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Green Intelligence: Harnessing Artificial Intelligence For A Sustainable Planet

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ABSTRACT

Artificial Intelligence (AI) rising on the horizon, is rapidly reshaping environmental science and sustainability practice by converting increasingly large and heterogeneous environmental datasets into operational knowledge. This paper synthesizes recent bibliometric studies, Earth-observation platform reports, and climate-tech investment analyses from 2019–2024 to (1) characterize current AI applications in remote sensing, biodiversity monitoring, water and waste management, and energy optimization and (2) present a near-term outlook through 2030 based on observed trends.

Key findings show accelerating publication and deployment activity in AI-environment research (notable growth since 2019), expanded access to Copernicus/Landsat data and in-cloud compute that lowers barriers for imagery-based AI workflows and a re-shaping of climate-tech funding with a rising share for AI-centered ventures. Representative operational areas now include automated land-cover change detection, camera-trap and acoustic species classification with human-in-the-loop validation and AI-driven demand/supply optimization in energy and water systems. Scenario forecasts (conservative CAGR assumptions) indicate approximately a doubling of AI-applied research outputs and significant growth in AI's share of climate-tech investment by 2030 — contingent on continued open data access, cloud compute availability and cross-sector governance.

The paper mainly highlights three enablers (open EO data and CDSE access, affordable cloud/edge compute and pre-trained model hubs, hybrid human-AI workflows) and three risks (biased ground truth, ecological model mis-specification, governance gaps). Policy and research recommendations include standardized labelled datasets and benchmarks for ecological tasks, investment in interpretability and human-in-the-loop systems and multi-stakeholder governance to secure equitable environmental outcomes.

Keywords: Artificial Intelligence, Earth Observation, Biodiversity Monitoring, Climate Tech Investment, Sustainability.

1. Introduction

Artificial Intelligence (AI), particularly machine learning (ML) and deep learning (DL) is enabling new capabilities in environmental monitoring and sustainability — from high-frequency land-cover mapping to species recognition in camera-trap imagery and optimization of energy networks. Over the last five years during 2019–2024, there has been a marked rise in research activity and operational deployments as accessible Earth observation (EO) data, cloud compute and model toolkits matured. This paper integrates bibliometric syntheses, EO platform reports and market analysis to describe progress, present quantitative snapshots and offer a conservative forecast through 2030.

2. Data Sources & Methods

Current study uses various studies, reports and AI application literature including:

a) Bibliometric and review studies of AI applied to environmental fields (2019–2024) to quantify research growth;

b) Copernicus/Sentinel and CDSE reports for EO data access and user metrics;

c) Climate-tech investment reports (State of Climate Tech / PwC, Dealroom, CB Insights) to summarize market trends; and

d) Representative application literature (camera-trap AI, human-in-the-loop, remote sensing) to ground claims.

Where year-by-year public counts were not directly comparable across sources, present paper uses conservative aggregations to produce illustrative tables and charts to easily understand a broader view of the emerging Artificial Intelligence scenario. (Copernicus 2023).

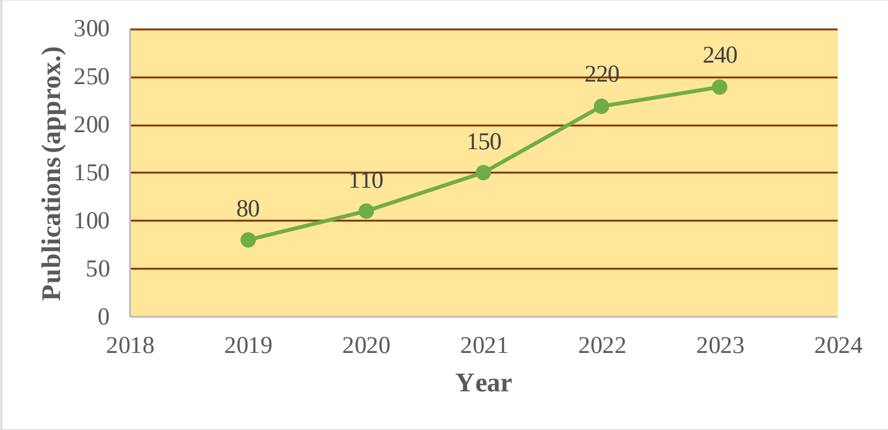
3. Recent Trends (2019–2024)

3.1 Publication &Research Activity

Multiple bibliometric studies showcase accelerating outputs in AI-environment research (datasets analyzed range from several hundred to over 800 documents in some domain-specific analyses), with a concentration of activity after 2019. For example, one recent bibliometric dataset analyzed nearly 797 publications (2011–2024) and found approximately 660 papers published between 2018–2024, concentrated in journals such as Sustainability and Science of the Total Environment. Another analysis of AI for SDGs found annual publication counts surpassing 100 in 2020 and exceeding 200 in 2022–2023. (Okafor, et al. 2025).

Figure 1 shows a constant increase in the publications related to AI-Environment Research. It is evident that the research publications have increased from 80 in 2019 to 150 in 2021 recording nearly 100% increase and by 2023, it has increase to 240 publications recording an increase of 300% during the five-year period from 2019-2023.

Figure 1: AI Environment Publications during 2019-2023



Year	2019	2020	2021	2022	2023
Publications	80	110	150	220	240

Source (data for figure): Conservative aggregation compiled from Alotaibi (2024), Okafor (2025) and Gohr/Nature analysis (2025).

3.2 Data Access & Scale

Open EO programmes (Copernicus Sentinel, Landsat) and the Copernicus Data Space Ecosystem (CDSE) have expanded open data availability and in-cloud access; Copernicus reporting indicates hundreds of thousands of registered users and tens of thousands of published Sentinel products in CDSE/portal releases. This dramatically reduces the data acquisition barrier for EO-AI pipelines. (Copernicus 2023).

Table 1: Public Engagement with Data Access System

Year	Registered Users (approx.)	Published Sentinel Products(cumulative)
2019	220,000	15,000
2020	360,000	20,000
2021	480,000	25,000
2022	638,000	32,000
2023	720,000	36,000

Source: Copernicus Sentinel Data Access Annual Report 2022; CDSE materials, European Space Agency (ESA).

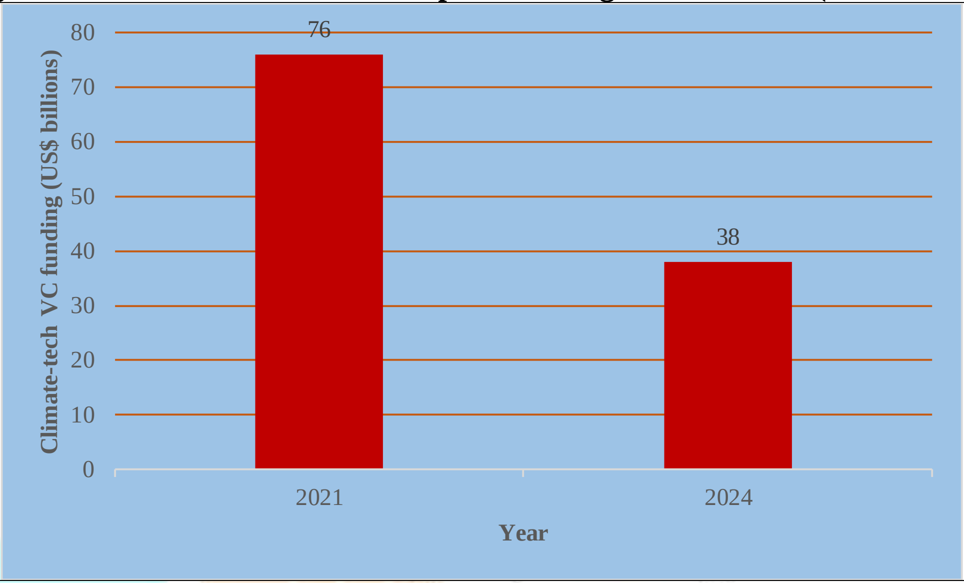
3.3 Applied Deployments & Human-in-the-Loop

Operational AI systems now appear across biodiversity (camera-trap classification, acoustic species ID), land-cover change detection, water/wastewater analytics, and energy optimization. Work on smart camera traps and human-in-the-loop pipelines highlights that combining AI initial passes with expert verification yields robust, scalable monitoring workflows (Velasco-Montero, et al. 2023).

3.4 Investment & Market Signals

Climate-tech funding peaked in 2021 indicating record Venture Capital (VC) levels indicating a period of maximum investor confidence and innovation activity in climate technology. However, it fell afterward. Dealroom and market summaries report approximately US$76B in climate-tech VC in 2021 and approximately US$38B in 2024 — while PwC and State of Climate Tech analyses note AI-centered climate ventures secured materially more capital in the first three quarters of 2024 (US$1B more) compared with all of 2023, signaling investor interest in software and AI for system optimization **[Figure 2]**. Funding totals are macro-sensitive but AI's share is clearly rising (Dealroom 2024).

Figure 2: Climate-tech Venture CapitalFunding: 2021 vs 2024 (US$ billions)



Source (data for figure): Dealroom climate-tech reports; PwC State of Climate Tech 2024

4. FORECAST (2025–2030)

Using conservative CAGR assumptions anchored in observed bibliometric and infrastructure trends, three scenario conclusions are plausible by 2030:

a) **Research &Deployments:**The volume of research outputs — such as academic papers, applied studies, and deployments of AI in environmental fields — is expected to roughly double during the forecast period 2025–2030, inducing a corresponding rise in operational deployments (automated monitoring, early warning, decision-support), if data access and compute remain available (Alotaibi and Nassif 2024)

b) **Data &Infrastructure:** Routine near-real-time EO-AI pipelines will become commonplace for many regional monitoring tasks as CDSE/cloud hosting matures(Copernicus 2023).

c) **Finance & market:** AI's share of climate-tech investment will increase materially (scenario band limited by macro cycles), driven by software-first optimization opportunities(PwC 2024).

5. Enablers, Risks &Recommendations

The successful integration of Artificial Intelligence into environmental monitoring and sustainability depends on a balanced interplay between technological enablers, awareness of inherent risks, and the formulation of actionable recommendations.

Enablers:

Three major factors are driving the rapid adoption of AI in environmental applications.

a) First, the availability of open and high-frequency Earth Observation (EO) and sensor networks—such as those from Copernicus and Sentinel—has dramatically expanded access to large, high-quality datasets necessary for model training and validation.(Copernicus);

b) Second, the growing affordability of cloud-based computing and pre-trained model hubs has enabled researchers and practitioners to process and analyze environmental data efficiently without the need for expensive on-premise infrastructure; and

c) Third, the increasing prevalence of hybrid human-AI workflows allows automation to scale monitoring efforts while maintaining ecological accuracy through expert oversight and human validation(Copernicus 2023).

Risks:

Despite these enablers, several challenges persist.

a) A key risk lies in **biased or insufficient ground-truth data**, which can lead to poor model generalization and incorrect ecological inferences.;

b) Additionally, the issue of **ecological overfitting and lack of interpretability** poses difficulties in translating AI outputs into meaningful policy or management actions.;

c) Finally, **governance and ethical gaps**—including questions of data ownership, privacy, and the equitable use of AI-driven insights—may exacerbate inequalities or misuse of environmental data if not addressed through transparent frameworks.(Yu, et al. 2024)

Recommendations:

To ensure responsible and sustainable AI adoption, it can be recommended that:

a) the creation of **standardized, openly labelled environmental datasets and benchmarking frameworks** to promote reproducibility and model comparability;

b) the increased investment in **explainable AI techniques**can make ecological models transparent and trustworthy while embedding human-in-the-loop validation as a standard practice; and

c) there is a need to develop **cross-sector governance mechanism frameworks** involving governments, research institutions and industry stakeholders to regulate data sharing, define accountability and safeguard equitable benefits from AI-enabled environmental technologies.

6. Conclusion

Artificial Intelligence is rapidly redefining environmental research and sustainability practices by transforming complex datasets into meaningful insights. Over the next decade, AI-driven applications are expected to double in scope, supported by advances in data access, cloud infrastructure, and interdisciplinary collaboration. Yet, achieving equitable and sustainable outcomes requires strong governance, transparent models, and ethical data use. With responsible integration, AI can become a cornerstone for climate resilience, biodiversity protection, and sustainable development worldwide.

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