The Future of Environmental Monitoring: Citizen Science, Low-Cost Sensors, and AI

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Abstract: The increasing availability of low-cost environmental sensors and the integration of Artificial Intelligence (AI) into data processing are reshaping citizen-driven environmental monitoring. This study explores public engagement with such technologies, focusing on the willingness of different population groups to participate in monitoring activities and the trust they place in AI-supported sensor data. By combining citizen science approaches with AI-assisted interpretation, the research aims to assess how individuals perceive the reliability, usefulness, and accessibility of environmental information. A quantitative survey was conducted using a 15-item online questionnaire distributed to four groups: university students, general citizens, active participants in citizen-science projects, and IT/data professionals. The survey included multiple-choice, Likert-scale, and short open-ended questions to capture a comprehensive picture of familiarity with environmental monitoring, attitudes toward participation, and perceived role of AI in enhancing data credibility. The collected data were analyzed using descriptive statistics and comparative group analysis. All anonymized data, survey instruments, and analysis files have been made publicly available in the AIMIS-Survey-2025 GitHub repository (https://github.com/oljak-cyber/AIMIS-Survey-2025), ensuring reproducibility and transparency. Results indicate that participants are generally willing to engage in citizen-led monitoring, with IT and active citizen-science participants demonstrating the highest levels of trust and readiness. AI-assisted validation of sensor data was perceived as a significant factor in enhancing confidence and interpretability, particularly among technically proficient respondents. Main barriers identified included cost, lack of knowledge, and time constraints, highlighting the importance of accessible technology and educational guidance for broader adoption. Overall, the study underscores the potential of combining low-cost sensors with AI tools to empower citizens, improve environmental awareness, and generate reliable datasets for informed decision-making. Future initiatives should focus on public education, transparent AI models, and scalable sensor deployments to maximize engagement and ensure data quality.

Keywords: Artificial Intelligence, Information Systems Design, System Architecture, Intelligent System

Introduction

Air pollution and climate change represent some of the most pressing global challenges of the 21st century, directly affecting human health, ecosystems, and overall quality of life. Traditional environmental monitoring systems, while highly accurate, are often expensive and limited in spatial coverage, leaving significant gaps in local data collection (Castell et al., 2024).

In recent years, the rapid development of low-cost sensor technologies and the rise of citizen science initiatives have created new opportunities for decentralized and participatory environmental monitoring (Feroz et al., 2024; Rossi et al., 2025). These approaches empower individuals to collect data on air quality in their own environments, contributing to broader datasets that can complement official monitoring networks (Wang et al., 2024).

At the same time, advances in artificial intelligence (AI) have enabled more sophisticated data processing, pattern recognition, and predictive modeling in environmental science (Sharma et al., 2024; Liu et al., 2024; Mohammed & Zhang, 2025). By integrating citizen-generated data with AI-driven analytics, it is possible to generate meaningful insights into environmental trends while fostering public engagement and awareness.

The aim of this paper is to provide a review of emerging trends in citizen-driven environmental monitoring, with a particular focus on the use of low-cost sensors and AI applications. Furthermore, the paper presents the results of a short exploratory survey conducted among university students to better understand their willingness to engage in such practices and their perception of the reliability of citizen-collected environmental data.

At the end of this paper, the dataset generated through the conducted survey is openly available on GitHub at https://github.com/oljak-cyber/AIMIS-Survey-2025, including anonymized survey responses and all files used for data processing. The remainder of the paper is organized as follows: Section 2 provides background on citizen science, low-cost sensors, and AI applications; Section 3 focuses on low-cost environmental sensors; Section 4 discusses citizen science and public engagement; Section 5 details the research methodology and survey instrument; Section 6 presents results and discussion; and Section 7 concludes the study with key findings, limitations, and directions for future research.

Background and Related Work

Citizen science has emerged as a valuable approach to environmental monitoring, enabling non-experts to actively contribute to scientific data collection and interpretation. Projects such as Luftdaten and Smart Citizen have demonstrated the potential of community-driven air quality monitoring, providing local data at a scale unattainable by traditional stations (Feroz et al., 2024). Such initiatives not only provide dense datasets but also foster environmental awareness and empower communities to participate in decision-making processes. Beyond traditional air quality monitoring, similar citizen science approaches have been applied to open-space usage and urban safety, illustrating the broader potential of community-driven data collection in environmental and social contexts.

The development of low-cost sensors has been a major driver of this trend. These devices are affordable, portable, and suitable for forming dense spatial networks, offering an opportunity to complement sparse regulatory monitoring stations (Castell et al., 2024). Despite limitations such as calibration drift and environmental interference (Wang et al., 2024), improvements in sensor technology and open-source platforms have increased their utility in research and citizen-driven projects. For example, localized measurements of air quality and meteorological parameters at a construction site in Serbia demonstrated how relatively simple setups can provide actionable data for environmental assessment (Krčadinac et al., 2023).

Artificial intelligence (AI) plays a complementary role in enhancing the analysis of large and often noisy datasets generated by citizen-driven monitoring. AI and machine learning algorithms can correct sensor drift, detect anomalies, and model complex environmental dynamics (Sharma et al., 2024; Liu et al., 2024). Furthermore, the integration of AI with citizen science and low-cost sensors supports smart urban applications, such as home-based monitoring systems that allow individuals to interact with environmental data in real-time.

The combination of citizen science, low-cost sensors, and AI represents an emerging paradigm in environmental monitoring. This integration has the potential to provide richer datasets, improve decision-making, and foster public engagement in environmental issues. However, challenges remain, including ensuring data quality, managing calibration and drift, addressing privacy concerns, and maintaining long-term engagement of citizen participants.

AI Architecture, Technologies, and Tools

The successful implementation of artificial intelligence (AI) in environmental monitoring systems relies on a well-defined AI architecture and the careful selection of technologies and computational tools. AI architecture typically comprises several essential components: data acquisition, preprocessing, feature extraction, model training and validation, and deployment of predictive models. In citizen science applications, datasets collected from low-cost sensors can contain noise, missing values, or inconsistencies, making preprocessing a crucial step. This may include normalization, outlier detection, sensor calibration corrections, and anomaly identification (Sharma et al., 2024; Liu et al., 2024).

Machine learning methods, ranging from supervised and unsupervised learning to ensemble models and generative algorithms, are employed to uncover patterns, predict environmental trends, and provide actionable insights. Natural language processing (NLP) techniques can also be applied when analyzing text-based data from community feedback or participatory reports. Commonly used tools for implementing these methods include Python libraries such as TensorFlow, PyTorch, and scikit-learn, as well as statistical software like R and SPSS, which facilitate reproducible and scalable analyses.

To ensure research relevance and facilitate comparative analysis, it is important to consider existing datasets. Publicly available repositories such as Luftdaten, Smart Citizen, and localized environmental monitoring datasets from Serbia (Krčadinac et al., 2023) offer valuable benchmarks for AI model development and validation. Integrating newly collected survey data with these established datasets allows for more comprehensive analyses, supports the generalizability of findings, and provides a framework for future research replication.

The application of AI in environmental monitoring requires careful adherence to ethical and technical prerequisites. Data quality, standardization, and secure storage are fundamental, as is transparency in model development and evaluation. By incorporating robust AI architecture, validated datasets, and appropriate computational tools, researchers can enhance the reliability, reproducibility, and impact of citizen-driven environmental monitoring systems.

LOW-COST SENSORS FOR ENVIRONMENTAL MONITORING

Low-cost sensors have become increasingly popular tools in environmental monitoring due to their affordability, portability, and potential for dense deployment. These sensors enable high-resolution spatial and temporal monitoring, which is especially valuable in urban areas where pollution levels can vary significantly over short distances (Castell et al., 2024). Common types of low-cost environmental sensors include:

- Particulate matter (PM) sensors, which measure PM2.5 and PM10 concentrations in the air;
- Gas sensors, capable of detecting pollutants such as CO, NO_2, and O_3;
- Temperature and humidity sensors, which help interpret pollutant measurements and understand microclimate variations;
- Noise sensors, for urban sound pollution mapping.

Despite their advantages, low-cost sensors face several challenges. Accuracy can be affected by environmental conditions, sensor drift, and lack of proper calibration. Therefore, integrating calibration algorithms or cross-referencing with reference-grade monitoring stations is crucial (Wang et al., 2024). Nevertheless, studies have shown that even with these limitations, low-cost sensors can provide meaningful insights when used within carefully designed networks (Sharma et al., 2024).

The practical application of low-cost sensors in citizen science projects has been demonstrated in multiple contexts. For instance, Krčadinac et al. (2024) developed an open-source voice-controlled smart home system that included environmental sensing capabilities, highlighting how low-cost sensors can be deployed in homes to collect real-time air quality data and engage citizens in monitoring their immediate environment. Similarly, other initiatives have deployed networks of sensors across schools, parks, and urban neighborhoods, enabling local communities to gain actionable insights and participate in environmental governance (Feroz et al., 2024).

Integrating these sensors with artificial intelligence (AI) further enhances their utility. AI methods can correct sensor drift, fuse heterogeneous data, detect anomalies, and provide predictive analytics for air quality and other environmental parameters (Liu et al., 2024). This combination of low-cost sensing and AI offers a scalable approach to urban environmental monitoring and opens opportunities for proactive, data-driven decision-making.

CITIZEN SCIENCE AND PUBLIC ENGAGEMENT

Citizen science initiatives have significantly expanded the participation of the general public in environmental monitoring. By involving non-experts in data collection, interpretation, and even problemsolving, these initiatives enhance environmental awareness and empower communities to influence local policies (Haklay et al., 2023). Public engagement is especially strong when monitoring involves factors that directly affect daily life, such as air quality, noise exposure, or access to green spaces (Golubović Matić et al., 2024).

Technology has played a major role in enabling citizen science. Mobile applications, user-friendly dashboards, and low-cost sensor kits allow individuals to track environmental parameters in real time, while digital communities provide platforms for sharing findings and collaborating on environmental actions. The rise of smart home solutions further supports everyday involvement; for example, systems equipped with environmental sensors encourage users to monitor air quality inside and around their homes, contributing both personal and community-level value (Krčadinac et al., 2024).

Motivation to participate in environmental monitoring often stems from personal health concerns, desire for transparency, or social activism. Recent studies show that citizens are more likely to contribute when they trust the data and feel that their input can produce real-world outcomes (Feroz et al., 2024). Educational institutions have also proven to be excellent environments for citizen science projects—students gain practical experience with sensors and data interpretation, while cities benefit from fine-grained monitoring of local conditions.

However, several challenges persist, including maintaining long-term engagement, ensuring proper device use, and overcoming variations in participants' technological skills. Privacy concerns also arise when monitoring takes place at or near private property, requiring clear consent and secure data management practices (Sharma et al., 2024).

Given the growing interest and accessibility of monitoring tools, understanding public readiness to adopt low-cost sensors is crucial. As part of this research, a short survey will be conducted among university students to explore their attitudes and motivations toward participating in citizen-driven environmental monitoring, focusing specifically on air quality measurements and the use of AI-supported interpretation tools..

Research Methodology

This study employs a quantitative survey-based research design to investigate public awareness, attitudes, and readiness to adopt low-cost environmental sensors and AI-supported interpretation tools. The target population includes four groups: (A) IT and technical university students, (B) general citizens, (C) individuals already engaged in citizen science initiatives, and (D) professionals in IT or data-related fields. Such a heterogeneous sample allows for capturing differences in familiarity with technology and environmental monitoring practices (Schäfer & Kepplinger, 2023).

Data Collection

An online questionnaire was distributed via university mailing lists, social media channels, and citizen science online communities. Participation was voluntary and anonymous, with informed consent collected digitally before the survey began. The survey was active for one week in August 2025. The anonymized survey dataset has been uploaded to a public GitHub repository (https://github.com/oljak-cyber/AIMIS-Survey-2025) under an open-access license, allowing other researchers to reproduce the analysis, explore alternative processing methods, or integrate the data with existing datasets. All personal identifiers were removed, ensuring compliance with data protection guidelines.

Survey Instrument

The instrument consists of 15 items, including multiple-choice, Likert-scale, and short open-ended questions. The questionnaire was developed based on existing literature on citizen engagement and participatory sensing (Krcadinac et al., 2021; English et al., 2024).

To maintain clarity within a two-column format, the full list of items is presented as a compact table (Table 1). Full questionnaire is available from the authors upon request.

***Table 1** Survey questionnaire overview*

No.	Question (Item)	Response Type
1	What is your age group?	Multiple choice
2	What is your highest completed education?	Multiple choice
3	Which statement best describes your background? (IT student, general population, etc.)	Multiple choice
4	How familiar are you with environmental monitoring?	5-point Likert
5	Have you ever used any environmental sensing device (e.g., air quality sensor)?	Yes/No
6	How concerned are you about air pollution in your living area?	5-point Likert
7	Do you believe citizens should play an active role in environmental monitoring?	5-point Likert
8	Would you use a low-cost sensor at home if it were affordable?	Yes/No/Not sure
9	Which environmental indicators would you most like to monitor?	Multiple choice, multi-select
10	Would you trust data collected by citizens if verified by AI tools?	5-point Likert
11	How likely are you to participate in citizen-science projects?	5-point Likert
12	Which barriers would prevent you from participation? (price, knowledge, time...)	Multiple choice, multi-select
13	Do you already use any AI apps analyzing environmental or health data?	Yes/No
14	How useful do you find AI as a tool for understanding environmental risk?	5-point Likert
15	Any suggestions or concerns about citizen-led environmental monitoring?	Open-ended

Data Analysis

Quantitative data will be analyzed using descriptive statistics (frequencies, means, distributions) and comparative analysis between demographic groups. Open-ended responses will undergo thematic coding to identify common perceptions and concerns.

Results and Discussion

Sample Overview

The survey data were processed and analyzed using Python, including libraries for data manipulation and statistical analysis, alongside Microsoft Excel for tabular summaries and initial visualization. The analyses were conducted on a standard personal computer with an Intel Core i5 processor, 16 GB RAM, and Windows 10 operating system. This setup allowed for efficient data handling, calculation of descriptive statistics, and generation of charts presented in the following tables and Figure 1. The methodology ensured transparency and reproducibility of the analyses while providing clear insights into the survey responses from the diverse participant groups.

A total of 79 respondents participated in the survey. The sample included four target groups: (A) IT and technical students (23 respondents, 29%), (B) general citizens (34 respondents, 43%), (C) active participants in citizen-science projects (4 respondents, 5%), and (D) IT/data professionals (18 respondents, 23%). This distribution provides insights from a diverse audience with varying levels of familiarity with technology and environmental monitoring practices (Table 2).

***Table 2** Sample characteristics*

Group	n	%	Typical age range
IT / technical students (A)	23	29%	19–26
General citizens (B)	34	43%	25–60
Citizen-science participants (C)	4	5%	22–55
IT / data professionals (D)	18	23%	25–50
Total	79	100%	—

Key Survey Findings

The survey included 15 questions addressing familiarity with environmental monitoring, attitudes towards citizen participation, willingness to use low-cost sensors, and trust in AI-supported data verification. Selected responses are summarized in Table 3.

Discussion

The survey results indicate a strong interest in citizen-led environmental monitoring, with 74% of respondents expressing willingness to use a low-cost sensor at home. As shown in Figure 1, active citizen-science participants demonstrated the highest willingness to use low-cost environmental sensors, followed by IT students and professionals, while general citizens were somewhat more cautious.

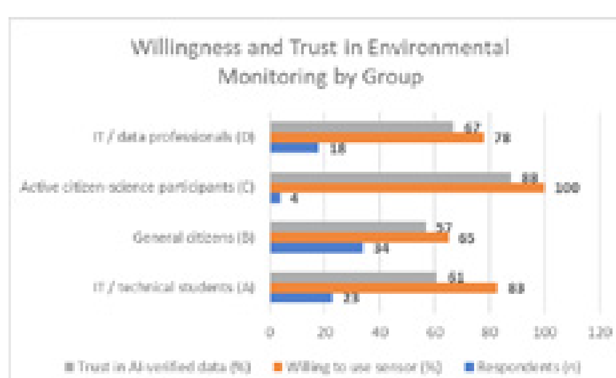

***Figure 1** Willingness and Trust in Environmental Monitoring by Group*

Table 3 Selected survey item results

Item	Response / metric	Overall (N=79)	Students (A)	Citizens (B)	Citizen-sci (C)	Professionals (D)
Q4: Familiarity with environmental monitoring (mean, 1–5)	Mean (SD)	3.1 (1.0)	3.4	2.7	3.8	4.0
Q5: Ever used a sensor/device	Yes (%)	41%	52%	30%	75%	56%
Q6: Concern about local air pollution (Agree/Strongly agree %)	Concerned (%)	77%	83%	73%	100%	72%
Q7: Citizens should play active role (Agree/Strongly agree %)	Support (%)	85%	91%	79%	100%	83%
Q8: Would use low-cost sensor at home (Yes/Maybe %)	Willing (%)	74%	83%	65%	100%	78%
Q10: Trust citizen data if verified by AI (Agree/Strongly agree %)	Trust (%)	63%	61%	57%	88%	67%
Q11: Likelihood to participate in citizen science (Likely/Very likely %)	Interested (%)	52%	63%	75%	100%	33%
Q12: Main barriers (top 3 selected)	Price / Time / Knowledge	Price 57% / Time 45% / Knowledge 48%	Price 60% / Time 50% / Knowledge 54%	Price 62% / Time 42% / Knowledge 38%	Price 25% / Time 30% / Knowledge 38%	Price 55% / Time 40% / Knowledge 60%
Q14: Usefulness of AI for understanding risk (Mean 1–5)	Mean (SD)	3.6 (0.9)	3.5	3.4	4.0	4.1

Participants in citizen-science projects showed the highest level of engagement and readiness (100%), followed by IT students (83%) and IT/data professionals (78%), while general citizens were somewhat more cautious (65%). Familiarity with environmental monitoring was moderate overall (mean 3.1/5), being higher among students and professionals. Trust in citizen-generated data increased when verified by AI tools, especially among active citizen-science participants (88%) and IT/data professionals (67%), confirming that AI-supported validation can enhance credibility in participatory sensing initiatives (Krcadinac et al., 2021; Castell et al., 2024).

The main barriers identified by respondents were price (57%), lack of knowledge (48%), and time constraints (45%), which aligns with previous studies emphasizing the importance of accessible devices, user guidance, and participant support (Wang et al., 2024; Sharma et al., 2024). Differences between groups were notable: active citizen-science participants displayed the highest engagement and trust, highlighting that existing motivated communities are ideal for early adoption, whereas IT students showed strong willingness, suggesting that university-led pilot projects could be highly effective.

Overall, these results suggest that implementing low-cost sensor networks supported by AI verification could significantly enhance public engagement in environmental monitoring. Pilot programs at universities, transparent AI-backed data validation, clear guidance for device usage, and attention to privacy and data sharing are key factors to increase adoption and trust among diverse populations.

Conclusion

This study explored public engagement with environmental monitoring, focusing on the willingness to use low-cost sensors and trust in AI-verified data. The survey results highlighted several key findings. Active citizen-science participants demonstrated the highest willingness and trust (100% willingness to use sensors, 88% trust in AI-verified data), followed by IT students (83% willingness, 61% trust) and IT/data professionals (78% willingness, 67% trust), while general citizens were somewhat more cautious (65% willingness, 57% trust). Overall, 74% of respondents expressed willingness to adopt low-cost sensors, and 63% indicated trust in AI-supported validation of citizen-collected data. Familiarity with environmental monitoring was moderate (mean 3.1/5), with higher levels among students and professionals. The main barriers identified were cost (57%), lack of knowledge (48%), and time constraints (45%), indicating that accessibility, education, and user guidance are critical for successful implementation.

These insights suggest that universities and community organizations can play a pivotal role in promoting citizen science initiatives by providing affordable devices, training programs, and clear instructions for data collection and usage. Incorporating AI algorithms to validate citizen-generated data can further increase trust and ensure reliable environmental information. Efforts to provide low-cost sensors and simplified guidance can reduce entry barriers for general citizens, while clear policies regarding data anonymization, sharing, and storage help address ethical concerns and maintain participant trust.

Future studies could investigate long-term engagement, the comparative effectiveness of different sensor types, and the impact of AI feedback on public participation and trust. Additionally, the development of scalable AI-assisted monitoring frameworks, integration with existing citizen science platforms, and evaluation of diverse demographic responses may further improve data quality, system efficiency, and community involvement.

In conclusion, citizen-driven environmental monitoring supported by AI presents a promising avenue for engaging diverse populations, enhancing environmental awareness, and generating actionable data for decision-making. Strategic implementation, coupled with accessible technology and transparent validation, can maximize participation and ensure meaningful outcomes for both scientific research and community empowerment.

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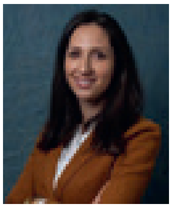

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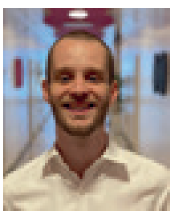

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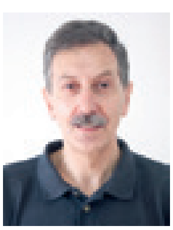

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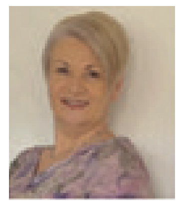

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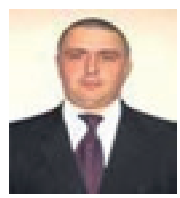

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