceanic and Atmospheric Administration
NO_x	:	Oxides of Nitrogen
O_3	:	Ozone
PM	:	Particulate Matter
PM_1	:	Particulate Matter having aerodynamic diameter less than 1 micron
PM_{10}	:	Particulate Matter having aerodynamic diameter less than 10 microns
$PM_{2.5}$	:	Particulate Matter having aerodynamic diameter less than 2.5 microns
QGIS	:	Quantum Geographic Information System
SO_2	:	Sulphurdioxide
TROPOMI	:	Tropospheric Monitoring Instrument
TSP	:	Total Suspended Particulates
VIIRS	:	Visible Infrared Imaging Radiometer Suite

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Nepal has established a robust legal and policy framework for environmental protection including air quality management. The Constitution of Nepal guarantees citizens the right to live in a clean and healthy environment. To uphold this mandate, the Environment Protection Act and the Environment Protection Regulation promote environmentally sustainable development. Key policies, including the National Environment Policy and the 16th Periodic Plan, emphasize pollution reduction across sectors. Additionally, the National Ambient Air Quality Standards (NAAQS) establish permissible limits for air pollutants. The Department of Environment, under the Ministry of Agriculture, Forests and Environment, as primary authority responsible for air quality management in Nepal.

Nepal has made steady progress in expanding a real-time air quality monitoring network since 2016, with 31 monitoring stations now installed in major cities and environmentally sensitive regions such as Rara National Park. The Department of Environment disseminates real-time information on $PM_{2.5}$, PM_{10} and TSP through its online portal (https://pollution.gov.np), helping inform the public and support decision-making.

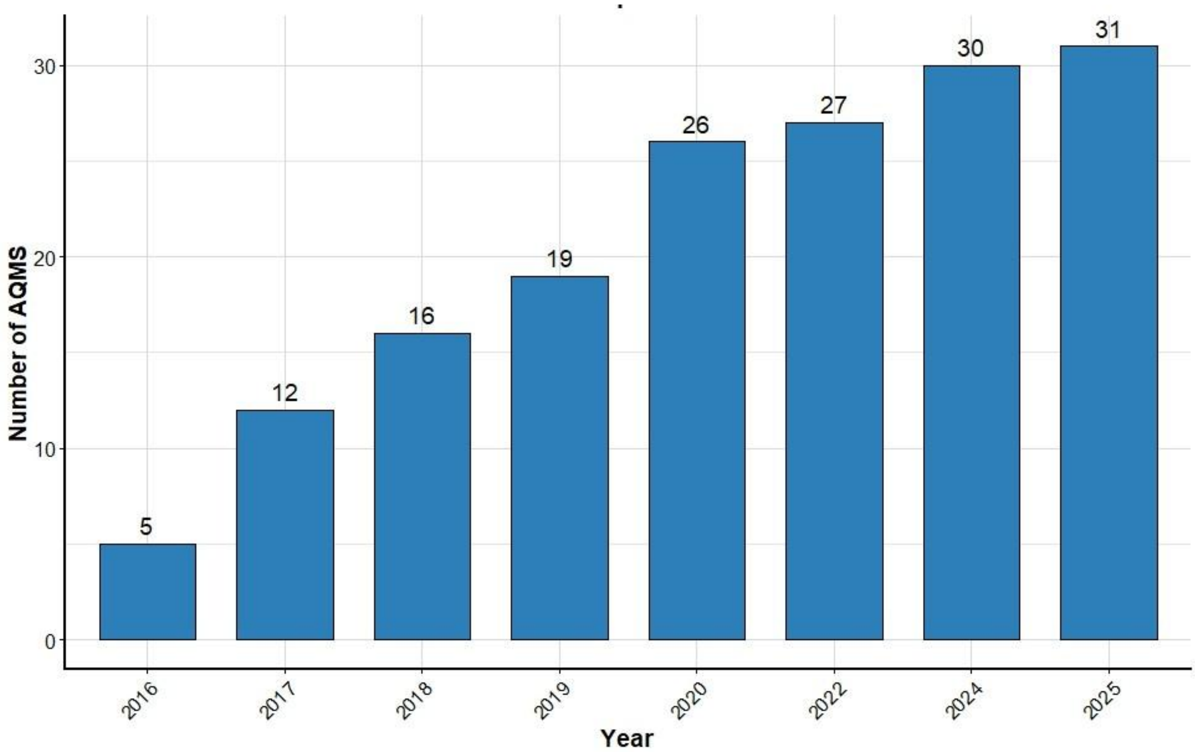


Figure 1: Cumulative growth of Air Quality Monitoring Stations (AQMSs) over time

Since 2016, over the seven provinces, number of AQMSs has increased and reached 31 by 2025 (Figure 1 and Figure 2).

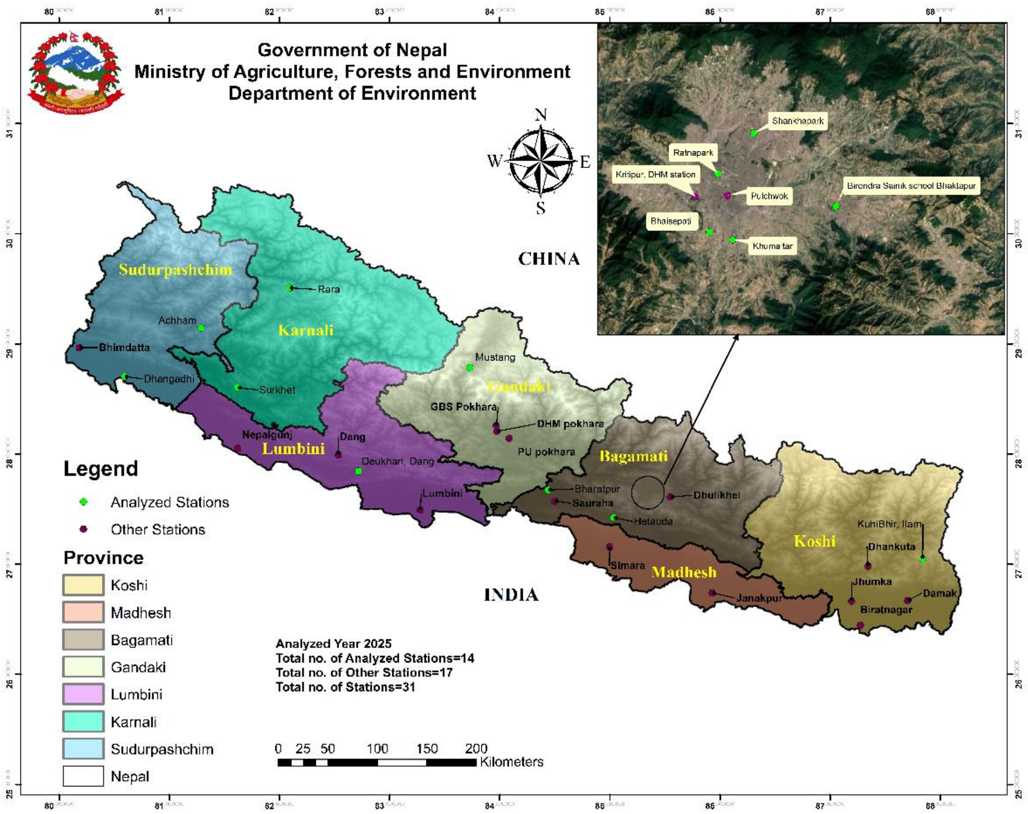


Figure 2: Distribution of AQMSs in Nepal

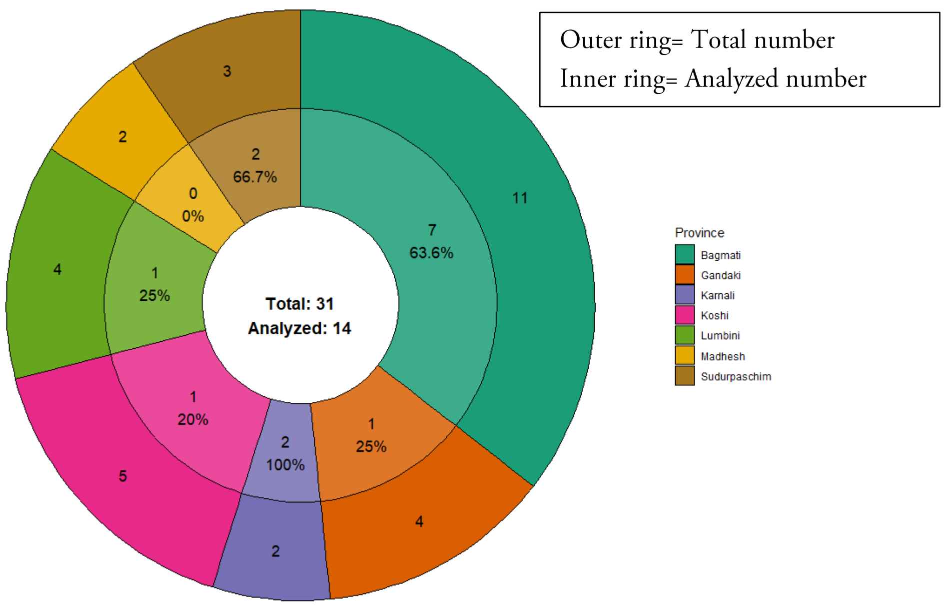


Figure 3: Provincial Distribution of the AQMSs installed and AQMSs considered for data analysis

These installed AQMSs represent the air quality of both urban and rural environments. All these stations measure PM_1, $PM_{2.5}$, PM_{10} and TSP. AQMSs at Ratnapark, Dhulikhel, Khumaltar and Lumbini measure CO, SO_2, NOx, and O_3, and AQMSs at Sauraha and Pulchowk measure O_3 in addition to particulate matter.

This Status of Air Quality in Nepal: Annual Report 2025 includes analysis of air quality data ($PM_{2.5}$, PM_{10} and TSP) from fourteen AQMSs (Table 1 & Figure 3). The analysis was clustered according to physiographic and climatic representation. Data from the remaining stations were excluded due to limited data availability and exclusion criteria (detailed in section 1.4).

Table 1: List of AQMSs Used for Data Analysis

SN	Name of AQMS	Location	Province Name	Coordinate	Elevation (masl)	Region
1	Ilam	Kuhibhir, Ilam	Koshi	87.8408° E, 27.0478° N	2838	High mountain and Himalaya region
2	Mustang	District Administration Office, Jomsom, Mustang	Gandaki	83.730007 ° E, 28.784071° N	2730	
3	Rara	Rara National Park, Mugu	Karnali	82.0938° E, 29.5083° N	3121	
4	Bhaisipati	Bhaisipati residential area office, Lalitpur	Bagamati	85.3023° E, 27.6531° N	1347	Middle mountain region (Kathmandu)
5	Bhaktapur	Sainik Aawasiya Mahavidyalaya, Bhaktapur	Bagamati	85.4175° E, 27.6738° N	1327	
6	Khumaltar	ICIMOD, Khumaltar, Lalitpur	Bagamati	85.3234° E, 27.6467° N	1327	
7	Ratnapark	Shankhadhar Park, Kathmandu	Bagamati	85.3100° E, 27.7000° N	1317	
8	Shankhapark	Shankhapark, Kathmandu	Bagamati	85.3428° E, 27.7328° N	1339	
9	Achham	Oli Gaun, Mangalsen, Achham	Sudurpashchim	81.2892° E, 29.1427° N	1485	Middle mountain region (Others)
10	Surkhet	Karnali Province Police Office	Karnali	81.621024, 28.602925	729	
11	Bharatpur	District Administration Office, Chitwan	Bagamati	84.4384° E, 27.6725° N	213	Tarai and Dun Valley
12	Deukhuri, Dang	Rapti Rural Municipality Office, Dang	Lumbini	82.7162° E, 27.8450° N	311	
13	Dhangadhi	Dhangadhi Sub Metropolitan City office	Sudurpashchim	80.5945° E, 28.704133° N	178	
14	Hetauda	Hupra Chaur, Hetauda, Makawanpur	Bagamati	85.0344° E, 27.4227° N	458	

1.1.1 National Ambient Air Quality Standards (NAAQS), 2026

The GoN has endorsed NAAQS in 2026. The NAAQS gives maximum concentration for parameters including particulate matter, trace gases, heavy metal and others, as shown in the Table 2.

Table 2: National Ambient Air Quality Standards, 2026

SN	Parameters	Unit	Averaging time	Maximum concentration
1	$PM_{2.5}$	µg m^{-3}	Annual	25
			24-hr	40
2	PM_{10}	µg m^{-3}	Annual	70
			24-hr	120
3	TSP	µg m^{-3}	24-hr	230
4	Ozone	µg m^{-3}	8-hr	157
5	Sulphur Dioxide	µg m^{-3}	Annual	50
			24-hr	70
6	Nitrogen Dioxide	µg m^{-3}	Annual	40
			24-hr	80
7	Carbon monoxide	µg m^{-3}	8-hr	10,000
8	Lead	µg m^{-3}	Annual	0.5
9	Benzene	µg m^{-3}	Annual	5

1.2 OBJECTIVES

The overall objective of this report is to present the air quality status of Nepal for the year 2025, based on data from fourteen ground-based AQMSs distributed across the country, complemented by satellite observations.

The specific objectives are:

- To determine the status of air quality based on $PM_{2.5}$, PM_{10} and TSP.
- To analyze air quality across different regions of Nepal utilizing modeling techniques and satellite observations.

1.3 PARAMETERS ANALYZED FROM AIR QUALITY MONITORING STATIONS

The following parameters were analyzed in this report.

- $PM_{2.5}$: Includes particulate matter with an aerodynamic diameter less than or equal to 2.5 µm and is important in terms of health impacts.
- PM_{10}: Includes particulate matter with an aerodynamic diameter less than or equal to 10 µm.
- TSP: Includes all solid and liquid droplet particulate present in the air.

1.4 METHODS

1.4.1 Committee for Providing Strategic Direction and Oversight

A multi-agency committee (Annex-1) was formed to support report preparation, offering strategic guidance, decision-making support, and direction for data analysis. Additionally, experts from relevant institutions were engaged to provide technical insights and feedback, further strengthening the report's quality and completeness.

1.4.2 Data Averaging

Hourly averages were calculated from minute-level data only when at least 75% of the observations within an hour were available. Daily averages were then computed from hourly data, provided that at least 75% of the hourly observations for a day were valid. Similarly, monthly averages were derived from daily data when at least 75% of the days within a month contained valid observations. Methods of air quality monitoring and data analysis have been mentioned afterwards.

Quarterly Average Data

Quarterly average data were calculated from monthly averaged data. For a given AQMS, the quarterly mean was computed only when monthly average data were available for at least two of the three months within the respective quarter.

Annual Average Data

Annual average data were calculated based on quarterly averages. For a given AQMS, the annual mean was computed only when all four quarterly averages were available for the respective year.

Particulate matter (PM) measurement method

The Environmental Dust Monitor (Grimm EDM 180+) was used for ambient dust measurement. The instrument utilizes laser light-scattering technology to count and size airborne particles. Particles in the sampled air are classified according to their size and number within the measuring chamber using scattered-light measurements. During operation, a small measuring volume is exposed to a laser beam equipped with downstream optics. For environmental measurements, the concentration of particles is generally low enough that statistically only one particle is present in the sensing volume at a time. The scattered light emitted by each particle is collected by a second set of optics with a defined opening and scattering angle, reflected to a detector by a mirror, and its intensity is measured. Particle size is proportional to the intensity of the scattered light signal. The particle count rate is determined from the number of detected particles and the volume flow rate. When particle diameter and density are known, particle mass is derived from the particle count based on the assumption that the particles are spherical in shape.

A semiconductor laser serves as the light source in the EDM 180+ spectrometer. To minimize the influence of refractive indices, the 90° scattered light is directed to a receiver diode by a mirror with an opening angle of approximately 120°. After amplification, the electrical signal from the diode is classified into 31 size channels according to signal strength, allowing the determination of particle size distribution. The instrument operates at a sample flow rate of 1.2 L/min.

1.4.3 Data Acquisition

The EDM instrument has the highest measurement resolution of six seconds, were taken on a minute basis. The data was logged as one-minute averaged in CSV format into the data logger installed at each AQMS. This data logger system transmitted the data to the central server located at the National Information Technology Centre (NITC), Singha Durbar, Kathmandu. The data is then made available via pollution.gov.np for monitoring and analysis.

1.4.4 Data Cleaning

Particulate Matter (PM)

For data analysis, the downloaded minute-level data were first subjected to a cleaning procedure. A threshold value of 1500 µg m^{-3} was applied to all three particulate parameters ($PM_{2.5}$, PM_{10}, and TSP) based on the instrument manufacturer's recommendations. Repeated records, as well as negative and null values, were removed prior to further analysis.

1.4.5 Data Analysis Method and Plots/Graphs Used in the Report

For this report, AQMSs with data completeness criteria were grouped into three geographical regions according to physiographic subdivision of Nepal: high mountain and Himalaya, middle mountain (Kathmandu Valley and other middle mountain region) and Tarai and Dun Valley for spatial analysis (Figure 4).

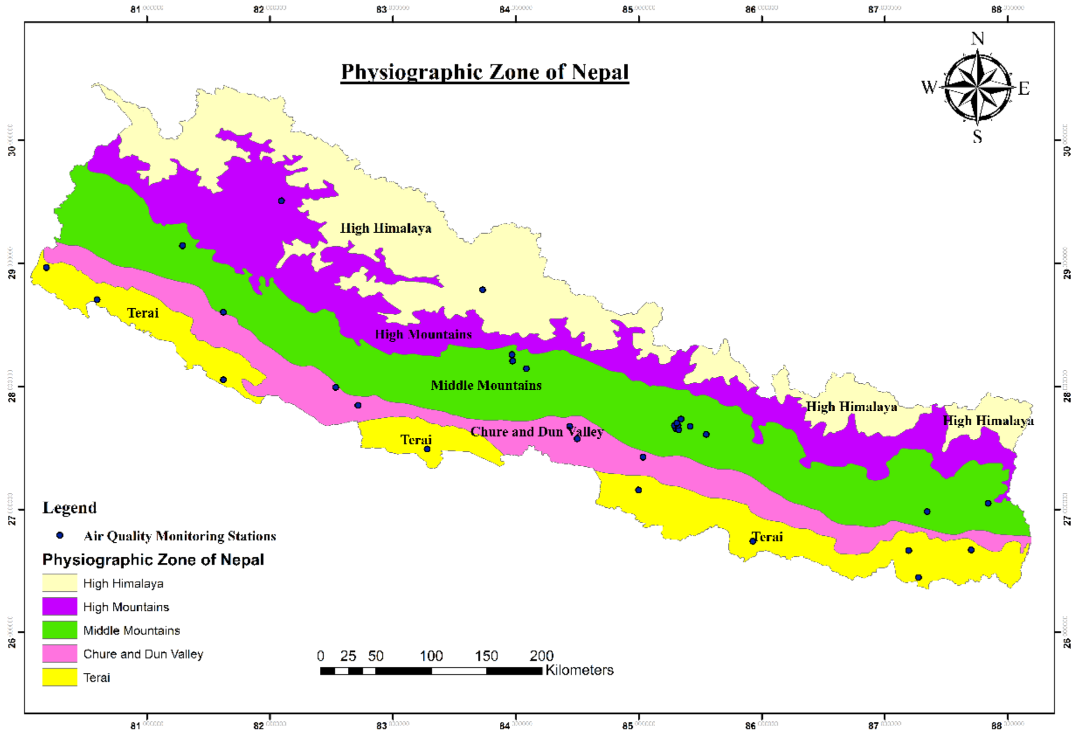


Figure 4: Distribution of AQMSs according to physiographic zone of Nepal

Among the stations considered for data analysis due to availability of data, the high mountain and Himalaya region comprised two stations: Rara and Mustang. The middle mountain region included five stations within the Kathmandu Valley (Bhaisipati, Bhaktapur, Khumaltar, Ratnapark and Shankhapark) and two stations outside the valley (Achham and Ilam). The Tarai and Dun Valley region covered five stations: Bharatpur, Deukhuri Dang, Dhangadhi, Hetauda and Surkhet.

Various analytical tools were employed for data analysis, with findings presented through various graphs and maps. Python was utilized to automate the retrieval of large datasets from the central server. While statistical analysis and visualization were conducted using R software (R Core Team, 2024), supported by packages such as openair, ggplot2 etc. Satellite data analysis was carried out using HYSPLIT, Google Earth Engine (GEE), and QGIS (2024), enabling comprehensive spatial and temporal assessments.

Combined line plots were developed to present daily and monthly average trends for each region within a single figure, while bar charts were used to illustrate the compliance status of particulate matter concentrations. Prior to regional visualization, data from individual stations were analysed using the R program. Wind direction patterns were analysed using HYSPLIT model.

For the purpose of seasonal interpretation, the year was divided into four seasons: winter (January, February and December), pre-monsoon (March to May), monsoon (June to September), and post-monsoon (October and November).

Furthermore, calendar plots of selected stations were prepared to visualize the daily Air Quality Index (AQI) based on $PM_{2.5}$ concentrations. AQI values were calculated using the breakpoints as in Table 3, and corresponding AQI categories and colour codes were applied accordingly. The breakpoints were adopted from the national Air Quality Index (AQI) approved by a ministerial decision of the Government of Nepal on 14^{th} August 2018 through the then Ministry of Forests and Environment (MoFE).

Table 3 : AQI and AQI Break Points for $PM_{2.5}$

Air Quality Index (AQI) Range	Levels of Health Concern	Colours	$PM_{2.5}$ (µg m^{-3}) 24-hours average, break points
0 to 50	Good	Green	0-20
51 to 100	Moderate	Yellow	20-40
101 to 150	Unhealthy for Sensitive Groups	Orange	41-60
151 to 200	Unhealthy	Red	61-160
201 to 300	Very Unhealthy	Purple	161-260
301 to 400	Hazardous	Maroon	261-360
401 to 500	Very Hazardous	Maroon	>360

Source: MoFE

Each category corresponds to a different level of health concern. The seven levels of health concern can be described as:

- "Good" AQI is 0 to 50. Air quality is considered satisfactory, and air pollution poses little or no risk.
- "Moderate" AQI is 51 to 100. Air quality is acceptable; however, for some pollutants there may be a moderate health concern for a very small number of people.
- "Unhealthy for Sensitive Groups" AQI is 101 to 150. Although general public is not likely to be affected at this AQI ranges, people with lung disease, older adults and children are at a greater risk from exposure to ozone, whereas persons with heart and lung disease, older adults and children are at greater risk from the presence of particles in the air.
- "Unhealthy" AQI is 151 to 200. Everyone may begin to experience some adverse health effects, and members of the sensitive groups may experience more serious effects.
- "Very Unhealthy" AQI is 201 to 300. This would trigger a health alert signifying that everyone may experience more serious health effects.
- "Hazardous" AQI is 301 to 400. This would trigger a health warning of emergency conditions. The entire population is more likely to be affected.
- "Very Hazardous" AQI is 401 to 500. This would trigger health warnings of emergency conditions. The entire population is more likely to be affected.

1.5 SATELLITE DATA ANALYSIS

Images of forest fire events were taken from the NASA (National Aeronautics and Space Administration) FIRMS (Fire Information for Resource Management System) website. NASA FIRMS integrates satellite observations from the MODIS and VIIRS satellite instruments to detect active fires and thermal anomalies and deliver this information in near real-time to decision makers through email alerts, analysed data, online maps and web services. Similarly, true colour satellite imagery was also downloaded from the FIRMS website. NASA Worldview Snapshots interface generates a true colour or derived data product satellite imagery subset at a spatial resolution of 250 meters. These subsets were generated from the data record of daily corrected reflectance satellite imagery for listed satellite/sensor assets. Subsets were dynamically generated within the NASA Worldview Snapshots application using source imagery provided by the Global Imagery Browse Services (GIBS).

The data from the ESA Copernicus TROPOMI instrument on board the Sentinel 5p satellite were used. The CO and NO_2 data for various time periods were downloaded from the Copernicus Sentinel-5P Mapping Portal. Then further analysis and visualization were done using QGIS.

Analysis of Aerosol Optical Depth (AOD)

The MCD19A2 V6.1 data product was used for analysis of AOD. This is a MODIS Terra and Aqua Combined Multi-Angle Implementation of Atmospheric Correction (MAIAC) Land AOD gridded Level 2 product produced daily at 1 km resolution. Here AOD over land retrieved in the MODIS Green band (0.55 µm) was selected for the AOD analysis. The data were processed using a two-step quality control procedure. Initially, cloud-contaminated pixels were identified and removed using the AOD Uncertainty band with a threshold value of 0.6, as the standard

AOD_QA band was unavailable for some pixels within the study area. Subsequently, non-physical negative values and extreme AOD retrievals greater than 3.0 were excluded. The MAIAC standard uncertainty criterion (Uncertainty < 0.15 + 0.15 × AOD) was further applied to retain only high-confidence retrievals. Finally, a scale factor of 0.001 was used to convert the raw data into physical AOD units. Monthly average of AOD for all months of 2025 were calculated using the Google Earth Engine. The annual average AOD was subsequently calculated from the monthly averages in Python. Further data analysis and visualization were performed using QGIS.

Air Trajectory Analysis

To examine the wind patterns and air mass transport influence in selected stations the HYSPLIT model, developed by the National Oceanic and Atmospheric Administration (NOAA) Air Resources Laboratory was utilized. The model was driven using the Global Forecast System (GFS) dataset with 0.25-degree resolution.

Five-day (120-hours) backward trajectories were calculated for selected days with high pollution episodes for selected stations. The trajectory calculations were performed at three-hour intervals. The starting height for each trajectory was set at 200m above ground level.

CHAPTER 2: RESULTS

The result of data analysis from stations was presented into three different clusters based on physiographic zone of Nepal: high mountain and Himalaya region, middle mountain region and Tarai and Dun Valley region.

2.1 HIGH MOUNTAIN AND HIMALAYA REGION

Two AQMSs were located in high mountain and Himalaya region: Rara and Mustang. These stations were established in 2020 and July, 2025, respectively. The meteorological conditions at each AQMS vary because of their different geographical locations. The Rara AQMS is situated at Milichaur within Rara National Park, where human activities are extremely limited. The Mustang AQMS is located within the premises of the District Administration Office Jomsom in Mustang District, is the only station in Trans-Himalayan region; hence both are considered as the background stations.

$PM_{2.5}$

Daily average:

Figure 5 illustrates the daily variation of $PM_{2.5}$ concentration at two monitoring stations of high mountain and Himalaya region. The gaps in the figure indicates missing data. Higher concentration for Mustang AQMS was during December and for Rara AQMS was during April.

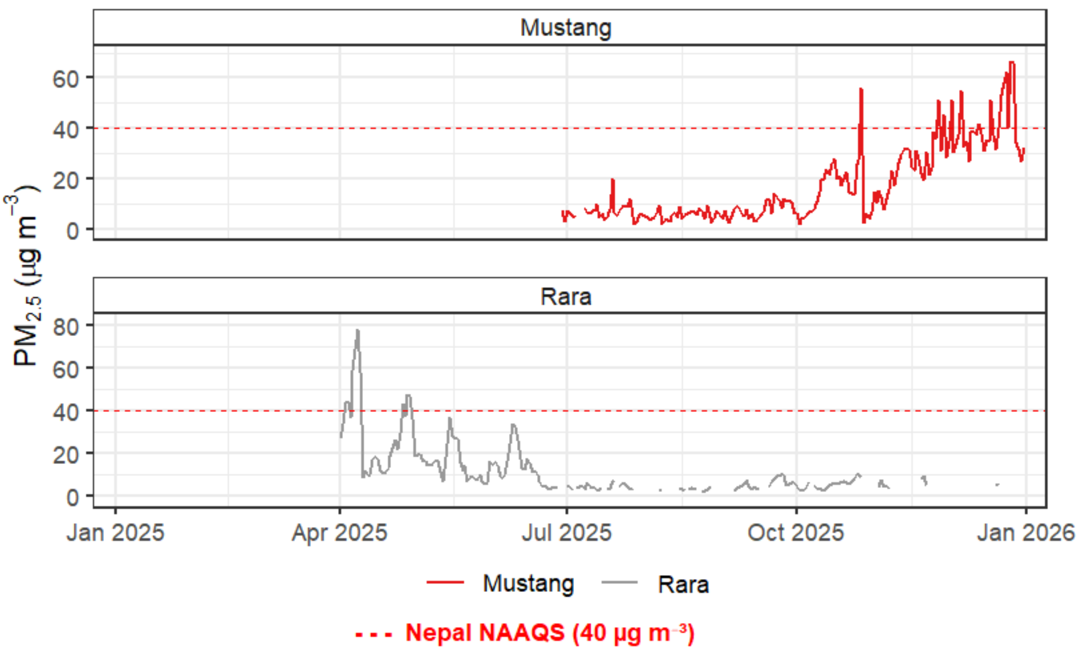


Figure 5: Daily average of $PM_{2.5}$ at different monitoring stations of high mountain and Himalaya region

Compliance status:

The total number of days with valid data for Mustang and Rara two stations were 183 and 192. Based on the available measurements, the Mustang AQMS had the 7.1% percent and Rara AQMS had 4.7% of days exceeding the NAAQS for $PM_{2.5}$ (Figure 6).

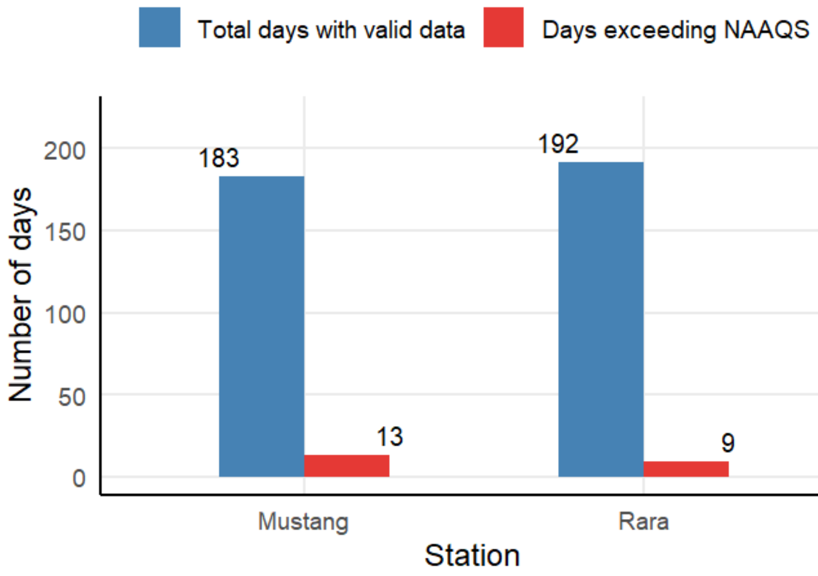


Figure 6: Compliance status of $PM_{2.5}$ at different monitoring stations of high mountain and Himalaya region

Monthly average:

The monthly average $PM_{2.5}$ concentration at Rara AQMS peaked in April (30.4 μg m^{-3}) and declined through the following months, remaining relatively low from June to October. At Mustang AQMS, concentrations were lowest in July to August and increased steadily toward a peak in December (40.8 μg m^{-3}) (Figure 7).

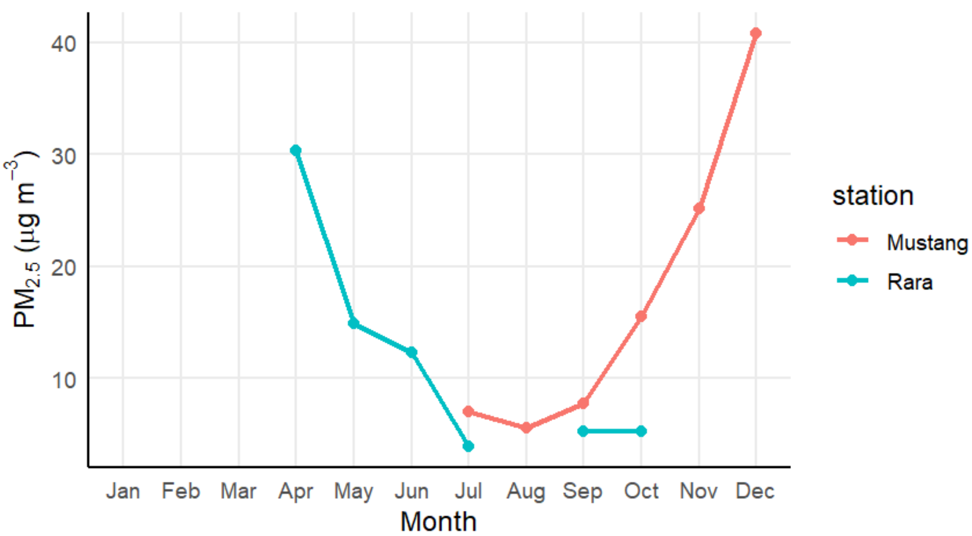


Figure 7: Monthly average of $PM_{2.5}$ at different monitoring stations of high mountain and Himalaya region

PM_{10}

Daily average:

Figure 8 illustrates the daily variation of PM_{10} concentration at two monitoring stations of high mountain and Himalaya region stations. Higher concentration was observed at Rara compared to Mustang.

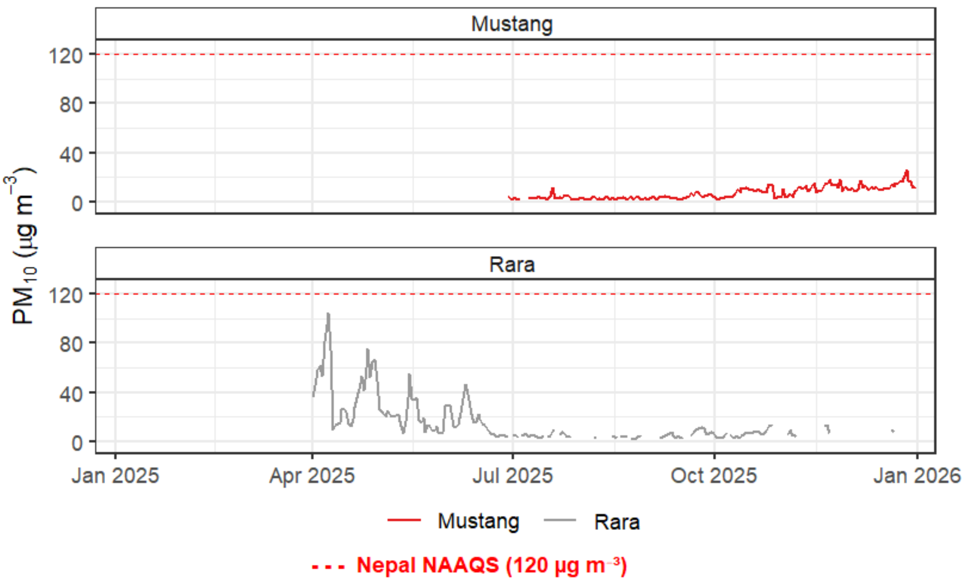


Figure 8: Daily average of PM_{10} at different monitoring stations of high mountain and Himalaya region

Compliance status:

The total number of days with valid data for Mustang and Rara stations were 183 and 192. Based on the available measurements, none of the stations had days exceeding the NAAQS for PM_{10}(Figure 9).

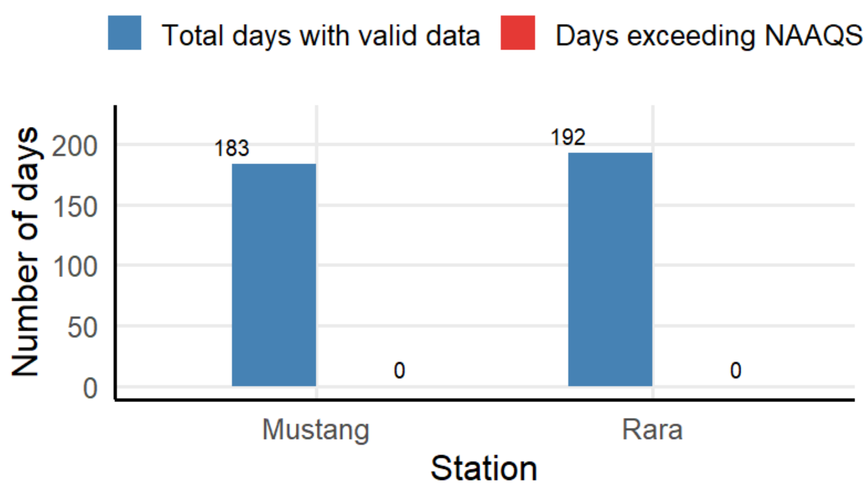


Figure 9: Compliance status of PM_{10} at different monitoring stations of high mountain and Himalaya region

Monthly average:

The monthly average PM_{10} concentration at Rara AQMS peaked in April (45.2 µg m^{-3}) and declined sharply through the subsequent months, reaching its lowest values in July. At Mustang AQMS, concentrations remained low from July through October before increasing slightly toward December (12.9 µg m^{-3}) (Figure 10).

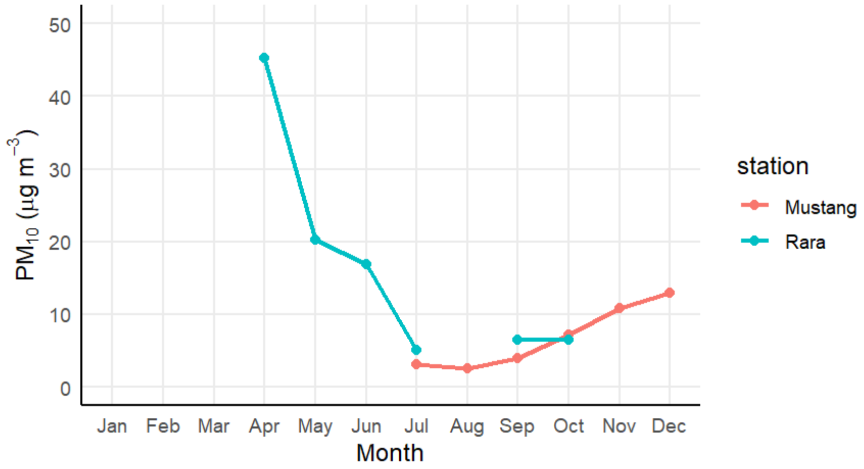


Figure 10: Monthly average of PM_{10} at different monitoring stations of high mountain and Himalaya region

TSP

Daily average:

Figure 11 illustrates the daily variation of TSP concentration at two monitoring stations in the high mountain and Himalaya region. Higher concentration was observed during December at Mustang AQMS and during April at Rara AQMS

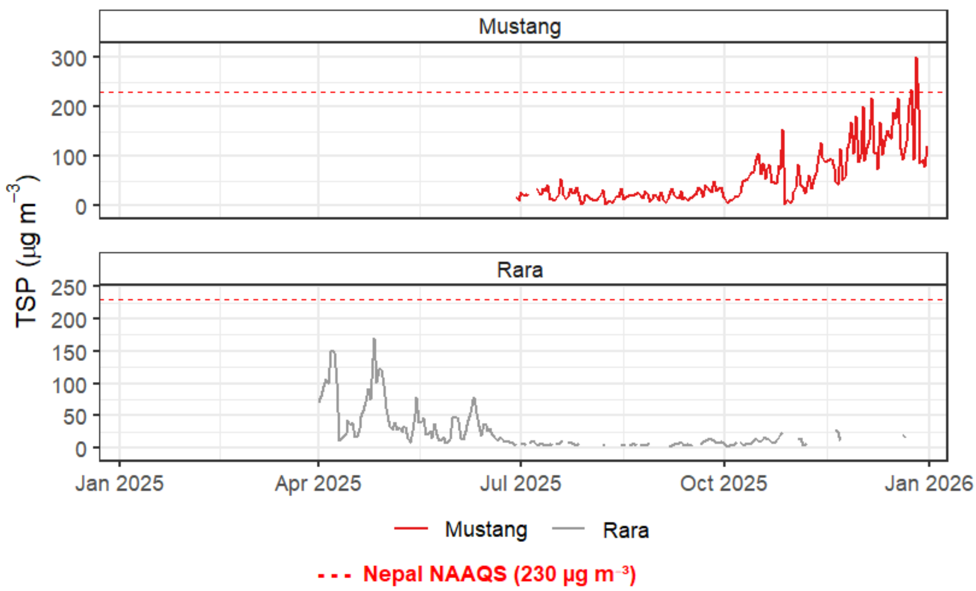


Figure 11: Daily average of TSP at different monitoring stations of high mountain and Himalaya region

Compliance status:

The total number of days with valid data for Mustang and Rara stations were 183 and 192 respectively. Based on the measurement, Rara did not have any days exceeding the NAAQS, whereas Mustang had only two days, exceeding the NAAQS for TSP (Figure 12).

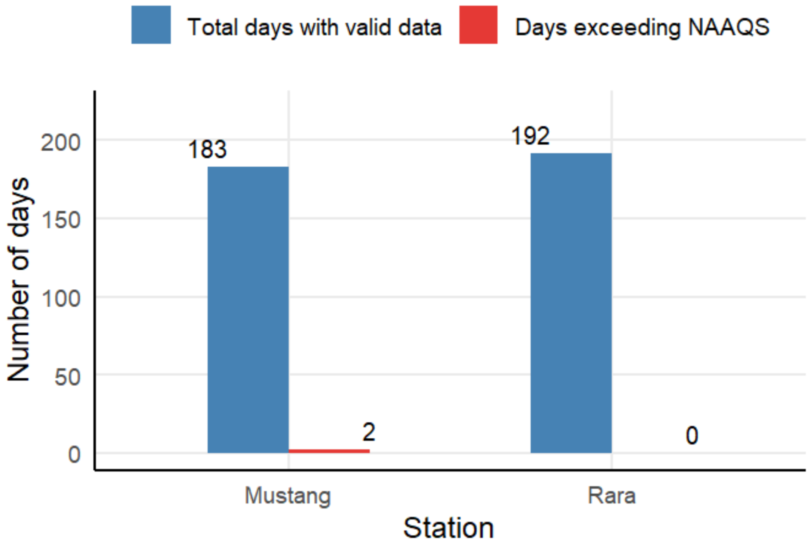


Figure 12: Compliance status of TSP at different monitoring stations of high mountain and Himalaya region

Monthly average:

The monthly average TSP concentration at Rara AQMS peaked in April (78.2 µg m^{-3}) and declined sharply through the subsequent months, reaching its lowest values in July to August. At Mustang AQMS, concentrations remained low from July to September before rising steeply to a peak in December (142.4 µg m^{-3}) (Figure 13).

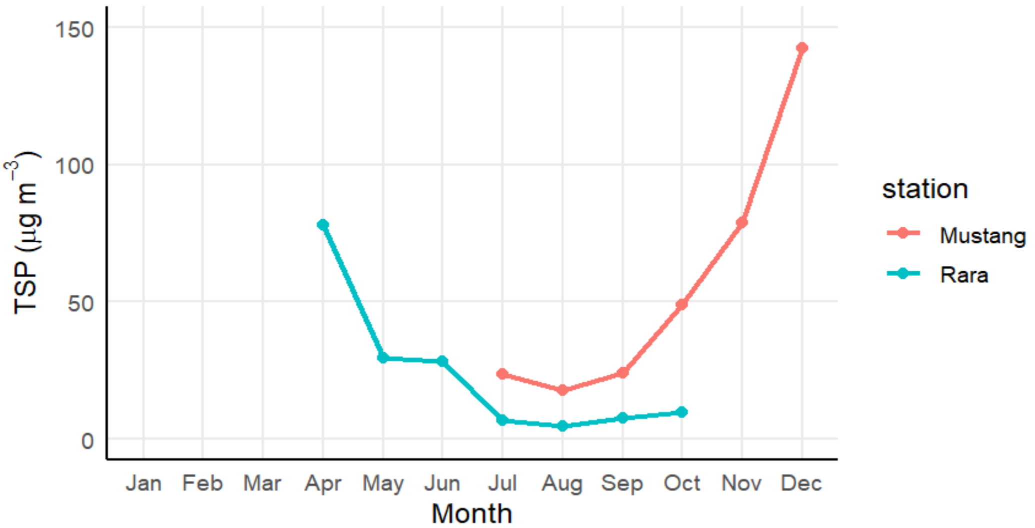


Figure 13: Monthly average of TSP at different monitoring stations of High mountain and Himalaya region

2.2 MIDDLE MOUNTAIN REGION

Stations in the middle mountain region were grouped under two categories- Kathmandu Valley and other stations outside the Kathmandu Valley. This region comprises a total of seven stations, including five within the Kathmandu Valley and two in other middle mountain regions. Stations in this region includes AQMSs from urban areas and non-urban areas.

2.2.1 Kathmandu Valley

Kathmandu Valley includes five AQMSs: Ratnapark (established in 2016); Bhaisipati, Bhaktapur, and Shankhapark (established in 2017); and Khumaltar (established in 2022). Bhaisipati AQMS is located at the premises of Bhaisipati Residential Area Office in Lalitpur, while Bhaktapur AQMS is situated at premises of Sainik Awasiya Mahavidyalaya in Bhaktapur Municipality. Similarly, Shankhapark AQMS is located near the Ring Road in Kathmandu, Ratnapark AQMS is situated at Shankhadhar Park near Rani Pokhari, and Khumaltar AQMS is installed on the rooftop of the ICIMOD building in Lalitpur.

These stations primarily represent urban residential and commercial environments influenced by vehicular emissions, road dust re-suspension, solid waste burning, residential emissions, and nearby industrial activities such as brick kilns, boilers. Seasonal pollution from forest fires during the pre-monsoon period also contributes significantly to air quality deterioration in the valley.

$PM_{2.5}$

Daily average:

Figure 14 illustrates the daily variation of $PM_{2.5}$ concentration at five monitoring stations of Kathmandu Valley. Days in April had the highest concentration in all available stations.

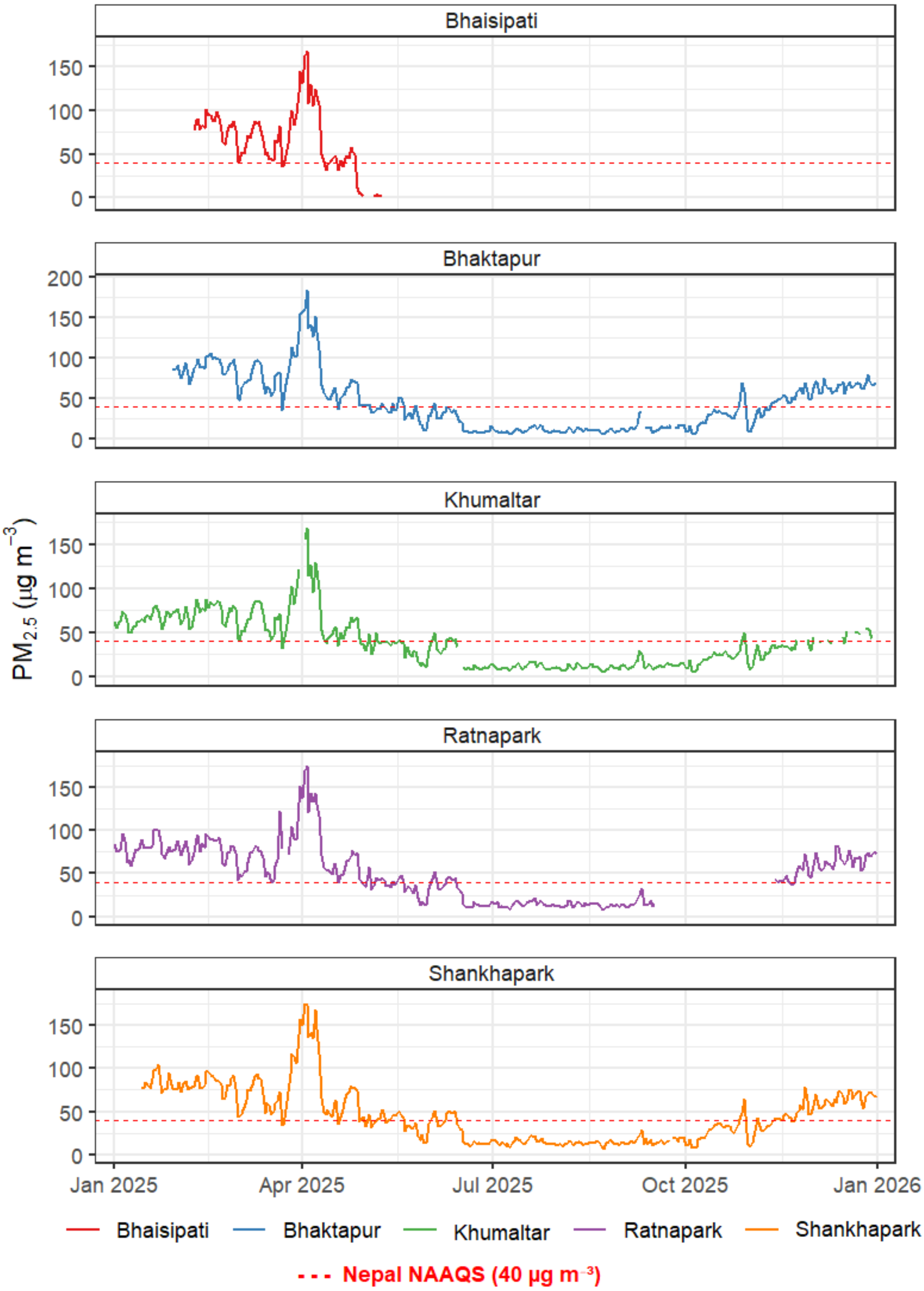


Figure 14: Daily average of $PM_{2.5}$ at different monitoring stations of Kathmandu Valley

Compliance status:

The total number of days with valid data for Bhaisipati, Bhaktapur, Khumaltar, Ratnapark and Shankhapark stations were 88, 335, 344, 306 and 351 respectively. Based on the available measurements, $PM_{2.5}$ concentrations exceeded the National Ambient Air Quality Standards (NAAQS) on 81.8% of monitored days at Bhaisipati, 58.2% at Ratnapark, 50.1% at Shankhapark, 46.0% at Bhaktapur, and 40.7% at Khumaltar. (Figure 15).

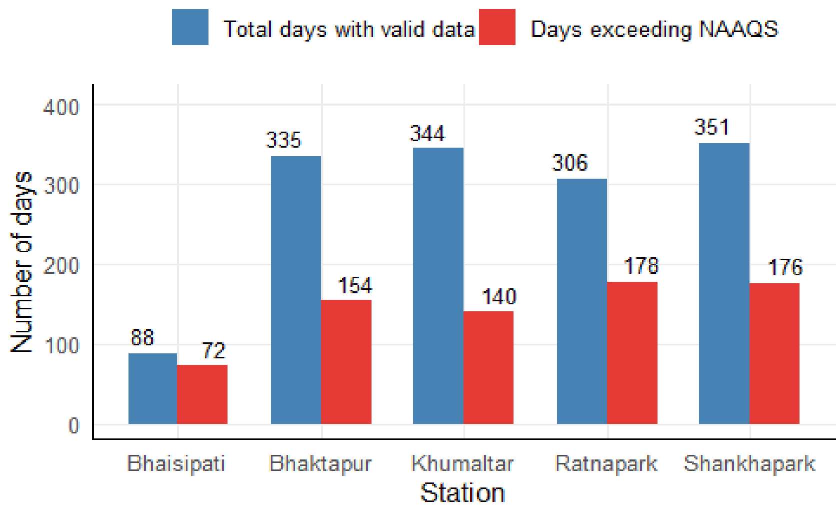


Figure 15: Compliance status of $PM_{2.5}$ at different monitoring stations of Kathmandu Valley

Monthly average:

The monthly average $PM_{2.5}$ concentrations at all five Kathmandu Valley stations exhibited a consistent seasonal pattern, with peaks during January to April (ranging 64.2 to 89.7 µg m^{-3}) and lowest values during July to August (9.8 to 14.9 µg m^{-3}). Concentrations and increased again from October onward. Bhaktapur recorded the highest monthly average in February, while all stations followed closely similar seasonal trajectories, indicating a shared influence of meteorological conditions and emission sources across the valley (Figure 16).

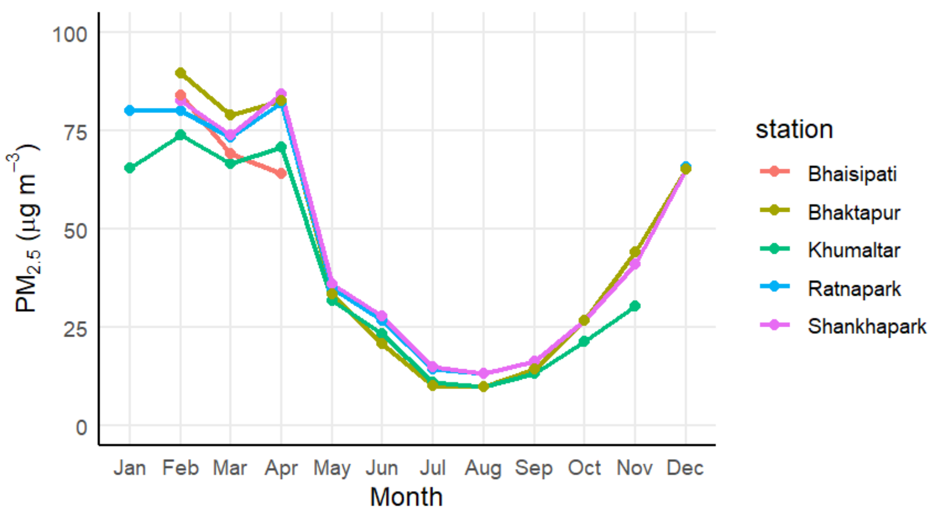


Figure 16: Monthly average of $PM_{2.5}$ at different monitoring stations of Kathmandu Valley

Calendar Plot

The calendar plot for $PM_{2.5}$ of Ratnapark AQMS (Figure 17) showed that the AQI reached the "Very Unhealthy" category on April 2 and 3. The "Unhealthy" AQI category was also observed on many days during January, February, March, April, and December. In contrast, during July, August, and September, almost all days fell under the "Good" air quality category.

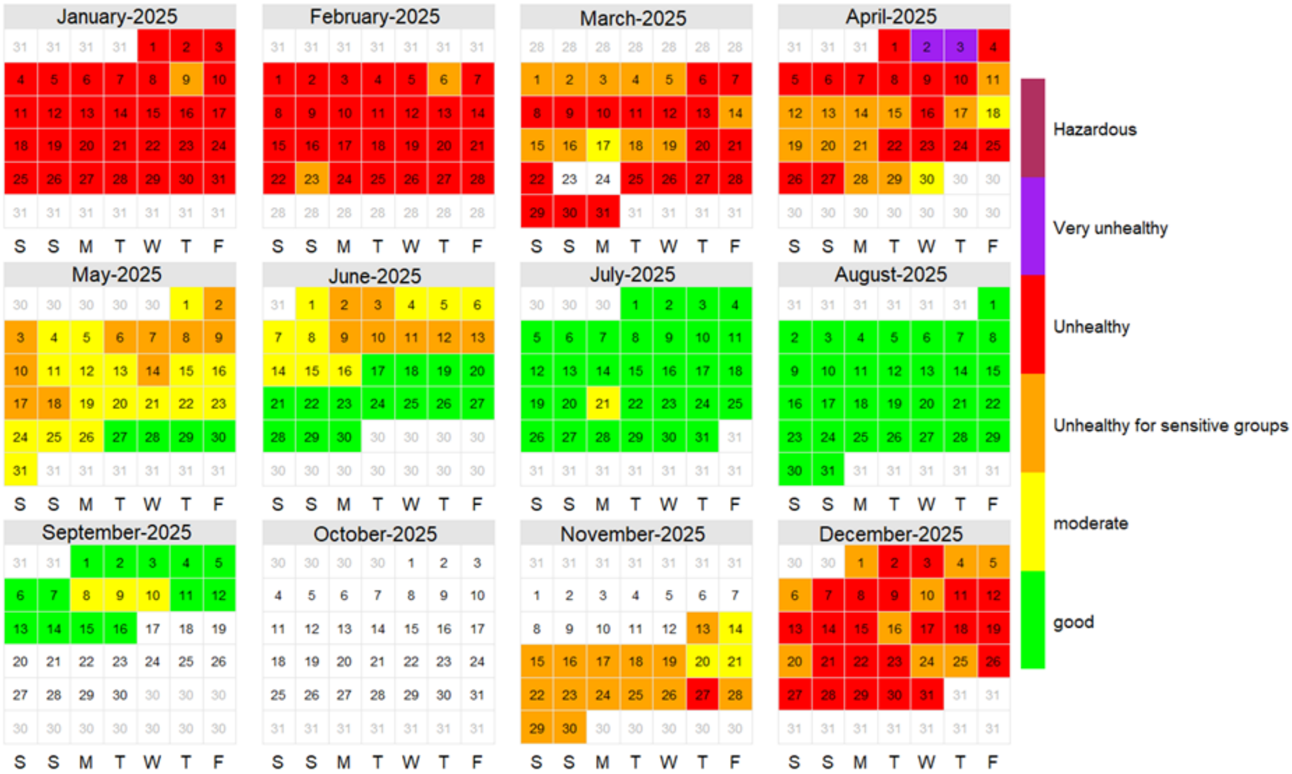


Figure 17: Calendar plot of Air Quality Index (AQI) category based on $PM_{2.5}$ for Ratnapark AQMS

PM_{10}

Daily average:

The figure illustrates the daily variations of PM_{10} concentration at five monitoring stations of Kathmandu Valley. Days in April had the highest concentration across all available stations (Figure 18).

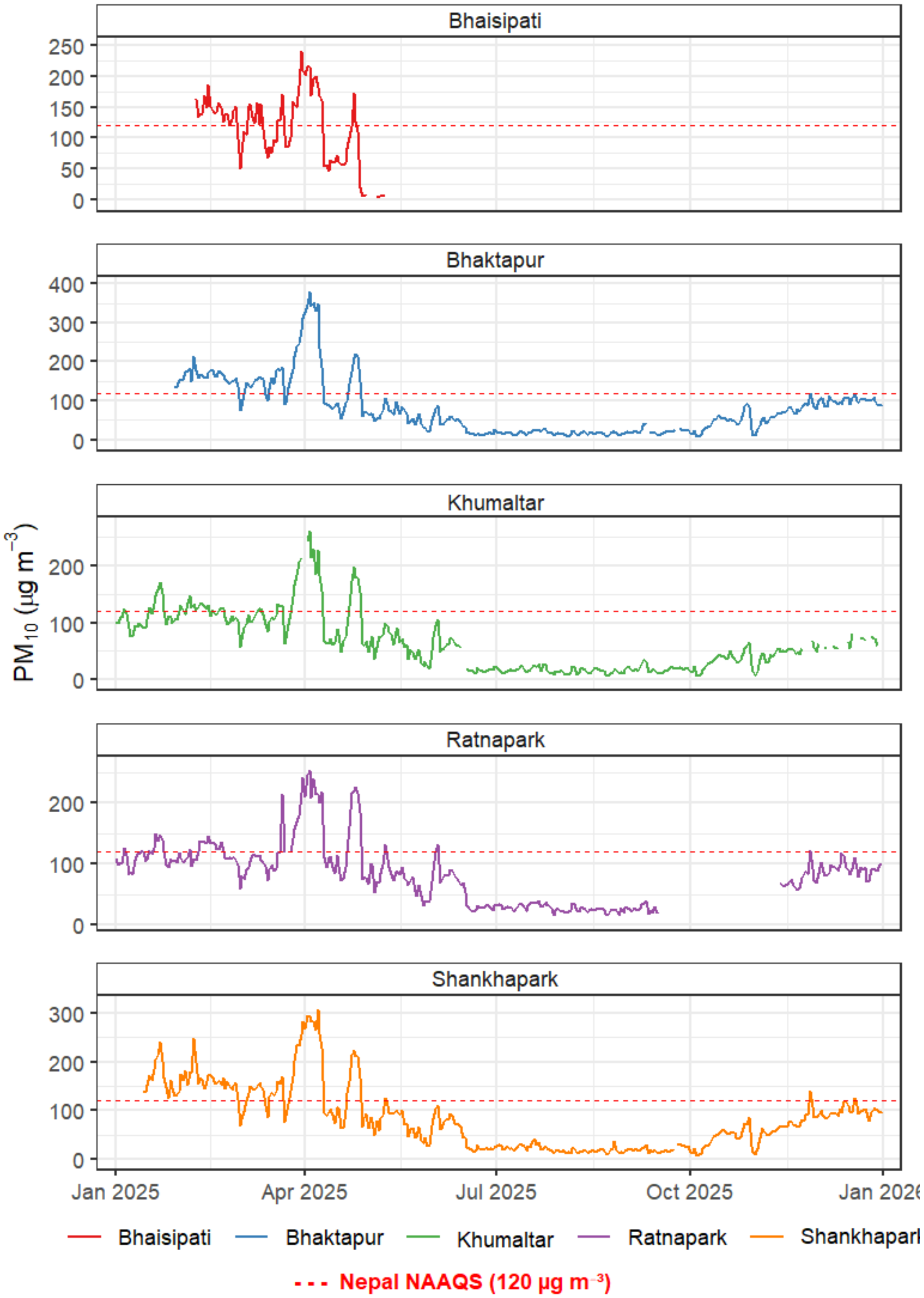


Figure 18: Daily average of PM_{10} at different monitoring stations of Kathmandu Valley

Compliance status:

The total number of days with valid data for Bhaisipati, Bhaktapur, Khumaltar, Ratnapark and Shankhapark stations were 88, 335, 344, 306 and 351 respectively. Based on the available measurements, PM_{10} concentrations exceeded the National Ambient Air Quality Standards (NAAQS) on 53.4% of monitored days at Bhaisipati, 25.1% at Shankhapark, 20.9% at Bhaktapur, 15% at Ratnapark, and 14.2% at Khumaltar. (Figure 19).

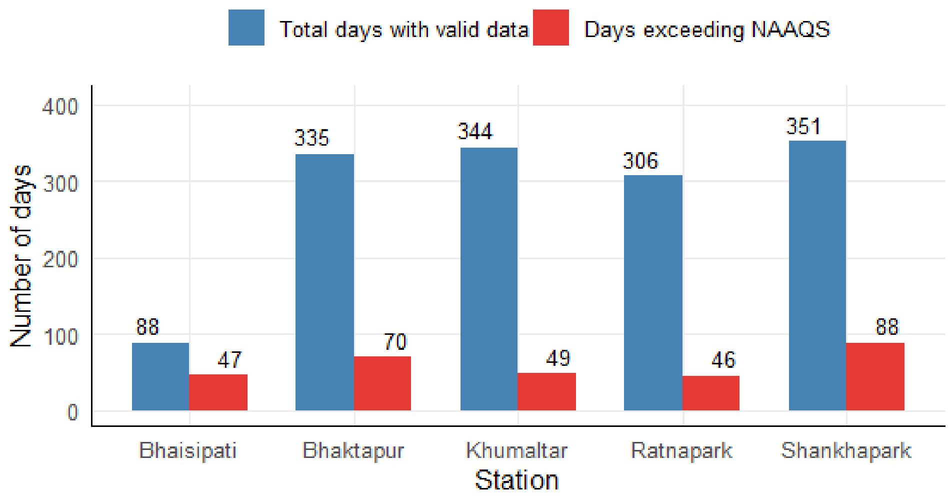


Figure 19: Compliance status of PM_{10} at different monitoring stations of Kathmandu Valley

Monthly average:

The monthly average PM_{10} concentrations at all five Kathmandu Valley stations showed a consistent seasonal pattern, peaking during February to April (ranging 103.4 to 172.8 µg m^{-3}) and reaching their lowest values during July to September (14.7 to 30 µg m^{-3}). Bhaktapur and Shankhapark recorded the highest monthly averages in February to March. Concentrations increased again from October onward, with some stations approaching 99.9 µg m^{-3} by December. (Figure 20).

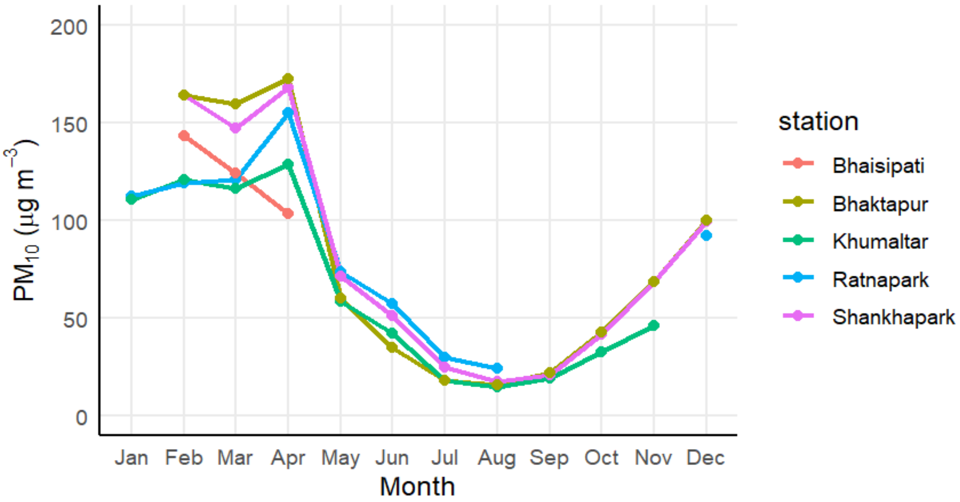


Figure 20: Monthly average of PM_{10} at different monitoring stations of Kathmandu Valley

TSP

Daily average:

As concentration of TSP was not measured in Khumaltar and Bhaktapur stations, Figure 21 illustrates the daily variations of TSP concentration at three remaining monitoring stations - Bhaisipati, Ratnapark and Shankhapark. All the monitored stations exhibit a similar trend, with elevated concentration observed from January through May.

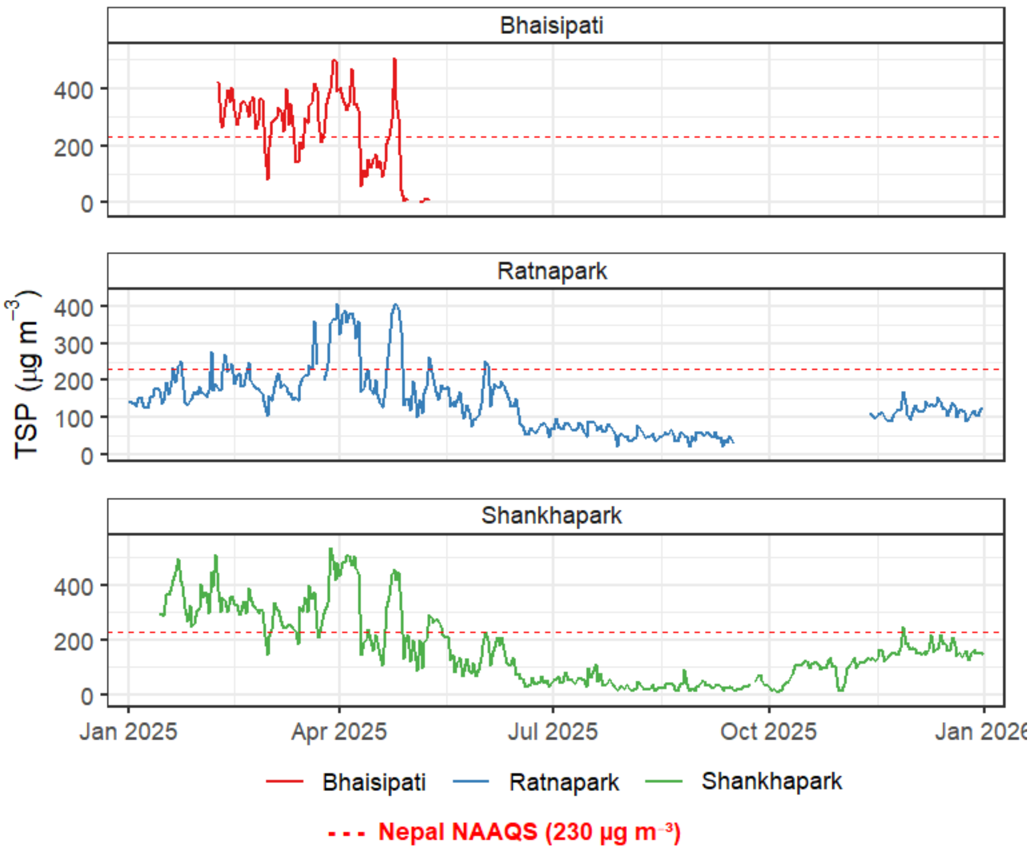


Figure 21: Daily average of TSP at different monitoring stations of Kathmandu Valley

Compliance status:

The total number of days with valid data for Bhaisipati, Ratnapark and Shankhapark stations were 88, 306 and 351 respectively. Based on the available measurements, TSP concentrations exceeded the National Ambient Air Quality Standards (NAAQS) on 65.9% of monitored days at Bhaisipati, 27.4% at Shankhapark, and 11.4% at Ratnapark. (Figure 22).

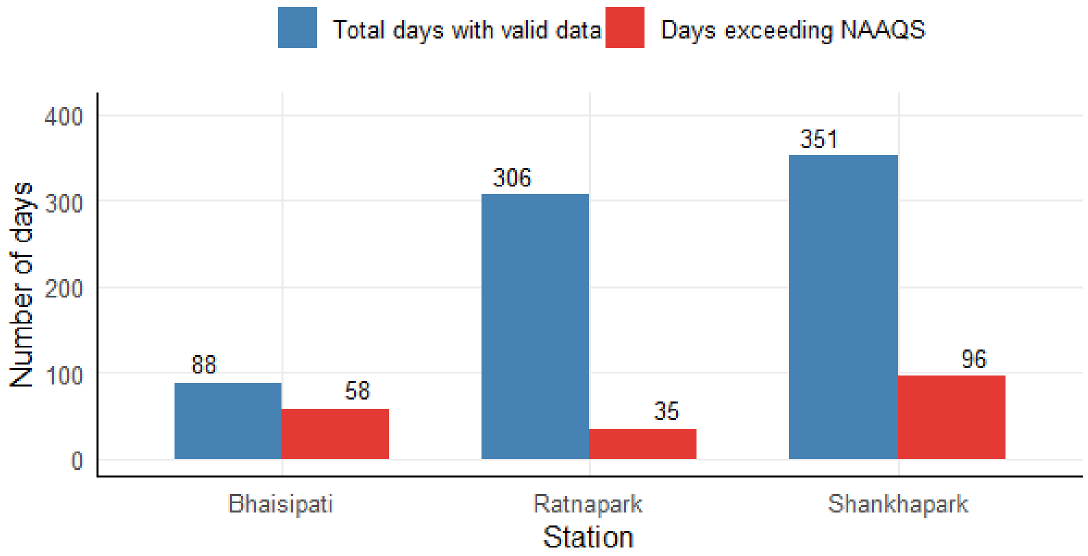


Figure 22: Compliance status of Total Suspended Particulate Matter (TSP) at different monitoring stations of Kathmandu Valley

Monthly average:

TSP data were available for three stations in the Kathmandu Valley: Bhaisipati, Ratnapark, and Shankhapark. Monthly average TSP concentrations peaked during January to April, with Shankhapark and Bhaisipati recording the highest values (166 to 341.4 µg m^{-3}). Shankhapark, with the most complete annual record, showed a sharp decline from April through August (29.6 µg m^{-3}) coinciding with the monsoon season, followed by a gradual increase through December (163.6 µg m^{-3}) (Figure 23).

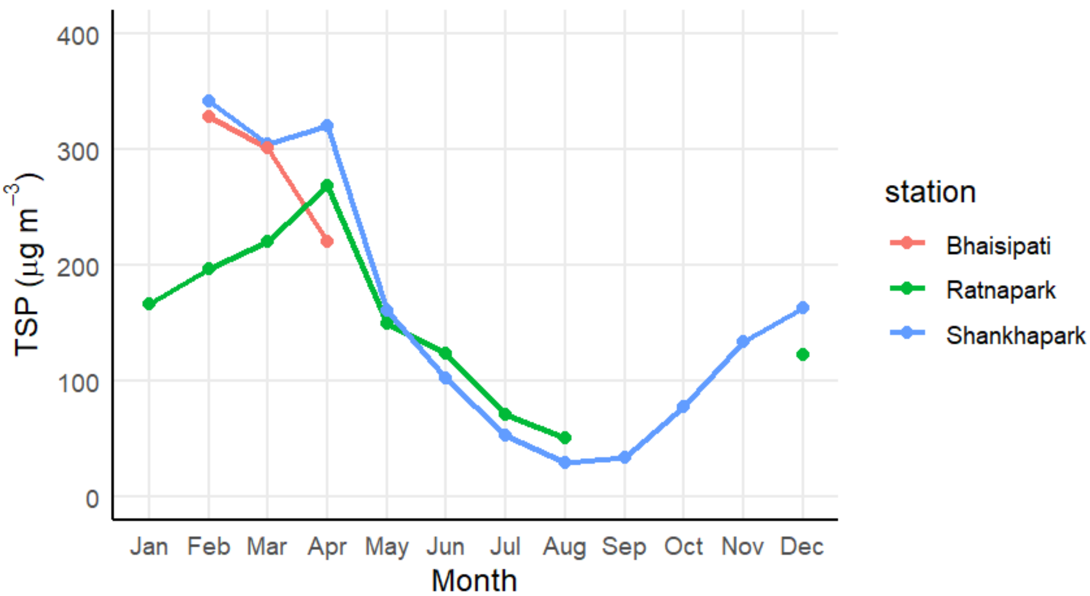


Figure 23: Monthly average of Total Suspended Particulate Matter (TSP) at different monitoring stations of Kathmandu Valley

Polar Plot

The bivariate polar plots illustrate the relationship between $PM_{2.5}$ concentrations, wind speed, and wind direction across seasons, where red colour indicate higher concentrations and blue colour indicate lower levels.

Overall, higher $PM_{2.5}$ levels was generally observed during low wind speed conditions, while stronger winds and rainfall led to better dispersion and lower concentration. In winter and post-monsoon seasons, elevated pollution levels were mainly associated with calm conditions and easterly to north-easterly winds, indicating pollutant accumulation. The pre-monsoon season showed elevated pollution which were mainly associated with calm conditions and northerly and southerly to north-westerly winds due to improved atmospheric mixing, while the monsoon season recorded the lowest levels due to washout by rainfall.

The results (Figure 23) clearly highlighted that seasonal meteorological conditions, particularly wind speed and wind direction, played a key role in controlling $PM_{2.5}$ variability, with distinct transport patterns observed across different seasons.

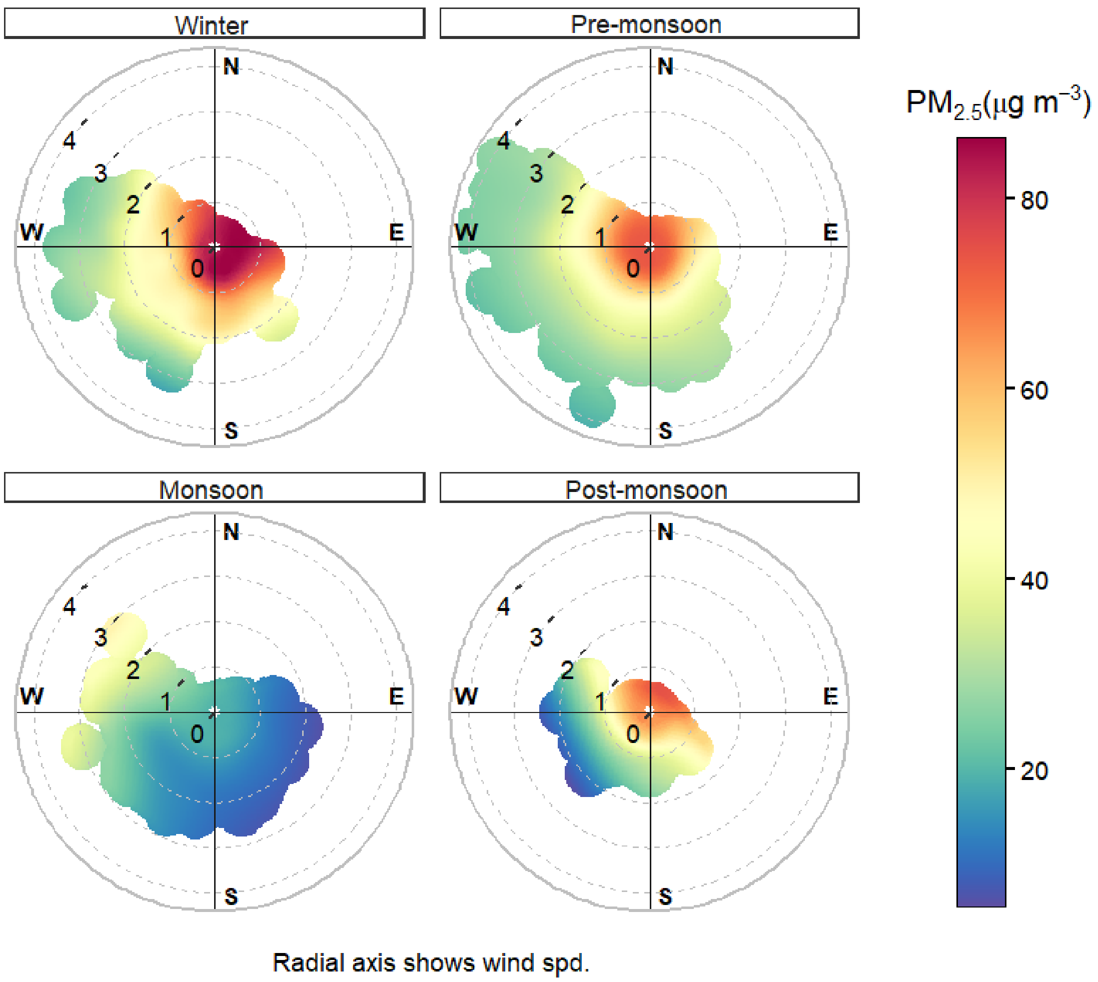


Figure 24: Seasonal Polar Plot for the Ratnapark AQMS

Back Trajectory Analysis Using HYSPLIT of Ratnapark AQMS

A significant high-pollution episode was observed on 2–3 April, as indicated by the calendar plot (Figure 17) of the Ratnapark AQMS. To identify the potential source regions contributing to this event, 72-hour backward air mass trajectories were generated using the HYSPLIT model at 3-hour intervals for both days (Figure 25). The backward trajectories were plotted together with active fire events detected during the trajectory period from 30 March to 3 April, obtained from the NASA FIRMS database.

The trajectory analysis showed that the air masses arriving in Kathmandu during the episode mainly originated from the southern and western regions. These pathways coincided with areas experiencing a high density of active forest fires during the same period. The spatial correspondence between the trajectory routes and forest fire hotspots suggested that biomass burning emissions from the southern and western regions significantly contributed to the elevated pollution levels observed in Kathmandu.

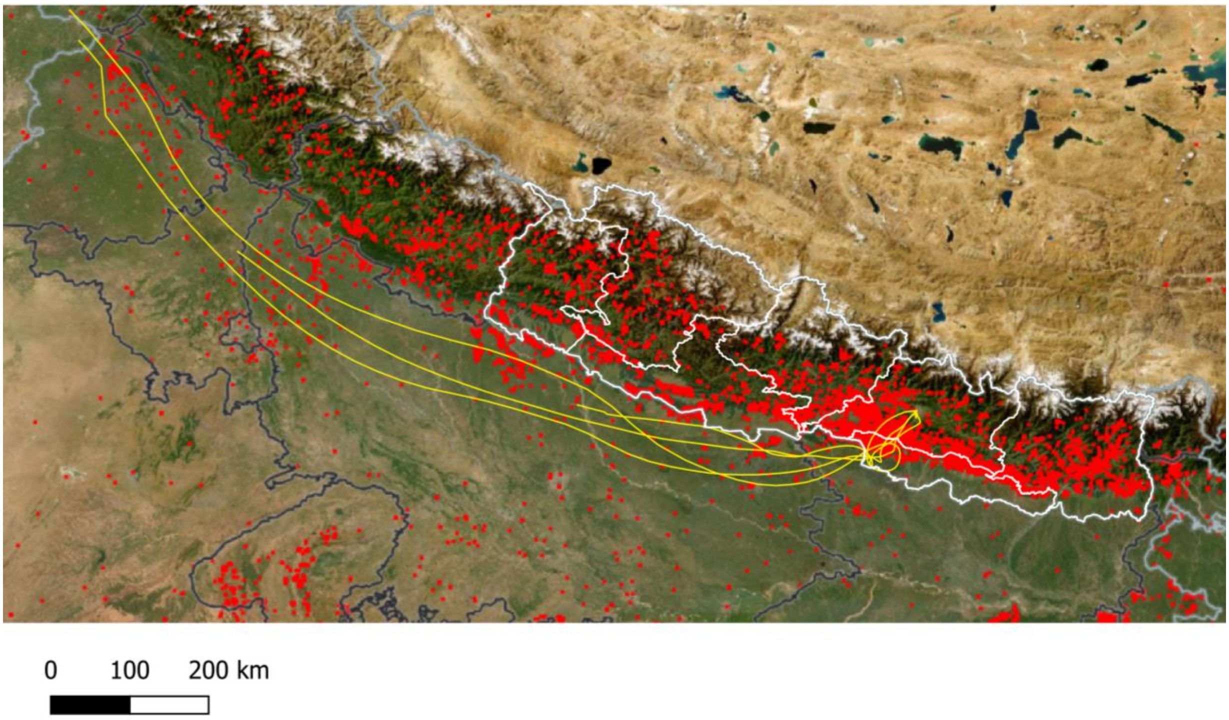


Figure 25: HYSPLIT back trajectories clusters (yellow lines) and active forest fire hotspots (red dots) for Ratnapark AQMS

2.2.2 Other Stations of Middle Mountain Region

Other stations on the middle mountain region includes Achham and Ilam, established in 2024. The Achham AQMS lies at Oli Gaun of Mangalsen municipality in Achham District of Sudurpashchim Province whereas, Ilam AQMS is located at Kuhibhir, a well-known tourist destination in Ilam.

Both Achham and Ilam AQMSs represents the mountain/background environment and are located in a rural area, where air pollution is mainly influenced by transported pollutants and seasonal forest fires.

$PM_{2.5}$

Daily average:

Figure 26 illustrates the daily variation of $PM_{2.5}$ concentration at two monitoring stations of middle mountain region. The higher concentration was observed during April for Achham AQMS and during December for Ilam AQMS.

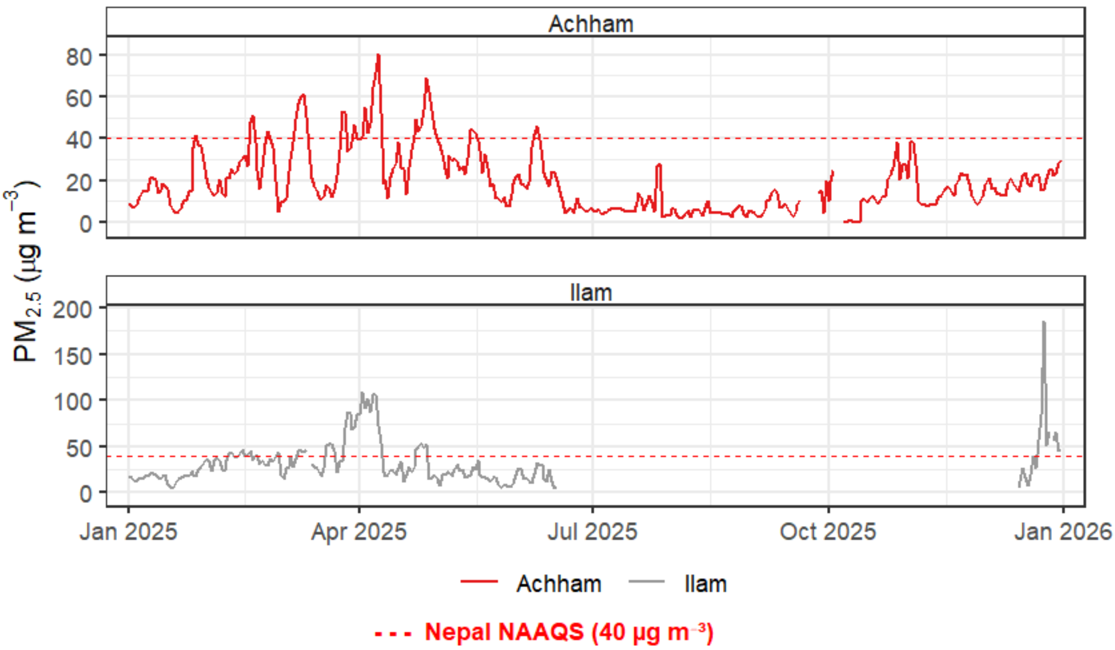


Figure 26: Daily average of $PM_{2.5}$ at different monitoring stations of middle mountain region

Compliance status:

The total number of days with valid data for Achham and Ilam stations were 356 and 185 respectively. Based on the available measurements, Ilam AQMS had the 24.9% and Achham AQMS had the 9.8% of days exceeding the NAAQS for $PM_{2.5}$ (Figure 27).

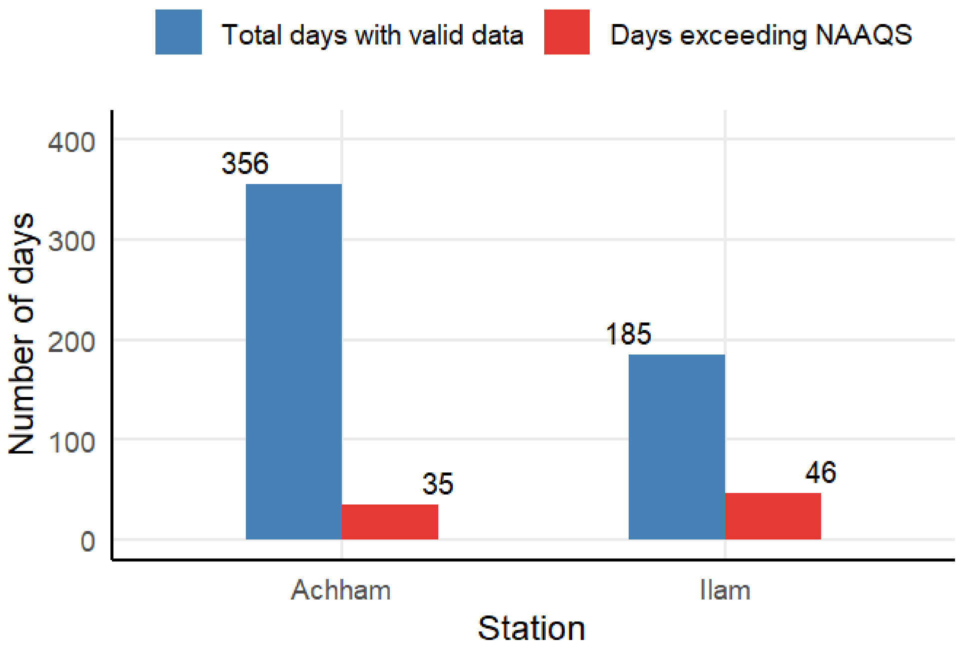


Figure 27: Compliance status of $PM_{2.5}$ at different monitoring stations of middle mountain region

Monthly average:

The monthly average $PM_{2.5}$ concentrations at Achham and Ilam stations followed a similar pattern during the overlapping observation period (January to May), with both stations rising to a peak in April (41.5 & 46.9 µg m⁻³). At Achham, where full annual data were available, where concentrations declined sharply from May onward, reaching the lowest values in August (4.8 µg m⁻³) during the monsoon season, then gradually increasing to 19.5 µg m⁻³ by December (Figure 28).

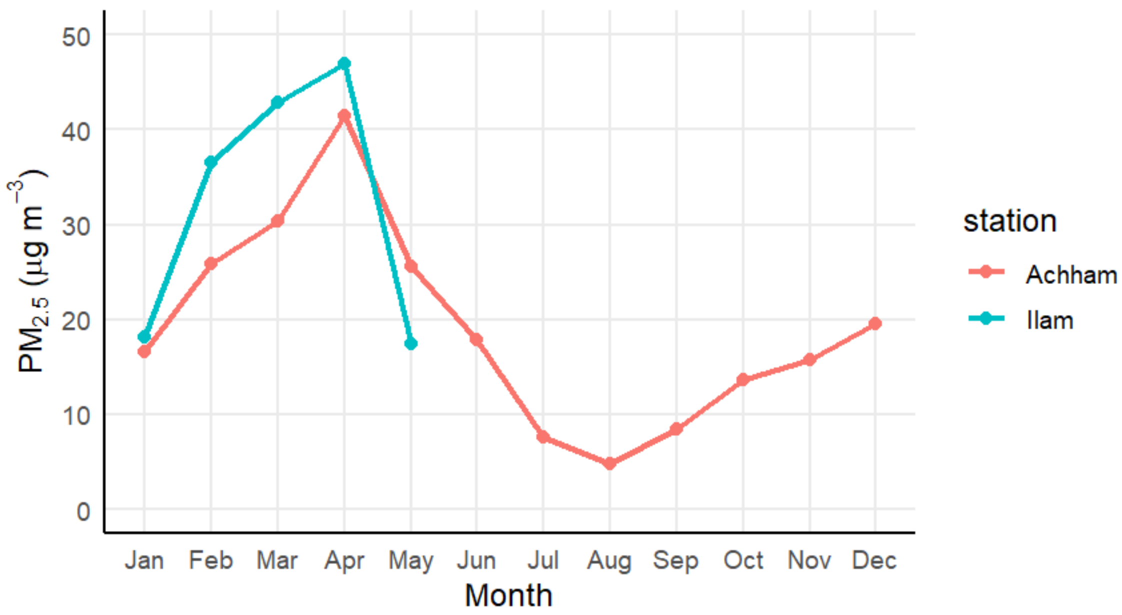


Figure 28: Monthly average of $PM_{2.5}$ at different monitoring stations of middle mountain region

Calendar plot

Calendar plot for $PM_{2.5}$ (Figure 29) at the Achham AQMS indicated that the AQI reached the "Unhealthy" category on a few days during March and April. In contrast, during the remaining months, almost all days fell within the "Good" air quality category.

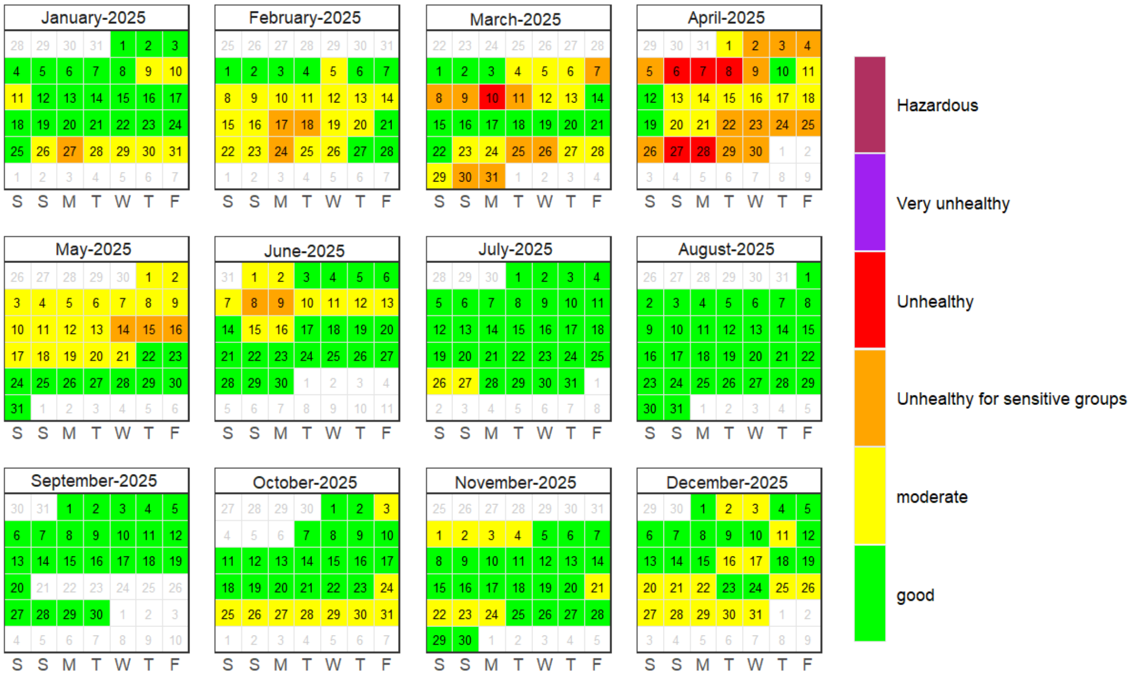


Figure 29: Calendar Plot of AQI Category Based on $PM_{2.5}$ for Achham AQMS

PM_{10}

Daily average:

Figure 30 illustrates the daily variation of PM_{10} concentration at two stations. The higher concentration was observed during April for Achham AQMS and during December for Ilam AQMS.

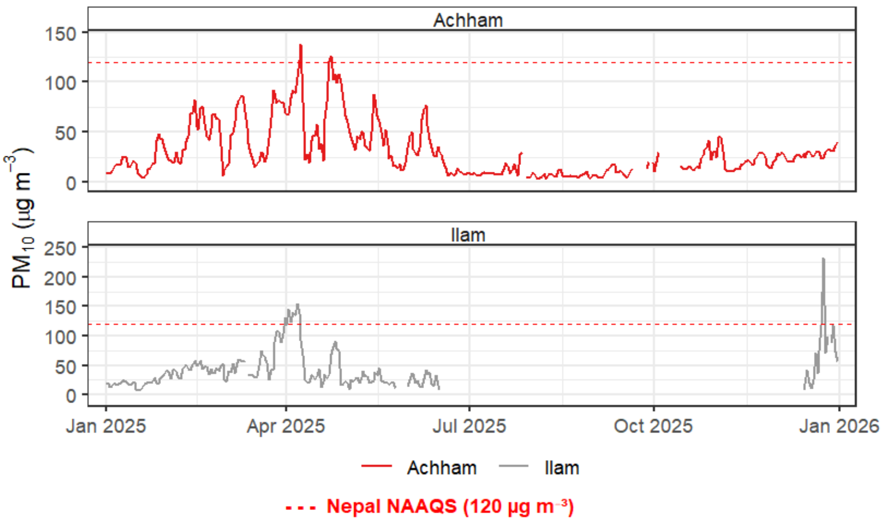


Figure 30: Daily average of PM_{10} at different monitoring stations of middle mountain region

Compliance status:

The total number of days with valid data for Achham and Ilam stations were 347 and 180 respectively. Based on the available measurements, Achham AQMS had the 4 days and Ilam AQMS had 8 days of exceeding the NAAQS for PM_{10} (Figure 31).

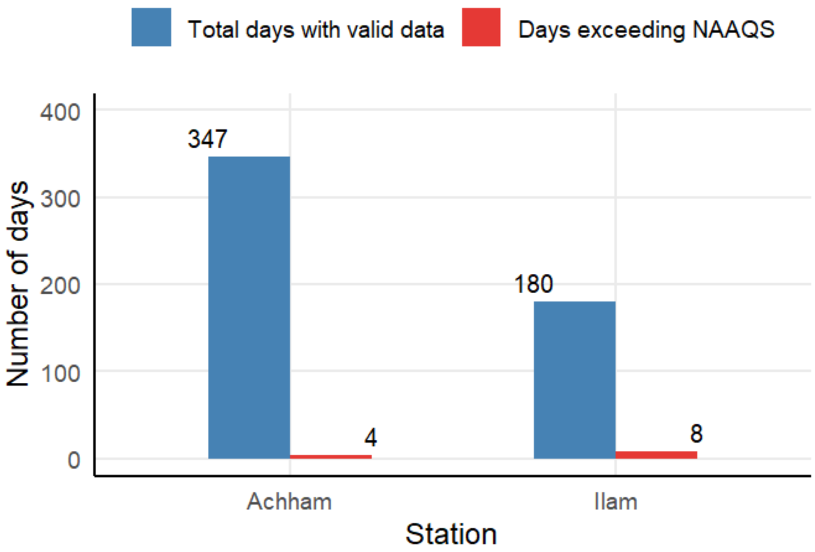


Figure 31: Compliance status of PM_{10} at different monitoring stations of middle mountain region

Monthly average:

The monthly average PM_{10} concentrations at Achham and Ilam stations followed a similar pattern during the overlapping observation period (January to May), with both stations rising to a peak in April (64.5 & 75.2 µg m^{-3}). At Achham, concentrations declined sharply from May onward, reaching the lowest values in August (6.6 µg m^{-3}) during the monsoon season, then gradually increasing to 27.8 µg m^{-3} by December (Figure 32).

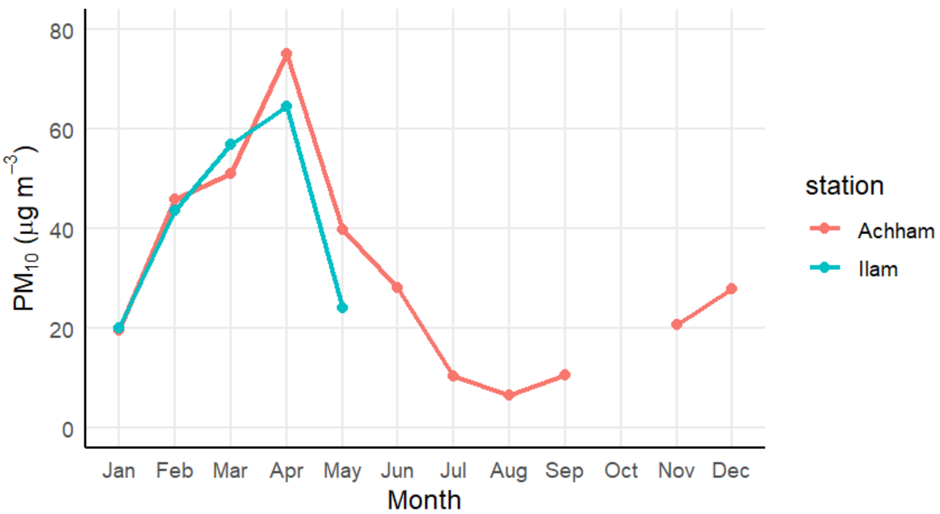


Figure 32: Monthly average of PM_{10} at different monitoring stations of middle mountain region

TSP

Daily average:

Figure 33 illustrates the daily variation of TSP concentration at two monitoring stations. For Achham AQMS, higher concentration was observed during February to May and for Ilam AQMS highest concentration was observed during December.

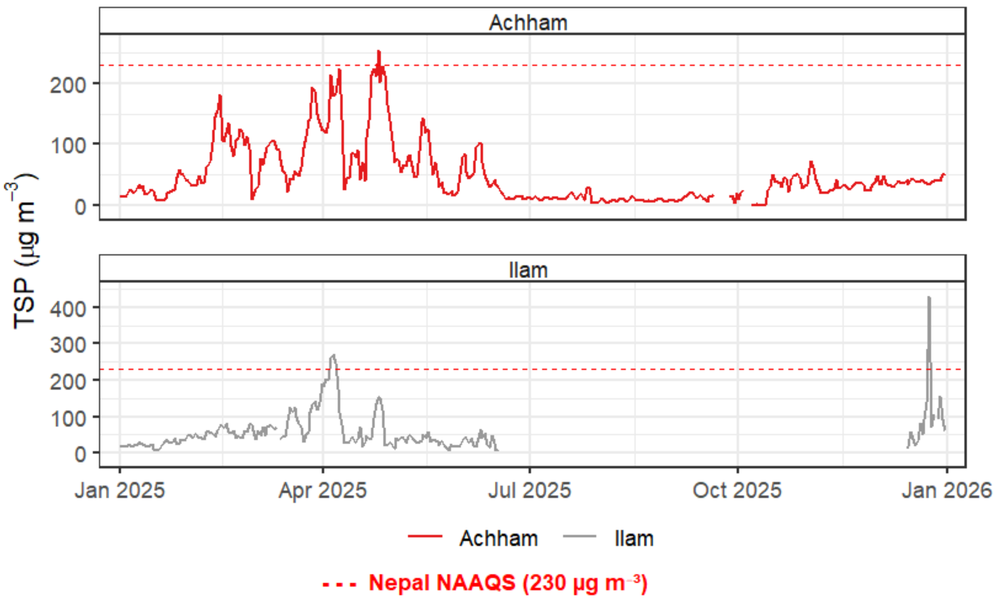


Figure 33: Daily average of TSP at different monitoring stations of middle mountain region

Compliance status:

The total number of days with valid data for Achham and Ilam stations were 356 and 185. Based on the available measurements, Ilam AQMS had only 4 days exceeding the NAAQS for TSP (Figure 34).

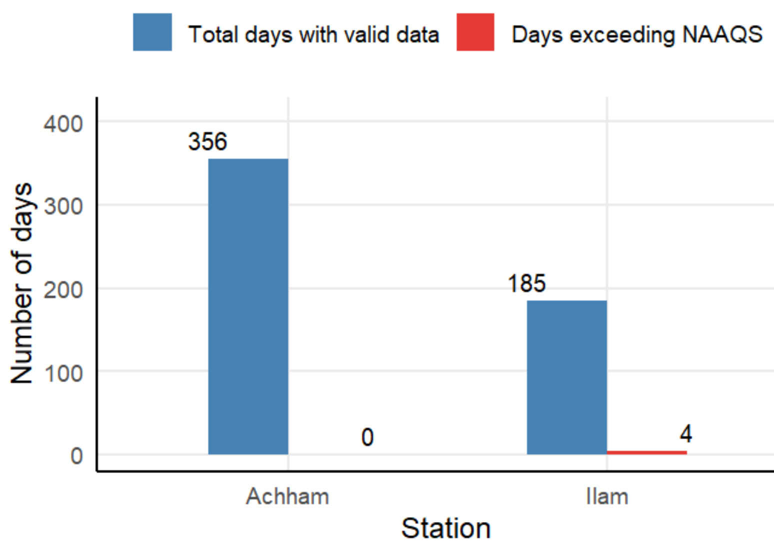


Figure 34: Compliance status of TSP at different monitoring stations of high mountain and Himalaya region

Monthly average:

Monthly average TSP concentrations at Achham and Ilam stations both peaked in April, reaching 143.7 µg m^{-3} & 98.5 µg m^{-3}, respectively. At Achham, where full annual data were available, concentrations declined sharply from April through August (7.9 µg m^{-3}) during the monsoon season, followed by a gradual increase through December (38.6 µg m^{-3}). Ilam had limited data coverage, with observations available for January to june and a single data point in December (91.7 µg m^{-3}) (Figure 35).

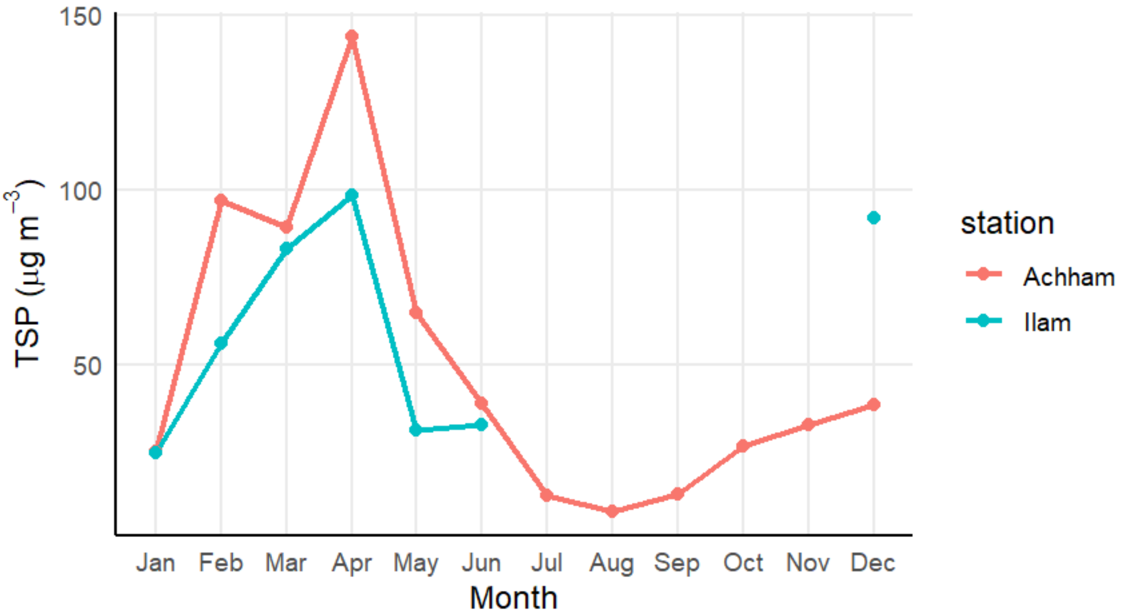


Figure 35: Monthly average of TSP at different monitoring stations of middle mountain region

Polar Plot

The polar plots (Figure 36) illustrate seasonal variation of $PM_{2.5}$ in relation to wind speed and wind direction.

Pre-monsoon period indicates higher concentrations especially under low wind speeds and also during moderate to high wind speed showing strong influence of local emissions as well as regional transport. Winter also showed relatively elevated levels, especially under moderate to high wind speed conditions indicating influence of regional transport.

However, post-monsoon showed a moderate increase in the $PM_{2.5}$ concentrations with stable atmospheric conditions and lower mixing. The monsoon period had minimum $PM_{2.5}$ concentrations due to efficient removal by rainfall and high atmospheric dispersion. The high pollution events during moderate to high wind speed indicates the pollution transported from other regions.

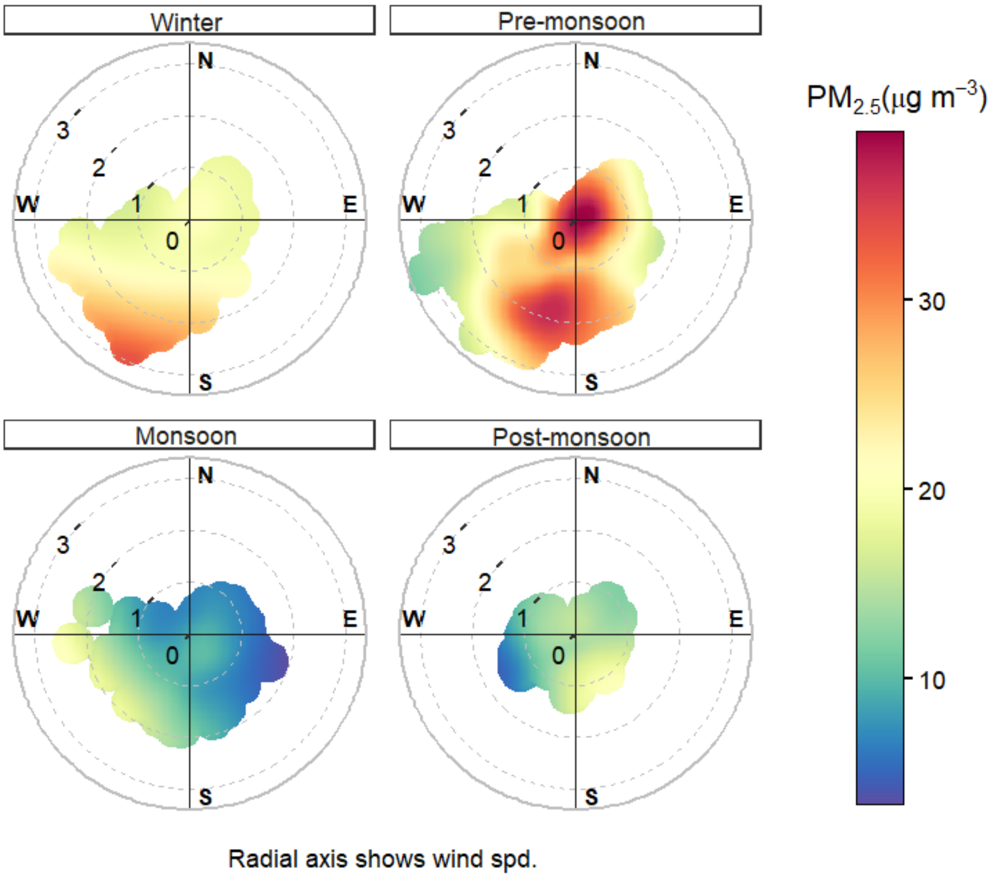


Figure 36: Seasonal Polar plot for Achham AQMS

Back Trajectory Analysis Using HYSPLIT of Achham

At the Achham AQMS, the highest monthly average $PM_{2.5}$ concentration was observed in April, during which five days fell under the "Unhealthy" air quality category (Figure 28). To investigate the potential source regions contributing to this pollution episode, a 72-hour backward trajectory analysis was performed using the HYSPLIT model for 6 April 2025, initialized at 00 UTC. The trajectories were generated at three-hour intervals, resulting in eight individual backward trajectories. These trajectories were subsequently clustered into four groups to identify the dominant air mass transport pathways influencing the monitoring site (Figures 36 and 37). The backward trajectories were plotted together with active fire events detected during the trajectory period from 3 to 6 April, obtained from the NASA FIRMS database.

The HYSPLIT trajectory analysis revealed that the air masses influencing Achham during the pollution episode were predominantly transported from the western sector. During the same period, a large number of active forest fires were detected along the identified transport pathways. The coincidence of air mass movement with forest fire hotspots suggested that emissions from biomass burning likely contributed substantially to the elevated $PM_{2.5}$ concentrations observed at the Achham AQMS likely contributed substantially to the elevated $PM_{2.5}$ concentrations observed at Achham.

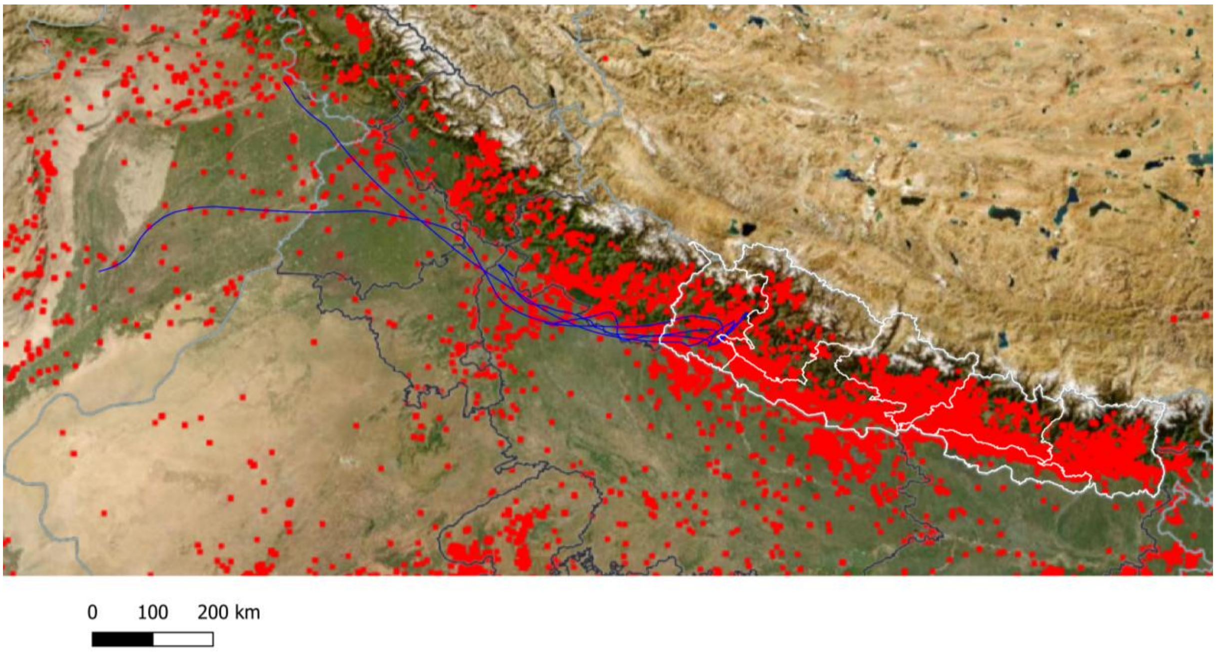


Figure 37: HYSPLIT back trajectories clusters (blue lines) and active forest fire hotspots (red dots) for Achham AQMS

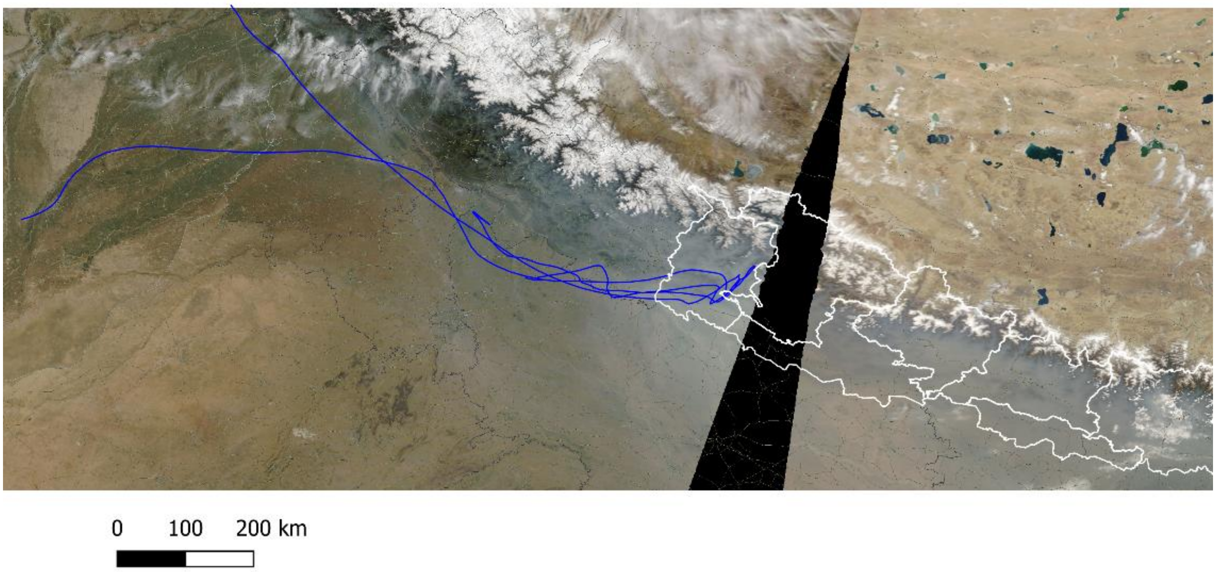


Figure 38: HYSPLIT back trajectories clusters (blue lines) for Achham AQMS and true colour image of April 6 in the background (TERRA MODIS)

2.3 TARAI AND DUN VALLEY REGION

The Tarai and Dun Valley region includes five AQMSs: Surkhet (established in 2019), Bharatpur, Hetauda, Dhangadhi (established in 2020), and Deukhuri Dang (established in 2024). Surkhet AQMS lies inside premises of Karnali Province police office at Birendranagar Municipality in Surkhet District, Karnali Province. Bharatpur AQMS is located within the premises of the District Administration Office, Bharatpur, Chitwan, Bagamati Province. Hetauda AQMS is situated adjacent to the Ward No. 4 Office at Hupra Chaur, Hetauda Sub-Metropolitan City, Makawanpur District, Bagamati Province. Similarly, Dhangadhi AQMS is located at Khulla Manch in Dhangadhi Municipality, while Deukhuri Dang AQMS is situated within the premises of the Rapti Rural Municipality Office at Masuriya, Deukhuri Dang, Lumbini Province. Bharatpur AQMS represents an urban area mainly influenced by vehicular emissions. Hetauda AQMS is affected by emissions from vehicles and nearby industries, while dust from the adjacent football ground also contributes to particulate pollution. Dhangadhi AQMS experiences pollution primarily from vehicles, industries, agricultural residue burning during the pre-monsoon season, and transboundary air pollution due to its proximity to the border. Similarly, Deukhuri Dang AQMS, installed in June 2024, represents a semi-urban environment influenced by vehicular emissions, residential activities, forest fires, and transboundary air pollution.

$PM_{2.5}$

Daily average:

Figure 39 illustrates the daily variation of $PM_{2.5}$ concentration at five monitoring stations of Tarai and Dun Valley region. Higher concentration was observed during winter, pre monsoon and post monsoon for all the analyzed stations for all available data.

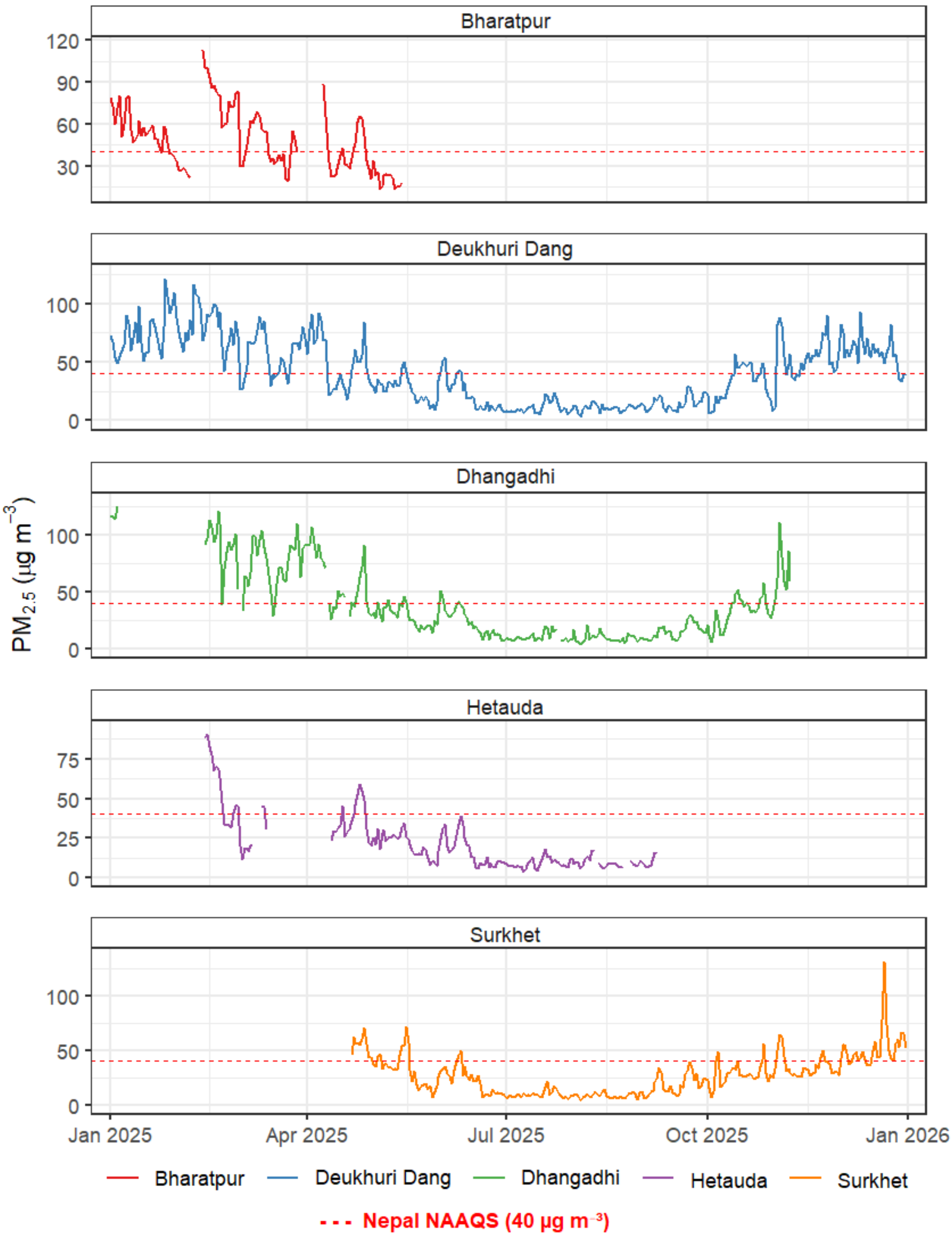


Figure 39: Daily average of $PM_{2.5}$ at different monitoring stations of Tarai and Dun Valley region

Compliance status:

The total number of days with valid data for Bharatpur, Deukhuri Dang, Dhangadhi, Hetauda and Surkhet stations were 118, 365, 269, 173 and 255 respectively. Based on the available measurements, $PM_{2.5}$ concentrations exceeded the National Ambient Air Quality Standards (NAAQS) on 55.1% of monitored days at Bharatpur, 47.1% at Deukhuri Dang, 33.1% Dhangadhi, 22% at Surkhet, and 12.1% at Hetauda for $PM_{2.5}$ (Figure 40).

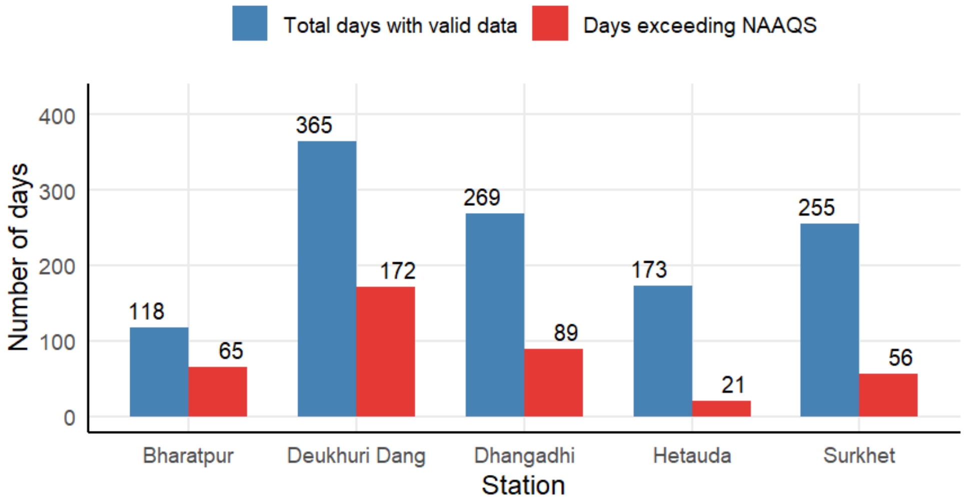


Figure 40: Compliance status of $PM_{2.5}$ at different monitoring stations of Tarai and Dun Valley region

Monthly average:

Monthly average $PM_{2.5}$ concentrations at the five Terai and dune valley stations showed elevated values during winter and pre-monsoon months, with Deukhuri Dang and Dhangadhi recording the highest values in January and February (73.5 & 80.3 µg m^{-3}). Bharatpur also showed elevated concentrations in January and February (55.5 & 66.9 µg m^{-3}). All stations converged to their lowest values during the monsoon season (July to September, 8.3 to 18.6 µg m^{-3}). Surkhet and Hetauda, with data available from May onward along with Dhangadhi and Deukhuri Dang, showed a gradual post-monsoon increase (Figure 41).

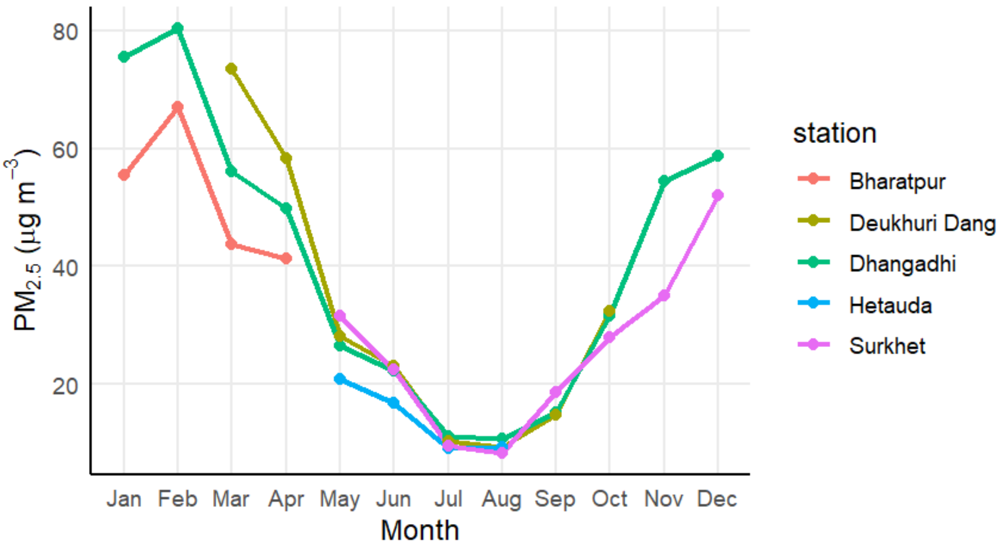


Figure 41: Monthly average of $PM_{2.5}$ at different monitoring stations of Tarai and Dun Valley region

Calendar plot

Calendar plot for $PM_{2.5}$ (Figure 42) for the Deukhuri AQMS showed that most days in January and February were classified under the Unhealthy AQI category, while a few days in March, April, November, and December also experienced Unhealthy conditions. In contrast, during July, August, and September, almost all days fell within the Good to Moderate air quality categories.

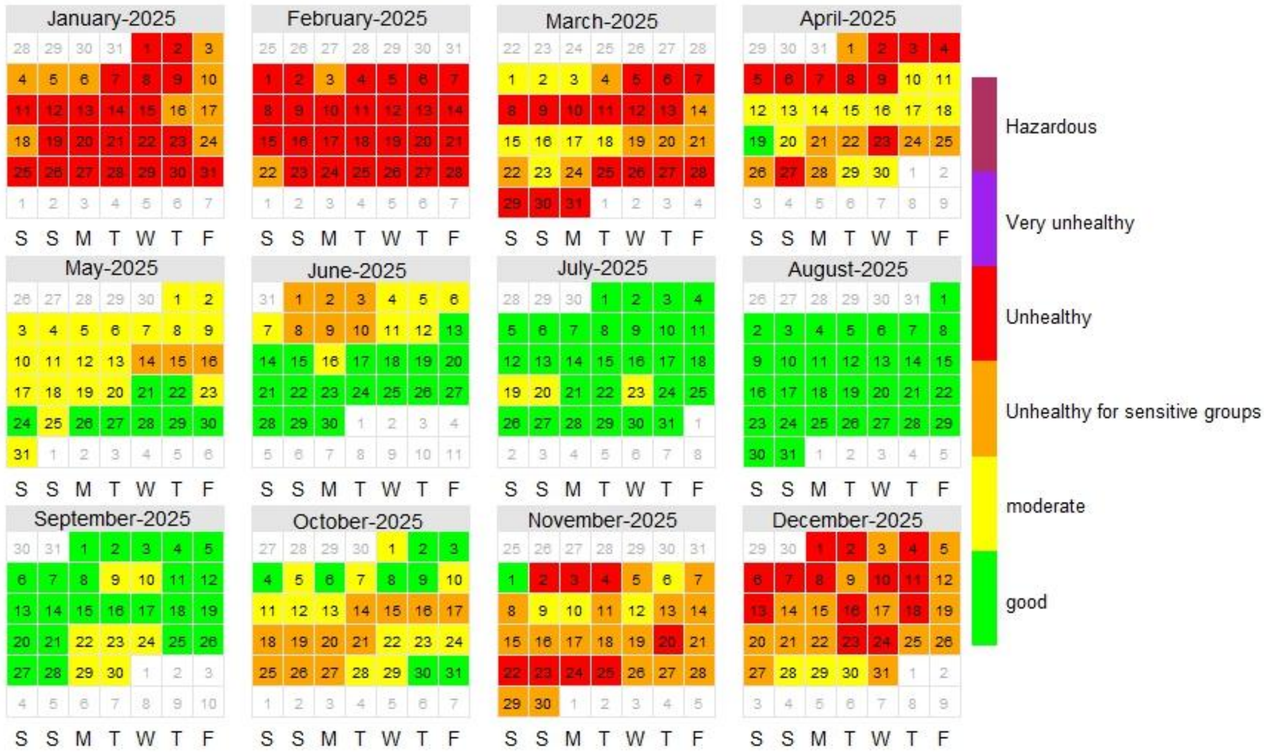


Figure 42: Calendar Plot of Air Quality Index (AQI) Category Based on $PM_{2.5}$ for Deukhuri Dang AQMS

PM_{10}

Daily average:

Figure 43 illustrates the daily variation of PM_{10} concentration at five stations. Higher concentration was observed during winter, pre monsoon and post monsoon days for available data.

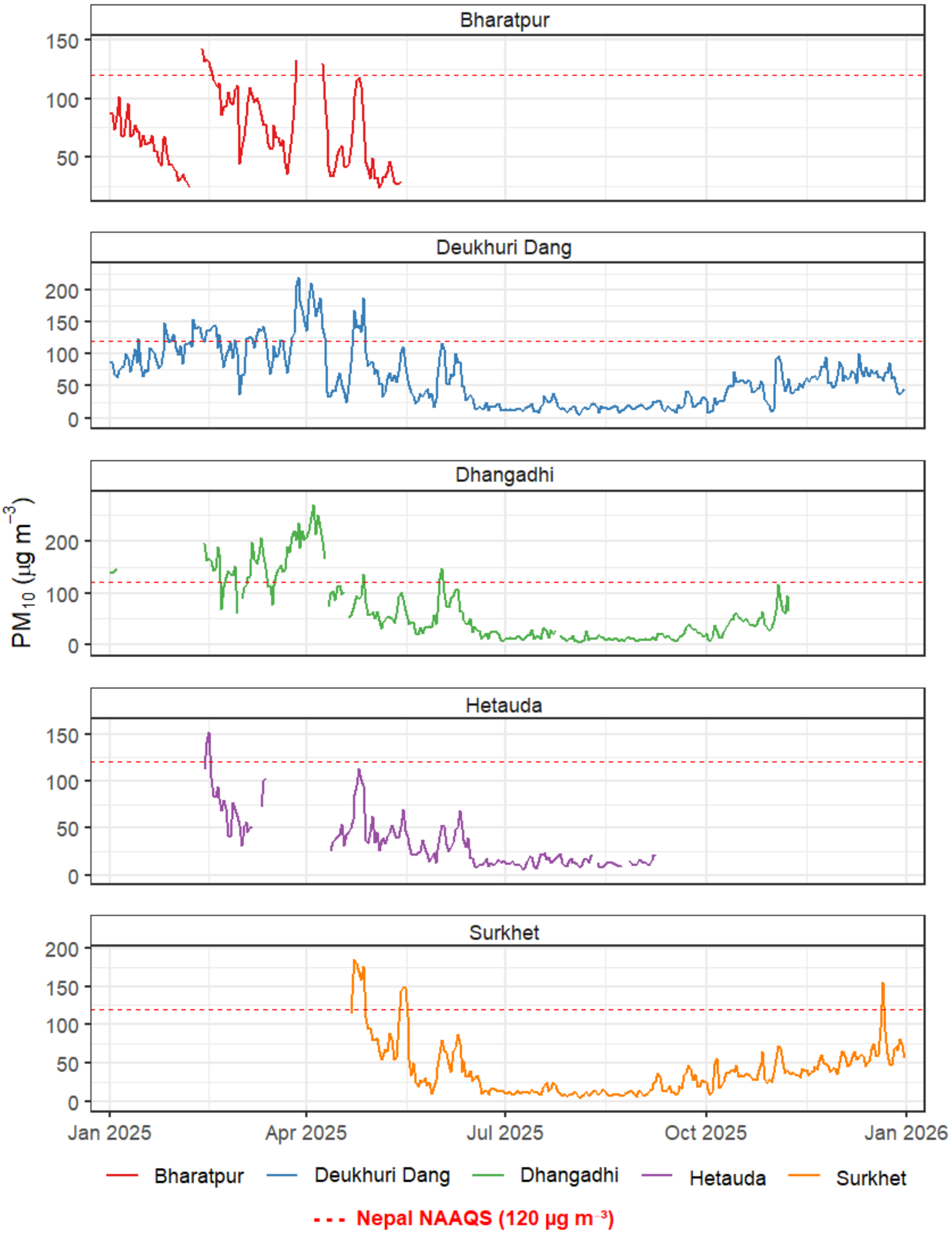


Figure 43: Daily average of PM_{10} at different monitoring stations of Tarai and Dun Valley region

Compliance status:

The total number of days with valid data for Bharatpur, Deukhuri Dang, Dhangadhi, Hetauda and Surkhet stations were 118, 365, 269, 173, 255 respectively. Based on the available measurements, PM_{10} concentrations exceeded the National Ambient Air Quality Standards

(NAAQS) on 78.8% of monitored days at Bharatpur, 19.3% Dhangadhi, 13.7% at Deukhuri Dang, 3.9% at Surkhet, and only 2 days at Hetauda for PM_{10} (Figure 44).

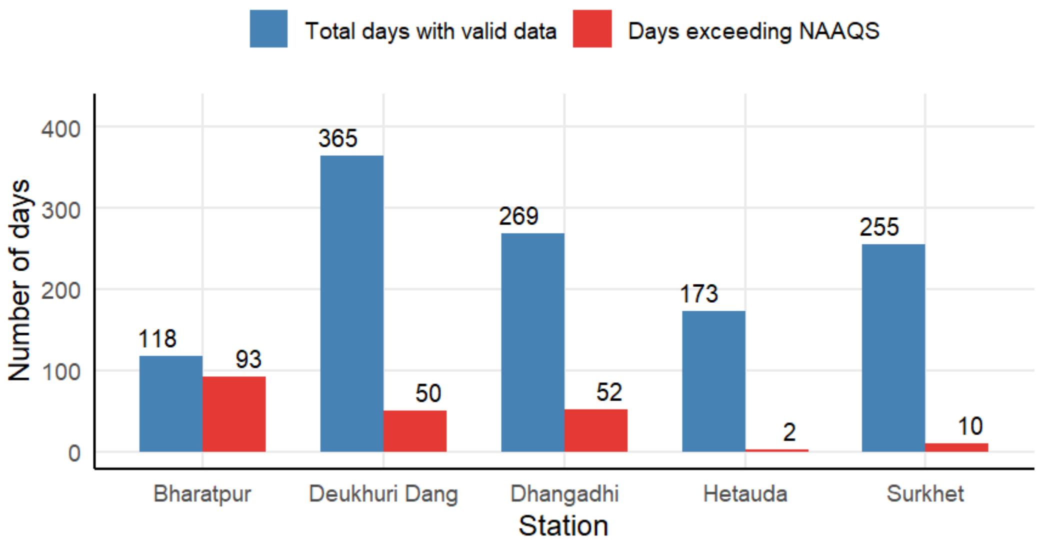


Figure 44: Compliance status of PM_{10} at different monitoring stations of Tarai and Dun Valley region

Monthly average:

Monthly average PM_{10} concentrations at the five Terai and Dune valley stations were highest during winter and pre-monsoon months, with Dhangadhi recording the highest value in March (159 µg m^{-3}), followed by Bharatpur and Deukhuri Dang peaking in February and March (135.1 & 119.4 µg m^{-3}). All stations converged to their lowest values during the monsoon season (July to September, 10.2 to 21.6 µg m^{-3}). Post-monsoon concentrations increased gradually through December, with Deukhuri Dang reaching 65.8 µg m^{-3}(Figure 45).

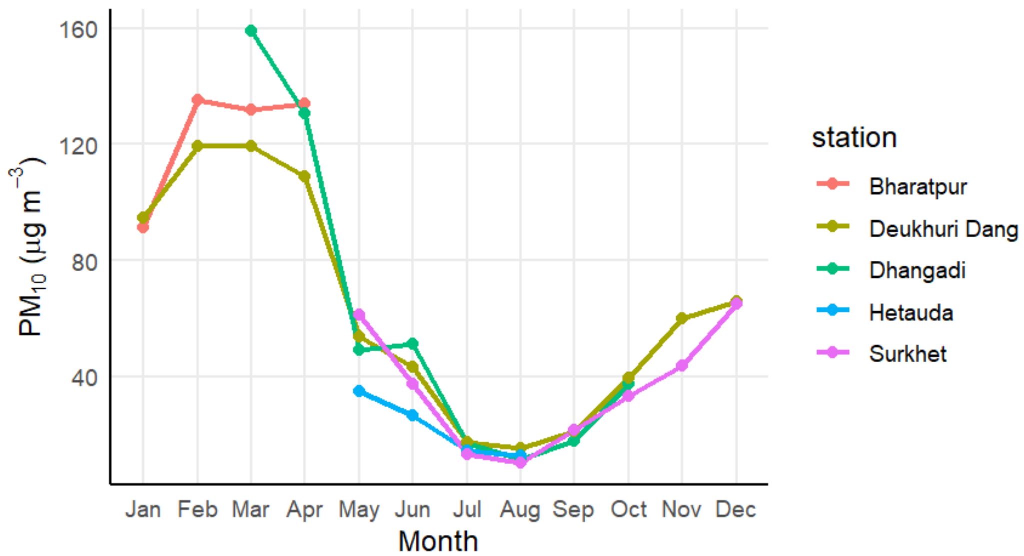


Figure 45: Monthly average of PM_{10} at different monitoring stations of Tarai and Dun Valley region

TSP

Daily average:

Figure 46 illustrates the daily variation of TSP concentration at five monitoring stations of Tarai and Dun Valley region. Higher concentration was observed during winter and pre monsoon for all the available stations for available data.

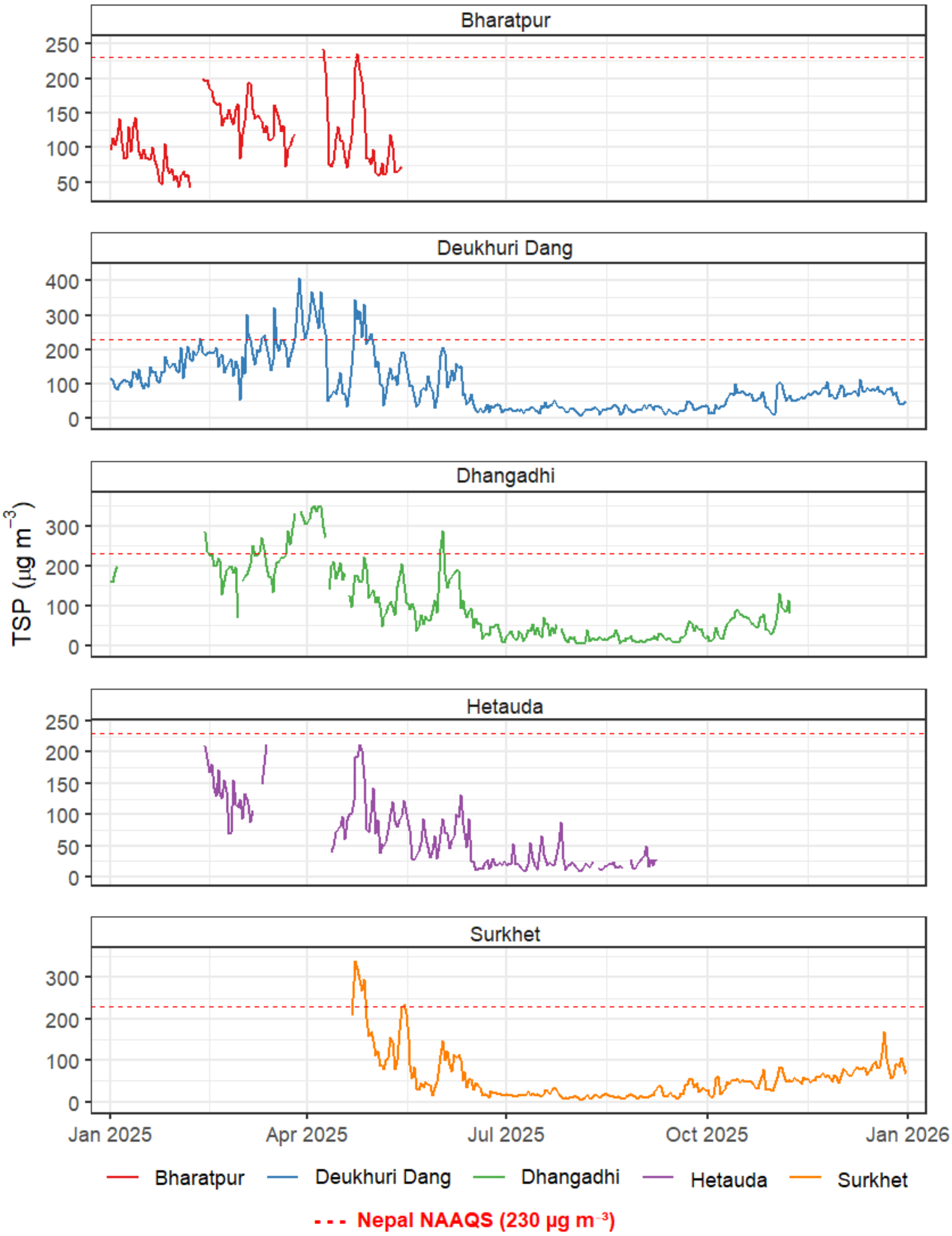


Figure 46: Daily average of TSP at different monitoring stations of Tarai and Dun Valley region

Compliance status:

The total number of days with valid data for Bharatpur, Deukhuri Dang, Dhangadhi, Hetauda and Surkhet stations were 117, 365, 267, 173, 255 respectively. Based on the available measurements, the number of days on which TSP concentrations exceeded the NAAQS was 29 at

Deukhuri Dang, 25 at Dhangadhi, 7 at Surkhet, and 2 at Bharatpur. The Hetauda AQMS did not exceed the single day throughout the measurement period for TSP (Figure 47).

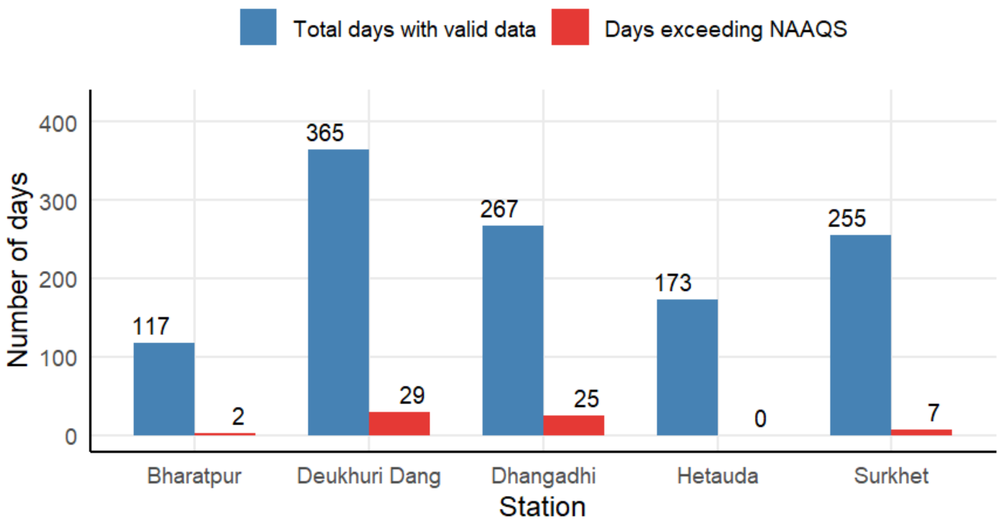


Figure 47: Compliance status of TSP at different monitoring stations of Tarai and Dun Valley region

Monthly average:

Monthly average TSP concentrations at the Terai and dune valley stations peaked during March and April, with Deukhuri Dang and Dhangadhi recording the highest values (219.4 & 230 µg m^{-3}). Bharatpur showed relatively stable concentrations during February to April (132.1 to 135.1 µg m^{-3}). All stations with monsoon season available data reached their lowest values during July to September (12 to 32.3 µg m^{-3}), followed by a gradual post-monsoon increment. Bharatpur had the most limited TSP data coverage, with observations available only for January to April (Figure 48).

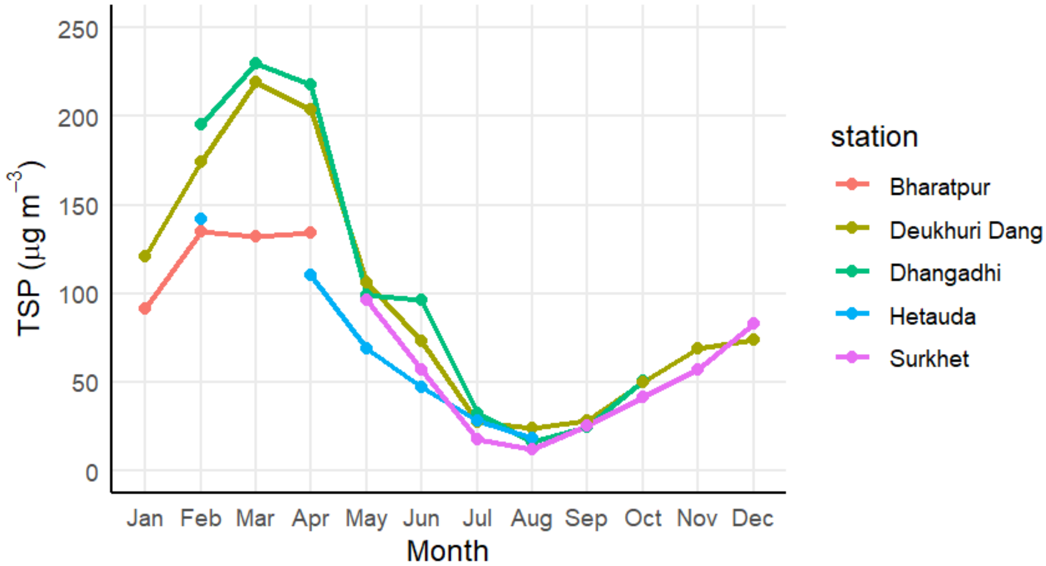


Figure 48: Monthly average of TSP at different monitoring stations of Tarai and Dun Valley region

Polar Plot

The polar plots showed the relationship between $PM_{2.5}$ concentration, wind speed, and wind direction across seasons.

Higher $PM_{2.5}$ levels were observed during winter under low wind speed conditions, particularly from easterly to north-easterly directions, indicating pollutant accumulation. The monsoon season recorded the lowest concentrations due to strong atmospheric mixing and rainfall washout. Pre-monsoon showed moderate and more evenly distributed levels, while post-monsoon again showed an increased under calm conditions, reflected the re-establishment of stable atmosphere and local emissions influence (Figure 49).

Overall, seasonal meteorology especially wind speed and rainfall strongly controlled $PM_{2.5}$ variations, with a dominant east-west transport pattern evident across seasons.

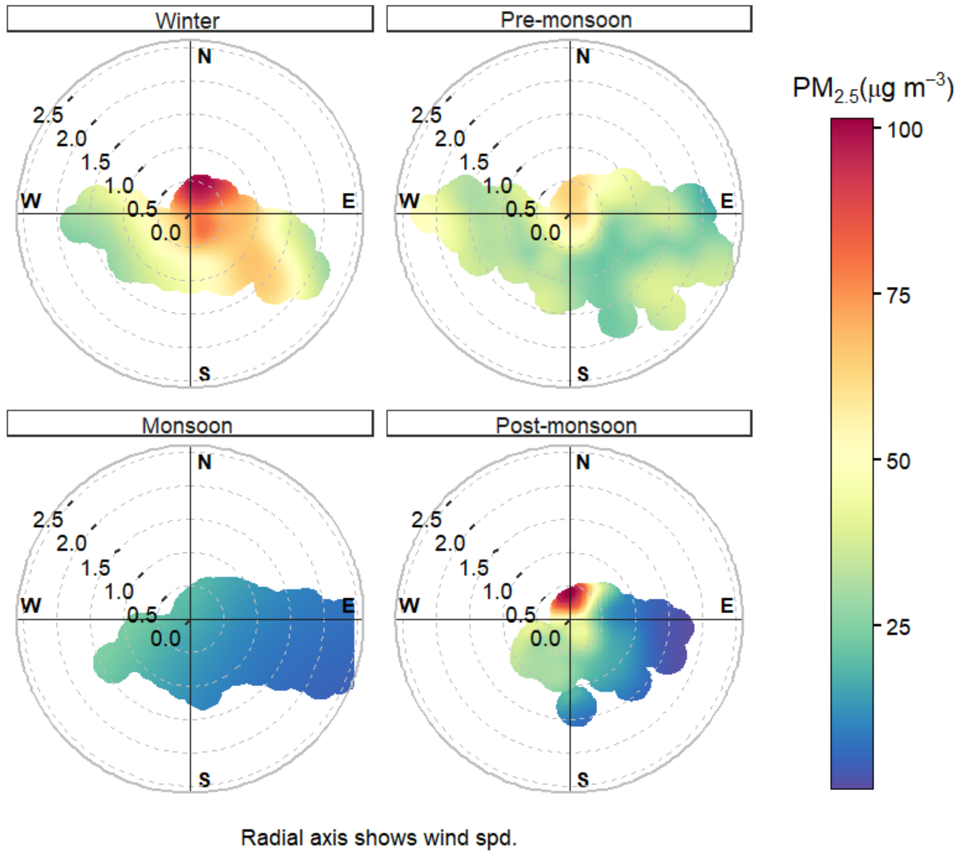


Figure 49: Seasonal Polar plot for Deukhuri Dang AQMS

Back Trajectory Analysis Using HYSPLIT of Deukhuri Dang.

In Deukhuri Dang the highest daily average was recorded on January 26, 2025. Following figure illustrated the 72-hour HYSPLIT back trajectory analysis for Deukhuri, Dang, initialized at 00 UTC on 26 January 2025. Trajectories were generated at three-hour intervals, producing eight individual back trajectories to examine the potential source regions influencing the site. Then those eight trajectories were clustered to four trajectories.

The HYSPLIT trajectory analysis revealed that the air masses influencing Deukhuri Dang during the pollution event were primarily transported from the western sector (Figure 50).

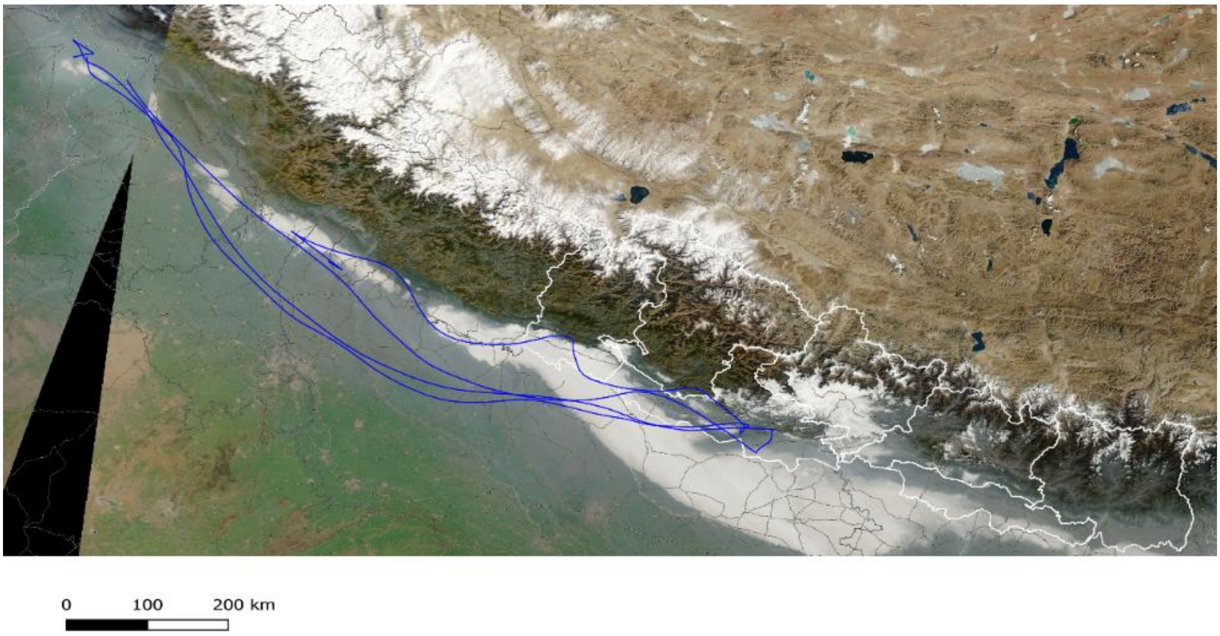


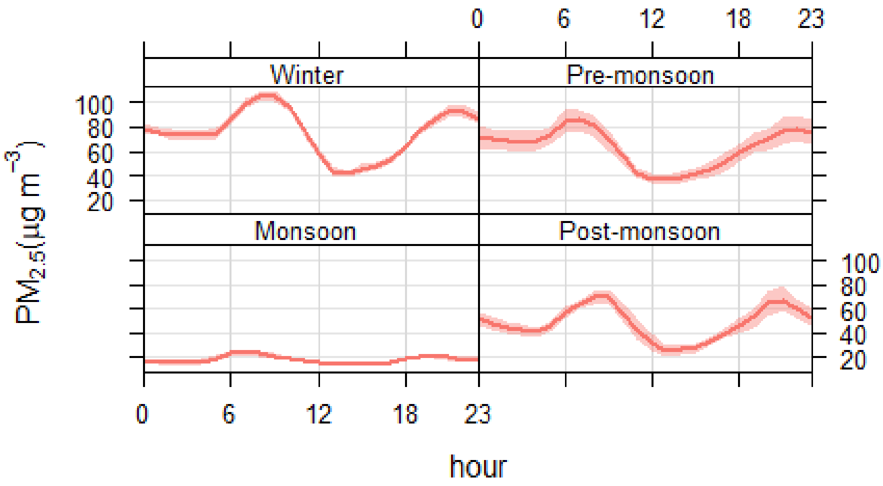
Figure 50: HYSPLIT back trajectories clusters (blue line) for Deukhuri Dang AQMS

2.4 DIURNAL PATTERN OF POLLUTION

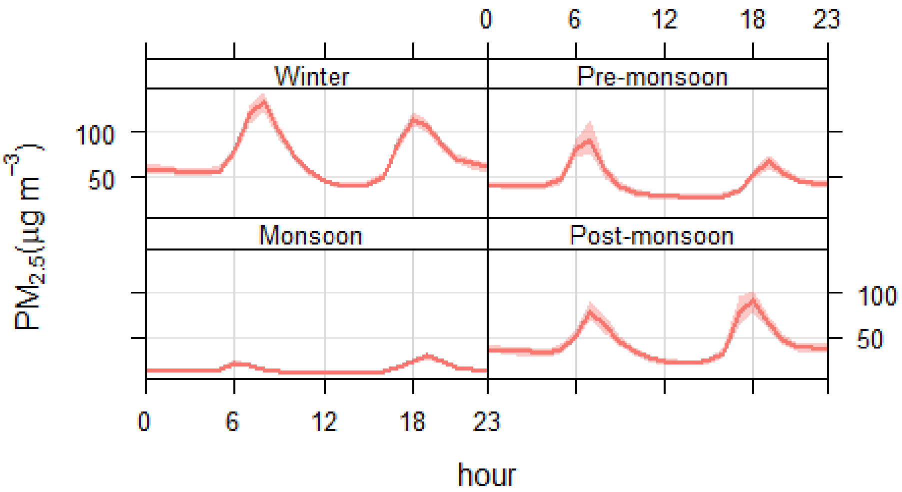
The seasonal diurnal variation of $PM_{2.5}$ observed at the Ratnapark and Deukhuri Dang monitoring stations shows broadly similar patterns, whereas the Achham AQMS exhibits a comparatively different profile (Figure 51). The variations in local emission sources and atmospheric conditions might have also contributed to differences in the diurnal behavior among the stations. During winter, Ratnapark and Deukhuri Dang stations showed a pronounced bimodal pattern with distinct morning and evening peaks. In contrast, the Achham AQMS displayed a relatively flatter diurnal profile with substantially lower concentration levels, possibly due to lower local emissions and more effective atmospheric dispersion.

During the pre-monsoon season, both Ratnapark and Deukhuri Dang stations showed reduced peak intensity along with a noticeable afternoon minimum. In the monsoon season, $PM_{2.5}$ concentrations remained consistently low with minimal diurnal variation across all stations, likely due to precipitation induced wet scavenging and enhanced atmospheric cleansing. During the post-monsoon period, Ratnapark and Deukhuri Dang again exhibit elevated morning and evening concentrations, which may be associated with increasing atmospheric stability and the influence of regional biomass burning events. Meanwhile, the Achham AQMS continued to show only modest diurnal variability.

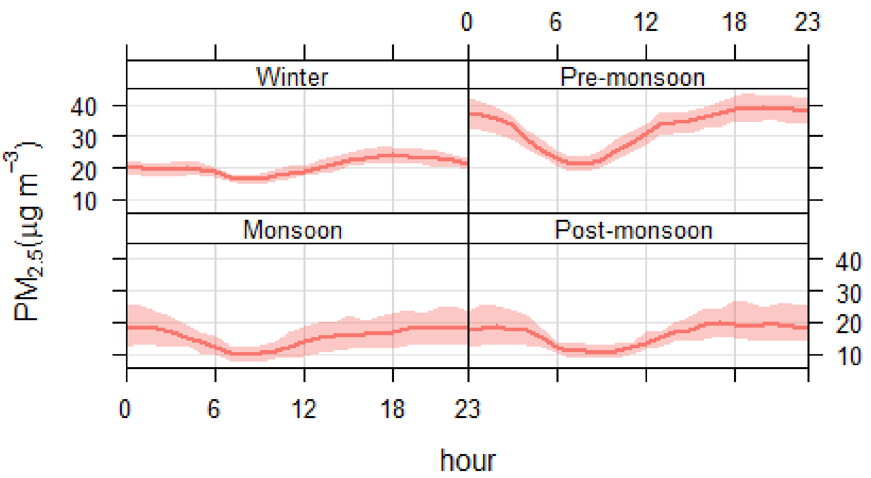
Although the seasonal behavior of $PM_{2.5}$ was generally consistent across the monitoring locations, significant inter-station differences were observed in concentration levels and diurnal amplitude. These variations highlighted the important role of local emission sources, topography, and micrometeorological conditions in influencing air quality. The findings emphasized the need for region-specific approaches in air quality assessment and management.



Ratnapark AQMS



Deukhuri AQMS



Achham AQMS

Figure 51: Seasonal and diurnal characteristics of $PM_{2.5}$ concentrations across different regions (the shaded part in the graph shows the 95% confidence interval)

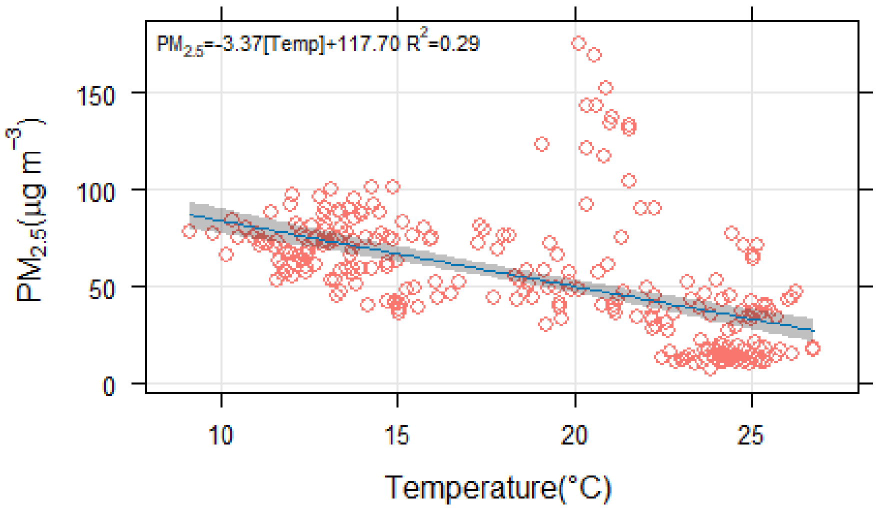
2.5 FACTORS AFFECTING AIR POLLUTION

2.5.1 Relationship with Temperature and Humidity

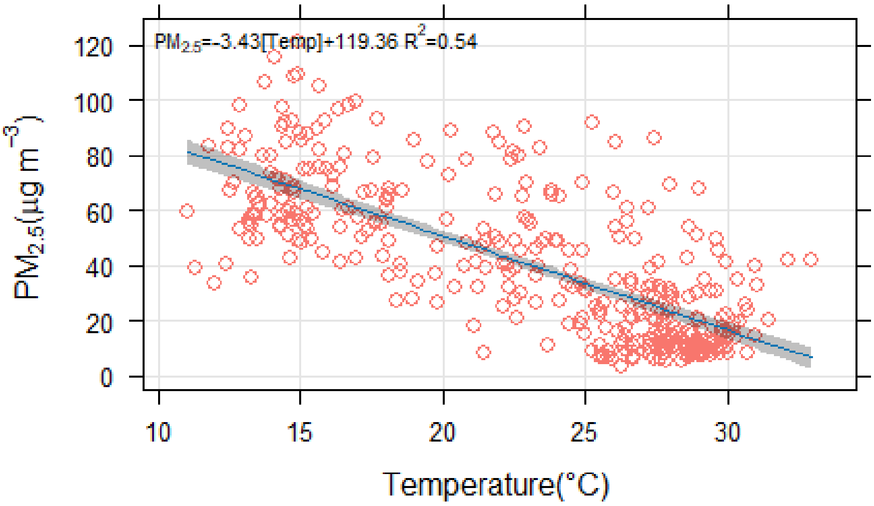
The influence of meteorological variables on $PM_{2.5}$ concentration exhibited notable variability across temporal scales and monitoring stations. At the hourly scale, simple linear regression model of $PM_{2.5}$ with atmospheric temperature showed a weak to moderate association at Ratnapark AQMS (R^2 = 0.30) and Deukhuri AQMS (R^2 = 0.33), while no relationship was observed at Achham ($R^2 \approx 0$). In contrast, relative humidity demonstrated negligible explanatory power across all three stations ($R^2 \leq 0.02$), suggesting that short-term $PM_{2.5}$ variability was not strongly governed by humidity alone (Figure 52).

At the daily scale, the linear regression model showed the more pronounced relationship between temperature with $PM_{2.5}$, at Deukhuri AQMS (R^2 = 0.54), indicating a weak to moderate influence. Whereas Ratnapark AQMS showed a similar but weaker relationship (R^2 = 0.29), while Achham AQMS again exhibited no meaningful association with temperature and weak relationship with relative humidity (R^2 = 0.19). Interestingly, relative humidity showed a substantial increase in explanatory power at daily level at Ratnapark AQMS (R^2 = 0.38), implying that humidity may have played a more important role in modulating day-to-day $PM_{2.5}$ variability, possibly through hygroscopic growth or secondary aerosol formation processes. However, its influence remained negligible at Deukhuri and Achham stations (Figure 52).

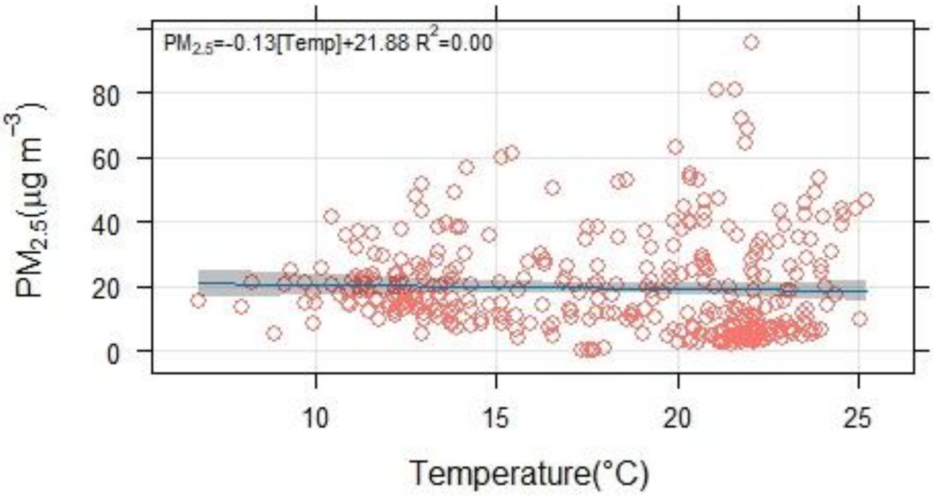
Temperature



Ratnapark AQMS

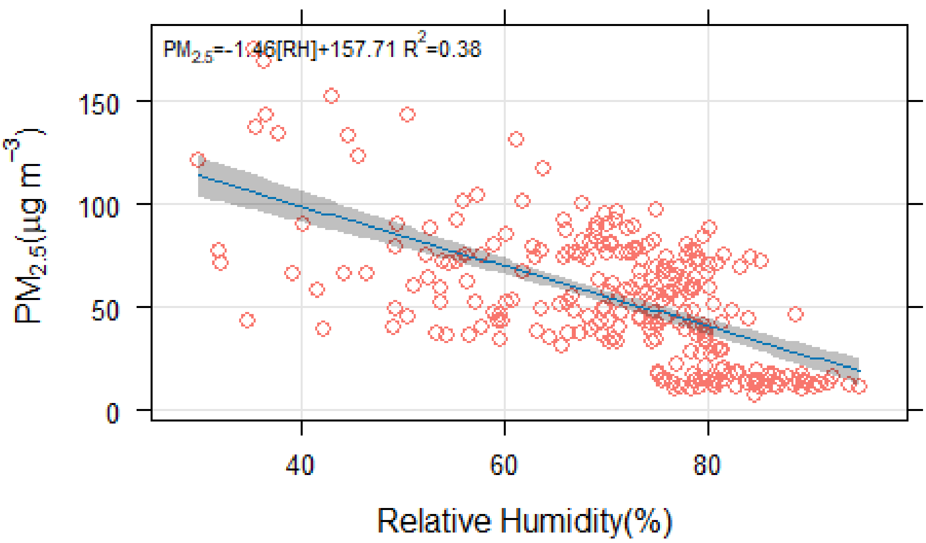


Deukhuri, Dang

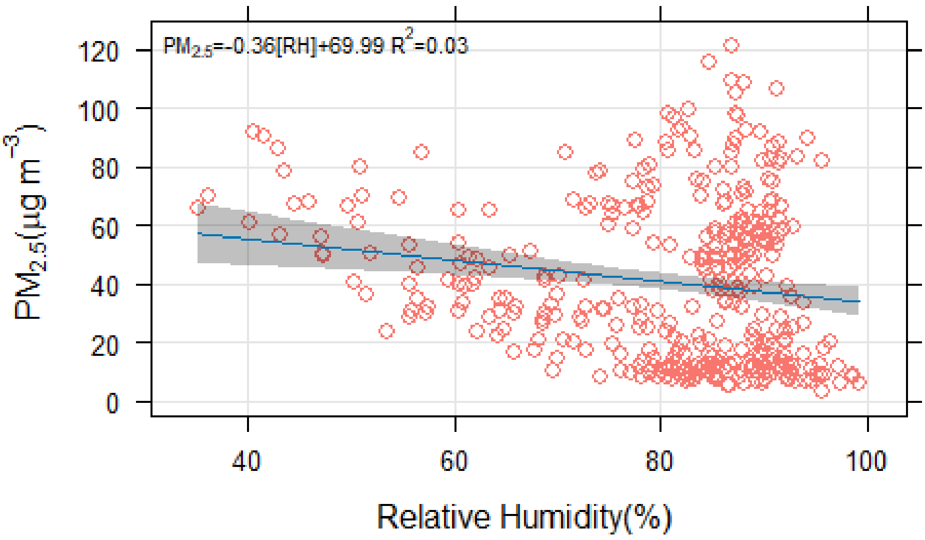


Achham AQMS

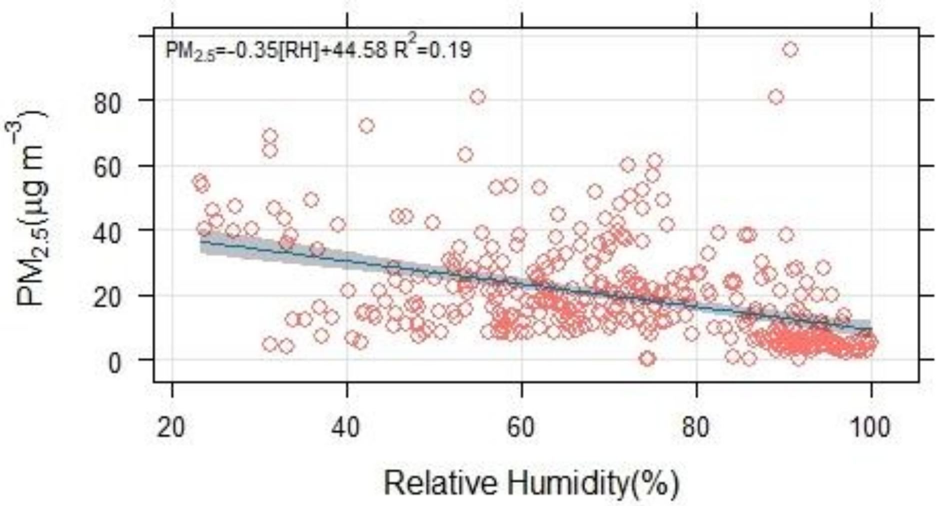
Relative Humidity



Ratnapark AQMS



Deukhuri, Dang



Achham AQMS

Figure 52: Relationship of Daily averaged $PM_{2.5}$ concentration with Temperature and Relative humidity

These results highlighted that (i) meteorological controls on $PM_{2.5}$ were scale-dependent, with stronger relationships emerging at daily aggregation, and (ii) spatial heterogeneity was significant, likely reflecting differences in emission sources, local meteorology, and atmospheric processes. The consistently negligible R^2 values at Achham AQMS suggest that $PM_{2.5}$ variability may have been dominated by non-meteorological factors such as local emissions or regional transport, which were not captured by simple linear relationships with temperature and humidity.

2.5.2 Satellite Observations

NO_2 and CO concentration over Nepal

Satellite imagery plays an important role in identifying air pollution sources and assessing their spatial distribution (Veefkind et al., 2012). Various satellite products were used to monitor pollutants such as NO_2, SO_2, CO, and $PM_{2.5}$, as well as to detect potential emission sources including industrial activities, vehicular emissions, forest fires, and biomass burning (Van Donkelaar et al., 2010). Satellite based observations also support the identification of pollution hotspots and the evaluation of transboundary air pollution conditions (Hammer et al., 2020).

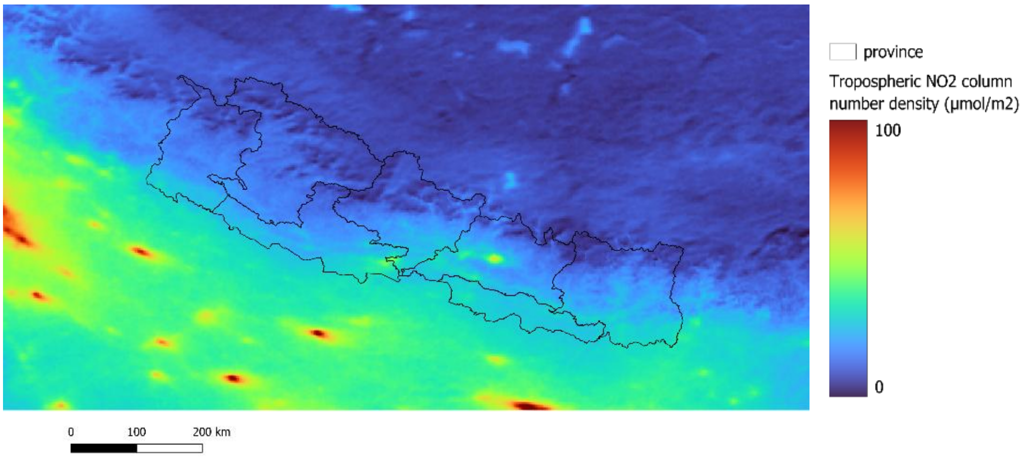


Figure 53: Annual mean tropospheric NO_2 Concentration in 2025

Nitrogen oxides (NO_x) are mainly produced from fossil fuel combustion associated with vehicular traffic and industrial processes along with biomass burning and wildfire events. Besides its direct impacts on human health, NO_2 also plays an important role in the formation of ground level ozone and fine particulate matter which is very harmful for human health (Fioletov et al., 2025; Huber et al., 2026). The annual mean tropospheric NO_2 concentrations were observed to be relatively high in areas with intensive economic and industrial activities (Figure 53). Elevated concentrations in 2025 were particularly evident in the Kathmandu Valley, likely associated with dense vehicular traffic, and in the Lumbini region, which may be influenced by industrial emissions.

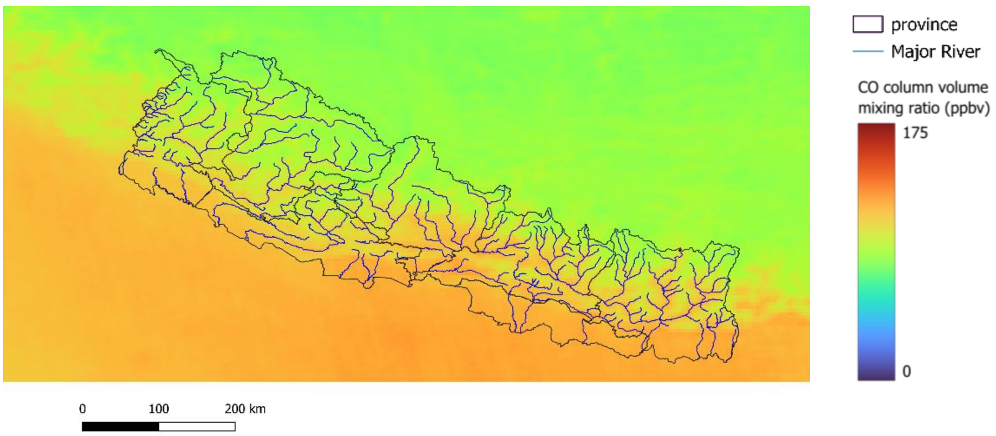


Figure 54: Annual mean CO Concentration in 2025

Carbon monoxide (CO) is a harmful gaseous pollutant that reduces the oxygen-carrying capacity of blood. Atmospheric CO concentrations vary spatially, and the gas generally remains in the atmosphere for approximately one month (Jalali et al., 2022). The major source of CO is the incomplete combustion of carbon containing fuels. Key emission sources include vehicular transport, industrial activities, fuel combustion, and household energy use. Forest fires and agricultural residue burning also contribute significantly to atmospheric CO levels (Tang et al., 2026).

The spatial distribution of annual CO concentrations in 2025 showed relatively higher levels across the southern, central, and eastern parts of Nepal, particularly in the Tarai and middle hill regions (Figure 54). In contrast, lower concentration was observed in the western hills and the northern Himalayan region. The Kathmandu Valley and surrounding areas also exhibited comparatively elevated CO levels, likely reflecting the influence of dense population, high vehicular activity, residential fuel use, and localized emission sources. In addition, terrain and valley meteorology might have enhanced pollutant accumulation and limited dispersion (Panday & Prinn, 2009; Islam et al., 2022). The observed tendency of higher concentrations aligning with river valleys further suggested the role of valley channeling effects, where river corridors guide airflow, concentrate emissions, and support along valley transport under complex wind and inversion conditions.

Lower CO concentrations in the western hills and Himalayan region may have been associated with reduced anthropogenic activity and lower population density. Overall, the spatial variability of CO across Nepal reflected the combined effects of emission intensity, land use patterns, and terrain-driven atmospheric dispersion processes.

Spatial variability of AOD

Aerosols are fine particulate matter suspended in the atmosphere, including urban haze, smoke, dust, and sea salt (Seinfeld et al., 1998). Aerosol Optical Depth (AOD) represents the integrated concentration of these particles in a vertical column of air from the Earth's surface to the top of the atmosphere (King et al., 1992). It is derived from the scattering and absorption of sunlight by aerosols. Lower AOD values (< 0.1) indicate clean atmospheric conditions with good visibility, while higher values reflect increased aerosol loading and reduced visibility. Very high AOD (> 3.0) indicates extremely dense aerosol conditions that can significantly obscure sunlight (NASA Earthdata, 2020). In general, higher AOD is associated with higher particulate pollution, especially $PM_{2.5}$ (Li et al., 2023). Figure 55 shows the spatial distribution of average annual AOD over Nepal and surrounding regions on a 0–1 scale for comparison.

In 2025, elevated levels of AOD were observed in the Tarai region of the country, with particularly high concentrations in the eastern Tarai (Figure 55). The emergence of the Tarai region as the pollution hotspot might be attributed to combine effect of both local and transboundary air pollution (Shrestha et al., 2026).

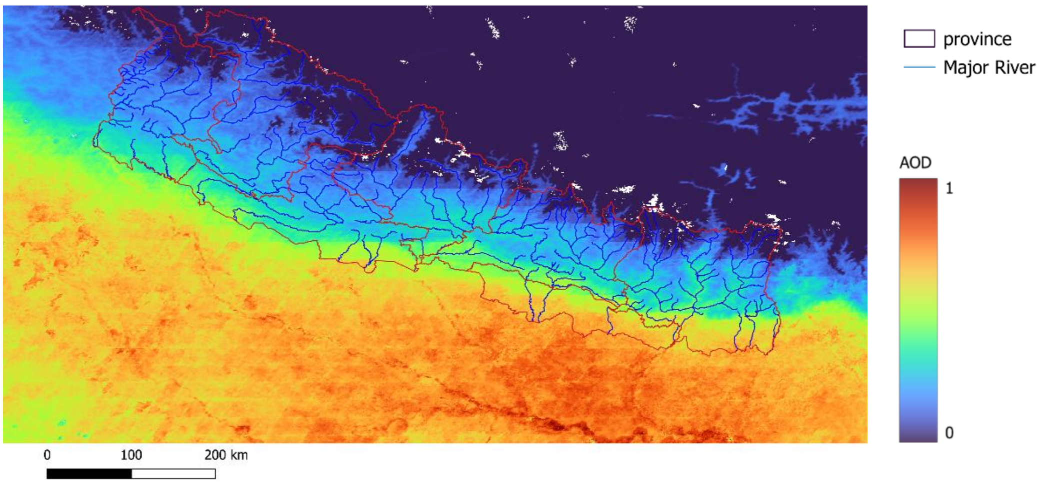


Figure 55: Annual mean AOD for 2025

Difference in mean annual AOD and CO between 2024 and 2025

Difference in mean annual AOD

The comparison of AOD between 2024 and 2025 showed a general reduction in aerosol loading over most parts of Nepal (Figure 56). The decrease was more evident in the central and southern regions, indicating improved atmospheric conditions. This reduction might have been linked to changes in emission intensity, precipitation scavenging, and variations in regional transport and meteorological conditions that enhanced dispersion (Hao et al., 2024; Adhikari & Regmi, 2025).

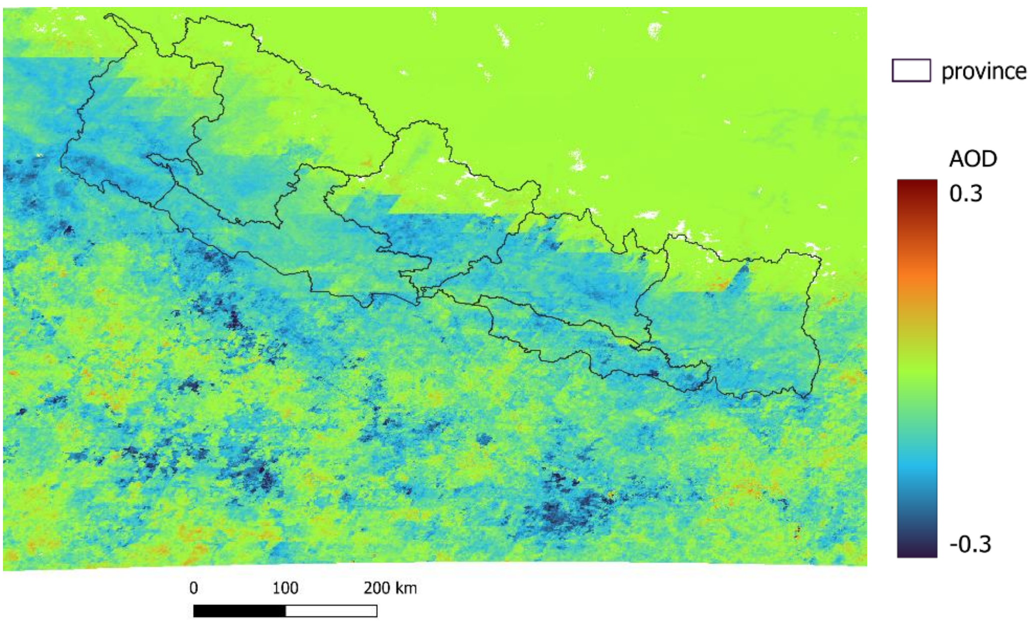


Figure 56: Difference in mean annual AOD between 2024 and 2025

Difference in mean annual CO

The comparison of CO concentrations between 2024 and 2025 showed an overall decreasing trend across most regions of Nepal (Figure 57). The reduction was more noticeable in urban and valley regions, suggesting a possible decline in combustion-related emissions or improved dispersion conditions. Variations in meteorological factors such as increased wind activity and boundary layer mixing may also have contributed to lower CO levels.

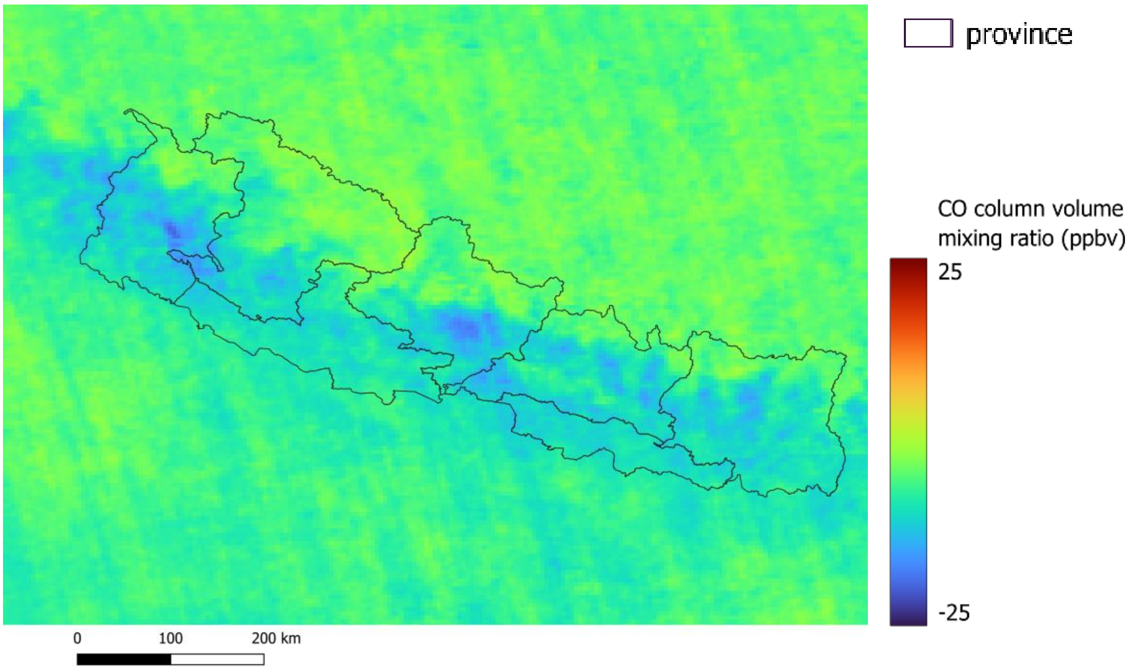


Figure 57: Difference in the mean annual CO in 2025 compared with 2024

2.6 FIRE EVENT AND AIR POLLUTION

NASA FIRMS (Fire Information for Resource Management System) utilizes satellite observations from the MODIS, VIIRS and Landsat instruments to detect active fires and thermal anomalies, delivering this information in near real-time. The fire event maps sourced from FIRMS, as presented in Annex 3, illustrated the spatial distribution and intensity of fire occurrences across the country and neighbouring region.

Satellite derived fire event data revealed a distinct seasonal pattern of fire activity across Nepal and neighbouring regions throughout the year. From January, fire events gradually intensified through February and March across Nepal. The fire season reached its peak during April. Satellite imagery showed the most widespread and intense fire events concentrated along the southern plains and mid-hills, coinciding with the hot and dry pre-monsoon season. Fire events in Nepal began to subside in May and significantly decreased from June to September due to the monsoon period. With the withdrawal of the monsoon, fire activity started to resume in October and continued to rise through November and December. During this period, fire events in Nepal were primarily recorded in the Tarai belt and western high mountain and Himalayan regions. The high number of fire events during March and April could be directly linked to elevated levels of air pollution observed during these months. Both forest fires and the burning of agricultural residue contributed significantly to air pollution emissions during this period.

The fire situation in neighbouring regions beyond Nepal presented a notably different scenario that has direct implications for Nepal's air quality. In the northern and north-western neighbouring region fire activity seems to be predominantly driven by large-scale agricultural practices rather than forest fires. Punjab and Haryana, in particular, are well known for intensive crop residue burning, which occurs on a massive scale following wheat and paddy harvest cycles. A forest fire dominated pattern was observed within Nepal during March to May, whereas fire events in the Indian region seems to be dominated by crop residue burning, were observed in April, May, and October to December, contributing to regional air pollution.

Emissions from fire events in Neighbouring region were transported eastward and north-eastward by prevailing winds, carrying smoke and fine particulate matter over hundreds of kilometres, which might have contributed to increased regional air pollution levels, including in Nepal. This transboundary movement of pollutants also increased the air pollution burden already imposed by domestic fire events within Nepal, resulting in persistently elevated concentrations of $PM_{2.5}$ and other harmful pollutants during both the pre-monsoon and post-monsoon periods. This dynamic pattern highlights the need for regional cooperation, coordinated monitoring frameworks, and joint air quality management strategies to effectively mitigate air pollution impacts across the region.

2.7 SUMMARY

The summary of analysis of data from fourteen real time AQMSs can be summarized in the Table 4 below:

Table 4: Summary Data

SN	Geographical region	Name of stations	Parameters	Daily average (µg m^{-3})			Annual Average (µg m^{-3})	Compliance status	
				Minimum	Maximum	Mean ± S. D.		Total days of valid measurement	Total days exceeding NAAQS
1	High mountain and Himalaya	Mustang	$PM_{2.5}$	1.9	66.4	17 ± 14.9	-	183	13
			PM_{10}	1.4	25.5	6.7 ± 4.9	-	183	0
			TSP	2.6	298.9	55.9 ± 54.5	-	183	2
2		Rara	$PM_{2.5}$	1.9	77.9	11.4 ± 12.6	-	192	9
			PM_{10}	2.3	104.2	16 ± 18.3	-	192	0
			TSP	2.8	169.8	25.7 ± 32.4	-	192	0
3	Middle mountain	Achham	$PM_{2.5}$	0.1	80.5	19.9 ±14.6	21.1	356	35
			PM_{10}	3.5	137.9	30.2 ± 25.9	32.0	347	4
			TSP	0.1	254.7	48.1 ± 49.1	51.6	356	1
4		Bhaisipati	$PM_{2.5}$	2.1	167.8	66.5 ± 36.5	-	88	72
			PM_{10}	3.3	240.1	113.5 ±58.2	-	88	47
			TSP	3.5	506.5	260.1 ±131.7	-	88	58
5		Bhaktapur	$PM_{2.5}$	5.4	184.4	43.5 ±34.0	46.7	335	154
			PM_{10}	7.8	380.7	78.2 ±70.2	85.1	335	70
6		Ilam	$PM_{2.5}$	3.2	185.1	32.1 ± 24.5	-	185	46
			PM_{10}	3.3	232.1	42.8 ± 33.9	-	180	8
			TSP	3.2	428.8	58.8 ± 54.7	-	185	4
7		Khumaltar	$PM_{2.5}$	4.6	169.0	38.1 ±28.2	37.0	344	140
			PM_{10}	6.5	260.7	63.9 ±50.0	62.3	344	49

SN	Geographical region	Name of stations	Parameters	Daily average (µg m^{-3})			Annual Average (µg m^{-3})	Compliance status	
				Minimum	Maximum	Mean ± S. D.		Total days of valid measurement	Total days exceeding NAAQS
8	Middle mountain	Ratnapark	$PM_{2.5}$	7.1	175.2	49.8 ±32.6	-	306	178
			PM_{10}	15.1	253.9	82.6 ±50.5	-	306	46
			TSP	21,5	407.0	143 ±82.5	-	306	35
9		Shankhapark	$PM_{2.5}$	7.1	175.0	45.6 ±32.5	46.7	351	176
			PM_{10}	8.8	306.7	83.4 ±65.5	85.9	351	88
			TSP	9.1	532.7	164.8 ±131.1	170.2	351	96
10	Tarai and Dun Valley	Bharatpur	$PM_{2.5}$	13.4	112.5	48.1 ± 22.0	-	118	65
			PM_{10}	23.9	142.1	69.1 ± 30.4	-	118	7
			TSP	41.5	241.3	115.4 ± 45.8	-	117	2
11		Deukhuri Dang	$PM_{2.5}$	3.2	121.4	40.8 ± 27.4	41.0	365	172
			PM_{10}	4.4	220.9	62.8 ± 45.5	63.2	365	50
			TSP	6.3	409.2	96.9 ± 80.1	97.5	365	29
12		Dhangadhi	$PM_{2.5}$	3.4	125.5	36.9 ± 30.9	-	269	89
			PM_{10}	4.1	270.8	64.9 ± 62.2	-	269	52
			TSP	4.6	351.8	100.5 ± 90.3	-	267	25
13		Hetauda	$PM_{2.5}$	3.4	90.6	20.9 ± 17.2	-	173	21
			PM_{10}	5.0	152.0	33.9 ± 28.0	-	173	2
			TSP	80.3	212.1	62.6 ± 51.9	-	173	0
14		Surkhet	$PM_{2.5}$	4.0	130.8	26.8 ± 18.1	-	255	56
			PM_{10}	4.9	184.5	39.9 ± 34.5	-	255	10
			TSP	5.4	338.9	56.7 ± 57.3	-	255	7

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2.8 ANNUAL AVERAGE

Based on data availability from the AQMSs. The annual average $PM_{2.5}$ concentration at each station was classified into three categories (Annex 4):

a. Stations with annual average $PM_{2.5}$ concentrations below the NAAQS annual standard of (25 µg m^{-3});
b. Stations with annual average $PM_{2.5}$ concentrations between the NAAQS annual standard (25 µg m^{-3}) and the 24-hour standard (40 µg m^{-3}) and
c. Stations with annual average $PM_{2.5}$ concentrations exceeding the 24-hour standard of (40 µg m^{-3}).

Among all stations, Achham in Sudurpashchim Province records the lowest concentration at 21.1 µg m^{-3}, placing it in the acceptable range below 25 µg m^{-3}. In contrast, Deukhuri, Dang in Lumbini Province registers 41.0 µg m^{-3}, crossing the critical threshold of 40 µg m^{-3}. The most severely polluted stations are concentrated in Bagamati Province, particularly within the Kathmandu Valley, where both Shankhapark and Bhaktapur record 46.7 µg m^{-3}, while Khumaltar shows a relatively lower but still moderate level of 37 µg m^{-3}.

It is also notable that several provinces including Karnali, Gandaki, Madhesh, and Koshi have no monitoring stations represented on the map, indicating significant data gaps that limit a comprehensive national assessment.

All monitored stations having annual average data except Achham exceed Nepal's national annual $PM_{2.5}$ standard of 25 µg m^{-3}, underscoring the urgent need for expanded monitoring and strengthened air quality management across the country.

In case of PM_{10}, out of five monitoring stations three stations meet the NAAQS for annual average concentrations. These include Achham, Deukhuri Dang, and Khumaltar stations. Among these, Khumaltar is located within the Kathmandu Valley and the other two stations are outside the Kathmandu Valley. Among them two stations within Kathmandu valley, Shankhapark and Bhaktapur exceeded the annual standard.

CHAPTER 3: CONCLUSION

In this report, air quality data from fourteen Air Quality Monitoring Stations (AQMSs) across Nepal were analyzed based on data availability, revealing significant spatial and temporal variations in pollution levels across the country. The AQMSs were grouped according to the physiographic zones of Nepal: high mountain and Himalayan region, the middle mountain region, and the Tarai and Dun Valley region. The high mountain and Himalayan region includes the Rara and Mustang stations. The middle mountain region was further subdivided into Kathmandu Valley stations (Bhaisipati, Bhaktapur, Khumaltar, Ratnapark, and Shankhapark) and other stations (Achham and Ilam). The Tarai and Dun Valley region includes Bharatpur, Deukhuri Dang, Dhangadhi, Hetauda, and Surkhet stations.

In the high mountain and Himalayan region, both Mustang and Rara stations recorded their lowest concentrations during the monsoon months of July to August. Despite their remote, high-altitude locations, Mustang exceeded the NAAQS) 24-hour $PM_{2.5}$ limit on 7.1% of monitored days, while Rara exceeded the same limit on 4.7% of monitored days, based on available data. For PM_{10}, daily concentrations at both stations remained within the NAAQS 24-hour limit throughout the monitoring period.

In the Kathmandu Valley cluster of the middle mountain region, data availability ranged from 88 days at Bhaisipati to 351 days at Shankhapark. Monthly average concentrations of particulate matter at all five stations exhibited a consistent seasonal pattern, with peaks during January to April and lowest values during July to August, indicating strong influence from both meteorological conditions and emission sources within the valley. Among these stations, Shankhapark, which had the highest data availability, recorded exceedances of the NAAQS 24-hour limits for $PM_{2.5}$ on 50.1% of monitored days, while exceedances for PM_{10} and TSP were 20.9% and 27.4%, respectively.

At stations outside the Kathmandu Valley in the middle mountain region (Achham and Ilam), $PM_{2.5}$ concentrations followed a similar seasonal pattern during the overlapping observation period (January to May), with both stations peaking in April. At Achham, where full annual data were available, exceedances of the NAAQS 24-hour limit for $PM_{2.5}$ and PM_{10} were 9.8% and 1.2% of monitored days respectively.

In the Tarai and Dun Valley region, data availability ranged from 118 days at Bharatpur to 365 days at Deukhuri Dang. Monthly average $PM_{2.5}$ concentrations across all stations were highest during the winter and pre-monsoon seasons, with Deukhuri Dang and Dhangadhi recording peak values in January and February. All stations recorded their lowest concentrations during July to September. At Deukhuri Dang AQMS, where full annual data were available, percent of days exceedance of the NAAQS 24-hour limits were 33.1% for $PM_{2.5}$, 13.7% for PM_{10}, and 7.9% for TSP.

Seasonal analysis indicates that winter and pre-monsoon periods were the most polluted seasons in Nepal. During winter, elevated pollution levels were primarily driven by unfavorable meteorological conditions and temperature inversions that trap pollutants near the surface. During the pre-monsoon season, high pollution levels can largely be attributed to forest fire emissions, as confirmed by satellite-based fire observations (NASA FIRM), which show peak fire activity in April, as well as strong transboundary transport of pollutants from neighboring regions.

This transboundary influence was further supported by HYSPLIT back trajectory analysis of selected stations during high pollution episodes, highlighting the contribution of regional transport pathways and underscoring the need for coordinated and time sensitive control measures. Spatial analysis using both satellite and ground based observations indicates elevated aerosol loading and pronounced CO hotspots, particularly in the eastern Tarai and Kathmandu Valley. Higher tropospheric NO_2 levels observed from satellite data over the Kathmandu Valley, compared to other parts of the country, indicate strong vehicular emission sources in the region. These pollution patterns persist during both winter, pre-monsoon and post monsoon seasons, driven by a combination of local emissions and regional transport. In contrast, the western hills and Himalayan regions of the country generally exhibit lower pollution levels due to reduced emissions and more favorable atmospheric dispersion conditions. At the same time, reductions in annual mean AOD and CO concentrations derived from satellite observations indicated that air quality generally improved across Nepal in 2025 compared to 2024, with the most notable improvements occurring in urban, valley, and southern part of the country.

The findings of this study have important implications for air quality management in Nepal. Persistently high concentrations of $PM_{2.5}$, CO, and aerosol loading in the Kathmandu Valley and Tarai and Dun Valleys, both of which are densely populated regions, indicate substantial anthropogenic emissions, particularly from vehicular traffic, industrial activities, and other urban sources. $PM_{2.5}$ remains a critical air quality concern nationwide, with four out of five stations exceeding the national annual standard of 25 $\mu g\ m^{-3}$, and only Achham meeting the limit. The highest concentrations were consistently observed in the Kathmandu Valley. For PM_{10}, results showed mixed compliance, with three stations meeting the NAAQS, including Khumaltar within the Kathmandu Valley, while Shankhapark and Bhaktapur exceed the standard, indicating persistently higher particulate pollution in the valley.

Therefore, air quality management strategies should prioritize the Kathmandu Valley and Tarai and Dun Valleys through strengthened vehicle emission standards, promotion of cleaner fuels, control of biomass burning, and stricter regulation of industrial emissions. Action plans targeting winter and pre-monsoon pollution episodes are essential for reducing peak concentrations. In addition, enhanced regional cooperation with neighboring countries is crucial for addressing transboundary air pollution. Finally, integrating satellite observations, atmospheric model outputs, and ground-based monitoring, along with enforcement linked reporting mechanisms, will support more effective, evidence based air quality management and policy implementation in Nepal.

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ANNEX 1: COMPOSITION OF TECHNICAL COMMITTEE, 2025

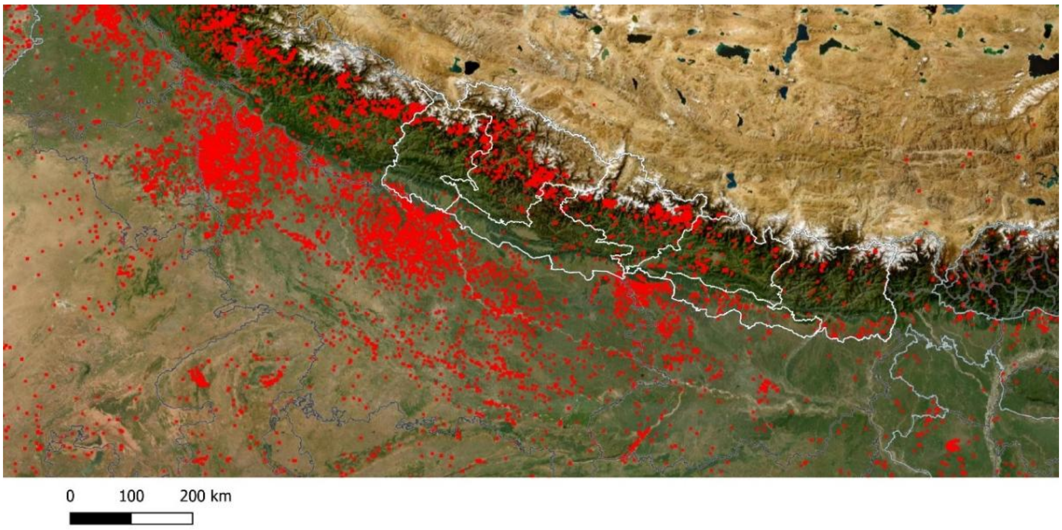
SN	Name	Organization	Designation
1	Mr. Saroj Kumar Chaudhary, Deputy Director General	Department of Environment	Coordinator
2	Mr. Kanchan Kumar Nayak, Senior Divisional Chemist	Department of Environment	Member
3	Dr. Kundan Lal Shrestha, Professor	Kathmandu University	Member
4	Dr. Ramesh Prasad Sapkota, Professor	Tribhuvan University, Central Department of Environmental Science	Member
5	Mr. Keshab Raj Joshi, Environment Inspector	Ministry of Agriculture, Forests and Environment	Member
6	Mr. Sudarshan Humagain, Meteorologist	Department of Hydrology and Meteorology	Member
7	Mr. Suresh Pokhrel, Air Pollution (Observation) Analyst	ICIMOD	Member
8	Mr. Govinda Prasad Lamichhane, Environment Inspector	Department of Environment	Member
9	Mr. Prakash KC, Environment Inspector	Department of Environment	Member
10	Mr. Sameer Panthi, Account Officer	Department of Environment	Member
11	Ms. Nabina Maharjan, Environment Inspector	Department of Environment	Member Secretary

ANNEX 2: LIST OF EXPERTS CONTRIBUTED AND REVIEWED IN THE REPORT

Following are list of experts beside the members of the data analysis committee, who reviewed the report and gave valuable feedbacks.

SN	Name of Expert	Organization
1	Ms. Bina Ghimire, Assistant Professor	Trichandra College
2	Dr. Amrit Sharma, Assistat Professor,	Patan Multiple College
3	Dr. Rajesh Poudyal	Expert
4	Mr. Niroj Timalsina	Sunakhari Research Consult Pvt. Ltd.
5	Dr. Nosan Bhattarai	Expert
6	Mr. Sabit Desar, Environment Inspector	Department of Environment
7	Ms. Arati Shrestha, Environment Inspector	
8	Ms. Manisha Ghimire, Environment Inspector	
9	Ms. Sadikshya Osti, Environment Inspector	
10	Ms. Swasti Shrestha, Environment Inspector	
11	Ms. Pradipika Acharya, Chemist	
12	Ms. Hasana Shrestha, Environment Inspector	

ANNEX 3: FOREST FIRE EVENTS



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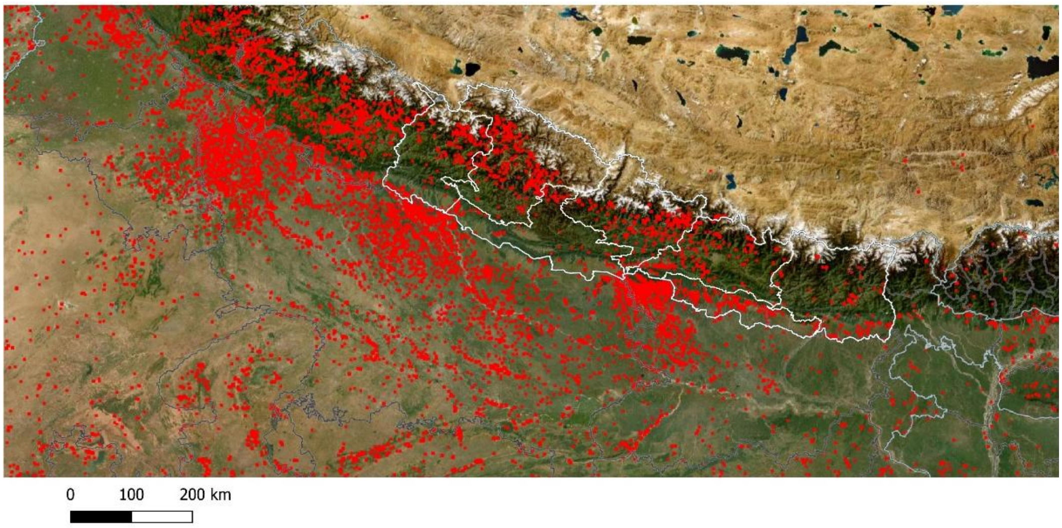

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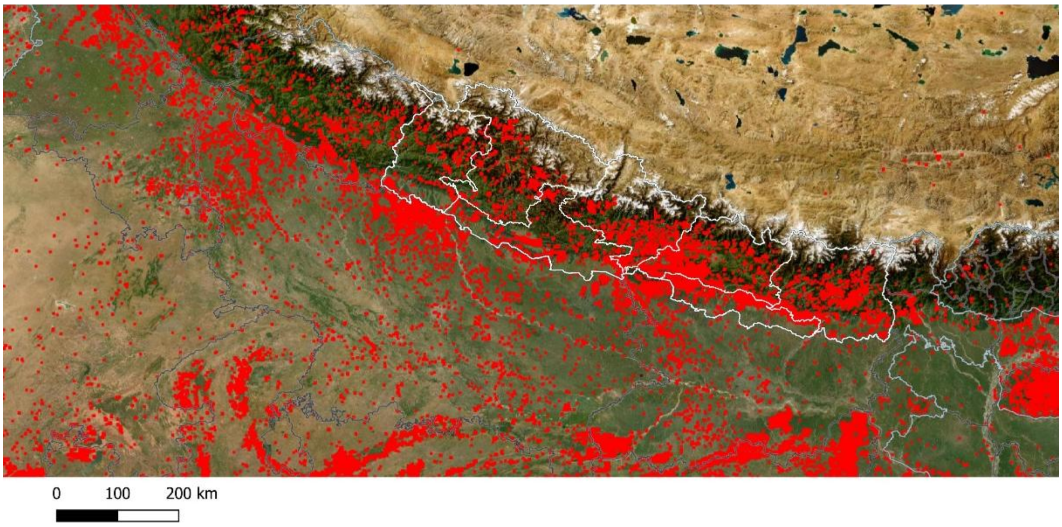

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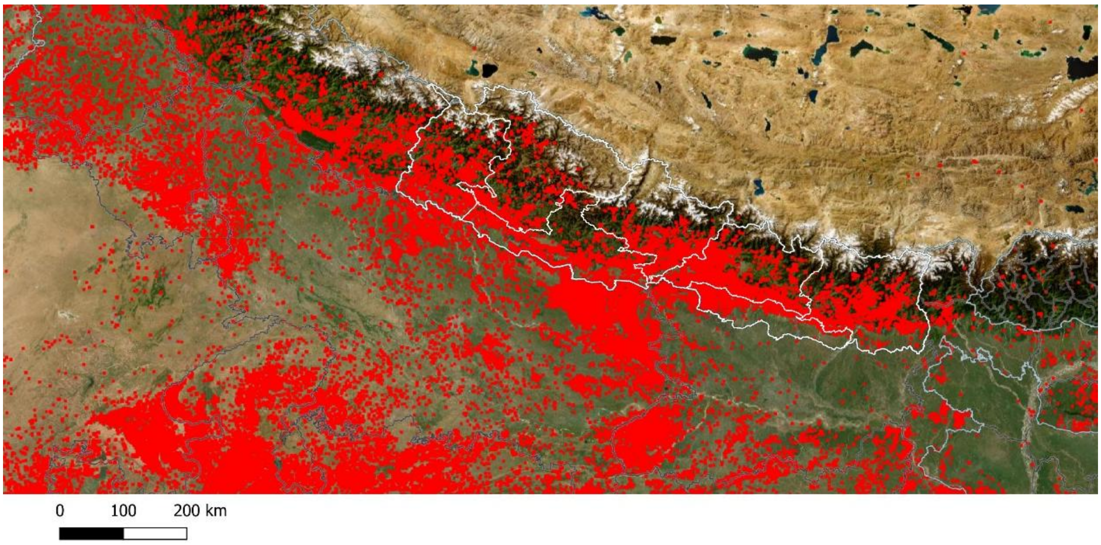

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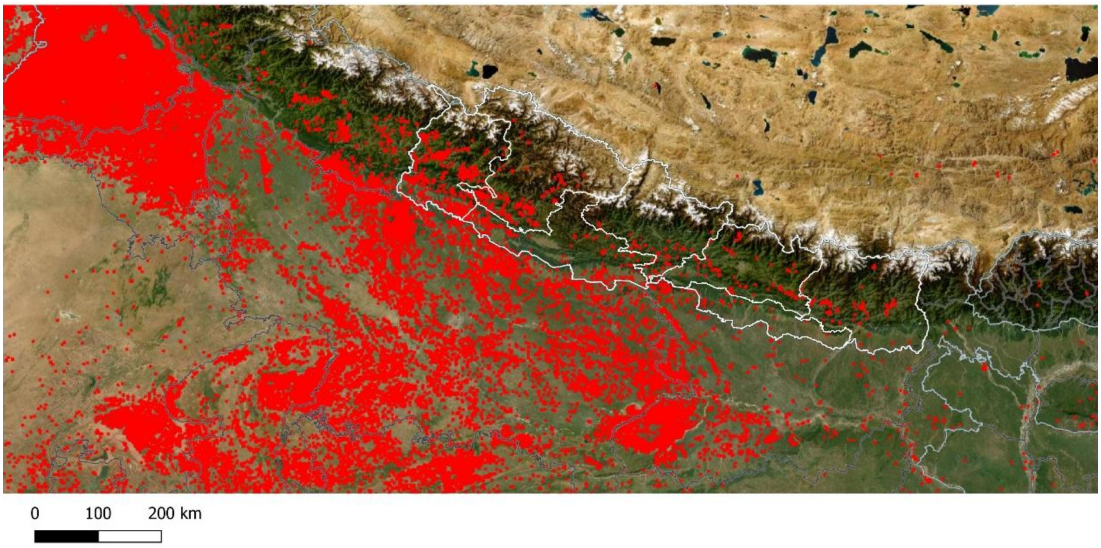

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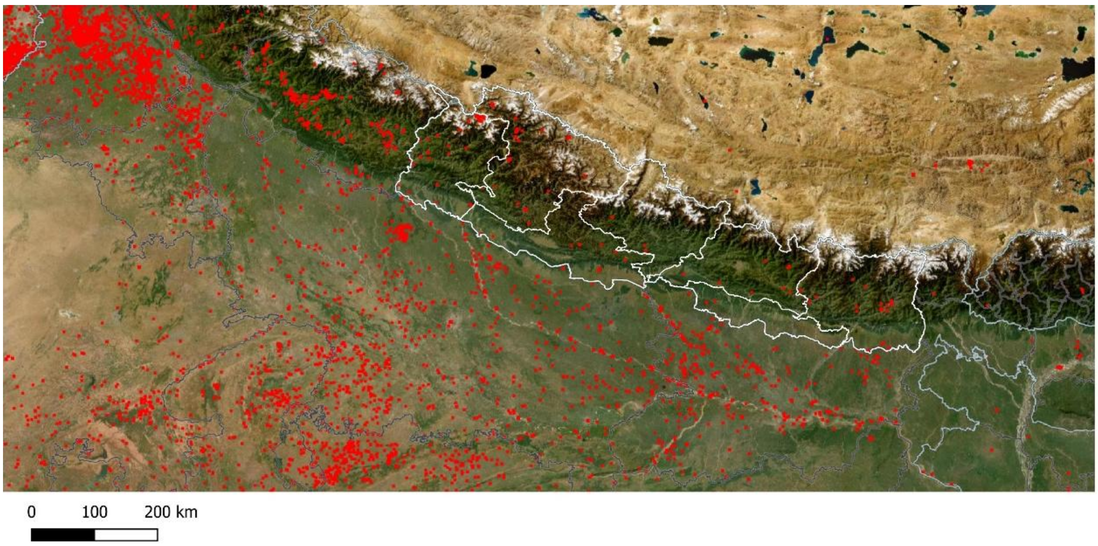

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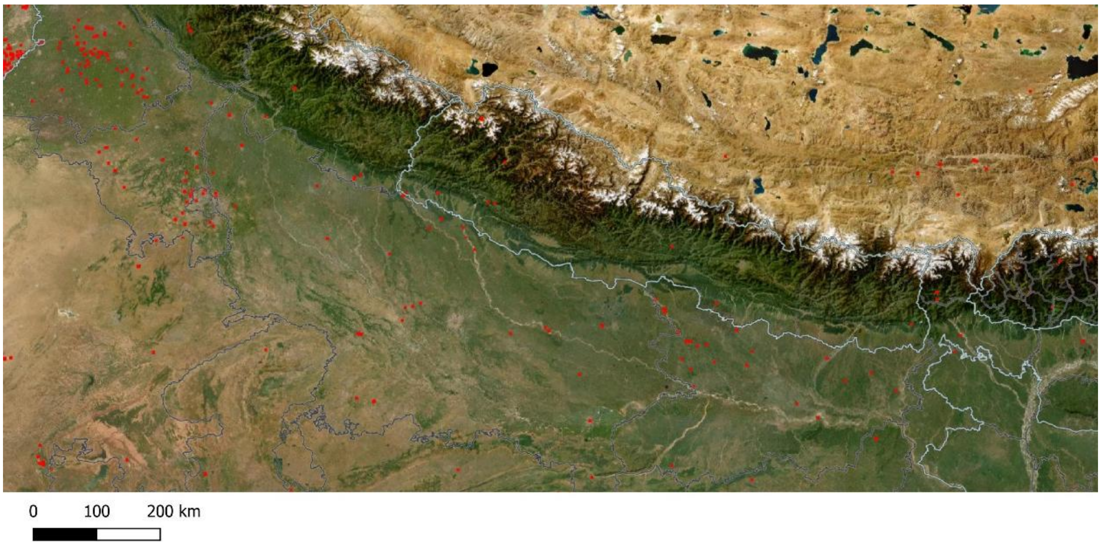

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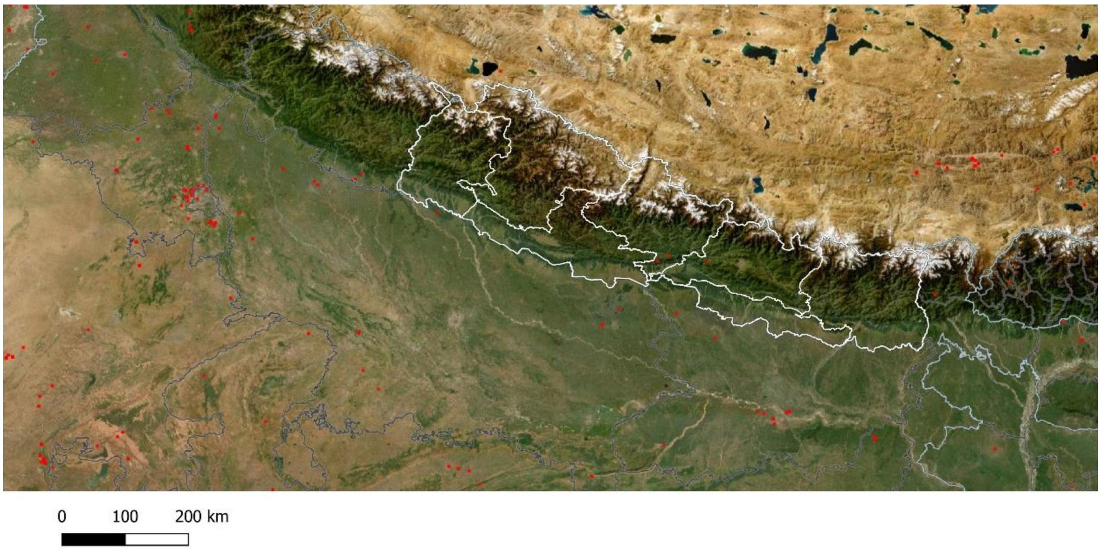

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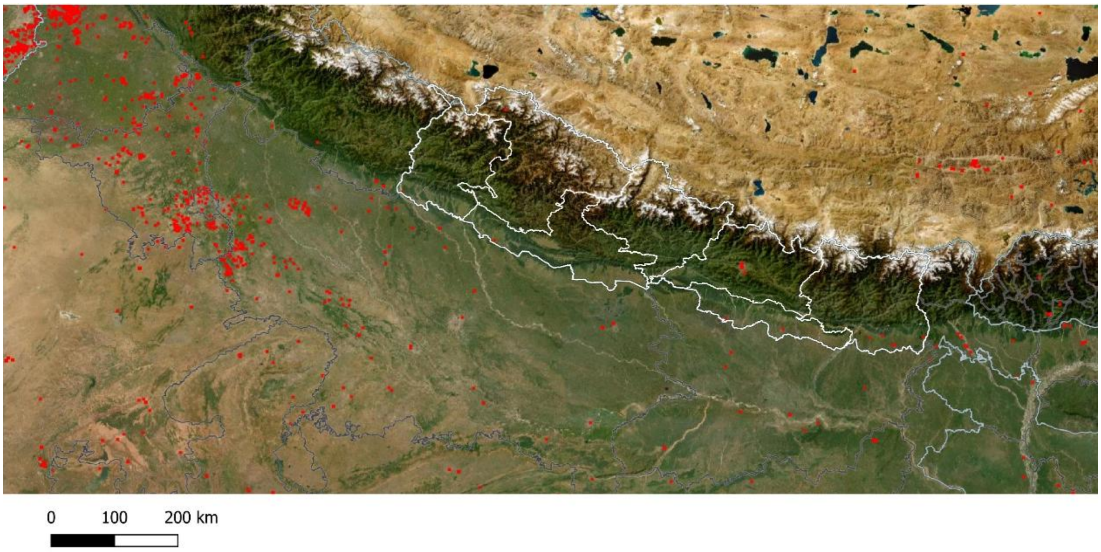

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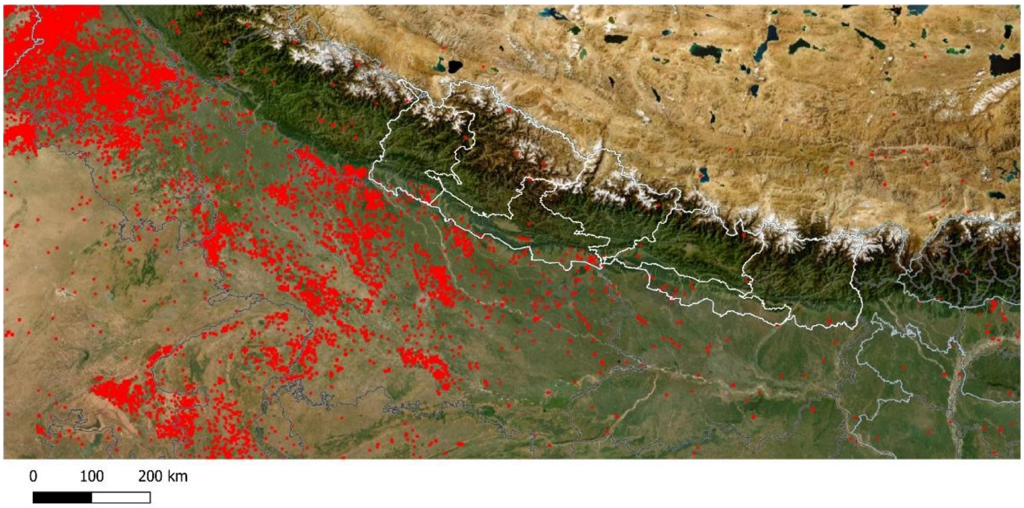

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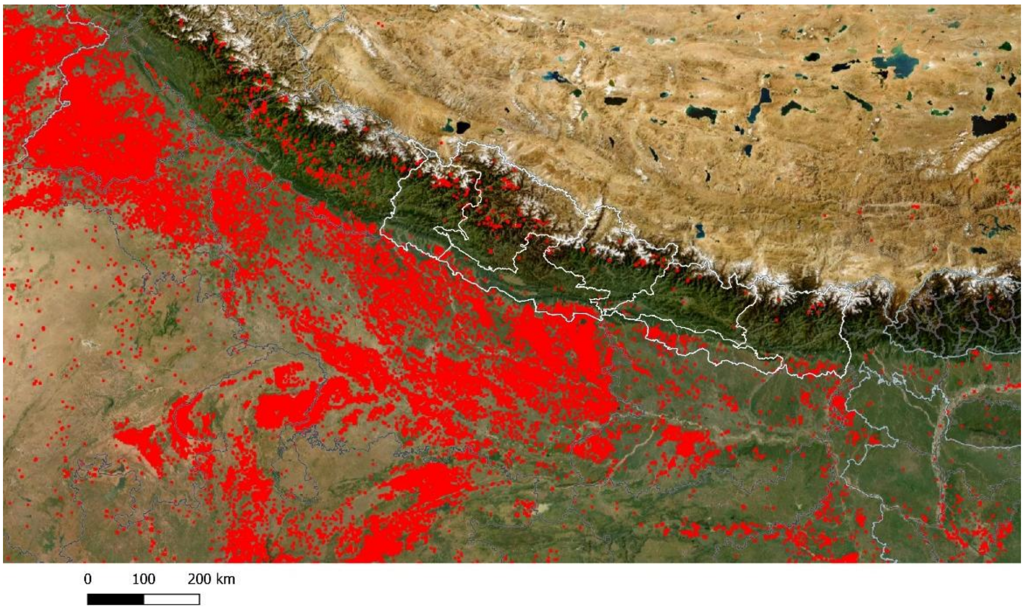

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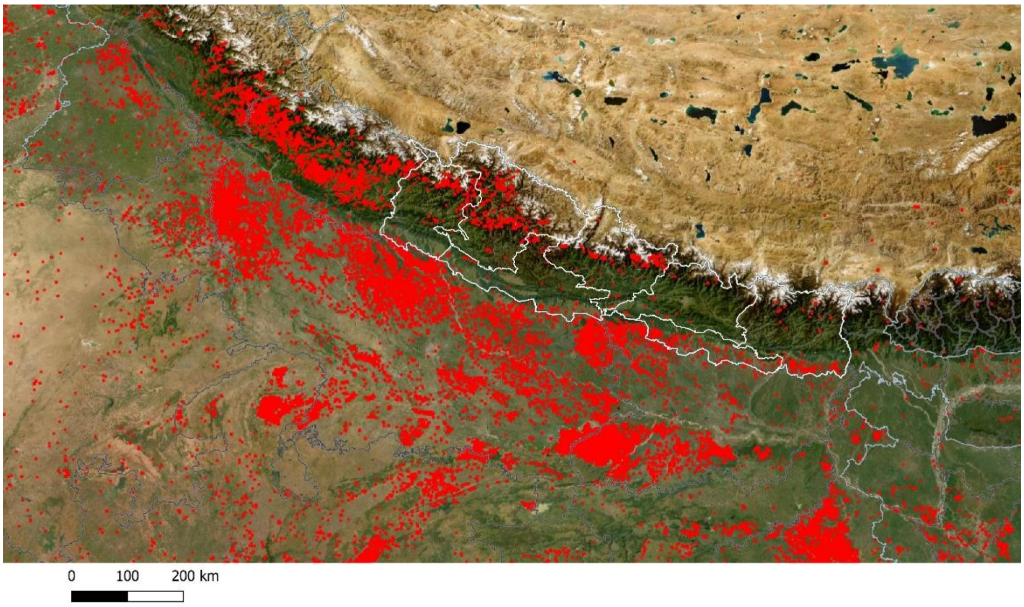

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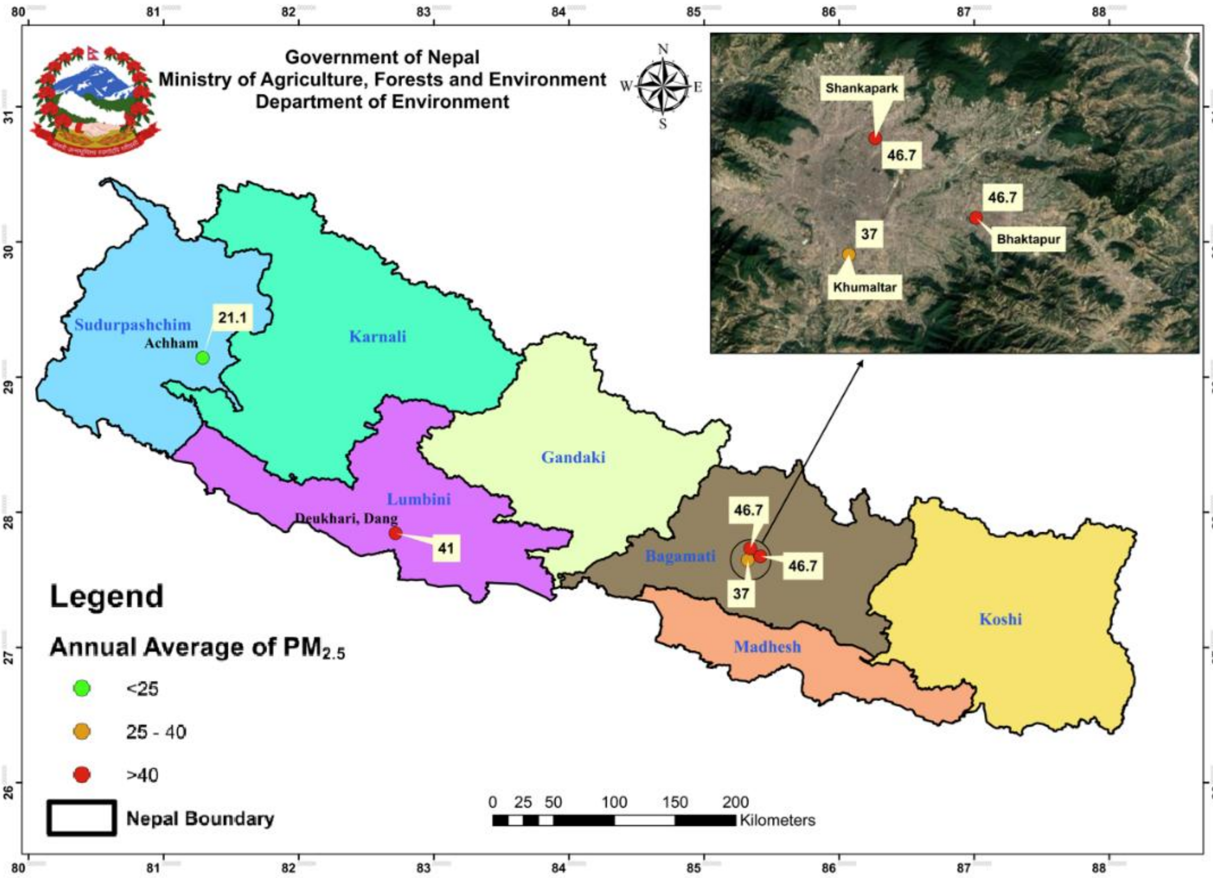
ANNEX 4: ANNUAL AVERAGE OF $PM_{2.5}$



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