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Conservation Technology Research 2000–2026 Mapping Themes Methods and Application Domains: A Bibliometric Approach

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ABSTRACT

This study aims to map the intellectual structure, thematic evolution, and application domains of conservation technology research published between 2000 and 2026 using a bibliometric approach. Data were collected from the Scopus database and analyzed using VOSviewer to examine publication trends, keyword co-occurrence, thematic clustering, and temporal developments. The results reveal that conservation technology research is strongly centered on sustainable development, which acts as the main conceptual hub connecting various domains such as energy transition, environmental protection, water and soil conservation, and ecological monitoring. Cluster analysis indicates that the field is structured around key themes including renewable energy and emission control, environmental remediation, ecosystem conservation, and biological research. The temporal analysis shows a clear shift from traditional ecological studies toward applied technological solutions and, more recently, toward sustainability innovation and energy-focused research. Furthermore, density analysis highlights the dominance of established topics such as sustainability and energy, while also identifying emerging areas such as machine learning and remote sensing as potential future research directions. This study contributes by providing a comprehensive overview of conservation technology research and offers insights into its interdisciplinary nature, evolution, and future opportunities.

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1. INTRODUCTION

The increasing degradation of ecosystems, biodiversity loss, and climate change impacts have intensified global efforts to develop more effective conservation strategies. Traditional conservation approaches, which often relied heavily on manual observation and localized ecological knowledge, are gradually being complemented by technological innovations capable of improving monitoring, data analysis, and decision-making processes. Conservation technology refers to the application of technological tools and scientific methods to protect natural resources, ecosystems, and biodiversity. These technologies include remote sensing systems, artificial intelligence, data analytics, robotics, and sensor networks that support environmental monitoring and ecosystem management [1]. By integrating these technological tools into conservation practice, researchers and practitioners are able to collect more accurate environmental data, identify ecological threats earlier, and implement targeted conservation interventions.

Over the past two decades, the rapid development of digital technologies has significantly transformed conservation science. Tools such as drones, camera traps, acoustic sensors, and satellite imagery have enabled researchers to monitor wildlife populations and environmental changes at unprecedented spatial and temporal scales. For example, aerial drones are increasingly used to survey habitats, track wildlife movements, and detect illegal activities such as poaching or deforestation. The declining cost and improving performance of such technologies have made them more accessible to conservation organizations worldwide, thereby expanding their use in biodiversity monitoring and ecosystem management [2]. Similarly, advances in machine learning and artificial intelligence have facilitated automated analysis of large ecological datasets, allowing conservationists to detect species and ecological patterns more efficiently than traditional manual approaches.

In addition to improving monitoring capabilities, conservation technology also supports evidence-based conservation decision-making. Evidence-based conservation emphasizes the systematic use of scientific data and research findings to guide conservation policies and management actions. By integrating technological tools with scientific evidence, conservation practitioners can better evaluate the effectiveness of conservation interventions and identify strategies that yield the most beneficial outcomes for ecosystems and species protection [3]. Technologies such as geographic information systems (GIS), ecological modeling platforms, and environmental data networks provide important analytical capabilities that help decision-makers prioritize conservation actions and allocate limited resources more efficiently.

Despite these technological advances, the research landscape of conservation technology remains highly interdisciplinary and rapidly evolving. Studies in this field span multiple domains including ecology, environmental engineering, information science, and sustainability studies. As a result, the growing volume of publications related to conservation technology can be difficult to synthesize and evaluate comprehensively. Bibliometric analysis offers a systematic approach to address this challenge by quantitatively analyzing scientific publications, citations, and collaboration networks. Through bibliometric methods, researchers can identify publication trends, influential studies, emerging themes, and research gaps within a specific field [4]. By mapping the intellectual structure of a research domain, bibliometric analysis provides insights into how knowledge develops and which areas require further investigation.

In recent years, bibliometric approaches have increasingly been applied to environmental and sustainability research to understand the evolution of scientific knowledge and identify emerging research directions. By analyzing citation networks, keyword clusters, and collaboration patterns, bibliometric studies reveal how different research themes evolve over time and how scientific communities interact. Such analyses not only help researchers understand the historical development of a research field but also support strategic planning for future research initiatives (Baker et al., 2020). Within the context of conservation technology, bibliometric mapping can provide valuable insights into dominant research themes, commonly used methodological approaches, and the various application domains in which conservation technologies are implemented.

Although conservation technology research has expanded significantly in recent decades, the existing literature remains fragmented across multiple disciplines and application areas. Many studies focus on specific technologies or case studies, such as the use of drones for wildlife monitoring or machine learning for species detection, without providing a comprehensive overview of the broader research landscape. As a result, there is limited understanding of how conservation technology research has evolved over time, what methodological approaches dominate the field, and which application domains receive the most scholarly attention. Furthermore, emerging technologies such as artificial intelligence, blockchain systems, and advanced sensor networks are rapidly transforming conservation practices, yet their integration and research trajectories remain insufficiently mapped. Without a systematic synthesis of the literature, researchers and practitioners may find it difficult to identify knowledge gaps, research opportunities, and collaboration networks within the field. Therefore, a bibliometric analysis covering the period from 2000 to 2026 is needed to map the thematic evolution, research methods, and application domains of conservation technology research in order to provide a clearer understanding of its intellectual structure and future research directions. The objective of this study is to analyze the development of conservation technology research between 2000 and 2026 using a bibliometric approach.

2. METHODS

This study employed a bibliometric research design to systematically analyze the development of conservation technology research between 2000 and 2026. Bibliometric analysis is a quantitative method used to evaluate scientific publications through statistical examination of bibliographic data such as authors, citations, keywords, and publication sources. This approach allows researchers to identify patterns of knowledge production, research trends, and the intellectual structure of a particular scientific field. In this study, bibliometric techniques were used to map the evolution of research themes, methodological approaches, and application domains within conservation technology. By examining large volumes of scholarly publications, bibliometric analysis provides a comprehensive overview of how research in this field has expanded and diversified over time.

The data for this study were collected from major academic databases that index peer-reviewed scientific literature, such as Scopus and Web of Science, which are widely used in bibliometric studies due to their broad coverage and reliable citation information. Relevant publications were identified using keyword combinations related to conservation technology, including terms such as “conservation technology,” “environmental monitoring technology,” “wildlife monitoring,” “remote sensing for conservation,” and “digital conservation tools.” The search was limited to publications published between 2000 and 2026 and focused primarily on journal articles and review papers to ensure the quality and relevance of the dataset. After the initial search process, duplicate records and publications that were not directly related to conservation technology were removed through a screening process based on titles, abstracts, and keywords.

3. RESULTS AND DISCUSSION

3.1 Keyword Co-Occurrence Network Visualization

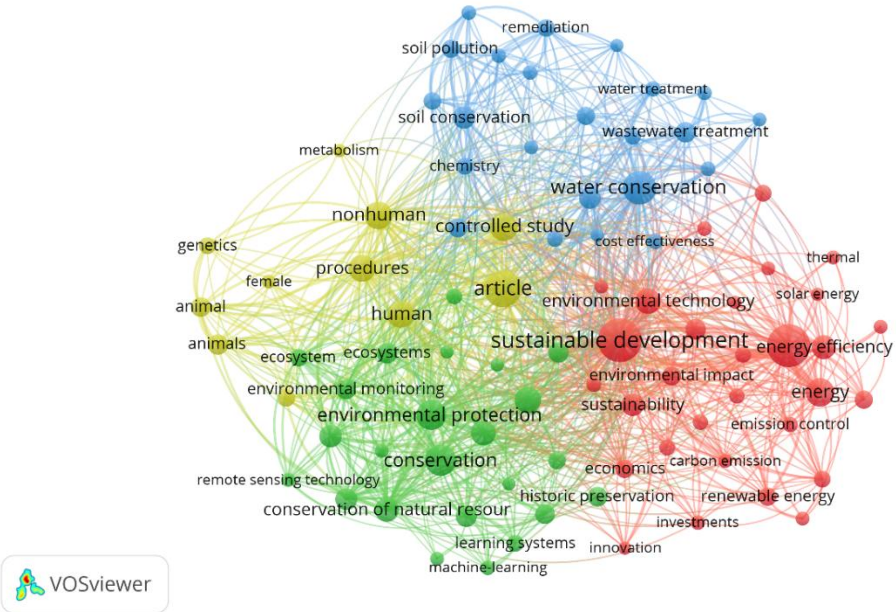

Figure 1. Network Visualization
Source: Data Analysis, 2026

Figure 1 reveals a complex and well-structured intellectual landscape of conservation technology research, organized into several interconnected thematic clusters. At the center of the network lies "sustainable development", which acts as the dominant and most influential node. Its central position and strong linkages to multiple clusters indicate that conservation technology research is fundamentally anchored in sustainability discourse. This suggests that most technological innovations in conservation are not developed in isolation, but rather framed within broader goals such as environmental sustainability, resource efficiency, and long-term ecological balance.

The red cluster represents the energy and sustainability transition domain. Key terms such as energy, energy efficiency, renewable energy, carbon emission, and emission control highlight a strong focus on technological solutions aimed at mitigating climate change. This cluster reflects how conservation technology increasingly overlaps with clean energy innovation and decarbonization strategies. The presence of terms like investment and economics also indicates that this area is not purely technical, but integrates economic feasibility and policy considerations, suggesting a multidisciplinary approach that combines engineering, environmental science, and economic analysis.

The blue cluster is centered around water and soil-related technologies, with prominent keywords such as water conservation, wastewater treatment, soil pollution, remediation, and water treatment. This cluster reflects a major application domain of conservation technology, focusing on environmental restoration and pollution control. The strong interconnections among these terms indicate that research in this area is highly integrated, often combining chemical, engineering, and environmental science approaches. It also suggests that technological interventions in water and soil systems are among the most mature and widely studied areas within conservation technology.

The green cluster represents ecological conservation and environmental protection. Keywords such as conservation, environmental protection, ecosystems, environmental monitoring, and machine learning indicate a growing emphasis on biodiversity conservation supported by digital technologies. The inclusion of remote sensing technology and learning systems highlights the increasing role of data-driven approaches in monitoring ecosystems and supporting decision-making. This cluster demonstrates how conservation technology is evolving toward more intelligent and automated systems, integrating ecological knowledge with advanced computational tools.

The yellow cluster appears to focus on biological and experimental research contexts, including terms such as nonhuman, animal, genetics, procedures, and metabolism. This suggests that a portion of conservation technology research is rooted in life sciences and experimental methodologies, particularly in understanding species behavior, genetics, and ecosystem interactions. The connection of this cluster with others indicates that biological insights are increasingly being integrated with technological applications, reinforcing the interdisciplinary nature of the field.

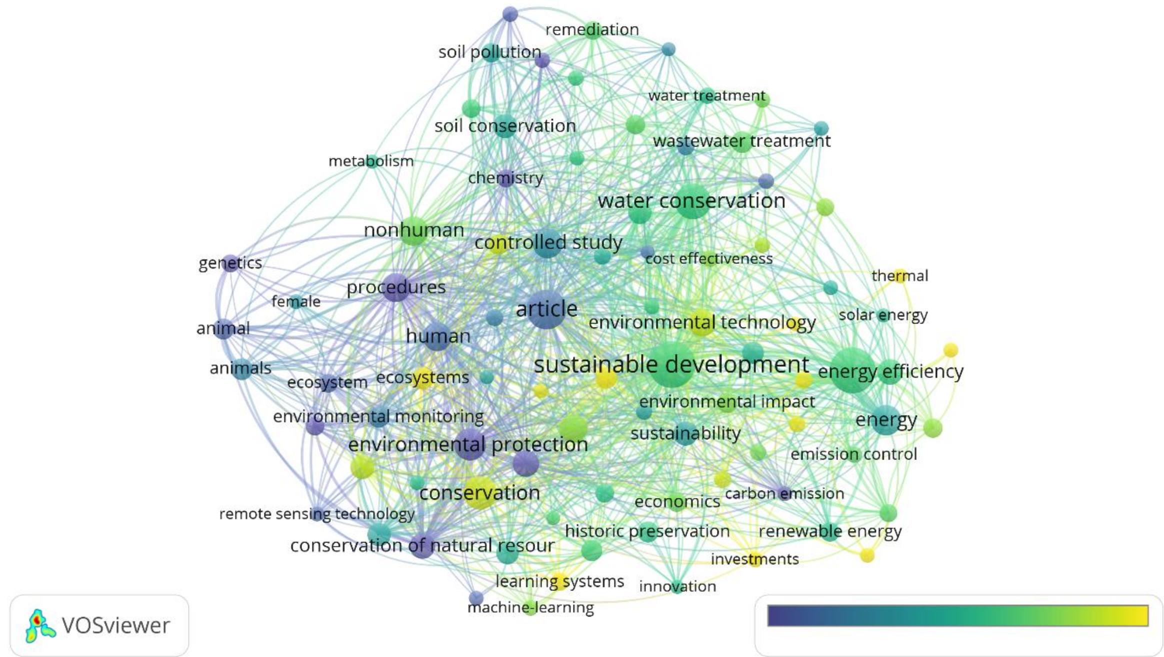

Figure 2. Overlay Visualization

Source: Data Analysis, 2026

Figure 2 insight into the temporal evolution of conservation technology research, where color gradients (from blue/purple to green and yellow) indicate the progression from older to more recent topics. At the core of the network, "sustainable development" remains a consistently dominant theme across time, bridging both earlier and more recent research streams. Surrounding this core, foundational topics such as environmental protection, conservation, ecosystems, and animal studies appear in darker blue and purple tones, suggesting that early research (2000s–early 2010s) was primarily rooted in ecological and biological conservation, with a strong emphasis on understanding natural systems and biodiversity.

As the field evolves, the visualization shifts toward green-colored nodes, representing the middle phase of development, where technological integration becomes more prominent. Topics such as water conservation, wastewater treatment, soil conservation, remediation, and environmental technology indicate a transition toward applied and engineering-based solutions. This phase reflects the growing adoption of interdisciplinary approaches, combining environmental science with chemistry, engineering, and resource management. It marks a period where conservation research begins to move beyond observation into intervention, emphasizing practical solutions for environmental degradation and resource efficiency.

In the most recent phase, highlighted by yellow nodes, the research focus shifts toward energy transition and sustainability innovation, with keywords such as energy efficiency, renewable energy, carbon emission, emission control, and investment. This indicates that contemporary conservation technology research is increasingly aligned with global sustainability agendas, particularly climate change mitigation and green energy systems. Additionally, the emergence of terms like machine learning, innovation, and economic considerations suggests a forward-looking direction that integrates digital technologies and policy-driven approaches.

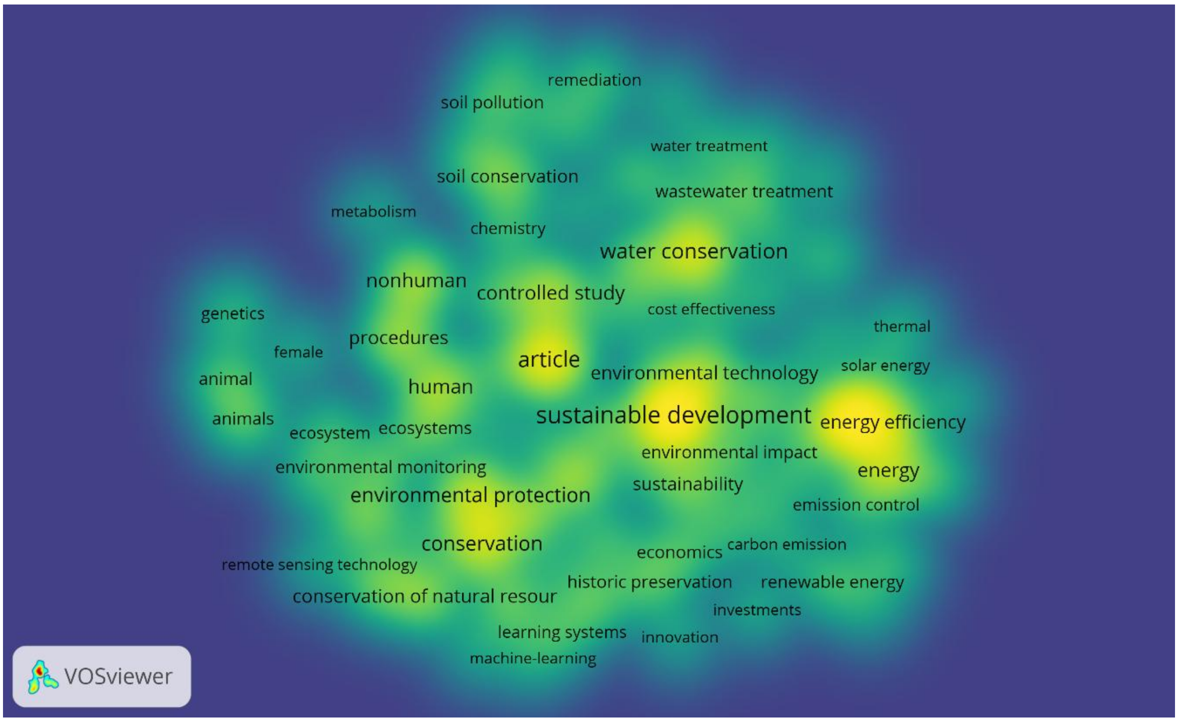

Figure 3. Density Visualization
Source: Data Analysis, 2026

Figure 3 highlights the most intensively researched and frequently occurring topics within conservation technology research. Bright yellow areas indicate high-density keywords, with "sustainable development" emerging as the central and most dominant theme. This is closely followed by terms such as energy, energy efficiency, environmental protection, water conservation, and article, suggesting that the literature is heavily concentrated on sustainability-driven technological solutions. The strong density around energy-related topics indicates that conservation technology research is increasingly aligned with global priorities such as renewable energy adoption, emission reduction, and climate change mitigation.

Beyond the central hotspots, moderately dense areas (green zones) reveal supporting but still significant themes such as wastewater treatment, soil conservation, remediation, environmental technology, and conservation of natural resources. Meanwhile, lower-density areas (blue zones), including machine learning, remote sensing technology, and genetics, indicate emerging or less-explored topics that hold potential for future research development.

3.2 Citation Analysis

Table 1. Top Cited Documents

Citations	Authors and year	Title	Source
9,714	[5]	A safe operating space for humanity	Nature, 461(7263), pp. 472–475
6,851	[6]	Soil carbon sequestration impacts on global climate change and food security	Science, 304(5677), pp. 1623–1627
6,284	[7]	Global food demand and the sustainable intensification of agriculture	Proceedings of the National Academy of Sciences, 108(50), pp. 20260–20264
6,240	[8]	Extinction risk from climate change	Nature, 427(6970), pp. 145–148
6,119	[8]	Extinction risk from climate change	Science, 333(6043), pp. 712–717
6,025	[9]	Global threats to human water security and river biodiversity	Nature, 467(7315), pp. 555–561
5,285	[10]	Co3O4 nanocrystals on graphene as a synergistic catalyst for oxygen reduction reaction	Nature Materials, 10(10), pp. 780–786
5,282	[11]	A robust, simple genotyping-by-sequencing (GBS) approach for high diversity species	PLoS One, 6(5), e19379
4,186	[12]	Biofuels from microalgae—A review of technologies for production, processing, and extractions of biofuels and co-products	Renewable and Sustainable Energy Reviews, 14(2), pp. 557–577
3,499	[13]	Pretreatment technologies for an efficient bioethanol production process based on enzymatic hydrolysis: A review	Bioresource Technology, 101(13), pp. 4851–4861

Source: Scopus, 2026

Discussion

The findings of this bibliometric study reveal that conservation technology research has evolved into a highly interdisciplinary and sustainability-driven field, with sustainable development serving as its central conceptual anchor. The dominance of this theme indicates that technological innovations in conservation are increasingly aligned with global sustainability agendas rather than being confined to isolated ecological interventions. This reflects a paradigm shift in which conservation is no longer viewed solely as environmental protection, but as an integrated system that encompasses economic, social, and technological dimensions. The strong connectivity between sustainability and various technological domains highlights the role of conservation technology as a bridge between environmental science and applied innovation.

The cluster analysis further demonstrates that conservation technology research is structured around several major domains, particularly energy transition, environmental remediation, ecological monitoring, and biological research. The prominence of the energy-related cluster suggests that conservation technology is closely linked to climate change mitigation efforts, especially through renewable energy, energy efficiency, and emission control. This finding aligns with global policy priorities, where technological solutions are increasingly used to address carbon reduction targets and environmental sustainability. At the same time, the presence of clusters related to water and soil conservation indicates that traditional environmental challenges remain central, but are now being addressed through more advanced and integrated technological approaches.

The temporal (overlay) analysis provides additional insight into the evolution of the field. Early research was primarily focused on ecological and biological aspects, such as species conservation, ecosystems, and environmental monitoring. Over time, the focus shifted toward applied technologies, including water treatment, soil remediation, and environmental engineering solutions. More recently, the field has moved toward energy systems, sustainability innovation, and data-driven approaches. This progression reflects the increasing complexity of environmental challenges and the need for scalable, technology-enabled solutions. It also suggests that conservation technology is becoming more proactive and predictive, rather than reactive, in addressing environmental issues.

The density analysis highlights the concentration of research around core themes while also revealing emerging opportunities. While topics such as sustainable development, energy, and environmental protection are well-established and extensively studied, areas like machine learning, remote sensing, and digital monitoring technologies appear less dense but highly promising. This indicates that the future of conservation technology lies in the integration of digital and intelligent systems, which can enhance monitoring accuracy, enable real-time decision-making, and improve the efficiency of conservation interventions. The relatively lower density of these topics suggests that they are still underexplored and represent important avenues for future research.

4. CONCLUSION

This study concludes that conservation technology research has undergone a significant transformation from ecology-centered investigations toward a more integrated, technology-driven, and sustainability-oriented field. The bibliometric findings demonstrate that sustainable development serves as the core framework connecting diverse research domains, including energy transition, environmental protection, and resource management. The evolution of themes indicates a shift from traditional conservation approaches to the adoption of advanced technologies such as environmental engineering solutions and emerging digital tools. While established topics like energy efficiency and environmental protection dominate the literature, the emergence of areas such as machine learning and remote sensing highlights promising directions for future research

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