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Off-stage ecosystem service burdens: A blind spot for global sustainability

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Abstract

The connected nature of social-ecological systems has never been more apparent than in today's globalized world. The ecosystem service framework and associated ecosystem assessments aim to better inform the science–policy response to sustainability challenges. Such assessments, however, often overlook distant, diffuse and delayed impacts that are critical for global sustainability. Ecosystem-services science must better recognise the off-stage impacts on biodiversity and ecosystem services of place-based ecosystem management, which we term 'ecosystem service burdens'. These are particularly important since they are often negative, and have a potentially significant effect on ecosystem management decisions. Ecosystem-services research can better recognise these off-stage burdens through integration with other analytical approaches, such as life cycle analysis and risk-based approaches that better account for the uncertainties involved. We argue that off-stage ecosystem service burdens should be incorporated in ecosystem assessments such as those led by the Intergovernmental Platform on Biodiversity and Ecosystem Services and the Intergovernmental Panel on Climate Change. Taking better account of these off-stage burdens is essential to achieve a more comprehensive understanding of cross-scale interactions, a pre-requisite for any sustainability transition.

1. Introduction

The increasing human footprint on Earth and subsequent decline of Earth's life-support systems continues unabated with unpredictable impacts on present and future generations [1–3]. The connectivity of social-ecological systems is shaping these impacts in multiple ways, including the growing metabolism of cities [4, 5], increased long-distance flows of resources, people (e.g. refugees and migrants) and information [6], increased reliance on final and embedded imports and exports of natural resources (e.g. water, fiber, fisheries, minerals, fossil fuels) [2, 7, 8], growing carbon emission transfers [9], and the dispersal of animal and plant infectious diseases via the introduction of non-native species through trade [10, 11]. Earth is a large, coupled human and natural system consisting of many smaller coupled social-ecological systems linked in complex ways through flows of information, matter and energy [12–14].

These unprecedented spatial interdependencies link the management of ecosystems and the wellbeing of people in distant places [15, 16]. Neglecting the cross-scale effects of production and consumption patterns will have undesired and unexpected consequences for ecosystems and societies, now and in the future, and will jeopardise achieving the Sustainable Development Goals (SDGs). Disregarding cross-scale effects in ecosystem governance also affects local and regional sustainability. For instance, greenhouse gas emission abatement programs incentivising biofuel imports in one region can indirectly impact biodiversity, ecosystem structure and the wellbeing of people where biofuel crops are grown [17]. In seascapes, marine conservation in one region may increase the dependence on seafood imports from fishing grounds and aquaculture in regions that are weakly regulated, undermining their biological sustainability and the livelihoods of fishing communities [18].

Aspects of such cross-scale or off-site effects are increasingly acknowledged through the concept of 'leakage'—in which interventions to reduce environmental pressures at one site may be locally successful, but also displace and increase these pressures elsewhere—in research fields such as land-system science [19], sustainability modelling [20], sustainability governance [15, 21], and industrial ecology [2]. Many decisions are sensitive to leakage, ranging from climate change mitigation efforts for Reducing Emissions from Deforestation and Forest Degradation (REDD+) [22], the design of coastal management plans, protected area creation, design of Payment for Ecosystem Services schemes [23], and the impacts of renewable energy regulations on biofuel demand [24]. However, leakage is generally defined in terms of a single resource stock (e.g. carbon, forest land, fisheries), and often as a side issue (i.e. a leak to be plugged). Although some environmental leakage is receiving increased attention in general terms, quantitative analysis is rarely incorporated into ecosystem-assessments where cross-scale impacts of place-based decisions on biodiversity and ecosystem services are still barely considered [25, 26]. Further, acknowledging environmental leakage problems itself does not necessarily imply any accounting for such impacts [22, 24].

Here we suggest that place-based ecosystem management creates off-site and out-of-scope issues that transcend what is referred to as leakage in most environmental policy discourse. These are (i) systemic and affect multiple ecosystem properties beyond the realm of any single resource or sector (e.g. carbon, fishery); (ii) more difficult to identify as they can alter the flows and trade-offs among multiple ecosystem services in the non-intervening ecosystem; (iii) more uncertain due to diffuse and cumulative cross-scale impacts in the context of ecosystem threshold effects or tipping points, (iv) potentially irreversible through effects on biodiversity; (v) able to affect people's quality of life, directly and indirectly, through complex pathways; and (vi) difficult to measure using existing approaches and methods. We consider the ubiquitous and critical nature of 'off-stage' ecosystem service impacts, and strategies for how they can be not only acknowledged, but be brought into and quantified within mainstream ecosystem service frameworks.

More than a decade after the publication of the Millennium Ecosystem Assessment [1], the ecosystem services approach continues to attract scientific and policy interest [27, 28]. Many related policy initiatives are emerging, including the Aichi targets of the Convention on Biological Diversity, the Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services (IPBES) [29], a growing number of sub-global ecosystem assessments, and the rapid spread of new policy instruments for conservation such as Payments for Ecosystem Services programs, including REDD+ [30]. Yet, the ecosystem service framework cannot address profound sustainability challenges if it unintentionally supports decisions that yield unsustainable negative impacts elsewhere. In other words, if ecosystem-services science aims to help understand the effects of ecosystem management on human wellbeing more broadly and transform sustainability governance, it must not overlook the realities of the widespread cross-scale impacts resulting from social-ecological teleconnections [31–33]. Recognition of leakage has yet to be more systematically addressed in assessments and policy processes such as those underway in the IPBES and the Intergovernmental Panel on Climate Change (IPCC). Furthermore, leakage as currently conceptualised misses broader and more profound cross-scale impacts. We term these impacts of ecosystem management on biodiversity and ecosystem services, *off-stage ecosystem service burdens*; these may include leakage, but also refer to broader and more profound systemic burdens. We frame the need of a new approach to deal with such off-stage burdens in the context of global sustainability (not exceeding environmental limits) as well as considering distributional outcomes in terms of the groups of people that become winners and losers from the provision of ecosystem services and associated burdens.

The objective of the paper is to highlight and address a key blind spot in ecosystem-services science and ecosystem assessments, namely the need to recognize, identify and measure off-stage ecosystem service burdens that systematically arise from ecosystem management. We first locate the gap within the rapidly evolving research agenda on ecosystem services. Then we focus on the important role of ecosystem assessments and provide key examples to illustrate the extent to which they overlook significant off-stage burdens. Then we suggest alternative but complementary ways by which off stage ecosystem service burdens can be identified, and quantified in ongoing and future assessments, for example those carried out by the IPBES and the IPCC.

2. Minding the gap between ecosystem-services science and global sustainability

Advances in ecosystem-services science have yielded key insights about links between biodiversity, ecological functions and ecosystem services [34]. Social-ecological analyses of economic, cultural and governance factors [35, 36] have improved the design of cost-effective and equitable policy instruments to support the protection of ecosystems and biodiversity [37], and there has been a thrust in the development of new accounting systems such as WAVES, the Wealth Accounting and the Valuation of Ecosystem Services initiative [38] and new business reporting approaches [39]. But despite such developments, three kinds of problems limit the scope of ecosystem-services science to contribute to the transformative advancement of global sustainability. First, ecosystem management for ecosystem services has direct place-based impacts. There is an unbalanced attention to the *final benefits from* ecosystems [1] with less attention to negative *impacts on* the species and ecosystem functions underpinning those benefits [40]. The typical ecosystem-services approach is to delineate a study area, identify key ecosystem services arising, and assess how management scenarios are likely to affect those services in policy relevant units [41]. Negative impacts of the optimisation of a narrow set of ecosystem services are often not accounted for, unless they have a measurable effect on other ecosystem services within the scope of the study (in the form of *trade-offs*, e.g. [42]. Even in such cases, the distribution of impacts across social groups is seldom accounted for [43, 44].

Second, the impacts of place-based ecosystem management are frequently diffuse, delayed or indirect. As a result they are complex and hard to predict as ecosystem changes often arise from the cumulative impacts of many interacting biophysical processes or stressors [45]. Negative impacts from ecosystem management on non-targeted ecosystem services, either locally or distantly, are also of a subtle and diffuse nature due to the way they are co-produced by people along with other kinds of anthropogenic assets [46, 47]. For example fossil fuels are used when a provisioning service such as food is delivered in high-input intensive human-dominated systems such as agriculture. The agricultural system often impacts other ecosystem services, for example disrupting local nutrient cycles in ways that may not be felt for decades (e.g. [48]). Such impacts tend to be overlooked in ecosystem assessments. Similarly, in coastal areas, although poor water quality has often been attributed to contemporary runoff of nitrogen and phosphorus, the predisposition to a eutrophic state can often also be traced to historic overfishing, e.g. of abundant filter-feeding oysters [49]. Despite such cases of multi-causality, ecosystem-services science still largely focuses on a limited set of factors assumed to have non-interacting linear effects, although some effort is being put to incorporate some of this complexity through identifying thresholds, regime-shifts and non-linear impacts (e.g. [50, 51]).

Third, there has been too little attention to wider cross-scale or cross-location impacts. In particular, ecosystem assessments are mostly targeted at the jurisdictional scale (e.g. [41]), rarely focussing on interconnections *across* jurisdictions [25, 52]. As a result, ecosystem assessments tend to disregard those ecosystem service burdens that transcend local or national boundaries, and which affect people's wellbeing outside the assessments' spatial or temporal scope. There is therefore a risk that multiple uncoordinated local initiatives for ecosystem service management will lead to larger scale impacts on ecosystems elsewhere. These effects are likely to be both unrecorded and unmanaged. In this paper we explore this third problem, inextricably related to the previous ones, by assessing the nature of off-stage ecosystem service burdens and calling for them to be explicitly addressed in ecosystem assessments.

Table 1 compares our proposed term of 'off-stage ecosystem service burdens' with other terms from the sustainability science literature to clarify the distinction and the need to address off-stage burdens over and above more established phenomena. The terms are not mutually exclusive but tend to be applied differently given that they pertain to different disciplines such as environmental sciences, engineering and economics.

3. Place-based ecosystem assessments overlook off-stage ecosystem service burdens

Most ecosystem assessments have a limited scope since they tend to overlook the broad and systematic off-stage (distant, diffuse and delayed) ecosystem service burdens (figure 1).

Off-stage ecosystem service burdens occur in various forms. Here we illustrate four typical pathways based on biodiversity conservation policies, and the management of provisioning, regulating and cultural services. First, place-based ecosystem management, including biodiversity conservation policies, often

Table 1. Terms relating to environmental burdens due to ecosystem management and policy interventions.

Term	Description	General scope	Methodological approach
Ecological footprint	A measure of the area of land used through consumption and waste by a country or region over a year [53].	Biophysical	Footprint accounting
Ecological rucksack	The amount of materials used during the life cycle of a given product. It includes unseen or hidden upstream flows when obtaining natural resources [54].	Biophysical	Material flow analysis (MFA), Life cycle analysis (LCA)
Environmental externality	Situation where one actor's utility or production function includes variables whose values are chosen by others, and these others do not compensate or receive payments relative to the shifted values [56].	Biophysical, Economic	Environmental valuation
Environmental leakage	A displaced or shifted environmental impact from one area 'leaked' into other areas as a result of environmental policies. It is often used in climate policy to reflect the displacement of greenhouse gas emissions due to the intervention implemented within an area into other areas [22].	Biophysical	LCA, Environmental impact assessment (EIA)
Environmental offset	Environmentally beneficial activities undertaken off-site to counterbalance damaging impacts from resource extraction or development [55].	Biophysical	EIA
Off-stage ecosystem service burden	All the spill-over ecosystem services impacts (and associated effects on people) of ecosystem management within a place, over time and space. They include distant, diffuse and delayed impacts.	Biophysical and socio-economic	Ecosystem assessments, Ecological LCA, MFA, risk based EIA

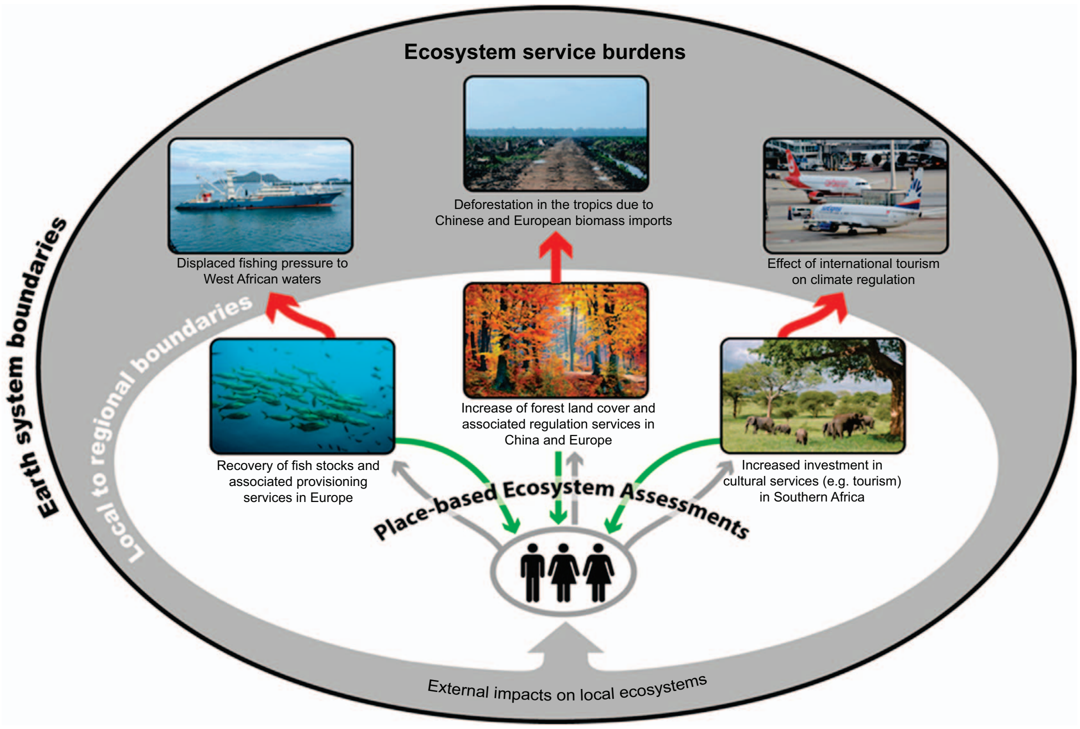

Figure 1. Current ecosystem-services assessments focus on the benefits, trade-offs and synergies provided by ecosystem services within a delimited (often jurisdictional) boundary (green arrows) and the impacts that human activities have over such ecosystem services therein (grey arrows). Ecosystem assessments tend to overlook off-stage ecosystem service burdens (red arrows) of place-based ecosystem management decisions, as they often occur in distant places (see supplementary material available at stacks.iop.org/ERL/12/075001/mmedia for more detail on the examples presented here and others) as well as their feedbacks (e.g. due to climate change) on local ecosystem (bottom arrow re-entering the smaller white ellipse). All images in figure 1 are catalogued as CC0 Public Domain (Creative Commons), extracted from Pixabay (photographers: Alexas, Dpatdfci, NickJack and Valiunic) and Wikipedia (photographers: Clipper and Hayden).

leads to ecosystem service burdens elsewhere that tend to be invisible to local stakeholder groups. For example, European policies for biodiversity conservation require the establishment of protected areas, such as the Natura 2000 network, which potentially displaces agricultural production to landscapes outside of Europe, from which commodities (e.g. food, feed, fibre and biofuel) are increasingly imported. It is well known that displaced agricultural expansion to places such as tropical forest frontiers has direct impacts on biodiversity and reduces forest carbon sequestration, with local consequences as well as wider implications, for example for global climate regulation [57]. Similarly, actions to establish marine protected areas at one site creates negative spill-over effects on other marine sites [18]. For instance, the protection of coral reefs in Australia might be increasing fish imports into the country, adding pressure on fisheries elsewhere [58]. However, most ecosystem assessments, have focused on the effectiveness of local biodiversity management, without acknowledging cross-scale impacts of management policies (e.g. [59]). Likewise, fishing restrictions in Europe have displaced pressure to West African waters adding to provisioning service burdens there which are often unaccounted in Europe-led ecosystem assessments (figure 1). These types of negative off-stage impacts associated with displaced production and/or extraction are part of the 'burden' of biodiversity conservation policies in many countries [60].

Second, off-stage burdens can arise from the management of provisioning services. Many examples related to agricultural production exist and are mentioned throughout the paper and in the online supplementary information. For instance, certain livestock management policies have favoured intensive practices whereby grazing or browsing animals are increasingly kept indoors with artificial food and light. In turn, this implies ecosystem services burdens hidden in the form of virtual water associated with the imports of feed such as maize, sunflower seed and soya beans [61].

Third, off-stage ecosystem service burdens arise typically from the management of regulating services such as those related to climate and water flows. There is literature on carbon leakage problems through commodity trade [62] and via land based carbon management through e.g. REDD+ [22]. There are also impacts of demand for renewable energy such as biofuels in developed countries promoting the expansion of oil palm plantations in Southeast Asia and Latin America with high impacts on tropical forests biodiversity and ecosystem services and the wellbeing of local communities [63, 64]. Similarly, there are off-stage water regulating service burdens through agricultural commodity trade [8, 32, 65]. For example, Canada is a major net exporter of virtual water worldwide [66], and exports of agricultural commodities from Canada have implications for other forest-based ecosystem services such as flood control, water filtering and carbon storage in the country [67]. Likewise, within the USA, domestic policies regarding intersectoral access to water and rural-urban water allocation do not account for the impacts of demand for virtual water through agricultural commodity production, in turn associated with the overexploitation of aquifer systems in key ecological areas such as the High Plains, Mississippi Embayment, and Central Valley [68]. Surprisingly though, ecosystem assessments hardly account for the fact that land use policies displace impacts of the exploitation of water-related ecosystem services elsewhere [13].

Fourth, ecosystem management for the supply of cultural services generates off-stage ecosystem service burdens. For example, in coastal regions of Kenya, economic valuation of cultural services including wildlife tourism dwarf local biodiversity use-values [69], a fact often used to support arguments for the conservation of their biodiversity rich ecosystems. However, such ecosystem service values fail to recognise that tourism is coupled with diffuse negative impacts on ecosystem services in other regions through air-travel emissions and climate change, as well as direct impacts of tourism infrastructure on local ecosystems and the flows of locally co-produced food, water or other provisioning services [70]. Tourism in the Antarctic provides another example, where travel agencies promote ecotourism as an ambassador for conservation, without acknowledging or compensating for the emission and consumption 'burden' of tourist visits, particularly their contributions to the climate change that threatens the same fragile Antarctic ecosystems tourists want to enjoy [71].

Since the Millennium Ecosystem Assessment [1] was launched, there have been sustained efforts to assess changes in biodiversity and ecosystem services in different parts of the world, including through an increased number of sub-global assessments (SGA) [72]. However, generally, such assessments have overlooked the breadth of off-stage ecosystem service burdens (e.g. [41]) (see supplementary information material for examples). For instance, increased demand for forest conservation and wood products in European countries—such as in the case of boreal forests in Finland—have placed increasing pressure and had negative ecological impacts on neighbouring forests in Russia, which in turn impact migratory species in boreal forests in Finland [73]. While the SGA study from Finland does calculate the value of forest recreation infrastructures through national parks [74], the cost of the ecosystem service burdens on Russian forest ecosystems are not acknowledged. Similarly, Japan's land management and economic activities create pressure on ecosystems in other regions of the world through imported virtual water [32] and embodied land [75]. However, the often praised Japanese Satoyama–Satoumi SGA [76] does not identify burdens on distant ecosystems. At the subnational scale, including the municipal level, studies such as the SGA of the Basque Country [77], focus on characterising landscapes supplying multifunctional ecosystem services but ignore the ecosystem service burdens associated with the dependence on natural resource imports from distant places which ultimately help achieve conservation goals regarding local multi-functional landscapes [64]. If the impacts of natural resource imports were accounted for in the Basque SGA it is likely that the resulting domestic ecosystem management would yield different results as the ones currently depicted.

4. Addressing off-stage ecosystem service burdens

For global sustainability to be achieved, ecosystem assessments and associated policy tools need to account for and measure impacts on ecosystems and people across sites and scales. The present lack of attention to off-stage burdens is partly because of the methodological difficulties and information costs involved in systematically addressing them and due to the absence of effective institutions that enforce liability for such burdens, but partly also because they have not been recognized as important components in ecosystem assessment frameworks (e.g. [1, 29]). We identify four approaches for science and decision-makers to better integrate understanding of system interconnectivity towards assessing off-stage ecosystem service burdens:

(i) Use proxies for off-stage (distant, diffuse and delayed) spill-over impacts including 'virtual water', or 'CO_2 equivalent emissions'. Databases and tools on international trade, e.g. the United Nations FAOSTAT (http://faostat3.fao.org), Comtrade databases (http://comtrade.un.org), and the Observatory of Economic Complexity (http://atlas.media.mit.edu), among others, could be used to estimate these, although only approximately, as it is impossible to accurately quantify all off-stage impacts. However, beginning to acknowledge the materiality of such impacts would expose the extent of ecosystem service burdens and could stimulate more precise measurement systems. Further, the unpredictable nature of ecosystem service burdens requires the adoption of a precautionary approach. When ecosystem-services science cannot attribute impacts with certainty to individual drivers of change, it could characterize the risk of cumulative impacts posed by each [45].

(ii) Develop ecological based LCA [78, 79] methods that incorporate diffuse ecosystem service impacts. LCA, standardized through ISO protocols, involves comprehensive assessment across entire commodity chains of the factors that contribute to stress or change in ecosystems ('mid-point impacts', e.g. global warming potential). It considers diverse impacts, including distant ones, of activities such as extraction of raw natural resources, waste disposal or recycling, manufacture and distribution, but without characterizing the final consequences for ecosystems and associated services [80]. Pairing the current ecosystem assessments with ecological LCA could involve mapping out and characterizing the extent and magnitude of the risks of impacts posed by place-based management of ecosystems across different regions. Assigning risks to distant ecosystems would differ from existing efforts to account for the ecosystem services *that contribute to* industrial production of final goods and services (e.g. [81]). An ecosystem services-centered LCA approach, could characterize consequences of the management of, for example, a marine protected area, considering how biological productivity there may contribute to goods and services, such as scuba diving eco-tourism (cultural ecosystem services), but also other factors including potential mid-point pollution impacts on marine life elsewhere, e.g. through eutrophication potential as an ecosystem service burden, where management standards are lower. This would possibly also require building on data and tools from other approaches that track resource flows across geographical scales [14, 33], for example approaches that deal with global material flow analysis [2, 32]. Eventually though, complementary innovative approaches need to be developed that go beyond existing tools, to address impacts whose significance remains uncertain, for example those arising from the introduction of non-native species or pathogen as well as the unintended disruption of unrecognized and fragile ecosystems.

(iii) When a country or region exports natural resources and thus suffers domestically from an ecosystem service burden, such country could develop an ecosystem-centred accounting approach *within* its national jurisdiction. 'Inclusive wealth' accounting procedures are being developed [82] and refined by the World Bank WAVES project (www.wavespartnership.org) [38]. There are also efforts underway to include condition metrics for ecosystems via the UN System of Environmental–Economic Accounting (unstats.un.org/unsd/envaccounting/seea.asp). However, we lack precautionary, risk-adjusted, inclusive wealth accounts that could account for domestic off-stage burdens, and new natural science metrics are needed to evaluate the condition of ecosystems for multiple services and to focus on those most at risk [83]. This approach would focus on the state of 'source ecosystems', and monitor their condition over time, seeking to detect the point at which further ecosystem service exports might place future supplies at risk, i.e. to track their proximity to tipping points or other kinds of deleterious thresholds across multiple ecosystem services. For example, instead of different countries independently recording the imports of palm oil or timber from tropical forests and adding totals up, assessments would add biophysical risk factors regarding the likelihood of impacts in terms of ecosystem flows from extracting stocks of palm oil or hardwood trees in the source ecosystems (including carbon-sequestration or water regulation). Such risk-adjusted inclusive wealth accounts should ideally link to cross-national accounts. Importing nations (of raw materials and ecosystem services) would account for the impact of their import decisions on off-site natural capital assets and associated ecosystem services most at risk.

(iv) Harmonize methodological aspects from other well-established research fields concerned with environmental impacts and risk analysis and facilitate information about the potential internalisation of ecosystem service burdens across time and space into policy. This would require bridging other sustainability research fields to complement current ecosystem assessments, for instance reaching out to fields that focus on environmental impact analysis [84], including area-based land footprint accounting, and hybrid physical and monetary environmentally extended (multi-regional) input-output analysis [65]. Recent advances in integrated assessments models [85] could also contribute to this task by identifying resource flows and ecosystem services trade-offs across distant places.

5. Conclusions

In a telecoupled planet, accounting for systematic off-stage (distant, diffuse and delayed) ecosystem service burdens is essential for transitioning towards global sustainability and for living within critical biophysical boundaries [51]. Ecosystem-services science and ecosystem assessments in particular, fall short from recognizing and quantifying ubiquitous off-stage impacts of placed-based ecosystem management actions and decisions that generally have impacts outside the jurisdictional or biophysical scale of ecosystem assessments. Such impacts may affect ecosystem properties so as to bring distant ecosystems closer to biophysical thresholds, or may directly reduce the wellbeing of people in distant areas now and in the future, who may be invisible to decision-makers at the local or jurisdictional scale. The recognition and quantification of currently hidden ecosystem service burdens is a first step in addressing this gap.

Off-stage ecosystem service burdens may well be an inconvenient truth, but neglecting them does not help to avoid their impacts. We argue for a transition towards an ecosystem-services science that explicitly seeks to uncover off-stage ecosystem service burdens. Meaningfully accounting for such burdens would have far-reaching policy implications. For example, REDD+ initiatives in developing countries already reflect the ambition to make forest conservation governance global rather than place-based, in initial recognition of the risk of carbon leakage. Similarly, there is a need for robust accounting of non-carbon related ecosystem-service burdens and their impacts on people, to meaningfully connect REDD+ to global sustainability. At present, existing carbon offsetting strategies are only linked to greenhouse gas emissions at source in industrialised countries with an incipient call for accounting for multiple global ecosystem and social impacts. Other polices that hinge on the potential use of ecosystem service frameworks, such as on biofuel subsidies, the Common Agricultural Policy in Europe, or international fishery agreements ought to be revised to account for off-stage ecosystem services impacts. This would be supported by greater public awareness and accountability (e.g. the oil palm industry with respect to downstream products, or pension investment funds) and due to higher-scale governance regimes (e.g. of fisheries, climate, or forests) that include management dimensions at national/regional/global scales and so explicitly seek to account for different forms of off-stage burdens.

Beyond sectoral environmental leakage, off-stage burdens are still largely underestimated in terms of diversity and significance in ecosystem-services science, so there is a need for assessments (and academic work ahead of such assessments) to work out how to handle this methodologically. In addition, mainstreaming the importance of off-stage ecosystem service burdens requires a greater awareness among consumers, governments and industry. For example, although some companies are improving global environmental management through standard corporate reporting [39] and voluntary pledges to promote 'zero deforestation' in the production of oil palm (e.g. [86]), many producers are also shifting to consumer markets with fewer sustainability requirements (e.g. Indonesia, China, India) and continuing business-as-usual practices [87]. Perhaps the moral principle of responsibility for such burdens could develop into increased legal responsibility via environmental regulations and court cases for damages elsewhere [88]. In such a context, global sustainability requires moving towards transnational environmental governance regimes, and this cannot be achieved under an ecosystem services lens that disregards off-stage ecosystem service burdens.

In the knowledge-policy interface there is a good opportunity for recognizing and embracing the tools and implications of tackling off-stage ecosystem service burdens. One such opportunity is with the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) to acknowledge social-ecological telecouplings across all scales, within their assessments. This would enhance the potential to inform opportunities for the sustainable ecosystem use and sustained wellbeing of people across the planet and identify the methodological challenges of assessing off-stage ecosystem service burdens. Similarly, implementing the Aichi targets of the Convention of Biological Diversity, should account for the unintended burdens that may be posed by nationally determined conservation policies if they disregard off-stage impacts.

The ecosystem services approach holds promise to communicate societal dependence on ecological life-support systems and to move towards a more sustainable future. However, its current application—without due account for the diversity and magnitude of off-stage burdens—fails to render visible the connections between changing lifestyles, expanding extraction frontiers associated with increased metabolic rates of natural resources, and off-stage impacts on ecosystem services, including the impacts on well-being of people in distant locations or future times. Unless connected in a systematic and meaningful way to the underlying social-ecological causes and effects of ecosystem service burdens, ecosystem-services science risks only scratching the surface of today's most pressing global sustainability challenges. It is thus imperative to recognize off-stage burdens, and that they are often borne by people who tend to be ignored by current and dominant ways of thinking about ecosystem services frameworks and approaches. To ignore the full breadth of off-stage ecosystem services burdens undermines the value of the ecosystem services framing as a lens for focusing efforts towards global sustainability.

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