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REDD+ in the context of ecosystem management

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The design and implementation of REDD+ projects requires understanding the local ecological, economic and social context. This paper analyzes how REDD+ influences the context of ecosystem management, from both a conceptual and an ecosystem-scale perspective. We analyze how REDD+ changes the economic interests in ecosystem management for different stakeholders, and present a case study demonstrating the economic benefits of sustainable forest use versus oil palm plantation in Indonesia. We also analyze the economic costs of carbon emissions from land use conversion, and show that in Kalimantan, Indonesia, net revenues from REDD+ need to be US$ 3/ton CO_2 to allow sustainable forest use to compete with oil palm on peat, and US$ 7/ton CO_2 for mineral soil. Subsequently we present four insights from our ecosystem analysis relevant for REDD+.

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Introduction

The Reducing Emissions from Deforestation and forest Degradation (REDD) mechanism was initiated in 2007 by the parties to the United Nations Framework Convention on Climate Change (UNFCCC). The basic aim of the REDD+ mechanism was to financially compensate developing countries for safeguarding the carbon sequestration and storage service provided by tropical forests [1,2]. Concern about forest management and other issues led to the formulation of a REDD+ policy that integrates the enhancement of forest carbon stocks, sustainable management of forests and conservation [3,4•]. So far there is no official agreement on a REDD+ policy under the UNFCCC. However, the concept is generally seen as having a large potential to enhance forest management, and an increasing number of pilot projects has been developed over the past few years [2,5]. Many of these projects are still donor-funded, but in both 2010 and 2011 around US$ 90 million of carbon credits from several REDD+ projects were sold on the (over-the-counter) voluntary carbon market [6].

In spite of the increasing attention devoted to developing the outlines of a global REDD+ policy, and the large number of pilot projects currently being set up, several key aspects of the REDD+ policy have not yet been fully resolved. These include developing baseline scenarios against which the enhanced storage of carbon can be measured, designing credible and efficient monitoring, reporting and verification (MRV) procedures, and developing local benefit sharing and forest management strategies [7•,8,9]. REDD+ projects generally take place on land that also has a range of other claims and potential uses that may not be compatible with carbon storage: on these lands deforestation and loss of carbon stocks is a particularly relevant baseline scenario. Therefore it is critical to understand the present and potential land uses and dynamics of ecosystems considered for REDD+ [10,11]. With an ecosystem services approach, the complex ecosystem dynamics, spatial and temporal scales, ecosystem services, stakeholders and values of ecosystem services can be analyzed (e.g. [12–14]).

The objective of this article is to analyze the implications of local ecosystem conditions for the local implementation of REDD+. In particular, we examine first how REDD+ changes the incentives of ecosystem managers and how this change may affect the supply of ecosystem services including both private and public ecosystem services. In this part of our analysis we follow a conceptual, micro-economic approach to analyze costs and benefits of land use change in the presence of REDD+. Second, we examine how REDD+ influences the costs and benefits of land use conversion at the local scale considering multiple ecosystem services provided by ecosystems. We illustrate this second part of our analysis with an example related to land use change in Indonesia. Based on our conceptual and our ecosystem scale analysis, we present a number of recommendations for the local implementation of REDD+.

REDD+ and ecosystem management: a conceptual perspective

Ecosystem services have been defined as 'the contributions from ecosystems to human welfare' and include both the economic goods and services provided by ecosystems to society [12,15,16]. Generally, ecosystem services are divided into provisioning services (materials that can be extracted from ecosystems), regulating services (processes regulated by ecosystems); and (iii) cultural services (non-material benefits supplied by ecosystems). Many ecosystems provide a bundle of different provisioning, regulating and cultural services [17,18]. Provisioning services are typically private goods whereas many regulating and cultural services have a public goods character, that is, are non-rivalrous and non-excludable [19•]. The price mechanism for the provision of public goods does not function well: consumers do not have an incentive to pay and producers do generally not have an incentive to supply [20]. Consequently, public intervention is needed to maintain or create an efficient allocation of such goods [21,22].

REDD+ aims to generate a payment mechanism for an ecosystem service previously only providing a non-market benefit, that is, carbon storage and carbon sequestration. The two aspects of storage and sequestration are not synonymous, storage represents a stock and sequestration a flux of carbon between ecosystems and the atmosphere. Some forest ecosystems store a large quantity of carbon (on a per hectare basis) but sequestration rates are relatively low (e.g. [23]). Other ecosystems, such as wooded savannas, may have a relatively low above ground stocks of carbon but their rates of carbon uptake from the atmosphere may be considerable. Carbon sequestration may also be relatively high in degraded and secondary forests that are recovering. REDD+ payments are conditional, restricting the use of some of the other ecosystem services that can be provided but which cause carbon emissions, for instance those involving intensive logging or land conversion.

In this paper, we analyze REDD+ and ecosystem management from a welfare economic perspective, focusing on the economic costs and benefits resulting from different ecosystem management options. However, clearly, ecosystems are not generally managed on the basis of economic arguments alone. This is particularly relevant for the case of REDD+, where local forest users, including indigenous communities, may have a complex and broad set of objectives, interests and constraints in forest management [24,25]. Hence, REDD+ payments provide one incentive in the complex decision making framework of stakeholders. Stakeholders in ecosystem management are often present at different scales. They include national, state or provincial and local governments, and national and local actors owning or having access rights to the ecosystem involved (e.g. [27]). Often, there is a range of stakeholders with different interests and rights using local ecosystem services, and the fair distribution of REDD+ payments over the various stakeholders is far from straightforward (e.g. [11]).

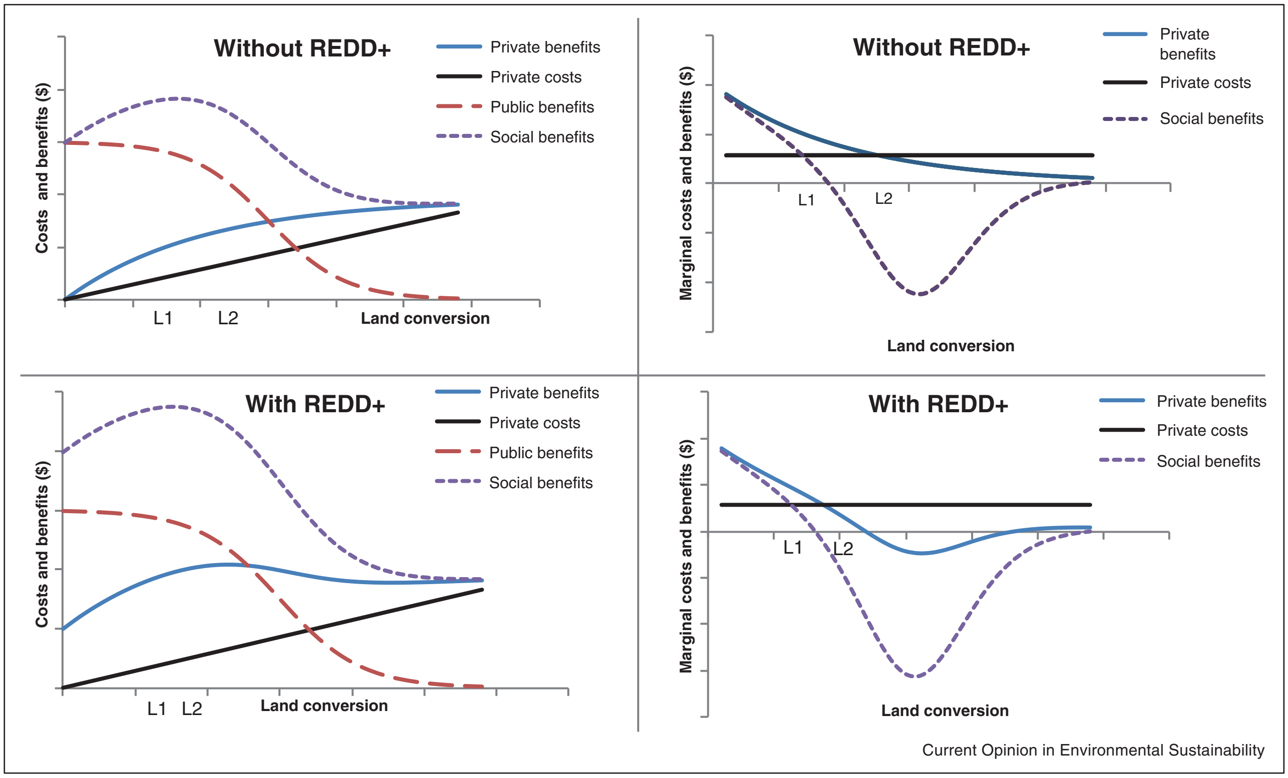
Maintaining the capacity of ecosystems to store and sequester carbon depends on the state and integrity of the ecosystem. Changes in adjacent parts of the same ecosystem or in neighboring ecosystems can affect the state and integrity of an ecosystem and subsequently its capacity to store or sequester above-ground, below-ground and/or soil carbon. For example, forest clearing and draining part of a peat dome (e.g. because of plantation development) leads to lower water tables and hence carbon emissions from peat oxidation in both the drained area and in adjacent parts of the peat dome. In addition, ecosystems may change in an unexpected and rapid way once thresholds in the ecosystem are exceeded [28,29]. For instance, shading may be reduced in degraded forests, which may therefore be more prone to forest fire, further reducing shading and subsequently increasing the chance of forest fires.

Figure 1 illustrates the application of REDD+ in the context of ecosystem management. The figure considers the supply of multiple ecosystem services and assumes non-linear ecosystem dynamics. For the purpose of the figure, public benefits are defined as the benefits from the ecosystem that accrue to communities at large including both public goods (carbon sequestration, biodiversity conservation, soil-erosion control, recreation, etc.) and common pool private goods (timber and non-timber forest products (NTFP) harvested by local villages in a jointly owned or managed ecosystem). The private benefits are those benefits that accrue to a private land owner involved in land conversion, for example, a plantation company. The sum of the public and private benefits is labeled 'social benefits'.

For reasons of simplicity, fixed costs ($/ha) are assumed for land conversion, for instance from forest to agricultural land. Public benefits decrease in a non-linear manner with decreasing forest cover, reflecting a threshold in the ecosystem [29]. At a threshold, ecosystem functions are critically impaired, leading to for instance major changes in species composition or hydrology and in turn affecting the supply of ecosystem services [14]. Private benefits from land conversion are marginally decreasing. This reflects potential price effects resulting from oversupply of the product in the market, or that increasingly unfavorable land is taken in production.

The left hand side of Figure 1 shows the total costs and benefits, and the right hand side the marginal costs and benefits of land conversion. At point L1, the difference between the social benefits and costs of land conversion is at its maximum (left hand side) and the marginal social benefits equal the marginal social costs (right hand side). This point represents the *social* optimum amount of land conversion. At point L2 the difference between the private benefits and costs is the largest (left hand side) and marginal private benefits equal marginal private costs

Figure 1



Private and public benefits of land conversion, without (above) and with (below) REDD+. 'Social benefits' are interpreted as the sum of the private and public benefits. On the left hand side total costs and benefits of land conversion, on the right hand side the marginal costs and benefits. L1 indicates the social optimum amount of land conversion, L2 the private optimum (see text above). REDD+ payments for carbon sequestration change the private benefits of forest conservation and shift L2 to the left, indicating that it is efficient to conserve more forest.

(right hand side). This point indicates the optimum for the *private* land owner.

The implementation of a REDD+ payment scheme causes the private land owner to be rewarded for some of the public benefits generated on the land, in particular for carbon sequestration. This means that point L2 shifts closer to L1. Importantly, payments received for carbon do not necessarily cover other public benefits (i.e. positive externalities resulting from the supply of other ecosystem services) that may be generated by forest land, such as the regulation of water flows or biodiversity conservation. Therefore, L2 is not likely to coincide with point L1.

Although there is often a relation between safeguarding the carbon storage service and maintaining the supply of other ecosystem services, these do not necessarily coincide (as discussed in more detail in section 'The road to REDD+: insights from an ecosystem services approach'). Hence, also with REDD+ payments, not all public benefits of ecosystems are accounted and paid for, and therefore REDD+ cannot in itself be expected to lead to efficient and inclusive ecosystem management.

REDD+ and ecosystem management: an ecosystem perspective

In this section we present a review of REDD+ in the context of local ecosystem management. We focus our review on Indonesia, which is one of the countries of particular relevance to REDD+ given its high deforestation rate and the interest of the Indonesian government in the application of REDD+ (e.g. [30•]). We illustrate our review with an example showing typical benefits from ecosystem services under two competing land uses, oil palm plantation and forest. Recent estimates of deforestation rates in Indonesia differ from around 1% to around 2% per year (e.g. [31•,32]). The main drivers for deforestation in Indonesia are logging and plantation establishment, in particular for palm oil [33•,34]. Much of the deforestation takes place on peatlands, which suffer from a deforestation rate almost twice the national average [31•]. Peatland degradation leads to substantial CO_2 emissions owing to fires and oxidation of peat following drainage. The Government of Indonesia is well aware of the issues at stake, and has established a national regulatory framework for REDD+ activities [35]. The Indonesian Ministry of Forestry (MoF) launched regulations

Table 1

Net Present Value (US$/ha) from different ecosystem services in five land use types, for a 20-year discounting period and a discount rate of 15%. Indicative figures for Kalimantan

Land use	Secondary lowland forest on mineral soil	Secondary forest on peat soil	Palm oil on forest land on mineral soils	Palm oil on forest land on peat soils	Palm oil on degraded, mineral land
NTFP	600[a]	600[a]	–	–	–
Sustainable timber harvest	250[b]	250[b]	–	–	–
Palm oil	–	–	5210[c]	4350[c]	5560[c]
CO_2 emission (−)/sequestration (+)			−3790[d]	7060[e]	870[f]
Other regulating services[g]	40 to ~ 6000	40 to ~6000	–	–	–
Total	890 to ~ 7000	890 to ~ 7000	1420	−2710	6430

The price of Fresh Fruit Bunches (FFB) is based on Amzul [55], who also provides further detail on the market mechanisms for FFB in Indonesia. All monetary figures have been transferred to US$ 2010 based on an annual inflation of 3%, and all figures are rounded.
[a] Assuming net revenues of US$ 65/ha/year [40].
[b] Assuming net revenues of US$ 27/ha/year [40].
[c] Based on [38].
[d] Assuming that clearcut for plantation establishment leads to a one-off CO_2 emission of 931 ton CO_2/ha and that an oil palm plantation leads to the gradual capture of 336 ton CO_2/ha (based on [38]).
[e] As previous but with the continuous release of 90 ton CO_2/ha/year owing to peat oxidation [37].
[f] As previous but without peat oxidation and without the release of carbon owing to deforestation.
[g] No data specific for Kalimantan were available, the presented range is from [16].

for REDD+ and for commercial use of carbon sequestration in production and protected forests [36]. A key instrument for REDD+ projects in Indonesia is the Ecosystem Restoration Concession (ERC) in which the concession holder is obliged to perform restoration activities; he can subsequently generate revenue from carbon sequestration or other environmental services.

There are currently 40 (proposed) REDD+ projects throughout Indonesia, most of which are located in Kalimantan and Sumatra [37]. The size of REDD+ project areas is highly variable, ranging from 7000 ha to 3.2 mln ha. The three largest projects are Kutai Barat in the Heart of Borneo (3.2 mln ha), Berau Climate Action Project (2.2 mln ha) and the Leuser Ecosystem REDD+ Project in Aceh (2.3 mln ha) [37]. Most of these projects started only recently (<5 years), and it is still difficult to evaluate specific outcomes of these projects. Besides issues generally faced by REDD+ projects like leakage and high transaction costs, a specific issue for Indonesia is related to the ERC concessions; Indonesia only has a regulatory framework for ERC in production forest and not for protection forest [37].

A situation often faced by REDD+ projects in Indonesia and elsewhere is that forest conservation needs to compete with alternative land uses such as oil palm plantations, which can be highly profitable. We examine five land use types (i) lowland secondary forest on mineral soil; (ii) lowland secondary forest on peatland; (iii) palm oil plantation developed on mineral soil; (iv) palm oil plantation developed on peatland; and (v) palm oil plantation developed on degraded grasslands. Degraded grasslands in Indonesia are typically covered by *Imperata cylindrica* (alang alang grass). We include four types of services: (i) timber from sustainable harvesting; (ii) harvesting of NTFP; (iii) carbon sequestration; and in the case of oil palm plantations: (iv) production of palm oil. These four services are expressed in a monetary indicator. In particular, we express the economic benefits of NTFP, wood and palm oil (Fresh Fruit Bunches) production in terms of net revenue generated per hectare (ha). We also calculate the per hectare costs of CO_2 emissions in case of land conversion and following the drainage of paetland. Drainage is required for oil palm cultivation on this type of soil. Our data represent typical figures for lowland forests in Kalimantan, and are based on a review of different studies, as presented below.

The establishment costs and productivity (max 27 ton fresh fruit per ha per year) of high-productive oil palm plantations are based on [38]. The farm-gate prices of Fresh Fruit Bunches (FFB) of oil palm differ, for instance as a function of the quality of the fruit, and are also variable over time. The price of FFB has been assumed to be US$ 150/metric ton, based on typical prices for 2010 (see Table 1). The main NTFP in Kalimantan is rattan, which can comprise up to 75% of the total revenue from NTFP harvests in forests [39]. Valkenburg [40] finds average annual net revenues from NTFP harvesting of US$ 65/ha/year and net revenues from sustainable forestry in average quality secondary forest of US$ 27/ha/year, assuming a 35 years rotation cycle. A price of US$ 5/ton CO_2 is assumed for the economic costs of carbon emission. This is a conservative figure, when compared with values found in the climate change economics literature. For instance, in a review of 28 studies Tol [41] finds a median value of US$ 14/ton CO_2 for the marginal damage costs of emitted CO_2 and an average value of US$ 93/ton CO_2. The assumed price is also conservative compared to the price that can be obtained in the voluntary carbon market, which averaged US$6.0 per ton CO_2 in 2010 and US$ 6.2 in 2011, and to the price for avoided CO_2 emissions obtained in REDD+ projects which was US$ 12/ton CO_2 in 2011 [6]. Carbon impacts of palm oil development are calculated assuming a removal of all above-ground biomass in year 0, and a gradual sequestering of carbon in oil palm biomass over a 7 years period. In the case of oil palm development in peatland, there is a continuous release of carbon owing to peat oxidation, assumed to be 90 ton CO_2/ha/year [42] based on a drainage depth of one meter typical for oil palm. The discount rate applied in the illustration is 15% indicating the approximate costs of capital in Indonesia [43]. The results are shown in Table 1.

Note that the specific costs and benefits of land use change differ strongly as per the local environmental and social context, and Table 1 only presents indicative figures for one specific area, that is, Kalimantan. The main factors driving the outcomes of the cash-flow analysis are the price of Fresh Fruit Bunches, the price of carbon, and the discount rate. A low discount rate makes investment in oil palm plantation establishment, where full yields are reached only after 7 years, more profitable, but it also increases the present costs of future CO_2 emissions. A high discount rate has opposite effects and reduces the Net Present Value (NPV) of both plantation establishment and benefits from ecosystem services. See, for example, [16] for more information on the implications of discounting in the context of ecosystem management.

The costs of land acquisition have not been included in the analysis; these costs constitute a transfer of funds between stakeholders and the aim of the table is to show the net societal benefits of ecosystem services resulting from different types of land use. Land acquisition costs vary widely in Indonesia and they are, of course, very real for plantation companies and a major factor that drives their investment behavior. The figures presented in Table 1 do therefore not reflect the profits of oil palm production for the producer, for which consideration of land acquisition costs is required.

Table 1 shows that optimal land use, from a societal perspective, involves converting degraded grasslands currently covered with *I. cylindrica* grass into oil palm plantation. This option involves minimal loss of ecosystem services while allowing oil palm cultivation and even a modest amount of carbon sequestration. A recent review found that in all Indonesian provinces except Riau sufficient degraded land on mineral soil is available to allow swapping existing as yet unutilized licenses away from peat forest and peat land to land with mineral soils [37]. However, in practice, a substantial constraint is that most land on mineral soils is both more expensive than land on peat soils, and that ownership of mineral land is dispersed increasing the costs of obtaining land of sufficient size for large-scale plantation establishment. Hence, even though from a social planning perspective the conversion of peat land to oil palm is the least attractive option, this is exactly what is happening in much of Indonesia.

Table 1 shows costs and benefits of land use options in the absence of REDD+. REDD+ would not lead to costs for the emitters of CO_2 resulting from land degradation and peat oxidation. However it would reward land users and/or owners for the continued storage of carbon in the ecosystem. The specific payment to be received by the different stakeholders depends on the carbon price, the benefit sharing arrangement, the project development and transaction costs involved, and the baseline scenario quantifying the amount of carbon eligible for payment.

Using the cash flow analysis presented in Table 1, considering benefits from timber and NTFP in forests and assuming equal costs for land acquisition for REDD+ projects and oil palm establishment, the net revenue from carbon credits under REDD+ would have to be US$ 7/ton CO_2 to make carbon storage competitive with oil palm on mineral land. In other words, with a net revenue of US$ 7/ton CO_2, the NPV of plantation establishment equals the NPV of economic benefits from avoided CO_2 emissions, timber and NTFP, at a 15% discount rate. The actual price required in the carbon market, however, would need to be higher, in order to cover the project development and MRV costs. For peat land, the minimum net revenue from carbon storage would have to be US$ 3/ton CO_2 to make carbon storage competitive with oil palm, based on the assumptions presented above. For revenues below these, carbon storage would not be able to compete with a modern, high-yielding oil palm plantation. Required net revenues of US$ 3/ton CO_2 in the case of peatland and US$ 7/ton CO_2 in the case of mineral soil compare favorably to the average 2011 carbon price for REDD+ projects, which was US$ 12/ton CO_2 [6], provided that all foregone carbon emissions can be claimed under REDD+. However, as we mentioned before, the actual investment decisions guiding land use will not be based on economic grounds alone, with other factors such as access to land and policy makers critical in driving land use change.

The road to REDD+: insights from an ecosystem services approach

The previous two sections analyzed how REDD+ influences the economic incentives for ecosystem management, from a conceptual and from a local ecosystem management perspective. As mentioned earlier, we want to stress that ecosystem management is not driven by economic incentives alone, and that cultural and institutional factors may be equally or more important.

Nevertheless, analyzing the economic incentives for ecosystem management, and how they differ between stakeholders, offers a number insights relevant to the local implementation of REDD+. These insights apply to the local implementation aspect of REDD+ only, for a broader overview of recommendations for REDD+ we refer to, for instance, Chatterjee [5], Kanowski *et al.* [7•] and Busch *et al.* [30•].

REDD+ is an important instrument for promoting better land use – but it will by itself not lead to socially optimal land use. As illustrated in Figure 1, socially optimal forests management requires consideration of all economic benefits provided by forest ecosystem services, over a prolonged time period. Over the last years, the scope of REDD+ has increased, now covering multiple objectives including local livelihoods and sustainability. REDD+ was, however, not designed to lead to the safeguarding of all ecosystem services provided by forests and this expanding scope may already affect the effectiveness of REDD+ [44•]. Although REDD+ can have a positive effect on other ecosystem services, for instance regulating river flows or biodiversity conservation [45,46], REDD+ cannot be expected to lead to maintaining the supply of all other ecosystem services. Therefore, additional policies, including perhaps other payment mechanisms such as markets for biodiversity are required to ensure that forest conversion is checked at the level where also critical ecosystem services other than carbon sequestration are preserved. In many cases, payments for carbon storage alone may be insufficient to compete with alternative land uses, such as oil palm on mineral soils in Kalimantan, see Table 1. Nevertheless, the aggregated economic benefits from all ecosystem services provided by the forest may be competitive, for instance when also river flow regulation, the production of NTFP and biodiversity conservation are considered. Under current REDD+ design, payments for specific services cannot easily be 'stacked' [8,47]. Allowing payments for multiple ecosystem services for the same plot of land brings additional challenges, such as more complex design and higher transaction costs and potentially free riding [48,49]. It needs to be further examined if and under what conditions there is the potential to stack payments for different ecosystem services [50••].

REDD+ can only function in the context of an adequate institutional framework regulating local land and ecosystem management. Our analyses confirm that REDD+ is an important element in the promotion of more sustainable and more economic efficient forest use. Translating public benefits from carbon storage and capture into an actual payment for land owners and users provides an economic incentive for local ecosystem managers to maintain the globally important carbon storage and sequestration service. In practice, however, regulatory and institutional factors may prevent REDD+ from operating in an effective manner (e.g. [51,52]). For instance, a lack of transparency in registering plantation forestry and REDD+ concessions, and at times conflicting interests at different levels of government, are hampering the implementation of REDD+ in Indonesia. In addition, a large number of new concessions for forest conversion (including concessions on peatlands) have been given to industry in Indonesia in recent years. It is unclear if and how these lands can be used for REDD+, and what price should be paid for these concessions. Leakage is a related problem; REDD+ projects may increase the pressure on other remaining forests. Proper registration of land titles, monitoring of land use changes, and enforcement of land use plans is therefore required to shape an institutional environment in which REDD+ can effectively be applied.

Implementing REDD+ requires more explicit consideration of local ecosystem services and stakeholder interests. A significant worry among many local ecosystem users including indigenous people is that REDD+ projects could restrict the access or use options of forests that they have traditionally been using [53]. In many cases, people living in or close to a forest benefit from a whole range of ecosystem services that are fully or mostly compatible with the conservation of carbon stocks, including provisioning (e.g. NTFP), regulating (e.g. erosion control) and cultural services. There is therefore a need to better understand and especially communicate to local people how REDD+ projects may or may not influence local uses of the ecosystem. This needs to be combined with the further development of benefit sharing mechanisms for REDD+ [23,36]. Local payments from REDD+ should (more than) compensate potential impacts of any restriction in local ecosystem use (e.g. [29,54]), however timing is an issue, with REDD+ payments being conditional on changes in forest use and local forest users not always having the possibility to forego benefits from forest use before payments from REDD+ are received.

Implementing REDD+ and planning land use at the local scale requires consideration of complex ecosystem dynamics. Ecosystem change is a function of multiple drivers and is often complex, including non-linear and/or irreversible responses to stress [27]. As depicted in Figure 1, such changes can involve a threshold leading to rapid changes in the mix of services supplied by an ecosystem. These thresholds are prominent in, for instance, the dynamics of peat lands, where forest degradation can lead to more rapid degradation owing to positive feedback processes. Irreversible damage may occur where soil subsidence owing to drainage alters hydrological patterns and leads to enhanced flood risks. This is of particular concern where peat drainage for agricultural activities has taken place in riverine or coastal floodplains. By itself, REDD+ is not able to deal with these dynamics. For instance, if only part of a peat dome is preserved through a REDD+ project the establishment of an oil palm plantation adjacent on the same peat dome will lead to lower groundwater tables, forest degradation and CO_2 emissions. Land use planning, with consideration of medium and long-term ecosystem dynamics, is therefore critical to the successful implementation of REDD+.

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