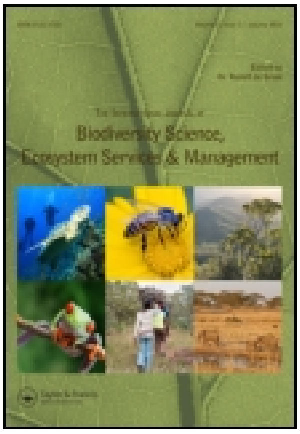

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Market mechanisms for financing the reduction of emissions from deforestation and degradation in developing countries (REDD) - learning from payments for ecosystem services schemes

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Market mechanisms for financing the reduction of emissions from deforestation and degradation in developing countries (REDD) – learning from payments for ecosystem services schemes

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At its 16th session in Cancun, the Conference of Parties of the United Nations Framework Convention on Climate Change decided on a framework for implementing the reduction of deforestation and degradation (REDD). This global compensation mechanism for the ecosystem services, such as carbon storage and sequestration by forests in the developing countries, however, left critical details untouched regarding future REDD negotiations. Among others, the question of how to design a proper financing mechanism for the final phase of REDD implementation remains. This article reviews theoretical approaches on payments for ecosystem service schemes and provides recommendations for future negotiations on funding REDD mechanisms. Of special interest is the classification of forest ecosystem services according to physical and economic characteristics, rivalry and excludability, scale and directional flow. These characteristics help to determine which kind of funding mechanism should be set up at the global scale. Carbon storage and carbon sequestration are classified as common-pool services, which are most efficiently provided through a market mechanism. However, market mechanisms for small sets of forest ecosystem services can lead to trade-offs, having negative effects on the provision of particularly biodiversity-dependent services. Potential trade-offs are identified and a strongly regulated market mechanism bundling global scale ecosystem services is recommended.

Keywords: policy tools; forest ecosystem service classification; public goods; open access; carbon sequestration and storage; trade-offs

Introduction

Human societies depend on the direct and indirect benefits they receive and obtain from ecosystems, defined as ecosystem services (Costanza et al. 1997; Daily 1997; MA 2005). The world's forests, for example, provide a variety of different ecosystem services at global, regional and local level (Table 1). How ecosystems are being used and managed influences their condition and their capacity to deliver ecosystem services. Management decisions are very often driven by economic reasoning (Debreu 1959) and market valuation of ecosystem services (Daly and Farley 2010). However, environmental economics tells us that due to the public goods character of many ecosystem services, the appearance of externalities, imperfect property rights and insufficient knowledge and information, markets often fail to efficiently allocate natural resources (Pigou 1932; Ostrom and Ostrom 1999; Glück 2000; Tietenberg 2006; Gómez-Baggethun et al. 2010; Wayburn and Chiono 2010). This holds true for forest ecosystems. Because not all the costs and benefits associated with the provision of forest ecosystem services – especially of regulating and habitat services – are reflected in market prices, individuals make short-term profits by cutting standing forests, selling timber and converting forests to agricultural land. The conversion of forests into agricultural lands leads to a loss of other ecosystem services, such as carbon sequestration and storage, and thus imposes on society's long-term negative side-effects (Kapp 1963; Eliasch 2008). The current market structure 'systematically favours conversion over conservation' (Kemkes et al. 2010: 2070).

As a way of correcting this market failure, a variety of policy tools have been developed: command and control regulation, penalties, economic instruments (property rights, payments) and public information (Libecap 2009; Loft 2009; Kemkes et al. 2010). Incentive-based economic instruments, such as payments for ecosystem service (PES) schemes, have become an increasingly popular policy instrument for securing a sustainable provision of ecosystem services at the local and national level (Muñoz-Piña et al. 2008; Pagiola 2008; Börner et al. 2010; Clements et al. 2010; Fisher, et al. 2010; Gong et al. 2010). One example for an international PES scheme currently being designed is the United Nations Framework Convention on Climate Change (UNFCCC) mechanism for reducing emissions from deforestation and degradation in developing countries (REDD) (Angelsen and Wertz-Kanounnikoff 2008; Gómez-Baggethun and Ruiz-Perez 2011).[1] The basic idea of REDD is to reduce greenhouse gas (GHG) emissions from deforestation and degradation and to increase carbon sequestration of forests in the developing countries[2] with the help of compensation by the developed countries (Loft 2009; Harvey and Dickson 2010; Pistorius et al. 2010). At its 16th session of the

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Table 1. Forest ecosystem services.

Services	Ecological processes and/or components providing the service (or influencing its availability) = functions	Examples
Provisioning		
Food	Presence of edible plants and animals	From harvesting forest wildlife or gathering plant-products
Water	Presence of water reservoirs	Forest lake
Fibre & fuel & other raw materials	Presence of species or abiotic components with potential use for timber, fuel or raw material	Timber, fibre and fuelwood, biofuels
Genetic materials	Presence of species with (potentially) useful genetic material	Genes and genetic information used for animal and plant breeding and biotechnology
Biochemical products and medicinal resources	Presence of species or abiotic components with potentially useful chemicals and/or medicinal use	Biocides, food-additives, and drugs, models, tools, essay org.
Ornamental species and/or resources	Presence of species or abiotic resources with ornamental use	Wildlife used in e.g. fashion, handicraft, jewellery, worship, souvenirs
Regulating		
Air quality regulation	Capacity of ecosystems to capture aerosols & chemicals from the atmosphere	Capturing dust particles, NO_x fixation
Climate regulation	Influence of ecosystems on local and global climate through land-cover and biologically mediated processes	Carbon sequestration and storage
Natural hazard mitigation	Role of forests in dampening extreme events (e.g. protection against flood damage)	Reduction of storm and flood damage
Water regulation	Role of forests in water infiltration and gradual release of water	Buffering of extremes in run-off and river discharge
Waste treatment	Role of biota and abiotic processes in removal or breakdown of organic matter, xenic nutrients and compounds	Filtering of rainwater and run-off water
Erosion protection	Role of vegetation and biota in soil retention	Soil retention and prevention of landslides/siltation
Soil formation and regeneration	Role of natural processes in soil formation and regeneration	Decomposing litter & biomass
Pollination	Abundance and effectiveness of pollinators	Habitat for pollinators of crops and wild plants
Biological regulation	Control of pest populations through trophic relations	Reduction/prevention of crop, livestock and/or human diseases by providing a barrier or habitat for control vectors
Habitat[a]		
Life-cycle maintenance, esp. nursery habitat	Importance of ecosystems to provide breeding, feeding or resting habitat for transient species	Provide reproduction habitat for species with commercial value that spend their adult life elsewhere
Gene-pool protection	Maintenance of a given ecological balance and evolutionary processes	Provide habitat for resident plants and animals and migratory species and thus contribute to biodiversity and evolutionary processes
Cultural & Amenity		
Aesthetic information	Aesthetic quality of the landscape, based on, for example, structural diversity, 'greenness', tranquillity	Non-recreational enjoyment of scenery
Opportunities for recreation and tourism	Landscape features, attractive wildlife	Hiking, collecting mushrooms, bird watching
Inspiration for culture, art and design	Landscape features or species with inspirational value to human arts, etc.	Books, paintings of forest landscapes
Cultural heritage and identity	Culturally important landscape features or species	Many people value a 'sense of place' which is often associated with forests
Spiritual & religious inspiration	Landscape features or species with spiritual & religious value	Many individuals and religions attach spiritual values to forests
Cognitive information/education & science	Features with special educational and scientific value/interest	Formal & informal education in nature; ecosystems incl. forests influence the type of knowledge systems developed by different cultures

Notes: The main difference to the MA (2005) is that supporting (of habitat) services are limited to the nursery and gene-pool function and that biodiversity is not recognised as a separate service.
[a]Habitat services are also termed supporting services.
Source: Adapted from de Groot et al. (2010), de Groot and van der Meer (2010) and Kumar (2010).

Conference of Parties (COP) in Cancun in December 2010, the UNFCCC decided upon a general framework for REDD (Parker 2010). It is an outline for a stepwise implementation of the mechanism, which defines the cornerstones, but leaves critical details to be decided upon in future negotiations (Cuypers et al. 2011). Amongst others, a very controversial aspect of the REDD negotiations was left unanswered: the question of how to design a proper financing mechanism for the final phase of REDD implementation.

Farley and Costanza (2010), Farley et al. (2010), Kemkes et al. (2010) and Fisher et al. (2009) recently discussed the importance of the economic and spatial characteristics of ecosystem services for developing economic instruments for the sustainable provision of these ecosystem services. In this article, I will first assess the economic characteristics, such as rivalry and excludability of the ecosystem services, that are targeted by the REDD mechanism, that is, carbon sequestration and storage. I will then focus on the spatial distribution of these services, in order to derive insights for designing a proper financing mechanism for the final phase of REDD implementation.

The combination of 'rivalry' and 'excludability' determines whether property rights, which are prerequisites for marketability, can be assigned to a certain ecosystem good or service (Ostrom 1999; McKean 2000; Tietenberg 2006; Engel et al. 2008; Daly and Farley 2010). 'Rivalry' or 'substractability' is defined as the property of a good whereby one person's use diminishes other people's use (Samuelson 1954; Ostrom and Ostrom 1999; Daly and Farley 2010; Mankiw 2011), that is, when the benefits derived from an ecosystem service are depleted by additional users (Pearce 1976; Biller 2003; Wayburn and Chiono 2010). Rivalry is an inherent, physical characteristic of a good or service (Romer 1991; Ostrom et al. 1999; McKean 2000; Mantau et al. 2001; Daly and Farley 2010). 'Excludability' is the property of a good whereby a person can be prevented from using it, that is, the ability to control the use of a good or resource (Biller 2003; Wayburn and Chiono 2010; Mankiw 2011). Excludability not only depends on the physical property inherent to the good, but is also an economic and legal concept (Mantau et al. 2001; Bouriaud and Schmithüsen 2005) 'that when enforced allows an owner to prevent others from using it' (Daly and Farley 2010: 73). For the design of economic instruments, it is also important to identify the spatial distribution of providers and beneficiaries of an ecosystem service (Brosio 1986 cited by Mantau et al. 2001; Pfaff et al. 2007; Fisher et al. 2009). This information is indispensable when planning management interventions and deciding upon governing institutions at a local and regional level (Mantau et al. 2001; Chan et al. 2006; Naidoo and Ricketts 2006; Fisher et al. 2009).

Influencing land use and management decisions by incentivising the provision of a small number of ecosystem services of a certain ecosystem – such as carbon storage and sequestration in the case of REDD – will have effects on its system properties, processes and components (Böttcher and Lindner 2010; de Groot et al. 2010). Forest ecosystems, for example, provide a variety of ecosystem goods and services (Table 1). Some of these services are produced jointly because one good inadvertently results in the production of another, for example, biomass and carbon sequestration (Glück 2000; Mantau et al. 2001; Urquhart 2006). Therefore, trade-offs have to be taken into account when designing a funding mechanism in order to prevent perversely incentivising the degradation of other highly important ecosystem services. This will require an understanding of the underlying ecological processes that lead to the provision of these goods and services. Indicators are needed that allow a quantification of the effects of different management options on the provision of non-carbon ecosystem services across different spatial scales (de Groot and van der Meer 2010).

This article develops as follows: A brief introduction to the REDD mechanism is given in Section 2, followed by an analysis of the economic characteristics and the spatial distribution of ecosystem services directly targeted by the REDD mechanism in Section 3. Potential trade-offs in the provision of forest ecosystem services that may occur due to incentivising the provision of carbon storage and sequestration will be identified in Section 4. Concluding remarks can be found in Section 5.

Reducing emissions from deforestation and degradation

As major carbon sinks and carbon pools, forest ecosystems constitute a significant part of the global carbon cycle.[3] Carbon sequestration and carbon storage, that is, the carbon absorption capacity of forests, are therefore considered highly important ecosystem services at a global scale (Costanza 2008; Haines-Young and Potschin 2010). However, deforestation and degradation not only take away these natural carbon sinks, but also release CO_2 through the combustion of biomass and decomposition of remaining plant material and soil carbon (Denman et al. 2007; van der Werf et al. 2009).

Measures to reduce CO_2 emissions by REDD took centre stage during international negotiations at the 11th session of the UNFCCC COP in 2005 (Angelsen and Atmadja 2008; Loft 2009). A general agreement was finally reached at COP 16 in Cancun in 2010, after 5 years worth of negotiations. The agreement outlines the content and phased process for an implementation of the mechanism and explicitly states which activities by the developing countries the mechanism entails (UNFCCC 2010). In revision of early proposals, which had restricted the activities to (a) reducing emissions from deforestation and (b) reducing emissions from forest degradation, further activities were added; (c) conservation of forest carbon stocks; (d) sustainable management of forest; and (e) enhancement of forest carbon stocks (UNFCCC 2010, para. 70). The acronym was changed from REDD (covering activities (a) and (b)) to REDD+ (where the plus stands for activities (c)–(e)). The inclusion of the activities (c)–(e) widens the scope of REDD. While originally only the protection of carbon stocks was encompassed, measures to enhance carbon sequestration are now an integral part of the mechanism. This increases the chances of trade-offs between the enhancement of carbon sequestration and carbon storage on the one hand, and habitat services, such as gene-pool protection, on the other (see Section 4). At the same time, the general agreement was reached that developed countries needed to support these activities by providing adequate and predictable financing and technology (UNFCCC 2010, para.76), and that 'safeguards' for the conservation of biodiversity, natural forests and their ecosystem services 'should be promoted and supported' (UNFCCC 2010, para. 69 and Annex I). However, the Cancun Agreement on REDD+ was held very broad: most of the crucial details of REDD+ remained undecided (for an overview of further negotiation needs, see Parker (2010) and Cuypers et al. (2011)).

The implementation of REDD+ is designed as a phased approach. In its first phase, the developing countries should develop not only national strategies but also policies and measures, as well as enhance capacity building. Financing for the first and second phases of REDD+ will be provided by the developed countries through 'bilateral and multilateral channels', that is, public funding (UNFCCC 2010, para. 76). The subsequent phase places focus on the implementation hereof. The ultimate goal is the transition into and completion of a result-based phase, where emission reductions and forest carbon stock enhancement can be fully measured, reported and verified (UNFCCC 2010, para. 73). Exactly how predictable and adequate financing will be provided when the implementation of REDD+ reaches its final phase, the result-based action, is subject to upcoming negotiations.

The financing need for REDD+ is substantial. The Eliasch Report (2008) estimates that the financing required to halve emissions from the forest sector by 2030 could be between US$17 and US$33 billion per year; Kindermann et al. (2008) modelled the costs for halving tropical deforestation by 2030 on estimations of US$17.2–28 billion per year. In comparison, Trines (2007) calculated the minimum annual costs of a 66% reduction in emissions resulting from deforestation and forestry between now and 2030 at US$25 billion a year. These financial resources are needed as a prerequisite for a global REDD+ mechanism for the development of institutions and governance structures that clarify land tenure and assure law enforcement. Investments are needed for capacity building, that is, the measurement and monitoring of reductions. Additional financing is necessary for on-going reductions in emissions, especially opportunity costs. These costs arise from foregone profits from deforestation or the costs of adopting more sustainable forest use.

Different options for generating and allocating sufficient funding have been discussed within the last years of negotiations, amongst them voluntary contributions, a sector-specific trading scheme and the integration of REDD credits into the international carbon market (Verchot and Petkova 2010). A highly debated question is whether it will be a pure market mechanism by which funds are allocated or whether there will be an international fund as allocation mechanism (Parker et al. 2009; Schmidt 2009; Loft 2010; O'Sullivan et al. 2010; Olander et al. 2011). Many academics and negotiators favour a market-based mechanism due to efficiency reasons and because it is considered most promising in delivering sufficient long-term funding. Those arguing for an international fund emphasise the potentially more equitable allocation of funding (for an overview see Brown et al. (2008), Parker et al. (2009) and Verchot and Petkova (2010)).

Economic and spatial characteristics of forest ecosystem services

In recent years, several classification schemes for ecosystem services characteristics have been developed for different purposes, such as valuation (de Groot 2006; Boyd and Banzhaf 2007), management (Wallace 2007; Costanza 2008; de Groot et al. 2010) or communication (de Groot et al. 2002; MA 2005). The typologies used depend on the purpose of the classification framework (Fisher and Turner 2008). In the context of this article, a classification is undertaken that includes those characteristics of ecosystem services which are crucial for determining an effective and efficient institutional arrangement for funding the provision of ecosystem services (especially carbon sequestration and storage).

A set of three characteristics has been identified for this purpose: The public–private goods aspect, that is, the combination of 'rivalry' and 'excludability' amongst others determines whether a market allocation of these goods will achieve a socially desirable level of provision (Randall 1983; Mantau 1994; Daly and Farley 2010). The scale at which institutions and laws are established should be influenced by the scale at which the services are provided (Engel et al. 2008; Kemkes et al. 2010). Additionally, the directional flow of ecosystem services adds information about the beneficiaries of the ecosystem services, which is relevant when designing legal approaches for excludability (Loft 2009; Farley and Costanza 2010). Hence, the spatial characteristics of ecosystem services are crucial aspects which need to be taken into account when considering institutional arrangements. Collectively, these characteristics can provide the necessary information on whether and in which form economic institutions are appropriate for the sustainable, just and efficient allocation of resources towards the provision of ecosystem services (Randall 1987; Farley and Costanza 2010).

Excludability and rivalry

The presence and combination of the characteristics 'excludability' and 'rivalry' tells us what type of economic good an ecosystem service is. Not all ecosystem services are completely rival and/or completely excludable.

Depending on their physical and economic characteristics, that is, the combination of rivalry and excludability, the ecosystem services provided by forests can be classified within a continuum between a pure private (or market) good which is rival and excludable, or a pure public good that is non-rival and non-excludable (see Table 2; Buchanan 1967; Bonus 1980; Ostrom and Ostrom 1999; Mantau et al. 2001; Fisher et al. 2009; Kemkes et al. 2010). Depending on this classification, we can determine whether market forces will be able to provide and/or efficiently allocate these goods and services (Daly and Farley 2010).

There is some confusion regarding the goods character of the two ecosystem services primarily targeted by the REDD+ mechanism, that is, carbon storage and carbon sequestration. Some authors consider carbon sequestration being 'possibly the clearest example of a public good' (Engel et al. 2008; Wayburn and Chiono 2010). Others argue that carbon sequestration is part of the waste absorption capacity of forests (Farley et al. 2010; Kemkes et al. 2010) and that 'we should not confuse rival waste absorption capacity for which rationing is desirable with the non-rival climate stability it generates which cannot be rationed' (Farley and Costanza 2010: 2065). To find out whether a proposed REDD+ market solution for the ecosystem services, carbon sequestration and storage, is feasible, it is thus necessary to determine the present degree of 'excludability' and 'rivalry' and to classify them accordingly among the continuum of public and private goods.

Excludability

'Excludability' is commonly defined as the ability to control the use of a good or resource (Buchanan 1967; Ostrom and Ostrom 1999; Biller 2003; Wayburn and Chiono 2010; Mankiw 2011). However, there is some debate over what constitutes the ability to control the use of a natural good or resource. McKean (2000) considers excludability as an inherent, physically given quality not susceptible to manipulation. She then differentiates between the 'goods' characteristic and the 'social institutions' humans have attached to them, that is, the property rights. Daly and Farley (2010), Kemkes et al. (2010), Mantau et al. (2001), Randall (1983) and Bouriaud and Schmithüsen (2005) stated that excludability is not a property of the resource per se. According to them it is a political and economic concept that requires the establishment of laws and institutions, and it may not be prohibitively costly to enforce these laws. No good or service is excludable in the absence of institutions that create and protect ownership, unless the possessor of that good has the physical ability to prevent others from using it. Hence, the excludability of an ecosystem service presupposes technology or institutions, including the definition of a property right and enforcement thereof, which make it possible to prevent others from using the goods or services. For tangible goods and services such as timber or non-timber forest products (NTFPs), it is fairly easy to create institutions that provide and enforce exclusive property rights. Slightly more complex institutions are required to create exclusive property rights to intangibles such as information contained in genetic resources (Daly and Farley 2010). Examples for excludable forest ecosystem services are the provisioning services fibre, fuel and other raw materials, in the form of timber and NTFPs. Once a tree is cut down or a fruit is collected, one can physically prevent others from using its timber. In order to do this, the person would need to have the (property) right for exclusion and an institution that enforces the property right. There are also ecosystem services that have physical characteristics that make it almost impossible to create an institution capable of giving exclusive ownership. If, for instance, a privately owned forest provides climate regulation, it is impossible to exclude neighbouring communities from benefiting from this service and no institutional framework will be able to establish excludability for it (Daly and Farley 2010; Kemkes et al. 2010).

The activities eligible under the current REDD+ framework concern the carbon already stored in forests and the enhancement of the sequestration capacity of these forests. It is physically possible to exclude others from the carbon already stored in the biomass. However, it is almost impossible to exclude a single interest group from another interest group's forest carbon sink. The reason for this is that it is physically impossible for a tree to capture the carbon emitted by one party but not capture the carbon emitted by other parties. Without an institutional arrangement, carbon sequestration and storage are non-excludable. The creation of an institutional arrangement could allow you to exclude others. Examples for an institutional set-up for exclusive rights for carbon sequestration are the mechanisms of the Kyoto Protocol concerning afforestation and reforestation. The Kyoto Protocol Clean Development Mechanism (CDM) created carbon credits (CERs) at the international level, while national laws define the scope of legal rights in terms of their origin, right of ownership, transfer and use, as well as their denominations (Olschewski et al. 2010; Peskett and Brodnig 2011). By establishing CERs and defining ownership of these, excludability is created. The institutional regime for carbon sequestration under the Kyoto Protocol and respective national legislations, however, do not cover standing forests. A market mechanism for REDD would presuppose a similar institutional framework on the international level, that is, the definition of carbon rights for carbon sequestration and storage of standing forests.

Rivalry

'Rivalry' means that the benefits derived from an ecosystem service are depleted by additional users (Musgrave RA and Musgrave PB 1973; Biller 2003). Rivalry is an inherent, physical property of a good or service (McKean 2000; Mantau et al. 2001; Farley and Costanza 2010). Most provisioning forest ecosystem services, like fibre, fuel and

Table 2. Classification of categories in the continuum between private and public goods & services, and recommended policy approach.

	Excludability			
	Full excludability		No excludability	
Rivalry	Classification	Policy approach	Classification	Policy approach
Rival & scarce	*Pure private or market ES* *Examples:* Timber, fuelwood and NTFPs (Biller 2003; Engel et al. 2008; Farley and Costanza 2010).	Property rights usually exist, if not they need to be defined. Market-based i.e. individual payments are recommended (Biller 2003; Engel et al. 2008).	*Common pool ES* *Examples:* Unregulated access and usage of large forest areas; carbon sequestration (Brander and Taylor 1997, Farley and Costanza 2010).	Definition of property rights, payments for use. Under certain circumstances, regulatory creation of demand necessary e.g. tradable pollution permits.
Rival & abundant (or congestible)	*Congestible club/toll ES* *Example:* Recreational service of a forest/park, which can be physically fenced (Farley and Costanza 2010).	Regulation of use through the definition of property rights and obligatory payments by benefiters for access or use and maintenance. (Biller 2003; Kemkes et al. 2010).	*Congestible public ES* *Example:* Provision of oxygen by forests. (Farley and Costanza 2010).	Secure provision through command and control regulation, finance through collective institution.
Non-rival	*Inefficient market ES* *Example:* Information contained in genetic resources of forest ecosystems.	Commodification and marketability is possible but not recommended, because it creates barriers for science and innovations. Instead secure provision through command and control regulation, finance through collective institution (Kemkes et al. 2010; Daly and Farley 2010).	*Pure public ES* *Example:* Climate regulation provided by forests.	Secure provision through command and control regulation, finance through collective institution.

Notes: ES, ecosystem services; NTFP, non-timber forest product.
Source: Adapted from Farley and Costanza (2010), Kemkes et al. (2010), Daly and Farley (2010) and Mantau et al. (2001).

other raw materials in the form of timber and NTFPs, are rival – if one person uses these products, there will be less timber and NTFPs for others. On the other hand, most regulating ecosystem services are purely non-rival. Examples for non-rival forest ecosystem services are storm protection and erosion protection (Haines-Young and Potschin 2009). Both services will be equally available to neighbouring communities.

In this article, I argue that carbon sequestration and storage in standing forests are rival ecosystem services. Given that forests as carbon sinks have become scarce in relation to existing emissions, they can only sequester a limited amount of carbon. However, this is not an entirely unchallenged view, as others argue that carbon sequestration is a non-rival good or service for which consumption by one person does not reduce the amount available to anyone else (Notman et al. 2006; Engel et al. 2008). A cause for the differing opinions on the economic characteristics of carbon sequestration and storage could be rooted in the understanding of rivalry. While most authors merely differentiate between rival and non-rival goods and services (e.g. Biller 2003; Costanza 2008), Buchanan (1967) described different levels of rivalry, and Randall (1983) introduced an additional criterion, 'congestibility', to further distinguish between rival and non-rival goods (see also Mantau et al. (2001) who introduced different levels of rivalry related to the degree of congestion). According to Randall (1983: 134), congestibility describes a good 'which is non-rival for some number of users, while rivalry sets in as that number increases and becomes intense as the number of users approaches the capacity constraint'. An example is the recreational service of a forest. The appreciation of the forest by one person would not be affected by another person walking around in it; yet if there were hundreds of people walking around in the forest, the quality of the recreational experience would diminish (Kemkes et al. 2010). In a very recent publication, Farley and Costanza (2010: 2065) argued that 'congestibility is a question of scarcity or abundance, not rivalry or non-rivalry'. A classic example for congestion helps illustrate this point: A road with only few cars leaves enough space for each car – there is no need to compete for space. Farley and Costanza (2010) argued that this is because the space is abundant. When the road becomes congested, the space becomes scarce. The atmosphere as a carbon sink is another example: It has always been rival (if one person emits a certain amount of carbon there is less for others to emit), but until the industrial revolution, it was abundant. By now, we have realised that there is only a limited sequestration capacity left before the concentration of carbon and other GHGs in the atmosphere will lead to a dangerous anthropogenic interference with the climate system. The previously rival and abundant sink capacity has thus become rival and scarce. Accordingly, there can be goods and services that are rival and scarce (e.g. timber), rival and abundant (e.g. a single person enjoying the recreational service of a forest) and non-rival (e.g. storm protection). As elements of the waste absorption capacity of a forest ecosystem, carbon sequestration and storage are rival and scarce services because the uptake and storage of CO_2 from one emitter reduces the forest's capacity to absorb and store CO_2 from another (Farley et al. 2010; Kemkes et al. 2010).

Classification and policy approach

In the absence of institutions that assign and enforce property rights for the ecosystem services, carbon sequestration and storage, these services can be classified as non-excludable but rival, that is, common-pool services, which are freely available as long as we do not have the appropriate institutions (Table 2). Thus, defining and enforcing property rights (group, individual or government property, see Ostrom et al. (1999)) for carbon sequestration and storage is a first step. However, users are usually unwilling to pay for freely available services. 'Cost minimizing users have little incentive to contribute their share to supplying a service when they can continue enjoying it free of cost (free-rider effect)' (Wayburn and Chiono 2010: 400). In those cases where it is physically impossible to exclude others from the use of the service, it becomes necessary not only to define and enforce property rights for the provisioned service, but to create demand through regulation, for example, by establishing a market for tradable pollution permits (Wayburn and Chiono 2010). In the absence of an international institution, no market demand exists for carbon storage and carbon sequestration of standing forests. Such a demand needs to be created by regulatory intervention as is being negotiated at the international level for REDD+. Market demand is created by setting a limit for the amount of carbon emissions (cap) for industrialised countries, and the definition of tradable emissions permits representing the right to emit a specific volume of carbon (Daly and Farley 2010). Market supply is created if additional permits are issued for the additional amount of carbon that is sequestered and stored by forests compared to a reference emissions scenario that is linked to historical deforestation rates of forest-rich developing countries (Farley et al. 2010; Kemkes et al. 2010; for a discussion of options for setting a reference scenario see Angelsen (2008)).

Spatial characteristics

Identifying the spatial characteristics of ecosystem services is essential for a number of reasons. From a legal perspective, international cooperation is necessary when a resource is transferred or a pollution spills over international borders (Bodansky 2010). For regulatory interventions or the design of economic instruments, it is important to identify the spatial distribution of providers and beneficiaries of an ecosystem service (Mantau et al. 2001; Pfaff et al. 2007; Fisher et al. 2009). This information is indispensable when planning management interventions and deciding upon governing institutions at a local and regional level (Chan et al. 2006; Naidoo and Ricketts 2006; Fisher et al. 2009). If we want to know what type of policy instrument is economically most efficient, the spatial characteristics are relevant for the identification of associated transaction costs (Kemkes et al. 2010). The subsequent question in the design of economic instruments, that is, whether the provider of an ecosystem service has to disburse the beneficiary in case one fails to continue providing the ecosystem service (polluter pays principle), or if the beneficiary has to pay for the provision of the ecosystem service (beneficiary pays) is a matter of equity (Loft 2009; Bodansky 2010).

In order to identify providers and beneficiaries of forest ecosystem services, the spatial distribution of ecosystem services should therefore be characterised by their scale and directional flow (Costanza 2008). The scale can be defined as 'the geographic extent to which benefits accrue' (Kemkes et al. 2010: 2072). Categories might include the following:

- local
- regional and national
- global

The directional flow can be described as 'the flow from the point of provision to the point of use' (Haines-Young and Potschin 2010: 115) or as the 'relationship between service production and where the benefits are realized' (Fisher et al. 2009: 650). Fisher et al. (2009) propose the following categories (Figure 1):

- ' "In situ": the services are provided and the benefits are realized in the same location', for example, NTFPs (Figure 1a).
- ' "Omni-directional": the services are provided in one location, but benefit the surrounding landscape without directional bias', for example, carbon sequestration by forests (Figure 1b).
- ' "Directional": the service provision benefits a specific location due to the flow direction', for example, storm protection, soil erosion prevention and water regulation (Figure 1c and d).

Forests sequester and store carbon locally. But the benefits of carbon sequestration and storage accrue globally because absorbing carbon from the atmosphere and storing it in another compartment benefits everyone around the globe. Other forest ecosystem services, like nursery habitat provision and gene-pool protection, are provided locally, but benefits also accrue regionally and globally. Likewise,

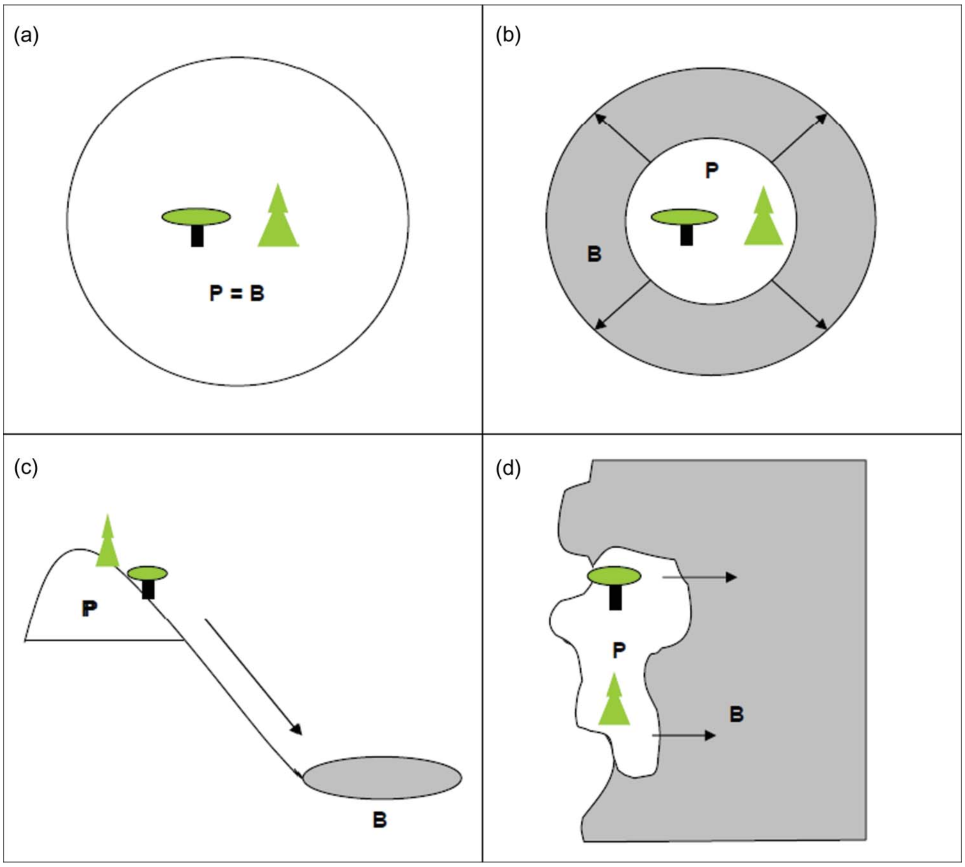

Figure 1. Directional flow of ecosystem services. (a) 'In situ' services are provided in the same location as the realised benefits; (b) 'Omni-directional' services are provided in one location, but benefit the surrounding landscape without directional bias; (c) 'Directional' services provide benefits at a downstream location; (d) 'Directional' services provide benefits at an inland location.
Notes: Directional flow from point of service provision (P) and area where benefits are realised (B).
Source: Adapted from Fisher et al. (2009).

water regulation services are provided locally but have a directional flow, whereas beneficiaries are downstream or regionally distributed (Fisher et al. 2009; Kemkes et al. 2010).

As concluded above, carbon sequestration and carbon storage are common-pool services that depend on regulatory intervention in order to create a market which can then function as an instrument for allocation. For carbon sequestration and carbon storage as global, omnidirectional forest ecosystem services, a regulatory definition of tradable emission permits and the creation of demand would need to be introduced in which a global beneficiary pays the local provider for the provision of the service (Olschewski et al. 2010). Since the benefits cross national borders, an international institution for the specification of the regulatory framework needs to be established. The spatial characteristics should be taken into account while deciding on how to share the burden of financing the provision of these services. Due to equity concerns, that is, the historical responsibility of industrialised countries for GHG emissions and the limited financial capacity of the developing countries to reduce emissions, it was decided during negotiations at the UNFCCC to follow a 'beneficiary pays' principle, that is, defining the industrialised countries as the buyers of the services (Loft 2009; Streck 2009).

Trade-offs in the provision of forest ecosystem services

Wunder (2005: 4), as a proponent of PES schemes, assumes a 'separable nature of different ecosystem services'. This statement may hold true from an economic perspective, as it is possible to classify each of the different goods and services provided by forests along the continuum of private and public goods. Management activities and policy instrument may also target specific forest ecosystem services. Some forest ecosystem services are, however, produced jointly because they depend on the same ecosystem functions, that is, one good inadvertently results in the production of another, such as biomass and carbon sequestration (Urquhart 2006). In forest management, increasing the output of one service will change the supply of a bundle of other services provided by forest ecosystems (de Groot and van der Meer 2010). When clear-cutting a mature forest for timber production and subsequent conversion to a plantation, for instance, its water regulation services usually decrease. Trade-offs may thus occur when a set of ecosystem services is enlarged (see figure 2 in Böttcher and Lindner (2010)). Standing, mature forests have a high performance in the provision of food from harvesting forest wildlife or gathering plant products, erosion prevention and the provision of habitat for resident plant and animal species. To a lesser extent they provide energy resources, genetic resources, natural medicines, biochemicals, ornamental resources, air quality regulation, climate regulation water regulation, pollination, aesthetic information, recreation, inspiration spiritual and religious information and educational information. All these services (except for energy resources, such as biofuels and fuelwood) decline, in case the forests are converted to an intensively managed forest ecosystem that maximises the output of raw materials, energy resources and carbon sequestration (de Groot and van der Meer 2010).

The scope of REDD+, as agreed upon in Cancun in addition to the reduction of emissions from deforestation and degradation, also encompasses the 'sustainable management of forests' and the 'enhancement of forest carbon stocks' (UNFCCC 2010). Therefore, REDD+ includes two general management strategies: it incentivises the conservation of standing, mature forests, because these forests have the highest carbon storage (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen 1998; Böttcher and Lindner 2010). The conservation of standing, mature forests has a high potential for synergies between climate change mitigation and the provision of non-carbon ecosystem services. The second management option incentivised by REDD+ is the increase of carbon sequestration while sustainably managing forests or enhancing the forest carbon stocks of managed forests. With respect to the second management option, concerns have been raised that this could lead to a conversion of managed forests with natural species to highly managed forests with exotic, fast-growing tree species such as Eucalyptus (Pistorius et al. 2010). This potentially leads to a decrease in particularly biodiversity-dependent services, such as nursery habitat or gene-pool protection, because there is no financial incentive for forest owners to provide them, which might be even more valuable (Loft 2009; Farley and Costanza 2010; Pistorius et al. 2010). In addition to this, Pistorius et al. (2010) criticise the unclear definition of the term 'sustainable forest management'. They argue that management activities have different impacts on forests and the ecosystem services they provide, depending on the kind of activity and the specific circumstances of the area where they are implemented. A REDD+ funding mechanism that is designed as a pure market for carbon sequestration poses the risk of economically ignoring the trade-offs that occur with the provision of non-carbon ecosystem services. Therefore, a systematic approach is needed to show the potential consequences of the management decisions regarding trade-offs in ecosystem service provision (de Groot and van der Meer 2010). One possibility is to include a set of regulations for a mandatory trade-off analysis, analogous to the CDM regulations which require conducting an environmental impact assessment prior to project development (Loft 2010). A prerequisite is to gain an understanding of the causal relationships between the ecological processes that lead to the provision of the ecosystem services of the forest in question. Furthermore, indicators are needed that allow a quantification of the effects of different management options on the provision of non-carbon ecosystem services across different spatial scales (de Groot and van der Meer 2010). Based on these indicators, a quantification would allow the consideration of the trade-offs in the design of payment schemes.

A number of instruments exist to analyse the implications of management changes. Amongst them are participatory scenario analysis and modelling approaches which can be used as a method of predicting and describing plausible futures by combining alternative decisions with projected demographic and socio-economic changes, land use, climate and other factors (Walz et al. 2007). The generation of GIS-based maps showing where different ecosystem services are produced will allow an evaluation of the spatial concordance between areas that produce ecosystem services and those that are valuable to carbon storage (Naidoo et al. 2008). Mapping can also be used to identify the locations of beneficiaries. The accounting and valuation of the ecosystems services provided and lost when depleted as a consequence of a change in management will help identify the costs and benefits that different stakeholder groups may face (Boyd and Banzhaf 2007; Wallace 2007; de Groot and van der Meer 2010).

However, empirical information on the quantitative relationship between land use and ecosystem management and the provision of ecosystem services at the local and regional scale is still scarce (de Groot et al. 2010). Mantau et al. (2001) and Glück (2000), for example, highlight the need for increased knowledge about the relationship between timber production and the provision of other goods and services produced by forests. When developing indicators and designing instruments for trade-off analysis, it must be kept in mind that sufficiently detailed information to capture important trends in the provision of ecosystem services is supplied (Pistorius et al. 2010). Gathering the necessary information is costly (Muradian et al. 2010), especially in the case of REDD+. Monitoring deforestation and degradation requires remote-sensing techniques to detect forest cover changes, and regular and systematic forest inventories are necessary to measure the changes in forest carbon stocks. However, since the negotiation of the Kyoto Protocol, the costs for using remote-sensing technology have dropped and approaches such as community monitoring can pose a cost-effective alternative to professional surveyors while increasing community ownership of REDD+ projects (Skutsch et al. 2009).

Conclusion

In its current form, REDD+ has been designed as a mechanism through which developed countries provide financing for the provision of the ecosystem services carbon sequestration and carbon storage, by means of maintenance and appropriate management of forest ecosystems in the developing countries (Pistorius 2009). The question whether a pure market-based mechanism should be established for financing REDD+ depends on the economic characteristics and spatial distribution of these ecosystem services and on possible trade-offs with other ecosystem services provided by forest ecosystems. The analysis showed that due to the combination of economic characteristics carbon sequestration and carbon storage can be classified as common-pool services that depend on regulatory intervention in order to create a market which can then function as an instrument for allocation. As a consequence of the spatial distribution of carbon sequestration and carbon storage, that is, global, omni-directional forest, a regulatory definition of tradable emission permits and the creation of demand would need to be introduced, where a global beneficiary pays the local provider for the provision of the service (Olschewski et al. 2010). Since the benefits cross national borders, an international institution for the specification of the regulatory framework would need to be established.

Forest ecosystems are complex systems that depend on a variety of biophysical structures and processes which lead to the provision of ecosystem services (Farley and Costanza 2010). Altering this structure by improving a single ecosystem service, such as carbon sequestration, can lead to a change in the provision of a whole set of ecosystem services. Therefore, a purely 'Cosean' market-based mechanism that is created for only some forest ecosystem services will not lead to a sustainable, fair and efficient allocation of ecosystem services.

REDD+ in its final phase could thus be designed as a market mechanism. However, it would need strong corrective regulatory elements at the global scale that can secure the provision of non-marketable ecosystem services like nursery habitat, gene-pool protection or oxygen provision.

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Notes

1. For simplicity, REDD is used in this article to denote REDD+. For a definition of REDD+, see Section 2.
2. Therefore focusing on tropical forests and excluding most temperate and boreal forests.
3. The global present net rate of carbon sequestration by forests is 1.7 ± 0.5 Pg C yr^{-1} (Lal 2008). The current estimated total forest carbon stock (biomass, soil, dead wood and litter) is 652 Gt C (Food and Agriculture Organization 2010).

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