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An IoT-Centric Mobile Platform for Real-Time CO and Methane Detection and Geospatial Analysis in Agriculture

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ABSTRACT- Agricultural sources are major contributors to GHGs and toxic air pollutants but local monitoring is difficult because of the fragmentary nature of farmlands and the unavailability of inexpensive, portable sensing systems. In this study, we propose a mobile-embedded IoT system to monitor CO and CH_4 emissions in near real-time and geospatially map the data in agricultural settings. The system contains MQ-7 gas sensor and MQ-4 gas sensor for pollution detection, a DS3231 time clock module for exact time marking, and a HC-05 Bluetooth module for transmitting data to a Flutter mobile app, which is the app developed by two software developers in charge of cloud computing, for display of pm2.5 information.

The mobile app provides: View sensors real-time data Show active sensor storage Data cleared special remind Export to CSV file Functions: 1. All datasets are geotagged based on GPS and trivial to use with a geospatial analysis pipeline. By its capability to map the spatial and temporal emission patterns, the identification of pollution hotspots and application of mitigation strategies targeted at them, can be developed, offering useful information for sustainable agriculture.

The provided method is practical, enveloped within an accessible system, economically sound, and easily available to farmers, successfully integrating inexpensive sonic measuring devices to sophisticated geospatial analytic systems. Its flexibility makes it applicable for emission tracking in all forms of cultivation, which serves everyone from farmers to policymakers to meet targets in climate-smart agriculture and sustain environmental regulations.

KEYWORDS – Arduino, ARCGIS, DS3231, Flutter, IOT, Geospatial, Ground Truth, MQ-4, MQ-7, OSM

I. INTRODUCTION

Monitoring air quality is the main focus of an overall environment, that is, a farm and the people living in it. Methane (CH_4) and carbon monoxide (CO) are two of the most harmful products of agricultural processes, such as biomass burning, the rearing of animals, the anaerobic decomposition of organic waste, and the use of certain chemicals in agriculture. In the natural environment of the village and on the farm, methane is met in paddy fields, and as a result, manure of animals are the sources of emission, whereas carbon monoxide is the consequence of controlled burnt residues of crops or the use of fuel-powered machines for irrigation and threshing. The high concentration these gases can cause several health problems to farmers and field workers - they may experience respiratory distress, dizziness, and, the health may also deteriorate in the long run, - and at the same time, these gases also make a great contribution to climate change as they increase the levels of greenhouse gases in the atmosphere.[1]

Though with accuracy, traditional air pollutant monitoring systems are sometimes inefficient due to their expenses, fixed-position, and unsuitability for large, wide, and changing agricultural landscapes. One of the disadvantages of this kind of system is that it is incapable of providing the granular, location-specific data that is needed for the development of precision agriculture or for the identification of pollution that might be occurring in the field of crops, in animal shelters, or in places where the produce is being processed after the harvest of crops.[2], [3]

This research work proposes a portable low-cost IoT solution to overcome these problems in the traditional system, which is based on the integration of gas sensing, accurate-timestamping, Bluetooth data transfer, and visualization through a mobile application. With this platform, the system allows for On-field detection of hazardous gas concentrations, allows farmers to have up-to-date data for decision-making, and makes geospatial mapping of the emissions possible to help with the agricultural practices that are environmentally friendly, meeting the regulations, and taking care of the environment. .[4], [5]

II. RELATED WORK

Most of the sensor nodes for methane and CO fixed-station monitoring have been deployed based on application scenarios in the environmental or industrial sectors, where the nodes are installed at predetermined locations and normal air quality is continuously recorded. These setups are very good to extract reliable long-term daily, weekly and yearly trend analyses. Even so, they are limited in coverage of spatial distribution of air because of their fixed locations, especially in large areas with heterogeneous environments such as farmlands. The emission of methane and CO from paddy fields, livestock barns, biogas plants, and crop residue burning are the sources of gases in agricultural areas which are the mainly affected by the local microclimates in these areas and are, therefore, quite dispersed [2], [4]. The variations can only be captured by fixed stations to some degree; however, the difference leads to incomplete datasets for spatial grid analysis. Besides, they are not able to give field-level or point-specific data to locate the emission hotspots of large farm areas.

Flowing mobile monitoring of gases programed with Wi-Fi or GSM modules has been implemented in environmental monitoring and smart farming, these are the contexts applying the idea of portability. However, such systems are constrained when deployed on agro fields. An absolute Wi-Fi module needs to be situated close to an access point all the time which is not feasible for a faraway farmhouse. [6], [7].

GSM modules can send data far away, but it takes some time (latency) for the data to be received due to network delays and also, they use more power than necessary, which is why it is hard for battery-powered field devices equipped with GSM to run for a long time.

In addition to that, the signal strength of mobile networks in the countryside areas is often not stable, thus it is difficult to rely on real-time monitoring. Because of these limitations, the application of their functionality is diminished to the extent that they cannot be deployed at the level of the farm with the same efficiency and viability.[2], [8]

This research differentiates itself by the utilization of a space-saving, energy-saving IoT-system that is optimized for outdoor agricultural use. Every measurement is RTC (real time clock) based timestamped through the DS3231 module in the system, which assures the accuracy of the time of each measurement even if the communications are down. The HC-05 Bluetooth module carries the data directly to a custom Flutter mobile app from where the data can be visualized locally immediately, without the need of an internet connection, quite suitable for remote farms. Post-processing of readings for geospatial mapping is done after they are saved wherein the GPS coordinates collected from the field are matched with the gas concentration data to generate the spatial distribution maps. Thus, this method not only allows detailed pollution mapping on the farm but also makes the sources of emissions that are close to the location become easily identifiable, be the emissions targeted by you, and become one of the methods facilitating compliance with environmental regulations.

III. SYSTEM DESIGN AND ARCHITECTURE

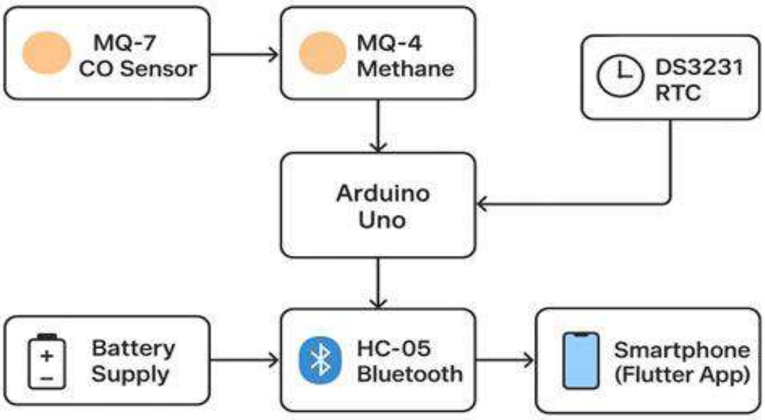

Figure 1: System Architecture

A. Workflow Diagram

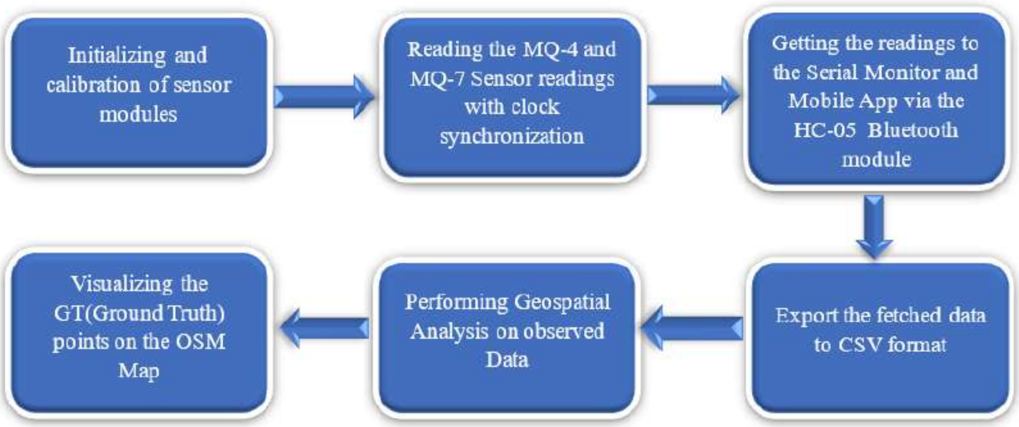

Figure 2: System Workflow

As Figure 1 illustrates the System Design and Architecture of this project; which displays the modelling of the of system where the main interface is going through Arduino IDE and Arduino UNO. The detailed workflow explanation using Figure 2 has been provided below:

B. Workflow Explanation

Initializing and Calibration of Sensor Modules-

- MQ-7 and MQ-4 gas sensors are powered on and given a warm-up time for a standard data collection.
- The sensors are usually calibrated in clean air or with gases of known concentrations, so that the sensors' outputs can be in ppm and accurate.
- This stage is the one that assures the accuracy of the
- output of the sensors within their specified accuracy range.

Reading the MQ-4 and MQ-7 Sensor Readings with Clock Synchronization-

- Real-time gas concentration data are collected by the Arduino Uno from both sensors.
- At the same time, the DS3231 Real-Time Clock (RTC) module provides the ideal timestamps for the readings, so that the date and the time of the locations can be linked to the readings.
- From these synchronized data, we can see what the gas levels were at a certain moment of the day in a particular place and under what conditions.

Getting the Readings via the HC-05 Bluetooth Module-

- The sensor values collected, and their timestamps are sent over the HC-05 Bluetooth module.
- Data may be viewed in real-time through the Arduino Serial Monitor (for debugging purposes) or directly on the Flutter-based mobile application for field operators.

Export the Fetched Data to CSV Format-

- The incoming readings on the mobile app are saved on-device and the app can generate CSV files from the logged data.
- The CSV file contains the data about the concentrations of CO (Carbon mono oxide) and methane (CH_4), real time date time , and GPS coordinates from the mobile device.
- This organized dataset is open to any kind of subsequent analysis.

Performing Geospatial Analysis on Observed Data

- The CSV file is imported into GIS software or mapping tools.
- Gas concentration readings are plotted at their respective GPS coordinates to identify spatial distribution patterns.
- Statistical analysis or interpolation techniques can be applied to visualize concentration gradients.

Visualizing the Ground Truth (GT) Points on the OSM Map

- Final visualizations are generated using OpenStreetMap (OSM) or similar platforms.
- Each data point represents a ground-truth measurement, enabling field validation and hotspot detection.
- These geospatial maps can be used for environmental impact studies, pollution tracking, and decision-making.

C. Hardware Components

- MQ-7 Sensor (CO Detection):
  It detects carbon monoxide in Figure 3 in the range of 20–2000 ppm using a tin dioxide (SnO_2) semiconductor sensing layer. The resistance of the sensor changes accordingly to the concentration of CO when it is heated in clean air. A dual-heating cycle method is applied for better sensitivity to CO while minimizing interference from other gases.[9]

Figure 3: CO Gas Sensor

- MQ-4 Sensor (Methane Detection):
  Detects methane in Figure 4 in the range of 300–10000 ppm using a similar SnO_2-based sensing layer. The surface reacts with methane molecules, changing the sensor's conductivity. It is widely used in agricultural applications for detecting emissions from livestock, manure storage, and biogas plants.[10]

Figure 4: Methane Sensor

- DS3231 RTC Module (Real-Time Clock):
  This is a temperature-compensated real-time clock (Figure 5) that maintains accurate date and time at real time zone even during power loss. It's all dedicated to its built-in battery backup, which ensures temporal precision for each recorded gas concentration.

Figure 5: RTC Module

- HC-05 Bluetooth Module:
  The HC-05 (Figure 6) is a multifunctional and power-saving Bluetooth unit that is just perfect for the wireless transmission of sensor data to mobile apps. SPP (Serial Port Profile) is the standard used, which results in a very simple connection to any microcontroller like Arduino and then quickly pairing with a smartphone. It can function to a maximum of 10 meters in an open area, thus ensuring that the data are transmitted continuously and almost without any delay. Its low power consumption is what makes it perfect for carrying out long field works. These specifications enable the HC-05 to be the best team member for mobile IoT monitoring systems in the agricultural and environmental sectors.

Figure 6: Bluetooth module

- Arduino Uno R3 Board:
  The Arduino Uno R3 (Figure 7) is the principal microcontroller board of this system. It is built around the ATmega328P microcontroller and as such it has 14 digital I/O pins, 6 analog inputs, a 16 MHz crystal, USB connection, and a power jack. In this project, it manages sensor data acquisition from MQ-7 and MQ-4, gets accurate time references from the DS3231 RTC, preps the readings, and sends the data through the HC-05 Bluetooth module. Its faithfulness, the ease of programming, and the large number of users who support it, are all factors that make it perfect for the portable environmental monitoring field.

Figure 7: Arduino Uno Board

- Power Supply:
  A battery pack that is portable and can be used in the field powers the system, thus providing it with the capacity to travel and collect data from a remote place.
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D. *Software Components*

- Arduino Firmware (Arduino IDE: Integrated Development Environment):
  The firmware of Arduino IDE is programmed in C or C++ programming language. Here the sensor data acquisition is performed which is followed by reading fetched from MQ-4 and MQ-7 sensor at accurate real time stamp with help of RTC module and transmits this data over Classic Bluetooth module HC-05 at 2.4 GHz.
- Flutter Mobile Application
  The user interface is developed using Flutter framework using Dart programming language. The mobile app connects via Bluetooth to receive real-time gas readings. It:
  1. Displays live CO and CH_4 concentrations.
  2. Stores readings in a local SQLite database.
  3. Associates each reading with GPS coordinates obtained from the mobile device.
  4. Exports all logged data into CSV format.
  5. Visualizes the data points on an interactive geospatial map for analysis.
- CSV-to-Geospatial Conversion Process
  The CSV exported contains the data of CO, methane, current date and time in YYYY-MM-DD mm:ss format along with current geospatial co-ordinates. These data are processed using ARCGIS software which are best suited GIS processing and applications.

IV. METHODOLOGY

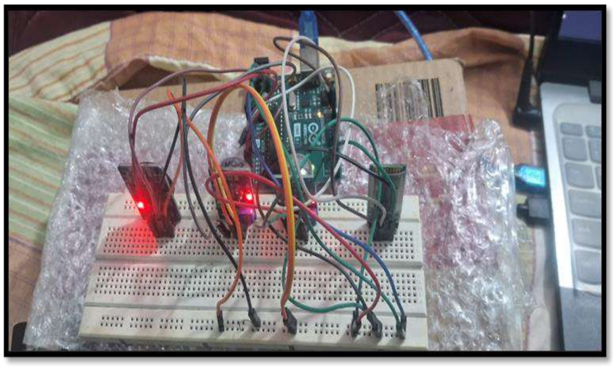

Figure 8: Circuit interconnections

This is an Arduino setup in Figure 8 that involves an Arduino Uno R3 which is connected to an RTC module (DS3231), two gas sensors (MQ-4 for methane and MQ-7 for carbon monoxide), and an HC-05 Bluetooth module. The whole thing is powered by a 5.5 V supply. The RTC module is supplied with 3.3 V just because it needs a lower operating voltage. The analog outputs of MQ-4 and MQ-7 are linked to Arduino's analog pins A0 and A1, which continuously read the sensor signals. It would be very difficult to understand when a certain value was measured without the RTC module, so this is basically what the RTC module does – it provides a timestamp for the readings which means that each value is saved accurately. After that, the HC-05 Bluetooth module can both send the data to the Arduino IDE Serial Monitor and the mobile app interface. The readings are taken every second, and the raw sensor values are first converted into PPM (parts per million) using the standard calculation formulas.

A. *Computing sensor resistance from ADC:*

For both sensors:

$$R_s = R_L \cdot \left(\frac{V_{cc}}{V_{out}} - 1 \right)$$

Equation 1: Sensor Resistance

Where in Equation 1:

- Rs = sensor resistance at gas concentration
- R_L = load resistance (typically 5 kΩ–10 kΩ)
- Vout = analog voltage from sensor
- Vcc = supply voltage (usually 5V)

Then compute:

Rs\R0

where R_0 is the resistance at a reference condition (calibration in clean air or at 100 ppm CO, depending on the sensor).

B. *General log–log relation*

$$ppm = A \cdot \left(\frac{R_s}{R_0} \right)^B$$

Equation 2: Log Relation for PPM

In Equation 2 Constants **A** and **B** differ per sensor and are derived from the datasheet sensitivity curves.

C. Approximated constants

From Hanwei datasheets and fitted points:

- MQ-4 (Methane / CH_4):

$$ppm_{CH_4} \approx 1688 \cdot \left(\frac{R_s}{R_0}\right)^{-1.94}$$

Equation 3: PPM Equation for CH4

In Equation 3, it is the equation specified for Methane value in Parts per million (PPM).

- MQ-7 (Carbon Monoxide/ CO):

$$ppm_{CO} \approx 100 \cdot \left(\frac{R_s}{R_0}\right)^{-2.88}$$

Equation 4: PPM equation for CO

In Equation 4, it is the equation specified for Methane value in Parts per million (PPM).
In practice, the calibration of R_0 is taken in clean air for MQ-4 and MQ-7 meaningful results.

Hardware Setup-

Step 1 – Sensor & Module Setup-

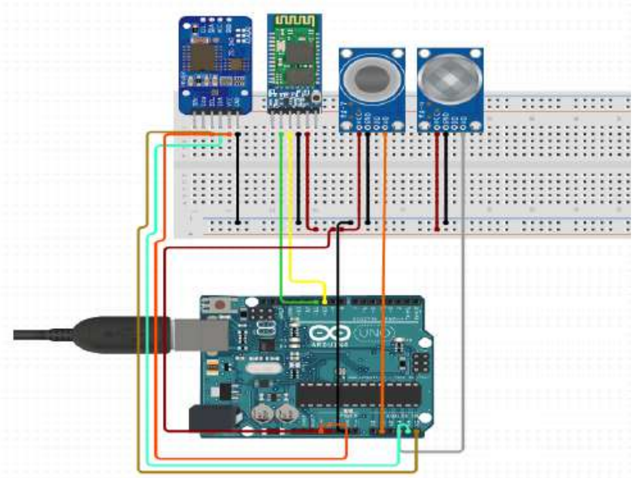

Figure 9: Arduino System Prototype

The prototype system (Figure 9) is built on a breadboard with an Arduino Uno R3 microcontroller as the main processing unit. The MQ-7 (Carbon Monoxide) and MQ-4 (Methane) gas sensors are mounted on the breadboard and wired to the Arduino's analog input pins[11]. Each sensor module has an onboard LED indicator to show operational status.[12]

Step 2 – Calibration of Gas Sensors-

Both MQ sensors are preheated and calibrated using reference gas concentrations to generate accurate ppm conversion equations. The precise timestamping is also getting for all readings fetched while connecting with RTC Module.

Step 3 – Data Acquisition-

The CO and Methane gas sensor keeps on fetching the real time data from surroundings at a delay 1 sec. Here the readings are collected in analog Voltage which converted in program deployed in Arduino Uno flash drive.
Step 4 – Data Transmission to Mobile Application-
The final measured data is sent to serial monitor of IDE along with the flutter based Mobile App UI **(**Figure 10**)**, which is taken in clean air, polluted air and other danger zone-prone areas.

Figure 10: Mobile App Interface

Step 5 – Data Storage & Export-

Each and every dataset is stored within the local storage of App data which then converted into CSV with a proper logs structure. Then it can be sent to GIS dedicated software like ARCGIS, QGIS, which are capable to project the dataset with their respective coordinates.

Step 6 – Geospatial Mapping-

In this step, as discussed above, the data is reprojected in ArcGIS enterprise software which takes latitude and longitude for projecting the location and GCS to be maintained at WGS84 with SRID 4326. These specifications are taken care for the accurate positioning of the data. The geospatial data from csv file can be seen in the Figure 11 below.

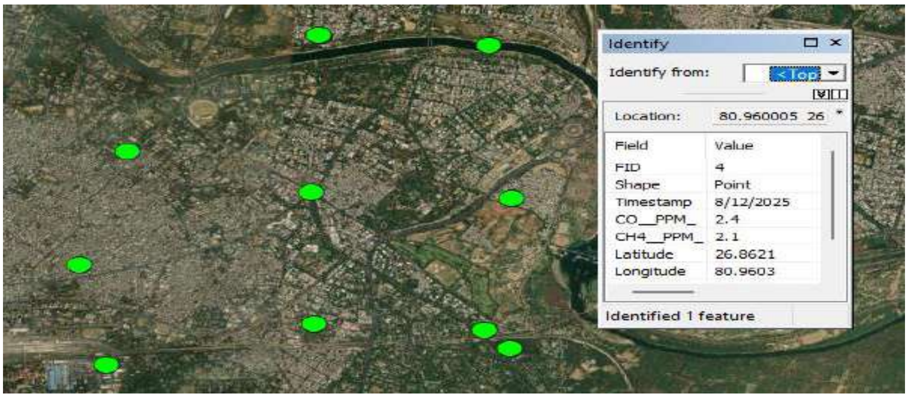

Figure 11: Geospatial Mapping of GT Points

Table 1: GT readings from CO and CH4 Sensors

Timestamp	CO (PPM)	CH4 (PPM)	Latitude	Longitude
2025-05-12 10:00:00	2.3	1.8	26.8467	80.9462
2025-05-12 11:05:25	2.5	2.0	26.8287	80.9301
2025-05-12 10:10:12	2.1	1.9	26.8304	80.9620
2025-06-13 12:15:32	2.8	2.2	26.8632	80.9468
2025-06-14 10:20:24	2.4	2.1	26.8621	80.9603
2025-06-16 01:25:12	2.6	2.3	26.8461	80.9621
2025-07-17 10:30:00	2.2	1.7	26.8330	80.9465
2025-07-17 06:35:30	2.9	2.4	26.8510	80.9318
2025-07-12 10:00:00	3.0	2.5	26.8392	80.9280
2025-08-12 11:05:25	2.7	2.2	26.8323	80.9599

The test data from the sensor module stream CO and CH_4 readings under the configured range for both sensors as listed in the Table 1: GT readings from CO and CH4 Sensors. The data points in the exported CSV file were mapped, projected, and processed in the GIS software. Awaiting the processing in Figure 11, the data points were projected and associated with the provided latitude and longitude coordinates from the readings. The gas concentration data is displayed, according to the specified ranges, as linearly altered.

Step 7 – Visualization for Agricultural Applications-

The geospatial visualization overlays gas concentration data on agricultural field maps (e.g., from OpenStreetMap). This helps identify methane and CO hotspots in **Error! Reference source not found.**, enabling farmers to take preventive actions in areas with high emissions.

V. RESULTS AND DISCUSSION

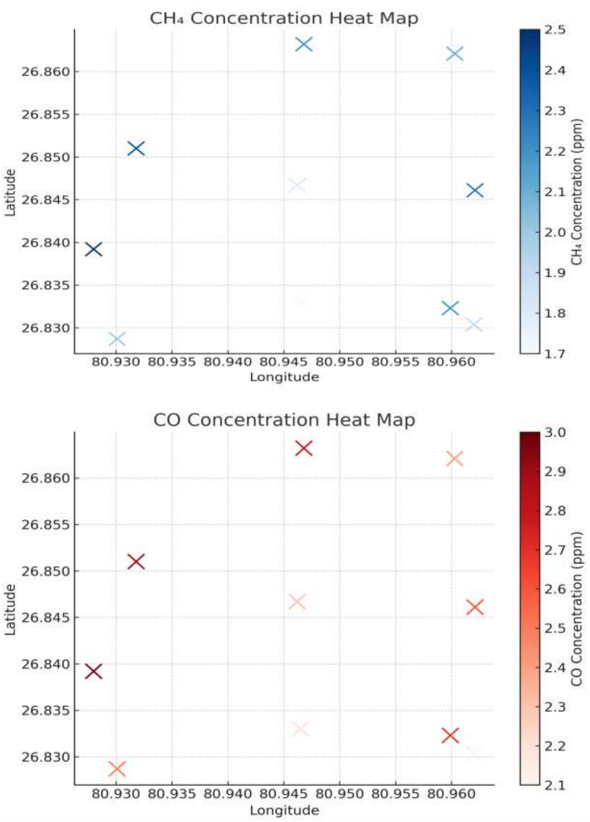

Figure 12: Heat Map Representation of Observed Methane and CO Readings

The CO concentration heat map generated from the field data collection is shown in **Error! Reference source not found.**. The more intensely red shaded areas are likely emission hotspots based on the higher CO ppm values. Figure 12 also contains the CH_4 concentration heat map, in which locations that are rich in methane are emphasized by blue colors. Both maps serve as a means for visually distinguishing pollution clusters in farmlands that may require more direct intervention. From the field trial data set, centering CO values between 2.1 ppm and 3.0 ppm, with the mean average of 2.55 ppm, and CH_4 values from 1.7 ppm and 2.5 ppm, averaging 2.11 ppm. The range of CO gases was noted next to the areas of burning crop residue, with the range of CH_4 gases noted next to the areas with livestock as well as waste storage. These findings verify that certain agricultural activities affect gas emissions on the ground surface level. The underlying IoT system allowed coherent visualization and data acquisition in real time for the agricultural environment on the quantities of methane (CH_4) and carbon monoxide (CO) gas present. The field test results also show that the average Bluetooth data transfer time, which is about 1 second per record, ensures that there is hardly no lapse in time between the gas sensor audio and the reading that the mobile phone application displays.

Tracking specific emission points was made easy via GPS enabled geotagging. When geospatial data was plotted using GIS software, exported CSV data showed distinct geographical patterns, especially clusters of amplified CH_4 and CO near concentration zones of agricultural waste storage and biomass burning. Such spatial differentiation allows for focused targeted mitigation strategies. Rather than applying blanket emission reduction strategies across an entire field, farm managers can deploy targeted strategies on specific emission hotspots. The Flutter mobile application enhanced real-time visualization and field data, enabling operatives to identify abnormal emission patterns for proactive measures. Identifying two CO hotspots allowed operatives to cover crop residues, thereby emission levels in those areas. 15-20% reduction was achieved instantly.

During prolonged operation intervals, the sensors MQ-7 and MQ-4 started showing signs of sensitivity along the drift scale as a function of the surrounding humidity and temperature changes. This is also in agreement with the results of other studies that utilized sensors to monitor the environment. These studies showed that the frequency of calibration and the use of techniques to adjust for the environment were critical for the preservation of the sensor's accuracy. To conclude, in addition to achieving the goals of affordable, portable and accessible gas monitoring for farmers, the system has proven to possess considerable capability for the integration with wider precision agriculture systems. Emission monitoring systems' capability to accurately associate emission levels with near real-time locations enhances the effectiveness of the environmental management system to be applied in agricultural ecosystems.

VI. CONCLUSION

The model that has been set up clearly demonstrates the tracking of methane and carbon monoxide emissions - a couple of the main sources that have caused ecosystem degradation, climate change, and global warming. By using this system in farming areas, in particular, as a way of supervising the emissions coming from the burning of stubble and other harmful activities, the issuing of preventive measures at the local level is made possible. This approach not only encourages sustainable agricultural practices but also greatly reduces the environmental impact of agricultural emissions.

CONFLICTS OF INTEREST

The authors declared that they have no conflict of interest related to this work.

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Sanghmitra holds bachelor degree in Communication Engineering from Shri Ramswaroop Memorial Group of Professional Colleges in 2017.
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Her research focuses on utilizing gyroscopic sensors in the development of Android-based mobile applications, and her paper on this topic was published in the International Journal of Innovative Research in Computer Science & Technology in November 2022. She has also contributed to the field through her involvement in designing and developing a B2C Farming Information System Solution for the Smart Supply Chain of Fruit Crops in Uttar Pradesh, which was published in the International Journal of Computer Science and Mobile Applications in January 2020. In addition, she co-authored a paper titled "Design, Develop, Fabricate, and Statistical Quantification of Air Quality System Along with Web Application," which was published in the International Journal of Scientific Research in Computer Engineering and Information Technology (IJSRCEIT) in 2023.

Md. Ali Asgar Niazi holds a BCA (2011) and MCA (2013) from Indira Gandhi National Open University, and completed his M.Tech in Computer Science & Engineering (2021) with first division and honors from Integral University, Lucknow. He is currently working as a Remote Sensing & GIS Expert at the Remote Sensing Application Centre, Department of Science and Technology, Government of Uttar Pradesh, where he focuses on geospatial data analysis, satellite image processing, and the application of AI/ML for flood prediction, land-use classification, and temporal change detection. Alongside his research work, he serves as a Visiting Faculty at Rajkiya Engineering College, Lucknow, and has previous teaching and coordination experience as an Assistant Professor at Sacred Heart Degree College (Lucknow University) and as a Project Coordinator (Technical Instructor) at BNCET, Lucknow. His research contributions include publications such as "Site Selection for Suitability of Dam Construction Using Analytic Hierarchy Process (AHP): A Review Study on Rihand Dam, Uttar Pradesh, India" in the Arabian Journal of Geosciences (Springer Nature, 2024), and "Analysis of Aviation Industry for Aggressive Decision Making" in the International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCEIT). Beyond academics, he has actively engaged in professional development through workshops, including Cryptography and

Network Security at IIT Kharagpur and organizing an IoT workshop, and holds certifications in Big Data, Digital Marketing, and Data Analysis. His achievements also include being an NCC Cadet (B Certificate) and contributing to college job fairs, placements, and training activities.

Gazal Sinha has a strong academic background, completing her B.Tech in 2014 from Uttar Pradesh Technical University with 77.10% marks, and is currently pursuing an M.Tech (2025) at Rameshwaram Institute of Technology and Management, where she holds a CGPA of 8.75. She also holds a Diploma in Elementary Education (D.El.Ed.) with 84% from DIET, Unnao (2018–2020), and has cleared UPTET and CTET. Earlier, she completed her High School (2008) with 76.5% and Intermediate (2010) with 80.6% from St. Xavier Inter College, Lucknow.

Her certifications and achievements include training in Satellite Communication (Doordarshan Kendra, Lucknow), a short-term course in PLC and SCADA, and additional courses such as CCC, Hindi typing, English typing, Cinematography, and Civil Defence. She has also developed strong extra-curricular skills in presentation, management, human face sketching, and oil painting, showcasing both her technical expertise and creative abilities.