Environment, Resource and Ecology Journal (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/erej.2024.080120
ISSN 2616-3756 Vol. 8 Num. 1

Ways to Improve China's Ecological Governance Effectiveness through Artificial Intelligence

Hongwei Zhan[1,a], Wei Liao[1,b,*]

[1]*School of Marxism, Chongqing Technology and Business University, Chongqing, China*
[a]*zhanhongwei@ctbu.edu.cn*, [b]*liaowei1@ctbu.edu.cn*
[*]*Corresponding author*

Keywords: China's Ecological Governance; Artificial Intelligence; Environmental Development; Sustainable Development

Abstract: Although China has made remarkable achievements in ecological governance, it is imperative to acknowledge the persisting challenges. Firstly, the ecological monitoring and early warning system exhibit noteworthy imperfections, and access to information is delayed. Secondly, data integration and analysis are slow, and management decision-making lacks timeliness and accuracy. Thirdly, the ecological governance model implemented by the government's central authority is not energetic, and cross-sectoral cooperation is insufficient. China's efforts to improve the effectiveness of ecological governance are hindered by these obstacles. As one of the most important technological developments in the digital age, research indicates that artificial intelligence can expand the coverage of ecological monitoring, increase the speed of information acquisition and processing in ecological governance, improve the timeliness and scientificity of ecological decision-making, and strengthen multi-party cooperation to promote innovation in ecological governance models. Applying artificial intelligence to China’s ecological governance will definitely improve its effectiveness and promote sustainable development goals.

1. Introduction

Since the founding of the People's Republic, China has achieved rapid advancements in its economy. However, these advancements have been primarily driven by rapid industrialization and urbanization. This accelerated development is due to the intensive exploitation and utilization of resources, leading to substantial challenges in China's ecological and environmental management. Consequently, China is faced with serious environmental issues, including pollution, ecological destruction, and resource depletion[1]. Environmental problems not only hurt people's health and quality of life but also have a long-term negative impact on national development[2], putting the stability of ecosystems and the well-being of people at risk. Because of this, China is paying more and more attention to environmental protection and has proposed that "building an ecological civilization is vital for sustaining the development of the Chinese nation"[3]. In 2023 the State Council Information Office issued a White Paper on China’s Green Development in the New Era. It pointed out that from 2012 to 2021, China successfully completed 960 million acres of afforestation.

However, the effectiveness of ecological governance has a great deal of space for improvement. Improving the effectiveness of environmental governance poses a pressing challenge. This paper believes that the comprehensive and effective use of high technologies such as artificial intelligence (AI) is a crucial solution.

Since McCarthy first proposed Artificial Intelligence (AI) at the Dartmouth Conference in 1956, AI technology has rapidly evolved and impacted the world's technology, industry and people's way of life [4]. As a representative technology of the fourth industrial revolution, AI is also used as a labor tool to improve human productivity. It's widely used in human life. AI can likewise work to improve the effectiveness of ecological governance.

This paper explores how AI can be used to make the effectiveness of ecological governance better in China, reveals its potentials and limitations, and puts forward some suggestions to achieve more efficient ecological governance and foster sustainable development.

2. Materials and Methods

2.1. Challenges Facing the Effectiveness of Ecological Governance in China

Environmental sustainability has long been an important concern for the international community. It is defined as "meeting the resource and service needs of present and future generations without compromising ecosystem health"[5]. To ensure the sustainable development of the ecological environment, a series of ecological management measures have been implemented to protect, restore, and manage the ecological environment using scientific approaches. This can help to reduce environmental pollution and ecological damage while achieving sustainable development in production and lifestyles. Ecological governance in the narrow sense refers to the prevention, treatment and restoration of the natural environment and resources under the guidance of the principles of ecology; Ecological governance in the broad sense refers to the collaborative co-governance of ecological matters within a healthy governance community, where diverse governance entities, guided by green values, engage in a multiplicity of participation and dialogue-based governance approaches. This collective effort encompasses public affairs pertaining to the ecological domain and aims to formulate environmentally sound decisions that align with the interests of the majority, thereby advancing activities or processes that foster the greening of the "natural ecology, political ecology, and social ecology" nexus[6]. There is no doubt that ecological governance has an important impact on the ecological environment and contributes to economic and social sustainability. Even though China has made progress in environmental protection and governance over the years, there are still specific issues.

The Vice-President of the Chinese Academy of Environmental Planning stated, "The capacity of environmental governance is still a remarkable deficiency, and reform measures for ecological civilization must be synergistic. Inadequate environmental infrastructure and local capacity for environmental governance persist". The effectiveness of ecological governance is directly impacted by deficiencies in environmental governance competence. Numerous factors contribute to the ineffectiveness of ecological governance in China, including the absence of a social and cultural atmosphere in which everyone is concerned about environmental issues and participates in monitoring and evaluating them, the incomplete formation of good ecological qualities among citizens, and the inadequacy of the ecological governance mechanism and the absence of adequate penalties[7].

2.2. Three Factors Hamper the Effectiveness of China's Eco-governance

The effectiveness of China's eco-governance is hampered by the following three factors.

First, ecological monitoring and early warning systems are imprecise, and information is not accessible timely. In the contemporary era of information, the expeditious acquisition, distribution, and processing of information are becoming crucial factors for the effectiveness of ecological governance. Environmental monitoring is an important part of environmental management and the safeguarding of biodiversity[8]. Consequently, the acquisition of precise and timely environmental information is a fundamental requirement for enhancing the effectiveness of ecological governance.

During the 14th Five-Year Plan period, the improvement of the quality of the ecological environment has entered a critical period of transition from quantitative change to qualitative change, and in the face of the more difficult and complex task of pollution prevention and control, there are still a number of deficiencies and challenges in the supply of monitoring services, institutional mechanisms, and basic capacity, as well as weak or even missing monitoring support. In order to accelerate the establishment of a sound and modern ecological environment monitoring system, the Ministry of Ecological Environment issued the 14th Five-Year Plan for Ecological Environment Monitoring, in which it was pointed out that China's ecological environment monitoring was facing new challenges, and that the supply of monitoring services was still inadequate, the effectiveness of the monitoring reform still needed to be consolidated, and the development of basic capacity was not balanced. Although the Chinese government has invested significant resources in enhancing environmental monitoring, it is undeniable that in certain regions and areas, monitoring facilities are still inadequate and early warning systems are not highly modernized. In China's ecological governance process, untimely environmental monitoring has resulted in numerous severe consequences. A typical case is the Sichuan Tuojiang River water pollution incident in 2004.

Second, data integration and analysis are slow, and management decisions lack timeliness and accuracy. As China's economy and society continue to advance, there has been a significant increase in the volume of ecological environment data. Consequently, the conventional approach of relying solely on manual data processing has become progressively inadequate in meeting the growing demands of data processing. During the water pollution incident in the Hejiang River in Guangxi in 2013, it is evident that there exist significant shortcomings in both the promptness and precision of manually collected detection data. Furthermore, the manual processing of data is susceptible to the influence of subjective factors. The subjective consciousness, experience, and cognition of each individual exhibit variation. Diverse individuals may hold varying perceptions and assessments regarding identical information. This subjectivity of human participation will affect the accuracy of processing results. Ecological environmental issues are extremely uncertain and intricate, and the volume of data is exploding. It is difficult to keep up with the rapid changes in the ecosystem due to the limited capacity of manual information processing, which cannot account for all potential factors and complex relationships. As a result, the understanding of ecological and environmental issues lags behind, management decisions are frequently founded on outdated data, and effective governance measures cannot be developed in a timely manner.

Third, the ecological governance paradigm characterized by a singular governmental entity has limited dynamism and suffers from a dearth of interdepartmental collaboration and coordination. China has consistently upheld political centralization[9], even in the realm of ecological governance. The unitary governance model, characterized by a high concentration of governance subjects, offers efficiency benefits in decision-making. However, this model's limitations in terms of the government's governance capabilities hinder the improvement of China's ecological governance system and significantly impede the country's innovative vitality in this field. The unitary governance model, characterized by a high concentration of governance subjects, offers efficiency benefits in decision-making. However, the government's governance capabilities are limited[10], which is not conducive to the improvement of the ecological governance system and impacts

China's innovative vitality in ecology. Under the administratively-led unitary governance model, the departmental monopoly limits the overall coordination of ecological governance. The ecological governance model of a single government body usually concentrates decision-making and execution power in its own hands. Each department works alone and does its own business in all aspects. The absence of a well-defined allocation of tasks and essential coordination among different departments poses challenges in data sharing. China possesses an extensive geographical expanse, resulting in varying manifestations of environmental dangers across different regions in terms of their forms, modes of creation, and consequential impacts[11]. The subject of how to foster collaboration among diverse departments and regions in order to effectively address a range of environmental concerns and mitigate issues such as fragmentation and inefficiency merits thoughtful consideration.

3. Results and Discussion

The subject of AI has witnessed significant advancements in recent years, leading to its transition from an area of academic research to practical implementation. This shift has introduced novel concepts and approaches that will be able to enhance the effectiveness of China's ecological environment regulation.

3.1. AI Expands Ecological Surveillance Coverage and Improves the Speed of Information Acquisition

In 2015, the United Nations Sustainable Development Summit adopted the 2030 Agenda for Sustainable Development, which put forth 17 Sustainable Development Goals, and called on countries and regions to mobilize all available resources, work together to promote scientific and technological innovation, and explore effective implementation paths and solutions for the implementation of the SDGs. Among them, SDG6 (Ensure availability and sustainable management of water and sanitation for all), SDG13 (Take urgent action to combat climate change and its impacts), SDG14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development), etc. are all related to the environment. Monitoring the environment is vital to achieving SDGs.

AI helps enhance environmental monitoring[12], The integration of AI with contemporary technologies, including sensors, satellite remote sensing technology, and 5G, enables the development of a comprehensive monitoring, analysis, and prediction platform. This platform has the capacity to enhance the scope of automated monitoring and early warning systems for environmental conditions, facilitating the timely detection of pollution indicators within the environment. Detection of the atmosphere involves a variety of monitoring constituents. Increasing the duration and frequency of monitoring by installing multiple types of sensors in various locations can expand the monitoring coverage area. Multi-sensor integration permits real-time monitoring of carbon dioxide, PM2.5, etc. in the atmosphere. A large number of sensor nodes form a sensor network, upon which a blockchain data supervision system is built[13], allowing for the comprehensive collection of multiple monitoring environment parameters. The data obtained is transferred to the data centre using the high-speed transmission capabilities of 5G technology, enabling more precise environmental monitoring. AI machines possess the capability to acquire knowledge through experiential learning, adjust their behaviour in response to novel inputs, and execute tasks in a manner that resembles human performance[14]. They are able to effectively perform complex tasks that are beyond the capabilities of conventional labour procedures, automatically determine the level of pollutant concentration based on monitoring data, send warning messages when exceeding the threshold, quickly discover the existence of problems.

AI has demonstrated remarkable proficiency in extracting features in image matching tasks, enabling the identification of small variations that may elude human perception. The efficient interface between satellite remote sensing and AI, as well as the refined processing of remote sensing images based on AI, can obtain high-precision ecological information on time, capture accurate attribute information in a large amount of heterogeneous remote sensing data, and carry out intelligent processing of the ecological environment images to achieve remote monitoring of the environment. AI (AI) is utilized in various applications such as image denoising, image enhancement, and target monitoring to enable rapid, dynamic, and global intelligent processing of ecological environment images. Its primary objective is to facilitate water pollution monitoring by efficiently and accurately accessing relevant data, thereby reflecting the actual state of water pollution. AI-based methods are capable of effectively detecting pollutants that may go unnoticed by traditional approaches, providing more precise and detailed data compared to conventional methods. Consequently, these techniques enable comprehensive and timely assessment of water quality and pollution levels, serving as a foundation for decision-making in water environment regulation. (i.e., Figure 1)

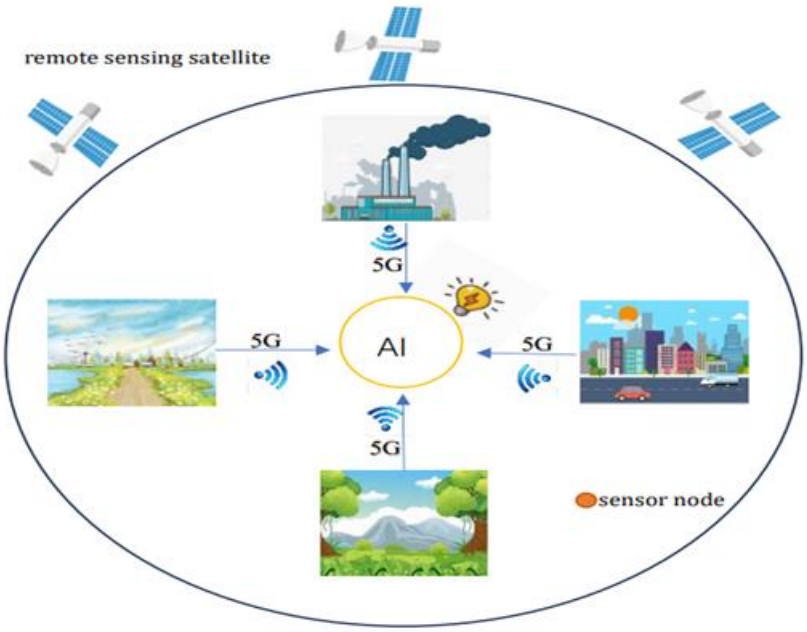

Figure 1: The remote sensing satellite and artificial intelligence work together to process ecological information.

3.2. AI speeds up the processing of data and makes decisions more quickly and scientifically

Nearly all human activities generate data, allowing us to gain new insights into the world, optimize resource utilization, and make informed decisions[15]. One of the key features of effective ecological monitoring is the frequent use of the data collected[16]. In the past, data handling methods that weren't very good couldn't promise that data would be correct and useful. This flaw can be fixed, though, with AI built on deep neural networks that can be used to analyse large amounts of data about ecological environments.

The powerful data processing and analysis capabilities of AI can effectively organize a large amount of heterogeneous data collected, and the use of text mining technology to filter raw ecological information can identify and filter redundant and ineffective information in a large amount of data and extract those environmental information that is truly useful, so as to rapidly

monitor pollution events and abnormalities, provide early warning of environmental threats, and provide prerequisites for timely adoption of ecological governance measures. The formulation and adjustment of ecological governance policies no longer rely solely on human experience, but are constructed based on AI data analysis and the deduction and prediction of policy outcomes.

With the help of satellite remote sensing images and historical data, we can perform complex calculations to accurately identify pollution sources across regions and even across time and space and their impact on environmental targets, and monitor and analyse the specific conditions of the ecological environment throughout the process. Additionally, AI has the potential to overcome information asymmetries and human emotional biases that have hindered the development of environmentally sustainable solutions[17]. Nepotism is prevalent in Chinese society, and rampant nepotism in local governments has also affected ecological governance. Personal emotions are inevitably involved when processing transmitted data. As AI lacks human emotions, it operates strictly in accordance with instructions, maintaining objectivity during the processing of ecological data. This enables it to offer more scientifically sound environmental assessments, aiding decision-makers in comprehending the true environmental circumstances. Consequently, decision-makers can base their ecological decisions on factual information, circumventing the impact of human emotions on decision-making, and thereby enhancing the scientific underpinning of ecological governance determinations.

3.3. Utilize AI to enhance multiparty cooperation and advance ecological governance model innovation

Effective ecological governance relies heavily on the quality of the information available for making appropriate decisions. Problems arise when the amount of information is large and inconsistent (i.e. from different sources) and the quality of the information cannot be determined in advance[18]. In 1998, the First International Conference on Natural Disaster Reduction Early Warning Systems adopted the Potsdam Early Warning Conference Declaration, stating that effective early warning depends on cross-disciplinary cooperation between all relevant departments based on science and technology. Chinese government emphasized the importance of resolving outstanding environmental issues and establishing an "environmental governance system with the government as the leader, enterprises as the main body, and social organizations and the public as participants". The cooperation between different departments is crucial in ecological governance.

The establishment of a comprehensive ecological information database will be facilitated by the integration of ecological monitoring data gathered by various environmental management departments, utilizing AI, cloud computing, the Internet of Things, and other relevant technologies. This information database not only aggregates vast amounts of data but also provides in-depth analysis of each region's unique characteristics, ecological conditions and specific issues. Moreover, these data analysis results will be shared and transmitted to relevant departments in a timely manner, effectively realizing information sharing and interoperability among cross-departmental governance entities, allowing all people to jointly participate in ecological governance, and thereby create a new environmental governance model. Its core feature is the joint participation of multiple subjects.

With the help of advanced technologies such as machine learning and deep learning, we can build highly accurate prediction models and classification models for environmental data. These models enable AI to learn complex correlations and potential patterns between data by analysing historical data and environmental parameters. Multiple subjects participate together, share resources, technology and experience, and propose different ecological governance measures. AI and virtual reality technology are combined to establish an ecological simulation system to visualize various environmental data and simulate the implementation of different policies and measures, presenting

the operating conditions of the ecosystem more vividly and intuitively and predicting its possible effects and potential risks, thus reducing trial and error costs and helping the government to reduce the cost of trial and error, help the government to formulate more targeted ecological governance measures, bring ecological governance policies closer to the actual situation, increase public participation, promote consensus, and promote the realization of the sustainable development goals. (i.e., Figure 2)

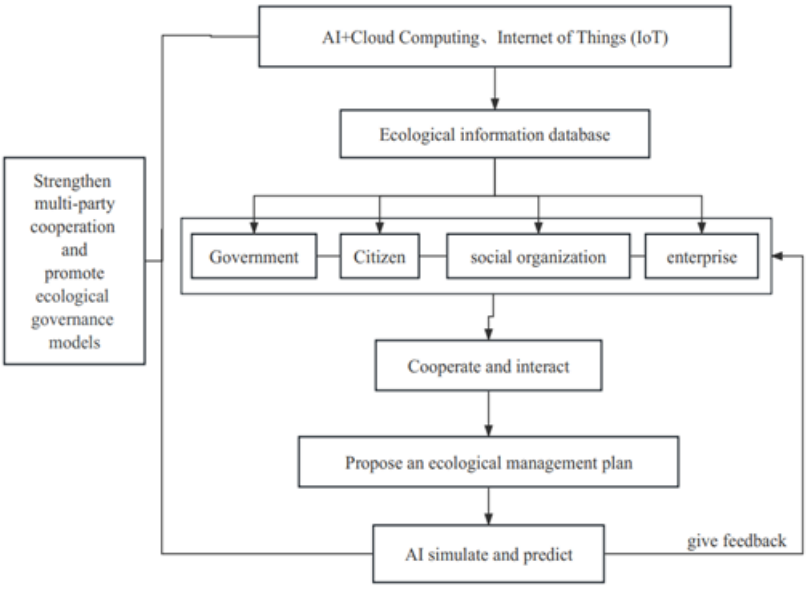

Figure 2: Ecological governance model for environmental data.

3.4. Potential Risks and Countermeasure Suggestions of AI Applications in China's Ecological Governance

While AI is integrated into China's ecological governance to provide new ideas and methods for improving the modernization of the ecological governance system and the governance capacity, a series of its problems in the field may also have a negative impact.

First, the algorithmic risk and negative environmental effects.

Environmental governance applications of AI rely heavily on data and algorithms. The algorithms and analysis models of AI are based on abstract theories, making it difficult to avoid technical errors. According to calculations by the Chinese education department, China's current gap in AI talents exceeds 5 million. The domestic supply and demand ratio is 1:10, which is a serious imbalance between supply and demand. Compared with developed countries, China's AI development is insufficient and there is a lack of relevant talent. Real-world data are gathered to train AI. It is relatively easy to collect data in most industries. In the field of environmental protection, ecological environment data are limited in terms of temporal scope and geographical distribution[19], and it is not easy to obtain relevant data[20] For instance, in the gathering of data concerning endangered animals, a substantial allocation of human resources and material investments is requisite. Owing to the intricacies of environmental factors, the pertinent data is perpetually susceptible to interference, thereby inducing bias in environmental data. After the integration of AI in data analysis and predictive modelling, there is a risk of exacerbating inherent environmental data biases. This has the potential to mislead decision-makers and lead to irremediable adverse consequences for environmental governance. Another study highlighted that contemporary deep neural networks, widely utilized today, can emit more than 280 tons of carbon

dioxide equivalent during extensive training sessions, surpassing five times the average carbon emissions produced over the lifecycle of a typical U.S. automobile. The establishment and operation of substantial computational facilities will result in high energy consumption and environmental issues such as carbon emissions, which will have a negative impact on the achievement of the Sustainable Development Goals (SDGs).

Suggestions: It is imperative to establish a comprehensive framework for evaluating AI systems. This framework should aim to minimize the influence of developer biases and algorithmic loopholes. Furthermore, it is crucial to incorporate pertinent knowledge from the environmental domain into the machine learning process. To achieve this, it is recommended to utilize diverse and balanced datasets. Additionally, it is essential to foster a deep integration of AI technology with ecological and environmental knowledge, thereby facilitating a transition towards environmentally sustainable practices. Moreover, efforts should be made to mitigate biases and discrimination within algorithms, while also reducing the computational complexity of AI processes. By doing so, issues such as excessive energy consumption and carbon emissions associated with AI applications can be minimized.

Second, the environmental data security and privacy exposure issues.

In ecological governance, AI algorithms need a lot of data. Some of this data is sensitive and involves national security and business secrets. If it is used badly, it could lead to a chain reaction of risks. In recent years both China and the relevant US technology development authorities have demonstrated quantum computing that is much faster than the most powerful classical computers, and while quantum computing will help with machine learning models and increase processing speeds, it will also increase the speed of hacking attacks[21]. In the "digital convenience" atmosphere created by AI technology, people are not always aware that their actions may lead to privacy leaks. Data breaches not only lead to the infringement of personal privacy but also possess the potential to adversely affect the security and long-term viability of the ecosystem. Eco-governance commonly entails the exchange of data among various organizations and institutions. Safeguarding the privacy and security of this data poses a significant challenge. Ensuring the secure transmission, storage, and sharing of data necessitates the implementation of robust communication protocols and encryption measures to mitigate the risk of unauthorized access or tampering. However, achieving such a level of security in practice is inherently arduous.

Suggestions: Network security requires the formulation of effective policies and measures at all levels (from individuals to the entire society). The resolution of this issue can be achieved through the establishment of explicit principles for safeguarding privacy, the establishment of regulations that ensure the legality and openness of data usage, the creation of regulatory bodies responsible for overseeing and enforcing these regulations, and the enhancement of technical and security measures.

Third, the risks of losing control over public opinion and ensuring justice.

The combination of AI and the Internet has accelerated the dissemination of information, resulting in increasing differences in environmental stances and increasingly sharp conflicts among various stakeholders, causing social resistance to the formulation and implementation of environmental policies. Unethical media outlets are prone to amplifying disparities in environmental governance stances with the aim of augmenting visibility and click-through rates. This practice leads to the dissemination of misinformation and public alarm, as diverse environmental perspectives and viewpoints rapidly proliferate. Consequently, the regulation of public opinion becomes more challenging, impeding the attainment of consensus on environmental governance policies. The predominant focus on the technical aspects of AI has prompted an increasing demand to delve into the social and ethical implications associated with this field. When considering resource allocation, the application of AI in ecological governance may involve allocation decisions of limited resources. The decision-making results of the algorithm may affect

the resource acquisition and benefit distribution of different groups or regions, which may trigger social dissatisfaction and unfairness, especially when resource allocation is biased towards certain interest groups or regions, this is more likely to happen. Uneven distribution of resource benefits will inevitably exacerbate social inequality and economic gaps. For example, in natural disaster risk management, if the algorithm prefers to protect wealthy areas and ignore disadvantaged areas, then AI technology cannot guarantee fair results but will lead to an increase in inequality.

Suggestions: Establish a transparent and timely information release and sharing platform, and enhance its interactive functions, so that the public can easily understand, participate in and provide feedback on environmental governance decisions, and reduce the possibility of public opinion crises. Establish and improve laws and regulations related to environmental governance, adhere to the people-centred approach to AI technology research and development, prevent possible risks of social injustice, and make up for the limitations of AI technology.

4. Conclusion

The study finds that China's ecological governance has many issues with information acquisition, transmission, and processing, primarily due to a lack of intelligence and modernization of technical means. The application of AI can significantly improve the efficiency of information acquisition, transmission, and processing in ecological governance, allowing decision-makers to respond and implement scientific solutions to ecological problems more rapidly. Opportunities and problems are concurrently present. To enhance the integration of AI (AI) in ecological governance, it is imperative to emphasize the reinforcement of the synergy between data-driven algorithms and environmental domain expertise. Additionally, the enhancement of relevant legal frameworks and regulations, as well as the strengthening of oversight and enforcement mechanisms, are crucial in mitigating or preventing potential risks. In addition to assuring the sustainable growth of technology, our objective is to foster the sustainable development of the natural environment.

References

[1] Wang W, Sun Y, Wu J. Environmental warning system based on the DPSIR model: A practical and concise method for environmental assessment [J]. Sustainability, 2018, 10(6): 1728.

[2] Sun, Y. P. The theoretical contribution of Xi's ecological civilization thought to environmental economics [J]. Journal of Nanjing University, 2019, 3: 1-9.

[3] Xi, J. P. Notes on the Resolution of the Central Committee of the Communist Party of China on the Major Achievements and Historical Experience of the Party's Centennial Struggle[J]. People's Weekly, 2021: 4-8

[4] McCarthy, J. Artificial Intelligence, Logic, and Formalizing Common Sense. Machine Learning and the City: Applications in Architecture and Urban Design, 2022: 69-90. https://doi.org/10.1002/9781119815075.ch6

[5] Morelli J. Environmental sustainability: A definition for environmental professionals[J]. Journal of environmental sustainability, 2011, 1(1): 2. http://doi.org/10.14448/jes.01.0002

[6] Shi, Y. G., Meng, Q. County ecological governance capacity: concept, elements and system construction[J]. Journal of Sichuan University (Philosophy and Social Science Edition), 2018, 5-13.

[7] Mol A P J, Carter N T. China's environmental governance in transition[M]//Environmental governance in China. Routledge, 2013: 1-22.

[8] Hays G C, Bailey H, Bograd S J, et al. Translating marine animal tracking data into conservation policy and management [J]. Trends in ecology & evolution, 2019, 34(5): 459-473.

[9] Maskin E, Qian Y, Xu C. Incentives, information, and organizational form[J]. The review of economic studies, 2000, 67(2): 359-378.

[10] He G, Lu Y, Mol A P J, et al. Changes and challenges: China's environmental management in transition[J]. Environmental Development, 2012, 3: 25-38.

[11] Fan, X. S. Progress of Research on International Early Warning System and Its Implications for Domestic Early Warning Research on Ecological Environment[J]. Acta Ecologica Sinica, 2021, 41: 7454-7463.

[12] Hino M, Benami E, Brooks N. Machine learning for environmental monitoring[J]. Nature Sustainability, 2018, 1(10): 583-588.

[13] Xu K. Artificial intelligence unlocks ecological environment governance—smart statistical monitoring based on meteorology [J]. Multimedia Tools and Applications, 2023: 1-13.
[14] Duan Y, Edwards J S, Dwivedi Y K. Artificial intelligence for decision making in the era of Big Data–evolution, challenges and research agenda[J]. International journal of information management, 2019, 48: 63-71. https://doi.org/10.1016/j.ijinfomgt.2019.01.021
[15] Alam J R, Sajid A, Talib R, et al. A review on the role of big data in business[J]. International Journal of Computer Science and Mobile Computing, 2014, 3(4): 446-453.
[16] Lindenmayer D B, Likens G E. The science and application of ecological monitoring[J]. Biological conservation, 2010, 143(6): 1317-1328. https://doi.org/10.1016/j.biocon.2010.02.013
[17] Cullen-Knox C, Eccleston R, Haward M, et al. Contemporary Challenges in Environmental Governance: Technology, governance and the social licence [J]. Environmental policy and governance, 2017, 27(1): 3-13. https://doi.org/10.1002/eet.1743
[18] Cortès U, Sànchez-Marrè M, Ceccaroni L, et al. Artificial intelligence and environmental decision support systems[J]. Applied intelligence, 2000, 13: 77-91. https://doi.org/10.1023/A:1008331413864
[19] Siddig A A H. Why is biodiversity data-deficiency an ongoing conservation dilemma in Africa?[J]. Journal for Nature Conservation, 2019, 50: 125719. https://doi.org/10.1016/j.jnc.2019.125719
[20] Overpeck J T, Meehl G A, Bony S, et al. Climate data challenges in the 21st century[J]. Science, 2011, 331(6018): 700-702. http://doi.org/10.1126/science.1197869
[21] Denning D E. Is Quantum Computing a Cybersecurity Threat? Although quantum computers currently don't have enough processing power to break encryption keys, future versions might[J]. American Scientist, 2019, 107(2): 83-86.