

# Transformation of Natural Resource Management in the Digital Era: a Review of Technology Integration, Social Justice, and Environmental Sustainability

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## ABSTRACT

This research examines the complexity of contemporary environmental issues through a holistic approach that integrates technological, social, economic, and ecological dimensions in natural resource management. Utilizing a qualitative literature review methodology of over 60 international literatures, this study identifies the interconnections between land degradation, climate change, and social injustice that threaten global stability. The main contribution is the development of the concept of "digital environmental governance" which integrates AI foundation models with participatory governance mechanisms for scalable yet locally relevant environmental monitoring. The findings show the economic urgency with global losses due to biodiversity loss reaching \$10 trillion per year, while the agricultural sector that provides 95% of the world's food is experiencing degradation on more than 60% of agricultural land. Research reveals that intensive agricultural practices, extractive industries, and resource distribution inequalities exacerbate environmental degradation and trigger social conflicts. Proposed solutions include the implementation of a circular economy, sustainable agriculture, and the integration of real-time sensor-based monitoring technology with local community wisdom. A multidisciplinary approach that synergizes stakeholders (government, private sector, academia, and communities) has proven essential for developing innovative policies that respond to the dynamics of environmental changes and ensure justice in natural resource management

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## INTRODUCTION

### Problem Background

The management of natural resources and the environment has become one of the most crucial challenges in the Anthropocene era, where human activities have a transformative impact on the planet's systems. The increasingly intensive pressure on the environment due to global population growth, massive urbanization, and ongoing industrialization has created a complex dilemma between the need for economic development and the preservation of ecosystems. This situation is exacerbated by land degradation, which has reduced the productivity of 23% of global terrestrial areas, with annual economic losses reaching \$235-577 billion due to the loss of ecosystem services, particularly in the agricultural sector (Mirzabaev et al., 2023; F. A. Putri, 2024). Indonesia, as an archipelagic country with extraordinary biodiversity wealth, faces specific challenges in managing 65.8 million tons of solid waste per year in 2017, which is expected to continue to increase significantly (Akinyi, 2024; Handini et al., 2025; Keck et al., 2025; Reber et al., 2022). The current environmental degradation not only impacts ecological aspects but also creates systemic threats to food security, water security, and global economic stability (Mirzabaev et al., 2023; F. A. Putri, 2024). Recent data shows that biodiversity loss has reached alarming levels, with the current extinction rate of species being 10-100 times higher than natural levels (Keck et al., 2025). This phenomenon threatens essential ecosystem services, including plant pollination worth over \$235 billion per year globally. Indonesia, as an archipelagic country with extraordinary biodiversity wealth, faces specific challenges in managing 65.8 million tons of solid waste per year in 2017, which is expected to continue to increase significantly (Akinyi, 2024; Handini et al., 2025; Keck et al., 2025; Reber et al., 2022). The current environmental degradation not only impacts ecological aspects but also creates systemic threats to food security, water security, and global economic stability (Mirzabaev et al., 2023; F. A. Putri, 2024). Recent data shows that biodiversity loss has reached alarming levels, with the current extinction rate of species being 10-100 times higher than natural levels (Keck et al., 2025). This phenomenon threatens essential ecosystem services, including plant pollination worth over \$235 billion per year globally. Meanwhile, the development of digital technology and high industry, while offering innovative solutions for environmental monitoring, also creates new pressures through the extraction of rare minerals and massive energy consumption. This paradox demands a holistic approach that integrates technological, social, economic, and ecological dimensions in the management of natural resources (AbdelRahman, 2023).

### Importance of the Issue

The urgency of managing natural resources and the environment sustainably is increasing in line with the acceleration of the global ecological crisis and its impact on human well-being. Recent reports indicate that over 24 billion tons of fertile land are lost each year in global agricultural lands, with 33% of the world's soil experiencing degradation due to various disturbances (Mirzabaev et al., 2023; Nandi et al., 2025). This situation not only threatens agricultural productivity but also exacerbates the food insecurity already faced by billions of people worldwide (Robinson, 2024). In Indonesia, projections show that

electricity consumption will triple by 2025, while waste production is also experiencing significant increases, intensifying pressure on the environment (AbdelRahman, 2023; Handini et al., 2025).

The social dimension of environmental management has crucial relevance in the context of intergenerational justice and long-term sustainability (Harsya et al., 2024; Ruhl, 1999). Community participation in environmental management has been shown to increase the effectiveness of conservation programs by up to 77.7%, with 52.21% of the community willing to actively engage in community meetings for environmental management (Ramadani, 2025; Ramadhani et al., 2024). Recent research also confirms that community-based approaches in sustainable forest management have significant positive impacts, with three key factors: the appropriateness of the empowerment process, the role of community empowerment workers, and the support of group leaders (Mees et al., 2019; Ramadani, 2025; Tambunan et al., 2024; Wiyono et al., 2023). This finding underscores the importance of integrating local wisdom with modern scientific approaches in creating sustainable and equitable solutions (Harsya et al., 2024; D. W. Kusuma et al., 2024; Ramadani, 2025; Rohendi et al., 2024; Ruhl, 1999; Tambunan et al., 2024). The economic aspects of the environmental crisis also demonstrate an urgent concern that cannot be ignored, with global economic losses due to biodiversity loss estimated at \$10 trillion per year (Keck et al., 2025; Nandi et al., 2025). The agricultural sector, which provides 95% of the world's food, faces serious threats from land degradation, with over 60% of degradation occurring in agricultural lands, including farmland and pasture (Mirzabaev et al., 2023; Nandi et al., 2025; F. A. Putri, 2024). In the context of climate change, drought has been responsible for almost half of all agricultural losses over the past 30 years, with 5% of global agricultural GDP lost each year due to climate-related disasters (Robinson, 2024). This phenomenon indicates that sustainable natural resource management is no longer an option, but a necessity to ensure global economic and social stability.

### **Research Objectives**

This research aims to comprehensively analyze the paradigm of sustainable natural resource and environmental management by integrating a multidisciplinary approach that encompasses ecological, technological, social, and economic dimensions (A. Kusuma & Firdaus, 2022; S. Nugraha, 2023). The main objective of the study is to evaluate the effectiveness of management strategies that combine green technology innovations with community participation based on local wisdom to create adaptive solutions to contemporary environmental challenges (D. W. Kusuma et al., 2024; Mees et al., 2019; Ramadani, 2025; J. Zhang et al., 2023). Specifically, this research seeks to identify an integration model between artificial intelligence and Internet of Things (IoT)-based environmental monitoring technology and traditional knowledge systems to enhance the effectiveness of ecosystem monitoring and management (Ajakwe et al., 2025; Chauhan & Sahoo, 2024; Lahudin et al., 2024; Olawade et al., 2024).

This research also aims to evaluate the role of green technology in improving the efficiency of natural resource utilization, particularly in the context of transitioning towards a sustainable circular economy (Becchetti et al., 2025; Jha et al., 2024; J. Zhang et al., 2023). Special focus is given to analyzing how technological innovations can support sustainable agricultural practices, effective waste management, and biodiversity conservation through an integrated approach (Gamage et al., 2024; Handini et al., 2025; Keck et al., 2025; Reber et al., 2022; Robinson, 2024). Additionally, this research examines the dynamics of community participation in environmental management programs by analyzing the factors that influence the willingness of communities to engage actively in conservation initiatives and sustainable development (Mees et al., 2019; Rafinzar et al., 2025; Ramadhani et al., 2024).

The methodological aim of this research is to develop an analytical framework that can integrate quantitative data from remote sensing technology with qualitative data from local knowledge and practices (Manapragada et al., 2025). This approach is expected to provide a more holistic understanding of the dynamics of socio-ecological systems and identify leverage points for effective policy interventions. This research also aims to analyze the contribution of digital technology in supporting the implementation of the Sustainable Development Goals (SDGs) (Jha et al., 2024; Menton et al., 2020), particularly related to natural resource management, climate action, and biodiversity conservation (Akinyi, 2024; Keck et al., 2025; Quigley, 2024).

### **Research Novelty**

The main novelty of this research lies in the integrative approach that combines artificial intelligence (AI) technology and the Internet of Things (IoT) with local wisdom in the context of natural resource and environmental management (Ajakwe et al., 2025; Chauhan & Sahoo, 2024; D. W. Kusuma et al., 2024; S. Nugraha, 2023; Ramadhani, 2025). Unlike previous studies that tended to focus on a specific dimension, this research develops a holistic framework that integrates real-time data from IoT sensors for environmental quality monitoring with the traditional knowledge of local communities in ecosystem management (Ajakwe et al., 2025; Chauhan & Sahoo, 2024; D'Amato & Korhonen, 2021). This methodological innovation allows for a more comprehensive analysis of the dynamics of socio-ecological systems and provides a strong basis for the development of adaptive strategies that are responsive to environmental changes (Arowolo et al., 2024).

Another aspect of novelty is the development of a community participation model based on a religio-cultural approach to strengthen community involvement in environmental management. This research introduces the concept of 'inclusive green technology' that not only focuses on technical efficiency but also considers social-cultural dimensions and the accessibility of technology for local communities (Ariani et al., 2025; Jha et al., 2024; Ramadhani et al., 2024). This approach differs from conventional green technology paradigms that often overlook the aspects of participation and community empowerment in its implementation (Ahmad et al., 2023; Loainak et al., 2023; Mees et al., 2019; Tambunan et al., 2024; Wiyono et al., 2023).

The significant theoretical contribution of this research is the development of the concept of 'digital environmental governance' that integrates AI foundation models for environmental monitoring with participatory governance mechanisms (Jha et al., 2024; Muhammad et al., 2025; Zen et al., 2019). This model offers scalable solutions for environmental monitoring challenges in vast areas while maintaining local relevance through the adaptation of machine learning algorithms based on the specific conditions of each ecosystem. This novelty provides an important contribution to the literature on environmental governance by demonstrating how digital technology can enhance, rather than replace, local knowledge systems and practices (Guarnieri et al., 2025; Jha et al., 2024; Muhammad et al., 2025; Strong et al., 2025; Zen et al., 2019).

The practical innovations of this research are also reflected in the development of new indicators and metrics to measure the effectiveness of technology-community integration in environmental management. This research introduces the concept of "adaptive resilience index" which combines objective data from technological monitoring with subjective assessments from local communities about ecosystem health and community well-being (Manapragada et al., 2025; Zen et al., 2019). This evaluation framework provides more robust tools to assess the success of environmental management programs and can be adapted to various geographical and cultural contexts, thus making a significant methodological contribution to the field of environmental management science (Ariani et al., 2025; Guarnieri et al., 2025; Rafinzar et al., 2025).

## LITERATURE REVIEW

### 1. Management of Natural Resources (NR)

The management of natural resources and the environment is a field of study that focuses on systematic efforts in managing the various natural potentials available on Earth, both renewable and non-renewable, to ensure sustainable utilization (A. Kusuma & Firdaus, 2022; S. Nugraha, 2023). The approach in this management emphasizes the balance between exploitation and preservation, considering ecological, economic, social, and political aspects. Amid the increasing pressure on the environment due to population growth, urbanization, and industrialization, sustainable management practices have become crucial to guarantee the availability of resources for future generations (Ayu Shinta Dewi, 2025; Wijayanti et al., 2020). The basic concepts of natural resource and environmental management include the principles of sustainability, efficiency, and justice in utilization (Harsya et al., 2024; S. Nugraha, 2023). Sustainability demands that the use of resources does not harm ecosystems and can continue without sacrificing its ecological functions. Efficiency refers to the economical yet optimal use of resources, while justice refers to the equitable distribution of benefits and burdens among community groups and across generations (Harsya et al., 2024). These three principles serve as the main pillars in the formulation of adaptive and effective management policies (Hutapea & Manurung, 2021).

The management of natural resources and the environment is multidisciplinary, as it requires not only a technical approach from environmental or forestry sciences, but also an understanding of economics, law, sociology, and even politics. The interaction between humans and the environment is the focus of attention, where humans act as agents of change as well as guardians of sustainability (Hallaj et al., 2024; S. Nugraha, 2023). Therefore, the participation of communities, the government, and the business world is crucial for the success of an environmental management system. Each stakeholder has moral and legal responsibilities to protect ecosystems from damage (Ramadhan et al., 2022).

The scope of natural resource management includes all activities related to the planning, utilization, monitoring, and evaluation of various types of resources such as water, land, air, forests, mines, and biodiversity (Akinyi, 2024; Keck et al., 2025; S. Nugraha, 2023). This scope, in addition to the quantitative dimension, also includes the quality and function dimensions of these resources. Management activities often involve environmental impact assessments, the application of environmentally friendly technologies, and the preparation of management plans based on local communities (L. M. Sari & Nugroho, 2023). In the current era of globalization, the challenges of managing natural resources have become increasingly complex due to external influences such as climate change, energy crises, and international trade. Therefore, a systems approach in management becomes important to understand the relationships between biotic and abiotic components in a landscape (Akinyi, 2024). This approach emphasizes the importance of integrating scientific data, stakeholder participation, and the utilization of information technology to create evidence-based decision-making (Z. Ismail et al., 2021; Mees et al., 2019; Ramadhani et al., 2024; Y. Zhang et al., 2020).

Legal and institutional aspects in natural resource management are also an important part of the management framework (Arsovski et al., 2012; S. Nugraha, 2023; Ostojić et al., 2023; STANIŠIĆ et al., 2025). Environmental law functions as a regulatory instrument in balancing individual rights and public interests. Institutions, both formal and informal, provide coordination mechanisms among parties involved in management, including conflict resolution mechanisms and oversight of policy implementation (STANIŠIĆ et al., 2025; von Lüpke et al., 2023). The effectiveness of these institutions heavily depends on human resource capacity and the quality of governance (Muhammad et al., 2025; Ostojić et al., 2023; STANIŠIĆ et al., 2025; Yuliana & Prabowo, 2020). The importance of the precautionary principle in natural resource management reflects the need for an anticipatory attitude towards the possibility of permanent damage to the environment (S. Nugraha, 2023). In many cases, preventive actions are more efficient and cost-effective compared to recovery efforts after environmental degradation has occurred (Nandi et al., 2025; F. A. Putri, 2024). This emphasizes that good management is not only reactive but also proactive in responding to threats and pressures on ecosystems (D. K. Putri & Wibowo, 2022). In addition to physical and institutional aspects, the social dimension in environmental management also plays a central role. The community's view of

natural resources, besides having economic value, also possesses cultural and spiritual value (Ariani et al., 2025). Community-based approaches and local empowerment become important strategies in ensuring the success of management programs (Loainak et al., 2023; Tambunan et al., 2024; Wiyono et al., 2023). Active participation from the community can enhance a sense of ownership, strengthen social control, and reduce the risk of conflict (Limsaku et al., 2025; Mees et al., 2019; Ramadhani et al., 2024; Suryani et al., 2021; Y. Zhang et al., 2020).

In the context of public policy, the management of natural resources and the environment must be designed to be adaptive and responsive to social-ecological dynamics (Muhammad et al., 2025; S. Nugraha, 2023). The adaptive approach acknowledges that environmental systems are complex and not always predictable, thus management must be accompanied by continuous learning and periodic evaluation. Top-down policies often fail because they do not take into account the local context and community aspirations; therefore, there is a need for integration between national policies and local initiatives (Utami & Suhendra, 2023; Y. Zhang et al., 2020).

Understanding natural resource and environmental management is not only a conceptual understanding of how to manage natural resources sustainably, but also a foundation for strategic thinking in facing environmental challenges in the present and future (S. Nugraha, 2023). There needs to be synergy between science, policy, technology, and local wisdom to produce fair and sustainable management for all living beings (D. W. Kusuma et al., 2024; Muhammad et al., 2025; Ramadani, 2025).

### 1. Types of Natural Resources

Natural resources (NR) are fundamental elements that support human life and the social and economic development processes around the world. NR includes all materials and energy that are naturally available on Earth and can be used for various life purposes, both directly and indirectly. NR is divided into two major groups: renewable resources such as water, land, forests, and solar energy, and non-renewable resources such as coal, petroleum, and metal minerals. The fundamental difference between the two lies in their regenerative capacity, which directly affects the sustainability of their use in the long term (M. T. Ahmed et al., 2020).

The utilization of natural resources has driven rapid progress in various sectors, ranging from industry, agriculture, to technology. Natural resources have become the main raw materials in the production of goods and services, as well as strategic commodities in international trade (Ayu Shinta Dewi, 2025; Gamage et al., 2024). However, the high intensity of exploitation of natural resources, especially non-renewable ones, often ignores sustainability principles. In this context, an integrated management approach is necessary so that the utilization of natural resources does not lead to ecosystem degradation and an increasingly severe environmental crisis (F. A. Putri, 2024; Robinson, 2024; Y. Zhou et al., 2021).

One of the main challenges in the utilization of natural resources is the disparity between natural capacity and human demand (Fan & Wang, 2024). Rapid population growth and rising living standards have put extraordinary pressure on available resources. For example, excessive exploitation of tropical forests for agricultural land or plantation industries has led to massive deforestation, resulting in the loss of biodiversity and disruption of the hydrological cycle (Firdaus et al., 2022; Gamage et al., 2024; Hallaj et al., 2024; Keck et al., 2025; Koo et al., 2024; Sloan & Sayer, 2019). Moreover, environmentally unfriendly mining exploration also causes land degradation and water pollution (Mirzabaev et al., 2023; F. A. Putri, 2024).

Types of natural resources have different ecological and economic characteristics, which influence the way and intensity of their utilization. Water, as a renewable resource, is crucial for life, agriculture, energy, and industry (Gamage et al., 2024; Robinson, 2024). However, in many areas, its availability is uneven and its quality is declining due to pollution from both domestic and industrial waste (Ayu Shinta Dewi, 2025; Handini et al., 2025). Meanwhile, fossil fuel resources such as petroleum and natural gas remain the backbone of global energy, even though their existence is increasingly depleting and their use generates high carbon emissions that impact climate change (Moss et al., 2020).

## **METHODOLOGY**

### **Research Approach**

This research uses a Qualitative Literature Review (QLR) approach to analyze and synthesize literature related to natural resource and environmental management. Unlike a systematic literature review that uses a highly structured protocol and is limited to strict inclusion criteria, a qualitative literature review allows for greater flexibility in exploring complex and multidisciplinary themes in environmental management. The QLR approach was chosen for its ability to integrate diverse theoretical perspectives and provide in-depth interpretations of complex socio-ecological phenomena.

*Qualitative literature review* is a research methodology that combines data or results from multiple studies to produce new knowledge, theories, and applications. In the context of this research, QLR is used to identify, analyze, and synthesize findings from various empirical studies that have been published in reputable international journals. This approach allows researchers to perform "reciprocal translation" of key concepts across studies and to develop more comprehensive descriptive and analytical themes.

### **Design and Review Strategy**

This research applies a thematic synthesis approach as the primary method in a qualitative literature review, following a three-stage framework that has proven effective in environmental research: (1) free line-by-line coding of findings from primary studies; (2) development of descriptive themes; and (3) generation of analytical themes that transcend the primary studies. Thematic synthesis is chosen for its ability to maintain an explicit and transparent relationship between conclusions and the texts from primary studies, while also facilitating the production of new concepts and hypotheses. This approach has

proven effective in research on natural resource management and environmental governance (Muhammad et al., 2025; Zen et al., 2019).

The review strategy adopts the Complex Adaptive Systems (CAS) paradigm to understand the dynamics of socio-ecological systems in the context of natural resource management. This framework enables a more comprehensive analysis of the complex interactions between technological, social, economic, and ecological dimensions in environmental management. This research also integrates a critical interpretive synthesis perspective to capture the theoretical and practical nuances of various approaches to sustainable environmental management.

#### **Data Sources and Selection Criteria.**

Literature search was conducted through reputable international academic databases including Scopus, Web of Science, ScienceDirect, PubMed, and Google Scholar to ensure comprehensive coverage of high-quality publications. Inclusion criteria include: (1) articles published in indexed journals; (2) publication years 2015-2025 to ensure relevance and currency of findings; (3) research focus on natural resource management, environmental management, or sustainability; (4) available in English or Indonesian; and (5) employing verifiable research methodology (Nurhadi Kumayza et al., 2025)..

The search strategy used a combination of keywords tailored to the terminology in the field of environmental management: "natural resource management", "environmental sustainability", "community participation", "technology integration", "green innovation", "ecosystem services", "biodiversity conservation", and "climate adaptation". The selection process was conducted iteratively to ensure diversity in theoretical and empirical perspectives within the study sample. Exclusion criteria included articles that focused solely on technical aspects without a socio-ecological dimension, publications that were not peer-reviewed, and studies with unclear methodologies (Gandhi et al., 2025).

#### **Analysis and Synthesis Process.**

Qualitative synthesis is conducted by integrating findings from various geographical, institutional, and methodological contexts to identify patterns, contradictions, and gaps in the existing literature. This research also applies reflexivity and bracketing as a form of self-reflection to control potential biases in data interpretation. The final analysis framework is developed through iterative refinement based on the synthesis themes that emerge from the data, ensuring that the resulting theoretical constructions are empirically grounded but conceptually robust.

## RESULTS AND DISCUSSION

### 1. Utilization and Its Impact on the Environment

In the agricultural sector, the intensive use of land and water resources is often accompanied by the use of chemicals such as fertilizers and pesticides. Although this increases productivity, it also has negative impacts on soil fertility, water quality, and human health. Land degradation due to erosion, salinization, and deforestation exacerbates these conditions (Hallaj et al., 2024; Mirzabaev et al., 2023). Therefore, sustainable agricultural practices that integrate conservation and resource efficiency become essential to implement (Fan & Wang, 2024; Gamage et al., 2024; Robinson, 2024; Y. Zhang et al., 2023).

The energy sector is a major user of natural resources, especially non-renewable ones. Dependence on fossil fuels not only depletes natural resource reserves but also worsens environmental conditions through carbon emissions that lead to global warming. The energy transition towards the utilization of renewable energy such as solar, wind, and biomass is now a primary focus in global sustainability strategies. Renewable energy is not only more environmentally friendly but also helps reduce dependence on increasingly scarce resources (Algarni et al., 2021).

The utilization of natural resources in the industrial sector also poses significant ecological challenges (Ayu Shinta Dewi, 2025). Many extractive industries, such as mining and metal processing, generate hazardous waste that contaminates air, water, and soil. This pollution has a direct impact on public health and the survival of other species. Therefore, the implementation of circular economy principles, which emphasize efficiency, recycling, and waste reduction, becomes highly relevant in the context of industrial natural resource management (Ayu Shinta Dewi, 2025; Becchetti et al., 2025; D'Amato & Korhonen, 2021; Fan & Wang, 2024; Garcia-Barragan et al., 2020; Handini et al., 2025).

In addition to the direct environmental impacts, the utilization of natural resources also has social consequences. Competition for access to natural resources, such as water and land, can trigger conflicts between community groups or even between countries. Disparities in resource distribution often lead to the marginalization of certain groups, particularly indigenous peoples and local communities that directly depend on nature. Therefore, the aspect of justice in the management of natural resources needs to be a primary concern in policies and development planning (Andersson et al., 2021; Harsya et al., 2024).

The environmental impact of the utilization of natural resources is not only local but can also spread regionally and globally. One striking example is the contribution of deforestation and fossil fuel burning to carbon emissions that accelerate global climate change. Climate change, in turn, exacerbates uncertainties in the availability of natural resources such as water and agricultural yields, as well as increases the risks of natural disasters such as floods and droughts. The integration of natural resource management and climate change mitigation has become inseparable (Guarnieri et al., 2025; Hansen et al., 2019).

Sustainable natural resource management requires a multidisciplinary approach that involves ecological, economic, social, and political aspects. Management strategies cannot merely focus on economic optimization; they must also consider environmental carrying capacity and the rights of local communities. Concepts such as political ecology, environmental justice, and sustainable development should be the foundation in decision-making related to natural resource utilization (Atapattu et al., 2021; Harsya et al., 2024). Community involvement in the planning and oversight processes is crucial to ensure that the use of natural resources is genuinely aligned with long-term common interests (Pascual et al., 2020; Robinson, 2024).

Awareness of the limitations of natural resources has spurred the emergence of various international initiatives for conservation and responsible management. The Convention on Biological Diversity (CBD), the 2030 Agenda with the Sustainable Development Goals (SDGs), and the Paris Agreement are some examples of global efforts that emphasize the importance of wise management of natural resources (Menton et al., 2020). However, the effectiveness of their implementation heavily relies on political commitment, institutional capacity, and active public participation (Lele et al., 2020; Mees et al., 2019; Ramadhani et al., 2024; STANIŠIĆ et al., 2025; Y. Zhang et al., 2020). Natural resources play a central role in the dynamics of development and human welfare. However, without wise and prudent management, the utilization of natural resources can become a source of complex ecological and social crises. Collaborative efforts from all parties, such as the government, private sector, academics, and society, are needed to maintain the sustainability of natural resources for a more sustainable and equitable future (Surono & Hidayati, 2024; Syahrani et al., 2024).

### **Instruments and Policies in Environmental Management**

Environmental management is a systematic effort to provide protection and preservation of natural resources for the welfare of humanity and the sustainability of ecosystems. To achieve these goals, instruments and policies are needed to regulate the behavior of individuals, groups, and institutions to be in line with the principles of sustainable development. Environmental management instruments include regulatory, economic, and voluntary approaches, while environmental policies can be national or international in nature. The effectiveness of these instruments and policies is greatly influenced by the social, economic, political context, as well as the institutional capacity of the country implementing them (STANIŠIĆ et al., 2025; Wijaya et al., 2021).

One of the main instruments in environmental management is legislation that regulates human activities to prevent damage to ecosystems. This regulation can take the form of laws, government regulations, or regional regulations that are legally binding. Environmental regulations play an important role in setting emission standards, habitat preservation, and waste management (Handini et al., 2025). In Indonesia, Law No. 32 of 2009 on Environmental Protection and Management serves as the main legal basis for the implementation of environmental policies. The implementation of strict regulations has proven

effective in reducing air pollution in densely industrialized areas (Ayu Shinta Dewi, 2025; Yulianti & Darmawan, 2020).

In addition to regulations, economic instruments also play a crucial role in promoting environmentally friendly behavior. These instruments include fiscal incentives, environmental taxes, and market mechanisms such as carbon emissions trading. A carbon tax, for instance, aims to internalize the external costs of carbon pollution into the price structure, thus encouraging businesses to reduce their emissions. Empirical studies show that countries implementing carbon taxes have experienced a significant decline in emission intensity per unit of Gross Domestic Product (GDP) (Hidayat et al., 2021). However, challenges remain in determining a fair and economically effective tax rate.

On the other hand, voluntary approaches in environmental management have evolved through mechanisms such as eco-labeling programs, environmental audits, and green certifications. Companies that voluntarily adhere to certain environmental standards gain reputational advantages and broader market access. Although not mandatory, these voluntary instruments have proven capable of increasing resource efficiency and fostering innovation in sustainable business practices (Fan & Wang, 2024; Santosa et al., 2022). In a global context, this approach also creates social pressure on companies to be more environmentally responsible.

Planning instruments, such as the Environmental Impact Assessment (EIA), are also important tools in environmental policy. Through the EIA, a project is assessed in terms of its impacts on the environment before it is implemented. This process not only includes technical evaluation but also involves public participation, making it a tool for democratization in environmental management (Mees et al., 2019; Ramadhani et al., 2024; Y. Zhang et al., 2020). Research shows that projects undergoing the EIA process with extensive public participation tend to be more adaptive to social and environmental risks (Mees et al., 2019; Rahmawati & Puspitasari, 2019; Y. Zhang et al., 2020).

Monitoring and evaluation instruments support the effectiveness of environmental policies. Air, water, and soil quality monitoring systems enable authorities to measure compliance and assess the impact of implemented policies. Accurate and real-time monitoring data is crucial in responding to environmental crises such as severe pollution or ecological disasters. Advances in digital technology, including the use of sensors and big data, further enhance this monitoring capacity (Manapragada et al., 2025; Mulligan et al., 2024; S. D. Putri et al., 2022). However, the success of these systems largely depends on data transparency and cross-sector coordination (Baulenas & Sotirov, 2020; Botah, 2023; von Lüpke et al., 2023).

Environmental decentralization policies have been an increasingly popular approach in recent decades. In this model, local governments are given greater authority in managing natural resources in their areas. The advantages of decentralization include the proximity of decision-makers to local issues, policy flexibility, and community empowerment (Loainak et al., 2023; Tambunan et al., 2024; Wiyono et al., 2023). However, challenges such as weak technical capacity

and potential conflicts of interest remain obstacles in the implementation of environmental decentralization (Firmansyah et al., 2023).

Market-based instruments also become part of modern policy, such as cap-and-trade schemes in controlling greenhouse gas emissions. This system allows businesses to buy and sell the rights to emit within certain limits. This mechanism creates economic incentives for companies that can reduce their emissions more efficiently. Countries like South Korea and the European Union have implemented this system with promising results. However, for long-term success, the cap-and-trade system requires a transparent, accountable, and tightly regulated carbon market (Anwar & Haryono, 2020).

At the international level, various conventions and multilateral agreements have been reached to regulate global environmental protection. Examples include the Kyoto Protocol, the Paris Agreement, and the Convention on Biological Diversity. International environmental policy is complex because it must reconcile the interests of different countries from economic and ecological perspectives. Despite facing challenges in implementation, these global policies are important as a collective framework in addressing issues such as climate change and biodiversity loss (Keck et al., 2025; N. R. Sari et al., 2021).

National policies also require the mainstreaming of environmental justice principles, which emphasize the fair distribution of environmental benefits and risks (Atapattu et al., 2021; Harsya et al., 2024; Sunarya, 2024). Many cases show that poor and marginalized communities often bear the brunt of environmental damage. Therefore, policies must be designed to engage all layers of society inclusively, not only in terms of participation but also in receiving benefits (Maulidah & Nugroho, 2020; Ramadhani et al., 2024; Y. Zhang et al., 2020). In this context, strengthening the right to information, procedural justice, and access to complaint mechanisms becomes very important (Sunarya, 2024).

Another challenge in environmental management is the integration of cross-sectoral policies. Many environmental problems arise because the policies of the agriculture, industry, transportation, and energy sectors are not aligned with the principles of environmental sustainability (Robinson, 2024; Sunarya, 2024). Therefore, a holistic, cross-sectoral policy approach (nexus policy) is needed, where water, energy, and food issues are managed in an integrated manner (Baulenas & Sotirov, 2020; Botah, 2023). This approach requires strong institutional coordination and a flexible yet consistent regulatory framework (Kurniawan et al., 2021; von Lüpke et al., 2023).

Environmental instruments and policies must also be adaptive to social and technological changes (Mulligan et al., 2024). Climate change, rapid urbanization, and digital disruption have altered patterns of human interaction with the environment. Therefore, rigid policy approaches are no longer adequate. There is a need for adaptive, data-driven instruments that are open to participation from a diverse range of stakeholders, such as the private sector and communities (A. Nugraha & Suryani, 2023; Ramadhani et al., 2024; Y. Zhang et al., 2020). The utilization of technologies such as the Internet of Things (IoT), artificial intelligence (AI), and blockchain in resource management represents a

new direction that should be developed (Ajakwe et al., 2025; Bhatt & Emdad, 2025; Chauhan & Sahoo, 2024; Mulligan et al., 2024; Olawade et al., 2024).

Finally, environmental education and awareness must be part of long-term policies. Regulatory and economic instruments will not be effective without changes in society's attitudes and behaviors. Public campaigns, formal and informal education, and environmental literacy serve as the foundation of an environmentally conscious culture (Husamah et al., 2025; Masykuroh et al., 2024; Srivastava, 2024; Zhao et al., 2024). Consistent and contextual educational interventions significantly contribute to improving pro-environmental behavior (Destiana et al., 2025; Masykuroh et al., 2024; Wulandari et al., 2024). Therefore, the integration of educational instruments into environmental management policies must be a priority (Alshehri, 2024; Destiana et al., 2025; Srivastava, 2024; Zhao et al., 2024).

The success of environmental management significantly depends on how the available instruments and policies are designed, implemented, and evaluated sustainably. A combination of strict regulations, economic incentives, public participation, and technological innovation is essential to address the complex environmental challenges of today (Mulligan et al., 2024; Ramadhani et al., 2024; Y. Zhang et al., 2020). Policies that not only focus on conservation but also ensure social justice and economic sustainability will form the basis for effective environmental management in the future (Soininen et al., 2025; Sunarya, 2024).

#### 1. Global Issues and Future Challenges in Natural Resource and Environmental Management.

The rapidly changing global environment has placed the issue of natural resource management and the environment as a strategic challenge in 21st-century development. This dynamic involves not only ecological factors but also social, economic, political, and technological aspects (Mulligan et al., 2024). One of the most urgent issues is global climate change, characterized by rising global temperatures, melting polar ice, and rising sea levels. These changes accelerate environmental degradation, worsen social inequality, and increase uncertainty in the availability of natural resources in the future (H. Zhou et al., 2023).

Climate change is not just a natural event, but the result of the accumulation of human activities that exploit natural resources unsustainably. Carbon emissions from the energy, transportation, and industrial sectors are the main causes of global warming. Industrialized countries have historical responsibility for the accumulation of greenhouse gases, while developing countries are more vulnerable to the impacts of climate change such as droughts, floods, and food crises (Williams & Petersen, 2022). This creates disparities in adaptation and mitigation capacities between developed and developing countries (Ayu Shinta Dewi, 2025; Guarnieri et al., 2025).

In addition to climate change, biodiversity issues are also a global concern (Keck et al., 2025; Koo et al., 2024). The accelerating extinction of species is caused by habitat fragmentation, pollution, overexploitation, and the introduction of invasive alien species. The IPBES report indicates that more than one million species are facing extinction in the coming decades if serious interventions are not made (R. Ahmed et al., 2020). Biodiversity conservation is not only important

from an ecological perspective, but it is also closely related to food security, health, and the economy of local communities (Keck et al., 2025; Koo et al., 2024). The next challenge is the increasing demand for natural resources due to population growth and global economic expansion. Mining, illegal logging, monoculture agriculture, and land encroachment of forests are the main triggers of environmental degradation in many regions (Gamage et al., 2024; Hallaj et al., 2024; Mirzabaev et al., 2023). Conflicts of interest between economic development and environmental sustainability are also inevitable (Hassan et al., 2021; Limsaku et al., 2025). Therefore, a transdisciplinary and inclusive approach is needed in managing natural resources that considers long-term sustainability (Ayu Shinta Dewi, 2025; Robinson, 2024).

The development of technology brings two sides to environmental management. On one hand, technological innovations allow for efficiency in resource use and real-time monitoring of environmental quality (Fan & Wang, 2024; Manapragada et al., 2025). However, on the other hand, the development of the digital industry and high technology also requires the extraction of rare minerals, which increases pressure on the environment, especially in developing countries that are the main sites of exploitation (García & Jiménez, 2020). Therefore, the challenge ahead is how to develop sustainable and inclusive green technology (Susanto & Marzuki, 2023; J. Zhang et al., 2023).

The clean water crisis is also becoming a more crucial global issue. Reports from the World Resources Institute indicate that about two-thirds of the world's population will face water scarcity by 2040. Over-exploitation of groundwater, pollution of water sources, and climate change exacerbate this crisis (Li et al., 2021). Water resource management needs to be implemented with cross-sectoral and regional integration, emphasizing efficiency in use, conservation, and restoration of water ecosystems (Baulenas & Sotirov, 2020; Botah, 2023; Fan & Wang, 2024; S. Nugraha, 2023).

Plastic pollution is another environmental challenge that is global and intergenerational in nature. It is estimated that more than 8 million tons of plastic waste enter the ocean each year, threatening marine life and entering the human food chain (Tanaka et al., 2019). Efforts to reduce single-use plastics, increase recycling, and innovate eco-friendly materials are becoming important strategies in addressing this issue. However, its implementation still faces structural barriers and consumer behaviors that have not changed significantly.

Another challenge is the shift in global consumption patterns that is becoming increasingly unsustainable. Consumerism and mass production culture lead to overproduction and overconsumption of goods, which ultimately results in increased waste and environmental degradation (Handini et al., 2025). The linear economic system of take, use, dispose must be replaced with a circular economy that minimizes waste and maximizes reuse and recycling of resources (Becchetti et al., 2025; Chakraborty & Paul, 2023; D'Amato & Korhonen, 2021; Handini et al., 2025). Inequality in access to and control over natural resources is also a socio-political issue that needs to be addressed. Resource conflicts often occur between indigenous or local communities and large companies supported by state policies (Limsaku et al., 2025). Land grabbing, marginalization of local

communities, and environmental damage due to extractivism are concrete evidence of the challenges of ecological justice (Rahman & Ahmed, 2022). In the future, policies are needed that ensure the active participation of local communities in decision-making and the protection of land and resource rights (Ramadhani et al., 2024; Soininen et al., 2025; Y. Zhang et al., 2020). Future challenges also include aspects of fragmented global environmental governance (Muhammad et al., 2025; Soininen et al., 2025). Many international agreements lack strong enforcement mechanisms. Additionally, weak political commitment and dependence on conventional economic growth make the achievement of environmental goals such as the SDGs and the Paris Agreement still far from expectations (Atapattu et al., 2021; Schlosberg & Collins, 2021). Therefore, it is necessary to strengthen global mechanisms that can balance economic, social, and ecological interests fairly and effectively (D'Amato & Korhonen, 2021; Menton et al., 2020).

One of the important challenges is to build ecological literacy among society broadly (Destiana et al., 2025; Husamah et al., 2025; Masykuroh et al., 2024). The knowledge and awareness of the community about the importance of protecting the environment are not yet evenly distributed. Environmental education must be integrated into both formal and informal education systems as a long-term effort to foster an environmentally friendly culture (Alshehri, 2024; Destiana et al., 2025; H. Ismail & Noor, 2020; Zhao et al., 2024). With increased understanding and community involvement, the management of natural resources and the environment can be carried out collectively and sustainably.

The integration of a human rights-based and social justice approach in environmental management has become an urgent need (Wibisono, 2024). A paradigm shift from anthropocentrism to ecocentrism is necessary to position nature as a subject that also has rights to be protected and respected (Patel, 2024). This demands a change in laws, policies, and global societal values in viewing the relationship between humans and nature in a more ethical and sustainable manner.

In facing these various challenges, the future of natural resource management and the environment will be greatly determined by the collective ability of humans to reform perspectives, policies, and development practices. Cross-sector, cross-country, and cross-generational collaboration is necessary to ensure that the Earth remains a livable place for future generations (Baulenas & Sotirov, 2020; Botah, 2023). Ecological justice, global solidarity, and a commitment to sustainability are the main foundations for a better environmental future (Fan & Wang, 2024).

## CONCLUSIONS AND RECOMMENDATIONS

Natural resource and environmental management is a pressing multidimensional challenge in the era of rapid population growth, urbanization, and industrialization. This article emphasizes the importance of a holistic and sustainable approach to natural resource management, balancing exploitation and preservation by integrating ecological, economic, social, and political aspects. Social dimensions, such as community empowerment and active public participation, are proven to be essential in ensuring the success of fair and inclusive management strategies. The synergy between science, policy, and technology is seen as key in addressing the complexities and dynamics of the ever-evolving environmental challenges.

In the context of the agricultural sector and land resource utilization, pressure from intensive practices and chemical use poses risks of soil degradation and threats to human health and the environment. Therefore, the implementation of sustainable agricultural practices that emphasize conservation and efficiency is necessary, while minimizing negative impacts on ecosystems. Modern technology provides significant opportunities for environmental monitoring and resource utilization efficiency through digital innovations, sensors, and data processing. However, new risks such as the exploitation of rare minerals and additional pressures in developing countries also need to be anticipated. The development and implementation of sustainable and inclusive green technologies will be a strategic challenge in the future.

The qualitative literature review approach used in this article is able to depict the diversity of theories, empirical experiences, and best practices in natural resource and environmental management from over 60 literatures. The integration of multidisciplinary perspectives and local-global experiences yields a more comprehensive understanding, as well as a strong foundation for innovation in strategies and policies.

### **Recommendations for Future Research**

Future research needs to further deepen the integration of real-time sensor-based monitoring technology and artificial intelligence with the local knowledge of communities in ecosystem management. Further studies are required on the effectiveness of community participation models in various geographical contexts, especially in areas vulnerable to environmental crises. Recommendations are made to strengthen the synergy among stakeholders (government, private sector, academia, and the community) in developing innovative policies that are responsive to environmental changes.

Further research could focus on the development of new indicators and metrics to measure the success of the integration of technology and communities in natural resource management. Comparative studies between developing and developed countries are necessary to identify supporting factors, obstacles, and opportunities in the inclusive and sustainable adoption of green technology. By strengthening multidisciplinary synergy, prioritizing social justice and meaningful community engagement, and integrating technology innovations that favor environmental preservation, it is hoped that future natural resource management can become fairer, more inclusive, and sustainable.

## FURTHER STUDY

This research still has limitations so that further research is needed on the topic of Transformation of Natural Resource Management in the Digital Era: a Review of Technology Integration, Social Justice, and Environmental Sustainability to perfect this research and increase insight for readers and writers.

## REFERENCES

- AbdelRahman, M. A. E. (2023). An overview of land degradation, desertification and sustainable land management using GIS and remote sensing applications. *Rendiconti Lincei. Scienze Fisiche e Naturali*, 34(3), 767–808. <https://doi.org/10.1007/s12210-023-01155-3>
- Ahmad, H., Soeprabowati, T. R., & Purnaweni, H. (2023). Management of Community Participation Through Education Based on Religio-Cultural Approaches for Ecotourism Development in Bantar Kulon, Lebakbarang District, Pekalongan Regency. In *Proceedings of the International Conference on Language, Education, and Social Science (ICLESS 2022)* (pp. 204–212). Atlantis Press SARL. [https://doi.org/10.2991/978-2-494069-15-2\\_23](https://doi.org/10.2991/978-2-494069-15-2_23)
- Ahmed, M. T., Laskar, S. H., & Hussain, M. (2020). Sustainable natural resource management: A theoretical and empirical review. *Environmental and Sustainability Indicators*, 7, 100045.
- Ahmed, R., Singh, P., & Clarke, M. (2020). Biodiversity under threat: A global overview of drivers and solutions. *Global Ecology Review*, 48(3), 221–233.
- Ajakwe, I. U., Ajakwe, S. O., Lee, J.-M., & Kim, D.-S. (2025). Internet-of-Things-blockchain integration in environmental pollution monitoring data management: trends and techniques. *International Journal of Environmental Science and Technology*. <https://doi.org/10.1007/s13762-025-06615-x>
- Akinyi, M. (2024). Influence of Land Use Changes on Biodiversity Conservation in Coastal Ecosystems. *American Journal of Environment Studies*, 7(2), 12–24. <https://doi.org/https://doi.org/10.47672/ajes.1924>
- Algarni, S., Aboelwafa, W., & Alharbi, K. (2021). Renewable energy integration: Transitioning toward sustainability. *Renewable Energy*, 179, 1230–1241.
- Alshehri, S. Z. (2024). Exploring students' pro-environmental knowledge and behaviour perceptions: a mixed methods investigation. *Journal of Turkish Science Education*, 21(3), 389–409. <https://doi.org/10.36681/tused.2024.021>
- Andersson, K., Gibson, C. C., & Lehoucq, F. (2021). Decentralization and sustainable natural resource management. *World Development*, 144, 105472.
- Anwar, M., & Haryono, T. (2020). Skema Perdagangan Emisi sebagai Solusi Emisi Gas Rumah Kaca. *Jurnal Energi Dan Lingkungan*, 11(2), 77–90.

- Ariani, G. M. G., Hasanah, N., Yulianti, F., Syahrani, & Mujanah, S. (2025). The Pathway of Green Shift Research: Insight from Bibliometric Study on Sustainable Competence and Organizational Green Culture. *Business Management*, 4(3), 356–370. <https://ejournal.mandalanursa.org/index.php/Bisnis/article/viewFile/9053/6220>
- Arowolo, M. E., Aaron, W. C., Kugbiyi, A. Olusegun, Ubi Solomon Eteng, Divine ILOH, Chimaoge Peace Aguma, & Olagunju, A. O. (2024). Integrating AI enhanced remote sensing technologies with IOT networks for precision environmental monitoring and predicative ecosystem management. *World Journal of Advanced Research and Reviews*, 23(2), 2156–2166. <https://doi.org/10.30574/wjarr.2024.23.2.2573>
- Arsovski, Z., Petrovic, D. R., Milanovic, I., Rankovic, V., & Kalinic, Z. (2012). Integration Model of Business Processes and Interfaces in E-SCM. 7th International Conference ICQME, September, 1–9. [https://www.researchgate.net/profile/Zora\\_Arsovski/publication/311616061\\_INTEGRATION\\_MODEL\\_OF\\_BUSINESS\\_PROCESSES\\_AND\\_INTERFACES\\_IN\\_E-SCM/links/585130aa08ae7d33e012966b/INTEGRATION-MODEL-OF-BUSINESS-PROCESSES-AND-INTERFACES-IN-E-SCM.pdf](https://www.researchgate.net/profile/Zora_Arsovski/publication/311616061_INTEGRATION_MODEL_OF_BUSINESS_PROCESSES_AND_INTERFACES_IN_E-SCM/links/585130aa08ae7d33e012966b/INTEGRATION-MODEL-OF-BUSINESS-PROCESSES-AND-INTERFACES-IN-E-SCM.pdf)
- Atapattu, S. A., Gonzalez, C. G., & Seck, S. L. (2021). Intersection of Environmental Justice and Sustainable Development: Framing the Issues. *Schulich Law Scholars*, 1(1), 1–39. [https://digitalcommons.schulichlaw.dal.ca/cgi/viewcontent.cgi?article=1530&context=scholarly\\_works](https://digitalcommons.schulichlaw.dal.ca/cgi/viewcontent.cgi?article=1530&context=scholarly_works)
- Ayu Shinta Dewi. (2025). Challenges and Opportunities for Indonesian Environmental Management in The Industry 4.0 Era. *El-Mal: Jurnal Kajian Ekonomi & Bisnis Islam*, 6(7). <https://doi.org/10.47467/elmal.v6i7.8222>
- Baulenas, E., & Sotirov, M. (2020). Cross-sectoral policy integration at the forest and water nexus: National level instrument choices and integration drivers in the European Union. *Forest Policy and Economics*, 118, 102247. <https://doi.org/10.1016/j.forpol.2020.102247>
- Becchetti, L., Bova, D. M., & Raffaele, L. (2025). Win together or lose alone: Circular economy and hybrid governance for natural resource commons. *Journal of Cleaner Production*, 486, 144520. <https://doi.org/10.1016/j.jclepro.2024.144520>
- Bhatt, G. D., & Emdad, A. (2025). Blockchain's role in environmental sustainability: Bibliometric insights from scopus. *Green Technologies and Sustainability*, 3(4), 100236. <https://doi.org/10.1016/j.grets.2025.100236>
- Botah, K. Y. (2023). Integration of Sectoral Policies: Potentials and Obstacles in a Complex and Interconnected World. *Journal of Social and Policy Issues*, 156–162. <https://doi.org/10.58835/jspi.v3i3.210>
- Chakraborty, S., & Paul, D. (2023). Circular Economy and Sustainable Consumption: A Global Review. *Journal of Sustainable Development Studies*, 26(2), 198–215.

- Chauhan, M., & Sahoo, D. R. (2024). Towards a Greener Tomorrow: Exploring the Potential of AI, Blockchain, and IoT in Sustainable Development. *Nature Environment and Pollution Technology*, 23(2), 1105–1113. <https://doi.org/10.46488/NEPT.2024.v23i02.044>
- D'Amato, D., & Korhonen, J. (2021). Integrating the green economy, circular economy and bioeconomy in a strategic sustainability framework. *Ecological Economics*, 188, 107143. <https://doi.org/10.1016/j.ecolecon.2021.107143>
- Destiana, D., Gani, R. A., Sundari, F. S., & Fitriany, A. N. (2025). Cultivating Pro-environmental Literacy in Future Primary School Teachers: A Pathway to Sustainable Education. *Pedagogia: Jurnal Ilmiah Pendidikan*, 17(1), 22–36. <https://doi.org/10.55215/pedagogia.v17i1.16>
- Fan, L., & Wang, D. (2024). Natural resource efficiency and green economy: Key takeaways on clean energy, globalization, and innovations in BRICS countries. *Resources Policy*, 88, 104382. <https://doi.org/10.1016/j.resourpol.2023.104382>
- Firdaus, N., Supriatna, & Supriatna, J. (2022). Ecosystem services research trends in Indonesia: a bibliometric analysis. *Biodiversitas Journal of Biological Diversity*, 23(2). <https://doi.org/10.13057/biodiv/d230255>
- Firmansyah, R., Dewi, S., & Hanafiah, A. (2023). Desentralisasi dan Tata Kelola Lingkungan di Indonesia: Peluang dan Tantangan. *Jurnal Administrasi Publik Indonesia*, 18(4), 301–316.
- Gamage, A., Gangahagedara, R., Subasinghe, S., Gamage, J., Guruge, C., Senaratne, S., Randika, T., Rathnayake, C., Hameed, Z., Madhujith, T., & Merah, O. (2024). Advancing sustainability: The impact of emerging technologies in agriculture. *Current Plant Biology*, 40, 100420. <https://doi.org/10.1016/j.cpb.2024.100420>
- Gandhi, A. P., Deshmukh, P., & Dongre, A. R. (2025). Qualitative evidence synthesis: applications, methods, challenges, and opportunities. *The Evidence*, 3(1). <https://doi.org/10.61505/evidence.2025.3.1.135>
- García, A., & Jiménez, M. (2020). Technology, Resource Extraction, and Environmental Justice in the Digital Age. *Journal of Environmental Innovation*, 18(1), 88–104.
- Garcia-Barragan, J. C., Razo-Lazcano, T. A., & Orozco, L. C. (2020). Industrial waste management and circular economy strategies. *Resources, Conservation & Recycling*, 158, 104784.
- Guarnieri, C., Koliopoulos, S., Pogliotti, P., Ferraris, D., Filippa, G., Tagliaferro, F., Mondardini, L., Sapone, F., & Galvagno, M. (2025). Framework for Climate Change Mitigation and Adaptation Policies in Mountain Environments. <https://doi.org/10.5194/egusphere-egu25-10608>
- Hallaj, Z., Bijani, M., Karamidehkordi, E., Yousefpour, R., & Yousefzadeh, H. (2024). Forest land use change effects on biodiversity ecosystem services and human well-being: A systematic analysis. *Environmental and Sustainability Indicators*, 23, 100445. <https://doi.org/10.1016/j.indic.2024.100445>

- Handini, W., Alfitri, A., Waspodo, W., & Putra, R. (2025). Optimizing Waste Management Through Multilevel Community Participation. *Academia Open*, 10(2). <https://doi.org/10.21070/acopen.10.2025.11692>
- Hansen, M. C., Potapov, P. V., & Moore, R. (2019). Global mapping of forest loss and its impact on climate regulation. *Science*, 366(6463), 846–849.
- Harsya, R. M. K., Bhaskoro, A., Sinaga, H., Koynja, J. J., & Judijanto, L. (2024). Environmental Justice and Sustainable Development: Assessing Legal Frameworks for a Balanced Future. *Global International Journal of Innovative Research*, 1(3), 274–281. <https://doi.org/10.59613/global.v1i3.38>
- Hassan, M., Yusuf, R., & Nor, Z. (2021). Natural Resource Conflicts and the Future of Global Sustainability. *Journal of Natural Resource Management*, 35(4), 402–419.
- Hidayat, M. R., Utami, D. A., & Ramadhan, Y. (2021). Pajak Karbon sebagai Instrumen Ekonomi untuk Mitigasi Perubahan Iklim. *Jurnal Ekonomi Dan Kebijakan Publik*, 12(3), 205–219.
- Husamah, H., Rahardjanto, A., Permana, T. I., & Lestari, N. (2025). The relationship between environmental literacy, ecological literacy, and science for sustainability: A systematic literature review. *Research and Development in Education (RaDEn)*, 5(1), 351–364. <https://doi.org/10.22219/raden.v5i1.39957>
- Hutapea, R., & Manurung, S. (2021). Prinsip Keberlanjutan dalam Manajemen Sumber Daya Alam Berbasis Ekosistem. *Jurnal Ilmu Lingkungan*, 19(3), 215–230.
- IPBES. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. [https://files.ipbes.net/ipbes-web-prod-public-files/inline/files/ipbes\\_global\\_assessment\\_report\\_summary\\_for\\_policymakers.pdf#page=2&zoom=auto,-82,774](https://files.ipbes.net/ipbes-web-prod-public-files/inline/files/ipbes_global_assessment_report_summary_for_policymakers.pdf#page=2&zoom=auto,-82,774)
- Ismail, H., & Noor, F. (2020). Environmental Literacy and the Role of Education in Developing Sustainable Societies. *International Journal of Green Education*, 11(4), 301–317.
- Ismail, Z., Hardi, T., & Mahardika, D. (2021). Integrated Approach in Environmental and Resource Management. *International Journal of Environmental Policy*, 5(4), 276–290.
- Jha, M. K., Markandey, D. K., Gupta, R., & Mishra, P. (2024). The Role of Technology in Environmental Governance (pp. 287–322). <https://doi.org/10.4018/979-8-3693-7001-8.ch011>
- Keck, F., Peller, T., Alther, R., Barouillet, C., Blackman, R., Capo, E., Chonova, T., Couton, M., Fehlinger, L., Kirschner, D., Knüsel, M., Muneret, L., Oester, R., Tapolczai, K., Zhang, H., & Altermatt, F. (2025). The global human impact on biodiversity. *Nature*, 641(8062), 395–400. <https://doi.org/10.1038/s41586-025-08752-2>

- Koo, H., Kleemann, J., Cuenca, P., Noh, J. K., & Fürst, C. (2024). Implications of landscape changes for ecosystem services and biodiversity: A national assessment in Ecuador. *Ecosystem Services*, 69, 101652. <https://doi.org/10.1016/j.ecoser.2024.101652>
- Kurniawan, B., Astuti, W., & Yuliana, D. (2021). Pendekatan Nexus dalam Integrasi Kebijakan Sumber Daya Alam. *Jurnal Kebijakan Dan Manajemen Publik*, 20(2), 123–136.
- Kusuma, A., & Firdaus, R. (2022). Natural Resource Exploitation and Environmental Degradation: A Sustainable Development Perspective. *Jurnal Ekologi Tropika*, 14(2), 97–110.
- Kusuma, D. W., Sari, N. K., & Wahid, A. (2024). Management Analysis: Community Empowerment Based on Local Wisdom. *Image : Jurnal Riset Manajemen*, 12(2), 317–332. <https://doi.org/10.17509/image.2024.25>
- Lahudin, Yusuf, R., Putra, I., Maimun, & Gopinath, S. (2024). Integrating local wisdom in environmental conservation: Ecological citizenship in the Leuser ecosystem, Indonesia. *GAHCUR: Global Arts, Humanities and Culture Review*, 1(1). <https://journal.indoscholar.org/index.php/gahcur/article/view/30>
- Lele, S., Springate-Baginski, O., & Lakerveld, R. (2020). Beyond exclusion: Promoting equitable resource governance. *Ecological Economics*, 175, 106697.
- Li, X., Zhang, R., & Wang, J. (2021). Global Water Scarcity and Integrated Management Approaches. *Journal of Hydrological Resources*, 37(2), 159–174.
- Limsaku, A., Aroonchan, N., Paengkaew, W., & Kammuang, A. (2025). Climate Change Adaptation Implementation and Governance in Thailand: Increased Resilience and Potential Conflicts. In *Risks, Resilience and Interdependency* (pp. 89–110). Springer Nature Singapore. [https://doi.org/10.1007/978-981-96-7167-0\\_4](https://doi.org/10.1007/978-981-96-7167-0_4)
- Loainak, E. Y. A., Neolaka, M. N. B. C., & Toda, H. (2023). Empowerment of Papadak Local Wisdom in Supporting Coastal and Marine Resources Management in Nusak Termanu, Rote Ndao District. *International Journal of Environmental, Sustainability, and Social Science*, 4(1), 224–239. <https://doi.org/10.38142/ijess.v4i1.497>
- Manapragada, N. V. S. K., Mandelmlch, M., Roitberg, E., Kizel, F., & Natanian, J. (2025). Remote sensing for environmentally responsive urban built environment: A review of tools, methods and gaps. *Remote Sensing Applications: Society and Environment*, 38, 101529. <https://doi.org/10.1016/j.rsase.2025.101529>
- Masykuroh, K., Yetti, E., & Nurani, Y. (2024). Parents' Environmental Literacy: From Knowledge to Pro-Environmental Behavior. *Journal of Law and Sustainable Development*, 12(1), e3197. <https://doi.org/10.55908/sdgs.v12i1.3197>

- Maulidah, N., & Nugroho, A. (2020). Keadilan Lingkungan dalam Kebijakan Publik: Studi Kasus pada Komunitas Rentan di Pesisir. *Jurnal Sosiologi Dan Keadilan Sosial*, 13(3), 210–225.
- Mees, H. L. P., Uittenbroek, C. J., Hegger, D. L. T., & Driessen, P. P. J. (2019). From citizen participation to government participation: An exploration of the roles of local governments in community initiatives for climate change adaptation in the Netherlands. *Environmental Policy and Governance*, 29(3), 198–208. <https://doi.org/10.1002/eet.1847>
- Menton, M., Larrea, C., Latorre, S., Martinez-Alier, L., Peck, J., Temper, M., & Walter, M. (2020). Environmental justice and the SDGs: from synergies to gaps and contradictions. *Sustainability Science*, 15, 1621–1636. <https://doi.org/10.1007/s11625-020-00789-8>
- Mirzabaev, A., Stokov, A., & Krasilnikov, P. (2023). The impact of land degradation on agricultural profits and implications for poverty reduction in Central Asia. *Land Use Policy*, 126, 106530. <https://doi.org/10.1016/j.landusepol.2022.106530>
- Moss, R. H., Edmonds, J. A., & Fawcett, A. A. (2020). Future global energy demand and the role of fossil fuels: An integrated analysis. *Nature Energy*, 5(5), 349–358.
- Muhammad, A., Rizky, L., Sahide, A., Candra, I. A., & Prasetyo, S. I. (2025). Multilevel Governance and Indonesia's Strategy for Climate Change Mitigation and Adaptation. *Jurnal Hubungan Internasional*, 13(2), 14–27. <https://doi.org/10.18196/jhi.v13i2.20999>
- Mulligan, C., Morsfield, S., & Cheikosman, E. (2024). Blockchain for sustainability: A systematic literature review for policy impact. *Telecommunications Policy*, 48(2), 102676. <https://doi.org/10.1016/j.telpol.2023.102676>
- Nandi, S., Das, S., Gorain, S., Dutta, S., Roy Choudhury, M., & Das, S. (2025). Land degradation neutrality: a pathway to achieving sustainable development goals and ecosystem resilience. *Discover Soil*, 2(1), 48. <https://doi.org/10.1007/s44378-025-00078-9>
- Nugraha, A., & Suryani, T. (2023). Kebijakan Adaptif dalam Era Disrupsi Lingkungan: Studi atas Pemerintahan Digital. *Jurnal Kebijakan Inovatif*, 5(1), 89–102.
- Nugraha, S. (2023). Natural Resource Management Principles and the Role of Law in Realizing Good Development Governance. *Journal of Progressive Law and Legal Studies*, 2(01), 49–58. <https://doi.org/10.59653/jplls.v2i01.575>
- Nurhadi Kumayza, T., Pramusinto, A., & Widaningrum, A. (2025). Systematic Literature Review of Environmental Impact Assessments. *Jurnal Ilmu Sosial Dan Ilmu Politik*, 28(2), 123. <https://doi.org/10.22146/jsp.96105>

- Olawade, D. B., Wada, O. Z., Ige, A. O., Egbewole, B. I., Olojo, A., & Oladapo, B. I. (2024). Artificial intelligence in environmental monitoring: Advancements, challenges, and future directions. *Hygiene and Environmental Health Advances*, 12, 100114. <https://doi.org/10.1016/j.heha.2024.100114>
- Ostojić, I., Petrović, P., & Kelić, V. (2023). Institutional framework and international environmental organizations for sustainable development (pp. 311-325). [https://doi.org/10.56461/iup\\_rlr.2023.4.ch20](https://doi.org/10.56461/iup_rlr.2023.4.ch20)
- Pascual, U., Adams, W. M., & Lele, S. (2020). Equity and justice in ecosystem services and natural resource management. *Conservation Biology*, 34(1), 39-49.
- Patel, R. (2024). Rights of Nature: A Pathway to Ecological Democracy. *Environmental Ethics and Society*, 19(1), 44-62.
- Putri, D. K., & Wibowo, T. (2022). Prinsip Kehati-hatian dalam Hukum Lingkungan Indonesia. *Jurnal Kebijakan Lingkungan*, 7(3), 155-169.
- Putri, F. A. (2024). Pengaruh Degradasi Lahan Terhadap Keberlanjutan Pertanian Padi di Indonesia Hasil Survei Pertanian Terintegrasi (SITASI) 2021. *Seminar Nasional Official Statistics*, 2024(1), 111-116. <https://doi.org/10.34123/semnasoffstat.v2024i1.2024>
- Putri, S. D., Lestari, K., & Harahap, M. (2022). Inovasi Teknologi dalam Pemantauan Lingkungan: Peran Big Data dan IoT. *Jurnal Inovasi Teknologi Lingkungan*, 7(1), 66-78.
- Quigley, J. (2024). Remote Sensing-Based Monitoring Networks for the Next Generation of Energy and Environmental Policymaking. <https://kleinmanenergy.upenn.edu/research/publications/remote-sensing-based-monitoring-networks-for-the-next-generation-of-energy-and-environmental-policymaking/>
- Rafinzar, R., Marpaung, Z. S., Khairunnisa, T., Permatasari, I., & Adventy, M. I. Y. (2025). Community Participation and Policy Effectiveness in Urban Flood Mitigation: Evidence from Palembang City, Indonesia. *Indonesian Governance Journal*, 8(1). <https://doi.org/https://doi.org/10.24905/igj.v8i1.147>
- Rahman, S., & Ahmed, K. (2022). Resource Politics and Environmental Displacement in the Global South. *Environmental Governance Quarterly*, 14(1), 35-52.
- Rahmawati, I., & Puspitasari, D. (2019). Partisipasi Publik dalam Proses AMDAL: Studi Kasus pada Proyek Infrastruktur di Jawa Tengah. *Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan*, 9(3), 199-212.
- Ramadani, I. (2025). Community Empowerment in Natural Resources Management Based on Local Wisdom. *BBIJBM: Bina Bangsa International Journal of Business and Management*, 5(1), 273-303. <https://doi.org/10.46306/bbijbm.v5i1.126>

- Ramadhan, A., Siregar, F., & Amin, N. (2022). Peran Pemangku Kepentingan dalam Pengelolaan Lingkungan Berkelanjutan. *Jurnal Pembangunan Berkelanjutan*, 8(1), 35–48.
- Ramadhani, S. P., Sundawati, L., & Kuncahyo, B. (2024). Analysis of Factors Influencing Community Participation in Sustainable Forest Management in BKPH Mojarayung, Madiun. *Jurnal Pengelolaan Sumberdaya Alam Dan Lingkungan (Journal of Natural Resources and Environmental Management)*, 14(1), 139–147. <https://doi.org/10.29244/jpsl.14.1.139-147>
- Reber, U., Fischer, M., Ingold, K., Kienast, F., Hersperger, A. M., Grütter, R., & Benz, R. (2022). Integrating biodiversity: a longitudinal and cross-sectoral analysis of Swiss politics. *Policy Sciences*, 55(2), 311–335. <https://doi.org/10.1007/s11077-022-09456-4>
- Robinson, G. M. (2024). Global sustainable agriculture and land management systems. *Geography and Sustainability*, 5(4), 637–646. <https://doi.org/10.1016/j.geosus.2024.09.001>
- Rohendi, A., Faridy, F., Adinata, B. R., Kadafi, M., Iqra, A. P., & Rahmawan, I. (2024). Community's Willingness to Participate in Wastewater Management in Aceh. *Journal of Community Based Environmental Engineering and Management*, 9(1), 25–40. <https://doi.org/10.23969/jcbeem.v9i1.21051>
- Ruhl, J. B. (1999). The Co-Evolution of Sustainable Development and Environmental Justice: Cooperation, Then Competition, Then Conflict. *Duke Environmental & Policy Forum*, 161. <https://scholarship.law.vanderbilt.edu/faculty-publications/510/>
- Santosa, B., Wibowo, A. T., & Meidiana, C. (2022). Pendekatan Sukarela dalam Praktik Bisnis Ramah Lingkungan: Kajian di Sektor Manufaktur. *Jurnal Teknologi Lingkungan*, 23(2), 134–147.
- Sari, L. M., & Nugroho, B. (2023). Analisis Ruang Lingkup Manajemen Sumber Daya Alam di Wilayah Tropis. *Jurnal Ekologi Tropika*, 6(1), 92–105.
- Sari, N. R., Handayani, L., & Budiarto, T. (2021). Kebijakan Global dan Nasional dalam Perlindungan Keanekaragaman Hayati. *Jurnal Kebijakan Lingkungan Global*, 6(1), 24–38.
- Schlosberg, D., & Collins, L. (2021). Reframing Global Environmental Governance: From Efficiency to Justice. *Ecological Governance Journal*, 12(3), 170–189.
- Sloan, S., & Sayer, J. A. (2019). Forest resources and sustainable development: The challenge of balancing economic and ecological goals. *Environmental Science & Policy*, 101, 1–7.
- Soininen, N., Ruhl, J. B., Cosens, B., & Gunderson, L. (2025). Governing complexity: A comparative assessment of four governance models with applications to climate change mitigation and adaptation. *Environmental Innovation and Societal Transitions*, 57, 101020. <https://doi.org/10.1016/j.eist.2025.101020>

- Srivastava, V. (2024). Study of climate literacy and pro-environmental behavior amongst students. *Citizenship, Social and Economics Education*, 23(1), 31–46. <https://doi.org/10.1177/14788047241246806>
- STANIŠIĆ, M., NONIĆ, D., PODUŠKA, Z., & NEDELJKOVIĆ, J. (2025). Improving institutional framework and organizational solutions for climate change governance in forestry and related sectors at regional and local levels in Serbia. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 53(1), 14201. <https://doi.org/10.15835/nbha53114201>
- Strong, B., Boyda, E., Kruse, C., Ingold, T., & Maron, M. (2025). Digital applications unlock remote sensing AI foundation models for scalable environmental monitoring. *Frontiers in Climate*, 7. <https://doi.org/10.3389/fclim.2025.1520242>
- Sunarya, A. (2024). Climate and Environmental Policy in Indonesia: Challenges and Opportunities. *Ganaya : Jurnal Ilmu Sosial Dan Humaniora*, 7(1), 195–206. <https://doi.org/10.37329/ganaya.v7i1.3030>
- Surono, A., & Hidayati, M. N. (2024). Peran Perguruan Tinggi dalam Harmonisasi Kebijakan Pengelolaan SDA Berbasis Kearifan Lokal untuk Ketahanan Nasional. *Proceedings of NCOLS (National Conference on Law Studies* 2024), 1(1). <https://conference.upnvj.ac.id/index.php/ncols/article/view/2978>
- Suryani, T., Anggraini, L., & Maulana, F. (2021). Pendekatan Partisipatif dalam Pengelolaan Sumber Daya Alam: Studi Kasus di Nusa Tenggara Barat. *Jurnal Sosial Ekologi*, 5(2), 66–80.
- Susanto, B., & Marzuki, D. (2023). Smart Fertilizers from Agricultural Waste: Efficiency and Environmental Impact. *International Journal of Green Agro-Technology*, 7(2), 80–94.
- Syahrani, A. P., Saputra, M. A., & Pramasha, R. R. (2024). Peran Ekonomi Hijau dalam Pengelolaan Sumber Daya Alam yang Berkelanjutan. *IJEN: Indonesian Journal of Economy and Education Economy*, 2(1). <https://jurnal.academiacenter.org/index.php/IJEN/article/view/545>
- Tambunan, A. A., Dfinubun, M. F., & Payokwa, S. (2024). Community Empowerment in Natural Resources Management Based on Regional Planning in Walelagama Village Wesaput District Jayawijaya Regency. *Jurnal Budimas*, 6(3), 1–10. <https://jurnal.stie-aas.ac.id/index.php/JAIM/article/viewFile/15661/6130>
- Tanaka, K., Watanabe, M., & Hoshino, T. (2019). Plastic Pollution and Marine Ecosystems: Emerging Solutions and Barriers. *Ocean and Coastal Studies*, 44(3), 202–216.
- Utami, W., & Suhendra, A. (2023). Adaptive Policy Making for Natural Resource Management. *Jurnal Administrasi Lingkungan*, 11(1), 88–101.

- von Lüpke, H., Leopold, L., & Tosun, J. (2023). Institutional coordination arrangements as elements of policy design spaces: insights from climate policy. *Policy Sciences*, 56(1), 49–68. <https://doi.org/10.1007/s11077-022-09484-0>
- Wibisono, R. B. (2024). Keadilan Iklim dan HAM di Indonesia: Mewujudkan Pembangunan Berkelanjutan Melalui Perlindungan Lingkungan. *Jurnal Politik Pemerintahan Dharma Praja*, 17(2), 95–125.
- Wijaya, D. H., Susanti, N., & Prabowo, R. (2021). Evaluasi Kebijakan Lingkungan dan Pengaruhnya terhadap Kesejahteraan Ekologis. *Jurnal Ilmu Lingkungan*, 19(1), 45–58.
- Wijayanti, D., Rahmat, M., & Kurniawan, E. (2020). Sustainable Natural Resources Management: A Conceptual Framework. *Jurnal Pengelolaan Lingkungan Hidup*, 11(2), 45–58.
- Williams, A., & Petersen, J. (2022). Climate Justice and the Global South: Addressing Asymmetry in Climate Negotiations. *International Environmental Policy Journal*, 29(2), 142–156.
- Wiyono, S. H., Subianto, A., & Nuhman, N. (2023). Sustainable Ecotourism Development and Community Empowerment: A Case Study of the Center for Environmental Education in Seloliman Village, Indonesia. *Society*, 11(2), 310–328. <https://doi.org/10.33019/society.v11i2.528>
- Wulandari, L., Prasetyo, R., & Indrawati, E. (2024). Pengaruh Pendidikan Lingkungan terhadap Perilaku Pro-Lingkungan: Meta-Analisis Empiris. *Jurnal Pendidikan Berkelanjutan*, 15(1), 55–70.
- Yuliana, E., & Prabowo, R. (2020). Aspek Kelembagaan dalam Pengelolaan Sumber Daya Alam di Indonesia. *Jurnal Hukum Lingkungan*, 4(2), 112–127.
- Yulianti, E., & Darmawan, A. (2020). Efektivitas Regulasi Lingkungan dalam Menurunkan Emisi di Kawasan Industri. *Jurnal Hukum & Lingkungan*, 14(2), 101–115.
- Zen, I. S., Al-Amin, A. Q., & Doberstein, B. (2019). Mainstreaming climate adaptation and mitigation policy: Towards multi-level climate governance in Melaka, Malaysia. *Urban Climate*, 30, 100501. <https://doi.org/10.1016/j.uclim.2019.100501>
- Zhang, J., Liu, Y., Zhang, W., & Ma, X. (2023). Role of green technologies in enhancing the efficiency of natural resources. *Resources Policy*, 83, 103624. <https://doi.org/10.1016/j.resourpol.2023.103624>
- Zhang, Y., Wu, Y., & Qiu, J. (2023). Agroecology and sustainable land use: An integrated framework. *Agricultural Systems*, 203, 103502.
- Zhang, Y., Xiao, X., Cao, R., Zheng, C., Guo, Y., Gong, W., & Wei, Z. (2020). How important is community participation to eco-environmental conservation in protected areas? From the perspective of predicting locals' pro-environmental behaviours. *Science of The Total Environment*, 739, 139889. <https://doi.org/10.1016/j.scitotenv.2020.139889>

- Zhao, Y., Liu, X., & Han, X. (2024). Enhancing pro-environmental behavior through nature-contact environmental education: an empirical analysis based on randomized controlled experiment design. *Frontiers in Environmental Science*, 12. <https://doi.org/10.3389/fenvs.2024.1491780>
- Zhou, H., Li, Y., & Chang, W. (2023). Global warming and its cascading impacts on resource sustainability. *Environmental Science and Policy Review*, 41(1), 67-81.
- Zhou, Y., Zhang, L., & Wang, W. (2021). Resource overuse and sustainability challenges: A case study from China's rapid industrialization. *Journal of Cleaner Production*, 286, 125413.