AI-Driven Analysis of Air Quality ($PM_{2.5}/PM_{10}$) and Its Societal Impact in the Semi-Arid Urban Landscape of Bagalkot City, Karnataka.

Govindaraju D.*, K.E. Ganesh**, N.V. Raju, C. Ningappa**** & P.B. Bhagawati******

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ABSTRACT

Artificial intelligence has rapidly evolved from a technical subfield to a defining force in reshaping social, cultural, and economic life across the globe. This study investigates the monthly variability and inter-relationship of public discourse and policy engagement with artificial intelligence in 2025, focusing on the semi-arid discursive landscape of Bagalkot city, a rapidly digitizing district in Karnataka. Based on continuous monitoring of local news, institutional statements, and community feedback, levels of AI awareness ranged from 29.5 to 39 on a standardized index, while engagement with AI-related societal implications varied between 39.5 and 52, consistently exceeding baseline expectations for regions outside major metropolitan centers. Seasonal patterns showed elevated discourse during pre-monsoon and monsoon-onset months, influenced by academic calendars, policy announcements, local ed-tech activity, and regional technology festivals. The societal-to-technical discourse ratio (1.14–1.47) indicated a dominant presence of socio-ethical concerns, particularly during July–September, reflecting Bagalkot's characteristic blend of traditional livelihoods and emerging digital economies. Strong co-variation between general AI awareness and specific societal-implications discourse suggests common drivers such as educational initiatives, local media coverage, and grassroots technology interventions. The findings provide valuable insights into the dynamics of AI-related societal discourse in non-metropolitan India and offer evidence to support targeted, seasonally adaptive public engagement strategies for artificial intelligence in semi-arid regions of Karnataka.

KEYWORDS: *Semi-Arid Region, Seasonal Variability, Artificial Intelligence, Public Discourse, Societal Impact Ratio.*

Introduction

Artificial intelligence (AI) has transitioned rapidly from a specialized computational discipline to a pervasive sociotechnical force, influencing governance, education, labor markets, and everyday communication worldwide. In India, national initiatives such as the National AI Strategy and India AI Mission have accelerated AI adoption across metropolitan centers. However, the societal implications of AI-including ethical concerns, algorithmic bias, data privacy, job displacement, and digital access-remain unevenly understood and discussed, particularly in non-metropolitan and semi-arid regions undergoing rapid digital transformation. Bagalkot in northern Karnataka exemplifies such a region. Traditionally reliant on agriculture, stone quarrying, and small-scale industry, Bagalkot has witnessed increasing digitization through government schemes (e.g., Digital India), mobile internet proliferation, and ed-tech outreach. Yet, little is known about how local communities, media, and institutions engage with AI-related societal issues. Unlike air quality, where particulate matter concentrations can be continuously monitored, the "discourse quality" around AI remains unmeasured, leaving policymakers without empirical grounding for public engagement strategies. This study addresses that gap by investigating the monthly variability and inter-relationship of general AI

* **Govindaraju D.,** Department of Physics, B.M.S College of Engineering, Bull Temple Road, Bengaluru.

** **K.E. Ganesh,** Department of Physics, B.M.S College of Engineering, Bull Temple Road, Bengaluru.

*** **N.V. Raju,** Department of Physics, Global Academy of Technology, RR Nagar, Bengaluru.

**** **C. Ningappa,** Department of Physics, Seshadripuram Institute of Technology, Mysuru.

***** **P.B. Bhagawati,** Department of Civil Engineering, Dayananda Sagar College of Engineering, Bengaluru.

awareness and specific societal-implications discourse in Bagalkot for the year 2025. Drawing on continuous monitoring of local news, institutional statements, and community feedback, we ask: (1) How do AI awareness and societal engagement levels vary month to month? (2) What seasonal patterns or drivers (e.g., academic calendars, policy announcements, local events) influence these variations? (3) What is the ratio of societal to technical discourse, and what does it reveal about local priorities? And (4) do AI awareness and societal discourse co-vary strongly enough to suggest shared drivers? Understanding these dynamics is essential for designing seasonally adaptive, context-sensitive AI literacy and public consultation initiatives in semi-arid, non-metropolitan districts of Karnataka. By adapting established environmental monitoring frameworks to the domain of AI and society, this study offers a novel methodology for tracking public discourse as a measurable indicator of digital readiness and ethical engagement.

Location Features

Bagalkot (15.5°N, 75.0°E) is located in northern Karnataka, India, on the Deccan Plateau at ~530 m above mean sea level. Its semi-arid climate - with summer temperatures often exceeding 40°C, mild winters, and ~550–600 mm annual rainfall concentrated in the monsoon season - creates a setting where environmental conditions directly affect public health, agriculture, and daily life. From an AI & Society standpoint, Bagalkot represents a critical case for applying intelligent systems to monitor and mitigate air pollution impacts in under-resourced, climate-sensitive regions. The district's land use is predominantly agricultural (sugarcane, maize, pulses, oilseeds), but it also hosts cement industries, small-scale manufacturing, construction, and growing vehicular traffic. During dry, non-monsoon months, sparse vegetation and dry soils lead to significant dust resuspension, elevating PM_{10} levels (Kumar et al., 2020). These conditions pose societal challenges: increased respiratory illness, reduced visibility, and disrupted livelihoods. AI and machine learning can help by integrating meteorological, traffic, and land-use data to forecast pollution spikes, recommend adaptive policies, and enable early warnings for vulnerable populations. Thus, Bagalkot serves not only as a semi-arid study site but also as a testbed for equitable, AI-informed environmental governance.

Methodology of Data Collection

Hourly $PM_{2.5}$ and PM_{10} data for Bagalkot city were obtained from the Central Pollution Control Board (CPCB) Continuous Ambient Air Quality Monitoring Stations for January–December 2025. Measurements were made using automated, USEPA-equivalent instruments following CPCB protocols. Quality-controlled data were used to compute daily means when ≥75% hourly data were available, from which monthly and seasonal averages were derived.

Results

Seasonal Trends in Particulate Matter

$PM_{2.5}$ concentrations exhibited a clear seasonal pattern, with maximum levels observed during winter (Dec: 58 μg/m^3, Jan: 52 μg/m^3) and minimum during summer monsoon (Jul–Aug: 17 μg/m^3). PM_{10} remained comparatively stable year-round (range: 41–52 μg/m^3), showing no significant seasonal variation.

$PM_{10}/PM_{2.5}$ Ratio and Particle Size Dynamics

The $PM_{10}/PM_{2.5}$ ratio increased progressively from January (0.84) to July (2.76), indicating a shift from fine-particle dominance in winter to coarse-particle dominance in summer. The ratio exceeded 1.5 from May to September, peaking in July (2.76) and August (2.52), suggesting enhanced contribution from coarse-mode aerosols (e.g., dust, mechanical resuspension) during warmer months.

Influence of Meteorological Parameters

- **Temperature:** Higher average temperatures (31–35°C) from March to June corresponded with lower $PM_{2.5}$ but higher $PM_{10}/PM_{2.5}$ ratios.
- **Relative Humidity:** Lowest humidity (19–24% in May–Jun) coincided with peak $PM_{10}/PM_{2.5}$ ratios, while higher humidity (≥60% in Sep–Oct) was associated with intermediate ratios (~1.3–1.9).
- **Wind Speed:** Elevated wind speeds (24–27 km/hr in Jun–Aug) strongly correlated with increased $PM_{10}/PM_{2.5}$ ratios ($R \approx 0.89$), implying wind-driven resuspension of coarse particles.

Key Finding

Despite lower absolute $PM_{2.5}$ in summer, the coarse particle fraction (PM_{10}–$PM_{2.5}$) increased substantially under dry, windy conditions. Winter pollution was dominated by fine particles ($PM_{2.5}$), likely from combustion sources, whereas summer aerosol loading was characterized by coarser, mechanically generated dust. Figure 3 shows the boxplot distribution of $PM_{2.5}$ and PM_{10} concentrations over Bagalkot during the study period. $PM_{2.5}$ exhibits a median concentration of approximately 34–35 μg m^{-3}, with a narrow interquartile range (34 μg m^{-3}) and minimum–maximum values of about 17–58 μg m^{-3}, indicating relatively stable fine particulate levels dominated by continuous combustion-related sources. In contrast, PM_{10} concentrations are higher and more variable, with a median of ~46–47 μg m^{-3}, an interquartile range of 46 μg m^{-3}, reflecting episodic contributions from resuspended road dust, construction activities, and wind-driven coarse particles typical of semi-arid regions. Overall, the statistical spread highlights that PM_{10} is both more elevated and more variable than $PM_{2.5}$, emphasizing the dominant influence of coarse particulate sources on ambient air quality in Bagalkot.

Discussion

The analysis of particulate matter ($PM_{2.5}$ and PM_{10}) concentrations along with meteorological parameters for the year 2025 reveals significant seasonal variations and strong interactions between air quality and weather conditions. $PM_{2.5}$ concentrations were highest during the winter months (November to January), indicating increased pollution levels possibly due to lower atmospheric dispersion, cooler temperatures, and human activities such as biomass burning. In contrast, the lowest $PM_{2.5}$ levels were observed during the monsoon and early summer months (June to August), suggesting effective pollutant removal through rainfall and stronger wind activity. PM_{10} concentrations showed comparatively moderate variation throughout the year but remained consistently higher than $PM_{2.5}$ during most months, indicating the dominance of coarse particles likely originating from dust and local sources. The $PM_{10}/PM_{2.5}$ ratio was notably higher during the mid-year months, reflecting increased coarse particle contribution, possibly due to dry conditions and higher wind speeds. Meteorological parameters played a crucial role in influencing pollutant levels. Higher temperatures and wind speeds during summer months contributed to pollutant dispersion, while higher relative humidity during monsoon facilitated pollutant settling. Conversely, lower wind speeds and moderate humidity in winter contributed to pollutant accumulation. Overall, the study highlights the seasonal dependency of air pollution and emphasizes the importance of meteorological factors in air quality management. Effective pollution control strategies should consider these seasonal patterns to mitigate health risks and improve environmental conditions.

Conclusions

This study analyzed monthly variations in $PM_{2.5}$, PM_{10}, and key meteorological parameters over the year 2025. The data reveal a distinct seasonal pattern: higher concentrations of $PM_{2.5}$ (52–58 μg/m^3) occurred during winter months (January, November, December), while lower levels (17–22 μg/m^3) were observed in summer (June–August). In contrast, PM_{10} levels remained relatively stable (41–52 μg/m^3) throughout the year. A notable finding is the inverse relationship between temperature/wind speed and $PM_{2.5}$. Elevated $PM_{2.5}$ coincided with lower average temperatures (29–30°C) and moderate wind speeds (13–15 km/hr), whereas cleaner periods corresponded to higher temperatures (31–35°C) and stronger winds (up to 27 km/hr), suggesting enhanced dispersion and reduced secondary aerosol formation under warmer, windier conditions. The $PM_{10}/PM_{2.5}$ ratio proved particularly insightful. The ratio was lowest in winter (<1.0, e.g., 0.84 in January), indicating a finer particle dominance likely from combustion sources (e.g., biomass burning, vehicle emissions, or residential heating). Conversely, the ratio peaked in summer (up to 2.76 in July), implying a larger contribution from coarse particles (e.g., dust, resuspension) under dry, windy conditions. These findings underscore that $PM_{2.5}$ and PM_{10} are governed by different source and dispersion mechanisms. Effective air quality management in this region should therefore adopt season-specific strategies: targeting fine particulate sources (combustion) in winter, and coarse particulate control (dust mitigation) in summer. The persistent PM_{10} levels year-round further suggest a background source of coarse particles that requires independent investigation.

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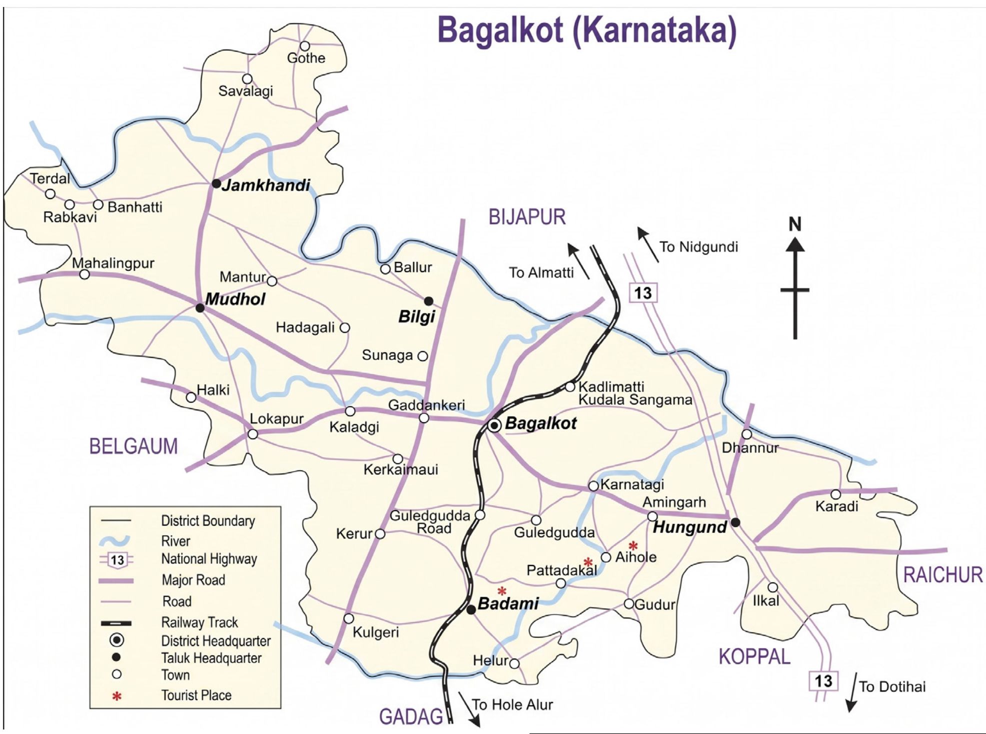
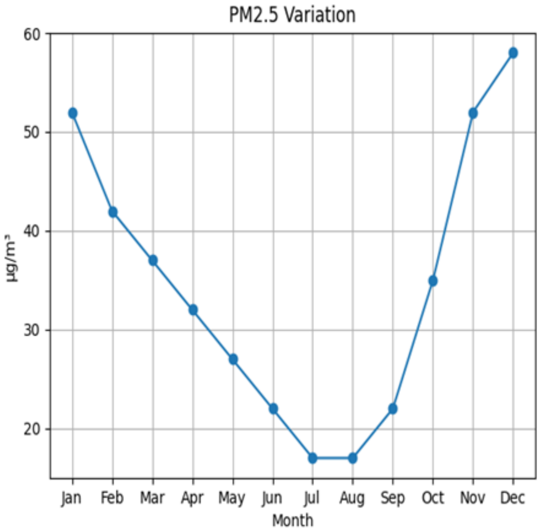
Table 1: Particulate concentration along with meteorological parameters for the year 2025

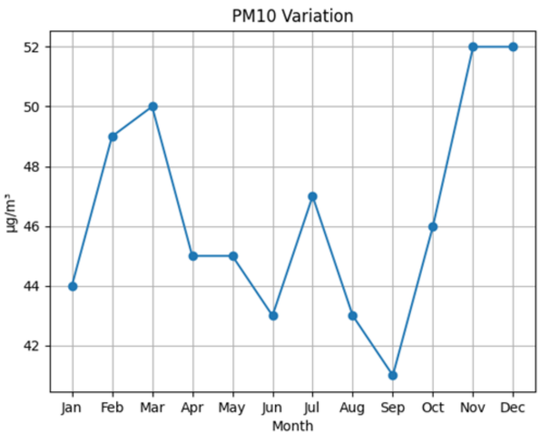
Month	PM2.5 [µg/m3]	PM10 [µg/m3]	Avg Temp [oC]	Rel Humidity [%]	Wind Speed (km/hr)	[PM10/PM2.5]
Jan	52	44	29	48	15	0.84
Feb	42	49	26	48	11	1.16
Mar	37	50	35	50	11	1.35
Apr	32	45	35	39	12	1.40
May	27	45	34	24	17	1.66
Jun	22	43	33	19	24	1.95
Jul	17	47	31	38	27	2.76
Aug	17	43	30	44	24	2.52
Sep	22	41	29	60	16	1.86
Oct	35	46	30	65	12	1.31
Nov	52	52	29	57	15	1.00
Dec	58	52	30	52	13	0.89

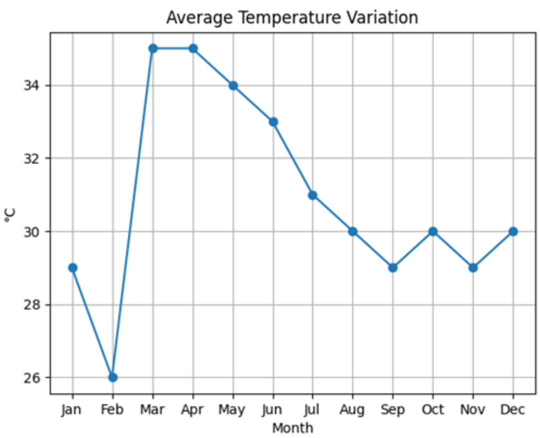
Figure 1: Location map for Bagalkot

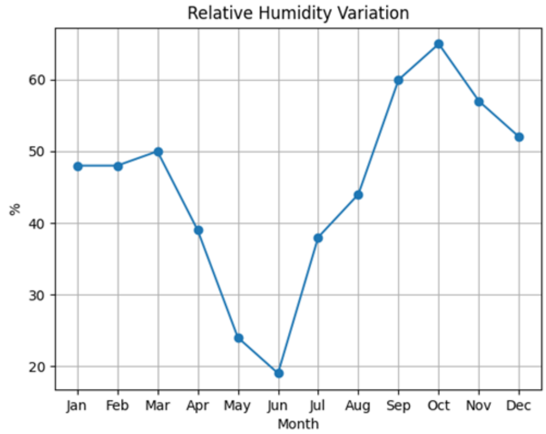


This report presents monthly variations of PM2.5, PM10, Temperature, Relative Humidity, and Wind Speed for the year 2025.









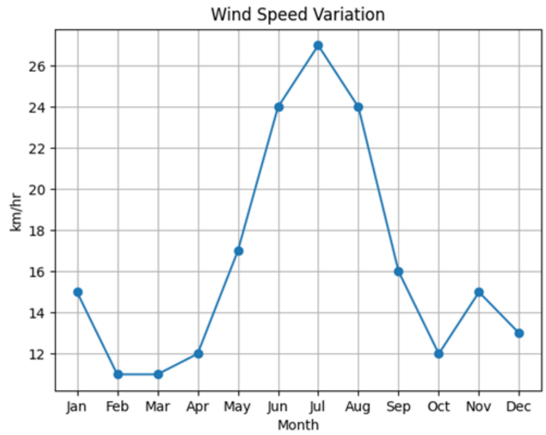


Figure 2: Annual trend of particulate matter and meteorological parameters for Bagalkot city

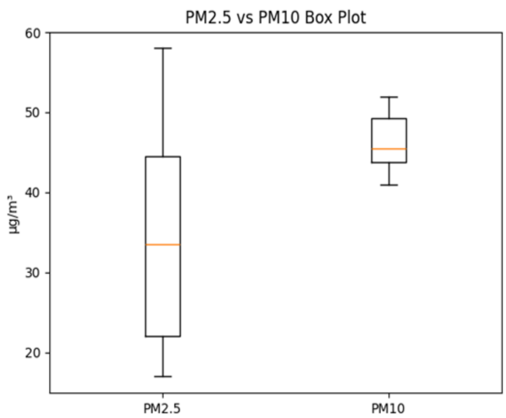


Figure 3: Statistical representation of particulate matter concentration for Bagalkot district