

# Proactive Environmental Crime Detection Using Machine Learning and Multi-Source Data Fusion

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## ABSTRACT

Traditional methods struggle to detect concealed environmental crimes. This study proposes an intelligent framework that uses machine learning and multi-source data fusion (environmental, operational, and logistics) to proactively identify risks such as illegal discharge and waste transfer. Empirical results show improved timeliness and accuracy of detection. Despite high initial costs, long-term economic benefits are substantial. Challenges remain in algorithmic transparency, data sharing, and legal compliance. The framework provides actionable intelligence for law enforcement, bridges data silos to enable coordinated responses, and contributes to digital forensics and sustainable governance. Future integration with blockchain technology could enhance the integrity of digital evidence for prosecution.

## KEYWORDS

Intelligent Algorithms, Environmental Crime Prevention, Machine Learning, Multi-Source Data Fusion, Proactive Risk Detection, Digital Forensics, Algorithmic Transparency

## INTRODUCTION

Amid the rapid wave of global industrialization and urbanization, the field of environmental crime has undergone profound changes, exhibiting complex characteristics such as intensified concealment, the renovation of technical means, and cross-regional collaborative crimes (Van Uhm & Nijman, 2022). As economic activities expand and resource demands surge, environmental crime has evolved from isolated illegal acts into a highly organized and technologically sophisticated form of misconduct. Illegal mining activities wantonly destroy surface ecology, the illegal transfer of hazardous waste pollutes soil and water sources, and the secret discharge of pollutants that exceed standards directly endangers air quality (Hilson & Murck, 2000). These illegal acts occur frequently, causing not only immeasurable damage to the ecological environment but also seriously threatening public health and the sustainable development of society (Baylis & Nowak, 2023; Carvalho, 2017).

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Moreover, the growing digitization of industrial processes and supply chains has introduced new vulnerabilities that are increasingly exploited by actors engaged in environmentally harmful activities. Cyber-enabled environmental crimes—such as the manipulation of pollution monitoring systems or the falsification of regulatory compliance data—are on the rise, posing significant challenges to detection and enforcement. In this evolving landscape, traditional law enforcement tools and regulatory frameworks are proving insufficient to address the scale, speed, and sophistication of contemporary environmental offenses.

Traditional environmental crime governance predominantly relies on manual inspections and ex-post enforcement, which presents many operational disadvantages (van Rooij et al., 2025). Data dispersion makes it impossible to form an effective information synergy, and the data mastered by various departments are isolated from each other, making it difficult to conduct comprehensive analysis (Pansara, 2024); Late warning makes many environmental crimes discovered only after they have serious consequences, and the best prevention and control opportunity is missed (Insufficient departmental coordination makes each department act independently when facing environmental crimes, and cannot form an efficient prevention and control network. Faced with the increasingly dynamic and intelligent criminal model, the traditional prevention and control system appears incompetent (Jerome, 2020; Shover & Routhe, 2005).

Fortunately, the rapid development of intelligent technologies such as big data, machine learning, and blockchain has ushered in a new era in the prevention and control of environmental crime risks (Chauhan & Sahoo, 2024). These technologies can achieve in-depth integration and real-time analysis of multi-source data, enabling the construction of a closed loop for risk prediction, precise attack, and traceability governance (Yue & Shyu, 2024). By leveraging these advancements, authorities can shift from reactive enforcement to proactive risk management, enhancing transparency, accountability, and inter-agency collaboration.

Against this background, this study aims to develop an intelligent algorithm–empowered system to prevent and control environmental crime risk, while exploring pathways for collaborative innovation between technological solutions and institutional frameworks (Adel, 2023; Lavorgna & Ugwudike, 2021). By integrating multidimensional data—including environmental monitoring, enterprise operational records, and administrative penalty histories—this research employs machine learning models to identify high-risk patterns associated with environmental offenses. The proposed system seeks to significantly enhance the accuracy and timeliness of risk detection, thereby strengthening the modernization of environmental governance. Ultimately, this work contributes to advancing ecological civilization and supporting the achievement of China’s dual carbon goals (Hu et al., 2025).

## **LITERATURE REVIEW**

Braithwaite (2020) provided a macro-theoretical foundation for environmental crime prevention and control for this study. His analysis of crime governance in a risk society offers insights into the design of adaptive strategies for environmental offenses amid complex social conditions. This study’s intelligent algorithm–enabled prevention framework is built on an understanding of the limitations of traditional regulatory systems. Moreover, Braithwaite’s general theory of crime control supports a multi-dimensional interpretation of environmental risk governance, guiding the construction of evaluation indicators and the assessment of algorithmic effects.

Simpson et al. (2013) provided practical guidance for corporate environmental crime prevention. Their risk control framework informs the application of intelligent algorithms in enterprise supervision. This research draws on the identified regulatory nodes to optimize algorithmic modeling, particularly by integrating enterprise operational data and detecting high-risk behavioral patterns. Their conceptual logic also helps structure application scenarios, improving the precision of law enforcement resource allocation and the effectiveness of detection.

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