# Preserving Biodiversity Assisted by Predictive Maintenance: Managing Ecological Displacement

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**Abstract.** The most remarkable trait of the breathing world is its diversity. Biodiversity refers to the variety of life on Earth, encompassing all forms of ecosystems and the ecological complexes that comprise them, as well as the diversity within and between species as well as across different ecosystems. Traditional wisdom is being eroded at the same time that living natural resources are being depleted, making it difficult to preserve biodiversity, as the 'ecosystem people' transformed into 'biosphere people' which further is transforming into ecological refugees. The critical urge for conservation of biological diversity amid climatic disorders, environmental damages etc., calls for varied national and international measures and the current digital technologies (sensors, drones, satellites) offer especially good opportunities to realize the Sustainable Development Goals (SDGs). The research places an exploration of how predictive maintenance technologies may essentially enhance the restoration and protection of the biodiversity. The present study shall try to focus upon the burning issues of Biodiversity that operates at differential levels in an ecosystem. Conclusively, suggesting the strategies and the discretions of techno-legal environment to preserve the same.

**Keywords:** Ecosystem, Environment, Digital Sustainability Solutions, Digital Twin, Predictive Maintenance

## 1 INTRODUCTION

The significant decline in biodiversity observed throughout the past five decades represents a vital worldwide challenge that demands urgent attention. The activities undertaken by humans have resulted in the endangerment of around one million species since the year 1970, and the implications of this phenomenon cannot be disregarded. Animal pollination is a crucial factor for the successful growth and reproduction of over 75% of food crops. However, it is concerning that there has been a fall of over 40% in the population of recognized insect species in recent decades. According to experts, the depletion of biodiversity exerts an equally substantial detrimental influence on ecosystems, comparable to the effects of climate change. Regrettably, the Earth experiences an annual extinction rate of approximately 10,000 species, surpassing the natural rate by a factor of one thousand. The loss of


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biodiversity threatens the ecosystem's ability to provide life sustaining resources such as fresh water, clean air, food security and health. Furthermore, there is also the potential danger of depleting priceless natural resources that possess untapped potential as reservoirs of innovative pharmaceuticals and biotechnological breakthroughs.

At the 1992 Rio Earth Summit, 150 countries, including India, ratified the Convention on Biological Diversity (CBD), is a global treaty aimed at addressing and reversing the current state of biodiversity decline Preserving biodiversity, making sustainable use of biodiversity components, and fairly distributing gains from genetic resource usage are the three main aims of the CBD. Under the CBD there are two protocols namely, Cartagena Protocol and the Nagoya Protocol which further facilitate its objectives. Its primary objectives are to ensure the well-being and preservation of the Earth and its inhabitants, as well as to promote fairness across generations. One of the worldwide aims for 2030 is the implementation of efficient conservation and management strategies for a minimum of 30% of the Earth's terrestrial areas, inland waters, coastal regions, and oceans. This objective specifically emphasizes the protection of areas that exhibit extraordinary significance in terms of biodiversity and the functioning and provision of ecosystem services. The Kunming-Montreal Global Biodiversity Framework is a significant achievement, as it was successfully negotiated and agreed upon in December 2022 at the Convention on Biological Diversity COP15 summit held in Montreal. The framework establishes novel objectives pertaining to the preservation, rehabilitation, and sustainable utilization of biodiversity and ecosystems, with a target completion date of 2030.

The summary report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) was discussed in the Paris agreement, and it expressed concern about the rapidity with which species are disappearing. The IPBES reports for 2023 indicate that there is an anticipated rise in the quantity of invasive alien species and their associated repercussions in the coming years. The proliferation and dispersion of Alien Species beyond their indigenous habitats have had a profound impact on the native biodiversity across many ecosystems worldwide, rendering them the second most significant peril to global biodiversity. This can be attributed to the amplified movement of individuals and commodities facilitated by globalization, as well as the detrimental effects of environmental degradation and climate change. Approximately 80% of nations' national biodiversity plans include objectives related to the control of invasive alien species. However, only a small fraction, specifically 17% of countries, have implemented national legislation or regulations that expressly address these concerns. In line of growing concern for preservation of biodiversity, the recent meeting of the CBD in Geneva affirmed the need for enhancing further the role and participation of indigenous tribes and regional population. To address the environmental disparities, it is imperative to cultivate a heightened recognition and understanding of the inherent conservation values held by indigenous communities.

## 2 ISSUES OF BIODIVERSITY DECLINE: ECOSYSTEM PEOPLE, BIOSPHERE PEOPLE, ECOLOGICAL REFUGEES

Humans can be classified into three overarching categories based on an ecological standpoint. In the context of ecosystems, human populations mostly fulfil their resource needs by relying on a restricted geographical area next to their settlements, employing practices such as gathering, low-input agriculture, and animal husbandry. Individuals living within the biosphere benefit from the utilization of resources obtained from the entirety of the biosphere, which are subsequently made accessible through various market mechanisms. Conversely, ecological refugees are individuals who have experienced a loss of access to their customary reservoir of natural resources, resulting in severely restricted access to resources via market channels. It pertains to environment-induced migration, a humanitarian problem which is a result of environmental degradation and shifting climate patterns. This pressing issue demands immediate attention and cannot be disregarded any further. Indigenous communities (tribes) are often at the heart of these issues; when faced with social and economic pressures, they often feel they have no choice but to leave their homes. Migration caused by environmental factors has recently surfaced as a pressing humanitarian concern that demands immediate attention in light of the ongoing destruction of our planet and the effects of climate change.

One significant consequence arises from the displacement of environmental refugees which broadly covers ecological as well as climate refugees per se, a group that currently lacks adequate protection under international legal frameworks. Such displacement does not hold legal weight because individuals who are forced to migrate across international borders as a result of environment-related circumstances often do not fulfil the criteria for refugee status as defined in the 1951 Refugee Convention. In a more recent study, Myers and Kent have provided a definition for environmental refugees as those who experience a loss of sustainable means of living in their native regions primarily due to environmental reasons of significant magnitude.

In contemporary India, the escalating population pressure within the biosphere has resulted in a significant conversion of ecosystem inhabitants into individuals classified as ecological refugees.

Natural catastrophes and other ecological concerns would force 1.2 billion people to seek refuge elsewhere by the year 2050, according to the Institute for Economics and Peace's worst-case scenario. International and national responses to this problem are still lacking, and protection for individuals impacted is insufficient, despite some progress. A "climate refugee" is not defined specifically, and the 1951 Refugee Convention does not apply to them. The latter only applies to those who are unable or unable to seek protection from their home nations because to a well-founded fear of persecution based on their race, religion, nationality, membership of a particular social group, or political ideas. Although climate change is included as a possible cause of migration in the 2018 Global Compact for Migration, this does not mean that

it can be used as a basis for asylum or refugee status at this time. Although there has been no official recognition of "climate refugees" by the EU, there has been an increase in concern and measures to help the nations most affected by climate change cope.

More than 376 million individuals have lost their homes due to natural disasters since 2008. This is the same as if every single person in Australia were forcibly removed from their homes every single year, or the displacement of one person every single second. While many took shelter within their own nation, others were compelled to flee as a result of the 36.2 million people displaced in 2022 alone due to climate-related natural disasters. The yearly global displacement of millions of people caused by environmental disasters requires urgent attention, as the number of people impacted is predicted to treble by 2050, according to the International Federation of Red Cross and Red Crescent Societies (IFRC).

About a quarter of the non-native plant species in India are invasive, and about 40% of those species are not native to the country. India and Norway have joined forces in a joint effort with the National Biodiversity Authority to form the Centre for Biodiversity Policy and Law (CEBPOL). The fundamental aim of this program is to foster the development of specialist knowledge and skills pertaining to biodiversity policies and laws. The primary objective of this project is to effectively meet the demands set out by both domestic and global regulatory systems concerning biodiversity. This includes the development and subsequent implementation of appropriate legislation to ensure compliance.

The concern of declining biodiversity is a significant one that necessitates urgent and collective consideration.

## 3 IOT FOR SUSTAINABLE DEVELOPMENT

Data collected online is kept in the cloud for further analysis using cutting-edge artificial intelligence techniques like machine learning and simulation approaches like the Digital Twin. Despite these advancements, neither production nor sustainability have grown commensurate. Amidst rising economic disparity, armed conflicts, rapid environmental decline, and broad scepticism of institutional authority, the digital revolution is taking place. The creation of novel digital infrastructure, including data centres, and the adoption of creative business models such as entirely decentralized blockchains, have given rise to additional environmental challenges due to their tremendous energy demand.

Additionally, the Digital Twin is a technological breakthrough which is attempting to proportionally grow productivity or sustainability across several spheres. The integration of digital information technology has facilitated the amalgamation of earth system data and models, enabling the creation of precise digital replicas of the Earth or its specific aspects, sometimes referred to as digital twins. A few examples of recent innovations include the BioDT project, which aims to create a digital twin of biodiversity with enhanced modeling, simulation, and prediction capabilities, for backing up the key policy initiatives like the EU Biodiversity Strategy 2030, UN

Sustainable Development Goals, Green Deal and other international objectives is one such illustration to measure the technological contribution in sustainable development. The notion of Society 5.0, often referred to as the Super Smart Society, integrates overarching objectives such as the Sustainable Development Goals (SDGs) with the potential advancements offered by emerging technologies. The concept has gained official recognition from the world's major countries, notably within the G20 (2019). The G20 (2023) Presidency's motto, "One Earth, One Family, One Future," effectively encapsulates its central theme, wherein the leaders commit to utilizing the G20's influential capacity and collective determination to comprehensively and efficiently execute the 2030 Agenda, thereby expediting advancements towards the Sustainable Development Goals (SDGs).

## 4 ROLE OF TECHNOLOGY TO PROTECT BIODIVERSITY

The integration of technology plays a pivotal role in facilitating sustainable development. There exist numerous instances in which technology has demonstrated its capacity to positively transform our society. By employing the principles of biomimicry, we are able to adapt nature's solutions to address human obstacles. Furthermore, through the introduction of novel advancements, we can enhance the efficiency and accessibility of renewable energy sources. Additionally, online tools have the potential to empower individuals worldwide by providing them with information regarding global environmental issues and facilitating their engagement in conservation efforts. The utilization of technology enables the creation of novel avenues towards achieving a sustainable future. In the context of examining biodiversity from a human-centric perspective, there is a tendency to direct attention towards certain species such as tigers, lions, polar bears, and elephants. These intriguing creatures contribute valuable attention to their respective ecosystems, but they represent only a fraction of the overall biodiversity. Thus, the AI or digital twin based technologies have the potential to manage the vastness of the biosphere and each and every aspect of the same.

The utilization of geospatial data, drones, and camera traps enables the acceleration and real-time execution of assessments that were formerly conducted regularly via field observations by zoologists and botanists. When it comes to information about the worldwide conservation status of species, few resources are as comprehensive and trusted as the Red List, which is maintained by the International Union for the Conservation of Nature. Thus, in the present Anthropocene age, the predictive maintenance via technological means has benefited the environment. The role that technology plays in constructing a use case for biodiversity is significant. One illustrative instance is Bioprospecting, which refers to the systematic exploration and investigation of various species and genetic resources present in the natural environment, with the aim of utilizing them in the domains of pharmaceuticals, agriculture, or cosmetics. The horseshoe crab played a crucial role in verifying the safety of the Covid-19 vaccine due to its ability to visually react to toxins in its blue

blood. Consequently, it was employed as a testing mechanism to confirm the lack of any detrimental ingredients in the vaccinations. Likewise, Environmental DNA (eDNA) represents a groundbreaking technological innovation that enables the assessment of DNA instead of relying on physical species detection to determine their presence within a certain geographical region. (https://www.naturemetrics.com/?ref=technologist.mit.edu)

The incorporation of technology to cater to the requirements of minority groups within society encompasses various aspects such as design, utilization, and regulation. This may entail the implementation of mechanisms that facilitate access to technology and ensure equitable distribution of its benefits. Additionally, it involves acknowledging and providing support for indigenous conservation initiatives, as well as developing technological solutions to enhance the safety of communities residing in wildlife habitats. For instance, by protecting both humans and elephants requires keeping track of their whereabouts.

The significance of technology is anticipated to grow in the endeavours aimed at mitigating the detrimental impacts inflicted upon the biosphere. The increase in invasive species and the excessive occurrence of eutrophication, leading to the development of algal blooms, requires the implementation of technological interventions to remove undesirable vegetation like weeds and seaweed, and to support ecosystem restoration. Companies are increasingly adopting the use of soil microbes as an alternative to chemical substances. Additionally, they are constructing protective coatings to ensure the viability of these microbes throughout storage and transportation. The company is currently involved in the application of CRISPR genome sequencing methods to investigate the feasibility of reviving and restoring extinct creatures, such as the Wooly Mammoth, into ecosystems. There is ongoing exploration by a corporation into the feasibility of producing synthetic palm oil. If successfully implemented on a wider scale, this initiative might potentially address the issue of deforestation in Southeast Asia, an area that serves as the native habitat for Orangutans.

Recent indicators of industry 4.0 have shown that predictive maintenance has a substantial impact on both financial and ecological outcomes. One of the few innovations to survive the test of time and become an indispensable tool for industry is predictive maintenance. From its origins in the 1940s to its contemporary uses, predictive maintenance is expected to continue enhancing operations for decades to come. The advent of the fourth industrial revolution has multiple folds enhanced the technique in sync with machine learning and artificial intelligence. It has become faster and more economical than preventive or corrective maintenance.

Illustrative instances of how technology can be purposefully crafted, employed, and governed to cater to the requirements of individuals who find themselves on the periphery of society encompass the establishment of mechanisms that facilitate accessibility and equitable distribution of advantages, heightened acknowledgment and reinforcement of indigenous endeavours in conservation, as well as the development of technological remedies aimed at enhancing the safety of communities residing in areas inhabited by wildlife.

# 5 DIFFICULTIES IN USING TECHNOLOGY TO PROTECT BIODIVERSITY

Problems can occur when trying to use technology solutions to protect biodiversity. Some examples are the necessity to improve data and digital infrastructure, as well as raise people's understanding of the importance of technology and its nature of application. The problem at hand is the ongoing effort to assign monetary value to biodiversity in order to advocate for its preservation. Although indigenous peoples have been working hard to protect their unique habitats and species out of a deep respect that goes beyond monetary concerns, their work is often overlooked. The Nagoya Protocol, as proposed at the Conference of Parties on Biodiversity, believes in the fair distribution of advantages gained from the use of genetic resources sourced from their various geographical locations, with an emphasis on ensuring that indigenous communities involved in their conservation receive appropriate compensation. Regrettably, this outcome has not been realized. Communities of indigenous people can often be found living in biodiversity hotspots. Consequentially their rights guaranteed by the law of the land may get overshadowed. The confidence and collaboration between local populations and those aiming to protect biodiversity could be harmed as a result. Data needs to be machine understandable and precisely labelled before it can be used by intelligent systems. Biodiversity data currently requires authentic and considerable data cleansing and labelling. The quality and standardization of biodiversity-related data is often a setback. If data collected from disparate locations is to be trusted as a source of information, it must be simple to process, cleanse, and combine with other data sets. However, such amalgamation must be authenticated. More extensive data connectivity and integration is needed than is currently in use. Therefore, methods must be developed to simplify the process of integrating and linking various data types for use by data scientists and engineers. There is a possible risk of formulating solutions for biodiversity challenges in the local areas lacking suitable input from institutions and populations within them as the organizations working in the spaces mostly are international.

# 6 RECOMMENDATIONS

It is imperative for biodiversity efforts employing technologies such as Artificial Intelligence (AI), Digital Twins, to give utmost importance to engaging with area specific laws and to incorporate privacy-enhancing technology to safeguard data privacy, if deemed necessary. Nations engaged in biodiversity conservation efforts, utilizing technological advancements for proactive maintenance, ought to establish a global data task force focused on identifying the factors contributing to the decline of biodiversity. The implementation of a centralized data aggregator will enhance the efficacy of individual driver monitoring activities by facilitating improved integration and correlation of driver data. When it comes to technology-based solutions, there is need to work closely with local institutions and communities to share knowledge and build capacity so that the solutions are appropriate for the region. Or more remote

organizations should be encouraged to get into task for such initiatives. The establishment of biodiversity markets is currently advocated as a best practice. However, it may be argued that this approach, which is based on neoliberal economic principles, is not the best way to address the critical problem of biodiversity loss.
Advancements in research, innovation, and technology serve as the foundation for the ability to achieve all of the Sustainable Development Goals, including those that specifically pertain to the environment.

# 7 CONCLUSION

The preservation of ecosystem, species, and genetic diversity is crucial since it plays a significant role in maintaining human evolutionary resilience, an attribute that has developed over an extensive period of billions of years. The utilization of technology enables us to undertake efforts aimed at mitigating or reversing ecological damage and enhancing our comprehension of species prior to their potential extinction. However, the effective implementation of such endeavours necessitates the presence of robust local governance and institutions, which are responsible for making informed decisions to protect our natural heritage. The rapid advancement of intelligent technology holds great promise in effectively addressing the disparity between awareness and action in mitigating biodiversity loss.

Nevertheless, it is imperative for governments to adequately equip themselves to adopt and adapt to these technologies, despite their ongoing advancements. The initial phase of this endeavour involves the automation of data gathering and aggregation, which is subsequently followed by the implementation of intelligent systems designed to facilitate the planning and execution of tasks while simultaneously minding the law and policy developments. The utilization of technology is justified by the imperative to conserve our invaluable ecosystems and safeguard life itself. The benefits significantly surpass the difficulties and risks that could arise.

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