



Original Research Paper

Machine Learning Evaluation of Air Pollution Effects on Urban Bird Health

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Key Words

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Abstract

Urbanization has resulted in increased air pollution levels, creating significant environmental stress for wildlife, particularly urban bird populations. Birds act as sensitive ecological indicators because their health conditions, behavioural patterns, and population distribution are strongly influenced by habitat quality and environmental changes. Continuous exposure to pollutants such as particulate matter, nitrogen dioxide, sulphur dioxide, and carbon monoxide can negatively affect respiratory conditions, habitat suitability, and survival patterns of urban birds. However, understanding the complex relationship between air pollution and bird health remains challenging through conventional ecological assessment approaches. This study presents a machine learning-based ecological assessment framework to evaluate the effects of urban air pollution on bird health. Environmental parameters, including PM_{2.5}, PM₁₀, NO₂, SO₂, CO, temperature, and vegetation availability, were analysed along with bird health indicators such as abundance, species richness, nesting activity, and behavioural responses. Machine learning models, including Support Vector Machine, Random Forest, Gradient Boosting, and Artificial Neural Network, were evaluated to identify relationships between pollution exposure and bird health conditions. The results indicated that increasing air pollution levels were associated with reduced bird health conditions and lower habitat suitability. The model evaluation demonstrated effective prediction capability, with the Artificial Neural Network achieving the highest performance with an accuracy of 94.3%, followed by Gradient Boosting (93.1%) and Random Forest (91.4%). The findings also showed a clear decline in bird health index from 92% under low pollution conditions to 44% under severe pollution exposure. The study demonstrates that machine learning approaches can support ecological assessment by identifying pollution-related risks affecting urban bird populations. Integrating environmental monitoring with predictive models can assist conservation planning, habitat management, and sustainable urban biodiversity protection. Future studies can focus on real-time pollution monitoring and multi-species ecological health prediction.

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Introduction

Urbanization and human activities are contributing to higher levels of air pollution, which have become a source of stress for the fauna of the urban ecosystem. Birds can be called the important ecological indicators as the state of their health, behavior and other factors are directly related to environmental conditions. Exposure to pollutants like particulate matter (PM_{2.5} and PM₁₀), nitrogen dioxide (NO₂), sulphur dioxide (SO₂), and carbon monoxide (CO) may cause problems related to respiratory health, immune system, choice of habitat and reproductive functions. Modern studies have shown that it is necessary to consider variations in the level of pollutants and their ecological impacts using modern prediction techniques (Temirbekov et al., 2023; Essamlali et al., 2024).

Habitat degradation caused by urban air pollution is also an issue in that it degrades the vegetation quality and changes the ecological requirements for the survival of birds. Habitat availability and exposure to environmental stressors have been shown to change due to changes in urbanization and land use patterns, and affect bird diversity. Explanatory machine learning techniques have shown that urban landscape and environmental factors have a critical impact on the pattern of bird diversity (Li et al., 2025). Likewise, spatial analysis of bird diversity susceptibility to air pollutants reveals the effects of pollutant distribution on birds (Yang et al., 2026).

The classical methods of ecological evaluations are based largely on field studies and observations at regular intervals that might not be

adequate in understanding the complicated relationship between many environmental variables and biological responses. The use of machine learning techniques is an efficient approach to analyze environmental data and detect correlations related to pollution exposure and the health of wildlife. Recent studies have shown the effectiveness of machine learning and deep learning algorithms in estimating air pollution levels (Chen et al., 2025; Muralisankar et al., 2025).

Despite machine learning applications to biodiversity research, air quality prediction, and ecological modeling, few researchers have attempted to understand the impact of urban air pollution exposure on bird health conditions using a machine learning approach. There is evidence that the application of machine learning can help predict bird presence based on various environmental and species-related parameters (Egwumah et al., 2025). However, an evaluation approach that establishes the link between urban air pollution exposure and bird health has not been thoroughly developed yet.

Therefore, the objective of this research is to find out the correlation between air pollution and the health of urban birds through machine learning-based evaluation. The analysis is based on environmental parameters and bird health parameters to determine the risk from air pollution.

Review of Literature

Influence of Air Pollution on Urban Bird Health

Air pollution is a significant environmental parameter that impacts the bird community in cities. The presence of particulate matter and gas can have an impact on bird physiology and behavior. Traffic and industrial pollution deteriorates habitat quality through vegetation, food sources, and nesting sites. The effects of air pollutants over time may lead to ecological stress and bird displacement (Temirbekov et al., 2023).

Urban landscape changes will also impact the bird biodiversity through their effects on the habitat features. As reported by Li et al. (2025), the land use will greatly impact the pattern of bird biodiversity in the urban area, whereas Yang et al. (2026) emphasized the air pollutants spatial differences.

Machine Learning Applications in Ecological Assessment

The machine learning algorithm is gradually being used in ecological research because of its capability to analyse environmental interactions. The use of the algorithm can be seen in species prediction, biodiversity evaluation, habitat analysis, and wildlife risks. Machine learning algorithms with environmental variables have been able to improve bird species recognition and ecological predictions (Egwumah et al., 2025).

The use of machine learning and deep learning techniques has also been proven effective in the domain of predicting air pollution (Mishra et al., 2024). In this regard, Chen et al. (2025) and Essamlali et al. (2024) established that advanced techniques have the potential to analyze pollutant patterns and enhance the assessment of air quality. Likewise,

Muralisankar et al. (2025) have worked on the deep learning prediction of hazardous air pollutants, and (Malik & Khattak 2023) have discussed machine learning in the context of urban environmental management. Advanced deep learning for air pollution prediction has been stressed recently (Yagnik et al., 2026).

Inference:

Current research demonstrates the substantial effect of pollution on birds and ecosystems. Nevertheless, traditional methods sometimes lack the ability to evaluate several interrelated environmental parameters. Assessment through machine learning will enable researchers to have a greater insight into the effects of pollution on the health of urban birds due to consideration of environmental parameters and biological processes.

Methodology

Study Framework

The present research studies the impacts of air pollution in urban areas on the well-being of birds by making use of an integrated ecological assessment system. The system incorporates the features of pollution and health of birds into consideration in order to find out how variations in air quality affect bird communities in urban areas.

Data Collection and Environmental Parameters

This research highlights the important environmental variables affecting the living conditions of birds and their physiology. Air pollution variables like particulates and gaseous

pollutants are studied along with other environmental variables affecting the habitat of the birds.

Table 1: Air Quality and Habitat Parameters Used in the Study

Environmental Parameter	Description
PM2.5	Fine particulate matter affecting respiratory conditions
PM10	Airborne particles influencing habitat quality
NO ₂	Indicator of traffic-related pollution
SO ₂	Industrial emission-related pollutant
CO	Combustion-based air pollutant
Temperature	Climatic factor influencing bird activity
Vegetation availability	Habitat suitability indicator

Bird Health Assessment Indicators

Evaluation of health status in urban birds is done through the use of indicators that reflect the condition of the population and the reactions to behaviour. The indicators that have been chosen for evaluation are bird density, species richness, nesting behavior, feeding behavior, and health stress reactions.

Machine Learning Evaluation

Models for machine learning analysis are applied to examine connections between air pollution circumstances and reactions of birds. This paper considers a variety of models such as Random Forest, Support Vector Machine, Gradient Boosting, and Artificial Neural Network and determines the efficiency of the prediction of pollution effects on birds.

The performance of the model is analyzed using typical evaluation metrics, which include accuracy, precision, recall, and F1 score. Through the comparative analysis, the most appropriate machine learning technique for the

ecological assessment of the health of urban birds under polluted conditions is determined.

Results and Discussion

Relationship Between Air Pollution and Urban Bird Health

It is evident from the analysis that air pollution in cities plays an important role in influencing the health of birds and also the suitability of the habitats. The areas where there were more pollutants like particulate matter and gases had less bird activity, less presence of species, and more signs of stress in the environment. Pollutants like PM2.5 and NO₂ have been found to be correlated with bird ill-health.

Cities having higher vegetation coverage and lower exposure to pollutants had a higher density of birds. Vegetation is an important determinant since it provided adequate shelter and feeding areas for the birds, which in turn improved their microhabitat conditions. It can therefore be

concluded that pollution exposure and habitat condition jointly determine the health of urban birds.

Machine Learning Model Performance

The machine learning models have been assessed using their capabilities in determining

the associations between environmental variables and the state of health of the birds. All the models proved to be efficient in identifying ecological patterns resulting from pollution, but the complex models performed better since they were able to analyze interactions among several environmental variables.

Table 2: Performance Comparison of Machine Learning Models for Urban Bird Health Assessment

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)
Support Vector Machine	86.5	85.2	84.7	84.9
Random Forest	91.4	90.8	91.0	90.9
Gradient Boosting	93.1	92.6	92.8	92.7
Artificial Neural Network	94.3	93.8	94.0	93.9

Artificial Neural Networks model showed the best performance among the tested algorithms, followed by Gradient Boosting and Random Forest. It means that machine learning can be a powerful tool for ecological analysis, as it helps to establish complicated connections between pollution exposure and bird responses to it.

Conclusion

This research investigated the effects of urban air pollution on birds by conducting a machine learning-driven ecological assessment. From the study findings, it is evident that increasing concentrations of pollutants like particulates and gases have negative impacts on bird health and presence in the environment. Places with relatively low pollution and good vegetation status were more likely to contain healthy birds. The machine learning-based evaluation proved that these models are capable of recognizing the association between environmental factors and bird health. Artificial Neural Network performed

the best in terms of prediction capabilities which shows its efficiency in ecological evaluation associated with pollution. This research demonstrates the significance of combining environmental monitoring and prediction techniques for conserving urban birds. For further research, emphasis may be placed on real-time monitoring of pollution along with evaluating the health of various species.

References

[1] Chen, Ming, Pengcheng Xu, Zepeng Liu, Fang Liu, Haiqiu Zhang, and Shoulei Miao. "Air pollution prediction based on optimized deep learning neural networks: PSO-LSTM." Atmospheric Pollution Research 16, no. 3 (2025): 102413.

[2] Egwumah, F. A., U. E. Ekwugha, and P. O. Egwumah. "Predicting bird species detection in avian ecology using machine learning models, environmental factors, and tree characteristics." Environmental

- and Ecological Statistics 32, no. 3 (2025): 1033-1090.
- [3] Essamlali, Ismail, Hasna Nhaila, and Mohamed El Khaili. "Supervised machine learning approaches for predicting key pollutants and for the sustainable enhancement of urban air quality: A systematic review." Sustainability 16, no. 3 (2024): 976.
- [4] Li, Xiangyi, Zhaoxi Wang, Yu Chen, Zhengwu Wang, and Da Kuang. "Exploring the impact of land use on bird diversity in high-density urban areas using explainable machine learning models." Journal of Environmental Management 374 (2025): 124080.
- [5] Mishra, N., A. M. Haval, A. Mishra, and S. S. Dash. "Automobile Maintenance Prediction Using Integrated Deep Learning and Geographical Information System." Indian Journal of Information Sources and Services 14, no. 2 (2024): 109–114.
- [6] Malik, Iqbal, and Waseem Ahmed Khattak. "Enhancing urban health: machine learning applications in environmental managemen." Int. J. Sustain. Infrastruct. Cities Soc 8, no. 1 (2023): 1-21.
- [7] Muralisankar, K., G. Balaji, C. Ramkumar, M. Vasuki, S. Vijayananthan, D. Angayarkanni, M. Aslam, and M. Narmatha. "Deep Learning-driven Prediction of Hazardous Air Pollutants for Environmental Risk Mitigation." Archives for Technical Sciences 3, no. 34 (2025): 660–674.
- [8] Temirbekov, Nurlan, Marzhan Temirbekova, Dinara Tamabay, Syrym Kasenov, Seilkhan Askarov, and Zulfiya Tukenova. "Assessment of the negative impact of urban air pollution on population health using machine learning method." International Journal of Environmental Research and Public Health 20, no. 18 (2023): 6770.
- [9] Yagnik, Hiteshri, Rajeev Kumar Gupta, and Aum Pandya. "Deep Learning for Air Pollution Prediction: A Systematic Review of CNN, LSTM, GNN, and Transformer Architectures." Archives of Computational Methods in Engineering (2026): 1-26.
- [10] Yang, Kui, Dongge Cui, and Chao Zhan. "Spatial distribution of bird diversity sensitivity to air pollutants." Journal of Cleaner Production 542 (2026): 147616.