Asian Science and Technology Innovation Journal

ASTIJ

Review Article

Biodiversity credits and offsets: A review of effectiveness, challenges, and future directions

Ichangdaw Boruah[1*], Soontaree Cheentam[1] and PathaninSangaroon[2]

[1]College of Innovative Management, Valaya Alongkorn Rajabhat University under Royal Patronage, Prathum Tani Province, Thailand.
[2]School of Health Science, Sukhothai Thammathirat Open University, Nonthaburi, Thailand.
*Correspondence: ichangdaw.bo@vru.ac.th

Citation: Boruah I, Cheentam S, SangaroonP. *Biodiversity credits and offsets: A review of effectiveness, challenges, and future directions*. ASTIJ. 2025; **1**(1): 14-23

Received: June 4, 2025
Revised: June 25, 2025
Accepted: June 25, 2025
Published: June 27, 2025

Abstract: This manuscript presents a comprehensive review of biodiversity credits and offsets as emerging mechanisms for mitigating biodiversity loss and strengthening conservation initiatives. Unlike carbon credits, biodiversity credits function as market-based instruments that provide measurable, traceable, and verifiable incentives for the protection, restoration, and sustainable management of ecosystems. Despite their potential, the implementation of biodiversity credit systems is impeded by challenges such as inconsistent assessment methodologies, insufficient governance structures, and inadequate regulatory oversight. The review underscores the need for standardized biodiversity metrics, integration with international environmental frameworks, and the establishment of ecological safeguards to ensure the delivery of genuine conservation outcomes. A comparative analysis with carbon credit systems highlights the critical importance of embedding biodiversity considerations within broader climate strategies. The paper concludes with strategic recommendations aimed at enhancing the credibility and effectiveness of biodiversity credit markets through transparent valuation mechanisms, participatory governance models, and inclusive engagement of local and Indigenous communities. In advocating for the up scaling of biodiversity credit systems, the review affirms their potential role in addressing the global biodiversity crisis and advancing the objectives of the Kunming-Montreal Global Biodiversity Framework.

Keywords: Biodiversity loss; Biodiversity credits; Carbon credits

1. Introduction

Biodiversity constitutes the foundational fabric of life on Earth, underpinning ecosystem functionality and delivering essential services that sustain human health and well-being. However, it is currently facing an unprecedented crisis, with a substantial proportion of species categorized as threatened or endangered [1]. The conservation of biodiversity is no longer a peripheral environmental issue but a critical imperative for the survival of human societies [2]. From microbial communities to apex predators and entire ecosystems, biodiversity supports vital ecological processes that ensure the provision of clean air and water, disease regulation, medicinal resources, and food security services increasingly threatened in the context of global climate change [3].

Anthropogenic pressures, particularly rapid population growth and escalating food demands, are driving widespread habitat degradation and accelerating the pace of biodiversity loss [4]. Historically marginalized in policy discourse, biodiversity decline is now recognized as a significant impediment to global progress across sectors including public health, economic stability, and sustainable development [5]. Key drivers of this decline such as agricultural expansion, anthropogenic climate change, overexploitation of natural resources, urban encroachment, and biological invasions are contributing to the degradation and destabilization of ecosystems at a planetary scale [6]. Without immediate, coordinated, and science-based global conservation interventions, the cascading consequences of species extinctions, habitat fragmentation, and ecosystem collapse are likely to become irreversible [7, 8].

Global biodiversity loss may be more severe than previously estimated, according to new assessments from underrepresented experts and overlooked taxa. However, significantly scaling up conservation investments and initiatives now could prevent the extinction of one in three species that would otherwise be at risk by 2100 [9, 10]. Nature-based solutions (NbS) can simultaneously benefit

climate adaptation, mitigation, and ecosystem health, but improved assessment methods and policy support are needed to maximize their effectiveness and minimize trade-offs [11, 12]. Biodiversity loss is among the top global risks to society, and there is broad recognition that action to halt and subsequently reverse biodiversity loss must be scaled up dramatically and urgently, introducing incentives in terms of biodiversity credit for positive actions could play a key role in reversing biodiversity loss decline [13]. Reforestation efforts often prioritize plantations, which can replace richer ecosystems, potentially reducing biodiversity and carbon storage [14].

Biodiversity credits, as opposed to traditional biodiversity offsets, represent an emerging and innovative financial instrument aimed at advancing conservation, ecological restoration, and sustainable development. Conceptualized as a market-based mechanism, biodiversity credits quantify, verify, and monetize positive ecological outcomes such as habitat restoration or species recovery thereby enabling their trade in environmental markets. These credits offer performance-based incentives for ecosystem stewardship, aligning financial investments with measurable biodiversity gains through a transparent and traceable framework [15].

Recognizing the urgency of the global biodiversity crisis, the international community took a significant step in 2022 with the adoption of the Kunming-Montreal Global Biodiversity Framework by 196 nations. This strategic commitment seeks to halt biodiversity loss by 2030 and ensure the sustainable use of natural resources by 2050. It emphasizes the integration of biodiversity conservation into national development agendas, policy frameworks, and global financial mechanisms to safeguard ecosystem services critical for human well-being and planetary resilience.

Further highlighting the gravity of the issue, the World Economic Forum's Global Risks Report (2024) identifies biodiversity loss, ecosystem degradation, and natural resource scarcity alongside extreme climatic events as among the most imminent threats facing humanity in the coming decade [16]. Intensifying climate driven phenomena such as heat waves, cold spells, and flooding events are direct consequences of anthropogenic climate change and ecosystem disruption. These trends not only endanger ecological integrity but also pose serious risks to public health, livelihoods, and socioeconomic stability worldwide [17, 18].

Enhancing biodiversity requires effective policies, farmer engagement, and practical tools like the Credit Point System to balance conservation restoration [19]. Biodiversity credits are distinct from carbon credits and biodiversity offsets. While carbon credits mitigate green-house gas emissions and biodiversity offsets compensate for ecological loss, biodiversity credits are designed to generate direct conservation benefits without linking to specific development impacts. They can be issued by conservation organizations or private entities based on verifiable biodiversity gains, such as increased species populations or restored habitats [20]. Carbon credits play an important role in climate strategies, but forest-related projects encounter financial, environmental, and social risks [21]. To address these, financial mechanisms are used alongside safeguards and physical risk mitigation measures. Biodiversity credits provide a non-offsetting way to finance conservation, but their success depends on standardized methods, inclusion of marine areas, respect for Indigenous rights, and strong regulatory integration to ensure real biodiversity gains [22]. Preserving tree diversity can enhance carbon sequestration, support ecosystem productivity, and provide significant climate, biodiversity, and societal benefits, making it a key focus for reforestation efforts [13]. The United Nations Collaborative Programmed on Reducing Emissions from Deforestation and Forest Degradation (UN-REDD+) program aims to reduce emissions from deforestation and forest degradation while enhancing forest carbon stocks and promoting sustainable development. This may include biodiversity credits as a mechanism for funding conservation efforts. REDD+ stands for "Reducing Emissions from Deforestation and Forest Degradation" and includes additional activities like the conservation and enhancement of forest carbon stocks and sustainable forest management.

This article provides a comprehensive review of the current landscape of biodiversity credits and offsets. Specifically, it aims to analyze their potential as conservation finance instruments, compare their design and governance with carbon credit mechanisms, and propose ways to improve the credibility, effectiveness, and equity of the sustainability credit market. Drawing on recent literature, case studies, and policy developments, the article identifies key challenges such as measurement inconsistency, risk of ecological simplification, and lack of social safeguards and discusses future directions to strengthen biodiversity markets within broader environmental governance systems.

2. Literature Reviews

2.1 Defining Biodiversity Credits and Understanding Their Mechanisms

Biodiversity credits have emerged as innovative financial instruments designed to incentivize measurable gains in biodiversity through market-based approaches. Properly designed, these credit systems hold potential to support large-scale conservation and ecological restoration efforts. Many scholars and organizations have explored the concept of biodiversity credits and their role in conservation financing. According to the Biodiversity Credit Alliance (BCA), a biodiversity credit is defined as "*a certificate that represents a quantified, evidence-based unit of positive biodiversity outcome that is durable and additional to what would have occurred in the absence of intervention."* This definition emphasizes measurability, ecological integrity, and additionality key principles necessary for ensuring the credibility and effectiveness of such mechanisms.

The British Ecological Society similarly describes biodiversity credits as *"measurable units of biodiversity that are purchased by individuals or organizations to contribute to biodiversity enhancement."* This framework supports the transition toward a "nature-positive" global trajectory, defined as halting and reversing biodiversity loss by 2030.

Biodiversity credits are distinct from biodiversity offsets in that they are not necessarily tied to compensatory mechanisms for development-related losses. Instead, they are often independent conservation actions that deliver quantifiable biodiversity benefits. These credits can be traded within voluntary or regulated markets, offering a flexible and scalable tool to engage both public and private sectors in biodiversity finance.

The global policy landscape has increasingly recognized the need for such tools. The Kunming-Montreal Global Biodiversity Framework (2022) and the Paris Agreement both call for ambitious actions to mitigate climate change and biodiversity loss. These frameworks emphasize the critical role of both governmental and non-governmental stakeholders in providing capital and implementing nature-based solutions. Such solutions not only target biodiversity recovery but also aim to enhance carbon sequestration and ecosystem service provision.

Despite growing international adoption over 108 countries have implemented biodiversity offset policies only a limited number (14 countries) possess formalized guidelines for assessing biodiversity outcomes. Furthermore, most frameworks rely heavily on habitat-based metrics, often neglecting species specific data, which may compromise ecological accuracy and monitoring effectiveness. The lack of standardized methodologies and the inconsistent use of biodiversity "currencies" hinder cross-comparison and long-term evaluation of offset efficacy [23, 24].

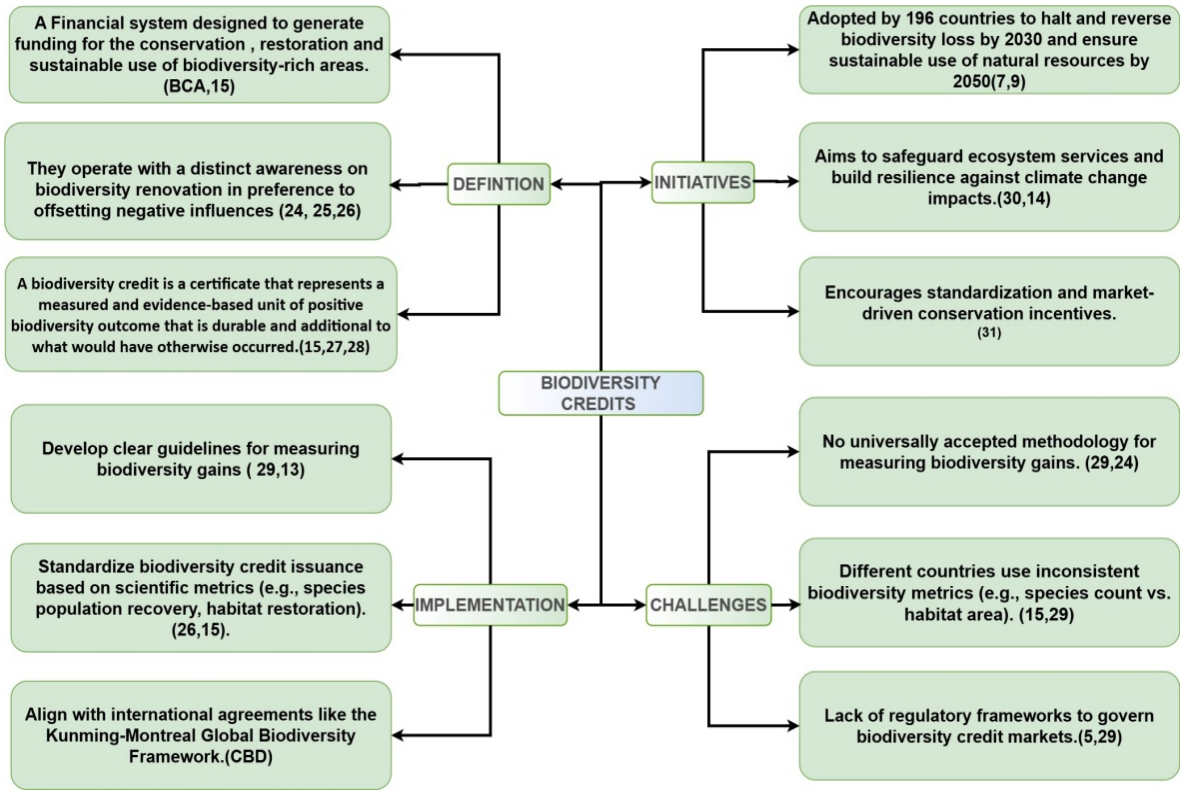

Figure 1. Presents a framework defining biodiversity credits from various perspectives, incorporating viewpoints from multiple organizations.

Biodiversity credits provide financial support for conservation, focusing on measurable biodiversity gains rather than offsetting losses. Global initiatives promote their use, but implementation requires clear guidelines, standardized scientific metrics, and international alignment. However, challenges include inconsistent measurement methods, varying country-specific metrics, and weak regulatory frameworks [33].

3. A comprehensive analysis of existing research on a specific topic

Many of the world's richest biodiversity hotspots are located in regions facing significant challenges such as poverty, corruption, large-scale resource exploitation, and rapid development [44]. Addressing this crisis requires not only effective conservation strategies but also sufficient and sustainable financing mechanisms. Establishing an economic system that recognizes the value of biodiversity could help prioritize its preservation, placing it on par with other resources, which would aid in reversing biodiversity decline and positively impact the climate [46, UNEP 2023]. Biodiversity finance, broadly defined, encompasses the financial resources and instruments deployed to support the conservation, sustainable use, and restoration of biodiversity and ecosystems [47]. Nature-based solutions (NbS) can simultaneously benefit climate adaptation, mitigation, and ecosystem health, but improved assessment methods and policy support are needed to maximize their effectiveness and minimize tradeoffs [11,12].

Several studies support the effectiveness and growing importance of biodiversity credit pro-grams while also highlighting key challenges and areas for improvement. For instance, Peng et al. (2024) provide a comprehensive overview of the core concepts, principles, and challenges of biodiversity credits, noting governance issues, pricing ambiguity, and risks of greenwashing.

Wauchope et al. (2024) emphasize measurement difficulties, particularly in defining what constitutes a unit of nature, and caution against ecological oversimplification. Forests and biodiversity are very strongly linked. The preservation of biodiversity in forests not only sup-ports species survival but also enhances resilience to environmental changes, thereby impacting plant diversity, soil develop-

ment, and carbon sequestration ensuring the continued availability of vital resources such as clean air, water, and climate regulation [31, 34]. By linking financial value to ecosystem services, nature credits encourage conservation efforts that restore natural habitats, support biodiversity, and contribute to sustainable development [35].

According to Popradit et al., (2015), Tropical Forest conservation is critical due to rapid de-forestation and human-induced environmental changes. Research conducted in Thailand investigated the impact of nearby village activities on forest structure and biodiversity. While the basal area remained stable, woody plant species diversity declined near the village, primarily due to a reduction in small samplings. This study suggests that although adult tree canopies indicate protection, forest regeneration is at risk due to seedling loss, threatening long-term sustainability.

Jonali et al., (2025) her studies offers a valuable overview of the emerging biodiversity finance nexus, highlighting the field's fragmented and largely theoretical nature. It proposes five key research pathways corporate strategies, reporting, stakeholder engagement, practical solutions, and case studies to guide future empirical and multidisciplinary work. The paper is clear and timely, though it could be strengthened with practical examples. Overall, it sets a strong foundation for advancing biodiversity conservation through financial mechanisms.

Fiegenbaum (2024) have pointed out that, how valuing ecosystem capacities can enhance risk mitigation and climate adaptation. By integrating biodiversity insurance and resilience value, ecosystem services can complement existing measures, strengthening both project stability and long-term climate resilience. Addressing biodiversity challenges require stronger transparent financial mechanisms stakeholder engagement, and alignment with global conservation goals to maximize ecological and social benefits. Biodiversity markets create economic incentives for conservation by ensuring measurable ecological outcomes, long-term certainty for investors, and sustainable funding for ecosystem restoration [37]. In this regard, biodiversity finance is gaining momentum in practice and public policy. Private capital supports biodiversity finance, but larger, high-impact projects depend on blended finance to balance risk and returns [32].

Table 1. Review of prior studies on biodiversity credits and offset.

Authors	Field of Study/ region	Evaluation of findings
Antonelli et al., 2025	Global	The study highlights that biodiversity-credit markets, if designed and regulated correctly, could succeed in funding conservation and restoration efforts where carbon-credit markets have struggled, by ensuring measurable and transparent biodiversity gains while engaging Indigenous and local communities.
Waochope et al., 2024	Global	The study does not focus on a specific geographic region. Instead, it provides a global review of biodiversity credit methodologies. It examines various biodiversity credit schemes, discussing how they define and measure biodiversity across different contexts. The research is based on a review of existing methodologies rather than fieldwork conducted in a particular location.

Authors	Field of Study/ region	Evaluation of findings
Ermgassen et al., 2019	Global	The study found mixed success in biodiversity offsets achieving "no net loss," with wetlands faring better than forests, higher multipliers improving outcomes, avoided loss offsets often failing, and inconsistent regulatory compliance, highlighting the need for better evidence and monitoring.
Webb et al., 2024	Australia	The study identifies challenges in integrating carbon and biodiversity credits in Australia, including issues related to policy alignment, market mechanisms, and ecological outcomes
Moilanen &Kotiaho 2020	Global	The study found that biodiversity credit methodologies face significant challenges in standardizing biodiversity measurement, with uncertainties in additionality, leakage, and permanence affecting their credibility and effectiveness

The study by Maron et al., (2025) explored how biodiversity offsets interact and can contribute to a nature positive future. Biodiversity offsetting aims to counterbalance development impacts on nature but is often ineffective and controversial. Despite its shortcomings, it offers clearer quantitative goals than other conservation methods, enhancing transparency. With limited alternatives, offsetting remains essential for biodiversity strategies, though its success depends on strict adherence to best practices and rigorous implementation. Irreplaceability based metrics enhance environmental markets by ensuring biodiversity gains, optimizing conservation investments, and balancing ecological and economic efficiency [25]. The emerging biodiversity credit market aims to reward conservation efforts, but its success hinges on robust governance, equitable benefit-sharing and scientific credibility. Biodiversity credits are a novel approach to finance conservation efforts while benefiting local communities and biodiversity custodians. However, much research indicates that safeguards are of-ten poorly implemented, and environmental protections remain underdeveloped.

Biodiversity credits and offsets reveal both their promise and limitations as tools for financing conservation. Numerous studies emphasize the potential of biodiversity credits to mobilize sustainable finance, promote ecosystem restoration, and deliver measurable ecological outcomes particularly when supported by robust governance, scientific credibility, and stakeholder engagement. However, persistent challenges such as measurement inconsistencies, governance gaps, pricing ambiguity, and weak safeguard implementation continue to undermine their effectiveness [15,16]. Comparative studies also show that while biodiversity credits offer unique advantages over carbon markets especially in reflecting ecological complexity, they require better integration with local contexts, stronger regulatory frameworks, and improved transparency to achieve nature-positive outcomes. This review underscores the urgent need for standardized methodologies, interdisciplinary collaboration, and equitable benefit-sharing to ensure that biodiversity finance delivers on its ecological and social promises. These studies highlight critical gaps in biodiversity measurement methodologies, which directly inform the framework proposed in this study.

4. Comparison with Carbon credits

Since the beginning of the 21st century, global greenhouse gas emissions have escalated rapidly, primarily driven by rising CO_2 emissions from emerging economies, leading to greater atmospheric concentrations and intensifying the greenhouse effect despite global mitigation efforts. A recent approach focuses on rewarding clean energy producers and encouraging the fossil fuel industry to improve efficiency and reduce emissions, resulting in the creation of carbon credits tradable certificates that permit the emission of one ton of CO_2 or its equivalent in other greenhouse gases [28]. Carbon and biodiversity are inextricably linked, As the demand for carbon credits increases, integrating biodiversity into these efforts is crucial, not only for ethical reasons but because healthy ecosystems are funda-

mental to carbon storage and the overall resilience of the planet [40]. On the other hand, learning from some of the strengths of the carbon market could help unlock much-needed finance for biodiversity conservation around the world. Framing biodiversity action as a natural extension of the more familiar carbon credit system may be an effective strategy to build broader support and understanding [12]. Key differences between the two systems are summarized in Table 2.

Table 2: Difference between biodiversity credit and carbon credit.

Biodiversity credit	Carbon credit
Focus on conserving and restoring ecosystems, species, and habitats.	Target the reduction or removal of greenhouse gas emissions.
Measured by improvements in habitat quality, species protection, and ecosystem health.	Measured in standardized units of CO_2-equivalent emissions reduced or sequestered.
Aim to protect biodiversity, enhance species populations, and restore ecosystems.	Aim to mitigate climate change by reducing carbon emissions or sequestering carbon.
Can be generated from projects like habitat restoration, species protection, and sustainable land management.	Often come from reforestation, renewable energy projects, and carbon capture initiatives.

While carbon credits have more established trading platforms, biodiversity credits face chal-lenges in standardizing metrics and ensuring ecological additionality. However, biodiversity credits offer co- benefits that carbon markets often overlook, such as ecosystem resilience and cultural value.

The paper by Schwerdtner Mánez and Clifton (2025) proposes a novel framework that integrates Payments for Ecosystem Services (PES) principles into the design of carbon and biodiversity credit schemes to ensure high integrity and equitable outcomes. Recognizing the lack of clear guidance on incorporating local community rights and participation in existing credit markets, the framework emphasizes free, prior, and informed consent (FPIC), equitable benefit-sharing, and community involvement throughout project development. It aims to create transparent, credible, and socially just credit systems that support both environ-mental goals and local livelihoods, bridging the funding gap for climate and biodiversity initiatives through responsible market-based mechanisms.

Tedersoo et al., (2023) propose a co-crediting system that values both carbon storage and biodiversity. Using technologies like DNA-based soil analysis and remote sensing, the approach enables better monitoring and encourages land use that supports ecosystem health. It offers a scalable solution to address climate change and biodiversity loss together. This integrated approach seeks to promote land use strategies that foster ecosystem resilience, discourage monoculture plantations, and support global environmental targets. By embedding biodiversity metrics within carbon credit schemes, the paper offers a practical and scalable pathway to tackle the twin challenges of climate change and biodiversity loss.

5.Challenges and Future direction of biodiversity credits

Rising atmospheric carbon dioxide levels resulting from fossil fuel combustion and deforestation have contributed significantly to global warming and air pollution prompting governments and organizations to implement strategies to reduce greenhouse gas emissions [41]. Through a systematic review of the literature in the field of biodiversity credit, we find that development of biodiversity credit shows early stages, similar to the initial development of carbon trading. While efforts focus on designing mechanisms and measurement frameworks, a key challenge is the emphasis on tradability over actual ecological benefits. Despite the involvement of various stakeholders, many governance structures fail to achieve meaningful biodiversity conservation. Significant public funding is necessary to bridge financing gaps and create stable conditions that attract long-term private investment in biodiversity conservation [42]. To be effective, biodiversity credit systems must prioritize ecological integrity,

establish transparent valuation methods, and implement strong regulatory frameworks to ensure both economic and environmental benefits [15].

Recent discussion on biodiversity credits highlights ongoing challenges, particularly in financial feasibility and methodological standardization. Biodiversity credits are focused on enhancing ecosystem health and preserving biodiversity in a way that reflects its intrinsic value, rather than just as a co-benefit to carbon reduction. These credits represent a shift towards valuing nature for its own sake, positioning it as a critical asset in achieving global environmental goals. As we look towards the future, biodiversity credits will likely play a pivotal role in shaping the next phase of sustainable market mechanisms and global conservation efforts. While markets can contribute by unlocking innovation and funding in otherwise inaccessible areas, achieving effective and equitable conservation will still require substantial direct investment from both public and private sectors. The effectiveness of biodiversity or nature credits in attracting substantial private finance depends on how they are structured and implemented. When used as a form of payment for ecosystem services, they have the potential to create stable and motivating incentives for landowners to preserve and manage biodiversity.

The report by the World Economic Forum and McKinsey (2023) explores the potential of biodiversity credits tradable units representing measurable nature gains as a tool to finance conservation and close the global biodiversity funding gap. Though still in early stages, these credits could help businesses meet sustainability goals, secure ecosystem services, and boost reputations. Market demand could grow significantly by 2050, but progress depends on strong standards, clear governance, and supportive policies to ensure high integrity and real impact.

Although the article emphasizes the necessity of strong regulatory frameworks for effective biodiversity credit markets, it lacks concrete real-world examples to illustrate these challenges and their implications. For example, The Australian biodiversity market faces criticism due to inconsistent metrics and insufficient monitoring, which undermines public trust and market performance [39]. This case underscores the need for robust institutional design, independent verification mechanisms, and clear ecological baselines to ensure credibility and long-term ecological outcomes. The Australian example highlights that without rigorous oversight, bio-diversity credit systems risk becoming symbolic rather than impactful, potentially facilitating greenwashing rather than meaningful conservation.

6. Conclusions

Nature-based solutions (NbS) are increasingly recognized as scientifically robust and ecologically sustainable strategies for protecting, restoring, and managing ecosystems in ways that simultaneously address biodiversity loss, climate change, and human wellbeing. By harnessing the inherent regenerative capacities of nature, NbS offer cost-effective and scalable approaches to enhance ecosystem services, promote climate resilience, and support socio-economic development.

Within this context, biodiversity markets represent a transformative mechanism for aligning economic incentives with conservation goals. These markets, when supported by scientifically validated, transparent, and equitable governance frameworks, have the potential to reconcile ecological preservation with economic development imperatives [50]. Properly designed biodiversity markets can channel investments into measurable conservation outcomes, foster multi-stakeholder engagement including Indigenous peoples and local communities and facilitate the longterm protection of critical natural resources. When integrated into sustainable development agendas, biodiversity markets can serve as a nexus for economic, environmental, and social sustainability [2].

Biodiversity credits, in particular, are emerging as a powerful financial tool within these markets. Unlike conventional biodiversity offsets, which are often compensatory in nature, biodiversity credits are designed to reward proactive and measurable gains in biodiversity. These credits quantify ecological improvements such as increased habitat connectivity, enhanced species populations, or restored ecosystem functions and translate them into tradable units. By attributing tangible economic value to ecological integrity, biodiversity credits incentivize conservation actions across sectors, particularly within agriculture, forestry, and infrastructure development [21]. This review has demonstrated the potential of biodiversity credits as an emerging financial mechanism that supports measurable conservation outcomes while aligning with global sustainability goals.

7. Patent

Author Contributions: I.B. is responsible for the overall conceptualization and design of the study and led the writing of the manuscript. I.B. reviewed the manuscript for important intellectual content. S.C. and P.S. provided revisions to the manuscript. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: I would like to express my deepest gratitude to all those who supported me throughout the writing of this manuscript. I am especially grateful to my academic mentor Dr Ananya Popradit, Suntaree Cheentam, Pathanin Sangaroon and Dr Issara Suwanabol for their invaluable insights and feedback. Special thanks to the peers for their valuable advice, and to the editorial team for their professionalism and encouragement. This manuscript would not have been possible without your support. Thank you all for being part of this endeavor.

Conflicts of Interest: No conflicts of interest.

References

[1] Josefsson, J., et al., *Compensating for lost nature values through biodiversity offsetting Where is the evidence?* Biological Conservation, 2021. **257**: p. 109117.
[2] Raven, P. and Mathis, W., *Maintaining biodiversity will define our long-term success*. Plant Diversity, 2020: p. 211–220.
[3] Yuan, R., Ning, Z., and Qing, Z., *The impact of habitat loss and fragmentation on biodiversity in global protected areas*. Science of the Total Environment, 2024. **931**.
[4] Kumari, R., Deepali, and Sonal, B., *Biodiversity loss: Threats and conservation strategies*. International Journal of Pharmaceutical Sciences Review and Research, 2021. **68**(1): p. 242–254.
[5] Roe, S., Streck, C., and Beach, R., *Land-based measures to mitigate climate change: Potential and feasibility by country*. Global Change Biology, 2021. **27**(22): p. 6025–6058.
[6] Wiebe, R.A. and Wilcove, D.S., *Global biodiversity loss from outsourced deforestation*. Nature, 2025.
[7] Hald-Mortensen, C., *The main drivers of biodiversity loss: A brief overview*. Journal of Ecology and Natural Resources, 2023. **7**(3).
[8] Pfenning-Butterworth, A. et al., *Interconnecting global threats: Climate change, biodiversity loss, and infectious diseases*. The Lancet Planetary Health, 2024. **8**(4): p. e270–e283.
[9] Isbell, F., et al., *Expert perspectives on global biodiversity loss and its drivers and impacts on people*. Frontiers in Ecology and the Environment, 2023. *21*(2): p. 94–103.
[10] Mair, L., et al., *A metric for spatially explicit contributions to science-based species targets.* Nature Ecology & Evolution, 2021. 5: p. 836–844.
[11] Key, I.B., Smith, A.C., et al., *Biodiversity outcomes of nature-based solutions for climate change adaptation: Characterising the evidence base*. Frontiers of Environmental Science, 2022.
[12] Weiskopf, S.R., et al., *Biodiversity loss reduces global terrestrial carbon storage*. Nature Communications, 2024. **15**: p. 4354.
[13] Porras, I. and Steele, P., *Making the market work for nature: How bio credits can protect biodiversity and reduce poverty*. IIED, 2020.
[14] Heilmayr, R., Echeverría, C., and Lambin, E.F., *Impacts of Chilean forest subsidies on forest cover, carbon, and biodiversity*. Nature Sustainability, 2020. **3**: p. 701–709.
[15] Peng, Y.Y., Jin, T., and Zhang, X.Q., *Biodiversity credits: Concepts, principles, transactions, and challenges*. Biodiversity Science, 2024.
[16] Antonelli, A., Ximena, R., Robert, C., and Pauline, N.K., *How biodiversity credits could help to conserve and restore nature*. Nature, 2024. **364.**
[17] Shivanna, K.R., *Climate change and its impact on biodiversity and human welfare*. Proceedings of the Indian National Science Academy, 2022. **88**(2): p. 160–171.
[18] Wunder, S., et al., *Biodiversity credits: Learning lessons from other approaches to incentivize conservation*. OSF Preprints, 2024.
[19] Jenny, M.,et al., *The credit point system: An innovative approach to enhance biodiversity on farmland*. Aspects of Applied Biology, 2013. **118**: Environmental Management on Farmland.
[20] Probst, B.S., et al., *Systematic assessment of the achieved emission reductions of carbon crediting projects*. Nature Communications, 2024. **15**: p. 9562.
[21] Schwerdtner Manez, K. and Clifton, J., *Biodiversity credits: A new currency to support nature conservation? Biodiversity*, 2025.
[22] Mori, A.S., et al., *Biodiversity–productivity relationships are key to nature-based climate solutions*. Nature Climate Change, 2021. **11**(6): p. 543–550.
[23] Fiegenbaum, H., *Complementing carbon credits from forest-related activities with biodiversity insurance and resilience value*. OSF Preprints, 2024.
[24] Marshall, E., et al., *A global analysis reveals a collective gap in the transparency of offset policies and how biodiversity is measured*. Conservation Letters, 2023. **17**: e12987.
[25] Bush, A., Katherine, H.S., and Nick, H., *Systematic nature positive future. Conservation Biology*, 2023. 38.

[26] Maron, M., et al., *Biodiversity offsets, their effectiveness, and their role in a nature-positive future*. Nature Reviews Biodiversity, 2025.

[27] Moilanen, A. and Janne, S.K., *Three ways to deliver a net positive impact with biodiversity offsets*. Conservation Biology, 2020. **35**(1): p. 197–205.

[28] Saraji, S. and Borowczak, D., *A blockchain-based carbon credit ecosystem*, 2023.

[29] Wauchope, H.S.,et al., *What is a unit of nature? Measurement challenges in the emerging biodiversity credit market*. Proceedings of the Royal Society B: Biological Sciences, 2024. **291**: 20242353.

[30] Aide, T.M., *The biodiversity credit market needs rigorous baseline, monitoring, and validation practices*. NPJ Biodiversity, 2024. **3**: 30.

[31] Brockerhoff, E.G., et al., *Forest biodiversity, ecosystem functioning, and the provision of ecosystem services*. Biodiversity and Conservation, 2017. **26**: p. 3005–3035.

[32] Caroline, F., Thomas, G., and Geoffrey, M.H., *Biodiversity finance*. ECGI Working Paper Series in Finance, 2023.

[33] [33] Tsakalidi, A.L., *Nature credits: A mechanism for environmental valuation and sustainability*. International Journal of Agriculture and Environmental Research, 2024. **10**(5).

[34] Pinmongkhonkul, S., et al., *Species diversity, aboveground biomass, and carbon storage of watershed forest in Phayao Province, Thailand*. Environment and Natural Resources Journal, 2023. **21**(1): p. 47–57.

[35] Gorissen, M.M., et al., *Habitat banking and its challenges in a densely populated country: The case of the Netherlands*. Sustainability, 2020. **129**: p. 3756.

[36] Popradit, A., Srisatit, T., Kiratiprayoon, S., et al., *Anthropogenic effects on a tropical forest according to the distance from human settlements*. Scientific Reports, 2015. **5**: p. 14689.

[37] Hutchinson, M.C. and Brian, L., *A bibliometric and systemic literature review of biodiversity finance*. Finance Research Letters, 2024. **64**.

[38] Ermgassen, S.O., et al., *The ecological outcomes of biodiversity offsets under "no net loss" policies: A global review.* Conservation Letters, 2019.

[39] Webb, J., et al., *Prospects for integration of carbon and biodiversity credits: an Australian case study review*. Sustainability Science, 2025.

[40] Torabi, N. and Bekessy, S.A., *Bundling and stacking in bio-sequestration schemes: Opportunities and risks identified by Australian stakeholders*. Ecosystem Services, 2015. **15**: p. 84–92.

[41] Gupta, Y., *Carbon credit: A step towards a green environment*. Global Journal of Management and Business Research, 2011. **11**(5).

[42] Zu Ermgassen, S.O., et al., *The current state, opportunities, and challenges for upscaling private investment in biodiversity in Europe*. Nature Ecology & Evolution, 2025. **9**: p. 515–524.

[43] Boruah, I., et al., *Biodiversity of birds in urban green space for support ecotourism activities in Valaya Alongkorn Rajabhat University Thailand*. Journal of Environmental Management and Tourism, 2021. **4**(52): p. 1131–1138.

[44] Wang, Z., et al., *Biodiversity conservation in the context of climate change: Facing challenges and management strategies*. Science of The Total Environment, 2024. **937**: p. 173377.

[45] Biodiversity Credit Alliance, High level principles to guide the biodiversity credit market. 2025. Available from: https://www.biodiversitycreditalliance.org/ (accessed 10 March 2025).

[46] Damiens, F.L.P., Backstrom, A., and Gordon, A., *Governing for "no net loss" of biodiversity over the long term: Challenges and pathways forward*. One Earth, 2021. **4**(1): p. 60–74.

[47] Cosma, S., Rimo, G., and Cosma, S., *Conservation finance: What are we not doing? A review and research agenda*. Journal of Environmental Management, 2023. **336**: p. 117649.

[48] Jonäll, K., Baeckström, Y., Elliot, V., and Arvidsson, S., *The biodiversity–finance nexus: A future research agenda*. Current Opinion in Environmental Sustainability, 2025. **72**: p. 101504.

[49] Tedersoo, L., et al., *Towards a co-crediting system for carbon and biodiversity*. People and Nature, 2023. **5**(5): p. 1146–1160.

[50] British Ecological Society, A beginners' guide to biodiversity credits. 2025. Available from: https://www.britishecologicalsociety.org/content/a-beginners-guide-to-biodiversity-credits/ (accessed 10 March 2025).

[51] DGB Groups, Biodiversity credits: An innovative financing mechanism for conservation. 2025. Available from: https://www.green.earth/blog/biodiversity-credits-an-innovative-financing-mechanism-for-conservation (accessed 10 March 2025).

[52] Convention on Biological Diversity, Kunming–Montreal Global Biodiversity Framework. CBD COP 15 Decision 15/4. 2025. Available from: https://www.cbd.int/doc/decisions/cop-15/cop-15-dec-04-en.pdf (accessed 10 March 2025).

[53] World Economic Forum, Biodiversity credit: Demand analysis and market outlook. 2025. Available from: https://www3.weforum.org/docs/WEF_2023_Biodiversity_Credits_Demand_Analysis_and_Market_Outlook.pdf(accessed 11 March 2025).

[54] World Economic Forum, Biodiversity Credits. 2025. Available from: https://initiatives.weforum.org/financing-for-nature/biodiversitycreditsinitiative (accessed 11 March 2025).

[55] IUCN, Nature-based solution. 2025. Available from: https://iucn.org/our-work/nature-based-solutions (accessed 11 March 2025).