COVER PAGE

Harnessing nature-based solutions for economic recovery: a systematic review

Alexandre Chausson[1], Alison Smith[1,2], Ryne Zen-Zhi Reger[3], Brian O'Callaghan[4,5], Yadira Mori Clement[6], Florencia Zapata[6], Nathalie Seddon[1,5]

1 Nature-based Solutions Initiative, Department of Biology, University of Oxford, Oxford, United Kingdom

2 Environmental Change Institute, University of Oxford, Oxford, United Kingdom

3 Department of Economics, Stanford University, Stanford, California, United States of America

4 Institute for New Economic Thinking, Oxford Martin School, University of Oxford, Oxford, United Kingdom

5 Smith School of Enterprise and the Environment, School of Geography and the Environment, University of Oxford, Oxford, , United Kingdom

6 Instituto de Montaña, Calle Gral. Vargas Machuca, #408, Lima, Peru

* Correspondence:

Nathalie Seddon

nathalie.seddon@biology.ox.ac.uk

Keywords: nature-based solutions, economic stimulus, green recovery, natural capital, climate economics, resilience, economic multiplier, biodiversity, sustainable development, nature finance

Disclaimer: This is the final peer-reviewed version of a paper accepted for publication by PLoS Climate, submitted to EarthArXiv to ensure immediate access. It has undergone peer review, and this version represents the final accepted version before design and production. The article is currently in production at PLoS Climate, and the data used in the systematic review analyses will be available through the PLoS Climate portal upon publication.

Abstract

Nature-based solutions (NbS) involve working with nature to address societal challenges in ways that benefit communities and biodiversity locally. However, their role supporting economic recovery from crises, such as those arising from conflicts or pandemics remains underexplored. To address this knowledge gap, we conducted a systematic review of 66 reviews on the economic impact of nature-based interventions. Most demonstrated positive outcomes for income and employment, though those with critical appraisal of underlying studies reported more mixed outcomes. These varied results were influenced by factors such as the balance between short-term and long-term gains, market conditions, regional effects, reliance on subsidies, and discrepancies between expected and actual economic benefits. National-scale economic growth assessments were scarce. Half of the cases featured nature-based food production investments, with much evidence from sub-Saharan Africa, East Asia and the Pacific. The few reviews comparing NbS with alternatives found that NbS delivered equal or better economic outcomes. NbS also provided broader benefits like food and water security, flood protection and community empowerment. We identified key factors influencing the delivery of benefits and trade-offs, finding that NbS must adhere to best practice standards, with community involvement being critical for equitable outcomes. Well-designed NbS can create diverse job opportunities at different skill levels, diversify income, and improve resilience, offering a rapid, flexible response to economic shocks that can be targeted at deprived communities. By integrating traditional, local and scientific knowledge, NbS can enable eco-innovation, and drive the transition to a clean and efficient circular economy, with high economic multipliers spreading benefits throughout economies. The evidence underscores the need to incorporate NbS in investment programs to concurrently address economic, environmental, and societal challenges. However, improved monitoring of economic, social and ecological outcomes and the development of comprehensive accounting systems are needed to better track public and private investments in NbS.

Introduction

The vital role of nature-based solutions (NbS) for reducing vulnerability to climate change [1, 2] whilst also increasing carbon sequestration and reducing greenhouse gas emissions [3, 4] is now widely recognized. There is also growing awareness that NbS could play a key role in recovery from economic shocks, including those related to conflicts or pandemics. Indeed, the COVID pandemic raised awareness of the importance of nature in addressing root causes of zoonotic disease emergence (human encroachment in wildlife habitat) and improving human wellbeing (e.g. [5]). However, despite the focus on 'building back better', there has been limited attention to how investments in nature can also drive economic recovery. By 2020, only 3% of COVID-19 recovery spending appeared likely to support investment in nature, while up to 17% risked negatively impacting it through new infrastructure, defense spending, and other measures [6]. Several barriers hinder the mainstreaming of NbS investments, including path dependency [7], siloed government decision-making [8, 9], the pervasive misconception that environmental protection harms business [10], limited awareness [11], lack of skills, and uncertainty over the economic benefits of NbS compared to alternatives [36].

Fiscal policy (i.e. government spending and taxation) can be a powerful lever for influencing total demand for goods and services, particularly during economic downturn (see [12, 13]), thereby promoting recovery. Faced with the need to act rapidly, economists have advised that policy makers should respond with measures that are "timely, targeted, and temporary". However, this implies little consideration for the long-term impacts of policy, meaning that the relative benefits of more socially useful or long-term activities might not be appropriately considered. Keynes suggested that priority investments during the latter stages of the US depression should be in "durable goods such as housing, public utilities, and transport", noting that "the necessities for such developments were unexampled" [14]. Given limited funds and capacity to secure finance, it is important that policymakers consider how short-term fiscal measures might influence long-term outcomes [6, 15]. This is particularly important in emerging market and developing economies (EMDEs), where fiscal space is often tightly constrained and new debt is expensive. Put differently, policies that bring long-term debt servicing costs should deliver long-term assets that support well-being ([6]; see S3 Text for a glossary of terms). Biodiversity and long-term resilience are just some of the factors that might be harmed when recovery investments do not consider long-term needs [16].

In the context of post-pandemic economic recovery, it has been proposed that investments in measures reducing greenhouse gas emissions might offer economic benefits equivalent to, or perhaps greater than, traditional investments [6, 17-20]. Building on investigations into low-carbon energy and energy efficiency during the Global Financial Crisis (GFC), (21-25), it was suggested that investing in nature could be an attractive option for rapid implementation [6, 19, 26].

NbS—formally defined by the United Nations Environment Assembly as "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems, which address social, economic and environmental challenges effectively and adaptively, while supporting human well-being, ecosystem services, resilience, and biodiversity benefits [27]" —have several characteristics that make them well-suited to support economic recovery. First, once designed, some NbS can be deployed relatively quickly [6, 28]. Second, they can create demand for both skilled labor (e.g., for mapping, design, monitoring and evaluation) and low-skilled labor, making them particularly useful in addressing high unemployment among unskilled workers [6, 29]. Third, many NbS are viable in rural areas where populations are vulnerable [19, 30, 31], unlike with other low-carbon initiatives such as public transport investment that require high population density to be cost-effective. Fourth, NbS can support climate change mitigation and adaptation and can be integrated with built infrastructure [1, 3, 4, 32]. They also support many other sustainable development goals by helping to address pollution, food, and water security, while protecting and restoring biodiversity and human well-being [33-36]. However, realizing these benefits requires conscientious design and implementation, informed by a robust understanding of potential trade-offs and equitable distribution of costs and benefits. Therefore, alongside their economic potential, it is crucial to understand when, where, and how NbS can deliver biodiversity, climate, and social benefits, and ensure that these gains are distributed fairly across different groups.

Previous research suggests that investments in nature (e.g., restoration) deliver high gross value added and higher returns per unit of investment than other sectors [10, 29, 37]. However, existing research is mainly limited to project-specific or sector-specific outcomes with a lack of evidence synthesis across the full range of NbS. Existing reviews typically cover specific sub-types of NbS, specific geographical locations, or a subset of economic outcomes. The highly dispersed nature of the evidence challenges the uptake of NbS research to inform fiscal policy measures. Furthermore, recent assessments [38] have not investigated economic recovery potential at a high enough granularity to compare short versus long-term economic characteristics of NbS, and their risks and opportunities. There is also a need to frame the evidence to support systemic policy change, requiring comparison of NbS to other economic recovery options. Finally, there has been a lack of focus on how different benefits are delivered, and how these socially disaggregate. In the absence of such information, nature can be sidelined in economic recovery policies, locking in the continued destruction of nature, with severe impacts for climate, biodiversity, and livelihoods. Economic stimulus packages therefore require robust evidence-based guidelines around what good investments in NbS look like and the benefits they can bring.

To address these issues, we conducted a systematic review of reviews [39] on the economic outcomes of investments in nature, and the pathways by which these benefits are delivered, focusing on jobs and labor demand, household income and business revenue generation, and economic growth. Reviews of reviews, or "umbrella reviews", predominantly carried out in health and medical fields, allow rapid assessment of the evidence across a broad range of outcomes, interventions, and contexts amidst a rapidly increasing number of primary research studies [40].

Our focus was guided by the recognition that decision-makers involved in fiscal policy —our prime target audience— focus on economic criteria such as fiscal multipliers (leading to GDP growth) and job creation. We recognize that GDP growth is an inadequate measure of human progress and well-being [41, 42], and that perpetual growth in a finite world severely jeopardizes progress towards addressing the climate and biodiversity crises [16, 43, 44]. A vast array of social and environmental factors shape well-being. These include material circumstances (e.g., income, livelihoods, health, the environment), social dynamics (e.g., community relations), and subjective wellbeing (e.g., psychological health) [45], many of which are closely tied to our relationship with nature, its ecosystems, landscapes, and nonhuman species [6, 46]. Therefore, although we focus on conventional economic outcomes for jobs, incomes and growth, we also discuss the vital role of NbS in supporting many of these wider societal benefits.

Our overarching questions are:

1) What is the distribution of the evidence on the economic impact of NbS between different regions, types of NbS, ecosystems and economic outcomes?
2) What are the reported economic impacts of nature-based solutions?
3) How do nature-based solutions contribute to economic impact?
4) What are the reported trade-offs and win-wins between economic impact outcomes, and biodiversity or climate outcomes?
5) How are costs and benefits distributed across social groups?

We address those questions by a) exploring the scope of NbS outcomes reported under the umbrella of 'economic impact' in the peer-reviewed literature; b) synthesizing this evidence with respect to geography, ecosystem, and type of intervention; c) highlighting trade-offs and win-wins in relation to biodiversity, climate, and social equity; and d) identifying how NbS deliver economic impacts (pathways and mediating factors). Unpacking when and where NbS deliver benefits, and for whom, is crucial to tailor and target NbS in fiscal policy measures to support broader climate and biodiversity objectives, including addressing potential trade-offs and win-wins for resilient development. Our primary method is a systematic review of the literature on the economic outcomes of NbS, but we supplement this with a review of the wider outcomes of NbS for sustainable development, and a detailed case study to add depth and nuance to our understanding. We also highlight knowledge gaps and biases in the literature, with recommendations for practitioners and researchers to support future evidence collection. In addressing these questions, our goal is to enable well-targeted scientific research on NbS to play a stronger role in informing fiscal policy. We conclude with a set of recommendations for policy makers.

Methods

Systematic review protocol

We drafted a systematic review protocol, including a conceptual framework (S1 Text), to catalogue evidence in a transparent and objective manner [47]. We revised the question scope (Table 1), search string, review selection criteria, and coding framework (see S1 Text and S5 Text) in early 2022 through meetings and workshops with an interdisciplinary group of experts in academia, civil society, and government, covering expertise on NbS and economic impact (see Acknowledgements and S1 Text). We designed the coding framework to ensure relevance for policymakers focusing on economic policy, including economic recovery, while also noting any reported outcomes for climate and biodiversity.

Table 1. The elements of the question scope underpinning the search string, review selection criteria, and exclusion criteria

Target	**Intervention**
Human individuals, groups, communities and economic sectors (e.g., agriculture, water, forestry, transport, energy).	Interventions managing, restoring, rehabilitating, creating, or protecting biodiversity, ecosystems (semi-natural or natural), or ecosystem services, including in working landscapes (agriculture, forestry, farms, fishing grounds) and urban green infrastructure.
Comparator	**Outcome**
We recorded whether reviews required their component studies to use a comparator (such as baselines, controls, or counterfactuals) but did not exclude reviews that did not.	Reported direct or indirect impacts on economies, including employment, income, or multiplier effects.

Searches and screening process

We ran the search string for English publications in SCOPUS and Web of Science CORE index collections incorporating indexed up to February 15, 2023, restricting the search to title, abstract content, and author keywords, and refining the search to articles tagged as review. We removed duplicates in EndNote (v8.2) and exported search results into Rayyan [48] for screening using a stepwise procedure, screening first reference titles, then abstracts. We progressively refined selection criteria for clarity and inter-reviewer consistency, and further refined these criteria after abstract screening to produce a manageable number of studies, based on time and team capacity constraints (see Table 1 and Table F in S5 Text). We included only those studies where the methodology for the review was clearly described.

Decisions at each stage of screening were conservative; we assessed studies for which inclusion eligibility was unclear at the next stage. We randomly selected at least 10% of references to check for inter-reviewer coding consistency with a Kappa test. If the Kappa coefficient was below 0.6 (the threshold at which inter-reviewer coding consistency is deemed sufficient; [49], we reviewed any emerging inconsistencies and revised the screening strategy and selection criteria for clarity. We carried out single reviewer screening cautiously, i.e. checking screening consistency throughout the process. Approximately 15% of all screening decisions at the abstract and full-text stages were made by at least two reviewers. Studies excluded during full text screening, and reasons for their exclusion, are available in the supporting information (S1 Table). Inclusion decisions were guided by whether the review reported one or more economic impact(s) stemming from nature-based interventions, regardless of the aim of the intervention. We did not narrow our scope to studies explicitly using the terminology of NbS or interventions meeting all NbS criteria [50, 51], because this would have excluded many relevant studies. Hence, hereafter we refer to nature-based interventions instead of NbS. In some reviews, the extent to which interventions supported biodiversity or local communities was heavily context dependent (depending on how the intervention was implemented). We did not exclude these reviews unless the information reported indicated that the interventions did not support (or were harmful) to biodiversity or local communities. In other words, if it was not clear whether an intervention fully met the criteria to be an NbS (with benefits for both biodiversity and local communities), we gave interventions the benefit of the doubt, but if it was clear that the intervention was not an NbS then it was excluded.

Coding strategy

The extraction of evidence from studies was guided by a coding framework developed from the conceptual framework (S2 Text) and entered in Excel by 3 coders (AC, AS, and RZR), with approximately 30% of the studies checked by at least 2 coders to ensure consistency. The coding framework captured data at three levels: for each review, for each intervention covered by a review, and for each outcome type recorded for an intervention.

For each review, we recorded bibliographic details and quality criteria such as whether the review was systematic and whether it excluded studies with no comparator. To map the distribution of evidence across geographies, we recorded which world regions or specific nations were associated with the evidence reported, following the World Bank regional classification scheme (2020) [52].

For each intervention, we recorded the broad category: (i) protection, (ii) restoration, (iii) other forms of management (hereafter management), (iv) creation of novel ecosystems, and (v) nature-based food production (see S2 Text for definitions). Ecosystems in which interventions took place were grouped into 28 categories, drawing from the typology devised for a systematic map of nature-based interventions to adaptation [1] to which we added categories for working landscapes (cropland, pastures, agroforestry, plantations, aquaculture) and urban green infrastructure.

For each outcome, we recorded the outcome type, description and direction of effect (positive, negative, mixed, no effect, or unclear). Outcomes were classed as mixed if a mix of positive and negative outcomes were recorded by the component papers of the review, or unclear where component papers found that evidence for outcome direction was inconclusive. Outcome types included i) income, revenue and profitability (thereafter income/revenue), ii) employment and labor demand (thereafter labor demand/job creation), iii) job security,

iv) skills and training, v) economic growth and multiplier effects (thereafter economic growth). These are all interconnected, as economic growth is a function of income, income is related to employment levels, and job security, skills and training all affect income and employment. For labor demand, we coded increased labor demand as a positive outcome on the macro level, noting that in some micro studies (e.g., for nature-based food production) increased labor was viewed as a negative outcome because it led to increased production costs.

Reported outcomes did not need to be associated with a comparator (for example, if a review reported overall revenue generated, it was coded as positive, unless a baseline assessment was provided indicating that income generation was insufficient to overcome opportunity costs). To characterize the extent of evidence for each outcome category, we also captured the number of underlying studies associated with each outcome statement (where the information was provided by the review). We did not explore whether there was any overlap in the primary studies covered by different reviews due to time limitation, but significant overlaps seem unlikely given that most reviews covered quite different combinations of intervention types and geographical regions.

In addition to recording the economic outcomes, we also recorded whether wider outcomes for ecology, climate change or social equity were considered by the assessments. Ecological outcomes included those associated with species conservation, habitat quality, diversity (e.g., species richness), or resilience of natural ecosystems. Climate change mitigation outcomes included avoided greenhouse gas emissions, or changes in below or above ground carbon storage. For climate change adaptation, we coded outcomes for addressing vulnerability (exposure, sensitivity, or adaptive capacity) to climate change impacts or other hydrometeorological hazards, including climate hazards which may or may not be explicitly linked to climate change. Equity effects were identified as any reported distribution of outcomes across social groups, either within communities embedded in the intervention landscapes, or between local communities and external stakeholders (government, private sector and investors, or civil society organizations). Outcomes were deemed to be positive for equity if they resulted in benefits for low income or marginalized groups, and negative if benefits flowed primarily to high income beneficiaries or those with political power and influence.

Data analysis and mapping

The evidence base was characterized through descriptive statistics, mapping the number and percentage of studies with respect to methodology, geographical region, intervention type, type of ecosystem, type of outcomes, and associations between economic outcomes and intervention type. We then analyzed the direction of reported economic outcomes (positive, negative, mixed, or neutral), any comparisons with alternative approaches, any reported effects on climate change (adaptation and mitigation), and trade-offs and win-wins. For each review, reported evidence disaggregated by intervention (by the review authors) was recorded as a distinct case. Where absolute numbers are shown in figures, we only report percentages in the text. When proportions or counts are provided without an explicit sample size, it should be assumed that the calculation includes the entire set of studies, interventions, or outcomes.

We summarize reported effectiveness of interventions to characterize the evidence base and guide future analyses. Meta-analysis was not possible given the heterogeneity of the evidence and the underpinning review methodologies. This also precludes weighing reported categorical outcomes by strength of evidence, although we recorded the number of underlying papers supporting each outcome within each review. Because of the heterogeneity and context-dependence of the evidence base (meaning that there were a relatively low number of reviews covering each specific combination of intervention type, outcome and context), the results should not be used to generalize the effectiveness of a particular intervention type. To test the impact of evidence quality on the likelihood of reporting a positive economic impact, we considered whether the review was categorized as systematic or not, whether critical appraisal was undertaken, and whether the sample size (the number of evidence points underpinning the reported effect), was associated with the likelihood of reporting a positive effect. We employed mixed effects logistic regression models using R version 4.4.1, accounting for the nested structure of the data (multiple observations within the same article). The lme4 package was used to fit these models, with articleID specified as the random effect to account for within-article correlations. The dependent variable was binary (positive effect, or not), and the independent variables included appraisal (yes or no), article type (systematic or not), sample size, intervention type, and outcome category. To maintain simplicity and address reduced sample sizes for sub-categories, separate models were run for each predictor variable (see S5 Text for full models). Confidence intervals for the model coefficients were calculated using Wald confidence intervals.

Pathways and mediating factors

Within each review, we inductively extracted the pathways and mechanisms through which nature-based interventions were reported to shape economic outcomes. Relevant passages were extracted into Excel, and progressively refined to identify emergent categories (see S2 Text, Pathway definitions). Interventions and outcomes described within a review can be associated with one or more pathway categories. For example, a nature-based food production intervention such as agroforestry may boost yield (and hence income) by improved ecosystem services (such as pollination and erosion protection) and could also be associated with increased income via payment for ecosystem service (PES) schemes designed to promote adoption or offset opportunity costs.

We also conducted an analysis of mediating factors, i.e. any factors reported to modify the outcome of the intervention (see mediating factors in S2 Text). First, we grouped mediating factors according to seven categories following categories of ecosystem-based adaptation constraints identified by Nalau et al. (2018) [53], in which most mediating factors fit. These are economic and financial, governance and institutional, social and cultural, biological, physical, or human resources. We added the category 'technical factors' to capture intervention design elements under the deliberate control of implementers (whether physical or biological). We then extracted and coded relevant passages by the relevant category. We coded mediating factors for each review, as disaggregating mediating factors for each intervention was not always possible. We counted the number of times each mediating factor category was represented across reviews (if more than one factor was identified in a review for a given category, we only counted that category once). The analysis of mediating factors and pathways is not exhaustive and is limited by the extent to which they were reported by review authors but provides an important window into the diversity of factors (internal or external) which shape the economic impact of nature-based solutions.

Trade-off and win-win analysis

We extracted all passages in the reviews explicitly mentioning trade-offs and win-wins and categorized them according to whether they specified trade-offs or win-wins between outcomes, between stakeholders, across time (e.g., short-term costs vs long term benefits), or spatially (e.g., costs in one area, benefits in another). Social trade-offs and win-wins were extracted from the previously coded material describing distributional effects and equity. We then identified emerging themes and summarized these narratively within each category along with descriptive statistics (number and percentage of studies reporting each category). We also explored associations between reported outcomes for climate (adaptation and mitigation) and economic impact, even if not explicitly reported as a trade-off or win-win by the underlying reviews.

As well as incomes and employment, NbS can deliver a wide range of societal and environmental benefits, many of which are crucial to support economic prosperity. To illustrate this, we conducted a supplementary analysis of a previous systematic review dataset, drawn from both academic and grey literature, which coded the outcomes of nature-based interventions for development in the Global South, focusing on interventions that delivered climate change adaptation outcomes [54].

Results

Studies *identified* and methodological approaches adopted

The number of articles retained or excluded at each stage of the searching and screening process is shown schematically in Fig 1. The search of literature reviews on the economic impact of nature-based interventions identified a total of 2,405 studies in Web of Science, and 1,261 in Scopus, resulting in 3,121 references after duplicate removal. After title, abstract and full text screening, 219 of these met initial selection criteria (S7 Table F in S5 Text). These were published across 99 academic journals, from 1996 to 2023. Only 66 of these specified a methodology, and therefore were included in our review. Of these, half (36) were categorized by the journal or labeled by the authors as systematic reviews, although not all conformed fully to established systematic review standards [47]. Only 21% (14) conducted some level of quality appraisal of the underlying studies, and only 29% (19) restricted the review to primary studies that used comparators (such as counterfactuals, baselines, or controls).

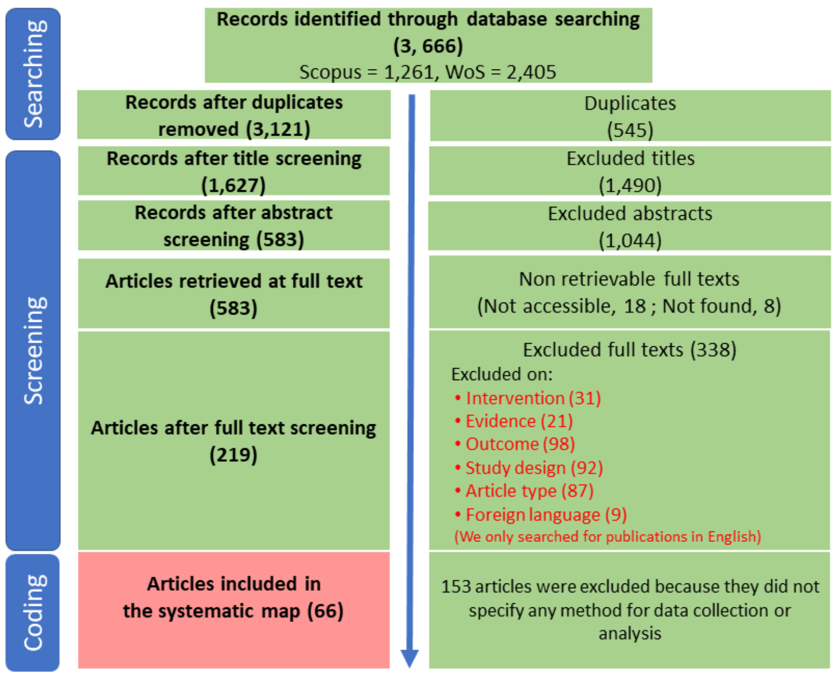

Fig 1. Schematic of systematic review stages from the searches to the coding of studies included in this review.

What is the distribution of the evidence on the economic impact of Nature-based Solutions?

Across the 66 reviews, we identified 95 intervention cases (as a review can have more than one intervention), reporting 168 distinct economic outcomes. The reviews reported between 1 and 9 intervention cases each (mean ± SD = 1.5 ± 1.4), and each intervention case was associated with between 1 and 4 reported outcomes (mean ± SD = 1.8 ± 0.8). Most outcome assessments were based on quantitative data (47%) or both qualitative and quantitative data (14%); 21% were qualitative, and for 18% the type of data was unclear.

Variation in numbers of reviews by region

The most frequently represented region (noting that reviews often cover more than one region) was sub-Saharan Africa (covered in 44% of reviews), followed by South Asia (35%), East Asia & Pacific (30%), Latin America & Caribbean (18%), and Europe & Central Asia (15%) (Fig 2a). For most reviews, the geographical scope of the data synthesized was global (27, 41% of studies), followed by national (21, 32%), regional (13, 20%), and sub-national (3, 5%). Only one review was local.

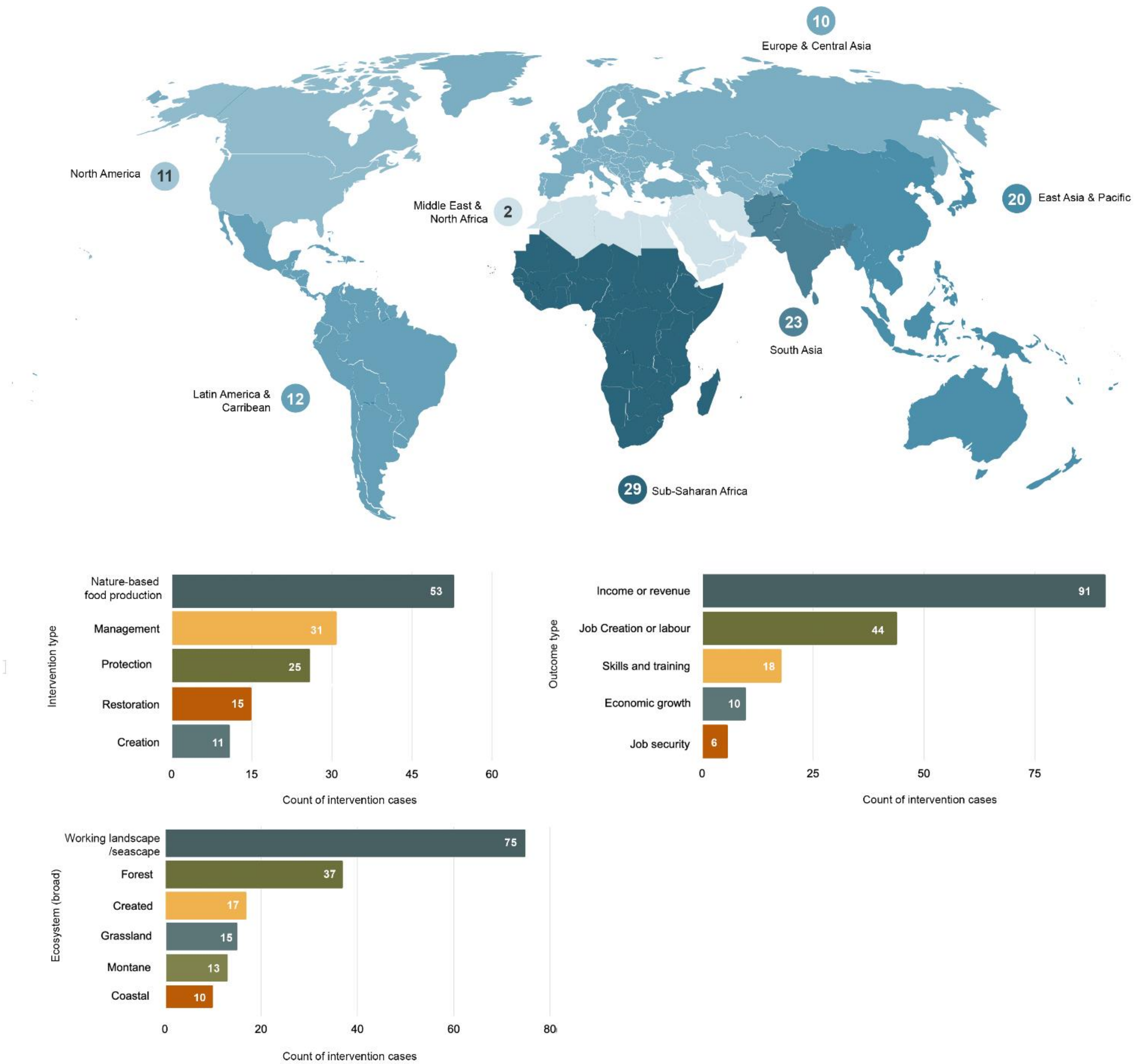

Fig 2. Number of reviews covering (a) world region (World Bank, 2020), and number of interventions by (b) the broad type of NbS (c) ecosystem category, and (d) economic outcome type. A review or intervention can

cover more than one of each category; note that only the most represented (top 6) ecosystem types are indicated.

Type of nature-based interventions

Intervention cases were associated with up to five different broad intervention types (i.e. protection, restoration, management, creation of novel ecosystems or nature-based food production; see S1 Text) (mean = 1.43, S.D. = 0.78). The most frequently represented type of intervention was nature-based food production (56% of cases) followed by management (33%), protection (27%), restoration (16%), and creation of novel ecosystems (12%) (Fig 2b). However, many interventions (31%) used a combination of these approaches (e.g., community-based natural management with natural resource use restrictions was coded as both protection and management). While 48% involved only nature-based food production, just 13% involved only management, 4% involved only creation of novel ecosystems, 4% involved only protection, and none involved only restoration.

Table 2 provides examples of the types of actions within each intervention category. Nature-based food production interventions involved a range of measures in rural working landscapes, plus one case of urban agriculture in South Africa. Of these, 45% involved measures targeting soil health (e.g., conservation tillage, cover crops, mulching), while 62% involved measures for above ground diversification (e.g., agroforestry (including silvopasture), intercropping, farmer-managed natural regeneration). Interventions involving elements of ecosystem protection included marine and terrestrial protected areas, resource use and access restrictions, and forest-based ecotourism. Interventions categorized as management involved community-based forest or fisheries management, forest management certification, grassland management, or indigenous practices to harvest NTFPs. Restoration measures included forest or rangeland restoration, or invasive species removal. Finally, interventions creating novel ecosystems involved urban nature-based solutions (e.g., green roofs or walls), or afforestation (i.e. planting trees on naturally treeless habitats or creating plantations of non-native species). Note that afforestation typically does not provide benefits for biodiversity, so it is not considered to be an NbS unless it is part of a process aimed at supporting landscape regeneration (e.g., by rehabilitating degraded land).

Table 2. Examples of nature-based interventions identified in included reviews, for each of the five broad intervention types. Interventions may not meet all guidelines for nature-based solutions (NbS) in practice, but we include evidence from all interventions because it is generally not possible to evaluate which are NbS with the information provided in each review, and it is also needed to build an understanding of what makes for effective NbS. A sample of references for each intervention is provided.

Intervention type	Specific intervention	Description	References
Nature-based food production	Agroforestry	Agroforestry practices including trees on farms, silvopasture and silvoarable systems, shade-grown crops, homegardens with trees, farmer managed natural regeneration.	Achmad et al. 2022; Castle et al. 2021; Duffy et al. 2021; Chomba et al. 2020; Low et al. 2023; Muthee et al. 2022; Vignola et al. 2022 ; Reich et al. 2021 ; Rosa-Schleich et al. 2019 ; Kerr et al. 2022
	Conservation agriculture	Soil health practices including no-till or reduced tillage, cover crops, mulching, residue retention diversified crop rotations	Rosa-Schleich et al. 2019; Reich et al. 2021; Mafongoya et al. 2016; Vignola et al. 2022; Yang et al. 2022
	Aquaculture	Aquaculture-integrated agriculture systems (AIAS) - a sustainable intensification approach that incorporates fish alongside fruits, vegetables, and livestock, focusing on increased sustainability, productivity, and efficiency, notably through waste, nutrient, and water recycling.	
Protection	Protected areas	Terrestrial or marine protected areas or reserves, as spaces designated and managed to protect marine ecosystems, processes, habitats, and species for biodiversity conservation, or to support the restoration and regeneration of resources for social, economic, and cultural aims.	Marcos et al. 2021; Lindsey et al. 2014; Thapa et al. 2022
	Community-forest management	Community forest management through various forms of tenure and institutional arrangement between local communities and public agencies, involving	Pelletier et al. 2016

		restrictions on natural resource use.	
Restoration	Rangeland restoration	Fencing rangeland or removal of livestock (seasonal or year-round) to restore the ecological services provided by rangeland ecosystems	Li et al. 2016; Yu et al. 2023
	Forest restoration	Re-establishment of forests through tree planting, or seeding on land classified as forest, or restoration through assisted recovery of damaged forest ecosystems, or natural forest restoration (spontaneous natural regrowth).	Adams et al. 2016; Angom and Viswanathan, 2022
	Invasive species management	Managing invasive species by funding and setting guidelines for control efforts. The intervention supports agencies and individuals responsible for eradication through contracts that mandate labor-intensive methods, training, and predefined pay scales.	Van Wilgen et al. 2022
Management	Forest management	Native (planted) or natural forest stands managed for rural economic development, to provide goods such as walnuts, NTFPs (non-timber forest products), timber, to promote soil and water conservation, or align with sustainable forest management certification standards.	Shigaeva and Darr, 2020; So and Lafortezza 2022
	Community-based natural resource management	Various forms of community-based or indigenous natural resource management, involving collaborations between international organizations and local communities in the context of sustainable development initiatives. These approaches devolve the management of natural resources to local communities.	Mbaiwa et al. 2013; Salim et al. 2023
Novel (i.e. ecosystem creation)	Urban green and blue infrastructure	Interventions involving the establishment of green roofs, green walls, or other green	Shackleton, 2021

		and blue spaces, corridors, and elements, to provide ecosystem services within urban or peri-urban areas.	
	Afforestation	The planting of trees on degraded or low productivity farmland, or on barren hills, to prevent soil erosion, mitigate flooding, to regenerate degraded farmland for livelihoods.	Angom and Viswanathan, 2022; Bryan et al. 2018

Ecosystem type

Most intervention cases (79%) were associated with working landscapes (croplands, grazing lands and agroforestry), followed by forests (39%), (primarily tropical and subtropical forests), grasslands (16%), plantations (13%), and coastal ecosystems (11%) (Fig 2c). Of these, 52 (55%) intervention cases only involved created ecosystems or working landscapes, 27 (28%) only involved natural or semi-natural ecosystems, and 11 (12%) involved a mix of semi-natural/natural and working landscapes or novel ecosystems. Few studies reported on freshwater habitats (6, 6%), urban green infrastructure (5, 5%), oceans and seas (5, 5%), or desert and xeric shrublands (5, 5%), and none reported evidence from interventions involving aquaculture, mangroves, or peatlands.

Economic outcomes

Overall, 96% of intervention cases reported outcomes for income/revenue, 46% for labor demand/job creation, 19% for skills and training, 11% for economic growth, and 7% for job security (Fig 2d). We also recorded the number of studies *within* each review that provided evidence to support each outcome assessment to understand the relative size of the evidence base. We found that 66% (1214) of the underlying studies provided evidence on income/revenue, followed by labor demand/job creation (21%, 391 studies), job security (6%, 109), economic growth (4%, 78), and skills and training (3%, 46).

Only 9 reviews reported evidence of indirect labor demand/job creation, such as where revenue from ecotourism provided indirect employment for transport and local food production to supply eco-lodges in Sri Lanka [55]. Of reviews reporting changes in labor demand/job creation only four reported on the length of employment, and only one quantified the proportion of short-term and long-term jobs [56]. Most outcome assessments were reported at the farm level or household level (35%), followed by community-level (14%), and sub-national scale (11%). Only 13 (8%) were national scale.

Associations between economic outcome and type of nature-based intervention

We mapped associations between intervention category and outcome type, treating combined interventions as a separate category (Fig 3). This revealed clusters of evidence for the income/revenue outcomes of nature-based food production (45 cases, 98% of all interventions involving nature-based food production) and combined interventions (27 cases, 93%), with smaller clusters for the labor outcomes of combined interventions (16 cases, 55%) and nature-based food production (20 cases, 43%), the income/revenue outcomes of management interventions (11 cases, 92%) and the skills or training outcomes of combined interventions (9 cases, 31%). Most of the limited evidence on economic growth and job security was associated with combined interventions (5 cases, 17%; and 4 cases, 14%, respectively).

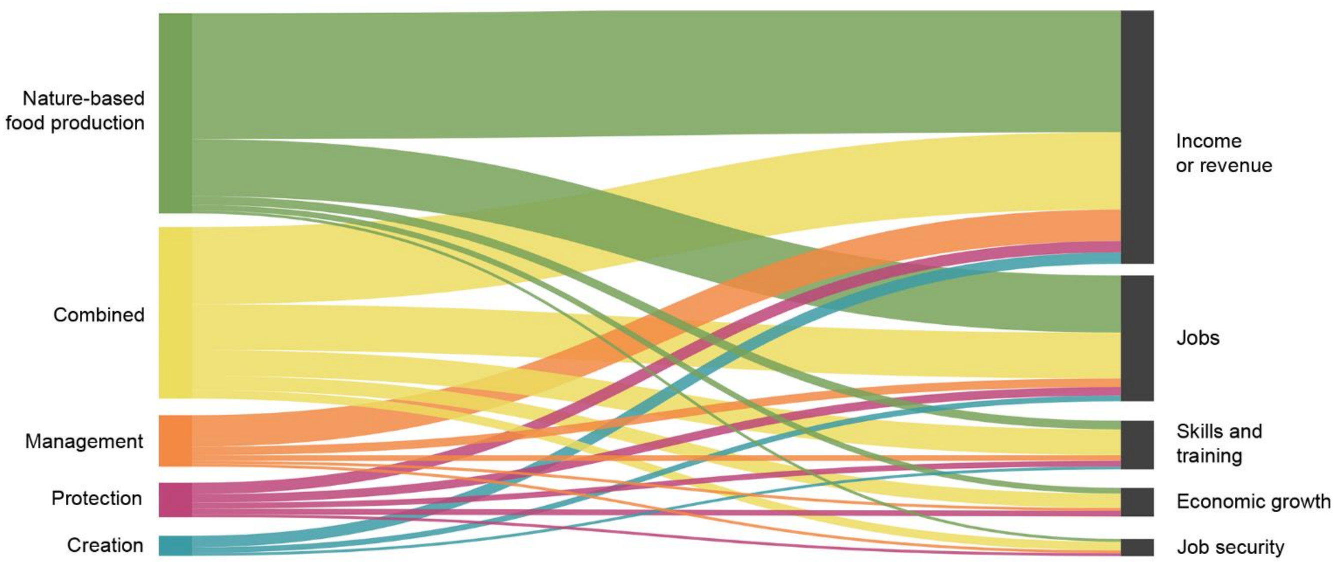

Fig 3. Systematic map of economic impact outcomes by each of the broad intervention types illustrated as a Sankey diagram, where the thickness of each band corresponds to the number of cases involving the linked intervention type and economic impact outcome

What are the reported economic impacts of nature-based solutions?

Most reported outcome effects were positive (65%), with 25% mixed and only a few unclear (5%), negative (3%), or neutral (2%) (Fig 4). The pattern for income/revenue outcomes matched the overall pattern, with most effects positive (67%), 25% mixed, and few unclear, negative, or neutral (3%, 2%, and 2% respectively). Two thirds (8, 67%) of the interventions framing increasing labor as negative (i.e. a cost) were associated with mixed positive and negative effects on labor demand. In contrast, where labor was framed as positive (for job creation; primarily for interventions other than nature-based food production) most reported outcomes (21, 75%) were positive.

However, the reviews that conducted critical appraisal reported a higher proportion of mixed effects (16, 53%) and a lower proportion of positive effects (12, 40%) compared to those that did not (26, 18% mixed and 97, 70% positive). Critical appraisal was found to be significantly associated with a decrease in the likelihood of reporting positive outcomes (Coefficient = -1.789, SE = 0.6815, z = -2.625, p = 0.009, 95% CI [-3.124, -0.453]; Table A in S5 Text). Outcome type did not affect the relationship, except for job security (Coefficient = -2.673, SE = 1.3478, z = -1.983, p = 0.047, 95% CI [-5.315, -0.032]; Table A in S5 Text) where there was a lower likelihood of a positive effect (see job security pathways below). In a separate model, intervention category was not significantly associated with the reported effect, whereas critical appraisal remained significantly associated with the likelihood of reporting a positive result (Coefficient = -2.072, SE = 0.7237, z = -2.863, p = 0.004, 95% CI [-3.490, -0.654]; Table B in S5 Text).

The review category (systematic or not) was not associated with effect. However, in this model, there was, again, a decreased likelihood of a positive effect reported for job security (Coefficient = -2.571, SE = 1.3089, z = -1.964, p = 0.050, 95% CI [-5.137, -0.006]; Table C in S5 Text). In a separate model examining the association with intervention category, there was a significant increase in the likelihood of reporting positive effects for nature-based food production (Coefficient = 1.267, SE = 0.613, z = 2.066, p = 0.039, 95% CI [0.065, 2.469]; Table D in S5 Text). This association may be explained by the higher proportion of 'nature-based food production' studies reporting positive effects, across economic impact categories, within the subset of systematic reviews compared to other intervention types. None of the other intervention types or outcome categories were associated with reported effect. Finally, we found no significant association between sample size and the reported effect (Table E in S5 Text).

In the subset of reviews which had conducted critical appraisal, mixed effects arose for different reasons. First, variability in underlying studies contributed to the overall mixed categorization, as different studies report varying results for the same intervention type. In some cases, short-term income gains are observed, but the sustainability of these gains over the long term is uncertain, or vice-versa, some interventions may not be immediately profitable but could offer benefits over a longer period. The effect on income/revenue generation was also affected by external factors, including market conditions, and region-specific effects, with some areas showing significant benefits while others did not. Many interventions rely on external subsidies for financial sustainability, and without these subsidies, they might not be viable in the short term, such as in the case of certification and community-forest management. Additionally, some studies reported a gap between expected economic benefits (e.g., from price premiums) and the actual realized benefits, leading to mixed outcomes.

Few outcomes were reported for job security, 50% of which were mixed, or for economic growth, of which most (90%) were positive. For example, revenues from the sale of NTFPs (e.g., aromatic resins in Ethiopia) can contribute substantially to national economies [57], nature-based ecotourism stimulates local business development [58], and restoration investments in the US were found to yield as many as 33 jobs per $1 million invested, with an economic output multiplier between 1.6 and 2.59 [10].

Proportionally more reported effects on income/revenue were positive for nature-based food production, while there were proportionally more mixed outcomes for interventions involving protection, management, or restoration. There were no clear differences between intervention types for employment outcomes, apart for interventions involving nature-based food production where a greater proportion of reported outcomes were mixed (for the reason mentioned above).

Overall, few cases (12) reported positive contributions to skills and training, with two cases reporting mixed effects, and two reporting neutral outcomes. Investments in capacity strengthening either targeted technical skill building for the intervention itself (e.g., extension and training programs for agroforestry [59], crop-livestock integration [60], to meet certification requirements [61], or for alien species management [62]), or were complementary (e.g., business skills to establish agri-businesses and micro-enterprises [58, 63]). Neutral effects reflected a lack of investment in capacity building (e.g. [64]), or where interventions did not require specialized skills (in turn providing low entry barriers to the labor market; [65]). Two reviews reported mixed effects, where the capacity building did not train workers with transferable skills, thereby limiting their opportunities to integrate into labor markets subsequently [56], or where the training prioritized quick environmental results over deep, enduring community benefits [62].

Viewing the number of underlying studies within each review reveals that although the overall patterns are similar, the evidence on skills and training and economic growth comes from a small number of studies (Fig 5).

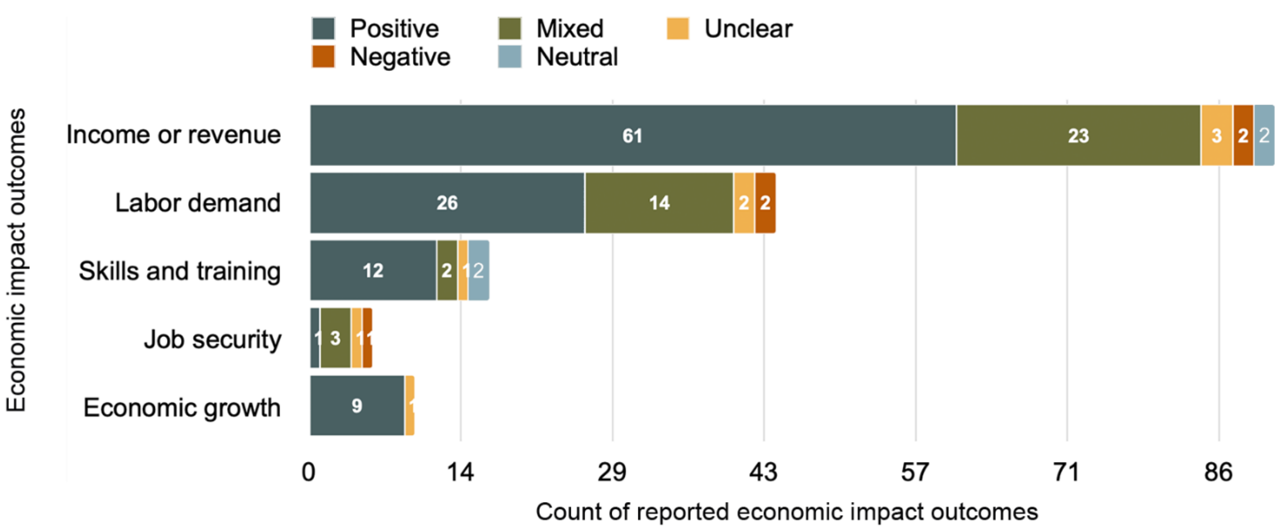

Fig 4. Number of reported outcomes, per economic impact category and effect direction

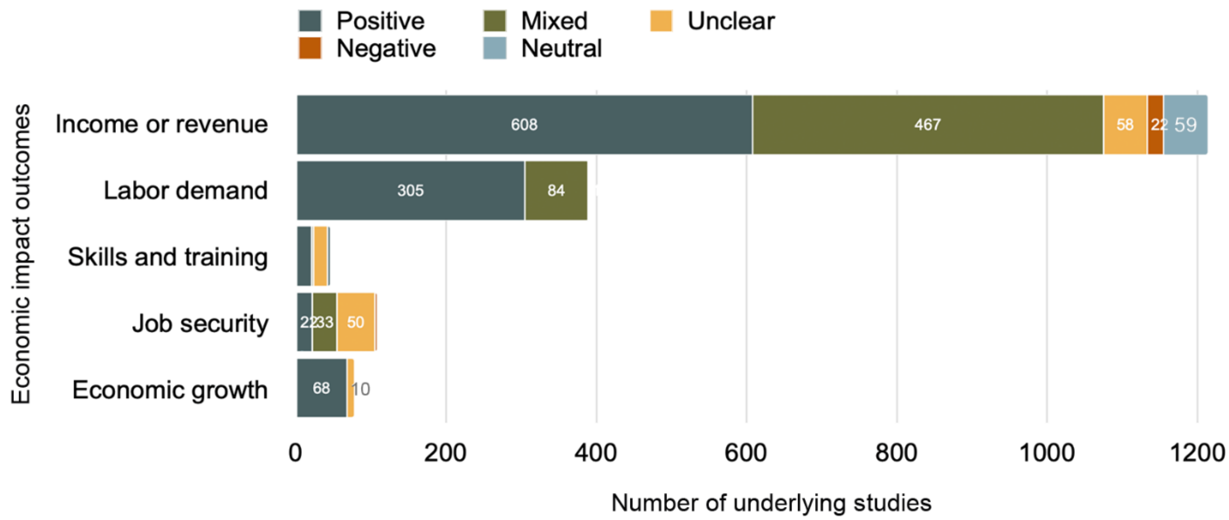

Fig 5. Number of underlying studies supporting reported outcomes

Effectiveness of nature-based interventions compared to alternative approaches

Overall, 24 (36%) of the studies compared interventions involving Nature-based Solutions (NbS) with either non-NbS alternatives (21, 32%) or other NbS (10, 15%). Of the 26 non-NbS comparisons, the majority (17, 65%) showed positive outcomes, 19% (5) were negative, and the rest (15%, 4) had mixed or no significant effects. These comparisons mainly focused on nature-based agricultural practices like conservation agriculture or agroforestry versus conventional methods, highlighting benefits such as improved soil health, water retention, increased yields over time, and reduced production costs [66-68]. Several reviews found agroforestry offered higher productivity and more stable yields than crop monocultures [59, 69]. Non-agricultural NbS comparisons (5 in total) explored revenue generation or profit margins. Interventions included forest management, where FSC certified management was found less profitable due to high costs outweighing price premiums [70], and decentralized forest management showing advantages for local communities over centralized approaches [57, 70]. Green urban infrastructure, like green roofs, was noted for not being cost-effective for building owners despite broader societal benefits [71]. Additionally, the restoration industry was reported to have employment multiplier effects comparable to traditional sectors like oil and gas or construction [10].

Through what pathways do nature-based solutions contribute to economic impact?

All but two of the 66 reviews contained evidence on the pathways by which economic outcomes were delivered. We identified 12 distinct pathways by which NbS contributed to income/revenue (across 61 reviews), 8 pathways for effects on labor demand/job creation (across 31 reviews), 8 for economic growth (out of 10 reviews), and 5 pathways for job security (across 5 reviews).

Outcome pathways

Income, revenue, or profitability pathways

These pathways fell into five overarching categories: 1) higher or new revenue generation (e.g., from the sale of goods (e.g., fish, NTFP, crops), services (e.g., offset credits), or property taxes), 2) avoided costs (e.g., energy savings from green roofs and walls, or reduced input costs for agriculture), 3) household income from employment generation, 4) labor shifts to off-farm jobs, which can be higher paid, and 5) household, business or community revenue from subsidies or payments for ecosystem services.

The most common pathway was where investment in nature-based food production influenced income (30 reviews, 50% of all income/revenue generation pathways), followed by revenue from payments for ecosystem service schemes (10 reviews, 17%), and revenue generation through ecotourism (8, 13%) (Fig 5). The least commonly cited pathways included revenue generation through offset credit sales (for carbon storage [72] or wetland restoration [10]), where green infrastructure generated employment or ecosystem services reducing costs (e.g., reduced energy consumption through the installation of green roofs [71]), marine protected areas increasing or sustaining fishery catch [73], and conservation easements or green infrastructure increasing property values and generating tax revenue [71, 74].

For eight out of the 12 pathways for income/revenue, most reviews reported positive effects (Fig 6). For nature-based food production, benefits occurred through reduced input and labor costs [66], reduced exposure to income volatility (such as from diversified income streams or resilience to extreme weather [75]), and increased yield or output [76-78]. Key to these pathways is the positive effect of nature-based food production on ecosystem services (e.g., pollination, pest control, soil health), thereby also improving job security [76] and climate change adaptation.

For the other four pathways, at least half of the outcomes were mixed. This included cases where price premiums for certified goods were insufficient to overcome implementation costs [79], where producers became over-specialized in the certified commodity, thereby becoming more exposed to price downturns [80], where offset credit revenues were less than opportunity costs of land-use restrictions [81, 82], where there was a lack of market access [83], or where yield fell after transitioning to agroforestry from monoculture [70, 84]. Other factors potentially negatively impacting income included choice of crops [78], costs of human-wildlife conflict [64], or lack of available off-farm employment following restrictions in land-use. The one review reporting a purely negative impact was where the equipment and labor costs of conservation tillage were generally not offset by increased yield, especially where herbicides were used [85].

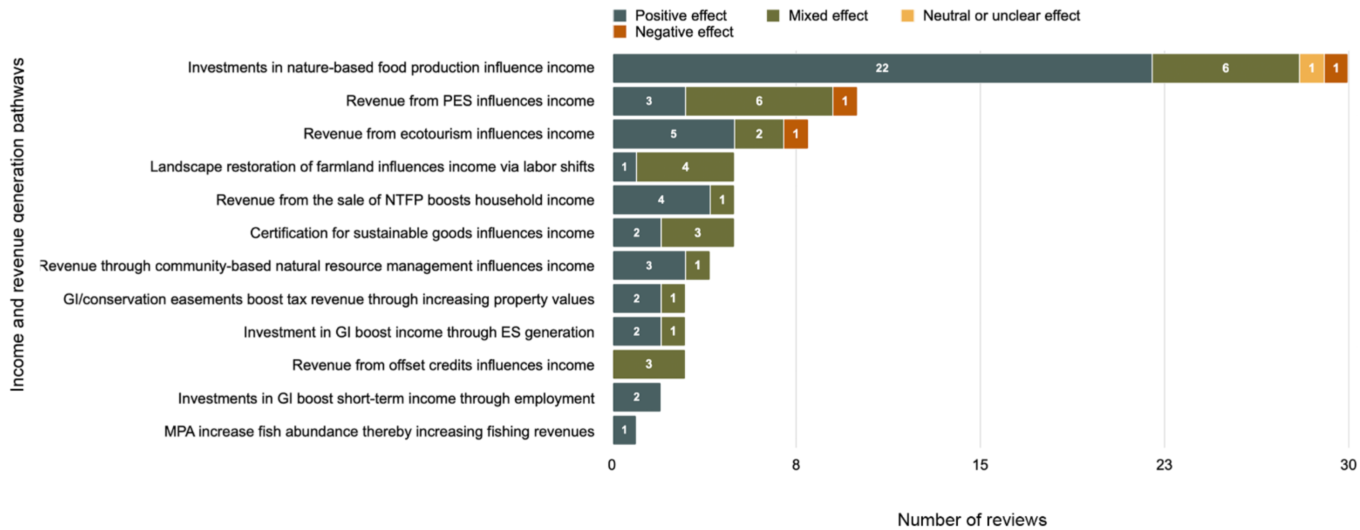

Fig 6. Count of reviews reporting each outcome pathway for income/revenue, along with the associated effect (GI = Green Infrastructure, e.g., green roofs and walls).

Labor demand/job creation pathways

The most common employment pathways involved nature-based food production (10, 32% of the reviews reporting labor pathways), ecotourism (6, 19%), green infrastructure or restoration investments (5, 16%), all of which generally increased labor demand (

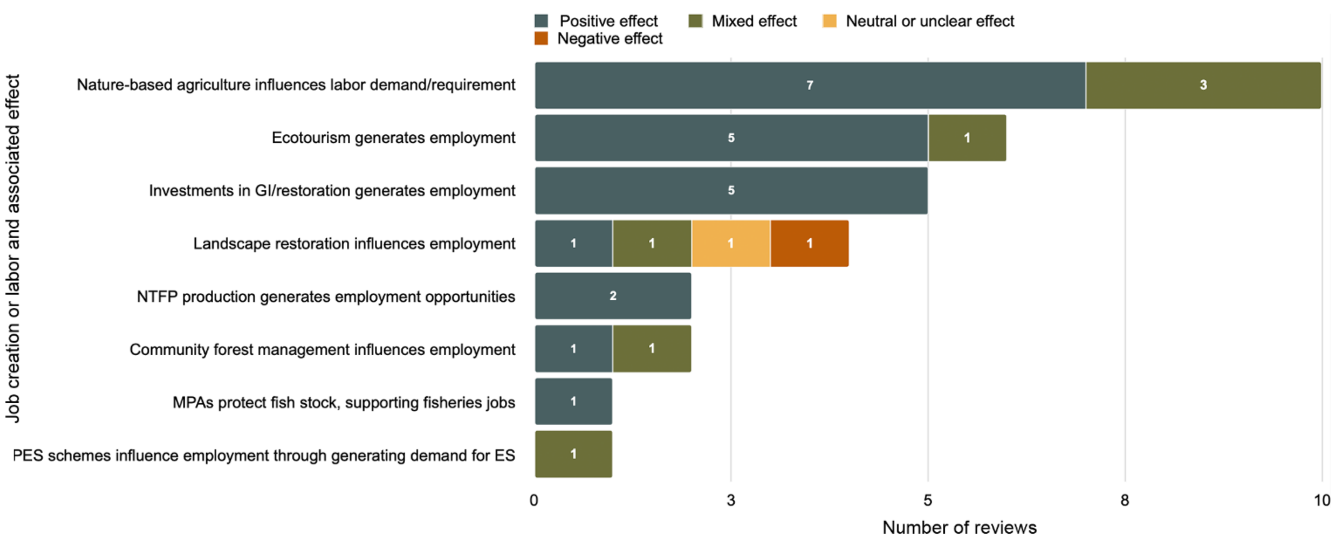

Fig). Positive employment outcomes also occurred through revenue generated by community forest management, and through increased ecosystem services including the sale of NTFPs or increased fishing revenue adjacent to MPAs [86].

Mixed or negative impacts on employment occurred where there was a lack of ecotourism (e.g., due to low wildlife densities or lack of investment in in tourism operation; [64]), from shifts to off-farm labor following land-use restrictions for landscape regeneration [83], or where nature-based food production led to increases and decreases in labor demand, such as through reductions in labor demands for agrochemical application and increasing labor demand for hedge maintenance [75].

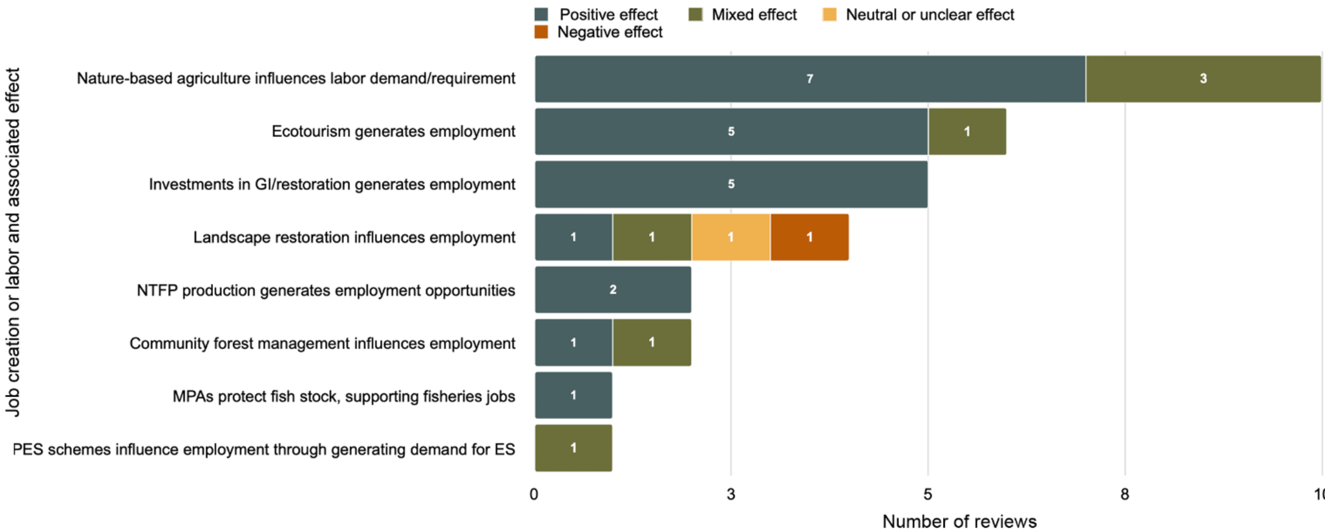

Fig 7. Count of reviews reporting each outcome pathway for labor demand/job creation, along with the associated effect.

Job security pathways

Job security was reported to increase where agricultural diversification stabilized revenue streams [76], or where community-forestry strengthened ownership, use and access rights [72]. However, a lack of focus on transferable skill development can lead to job insecurity once the intervention ends due to challenges in integrating other sectors [56], or due to a lack of formal employment opportunities (such as where urban green infrastructure is established and maintained by informal workers) [65]. Furthermore, although nature-based tourism can create jobs, the unpredictable nature of tourist demand, like during the COVID-19 pandemic, can result in revenue and job losses [58].

Economic growth pathways

Impacts on economic growth were reported to emerge through business creation and revenues generated by ecotourism, [58, 87], the sale of NTFPs [57, 85, 88, 89], and investments in restoration which generated labor demand, business-to-business expenditures, and household spending with high economic multipliers [10]. Mixed (though mainly positive) effects on household expenditure were found under PES schemes (although a lack of data was noted), with revenue from PES also contributing to infrastructure construction (e.g., schools, clinics, power grids) [83]. Practices like agroecology, permaculture, and organic farming, along with investments in value chains, can improve economic prosperity by increasing market access, regional trade, and product quality [90].

Mediating factors

Across outcome pathways, we identified up to 18 distinct mediating factors per review (avg = 5.8; S.D. = 3.9) across 63 (95% of) included reviews. Mediating factors often influenced more than one outcome pathway, either positively or negatively. They included factors internal to the intervention (e.g., the density of trees in agroforestry, or the degree of stakeholder engagement), or external (e.g., legislative and regulatory frameworks, or the level of public and private finance). The most frequently identified category was economic and financial, reported in 70% of reviews, followed by technical factors (65%), governance and institutional factors (55%), and social and cultural factors (47%) (Fig 8). Given heterogeneity in review methodology, quality, and scope of analysis, we advise caution in associating these proportions with overall prevalence. Mediating factors within each category are detailed in S4 Text and Table H in S5 Text.

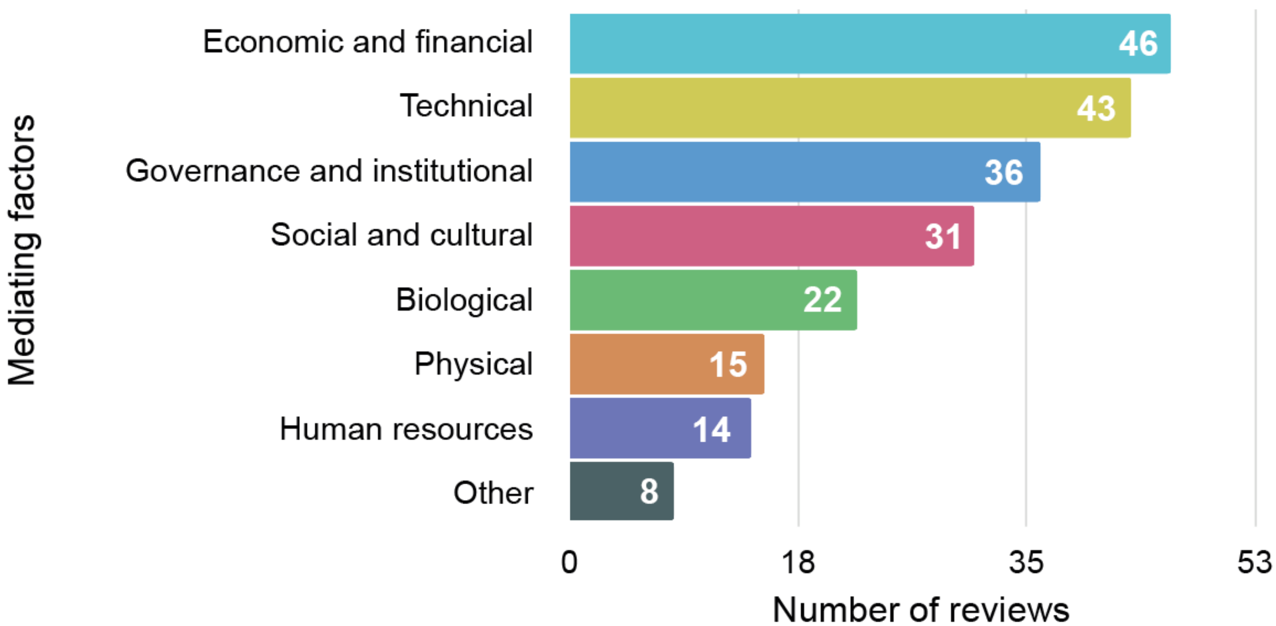

Fig 8. Prevalence of mediating factors identified across reviews. For each category, the number of reviews specifying one or more mediating factors was summed up. See S4 Text for category definitions.

What trade-offs and win-wins are reported?

Overall, 51 (77%) of the reviews explicitly reported evidence of trade-offs or win-wins, but 11 noted a lack of data. Trade-offs and win-wins were either between outcomes (37, 73%), between stakeholders (distributional effects and equity) (32, 63%), over space (7, 14%), or over time (7, 14%).

Among reviews reporting trade-offs or win-wins between outcomes, 24 (65%) reported trade-offs between economic impact and biodiversity or ecosystem health, and 20 (54%) reported win-wins with biodiversity or ecosystem health. The most frequently reported trade-offs or win-wins were between biodiversity and provisioning ecosystem services, e.g., production of food or timber. Only 12 reviews explicitly reported win-wins and no-trade offs. For the reviews reporting distributional effects (i.e. how costs and benefits disaggregate across social groups), most (28, 88%) highlighted mixed or negative effects on equity (e.g., where income inequality increased between social groups). Six studies found positive economic and equity impacts, such as more equitable land holdings and social stability [76], improved gender equity [91], or increased employment for marginalized groups [92]. However, three of these also reported negative equity effects, such improved income equity within group (herders) but not between groups (between herders and other rural land users) [93], or where labor burden disproportionately fell on women [92]. All reviews explicitly reporting on spatial or temporal dimensions focused on trade-offs rather than win-wins. For example, short-term trade-offs occurred where high implementation costs or slow system maturity in nature-based food production led to a period of reduced profit subsequently offset by longer term increased yield or more resilient production over time [59, 79]. Spatial trade-offs resulted from leakage, with displacement of ecosystem loss and degradation to neighboring areas [81, 94, 95].

Trade-offs between outcomes

The most frequently reported trade-offs were between biodiversity and income or profitability, which can arise due to several mechanisms. First, restricting the use of natural resources in areas that are being protected or restored can reduce incomes, e.g., when pastoralists lost their livelihoods due grazing bans aimed at restoring degraded grassland in China [81]. Second, some reviews noted cases where nature-based production methods were less profitable than conventional methods, e.g., if the shade cast by agroforestry trees reduces yield, or where agroforestry or organic cropping systems optimized for cash crops provide higher returns but lower biodiversity [59, 76, 80]. Third, high implementation or labor costs can reduce profits, e.g., for agroforestry [75] or conservation agriculture where manual weeding is necessary (the alternative being the use of herbicides, which involves a further trade-off with biodiversity) [96]. Fourth, poor intervention design or management focused on short term profits can lead to adverse biodiversity outcomes, e.g., where ecotourism geared at maximizing tourism leads to environmental damage in protected areas [55, 87], or in low biodiversity systems, such as tree monocultures (which are not NbS) [97]. Finally, ecosystem protection can be associated with increasing human-wildlife conflicts, reducing crop yield [70]. According to the sampled reviews, the extent of profitability trade-offs for nature-based food production depended on whether farmers received price premiums for nature-friendly products (e.g., through certification schemes) or whether compensation or subsidies offset opportunity and implementation costs (e.g., through PES for agroforestry) [59].

Win-wins between outcomes

Several win-wins were reported in the literature. Agro-diversification was reported to drive increased profits, either from greater yield (e.g., integrated crop-livestock farming [75]), access to premium prices in markets (e.g., agroforestry [59, 75]), the generation of multiple income streams [98], or reduced dependence on expensive inputs [92]. It was also found to reduce the risk of economic loss by promoting food production resilience, such as through crop rotation [75], intercropping [75], agroforestry [75, 76], or integrated crop-livestock farming [75]) (see outcome pathways for more detail). Other nature-based food production measures reported to enhance ecosystem services and boost yield included climate-smart agriculture which reduced soil salinity, sustaining soil health and soil ecosystem services [73], crop residue retention and increased weed herbivory rate under conservation agriculture [85], or mulching and zero tillage [99]. Agroecological approaches boosted productivity and food security by improving soil health and biodiversity, which in turn promoted diversified and stable livelihoods [92]. Finally, win-wins were observed for conservancy schemes adjacent to protected areas in Namibia which harmonized biodiversity conservation with local livelihoods [100], or where payment for ecosystem service programs boosted income while reducing grazing pressures on grasslands in China [93].

Relationship between economic impact and climate change effect

Most reviews did not directly compare economic impacts with effects on climate change adaptation or mitigation); therefore, we report associations between them instead. For adaptation, 23 (46% of those reporting on adaptation) found positive outcomes for both adaptation and economic impact, mainly in nature-based food production (see outcome pathways for more detail). Positive effects on both mitigation and economic outcomes were found in 11 (44%) studies reporting on mitigation, often through strategies like improved yields, reduced costs, or land regeneration while reducing emissions or enhancing sequestration. Trade-offs, where outcomes were positive for one and negative or mixed for the other, were noted in 44% of studies reporting effects on adaptation or mitigation. Trade-offs were commonly due to mixed labor effects in nature-based food production [e.g., 66, 73, 75, 101], with most of these studies also showing win-wins for income/revenue. Negative or mixed income effects were primarily linked to opportunity costs [88], equipment and labor costs [85, 102], or crop specific profitability [78]. Seven reviews highlighted positive effects on adaptation, mitigation, and income or profitability, focusing on soil health [66, 75], or above-ground diversification in nature-based food production [90, 98, 103].

Wider benefits

Our supplementary analysis of the previous systematic review dataset on the outcomes of nature-based interventions for development in the Global South [54] shows a wide range of development outcomes of which most (87%) are positive, 4% are mixed and 5% negative (the other 4% being unclear or having no effect). Direct impacts on local economies are the most frequently reported outcome, followed by food security and then rights / empowerment / equality (Fig 9).

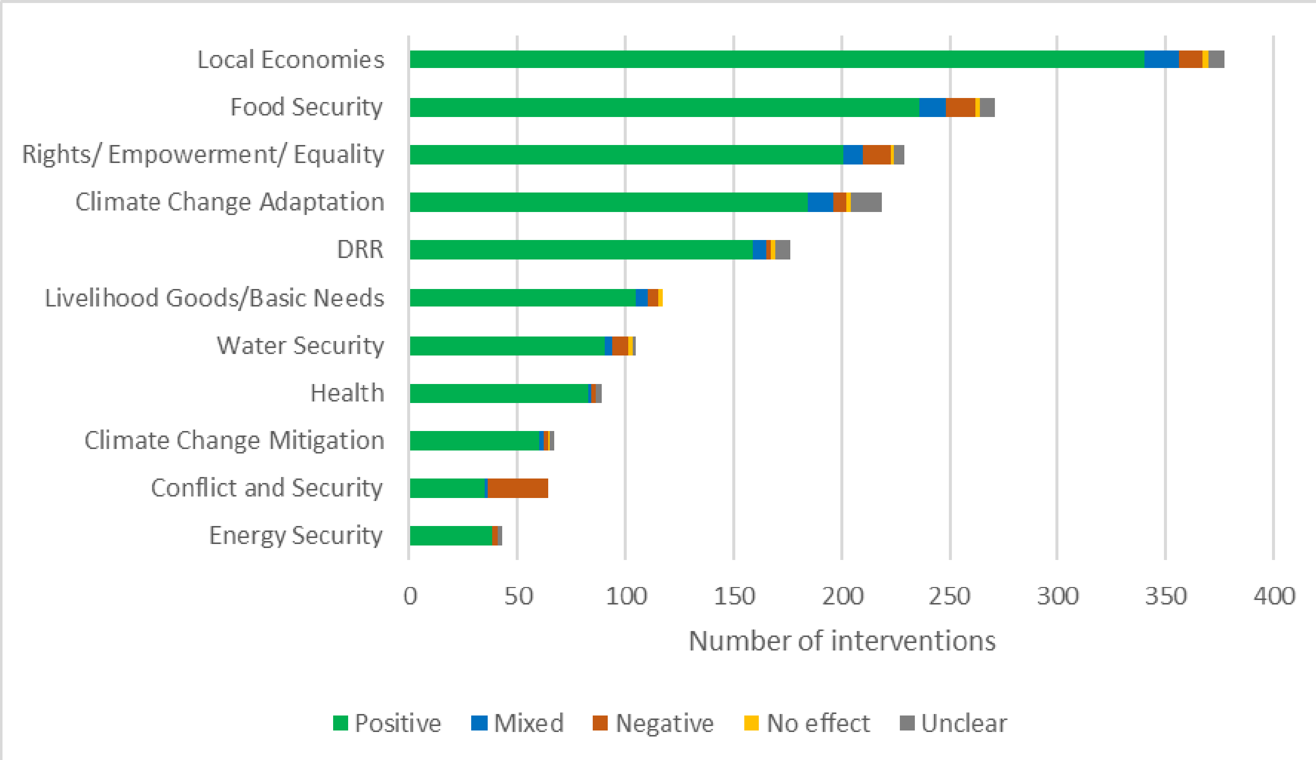

Fig 9. Development outcomes from nature-based interventions for climate change adaptation (based on the dataset created by Roe et al., 2021)

Although conventional direct economic outcomes for jobs, incomes and revenues are reported in the aggregated category of 'Local economies', all development outcomes can have indirect economic impacts. For example, improving household food security or livelihoods, or improving access to urban green spaces, can also improve physical and mental health (e.g. [104]), leading to lower healthcare costs [105, 106] and higher workforce productivity [107]. Similarly, benefits for climate change mitigation, adaptation and disaster risk reduction translate to lower economic costs of damage to infrastructure or crop production from storms, floods, droughts, or fires. For example, coral reefs offer coastal flood protection worth US$272 billion globally [108]. Economic benefits also arise when NbS reduce local conflicts and geopolitical instability through better management of natural resources. NbS can also encourage the empowerment of women, and their contribution to the formal economy, such as by starting new businesses (e.g. [109]). Finally, NbS can improve food and livelihood security and provide resilience to economic shocks when other sources of income are lost [54]. This is particularly important as calls for greater emphasis on resilience in economic policy grow stronger [110].

How are costs and benefits distributed across social groups?

Interventions not tailored to the needs of different social groups led to trade-offs for employment and income. Inequitable benefit distribution was attributed to 1) different opportunity costs, 2) elite capture, 3) conflict over ecosystem service use or benefit-sharing, or 4) and sociocultural and governance inequities. For example, gender inequity was exacerbated by engrained gender hierarchies subjecting women to unpaid labor burdens (e.g., PES schemes [83], agroforestry [96], conservation agriculture [96, 111], agroecological practices [92]), women having unequal access to land [59, 69], support from agricultural and extension services [59, 69], information, technology, or capital and markets [59, 70], or limited decision-making power [70].

Opportunity costs from NbS differ among social groups due to varying reliance on natural resources, such as where community forest management negatively impacted the most forest-dependent people [72, 79]. In some cases, interventions increased transaction costs for poorer, under-resourced households, such as where certification schemes and grazing bans pose risks of market concentration and benefit disparities, favoring wealthier stakeholders [80, 81, 93]. Market-oriented rangeland policies in China were criticized for undermining traditional pastoralism, disrupting the social-cultural fabric [81, 93]. Social trade-offs also occurred due to conflicts in ecosystem service use, such as where forest protection creates spatial trade-offs affecting water distribution [67, 70].

Elite capture in environmental interventions exacerbates inequality, noted in 12 reviews across various interventions (e.g., sustainability certifications, ecotourism, community-based natural management, protected areas). This disadvantages the poor and enhances disparities between participants and non-participants, especially in PES schemes [72, 83, 93]. Addressing these social trade-offs and mitigating inequalities requires targeted support for marginalized groups, such as helping them meet certification standards [112].

A few reviews noted social trade-offs in revenue sharing from ecotourism or community resource management between local communities and government agencies [63, 64]. Discussions included the imbalance in green roof investments, where private costs do not align with public benefits, suggesting a role for government subsidies to reconcile these differences and enhance societal gains [71].

Case study: Protected areas in Peru

Our systematic review was enhanced by a case study on Peru's protected area system (SINANPE), demonstrating how participatory governance leads to beneficial outcomes where NbS support local livelihoods (Box 2). SINANPE and local communities enter into landscape use contracts which facilitate local jobs and income from eco-tourism and selling sustainably harvested products at higher prices. Additionally, selling carbon offset credits helps fund the restoration, upkeep, and surveillance of these areas, creating jobs such as park ranger positions. Eco-tourism further stimulates the local economy by increasing demand for additional services, like handicraft sales, boosting income and job opportunities.

Discussion

To our knowledge, this is the first systematic review assessing the economic recovery potential of nature-based solutions across a wide range of intervention types and geographical contexts. Our goal was to provide a comprehensive overview to help integrate evidence on NbS into fiscal policy, particularly for addressing economic downturns.

We conducted a "review of reviews" to synthesise fragmented evidence from multiple interventions and diverse outcome measures, supplementing this with additional data from grey literature, primary studies, and a detailed country-level case study from Peru (see Box 2). Due to the variability in reported variables and review methodologies, a quantitative meta-analysis was not feasible, so results should be interpreted with caution. The distribution of evidence on economic impacts, pathways, and mediating factors varied according to the scope and focus of the underlying studies, and some recent evidence may not have been captured by existing reviews.

Despite these limitations, our approach offers valuable insights into the evidence base, allowing us to explore pathways and mediating factors in different intervention contexts. Here, we discuss the key findings, limitations of the review, gaps in the evidence, and opportunities for future research and synthesis.

Synopsis of key findings

Our mapping revealed evidence on a range of nature-based interventions but with significant gaps. We found 66 reviews reporting economic outcomes from these interventions, although few explicitly categorized them as NbS. The evidence was biased towards nature-based food production which accounted for 50% of cases, while only 19% covered ecosystem restoration and 15% focused on novel ecosystems, such as urban NbS. Geographically, most studies concentrated on sub-Saharan Africa (44 % of studies), South Asia (35%), East Asia and the Pacific (30 %), Latin America & the Caribbean (18 %), with more limited coverage in North America, Europe and central Asia, and the Middle East and North Africa. This distribution contrasts with the evidence base on ecosystem services and their valuation, which is concentrated in higher income countries [113, 114], as is evidence on NbS for climate change adaptation [1]. Some gaps may be due to our exclusion of non-English language studies, although some reviews included primary non-English literature, which helped capture additional evidence.

Most evidence on outcomes focused on income/revenue generation, predominantly at the household level, followed by changes in labor demand, including employment generation. Research on broader impacts on economic growth is limited, although available evidence indicates that nature-based interventions often deliver high gross value added and deliver returns per unit of investment that are comparable to or better than those from other sectors [10, 29, 37]. Overall, most reported effects were positive, indicating that investments in nature contribute to income generation and employment across various skill levels. A more nuanced picture emerged from reviews that critically appraise the underlying studies. These reviews report a significantly higher proportion of mixed effects (53%) and a lower proportion of positive effects (40%) compared to those that did not (18% and 70%, respectively). The mixed effects observed are attributed to variability in study results, differences between short-term and long-term gains, market conditions, regional effects, reliance on external subsidies, and discrepancies between expected and actual economic benefits. This variability aligns with the growing understanding that the effectiveness of NbS is mediated by a range of internal and external factors shaping the enabling environment. Among the few studies that compared the impact of investments in nature with alternative approaches, most found that NbS are more effective, particularly in terms of income/revenue generation.

Most reviews (76%) reported trade-offs or win-wins, especially trade-offs between biodiversity and livelihoods due to transaction or opportunity costs when interventions reduce agricultural output or limit natural resource use. However, these short-term opportunity costs can be managed through strategies such as securing price premiums, offering compensation or providing subsidies, which can ultimately benefit ecosystem health, biodiversity, and economic outcomes. Agro-diversification builds resilience, reducing economic risks associated with crop loss. We found positive associations with adaptation resulting from livelihood or crop diversification, which can boost profits through reduced costs, increasing outputs, or providing additional revenue sources such as non-timber forest products (NTFPs) [57, 66, 68, 75, 76]. Furthermore, positive associations with climate change mitigation were observed, mainly through nature-based food production practices that increased carbon sequestration (above or below ground) or reduced emissions, while simultaneously improving farming profitability and employment opportunities.

How do nature-based solutions deliver economic impact?

We identified several pathways by which NbS can impact income/revenue, revenue generation, and employment. Income/revenue arises from the sale of ecosystem goods or services , cost savings, subsidies or payments for ecosystem services. Direct effects on labor are linked to transitions to nature-based food production, green infrastructure implementation, and investments in ecotourism.

While evidence of indirect and induced job creation, and economic multiplier effects through business-to-business spending is limited, some studies found positive impacts for economic growth. However, they also highlight many mediating factors, including the type of ecosystem or restoration project (which affects the size of investment required), the causes and extent of ecosystem degradation, labor cost, government legislation (shaping regulatory requirements to invest in NbS), and regulatory standards (e.g., procurement rules or requirements to source local labor) [10]. For nature-based food production, mediating factors can reduce revenue, in turn affecting economic growth through reduced expenditure and investment in supply chains. These include low market prices, lack of market regulation, constraints in marketing channels or limited lobbying capacity, lack of access to credit, or elite capture [57, 106].

The importance of mediating factors makes it difficult to predict whether a specific NbS intervention will lead to positive or negative economic outcomes, or if trade-offs or win-wins will occur with other objectives, emphasizing the context dependency of NbS outcomes. A pathway can result in win-wins in one context and trade-offs in another, depending on mediating factors like market access, input costs, the ability to attain price premiums, or adequacy of subsidies or PES to offset opportunity costs. Outcomes are shaped by technical factors relating to intervention design, implementation, and management, but also by other internal and external economic, financial, governance, institutional, social, cultural, and to a lesser extent, biological factors. This highlights the importance of the broader social, economic, and bio-physical character of NbS, corroborating the evidence on how NbS reduce vulnerability [2], or how Ecosystem-based Adaptation (EbA) is effective [53]. This also reinforces the notion that NbS are actions which support biodiversity and human well-being [35] through enhanced and harmonious human-nature relations [46].

Is labor demand a cost or a benefit?

This review shows that NbS are often more labor intensive than other potential investment options, thus providing significant potential for job creation. For NbS food production, however, effects on labor varied with the mode of implementation [75]. For example, intercropping, agroforestry, and organic agriculture are generally found to increase labor demand [115], but conservation agriculture can either increase or decrease it for different cultivation stages; crop residue retention reduces the need for pre-tilling, but reduced tillage potentially increases the need for weeding unless herbicides are used [96]. Although most reviews treated labor as a cost, scaling-up nature-based food production can translate into employment opportunities for low-income households [96, 116]. These measures also provide job security through diversified income streams and reduced income volatility [76]. The perception of increased labor demand as either beneficial or negative depends largely on the economic context. From a fiscal policy perspective, job creation is prioritized during economic downturns and periods of high unemployment [117]. Governments typically view job creation positively because it helps reduce unemployment and can garner political support. In contrast, businesses may view increased labor demand negatively, as higher employment can lead to decreased profits if output per employee is reduced.

Promoting equity in economic impact

Social equity is a core dimension of sustainable development and foundational property of NbS [35, 50]. How effects (and costs, benefits) disaggregate across social groups has important material implications for achieving human well-being, notably by mediating the overall effectiveness of NbS [2, 118]. Positive impacts on jobs and incomes can mask trade-offs between social groups, highlighting the importance of considering equity, which remains under-reported in the literature [59, 83]. We found that social inequity occurred when interventions were not tailored to the needs of different groups, including consideration of vulnerabilities embedded in the sociocultural and governance context. This aligns with the scholarship on NbS (notably EbA) which calls for exploring how benefits disaggregate across groups, how this affects vulnerability, and in turn, how interventions can more effectively support adaptation [2, 119, 120]. A range of mediating factors shaped distributional effects, notably elite capture, differential opportunity costs per group (due to different types of livelihoods and dependencies on nature) or inequities embedded in the sociocultural or governance context, such as gender hierarchies. Many reviews across a range of intervention types highlighted elite capture as a major issue, and a crucial barrier in achieving equity in economic impact. This is a cross-cutting issue in natural resource management and development, whereby the powerful co-opt finance and benefits, thereby reinforcing unequal power relations [120] and jeopardizing progress towards the SDGs. Although the impacts of NbS on social equity are highly variable and context-specific, the articles collectively underscore the need for NbS to include mechanisms specifically addressing the needs of marginalized group and ensuring equitable benefit distribution. Addressing this requires ensuring local communities and disadvantaged groups, including women, children, disabled, and minorities, actively participate in intervention design and implementation to avoid skewed distribution of benefits (ibid). For example, SINANPE in Peru (see Box 2) seeks to engage vulnerable groups (e.g., women, Indigenous communities) in training to strengthen local capacities, organization skills and empowerment in resource management and conservation. Moreover, SINANPE operates a volunteer program for local people that provides training and a small stipend to support forest monitoring activities, involving 2,366 local community members in 2020.

Wider economic outcomes

Our supplementary analysis of the dataset from [54] demonstrated that NbS, if carefully implemented, bring substantial societal and ecological benefits that support economic prosperity, including climate change adaptation [1], climate mitigation (e.g. [3, 4]) and improved ecosystem health [121]. Well-governed NbS support food and water security, provide green space for recreation, help protect against floods, droughts and heatwaves, and support social empowerment, all of which improve community health, well-being and economic resilience [1]. This was also demonstrated by the case study of protected areas in Peru, where there was emphasis on supporting local livelihoods through agreements allowing sustainable NTFP harvesting for subsistence, along with capacity building through training. Because these public benefits have limited direct market value, and are difficult to quantify in monetary terms, it is crucial to consider plural market and non-market values to stimulate policies that are inclusive and respond to human well-being [114]. This will require new methods to account for the diverse values of nature [122]. Policy and project evaluations and appraisals should also look beyond short-term economic objectives, to ensure long-term resilience and avoid maladaptation [123]. Ultimately, this requires transitioning towards a new economic paradigm, where well-being is the core objective rather than GDP growth and capital accumulation [41, 44]. Such a transition would focus on regenerative human-nature relations, and thus enable a shift to circular economies that sustain both human well-being and the biosphere [42].

Comparison with other studies and evidence gaps for future research

In this section we compare the findings of our academic review with evidence from wider academic and grey literature and consider evidence gaps and priorities for further research.

Temporal dimensions of job creation

Although impacts on labor demand were commonly reported, we found a lack of evidence in the academic literature on the temporal dimensions of job creation (short-term vs long-term), despite growing evidence in the grey literature that NbS stimulates short-and long-term job creation [124, 125] (S4 Text).

Skills, training needs and job quality

The evidence in our review suggests that nature-based interventions can stimulate both low- and high-skilled jobs. This is supported by additional evidence from grey literature (S4 Text). For instance, In South Africa, establishing green infrastructure creates jobs that do not require specialized skills, allowing for easy entry into the labor market for low-skilled individuals [65]. On the other hand, technical extension and training programs build specialized skills and knowledge [59] and leverage local traditional knowledge [77] to scale NbS. However, there is still a gap in understanding job quality, despite the recommendation of the IUCN Global NbS Standard [50] to prioritize “decent work” in NbS as defined by the International Labor Organization [126]. These could build on the work of Vardon et al., 2022, who detail the role of natural capital accounting in driving greener recovery [127].

Economic impact at regional or national scales

Our analysis corroborates evidence from large-scale investments in nature in the grey literature (S4 Text), demonstrating strong job creation and protection to sustain crucial ecosystem services. Most employment outcomes were reported as positive effects (except for studies at the farm-scale that framed labor as a cost). Two studies from our review demonstrate high potential for job creation at national scale, in developing country contexts: [87] estimate that the forest tourism industry in China has employed half a million farmers, reducing poverty across 4,654 villages, and [116] report that 16,000 rural people in Kyrgyzstan were directly employed in the walnut value chain. Similarly, our case study in Peru showed creation of over 36,000 eco-tourism jobs (Box 2).

Direct impacts on growth and multipliers

Although there is compelling evidence that NbS can stimulate growth across a wide array of industries (e.g., via gross value added, economic multiplier effects) [10, 37] (S4 Text), this comes from relatively few studies. Most studies reported economic outcomes at the household or community level, reflecting a lack of mechanisms to track fiscal policy measures and government spending at broader scales, such as through national inventories [10], as well as general lack of systematic data collection and reporting on NbS implementation. This is challenging because NbS cut across traditional sectors (e.g., water, agriculture, infrastructure, environmental protection), implicating many public and private sector actors. There is no standard industrial classification, and public and private funding sources are diverse, making investment and outcome tracking difficult [37, 119]. To scale up the evidence base, we need comprehensive accounting systems that track both public and private investments in NbS, enabling the integration of this data into economic models for estimating the broader economic impacts of NbS activities, including indirect and induced effects [10].

Under-represented ecosystems

Although the available evidence shows that NbS in grassland, dryland, freshwater, coastal and marine ecosystems hold important potential for both job creation and income generation (S4 Text), we found a lack of evidence across these ecosystems, in contrast to forest ecosystems and working landscapes (43% and 72% of intervention cases, respectively). This aligns with known biases in the evidence base on NbS towards forest ecosystems [1, 128]. This is concerning, given the critical role of these ecosystems in supporting livelihoods (grasslands – [129, 130]; coastal ecosystems – [131]), climate change adaptation [1, 2, 108, 132] and mitigation [133, 134]. Understanding how NbS in these ecosystems can support economic impact, as well as biodiversity and climate benefits, is critical to increase ambition and guide their scaling-up.

Urban nature-based solutions

Surprisingly, we found little evidence on the direct economic impact of investments in urban NbS, although evidence from the grey literature helps to bridge the gap (see S4 Text). The extensive literature on urban green infrastructure focuses mainly on benefits for climate change adaptation [135], water treatment [136], and human health and well-being [137, 138], sometimes with economic valuation of the indirect outcomes. However, the few reviews that we found report important benefits for employment and income generation [65] and increased profits through reduced energy expenditure [71], with both also noting the potential for increased tax revenues. With the global urban population set to double by 2050 [139], NbS could provide a significant source of jobs and income for urban residents, in addition to benefits for health, human well-being, and climate change adaptation.

Comparison with alternative interventions

We found a lack of comparisons of economic outcomes of NbS investments versus alternatives, particularly outside the context of food production. Evidence is however growing, showing high economic multipliers for nature restoration compared to other sectors [37], with greater benefits for jobs and incomes than conventional alternatives across both high- and low-income countries [140]. Although natural capital investment policies have high potential economic multipliers [19], lack of comparisons makes it more challenging to mainstream NbS in fiscal policy [7, 9-11]. Unless this evidence-base is expanded significantly, economic stimulus policy may continue to focus primarily on traditional investments such as road construction or fossil fuel energy, despite the increasing emphasis on building back better and green economic recoveries [140]. On a regional or national scale, poor data collection on the economic outcomes of NbS investments limits cross-sectoral comparisons on the effects of stimulus measures.

Trade-offs and win-wins

Assessing trade-offs to optimize the design of NbS for equitable delivery of multiple benefits is crucial but challenging due to limited evidence. There were few holistic assessments covering multiple outcomes, except for the interactions between biodiversity and livelihoods, jobs, or income [59, 72, 83], and few studies considered temporal or spatial trade-offs. Better monitoring of outcomes across social, economic, ecological, and climate dimensions is crucial to capture the broader array of material and non-material benefits NbS can bring and manage potential trade-offs [1]. This includes disaggregated social assessments of costs and benefits, which is currently lacking [83]. Assessing NbS exclusively through a narrow lens, economic or other, can result in undervaluing NbS and thereby undermining human well-being [141].

Protocol for gathering evidence on economic outcomes

To expand the evidence base, we recommend that researchers and economists work with practitioners to develop guidelines to scale robust assessments of the economic outcomes of NbS. For example, this could learn from the guidance on well-being impact evaluation for conservation interventions developed by de Lange et al. (2017) [142]. Guidance on the use of standardized economic indicators is needed, such as full time equivalent (FTE) job years per unit investment or per Ha of land, while recognizing that the wide range of NbS sectors, contexts and study aims will inevitably require diverse indicators. It is also important to go beyond direct effects and account for indirect and induced impacts on jobs and revenue. Additionally, there is a lack of studies with comparators (e.g., suitable baselines, or counterfactuals such as controls). Although controls can have shortcomings (e.g., where the control and intervention sites evolve in different ways between sampling periods), comparators are crucial to infer impact. Randomized control trials could be explored for investments in some intervention types, if spillovers between control and treatment groups can be minimized, control and treatment groups are truly comparable, and measured indicators are of significance to the individuals and communities that are impacted. There is also a need to better track the social distribution of costs and benefits, as well as potential displacement of negative social and environmental impacts over space (e.g., leakage or potential displacement of jobs or incomes in other sectors), and time (e.g., short-term job creation of tree planting vs long term impacts on biodiversity and ecosystem services under natural regeneration).

Conclusion and recommendations for policy makers

This systematic review demonstrates that NbS can significantly contribute to economic recovery by stimulating economic output and creating employment. NbS can generate direct jobs and incomes, offering a high return on investment compared to other sectors. This leads to cascading benefits throughout the economy. Well-designed and carefully implemented NbS can respond flexibly to economic shocks, by providing diverse employment opportunities across different skill levels and targeting underserved communities and disadvantaged groups. NbS can also diversify income sources and enhance resilience to future shocks. By combining traditional, local, and scientific knowledge, NbS can be both socially and ecologically effective with potential to support green sector growth and eco-innovation, aiding the transition to a clean and efficient circular economy.

NbS can support additional benefits beyond those included in conventional economic assessments. They can restore biodiversity, help to address climate change, reduce reliance on costly resources, improve human health, and enhance resilience. By preventing climate-related damage, lowering healthcare costs, and bolstering economic stability, NbS support prosperity and resilience—outcomes crucial for human well-being but often overlooked in GDP measurements. It is crucial however to carefully design for equitable delivery of multiple benefits to all stakeholders, prioritizing vulnerable groups. To minimize trade-offs, interventions should be co-designed with Indigenous people and local communities and prioritize livelihoods. Enhancing the evidence base and monitoring of economic outcomes is also crucial.

Governments and investors should consider societal benefits and long-term resilience when investing in NbS, extending beyond traditional economic measures, short-term impacts, and market-based mechanisms [143]. A holistic policy framework is essential to support well-designed NbS that deliver multiple benefits, manage trade-offs, explicitly support biodiversity, are led by Indigenous people and local communities, and are not treated as a substitute for fossil fuel phaseout [35]. This transition can contribute to sustainable circular economies that sustain human well-being and biodiverse ecosystems.

Recommendations for policymakers

Based on our review, we recommend that:

1. NbS suited to the local context form a central component of national and regional investment programs for economic recovery, development and climate action, as they tackle multiple economic, environmental, and social problems.
2. National monitoring and evaluation frameworks are created by governments to track impact of fiscal policy measures and government spending on NbS, and their economic outcomes.
3. Economic assessments incorporate wider outcomes, beyond jobs, incomes, and revenues, gross value added and multipliers, to understand the full benefits and trade-offs of NbS compared to alternatives.
4. NbS are led by or designed and implemented in partnership with local communities, farmers, businesses, and/or Indigenous groups, in accordance with the four NbS guidelines [51] and the detailed IUCN global standard [50], to ensure social and ecological effectiveness and delivery of equitable benefits.
5. Government agencies are provided with adequate resources to support the implementation and design of high quality NbS, with or as part of sustainable livelihood-focused interventions, and to monitor environmental, social, and economic outcomes.
6. Governments and businesses invest in education and training programs to develop skills for design, implementation, and maintenance of NbS projects, creating high quality jobs and boosting innovation.
7. Funding is generated for researchers to work with practitioners, economic experts, and local communities, including Indigenous Peoples, to support robust assessment of the socio-economic outcomes of NbS interventions, ensuring attention to the correct use of counterfactuals and a comprehensive indicator set. Research is also needed to address evidence gaps on outcomes for job security, skills, and economic growth; for under-represented ecosystems (coastal, grassland, montane, mangroves, peatlands and urban); holistic assessments of synergies and trade-offs; and comparisons of NbS to alternative non-NbS interventions.

Box 2. The job creation and income generation potential of Peru's National System of Protected Areas

SINANPE, Peru's national system of protected natural areas (PNAs), includes 76 areas supporting ecosystem services vital for local livelihoods. Participatory governance, sustainable resource use contracts, "Aliados por la Conservación" certification, and eco-tourism promote income generation and subsistence livelihoods. The certification connects local producers to green markets, providing opportunities for people in or near protected areas. These programs supported communities during the pandemic, facilitated by the state's ability to leverage public, private, and international cooperation funds.

To boost climate change adaptation, the protected area system emphasizes ancestral knowledge and sustainable resource management. It promotes ecological resilience through preventative actions, control measures, and ecosystem restoration. SINANPE monitors climate change impacts on forest ecosystems, effectively reducing deforestation rates. National deforestation spiked to 203,272 Ha during the COVID-19 lockdowns in 2020 but decreased to 137,976 Ha in 2021, down from 148,426 Ha in 2019 [144].

Economic impact

Jobs: SINANPE employment grew by 35%, from 942 people in 2011 to 1,273 people in 2021 [145]. Park rangers accounted for 55% of the workforce in 2021, with 26% being women. A volunteer program trained and supported 3,750 community members in 2019 and 2,366 in 2020 with food and stipend [146, 147]. Tourist activities created 36,741 local jobs [148].

Income: Sustainable use contracts helped 4,587 families (21,100 people) in 2020, rising to 6,334 families in 2021 [149, 150]. They sell local products (e.g., vicuña fiber, chestnut and aguaje fruits), generating USD 1,332,293 income and USD 39,906 for SINANPE [149]. "Aliados por la Conservacion" certification benefits 1,788 families in 18 PNAs, selling diverse products in Lima and international markets. These value-added products from protected areas (e.g, aguaje beverage, chocolate and coffee products, handicrafts, textiles) are sold in Lima or in Europe and USA. Also, 388 eco-tourism contracts were renewed, benefiting 2,621 families [150].

Tourism revenue: Pre-pandemic, there were 2,736,650 visitors in 2019. Visitor numbers dropped to 722,593 in 2020 but increased to 1,422,335 in 2021 due to domestic tourism [149]. Entry ticket sales generated USD 6,839,250 in 2019, USD 2,408,424 in 2020, and 2,721,519 in 2021 [149]. In 2017 economic impact of tourism was approximately USD 723 million, with USD 165 million directly benefiting households and salaries, not considering multiplier effects [148].

Other benefits

Subsistence livelihoods: An additional 69 agreements for sustainable NTFP harvesting (bushmeat, aguaje fruits, various tree and shrubby species, non-viable taricaya eggs) were renewed, benefiting 829 families over 98,199 Ha in 15 PNAs [149].

Greenhouse gas mitigation: SINANPE has 3 REDD+ projects in 4 PNAs, covering 2 million Ha. These projects avoided deforestation of 95,000 Ha from 2008-2020, resulting in 36.6 million tCO_2e of verified emissions reductions [145]. Over 33 million carbon credits were sold, certified by the Verified Carbon Standard and Climate, Community, and Biodiversity standards [145]. Carbon finance funded training, park ranger employment, equipment, education, and livelihood support for local communities.

Acknowledgements

We extend our sincere gratitude to Erin Gray and Swati Utkarshini for their valuable comments and revisions to the systematic review protocol. We also wish to thank the two anonymous reviewers and the associate editor for their thorough and insightful feedback, which greatly enhanced the quality of this manuscript. Lastly, we are grateful to Dan Seddon for his excellent work in producing the graphics.

Funding statement

This work was supported with funding from the Oxford Martin School's Biodiversity and Society Programme (University of Oxford) and the Waterloo Foundation.

Competing interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. Please note that Nathalie Seddon serves as a Non-executive Director and Advisor at Nature-Based Insights, a consultancy providing services related to nature-based solutions.

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