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A Multifunctional 'Scape Approach for Sustainable Management of Intact Ecosystems—A Review of Tropical Peatlands

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Abstract: Nature is declining globally at unprecedented rates with adverse consequences for both ecological and human systems. This paper argues that only transformative change—a fundamental, system-wide reorganization—will be sufficient to arrest and reverse this loss and to meet globally agreed development goals, including the post-2020 Global Biodiversity Framework. In search for a credible platform to help facilitate such transformative change, this paper explores the potential of multifunctional 'scape approaches to improve sustainable management outcomes at scale. Beyond a current international focus on nature restoration, this paper emphasizes the urgency and criticality of confirming approaches for sustainably preserving large 'intact' natural areas. Through a semi-systematic review of contemporary academic and gray literature and derivation of a theory of change, the authors consider tropical peatland systems—which can interconnect multiple ecosystem types and be of global biodiversity and carbon sequestration significance—to help derive potentially broader sustainable ecosystem management lessons. Beyond identifying key considerations for implementing multifunctional 'scape approaches, the paper recommends further work to deepen understanding of the multidimensional 'value' of nature; strengthen governance frameworks; empower indigenous peoples and their knowledge sharing and community management; align nature-positive and climate-positive goals; andmobilize commensurate business and financial support.

Keywords: multifunctional 'scape approach; large intact wilderness spaces; sustainable management; ecosystems; transformative change; tropical peatlands; finance; business

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1. Introduction and Theory of Change

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) confirmed that nature is declining at rates unprecedented in human history, undermining the very bedrock of natural and human systems globally [1]. This global assessment of biodiversity comprised a systematic review of approximately 15,000 scientific and government sources and found that three-quarters of the land-based environment and two-thirds of the marine environment have been significantly altered by human actions. This threatens an estimated one million animal and plant species with extinction and increasing monetary and non-monetary costs to human wellbeing. The primary drivers of these changes are human-derived and include (in descending order of relative global impact to date) changes in land and sea use; direct exploitation of organisms; climate change; pollution; invasive alien species [1]. These latest findings build on previous studies, such as the Millennium Ecosystem Assessment (MEA) [2]—conducted over a decade ago—which also sounded alarms on global biodiversity loss and ecosystem degradation. They also integrate the latest findings on, and increasing influence of, climate change on natural and human systems [3]. Such global assessments demonstrate that, despite the launch of initiatives such as the United Nations Decade on Biodiversity (2011–2020) [4] and the United Nations Decade of Ecosystem Restoration (2021–2030) [5], efforts to reverse or even slow these drivers of change have not yet been successful at a global scale. Recent momentum, including the 15th Conference of Parties (COP15) of the United Nations Convention on Biological Diversity (CBD) where the post-2020 Global Biodiversity Framework was agreed, offers hope to progress action on nature at scale, measurably, and within necessary timeframes.

In contributing to upcoming and ongoing debates at the international and national levels, the authors contend that only transformative change—a fundamental, system-wide reorganization across technological, economic, and social factors, including paradigms, goals, and values [1]—will be sufficient to conserve, restore, and derive sustainable management models for nature and to meet interlinked global goals, such as the Sustainable Development Goals (SDGs), Paris Agreement climate commitments, Sendai Disaster Risk Reduction Framework, and post-2020 Global Biodiversity Framework.

In promoting such transformative change, the authors recognize that:

- Current approaches have not been effective in initiating or sustaining system change at a scale and pace necessary to offset the current drivers of nature degradation;
- Recent accelerations in nature degradation are as much a result of developmental, economic, security, social, equity, and moral issues as they are environmental and ecosystem issues;
- The scale and urgency of climate change impacts and biodiversity and ecosystem degradation will require engagement and change from local to global scales;
- The adage "prevention is better than cure" holds true when it comes to complex ecosystems, where preservation and conservation is infinitely preferable to restoration, particularly in terms of biodiversity value and ecosystem function.

From these premises, the authors derive a theory of change as a framework to guide the paper (Figure 1). This framework has been developed to be compatible with international discussions for the post-2020 Global Biodiversity Framework and other relevant climate and sustainable development frameworks.

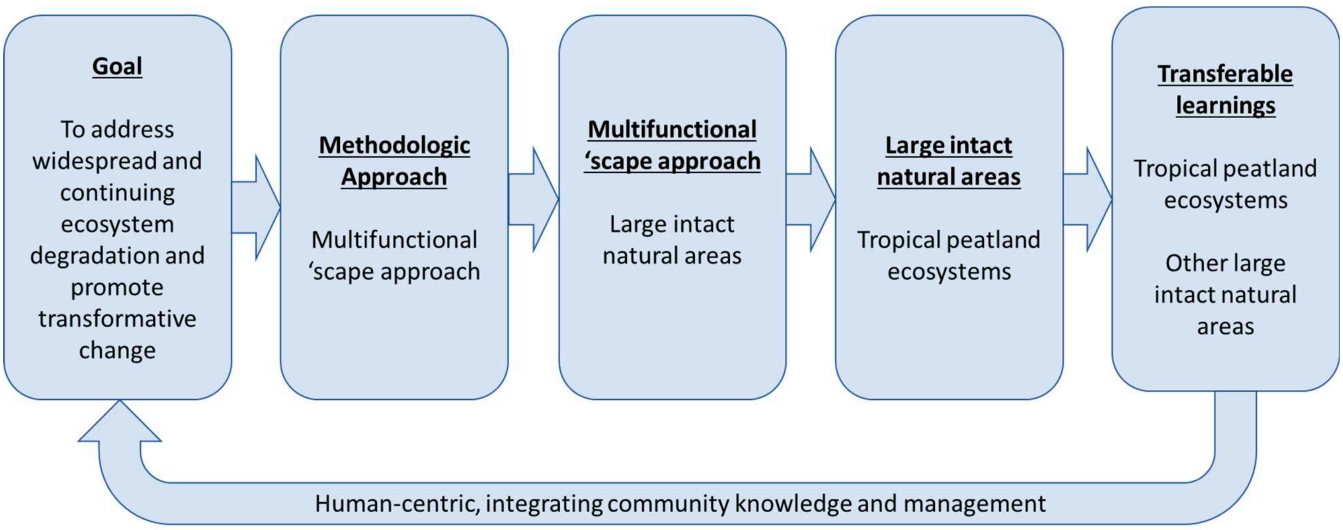

Figure 1. A theory of change as a framework to guide the paper.

The paper's theory of change is driven by a goal of addressing widespread and continuing ecosystem degradation and promoting transformative change. In the search for a credible platform to facilitate transformative change to address biodiversity and ecosystem degradation, this paper explores the potential of multifunctional 'scape approaches [3] to improve sustainable management outcomes at scale. This approach, introduced by IPBES, offers an integrated approach to ecosystem management, recognizing the central role of humans and the need for mixed land uses. (This paper is limited to consideration of terrestrial systems only.) While much contemporary international focus promotes ecosystem restoration—for example, the Bonn Challenge [6] and the United Nations Decade for Ecosystem Restoration [5]—this paper emphasizes the urgency and criticality of confirming approaches for preserving *intact* ecosystems. As such, within the multifunctional 'scape approach, the paper explores conservation of large intact natural areas and reviews tropical peatland ecosystems. Tropical peatland ecosystems often intersect multiple ecosystem types, such as forests, wetlands, rivers, and coastal ecosystems, and are increasingly under human pressures in many parts of the world. Additionally, sustainable management lessons for tropical peatlands may offer wins [7] on a range of critical local and global fronts, such as carbon sinks to mitigate climate change impacts [8], water regulation (quality and quantity), pollution management, biodiversity conservation, indigenous rights, and livelihood development, with potential lessons for management of other ecosystem types. In essence, the paper seeks to apply the principles of multifunctional 'scape approaches to tropical peatland ecosystems, with the goal of deriving lessons to benefit those local communities and (potentially) other ecosystems.

To further guide the paper, and in support of the theory of change, the authors pose the following research question: Do multifunctional 'scape approaches have the potential to support transformational change in the management of intact ecosystems, such as tropical peatlands, and, if so, what are some key factors to help facilitate this?

As such, the paper concludes with a review of the potential challenges and opportunities associated with the multifunctional 'scape approach for large intact natural areas to ultimately support greater understanding of dynamics to promote transformative change.

The paper draws upon a broad review of contemporary academic and gray literature, including key findings from recent IPBES (and joint Intergovernmental Panel on Climate Change (IPCC)) assessments [1,3] and a seminal study on nature-based economics [9], among other prominent academic literature. Select literature for this paper was drawn from a semi-systematic literature review conducted by J. Fisher for the United Kingdom Foreign, Commonwealth and Development Office (FCDO) on "The development of innovative landscape management regimes and nature-based solutions for Sub Saharan Africa, South-east and south Asia". The theory of change, derived by the authors, guides the paper's structure, conclusions, and recommendations, and is ultimately intended to help convey transferable learnings for academics, policymakers, and practitioners on improved preservation and management of intact ecosystems.

2. Multifunctional 'Scape Approach

2.1. Multifunctional 'Scape Approach for Intact Ecosystems

As far back as the 1990s, authors, such as those from ref. [10], promoted ecological approaches to resource management, including the fostering of open and collaborative decision-making processes and innovative ways to manage resources across mixed ownerships. In recent years, that evolution has continued in the conservation field away from the accumulation of protected areas towards the sustainable management of multifunctional 'scapes [11]. Multifunctional 'scapes may be characterized by their diversified land use and complex landscape structure, thereby potentially covering many, often competing, interests [12]. The same authors [12] acknowledge the need for system change to effectively manage for landscape multifunctionality, including stakeholder collaboration across spatial scales and sectors, as well as transitioning towards more sustainable land management practices. Multifunctional 'scapes can broadly constitute land-sparing and land-sharing measures to achieve a landscape connectivity matrix [13]. A central tenet of multifunctional 'scape approaches is that the supply of a more diverse set of (market and non-market) goods leads to a number of environmental, social, and economic benefits [12].

A multifunctional 'scape is defined as "a contiguous land-freshwater area defined by major geomorphological processes, such as major biomes, watersheds or geological systems" [3]. A 'scape may include a mosaic of habitats across all conditions of nature [3]. Figure 2 outlines a multifunctional 'scape across land, freshwater, and marine biomes, divided into three distinct spaces: (i) large, intact wilderness spaces/natural areas (blue circles), (ii) shared spaces, or varied mosaics of nature and people (yellow circles), and (iii) heavily modified anthromes (red circles).

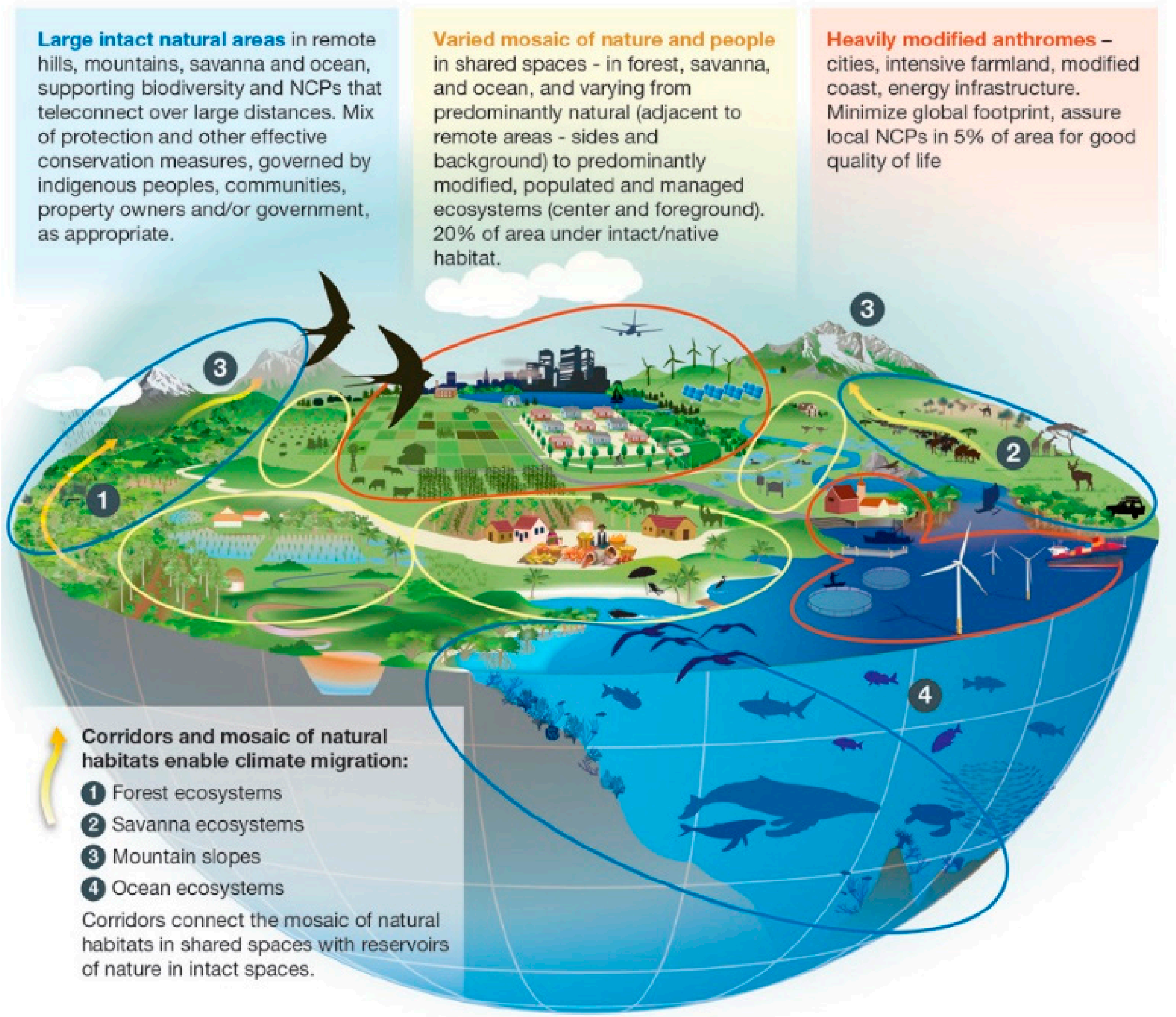

Figure 2. A multifunctional 'scape across land, freshwater, and marine biomes, including large, intact wilderness spaces, shared spaces, and anthromes, as outlined by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Source: [3]).

Management components stemming from multifunctional 'scape approaches include spatial planning concepts (as evidenced in Figure 2) aimed at optimizing the integrity of nature, provisioning for people and quality of life, whilst also reversing climate and other impacts on nature via its focus on people and contributions from nature [3]. Multifunctional solutions have the potential to produce multiple benefits compared to approaches focused on maximizing single indicators. Multiple authors (e.g., [3,12]) confirm a need for further research in multifunctional 'scape approaches, particularly around issues such as assessing and valuing multifunctionality to support sustainable management.

2.2. Large Intact Natural Areas

While this paper does reference mosaic and anthrome 'scapes, and their interactions and influence on neighboring 'scapes, the focus is on the dynamics of large, intact wilderness spaces. These spaces are defined as "*natural areas that are undisturbed by significant* *human activity, free of modern infrastructure and where natural forces and processes predominate*" [14]. Such spaces may connect over large spatial extents, comprising a mixture of protection and other effective conservation measures, governed by stakeholders including indigenous peoples, communities, property owners, and/or government, as appropriate [3]. These spaces may intersect more closely with indigenous, traditional, and/or local governance approaches [3].

This paper proposes that a multifunctional 'scape approach focused on large intact wilderness spaces provides a framework for triggering transformative change in the efforts to halt and reverse nature degradation across multiple scales. Evolving evidence supports an increased focus on preserving intact ecosystems, which may offer unique benefits (and opportunities) when compared to degraded ecosystem restoration. Intact wilderness spaces offer benefits such as greater carbon capture, sequestration, and storage above- and below-ground; greater resilience to shock events, such as droughts; increased biodiversity values, including intra-species genetic biodiversity and functional biodiversity; increased foundations for material and spiritual aspects of traditional, indigenous, and local cultures [15]. Additionally, greater intrinsic, biodiversity, and economic values of intact ecosystems are increasingly being confirmed in the literature. Conversely, highly degraded spaces may be less likely to provide biodiversity outcomes, more negatively impacted by climate change, and have less scope to support poverty alleviation (as natural capital is often the predominant form of accessible capital for marginalized and poor communities). Additionally, the timescale for a restored ecosystem to reach equivalent intrinsic, biodiversity, or economic values compared to an intact wilderness may be decades or never attained.

The authors selected tropical peatlands as a review case to examine multifunctional 'scape approaches for large intact natural areas for three reasons: (i) their importance globally as large intact natural areas in their own right (the Global Peatlands Initiative has highlighted the need to preserve peatlands in intact states [16]); (ii) their role in linking and influencing other biomes (e.g., intersecting ecosystems such as forests, other wetlands such as mangroves, and coastal systems) promotes a multi-ecosystem approach; (iii) their predominance globally as large intact natural areas (for the moment), but where rapid transition to heavily modified anthromes is occurring in select global regions. As such, tropical peatlands present an opportunity to learn about both the holistic costs of mismanagement at both local and global scales, the challenges and opportunities associated with restoration, as well as the potential benefits of multifunctional 'scape approaches to preserve key remaining intact systems.

3. A Review of Tropical Peatland Ecosystems

3.1. Introduction and the Value of Large Intact Peatlands

The Ramsar Convention on Wetlands [17] describes peat as partially decayed plant material that accumulates under waterlogged conditions over long time periods. Ref. [18] defines peatlands as areas "*with or without vegetation with a naturally accumulated peat layer at the surface*". As a general biome, peatlands occur globally and account for between 50–70% of wetlands across boreal, temperate, and tropical zones [18,19] (Figure 3). Despite covering just three percent of the Earth's land surface [20], intact peatlands are critical components of the global carbon cycle. They constitute the world's largest terrestrial carbon sink; store twice as much carbon as all the world's forests; store between ⅓-½ of the total soil carbon pool (~500 Gt); likely exceeding the carbon found in all the world's vegetation [21,22]. Intact peatlands also play important roles in balancing local and regional hydrological regimes (including flood and drought prevention and protecting the quantity and quality of local water sources), provide vital ecosystem services and livelihood opportunities for local communities, provide habitat for a rich range of plant and animal species, and control pollution, erosion, sediment movement, and sea-water intrusion [22,23].

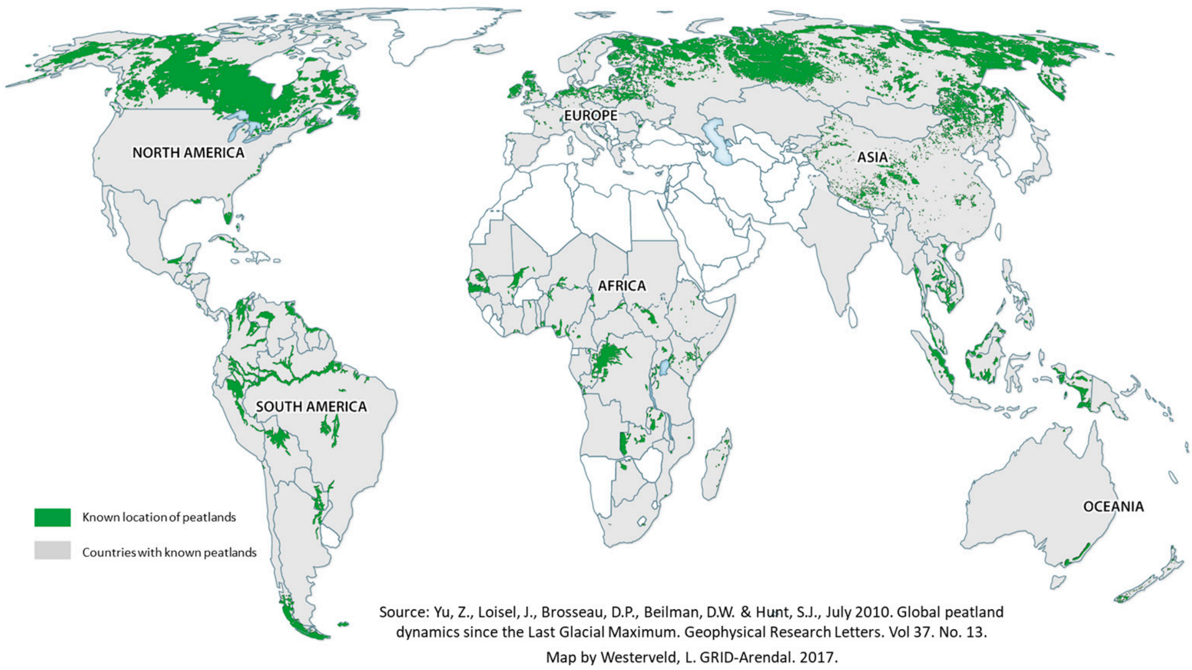

Figure 3. Estimated global distribution of peatlands, including tropical peatlands, across equatorial America, Africa, and Asia (Source: United Nations Environment Program [24], Minor changes made by authors to figure labeling).

As a subset, tropical peatlands comprise 11% of global peatland areas [25]. They are found in regions such as southeast Asia, equatorial Africa, and equatorial Latin America [21], with major known deposits in Indonesia, Papua New Guinea, Brazil, Peru, Malaysia, Congo, Zambia, Uganda, and the Democratic Republic of Congo [22]. The discovery of new tropical peatland systems, as well as the refinement of known tropical peatlands, continue as technology and research advances. For example, the first spatially explicit map of tropical peatlands in Cuvette Centrale, in the central Congo Basin—identified as the most extensive tropical peatland complex globally (~145,500 km^2)—occurred only recently [26].

Tropical peatlands are often accompanied by forests, which can be home to endemic flora and fauna biodiversity. Tropical peatlands may play important roles in maintaining nursey fauna populations and providing habitats for resting and wintering areas for migratory and domestic bird populations [23]. Intact tropical peatlands provide recreational (i.e., tourism), scientific, educational, and cultural benefits [23], and ref. [27] reports evidence of advancement of equalities and poverty reduction in intact tropical peatland systems in Indonesia.

3.2. Degraded Tropical Peatlands—Cause and Effect

An estimated fifteen percent of the world's peatland areas have been irreversibly damaged or are currently undergoing extreme degradation [28]. While this figure masks significant regional differences between intact and heavily modified anthromes, tropical peatland forests have been deforested at higher rates than other forest types in recent years. For example, it is estimated that almost 80% of tropical peatlands in southeast Asia have been deforested and drained [29], with annual deforestation rates of up to 8% recorded in some regions in recent years [20]. Many tropical peatland systems are increasingly exposed to destabilizing factors including land-use change, fire, and climate change, which are progressively intertwined, and each of which is examined briefly below.

Land-use change is arguably the predominant factor impacting large intact natural areas and, globally, it is estimated that nearly 50% of peatland damage and degradation is due to clearance for agriculture purposes [30]. In addition to plantation and smallholder agriculture pressures, tropical peatland systems are exposed to resource and infrastructure development and more specific challenges related to drainage (and fire, see below). As wetland systems, tropical peatlands are adversely impacted by drainage, which affects both the position of the water table and peat column moisture levels [21,31]. Peatland moisture levels play a critical role in sustaining above-ground biomass and resilience to fire, and in controlling the rate of aerobic microbial decomposition (or mineralization) of organic matter, and thus the rates of peat (and carbon) accumulation [21]. In short, drainage can expose tropical peatlands to above-ground biomass loss, fire, and shift peatlands from GHG sinks to sources. Such drivers of land-use change and peatland degradation are compounded by a mix of indirect socioeconomic-, policy-, and climate change-related factors. Land-use change and associated drainage may be the trigger factor for the transition from a large intact natural area ultimately towards a heavily degraded anthrome [31]. Fire is an important secondary factor for tropical peatland systems that can accelerate and broaden this transition.

In hotspots of land conversion, peatland transformation often occurs together with increased fire activity [21,32]. Tropical peatland fires comprise both flaming surface fires, which consume vegetation and litter and are generally short-lived, and smoldering fires, which burn at lower temperatures into and below the ground, consuming the peat itself as a fuel source and often extending for weeks or months [33]. Peat moisture content, which is affected by land-use change, is the primary determining factor for the ignition and extent of smoldering fires [33].

While tropical peatland fires have been recorded in multiple locations—from the Okavango Delta in Africa to Peru and Brazil in South America—they are typically considered occasional ecological events for intact systems. However, in some heavily modified tropical peatlands in southeast Asia, fire is now a regular feature of every dry season [34], with systems "exhibiting a rapidly escalating scale of fire extent, frequency and severity" [21]. Recent studies confirm that most fires occur on deforested land [35,36], during deforestation [35] and where drainage canals have been created [37]. Tropical peatland fires in southeast Asia are predominantly anthropogenic [36,38] but may be exacerbated by climate-related events. Fires are more likely to occur on degraded land than in protected areas of forest [39] and once burned, tropical peatlands are more likely to re-burn and recover towards fire-prone fern- and sedge-dominated open vegetation with very limited opportunity for forest recovery [21].

The social and economic costs of tropical peatland fires are evident locally and regionally, acutely and chronically. For example, "haze" (the persistent dense, toxic smoke) from smoldering peat fires not only brings "fatal damage to the forest soil, its microflora and micro-fauna" [40], it also constitutes transboundary environmental pollution events [41]. Haze from peatland fire events in Indonesia has reached as far as Thailand and the Philippines [42] and collectively impacted an estimated 150 million people with localized impacts including school closures, road disruptions, and cessation of outdoor labor (such as construction and agriculture), to regional impacts such as international disputes, aviation and shipping disruptions, and tourism downturns. The estimated loss and damages caused by Indonesian fires in recent years is USD 93.9 billion from the six largest events, dwarfing the costs of more publicized incidents such as the Aceh tsunami reconstruction [43]. Furthermore, it is estimated that regular peat fires in the region could be responsible for an additional 110,000 deaths per year via increased incidence of respiratory and cardiovascular conditions [44]. Recent economic assessments (e.g., [43]), that consider holistic impacts (including system disruptions, health costs, and carbon emissions) make both conservation and restoration of tropical peatland ecosystems cost-effective strategies. In short, fire is a natural phenomenon that may transition into a new state of frequency and severity when the cycle of land-use change shifts tropical peatlands from large intact areas to heavily modified anthromes.

Finally, depending on their state as large intact natural areas or heavily modified anthromes, tropical peatlands increasingly affect, and are affected by, climate change [45]. Tropical peatlands are potential hotspots for GHG emissions, particularly when drained [20,46], contributing an estimated 70% of global drainage- and fire-derived GHG emissions from organic soils [47]. Analyses of smoldering fires in southeast Asia confirm the release of ancient carbon sequestered from plants that were alive in the 14th century [33,48,49], transferring to the atmosphere in hours or days that which was built up over millennia. Peatland fires contribute up to 86% of fire emissions in equatorial Asia [50], and in 2015, fires in Indonesia in 1997 released carbon equivalent to 13–40% of all emissions from fossil fuels globally that year [51]. Additionally, while peatland fires cause temporary emissions peaks, the emissions from peat mineralization caused by drainage can occur continuously and are estimated to be of equivalent magnitude to fires [21]. As such, anthropogenic factors have already reversed some peatlands from long-term carbon sinks to acute carbon sources and this trend could accelerate, particularly in heavily modified anthromes. Furthermore, climate change may most profoundly affect heavily modified peatlands [33,41] and intensify their vulnerability to a virtuous cycle of degradation and fire.

3.3. Multifunctional 'Scape Approach for Tropical Peatlands

A review of tropical peatland systems demonstrates that a shift in state from large intact natural area to heavily modified anthromes is accompanied by a series of broad—and potentially significant regional and global—negative impacts. Whilst it may appear that the economic, environmental, and social values of intact tropical peatlands are high, it may also be true that the cost of the externalities of degraded tropical peatlands and their restoration back to a functioning ecosystem is high. As such, it appears that there are strong interlinked benefits of protecting large intact natural areas for both local and global benefits and to overcome past and ongoing management challenges. As such, the authors posit that tropical peatlands provide an opportunity to deliver a multifunctional 'scape approach, particularly focusing on large intact wilderness spaces connecting multiple ecosystem types (and likely also for other modified spaces in Figure 1). Further, knowledge development and investment in sustainable management of tropical peatland systems may likely produce learnings relevant for intersecting ecosystem types.

4. Considerations for a Multifunctional 'Scape Approach for Tropical Peatlands

As nature and biodiversity are recognized as essential components of our socioeconomic system, and terms such as nature-positive tend towards the mainstream, the authors examine some considerations for the implementation of multifunctional 'scape management approaches. Lessons from tropical peatland systems are integrated for illustrative purposes.

4.1. Overcoming a Predominant Contemporary Restoration Focus

Recent decades have seen significant focus on the restoration of degraded lands. Many large-scale initiatives by international bodies, such as the United Nations Convention to Combat Desertification (UNCCD), the United Nations Framework Convention on Climate Change (UNFCCC), and Reduced Emissions from Deforestation and Forest Degradation (REDD), have focused on forest restoration. For example, the Bonn Challenge is a global goal "to bring 150 million hectares of degraded and deforested landscapes into restoration by 2020 and 350 million hectares by 2030" [6]. The United Nations has labeled this decade (2021–2030) as the Decade of Ecosystem Restoration.

Whilst restoration is a critical element of the multifunctional 'scape approach for mosaics and heavily modified anthromes, preserving intact ecosystems will be critical in avoiding degradation, averting biodiversity loss, and sustaining traditional and indigenous livelihoods. Arguably, intact systems must be the first locations globally to achieve these goals. For example, key findings from tropical peatlands include evidence that protected areas, comprising largely intact systems, reduce the incidence of fire compared to non-protected areas [43]. The greatest reduction in fire was recorded in national parks, which typically comprise larger protected areas (and, therefore, likely reduced outside influences of activities such as drainage) and management plans. During Indonesia's 2015 fire event, soil moisture levels were up to 57% higher inside national parks than outside national parks, and between 2004–2015, protected areas were burnt out up to 79% less compared to surrounding areas [43]. In contrast, degraded ecosystems can trigger further degradation. For example, degraded peatland areas were found to have burnt up to eight times between 1990 and 2011 [52] and on a recovery trajectory not towards the original peatland forest ecosystem but to open vegetation instead [21].

As such, the spatial scale of intact spaces and adjacent land-use type also matters. Protected and conserved areas should sufficiently overlay the extent of large intact ecosystems they are targeting for protection. For example, a moratorium on deforesting primary forests in Indonesia only covers 32% of Indonesia's tropical peatlands, leaving many still vulnerable to degradation [53]. Additionally, intact tropical peatlands surrounded by plantation concessions or smallholder farms may become increasingly vulnerable to accidental or purposeful ignitions. Hence, to maintain the resilience of intact ecosystems, there is a need to ensure they remain large enough to be resilient and with special attention given to management at their boundaries near other (often incompatible) land uses.

Restoration efforts can be coordinated with protection and conservation of large intact tropical peatlands. For example, in Indonesia, it has been found that the benefits of restoration outweigh the costs, providing evidence to support Indonesian government plans to restore large areas of degraded peatland. A more ambitious program of restoration would yield even greater benefits, targeting areas susceptible to past fires, to maximize fire prevention [43]. Combined with effective protection and conservation of large intact spaces could go a long way towards a successful multifunctional 'scape management approach.

4.2. Polycentric Governance Model and Resilience Building

Multifunctional 'scape governance should provide linkages across functions, from local to international, government to non-government, intact and degraded ecosystems.

At the international level, there is no doubt that momentum to improve governance arrangements related to nature is increasing, from both within and outside the global nature-based community. Key overarching declarations have emerged from the United Nations. For example, the High Ambition Coalition for People and Nature (a UN initiative) set a goal of conserving at least 30% of the planet by 2030, aimed at halting the accelerating loss of species and protecting vital ecosystems. This global target is garnering increasing support, for example, from the IUCN World Conservation Congress (2021) and political leaders from over 90 countries have signed the Leaders Pledge for Nature to reverse the loss of biodiversity by 2030. Similarly, despite its title, the UN Decade of Ecosystem Restoration (2021–2030) includes "*a rallying call for the protection and revival of ecosystems all around the world . . . and aims to halt the degradation of ecosystems, and restore them to achieve global goals*" [5]. Most recently, target three of the post-2020 Global Biodiversity Framework, agreed to by all member states of the CBD, aims to protect 30% of natural areas by 2030 and is well aligned with the multifunctional 'scape approach [54].

Integrated approaches to nature are increasing in profile across interlinked communities at the international level, including discussions of the need for transformational change. For example, groups such as IPBES, IPCC, the International Resource Panel (IRP), and the UN Environment Program (UNEP) are increasingly reaching consensus around the need for "*rapid and far-reaching transformational change across all sectors of society and economy to tackle the interconnected issues of climate change, environmental degradation, and biodiversity loss*". In 2021, G7 leaders announced that "*our world must not only become net zero, but also nature positive, for the benefit of both people and planet*". Similarly, in 2021, the multilateral development banks issued a joint statement for nature, people, and the planet [55]. There is increasing rhetoric around shifting from "do less harm" to "creating positive outcomes" for nature, people, and the planet. IPBES is currently conducting an Assessment on Transformational Change.

Whether influenced by such top-down initiatives, bottom-up pressure, or under its own volition, business engagement on nature is also increasing. Global coalitions, such as Business for Nature, are examples of business and conservation organizations coming together; more than 1000 businesses are calling on governments to adopt policies now to reverse the loss of biodiversity by 2030; in finance, a new Taskforce on Nature-related Financial Disclosures [56], and the Science Based Targets Network is working on ways to enable companies and cities to set targets for climate and nature, all of which are intended to help direct investments towards a nature-positive future [57].

In terms of the multifunctional 'scape approach, there is also increasing recognition of the critical role for intact ecosystems to play in operationalizing international mandates, scientific targets, and government and business goals. For example, a group of Protected and Conserved Areas management authorities, agencies, and associated bodies issued a Joint Statement on Climate Change and Biodiversity to the UNFCCC COP26 and CBD COP15 to emphasize the critical role protected and conserved areas will have to play to resolve the joint climate change and biodiversity crises [58]. However, this will require protected and conserved areas to: (i) be governed and managed effectively and equitably, with sufficient resources, capacity, will, and commitment to achieve their outcomes in the long term; (ii) be recognized as part of land-use spatial planning and decision making (including management of boundary land uses); (iii) have the custodians and guardians of these places, including local communities, landowners, managers, and front-line workers (such as rangers) be recognized, supported, invested in, and protected [54,58]. Additionally, while the governance of protected and conserved areas is critical at local levels, it is also important to govern and manage such ecosystems as part of a global network of interlinked intact ecosystems (as promoted in multifunctional 'scape approaches). There is increasing acknowledgement of the need to include, and prioritize, "carbon-rich" protected and conserved ecosystems, such as tropical peatlands, and for greater connectivity of these spaces to help anchor nature recovery works globally. Arguably, the most critical current process is the recently agreed post-2020 Global Biodiversity Framework—a framework intended to be the nature-based equivalent to the Paris Agreement call to action on climate change. The Global Biodiversity Framework places critical importance on preserving intact ecosystems. It is hoped that an apex goal for nature, such as the 1.5 degrees warming limit target for climate, helps rally stakeholders around a unified target, across multiple governance levels and geographies.

However, many of these evolving and ambitious international initiatives are yet to be operationalized at lower governance levels. For example, tropical peatland fires provide an example of a need for improved regional governance systems to manage transboundary environmental challenges where localized land clearing may temporarily benefit a small number of people; however, the costs of fires (e.g., health, economic, social, environmental) are many magnitudes greater across both temporal and spatial scales (see Section 3.2). Such negative regional impacts are currently largely externalized. At national governance levels, the dual crises of biodiversity loss and climate change often come under separate sector portfolios, often leading to uncoordinated actions and poor integration into finance/economic development planning. There may still be opportunities at national levels to include biodiversity and climate measures in pandemic stimulus plans to enhance longer term resilience and health of intact and degraded ecosystems. Sixty six percent of governments globally have committed to restoring or protecting ecosystems in their climate targets, which offers another avenue for nature-based progress across nation states [59]. However, ultimately, many national and global impacts aggregate from local actions. Emerging local governance models, such as community-driven nature-based development or results-based management and financing systems, may offer opportunities as relevant technology and business models advance (e.g., satellite monitoring and management to support local "no burn" and "no deforestation" policies in and around tropical peatlands and peatland bonds to support low-impact sustainable local livelihoods).

Even economically focused outputs, such as the 2021 Dasgupta Review [9], acknowledge the need for legislative enhancements in addition to market-based approaches. The review calls for the improved regulation and protection of high-value areas, including the expansion and improvement of the management of Protected and Conserved Areas and restrictions on the exploitation of globally significant ecologically sensitive areas. The review recommends "polycentric governance" to help drive change where knowledge and perspectives across all levels are pooled and where information flows in all directions.

At the country level, governance and management lessons from Indonesia's experience with forest fires have shown that "bureaucratic inertia" has played a role [60]. For example, ref. [60] found that whilst almost 100 government agencies are liable for controlling forest fires, centralized decision-making processes at the level of president and regional governor result in institutions involved in fire management having less power and responsibility and being unable to be highly responsive in a timely manner. In response, the same authors recommend the devolution of government authority from the central to the local levels for better fire management. Many communities have their own local knowledge and expertise to respond to fires and could be given greater autonomy to act in both fire prevention and response. Such an approach would support the principles of polycentric governance.

Finally, a key feature of polycentric governance models can be to improve the resilience of ecosystems. This approach is supported by ref. [21], which emphasizes the importance of maintaining or restoring ecosystem resilience as being essential to long-term ecosystem sustainability.

4.3. Connecting Land Tenure, Poverty Alleviation, and Indigenous Community Empowerment

Indigenous peoples and local communities (IPLCs) can play an important role in managing intact wilderness spaces. Indeed, some of the world's most biodiverse ecosystems intersect with IPLCs, meaning that the active participation of such communities will be critical for their effective long-term and sustainable management. Globally, it is estimated that 50% of terrestrial land is collectively managed by indigenous peoples under customary tenure systems, and almost 40% of intact forest landscapes occur within indigenous lands [61]. While local people may harvest tropical peatlands to grow and obtain food, fiber, and other local products, evidence suggests that the decline of nature in such areas tends to occur less rapidly than under other land tenure and governance arrangements. Such approaches offer sustainable opportunities for poverty alleviation [27]. IPLCs may be more attuned to the sustainable management of tropical peatland systems given that they may be the first to be impacted by associated adverse impacts on local ecosystems (e.g., declining water quality/levels) and may also have strong spiritual and cultural connections. Hence, there is a need to support IPLCs and their management methods into intact multifunctional 'scape approaches.

There is increasing recognition of IPLC rights and sustainable management for tropical peatlands, as illustrated at the 2018 Meeting of the Global Peatland Initiative Partners, which reaffirmed a commitment to "*preserve the right of local communities to use natural resources in areas covered by peatlands, to maintain their traditional uses and to implement the principle of free, prior and informed consent in engaging in activities with local people, to help them use peatlands sustainably and to develop methods other than destructive practices*" [62]. Additionally, tropical peatlands often intersect with internationally designated Ramsar Convention wetlands, including recent convention recognition of a need for a renewed focus on poverty alleviation and gender equality around wetlands (including peatlands). Further, a multifunctional 'scape approach could provide such a socio-ecological framework for improved wetland management [63]. Scholars [27,64] recommend an enhanced knowledge generation and exchange for integrating the historical and local knowledge of environmental and social conditions into management approaches.

Local interactions between stakeholders, power dynamics, and justice also play important roles at the local levels. Research from Indonesia has found that even in cases where the illegal burning of peatland forests occurs, issues of justice can be complex, and caution should be exercised even in formal legal systems [65]. For example, a 2021 study [65] found that while it is often "commoners, farmers, and jobseekers in need of cash" who are charged in court for illegal clearing activities, "key actors, such as companies and landowners, were observed to be involved in providing funds for land clearing or burning, yet they remained legally untouchable". Hence, it is important to recognize such dynamics, particularly when proposing potential solutions. In such cases, a combination of alternative local employment generation may support "commoners, farmers, and jobseekers in need of cash", whilst greater accountability for key actors, such as companies and landowners, needs to be enforced by governments.

To complicate matters further, another Indonesian study [66] highlights that whilst government actions have focused on actions such as fire suppression, peatland rewetting, and early warning systems, there is far less focus on addressing the underlying causes of fires such as providing economic incentives for land preparation without burning. The study found that when farmer group organizations can benefit monetarily from existing systems (that may be destructive to nature) and influence decision-making processes via their patronage networks, there is a need to disempower such organizations, via law and policy, to reduce the incidence and duration of fires.

The above examples illustrate the complexity of local stakeholder dynamics and the role stakeholders can play—positively and negatively in nature-based management. However, a certainty is that local and indigenous stakeholders need to have confidence in their standing and in the fairness in the application of the rule of law in their own communities—whether it be related to land tenure, employment with companies, or running local organizations.

4.4. Nature-Based and Climate Financing

While global policy, local regulations, and disclosure requirements become better aligned towards nature-positive outcomes, appropriate economic and financial models remain outstanding to mobilize sufficient nature-based financing. Further, the aptness of monetary valuation of nature remains a concept that plagues conservationists and economists to this day, with related governance and management challenges.

A major factor affecting multifunctional 'scape approaches is the valuation of human-related activities and practices towards nature and, ultimately, perhaps even nature itself. It is estimated that more than half the world's economic output (USD 44 trillion) is moderately or highly dependent on nature. Further, the World Economic Forum (WEF) [67] estimates that the benefits of protecting at least 30% of the world's land and oceans outweigh the costs by a ratio of at least five to one. If nature is viewed as an asset and service-provider, then mismanagement of nature poses a cost and risk to us all. For example, without action, by 2030, nature loss could cost 2.3% of global GDP ($USD 2.7 trillion) and more than 10% of national GDP for some poorer countries [67]. The risk of the collapse of nature threatens our global food and health systems, and cases of governments and private companies being taken to court over the mismanagement of nature are increasing. As such, nature-based risk management and monetary valuation of ecosystem services are gaining traction in policy and business communities [68].

However, there is an ongoing, and yet unsettled, academic debate about nature and economics, as captured in publications such as ref. [69]. For example, should nature be valued in intrinsic ways or by economic valuation [70]? If so, who should conduct the valuation and what would they value—governments, companies, local communities, and/or indigenous peoples [70]? How should power differentials be accounted for [70]? Other authors highlight major differences and incongruities between the natural world and the world of financial capital [71] and that the way humans experience nature, or the simple right of nature to exist, cannot be measured in terms of natural capital [72]. A further argument is not whether monetary valuation is accurate, complete or true, but rather "under what conditions is monetary valuation useful?" [73], and that it is not a substitute for strong regulation and policy reform [72]. Finally, some debate that natural capital and its monetary valuation does not address the biggest economic forces at work: the economics of land-use change and the economics of climate change [9,71].

Hence, it is important to keep these greater economic forces in focus for multifunctional 'scape approaches, particularly where topics such as economic valuation and finance mobilization are proposed for the sustainable management of intact systems. In this regard, there is an urgent need for economic and financial models to better reflect the long-term value of intact ecosystems rather than the short-term value of commodities they may potentially produce. Building upon approaches such as Payment for Ecosystem Services (PES), eco-tourism, and Reduced Emissions from Deforestation and Degradation (REDD and REDD+), which have exhibited varying levels of success, new paradigms and models are emerging which may offer potential applications. For tropical peatlands, some authors emphasize the importance of business models for strengthening livelihoods and smallholder positions to ensure their interest in sustainable management approaches [74]. For the purposes of this study, and to explore current and emerging opportunities for investment in large intact wilderness spaces, the authors provide two broad categories for discussion: (i) nature-based economics and financing, and (ii) climate financing for nature.

4.4.1. Nature-Based Economics and Financing

If it is true that policy frameworks and economic models up to now have failed to recognize the true value of nature, then the Dasgupta Review commissioned by the United Kingdom Government [9] offers arguably the most comprehensive review of nature and economics ever conducted, and thereby a potential basis to help chart a nature-positive pathway forwards. The review builds on previous major works, such as The Economics of Ecosystems and Biodiversity (TEEB) [75], and adopts the philosophy that the current state of nature is not to the fault of economics, but instead "in the way we have chosen to practice it". It includes a scope for transformative change. While the review is certainly not without its detractors [76] and may not adequately address all the queries raised by scholars (e.g., [70–73]), it has certainly sparked debate and raised the profile of nature's current plight. Critically, regarding the multifunctional 'scape approach for intact ecosystems, the review does emphasize the need to increase protected areas and that it is most cost-effective to conserve nature rather than to restore it. Additionally, the review predicts that conserving and restoring natural assets will help to alleviate poverty, as natural capital contributes the bulk of wealth in low-income countries. In terms of changing the way economics is practiced, the review calls for a reframing of economic wealth, termed "inclusive wealth", which accounts for both human and natural capital, as highlighted by China's Gross Ecosystem Product and New Zealand's Living Standards Framework as early examples of natural capital and ecosystem services being integrated into national metrics [9].

Such contemporary work builds on pioneering efforts by researchers such as those in ref. [74] who recognized the need for both private and public sector financing to support nature-positive activities. Ref. [77] helped to pioneer and pilot a range of policy- and market-based approaches, including tax incentives to encourage responsible corporate behaviors, concepts such as conservation investment banking, and exploring markets for nature's goods and services. Such early research presented innovative and practical applications and strategies and importantly synthesized both successes and failures, thereby forming a basis for more advanced models today. Hence, while some economic norms are being currently challenged, piecemeal trials and innovations are emerging. For example, ecosystem-specific bonds, such as peatland bonds (where local communities are paid to help conserve intact peatlands), and wildlife bonds (the World Bank issued the first wildlife conservation bond, which makes a results-based payment for increasing numbers of endangered wildlife) [78] are two such emerging mechanisms. In addition to the potential of such specific "green" bonds, there are emerging approaches on insurance, being piloted in locations such as Mexico, where tourism entities, which are reliant on intact ecosystems to attract tourists, help fund the care and maintenance of those ecosystems for their continued business prospects. The concepts of wetland banking [79] and biodiversity offset programs [80,81] are also being explored under no-net-loss approaches.

At a national level, South Africa has introduced a biodiversity tax incentive that allows farmers or communities to receive a fiscal benefit if they set aside land as protected areas, and an Indian state has implemented a zero-budget natural farming policy, which has improved farmer livelihoods while enhancing soil biodiversity [67]. More specifically related to tropical peatlands, case studies in Indonesia show that between 2004 and 2015, peat fires caused a total of USD 93.9 billion in economic losses and that peatland restoration could have resulted in economic savings of USD 8.4 billion over the same period, making it a cost-effective strategy for reducing the impacts of peatland fires to the environment, climate, and human health [43]. Further, the cost of tropical peatland conservation and restoration may not have to be fully borne by single countries [43], as, for example, Singapore is willing to pay USD 643.5 million for the health benefits of reduced fire in Indonesian tropical peatlands [82]. While such examples may be illustrative, and yet to be proven at scale (or even in practice), their principles may form the foundation for future scalable nature-positive investments, including in high-value intact ecosystems as well as mosaic and heavily modified anthromes utilizing a multifunctional 'scape approach.

A recently proposed Financial Sector Guide for the Convention on Biological Diversity aims to mobilize financial institutions to ensure a nature-positive world. The guide is purported to be the first of its kind between the CBD (and partner organizations) and the financial sector. Additionally, potential financial sector advocacy includes calls for an ambitious and transformative post-2020 Global Biodiversity Framework; supporting nature-based financial initiatives such as the United Nations Environment Program Finance Initiative (UNEP FI), Principles for Responsible Investment (PRI), Business for Nature, and Finance for Biodiversity Pledge; public reporting via the Taskforce on Nature-related Financial Disclosures (TNFD). Additionally, the Network of Central Banks for Greening the Financial System (NGFS) has recognized that environmental degradation poses challenges to the broader financial system [83]. Additionally, the formation of asset management companies by mainstream financial institutions which are dedicated to natural capital, at scale, are emerging and are encouraging (e.g., [84]).

Contemporary guidance recommends two complementary pathways for private sector nature-based action: (i) to mainstream investments in nature that already demonstrate a positive business case, and (ii) where financial returns are not yet in place, to call on policymakers in governments and international institutions to create an enabling environment for investments in nature to become more financially attractive [67]. Further, the implementation of nature-positive policies could generate an estimated USD 10 trillion in new annual business value and create 395 million jobs by 2030, with potential far-reaching environmental, economic, and social benefits [67].

However, amidst such rapid progress, it must be acknowledged that there is a risk that natural capital accounting could lead to unintended damage to natural systems. For example, some case studies of nature monetization projects found that while aspects of monetization may benefit biodiversity conservation, such schemes need to be applied appropriately and require supportive policy or governance measures to ensure biodiversity conservation outcomes [68]. Hence, those authors conclude that in the absence of additional measures in place to accompany nature valuation frameworks, there is a real risk of biodiversity loss worsening as monetization tools are embedded and not used as intended [68]. Additional political resistance to the promotion of nature-based market mechanisms and to the expansion of protected and conserved areas (particularly amidst current food security concerns) must also be acknowledged.

The impact of funding structures on local communities, and the sustainability of interventions are also important issues to consider. Authors, such as those in ref. [85], raise two key issues when it comes to funding conservation and restoration efforts in tropical peatland systems. Firstly, there is often a lack of secure funding, particularly when it comes from non-local sources and does not provide sustainable financing. Secondly, empirical evidence from conservation and restoration efforts highlights that whilst direct costs for activities can be calculated accurately, indirect costs of addressing social challenges, such as expenses to engage local communities, are often not included nor quantified and can constitute up to half of total project costs. To remedy such challenges, a hybrid "green" governance model, combining an ecosystem services enterprise with active participation from the public sector, has been proposed [85]. Such an approach could potentially leverage local knowledge and labor capacities, create local enterprise opportunities, and provide strategic public sector support (regarding financing and compliance with regulations).

4.4.2. Climate Financing for Nature

There may be scope for the lessons learned in recent years on climate change policy and financing to help guide nature-based progress. For example, following the 2015 Paris Agreement, now ratified by 193 parties worldwide, we have witnessed the development of national climate actions plans (Nationally Determined Contributions) and subsequent financial structures and vehicles developed at national and international levels. As such, today, we see multiple billions of dollars being channeled into climate finance annually, which is expected to continue to rise. Notably, finance into climate change has mobilized the private sector at scale, 56% of global climate finance comes from the private sector [86], while a recent UN report [87] found that 86% of funding towards nature-based solutions comes from public funding.

Prior to the current financing structures established under the Paris Agreement, the seminal report on climate financing was arguably the UK government-funded Stern Review [88], which, for the first time, attempted to cost the impacts of climate change. The review included carbon pricing policy, standards and regulations, and private sector investment and innovation. Ultimately, by enabling the cost of climate change to be quantified, the review, it may well be argued, contributed to accelerated and more ambitious climate action. Furthermore, it may be argued that the Dasgupta Review [9] has potential to be the nature-based version of the Stern Review [88]. For example, the Dasgupta Review highlights progress on climate-related financial disclosures as an example of the potential for nature-based financial disclosures to follow [9].

Climate finance and nature-based finance may be increasingly intertwined. For example, climate finance is being aligned with the Sustainable Development Goals, of which nature features prominently. Much of this advancement is supported by IPCC special scientific reports on terrestrial, ocean, and cryosphere carbon cycles [89]. Ecosystem-based adaptation is a well-established concept and practice, and increasingly terrestrial carbon sequestration is being integrated into climate mitigation. The most recent UN Climate Conference of Parties (COP26) made progress on Article 6 [90], which is related to carbon markets, and which could extend to carbon pricing, including the monetary valuation of "standing" or "intact" carbon, such as that found in intact ecosystems.

While we have seen a proliferation of climate-based funding mechanisms to mobilize billions of dollars to low-carbon and climate resilient development—from the Green Climate Fund, the Climate Investment Funds, the Adaptation Fund, and others—we have not seen the same funding momentum yet around nature. However, we are increasingly seeing the foundations for such funding to be realized and the coming together of nature and climate initiatives. For example, the United Nations inaugural State of Finance for Nature report states that a USD 4.1 trillion financing gap exists to meet climate change, biodiversity, and land degradation targets by 2050 [87]. The report states that investments in nature-based solutions need to triple by 2030 and that this upscaling would equate to a cumulative total investment of up to USD 8.1 trillion and future annual investment of USD 536 billion [87]. Such quantification of combined climate change and nature financing requirements is an important step to understand the scale of challenges and opportunities.

4.5. Acknowledging Political Economy Factors and Tradeoffs

All change necessitates disruption to some degree, and transformative change will require significant disruption to the status quo, including the political will to trigger adequate change and maintain it. Many of the emerging topics discussed in this paper to support multifunctional 'scape approaches—from changes to governance and financing models—will require reconfigurations of social and organizational systems. Such a transition, particularly related to reorientations prompted by climate change, is commonly being termed a 'just (and inclusive) transition". However, whether restructuring society's energy systems, or changing our fundamental relationship with nature, it may cause upheaval in multiple aspects of society, with commensurate compromises required and delays likely. Such change also requires actions from governments, businesses, and consumers.

The integral role of the political economy in facilitating (or preventing) change in the management of ecosystems has been recognized for decades. As far back as the 1990s, authors such as those in ref. [10] highlighted that the management of ecosystems is strongly influenced by social and political judgments. More recently, ref. [91] has highlighted the importance of local politics, social orders, and cultural values in influencing sustainable land management, which is often at the core of success or failure. For example, ref. [91] touches on the potential contribution of factors such as cultural upheaval and the construction of new moral and spiritual boundaries in land management conflicts (using Yellowstone National Park in the United States as a case study). The factors identified by ref. [91] speak to the intractability and depth of some of the underlying causes of land management conflicts.

Recognizing tradeoffs is also an important first step when considering transformative change, and multifunctional 'scape approaches arguably incorporate elements of the recent book "The Wizard and the Prophet" by Charles C. Mann [92]. The book contrasts the diametrically opposed views about the environment of two key historical thinkers as a prompt for contemporary readers to consider the philosophical merits of each approach. In doing so, the author wrestles on one hand with the prophet's wisdom that humans should respect natural limits—which could arguably be manifest in the protection of large intact ecosystems—whilst on the other hand implementing the wizard's technological ingenuity to overcome limits—which could arguably be captured in modern management approaches, satellite technologies, and complex financing models. In essence, the three categories within the multifunctional 'scape approach capture elements of both the wizard and the prophet, but arguably raise the profile of the prophet compared to the often-noisier wizard. Importantly, such framing critically raises the issue of tradeoffs, which are arguably inevitable in approaches where sustainable development principles (optimizing economic, social, and environmental goals) are pursued.

4.6. Global Knowledge Exchange Opportunities

Large intact wilderness spaces exist across all global regions, comprising both shared and unique ecosystem and sociocultural contexts. The local knowledge and practices emerging at individual sites may have relevance more broadly. In essence, there may be impetus to "act locally, and share globally".

For example, as we have illustrated in the review of tropical peatlands that while their fate may be largely determined by local actions, the impacts of their management may be felt regionally and globally. Hence, there is an argument to be made for knowledge and management practices (and finance) to be exchanged between stakeholders. Where local tropical peatland management successes have been achieved at large intact sites, these lessons could be shared nationally, regionally, and globally. The facilitation of such a knowledge exchange could support the establishment of management (and valuation) systems in regions where tropical peatlands currently remain largely intact. For example, networks of knowledge exchange could be established between regions such as southeast and south Asia (where anthropogenic pressures are generally greater) and tropical Africa and Latin America (where large intact tropical peatlands remain and anthropogenic pressures may currently be less). Knowledge exchange may ultimately support policy development and the mobilization of financial support.

Such exchanges have already commenced but require support, acceleration, and scaling. For example, in 2018, at the 3rd Meeting of the Global Peatland Initiative Partners, Ministers of Environment from Indonesia, the Democratic Republic of Congo, and the Republic of Congo called for international collaboration to protect tropical peatlands [62]. Such countries could benefit from the support of the international community to promote greater knowledge exchange, policy development, and financial support.

5. Conclusions and Recommendations

5.1. Conclusions from the Review

This paper has explored the potential of transformative change, via a multifunctional 'scape approach, to improve sustainable management outcomes at scale. The paper has emphasized the urgency and criticality of confirming approaches for preserving large "intact" natural areas (in addition to the current international focus on restoration). The authors have used tropical peatland ecosystems, which often intersect multiple ecosystem types, to derive broader ecosystem management lessons. In Section 4, the challenges and opportunities of a multifunctional 'scape approach are highlighted, drawing upon tropical peatland research findings to identify key areas for further research and policy focus.

Finally, in response to the research question posed at the beginning of this paper, the authors believe that multifunctional 'scape approaches do have the potential to support transformational change in the management of intact ecosystems, such as tropical peatlands. Based on the findings in this paper, the authors provide some recommendations below to help guide policymakers and practitioners to facilitate such a transformational change.

The authors acknowledge the limitations of this paper, specifically in relation to the current rapid global change in approaches to climate change, biodiversity, nature, and business and financial understandings of potential risks if biodiversity is not considered in business cases. Firstly, it is a dynamic time for nature-based approaches and management: the post-2020 Global Biodiversity Framework was agreed in late 2022, and global action on nature is growing. Different approaches and new voices are emerging; hence, elements of science, management, and finance are all evolving rapidly. Secondly, regarding tropical peatlands, the paper draws heavily on case studies focused on southeast Asia. However, the authors are cognizant of examples emerging from other critical tropical peatland regions globally, such as the Congo Basin in west Africa [93,94] and lesser studied regions in Latin America, such as Peru [95]. As such, the paper's findings and preliminary recommendations have been structured with the potential exchange of learnings between academics, policymakers, and practitioners from different global regions in mind.

5.2. Recommendations for Further Work and Policy Consideration

Recommendations for multifunctional 'scape approaches, with a focus on large intact wilderness areas, for consideration from this paper include:

- **Protect intact ecosystems first, restore degraded systems secondarily—**The UN Decade of Restoration has focused attention on restoration, which is a necessary and increasing priority in many areas globally. However, the protection of intact ecosystems offers greater social, biological, and ecosystem values and cost effectiveness. Intact ecosystems, which are of high value in terms of biodiversity, global ecosystem connectivity, and climate change mitigation and/or adaptation, may be given highest protection priority. Based on the tropical peatland review findings, the authors believe that tropical peatlands fit into this category and should be prioritized—their spatial extent may be small, but their local and global impact is large. Whilst protection would be prioritized in regions and systems where large intact areas remain, in cases where mosaic and heavily degraded tropical peatland 'scapes exist, a combination of protection, social interactions, and restoration would be recommended. Hence, a multifunctional 'scape management priority system for intact and degraded systems could be:
    - ○ Protect intact ecosystems that are currently not under pressure, and support associated indigenous and other communities, policies, and financial frameworks to manage future anthropogenic (and climate) pressures and boundary areas adjacent to those intact systems;
    - ○ Manage intact ecosystems that are currently under pressure, and prioritize pressure reduction in and around boundary areas of those ecosystems;
    - ○ Reduce pressure on degraded peatland ecosystems and devise landscape-scale socio-ecological restoration programs.

All three approaches should have local communities (including indigenous groups and traditional landowners) at the center of local sustainable stewardship plans and connected to relevant financing support (see below). Additionally, protected and conservation areas should be enlarged in line with proposed international conservation goals.

- **Quantify benefits of intact ecosystems and costs of degraded systems to inform better management**—At a macro level, the holistic value of ecosystems and the services they provide is starting to be recognized. For example, the global contribution from nature is estimated at USD 44 trillion [67]. However, to promote better management at local and government jurisdiction levels—on the ground—there is a need for local resolution of ecosystem value. Intact ecosystems have important local, regional, and global impacts just as degraded ecosystems have equally important negative local, regional, and global impacts. Current estimates rarely communicate beyond bespoke academic or international organization articles and likely do not reach local communities and local decision makers. In the case of tropical peatlands, for example, positive ecosystem service externalities include flood management, water purification, local livelihood support, and globally significant carbon sequestration, while the negative ecosystem service externalities include smoldering haze fires (and transboundary environmental pollution), local and regional acute and chronic health impacts, disrupted local and regional transport, lost school and work time, and GHG emissions. It is past time that we quantify both these positive and negative externalities at local, regional, and even global levels to understand and communicate the costs and benefits of both sound and poor management. Finally, given the ongoing debate around the valuation of nature, further exploration of linkages between valuation and intactness could be explored. Could a "degree of intactness" measure be proposed to reframe valuation of healthy and functioning ecosystems? Could we think beyond traditional approaches of fitting nature within economic models and instead fit our economic models within measures of nature? For example, could a "degree of intactness", based on ecosystem function and other scientific measures, be associated with downstream economic values, without putting an economic price on the ecosystem itself? In this context, management would aim at reaching the highest level of "intactness". As a further step, could degree of intactness and results-based framing be linked to financing (e.g., well-managed intact wilderness spaces, close to their ultimate ecosystem function, receive enhanced financing support relative to less well-managed intact or mosaic systems)?
- **Support framework development for nature-based finance and mobilization of climate finance to improve multifunctional 'scape management and resourcing, particularly for large intact ecosystems**—The Dasgupta Review [9] estimates that only 20% of protected areas are currently being well managed. Furthermore, the review estimates that to protect 30% of the world's land and ocean and manage them effectively by 2030 would require an average investment of USD 140 billion annually [9]. Particularly, where ecosystems are high carbon (e.g., tropical peatlands), nature-based climate financing may be increasingly suitable to finance both protection (sequestering carbon) and restoration (reducing emissions).
- **Integrate ecosystem-specific evidence bases and recognize the criticality of intact wilderness boundary zones to promote sustainable management as part of multifunctional 'scape approaches**—Across all ecosystem types, the interfaces between large intact wilderness areas and mosaic or heavily modified anthromes are critical management transition zones. For example, tropical peatlands are unique ecosystems where above-ground and below-ground interactions must be explicitly understood for successful integrated management [29]. Critical to such integrated management and long-term thinking, boundary management issues are critical for maintaining intact tropical peatland systems that include management of fire risk and peat column water levels. In essence, beyond managing inside intact spaces, effective boundary

management between spaces (intact, mosaic, heavily modified) will be critical for the long-term sustainability of sensitive intact systems such as tropical peatlands.

- **Knowledge exchange on sustainably managing intact wilderness areas, building on and integrating local and indigenous knowledge bases**—Given the higher likelihood of indigenous and traditional landowners in and around large intact ecosystems, it stands to reason that their knowledge and engagement in devising management and financing frameworks will be critical. There is an integral role for such communities to be empowered in local sustainable management models and for financing (either nature-based, climate-based, or others) to be channeled to support such communities.
- **Aligning nature-positive and climate-positive goals and better integrating nature into green COVID-19 recovery packages and updated national climate action plans (NDCs)**—The UN climate and biodiversity conferences (COP27 and COP15, respectively) will go some way to better integrating climate-positive and nature-positive actions. There may be opportunity for progress on nature to benefit from the systems experiences in target setting, governance, implementation, and finance from the climate sector. Further, greater linkages of nature-based actions into the climate sector could also help to accelerate and scale up nature-positive actions more generally. A recent report [96], which analyzed over 3500 fiscal policies announced by leading economies in 2020, revealed that of the world's 50 largest economies' fiscal spending in the wake of COVID-19, just 2.5% were directed towards green initiatives. This is despite jobs from natural capital investments often having relatively low skills requirements and with the opportunity to support the poor and marginalized. The year of 2023 also marks the call for updated NDCs from countries globally, another opportunity to integrate nature-based measures and intact ecosystem protection. Multifunctional 'scape approaches could help raise the profile of specific critical intact ecosystems, such as tropical peatlands, for enhanced conservation, management, and financing. While it could be argued that tropical peatlands are of equivalent importance as tropical forests—for example, Indonesia's peatlands hold as much carbon as all the living biomass of the Amazon rainforest [48]—tropical peatlands do not receive commensurate scientific, management, or public focus. Scholars [20] believe that the role of peatlands is underappreciated in global climate change mitigation, biodiversity hotspots, ecosystem service provision, and human health and economic wellbeing strategies. Multifunctional 'scape approaches, by identifying intact tropical peatland systems ecosystems as part of broader large intact wilderness spaces, along with the coming together of climate- and nature-based approaches, could help raise the profile of these critical systems. We talk about tropical rainforests, but why not tropical peatlands as well? More specifically, efforts for research, knowledge exchange, management, and financing support should be targeted to sustainably conserve those intact tropical peatland systems (and support indigenous and local communities) in countries with the largest known deposits and in locations where pressures are largely absent or just emerging (including, but not limited to, regions in western Africa, northern regions in South America, and southeast Asia).

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