RUPES TYPOLOGY OF ENVIRONMENTAL SERVICE WORTHY OF REWARD

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Rewarding Upland Poor for Environmental Services

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Rewarding the Upland Poor in Asia for Environmental Services They Provide

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Abstract

The development of transparent and sustainable reward mechanisms for environmental services provided by upland farmers to downstream communities requires clarity on the relationship between land use and the type of environmental services provided. In the context of the RUPES project ('rewarding upland poor for the environmental services they provide'), a typology of environmental services is discussed that leads to the distinction of twelve 'proto-types' of situations where the upland-lowland relationship is focused on a specific environmental service function.

1 Introduction

Clean water and air, and an abundance of biota that share the earth with *Homo sapiens* were in the past provided as global public good to all of us free of charge. With the globally increasing pressure on natural resources this has changed, unfortunately. Access to the 'environmental services' that an abundance of 'natural capital' can provide has become a scarce good, as much has been converted to financial capital in the process of 'development' or has been negatively affected as an externality to human decision making processes (Tomich et al., 2004). Access to clean water, air and biological richness has become a scarce good, and in line with basic economic principles, has become more accessible to the rich than to the poor.

Poverty has many dimensions, but lack of access to clean water and living in areas with risks of landslides, floods and fire are not the least among them. While environmental degradation is generally caused by resource use, and thus proportionally more caused by the rich than by the poor, poverty and environmental degradation have a specific relationship. Environmental degradation enhances poverty – poverty may also enhance environmental degradation; somewhere this negative spiral has to be interrupted.

Regulatory frameworks by which governments impose a '**protection**' status on parts of the land and water domain, have often failed to be effective, as the historical and moral, or *de facto* established rights of local people are usually not adequately respected. Opportunity costs for the resource exploitation these people are no longer allowed to undertake are not compensated. The '***guardians***' who are supposed to effectively implement the protection status are underpaid and not respected by the societies in which they work, while the opportunities for increasing their income by a sell-out of the resource they are supposed to protect are substantial.

Yet, it is not only glum and doom. In substantial parts of the tropical world local forms of land use have emerged that allow people to make a living while protecting environmental resources at levels that are below the 'pristine' level of a (perceived) pure nature, but yet significantly above what it could be if other models of agricultural development were followed. This form of '***stewardship***' has been driven by the local benefits it provides and the positive environmental effects appreciated by outsiders are 'externalities' (i.e. effects not taken into account by farmers and other decision makers).

The 'agroforests' of southeast Asia (with counterparts in other parts of the humid tropics) are a prime example of how 'domesticated forests' can provide food, timber and income, while harbouring a substantial share of the original forest biodiversity – that lacks adequate protection elsewhere. Depending on commodity prices, investment opportunities and government policies, however, the managers of the agroforests are and can be tempted to replace their system by a monocultural plantation of oil palm, rubber or some other commodity. Who can blame them for doing so, if the outside world has not found ways to express their appreciation

Box 1. The RUPES partnership

RUPES (*Rewarding the Upland Poor for Environmental Service*) was formed through a funding partnership with the International Fund for Agricultural Development (IFAD), and is coordinated by ICRAF's Southeast Asia Regional Programme, based in Bogor, Indonesia.

RUPES was initiated at a February 2002 regional workshop in Indonesia, with 61 participants from potential consortium partners in 9 countries. With expertise provided by specially commissioned papers, working groups discussed the development of transfer payment mechanisms for environmental services. They agreed that a fundamental approach of RUPES would be to work in an action research mode. Other international organizations that are committed to rewarding managers of fragile ecosystems joined IFAD and ICRAF to form an International Steering Committee. They include the Centre for International Forestry Research (CIFOR), the World Resources Institute (WRI), Conservation International, Winrock International, the International Institute for Environment and Development (IIED), IUCN, Ford Foundation, the Nature Conservancy, WWF, and the Economy and Environment Program for Southeast Asia (EEPSEA).

After intensive review of 50 candidate areas, "action research sites" were initiated in the Ikalahan and Bhakun Ancestral Domains, Philippines, in Kulekhani, Nepal and in Bungo, Sumberjaya, and the Singkarak Lake watershed in Indonesia. Six "associate" research sites have been identified in Indonesia, Philippines, and southwestern China. They will share information and exchange experiences Vietnam and China have conducted studies, including surveys of RUPES-related research, and opportunities and constraints for RUPES projects. Sri Lanka and Laos are also exploring RUPES involvement.

for the environmental quality of the agroforest in a way that is meaningful for the farmers? Worse, government policies aimed at resource protection and expelling farmers from 'protected areas' may have forced farmers into poverty and further resource degradation elsewhere – without achieving positive impacts in the target area.

Cases such as this are at the core of the program started by a number of international and national partners to explore the mechanisms that can be used to '***reward upland poor for the environmental services they provide' (RUPES)*** (Van Noordwijk et al., 2005). In seeking positive rewards for '***services***' as alternative to and complement of regulation of '***disservices***', the nature of the relation between providers/ maintainers of environmental services and beneficiaries/stakeholders can change significantly. Where upland communities are often 'looked down upon' by people living in lowland capitals (while even their highest high-rise building does not warrant this to be literally true…), respect for their role in guarding essential environmental services can be a substantial change. Where 'lack of voice' is an important dimension of rural poverty, a real two-way communication around 'rewards' that are 'earned' (no charity is needed…) by real 'efforts' with measurable 'impact', can put the actors on a more equal footing. '***Environmental justice***' may be enhanced if those who use the largest share of the 'environmental resource space', pay for the maintenance and provision of these services, rather then see them as 'global public goods' that are most accessible to those with most power and resources anyway.

Before we can expect any such a 'reward' mechanisms to meet the expectations that it will be effective, efficient, transparent, sustainable, equitable and fair (Landell-Mills and Porras, 2002). The RUPES consortium (Box 1) is seeking to obtain direct experience in purposely selected 'action research sites', to obtain a better understanding of where and how the various mechanisms that are under current discussion can be used and to contribute to greater clarity of the underlying concepts (Fig. 1). Any given land use has impacts on a range of potential 'environmental services' and rewards for one might steer a land user in a direction that reduces other services (e.g. maximizing carbon storage may affect water and biodiversity). Various types of effort or activity can qualify actors as 'environmental service providers': absence of threats, mitigation and increase in filter functions (van Noordwijk 2004a).

Payments or rewards for environmental services (Fig. 1) originate (often through a nested structure of payment for water and electricity to a provider or via tax payments to a government entity that acts on their behalf) from 'beneficiaries' of the service, that we can describe

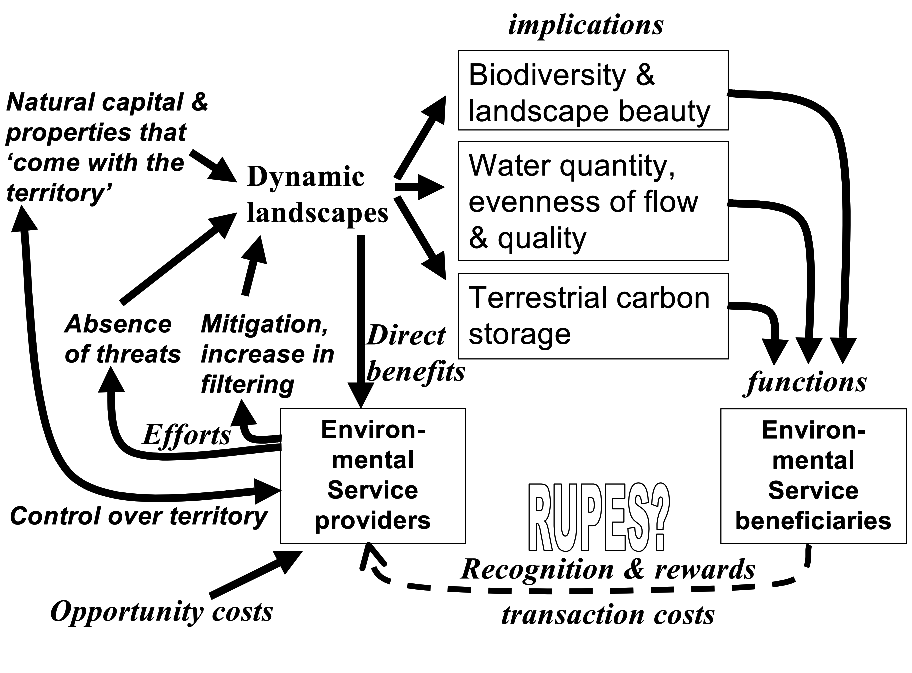


Figure 1. Basic scheme of rewards for environmental services where the landscape-level implications of land use can be perceived as environmental service functions

Box 2. RUPES terminology

Within the RUPES program a set of definitions of '***environmental service rewards***' has been adopted that follows the diagram of Figure 1:

Actors in the landscape: any person who can directly influence the conditions in a landscape, for example by farming, logging, forest management or mining.

Dynamic landscapes: Spatially delimited areas where 'actors' influence, extract and manage resources (vegetation, soil, water, fauna, mineral resources), often in a patchwork or mosaic of different intensities (including forestry, agriculture, animal husbandry, mining), that changes with time.

Natural capital: Inherent properties of a 'landscape' including the local climate, physical landscape, soil and mineral resources, vegetation and fauna, location

Effort: Any action taken that modifies the composition or function of elements of the dynamic landscape

Direct benefits: Landscape-level consequences that have functional value for the actors

Implications: The results of the actors effort in the landscape or the lateral flows of water, air, organisms or products out of the landscape that can be perceived as environmental services or disservices. Outcomes can include the continued local existence of biota, carbon and mineral stocks that may allow future exploitation or are valued in their own right for continued existence. The implications may be observable or quantifiable, while their value as an environmental service depends on the perception of the buyer.

Environmental Services: The results or implications of the dynamic nature of landscapes that are valued by external stakeholders as a service. Environmental services (ES) can be based on material flows (e.g. outgoing such as water, or ingoing such as terrestrial carbon sequestration) or internal environmental quality (such as continued existence of biodiversity or landscape beauty). We will here focus on four types of environmental services; (1) watershed services, such as regulation of water cycles and soil conservation; (2) biodiversity, including biodiversity of global significance and that of local functionality for functions such as pollination, pest control, food security; (3) carbon sequestration and storage; and (4) landscape beauty.

Stakeholders and beneficiaries: Any person or group that perceives itself to have a direct stake in the environmental services, and for whom these services can become a function that leads to (loss of) benefits.

Sellers of environmental services (ES providers): any actor or collection of actors who modify the landscape and through this modification provide environmental services to potential buyers of these services.

Buyers of environmental services: Any stakeholder who recognizes environmental services are being provided, and who can be morally, legally or rationally motivated to pay for these services.

ES reward/payment: Compensation for service, merit or effort, and/or incentive for maintaining or enhancing environmental service functions, received by the sellers or paid by the buyers of the environmental service(s). Compensation may be made in terms of direct payments, financial incentives, or in kind. Rewards and payments in kind may include the provision of infrastructure, market preference, planting materials, health and educational services, skills training, technical assistance or other material benefits. In addition to indirect and direct monetary payments rewards can take the form of land tenure security. Moral rewards, recognition and respect may address non-material aspects of poverty.

Mechanism: Any mechanism or institution by which rewards/payments are made available to intended beneficiaries. Development of a reward/payment mechanism involves identifying who receives the reward or payment, for what reason, when it is made, in what form, who delivers it and the source of the reward. Some examples of mechanisms can include direct payments to communities who use funds for local development, payments to individuals, land tenure conditional upon maintenance of services, forms of ecolabelling for premium prices.

Intermediaries: Institutions or persons who can link the buyers, or potential buyers, to the actors in the landscape and broker agreements for the continuation (or increase) in the supply of environmental services, in return for specific forms of rewards/payments.

Transaction (intermediation) costs: The costs involved in establishing and maintaining a transaction between buyers and sellers, these costs will generally include the costs for negotiating agreements, monitoring of the landscape consequences, enforcing contracts and the necessary institutional mechanisms.

To be continued…

Box 2 … continued

Supporters: Institutions or individuals – for example government agencies, NGO's, or donors – who provide an enabling environment and/or legal basis for reward mechanisms and support the function of intermediaries. The RUPES project is itself a 'supporter', facilitating the emergence (we hope) of honest brokers and intermediaries.

Obstructers: Institutions or individuals – for example government agencies, NGO's, or donors – who discourage the development of enabling environment and/or legal basis for reward mechanisms and hinder the functions of intermediaries.

Bundling of services: Any land use pattern can be said to 'produce' different types of environmental services that may be relevant to different groups of external stakeholders. 'Bundling' involves mechanisms that provide rewards to sellers that are based on payments made by a single buyer interested in multiple services, or by different groups of buyers for separate services.

as 'buyers' of the environmental service in a market-derived terminology (Box 2). The rewards (recognition, use rights, payments) are obtained by groups (often again in a nested structure) who are identified as 'environmental service providers', with transaction costs of establishing and maintaining the provider-beneficiary relationship a major concern. The relationship between what the 'service providers' (or 'sellers' in the market terminology) do or refrain from doing and the nature of the service functions appreciated by the 'buyers' is farm from direct. In fact it is the landscape-level interaction between natural capital and land use decisions that has direct implications for biodiversity and carbon storage on the site as well as the quantity, timing and quality of water originating from the area. These 'implications' are the basis of the 'environmental service functions' – but their functionality depend on the location and lifestyle of the 'buyers', as well as on the intermediaries (physical or information flows) between the landscape of origin and the 'buyers'. The interactions between the 'sellers' and their dynamic landscape can be analyzed in terms of ownership or control over territory and its associated 'natural capital', efforts that result in 'absence of threats' and efforts that actively modify the land cover in the area as a whole and/or modifying filter functions in specific landscape niches. The upland land users are expected to make decisions in this regard primarily ion view of direct benefits that they derive from the landscape (e.g. production, protection and spiritual functions). As in any

Box 3. Payments, Markets, Incentives and Rewards

Globally there is much current interest in 'payments for environmental services' (PES) and in 'markets' as a paradigm for relating demand and supply through a process of price adjustment. In Europe several decades of experience exist in providing financial incentives to farmers to adjust land use on their farms to the priorities at policy level. While initially these priorities where framed in relation to food supply and social (depopulation of rural areas in mountains) issues, the transition to environmental service priorities can build on to the existing incentive delivery mechanism and the experience in monitoring compliance. In parts of the United States of America the market paradigm has been used for allowing flexible mechanisms for achieving compliance to rules – for example through offset mechanisms (damage to environmental services at one place can be offset by improvements elsewhere, with a market for the certified 'improvements elsewhere'). In Latin America the concept of payments for environmental services has been applied, for watershed functions, biodiversity conservation as well as terrestrial carbon storage. Landell-Mills and Porras (2002) provide an overview of this experience and the way experience shows it is not a 'silver bullet' that will solve all problems – but requires an institutional and political context. Pagiola et al. (2002) discussed the application of these mechanisms to 'forest environmental services', where the issue of 'ownership' of the forest lands is a crucial one. The prevalence in densely populated Asia of conflicts over ownership of forest lands between the 'state' and local communities or individuals, in a complex historical context of state formation is likely one of the reasons that the European, North American and Latin American experience can not be directly translated to Asia.

Van Noordwijk et al. (2005) discuss a number of perspectives on rewards for environmental services from ecological, environmental governance, economics, social justice and integrated natural resource management perspective. They also provide hypotheses on preconditions for the 'market' and 'payment' based variants of the broader 'reward' concept.

complex system of this nature, any relationship between parts (represented by an arrow in the diagram) can become a 'bottleneck' or constraint to the overall functioning. Resilience of an environmental service reward scheme thus depends on the ability to monitor performance, learn from the experience and adjust.

In this contribution to the debate on payments and rewards for environmental services (Box 3) we will clarify the terminology on environmental services and the way they can be appreciated. In the analysis of the development/ environment tradeoff in land use options in the forest margins of the humid tropics, the Alternatives to Slash and Burn (ASB) program (Tomich et al., 2004) used a terminology of services based on a 'natural' classification system of biodiversity, carbon storage and watershed functions, that starts from the type of natural capital that is involved. The RUPES program was conceptualized on the same framework. In chapter 2 we will discuss the various services in the context of ES rewards.

The Millennium Ecosystem Assessment (see Box 4) effort has developed a grouping that starts from a human perspective, with functions such as 'provisioning', 'regulating', 'supporting' and 'cultural & spiritual values' as the entry point. We will, in chapter 3, explore how the two classification systems can be made compatible. In subsequent chapters we will explore how the

Box 4 Millennium Ecosystem Assessment

Inspired by the role that the Intergovernment Panel on Climate Change (IPCC) has played in bringing scientific evidence to the international negotiating table of the Framework Convention of Climate Change, the Millennium Ecosystem Assessment (MA) was initiated in 2001 by the United Nations Secretary-General Kofi Annan to report in 2005 on how changes in ecosystem services have affected human well-being, how ecosystem changes may affect people in future decades and what types of responses can be adopted at local, national or global scales to improve ecosystem management and thereby contribute to human well-being and poverty alleviation.

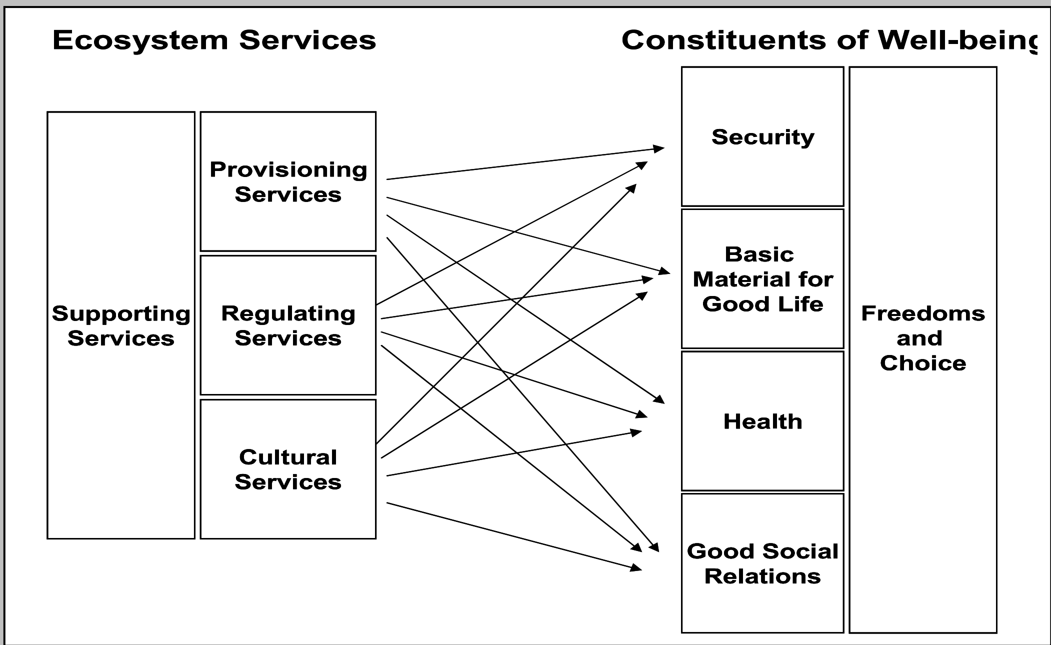


Figure 2. Ecosystem services conceptualized by the Millennium Ecosystem Assessment as the benefit people obtain from ecosystems (Alcamo et al., 2003)

In its framework for assessment (Alcamo et al., 2003; Fig. 2), the MA takes an human-centric perspective, by relating basic determinants of human well-being (freedoms and choice, security, basic material for a good life, health, good social relations) to the provisioning, regulating, supporting and cultural services that ecosystems can provide to people.

blending of the two perspectives can be used to develop a typology of 'environmental service reward mechanisms', that is cognizant of the spatial and temporal scale at which the environmental services are influenced by land use in the 'uplands' (used here in a generic sense as the origin of the flow of environmental services) and appreciated in the 'lowlands'.

In discussions on the needs and opportunities for 'environmental service benefit transfer' mechanisms, a number of steps can be distinguished:

1. We need to know what environmental service functions (ESF) really are (how they can be quantified, who will benefit) before any transfer of benefits is feasible. Therefore, the first step in any candidate 'case' has to be clarification of the way various ESFs for local and external stakeholders depend on alternative land use choices and management practices. This step involves answering a series of questions: A) What choices exist? B) Which ESFs are modified? C) Who benefits locally? D) Who benefits nationally/globally?
2. Which factors determine the current choices made by land users and how is this likely to change in the near future under a baseline or *status quo* (i.e. 'no ES rewards') scenario?
3. It is unlikely that a single mechanism for environmental service transfers meets all situations, so the third step has to evaluate various options and mechanisms for their feasibility: what does it take to induce farmers and local communities to choose land use practice X versus Y or Z?
4. For any environmental service transfer mechanism to work, it is essential that the overall policy environment is conducive, so attention needs to be paid to the existing policy context before attempting to apply a model that was successful in one case to other situations.
5. Environmental service transfers will need a 'pull' effect by creating awareness within groups of the intended beneficiaries that such transfers are reasonable and that mechanisms are under way to achieve the transfers. Unless those on both sides of the ES reward mechanism-negotiating table understand each other's position, the process can easily derail.

If biodiversity is regarded as a globally valuable 'commodity', then every part of the world has its own particular 'products' and so the rural poor who live in 'biodiversity hot spots' operate in a 'niche market', supplying goods that nobody else can replace or compete with. In carbon storage there is no such 'bargaining power', as C storage in any climatic zone is of equal value to the atmosphere, and, in a global market, financial rewards for C storage may be allocated according to 'efficiency' considerations.

The local/national values of biodiversity conservation and the maintenance of watershed functions are not covered by existing international conventions or commitments, and their recognition as part of national development objectives is, in most if not all countries, sub-optimal. The conventional approach to meeting objectives of biodiversity conservation and watershed functions is a 'regulatory' one, declaring specific areas out-of-bounds for agriculture or other human livelihood enterprises. This regulatory approach often leads to conflicts between governments and the rural poor living in the areas declared off-limits. These conflicts, and a lack of innovative ways to resolve them, maintain poverty, as well as degrading the environmental services. Innovations that combine 'carrots', 'sticks' and 'sermons', and reward the rural poor for the environmental services they actually provide are highly desirable.

To implement new mechanisms, however, the environmental services need to be quantifiable by transparent mechanisms, and we need recognition for the 'bundling of services' that derive from a choice of land use practices. Replacing an open-field agricultural system by a system that includes partial tree cover can have positive impacts on C storage, biodiversity as well as watershed functions, depending on the types of trees, the ways in which they are managed and the position they have in the landscape. Trade-offs between the environmental services exist (e.g. fast-growing trees may lead to more rapid increments in C stocks, but use more water and may be a risk to groundwater resources), and a system that evaluates the overall effects is highly desirable. So, on one hand we need clarity on the individual environmental services and the way they are influenced by changes in land use practices by upland communities, on the other hand we need a mechanism for bundling the benefit streams from the various stakeholders, to provide a single and clear signal to the decision-makers on the ground.

In this discussion paper we hope to contribute to the clarity of how 'environmental service functions' can be defined in the context of reward mechanism.

2 A natural classification system: watershed, biodiversity, carbon

2.1 Overview

A classification system of environmental services that is essentially based on the natural capital involved was used by the Alternatives to Slash and Burn (ASB) program (Tomich et al., 2004) (Table 1).

The analysis of 'development/environment' tradeoffs by Tomich et al. (2001) focused on the first three (biodiversity, carbon and watershed functions) as 'environmental service functions', with 'returns to labour' and 'returns to land' as primary economic axes and food security and local institutions on the development side. To match the more comprehensive approach of the Millennium Ecosystem Assessment (chapter 3), the productivity and profitability (P) and human health and landscape beauty (H) categories are added here. However, we will still focus on C, C and W dimensions here.

2.2 Biodiversity

2.2.1 Conserve what is still left

Biodiversity conservation may, at least in the long term, well be the most important of the environmental functions discussed here for the perpetuation of life on the planet, and even for the more anthropocentric notion of perpetuation of human life. However, there are still major conceptual as well as practical problems for an assessment, let alone measurement and quantification. It may also be the issue where it is hardest to identify ways in which 'actors' become 'environmental service providers'.

Where 'biodiversity' refers to the diversity of life, it is important to keep up with the current rewriting of biology textbooks in which 'plants' and 'animals' (and in more advanced versions 'fungi') used to be the main categories. Current molecular taxonomy recognizes a much greater diversity of groups within the Eukarya (organisms with a full cell nucleus) and between this group and the Eubacteria and Archaea (Fig. 3). Yet, from a human perspective 'proximity' (e.g. orang utan >

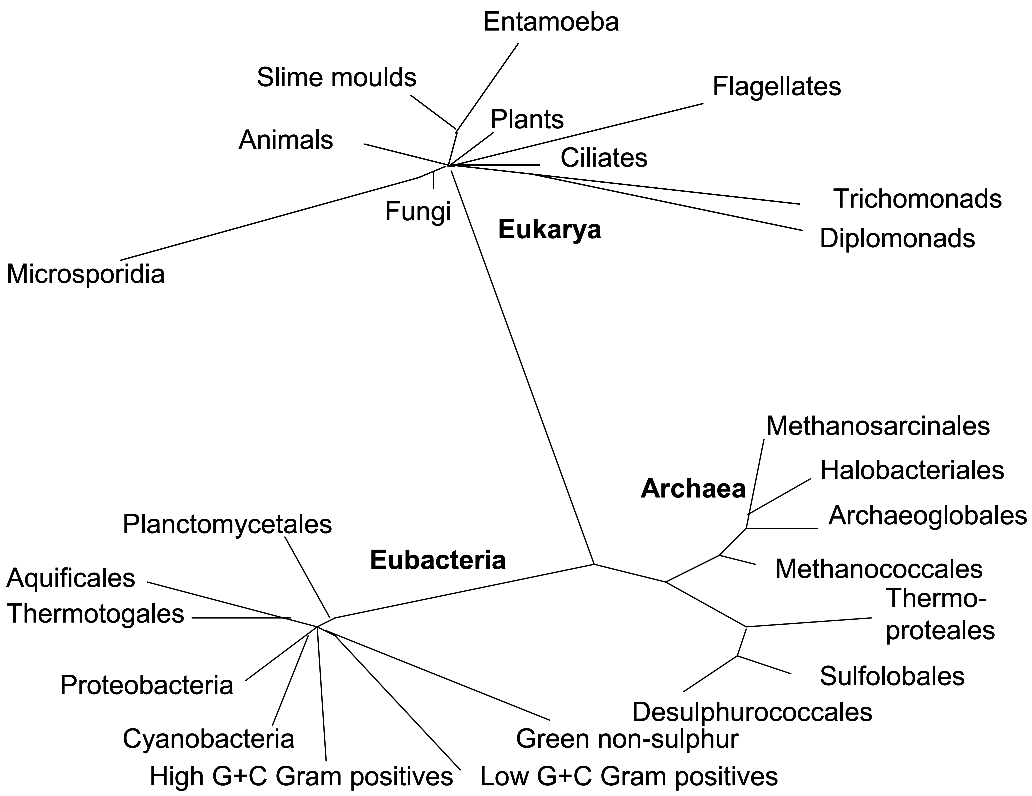


Figure 3. Current view of the 'tree of life' and genetic diversity among main groups in the molecular taxonomy of Gribaldo & Philippe (2002)

Table 1. Ecosystem service classification for assessment of land use change in the humid tropics, as used by Alternatives to Slash and Burn (ASB) consortium

Watershed functions (W)	
W1	Water transmission (total water yield per unit rainfall)
W2	Buffering (above average river discharge per unit above average rainfall)
W3	Gradual release of stored water supporting dry-season flows
W4	Maintaining water quality (relative to that of rainfall)
W5	Stability of slopes, absence of landslides
W6	Tolerable intensities of net soil loss from slopes by erosion
W7	Microclimate effects on air humidity and temperature
Biodiversity functions (B)	
B1	Protecting the integrity of conservation areas by preventing loss of habitat and threats at population level in the areas directly around core protection areas,
B2	Providing habitat for a sub-set of the original fauna and flora inside agriculturally used landscapes [1]
B3	Maintaining connectivity between protected areas via corridors,
B4	Creating opportunities for local-level 'restoration', in landscapes where connectivity is still maintained.
B5	Various forms of ex situ conservation.
Carbon stocks (C)	
C1	Protecting natural forest area, peat soils and other carbon storage areas
C2	Protecting above- and/or belowground carbon stocks in areas used for (agro)forestry and/or agriculture
C3	Restoration, increase in tree cover (in a 'sustainable harvest' regime the time-averaged C stock of a land use system does not depend on the growth rate, but on maximum stock at time of harvest)
C4	Accumulating wood and other products derived from recent plant production in, for example, the form of houses, furniture, paper, organic waste dumps.
Productivity and direct profitability (P)	
P1	Allowing extraction of potentially renewable resources
P2	Non-renewable resource mining
P3	Nutrient and water supply for agricultural crops, fodder and trees
P4	Biotic relationships: pollination, pests, diseases and their control
Human health & landscape beauty (H)	
H1	Regulation of pests and diseases
H2	Detoxification of air, water, food
H3	Spiritual, religious and aesthetic values
H4	Opportunity for active recreation (ecotourism)
H5	Ecological knowledge

Note:

1. This increases in relevance with the increasing loss of more natural habitat; it will only allow the conservation of part of the original species pool – with losers among the organisms that few people want to have in their backyard (tigers, elephants) or as direct neighbours (e.g., pests), and those that can not tolerate people as neighbours from their side

panda bears > birds > fish > snail > fungi) and 'use value' dominate the concern over extinctions, and most practical conservation concerns remain focused on mammals, birds or to-a-lesser-degree plants (IUCN red list: Baillie et al., 2004). If we look at the significance to humankind, the value of a wild relative of a domesticated crop or animal, or a species with greater-than-average likelihood of having pharmaceutical relevance (linked to families and/or environments with known prominence of 'secondary metabolites') is probably higher than that of other plants or animals; such considerations make 'valuation' of biodiversity a daunting task for which no standard and widely accepted procedures exist as yet (Swift et al., 2004).

The diversity of organisms that live in a landscape does not directly indicate the contribution that this area makes to global biodiversity. An area rich in species, but only containing species that have a wide distribution and are not threatened elsewhere makes only a small contribution to global diversity, while an area that contains few species, but globally unique ones ('endemic' species) contributes much more. The same holds true if we consider the genetic diversity at below-species level in the taxonomic hierarchy, or higher taxonomic entities (genera, families, orders) or an ecosystem typology (Hairiah et al. 2001b, Williams et al., 2001).

Adopting the general scheme (Fig. 1) to the specifics of biodiversity (Fig. 4), we can provide more detail on the 'natural capital', the 'threats' and the 'mitigation' side. The main positive impact people can have is causing a reduction (or absence) of 'threat factors', with a relatively small role for 'mitigation' effects such as restoration of landscape-level connectivity and 'ex situ' conservation. The main threats are loss of habitat, negative effects at population level (disturbance of reproductive cycles, overhunting, overharvesting, pesticide use and pollution) and the introduction of invasive species that can replace local species or eliminate them as a predator or in a disease role. The opportunities for conservation within 'agroforestry' landscapes are only recently explored by mainstream conservation agencies (Schroth et al., 2004; McNeely and Scherr, 2003)

By its nature, biodiversity is part of the 'natural capital' of a place, that who-ever lives there now has inherited. Part of the plant and animal species currently inhabiting any area where people live have followed human beings. From a local use perspective, these newcomers may be of no less value than the indigenous plant and animal species that they replaced. From a global biodiversity

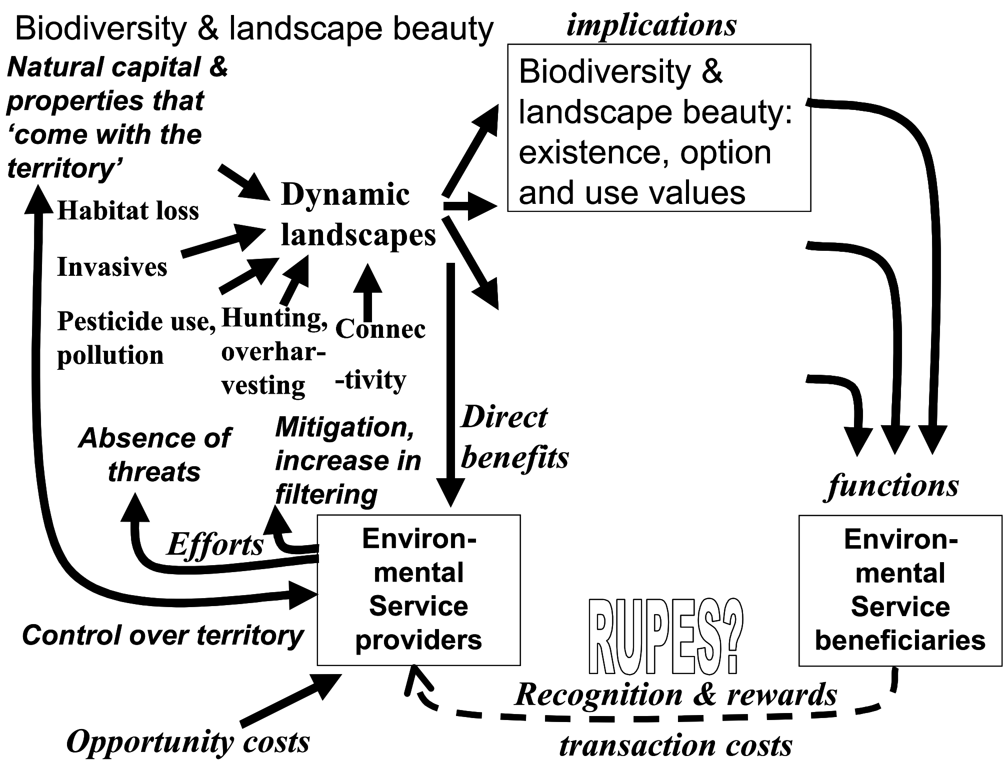


Figure 4. As Figure 1, but specific to the 'biodiversity and landscape beauty' function

perspective, however, replacing endemic (and thus globally rare) species with 'invasive exotics' is a substantial loss. Again, this indicates that local species richness per se is not a satisfactory indicator of 'biodiversity value'.

We can say that the natural capital 'comes with the territory'. It seems that about the only thing people can do is to decrease biodiversity, or at best slow down the rate of decrease. Creating new organisms, as is theoretically possible with biotechnological means, will not add to the 'biodiversity' with its generally accepted definition. Reintroduction of species in areas where they have disappeared may add to local richness and biodiversity, and be relevant if global populations are under threat – but again just slows down the loss, rather than increases global biodiversity. Conservation is thus the appropriate term at global scale – even though current attention has switched to 'landscape restoration' at local scale.

While 'invasives' are the downside of the greater connectivity of today's world for at least a subset of organisms, maintenance of connectivity between the 'islands' of protected areas in the 'sea of agriculture' is generally seen as positive. Where agriculturally used landscapes maintain connectivity from the perspective of plants and animals, this is generally seen as a positive attribute (as long as barriers to invasives are maintained at other levels). Part of the 'invasives' are deliberate introductions of plants and animals that are (or at least were an one stage) considered to be of use to farming systems (e.g. for 'soil improvement', 'agroforestry' or 'natural enemies of pests'). Once naturalized, complete eradication is virtually impossible, making introductions of new organisms a *de facto* irreversible act, if at least the new organisms are adapted to local climate and (agro)ecosystem.

The main options for providing 'environmental service functions' that potentially merit compensation and rewards in the biodiversity domain are:

- B1. Protecting the integrity of conservation areas by preventing loss of habitat and threats at population level in the areas directly around core protection areas,
- B2. Providing habitat for a sub-set of the original fauna and flora inside agriculturally used landscapes (this increases in relevance with the increasing loss of more natural habitat;
- B3. Maintaining connectivity between protected areas via corridors,
- B4. Creating opportunities for local-level 'restoration', in landscapes where connectivity is still maintained.
- B5. Various forms of *ex situ* conservation.

Providing habitat (B2) within the agriculturally used landscape will only allow the conservation of part of the original species pool – with losers among the organisms that few people want to have in their backyard (tigers, elephants) or as direct neighbours, and those that can not tolerate people as neighbours from their side. The current delineation of 'protected areas' (defining the distinction between B1 and B2) rests on historical processes and existing knowledge. New 'discoveries' are still possible and can change the conservation status of lands (Box 5).

Box 5. Consequences of 'discovery'

Only a small fraction of the existing biological diversity on Earth is adequately described in scientific terms. Any serious sampling effort in tropical forest canopy insects or soils is likely to yield many species that are 'new to science'. Yet, most of these will not noticeably influence the 'conservation value' of the area sampled. Discovery of new mammals in the size range of deer, cats or monkeys has become a rare event that draws a lot of attention. It also has consequences for the area where the discovery took place (likely to be declared a 'conservation area') and hence for the people living there. They may have known and hunted the animal for many generations without interference and now suddenly see themselves perceived as threat to a rare and endangered species. Although conservation organizations have for several decades been committed to support for local human communities, there is no standard procedure yet on how to deal with the human consequences of discovery of new species. In parts of Sumatra there are still rumours of the presence of a human-like organism ('*orang pendek*') – just imagine the dilemmas that start if such organisms are actually found: should they be treated as 'indigenous people' with prior rights of occupation to the area, as subjects of 'development' efforts in the context of Millennium Development Goals that apply to all humankind? What about the farmers and hunter/gatherers that currently live in the area? Will their livelihood options be affected negatively or positively? In the absence of answers to such questions it may be better not to 'discover' or 'disclose'.

As no single group of organisms can be used as 'indicator' for all others (even though certain groups may correlate with overall richness indicators), and direct assessment is only feasible for specific groups, one normally relies on 'habitat integrity' as criterion of the continuation of the 'service', with 'absence of encroachment' as indicator for B1. If a 'flagship' species is the specific focus of attention, a more direct monitoring can be relevant. The people who 'control the territory' may thus be seen as the main 'providers of the environmental service'. The word 'control', however, should be taken in an operational sense: it is not necessarily the *legal* owners of the land, but those who keep others from encroaching. For B2 and B4 criteria must be based on the absence of 'threats' (and/or prescription of more biodiversity-friendly practices), and/or actual presence of key groups that are taken as 'indicators' (despite the questions that surround any 'indicator'). For B3 a similar set of criteria can hold at 'patch' level, but in the context of a chain where the weakest part determines the overall functionality and value.

Few people will doubt that the biodiversity value of any piece of land will decrease with increasing intensity of agricultural management, aimed at harvesting crops that may or may not be part of the original flora of the area, but have undergone 'domestication' that makes them less compatible with other parts of the local ecosystem (which become labelled as 'pest and diseases'). The shape of the 'trade-off' curve between biodiversity value and land use intensity is, however, less certain. Yet, this shape has major implications on how societies can best achieve a balance between biodiversity conservation and production of food, feed and fibre. [Note: if one is focused on conserving one special species or a targeted species for some specific purpose this curve may have little relevance]

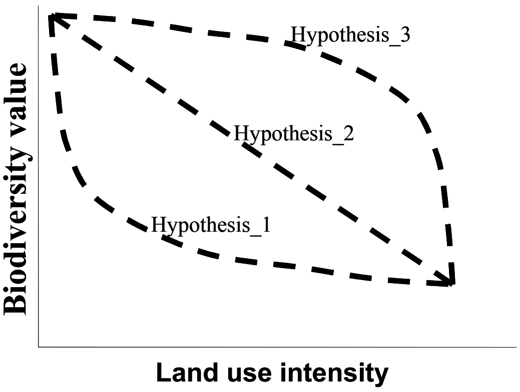


Figure 5. Three hypotheses on the way 'biodiversity value' will tend to decrease with increasing 'land use intensity'; for further discussion see text

Three hypotheses indicated in figure 5 are:

Hypothesis 1: *'A substantial component of the local flora and fauna is likely to be sensitive to and incompatible with agricultural use, and will thus tend to disappear (or be eradicated) in early phases of land use intensification; once this part of the biodiversity is lost further intensification will be of little consequence for on-site loss of biodiversity, but may actually help in as far as higher yields per unit area decrease 'land hunger' for further agricultural expansion'*

Hypothesis 2: *'Loss of biodiversity value is approximately proportional to the increase in land use intensity'*

Hypothesis 3: *'By appropriate management of above- and below-ground biota, substantial conservation of biodiversity for national and global benefits can be achieved in mosaics of land-uses at differing intensities of management, allowing for biodiversity conservation along with gains in sustainable agricultural production'*

As indicated in Figure 5 these hypotheses suggest alternate forms of the trade-off curve between agricultural land use intensity and biodiversity values, but the wording of hypothesis suggests that specific efforts can modify the shape of the curves.

Current research in the CSM-BGBD (Conservation and Sustainable Management of belowground biodiversity) project of a consortium of 7 tropical countries coordinated by CIAT-TSBF will test this third, 'optimistic' hypothesis. Yet, empirical evidence is thin on the ground, so outcomes closer to hypothesis 2 or even 1 would not be unexpected. Evidence for plant species richness obtained during the surveys of the Alternatives to Slash and Burn (ASB) project in Jambi (Fig. 6) indicate an outcome that may be close to hypothesis 2, although in more limited parts of the range both the convex curve of hypothesis 1 and the concave curve of hypothesis 3 can be recognized (if one wants…).

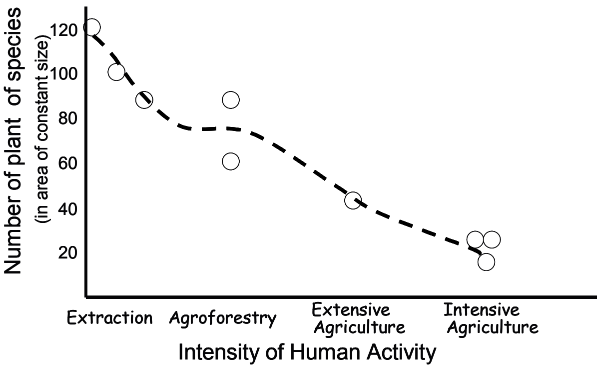


Figure 6. Plant species richness across a land use intensity gradient in Jambi (Murdiyarso et al., 2002; Van Schaik and Van Noordwijk, 2002)

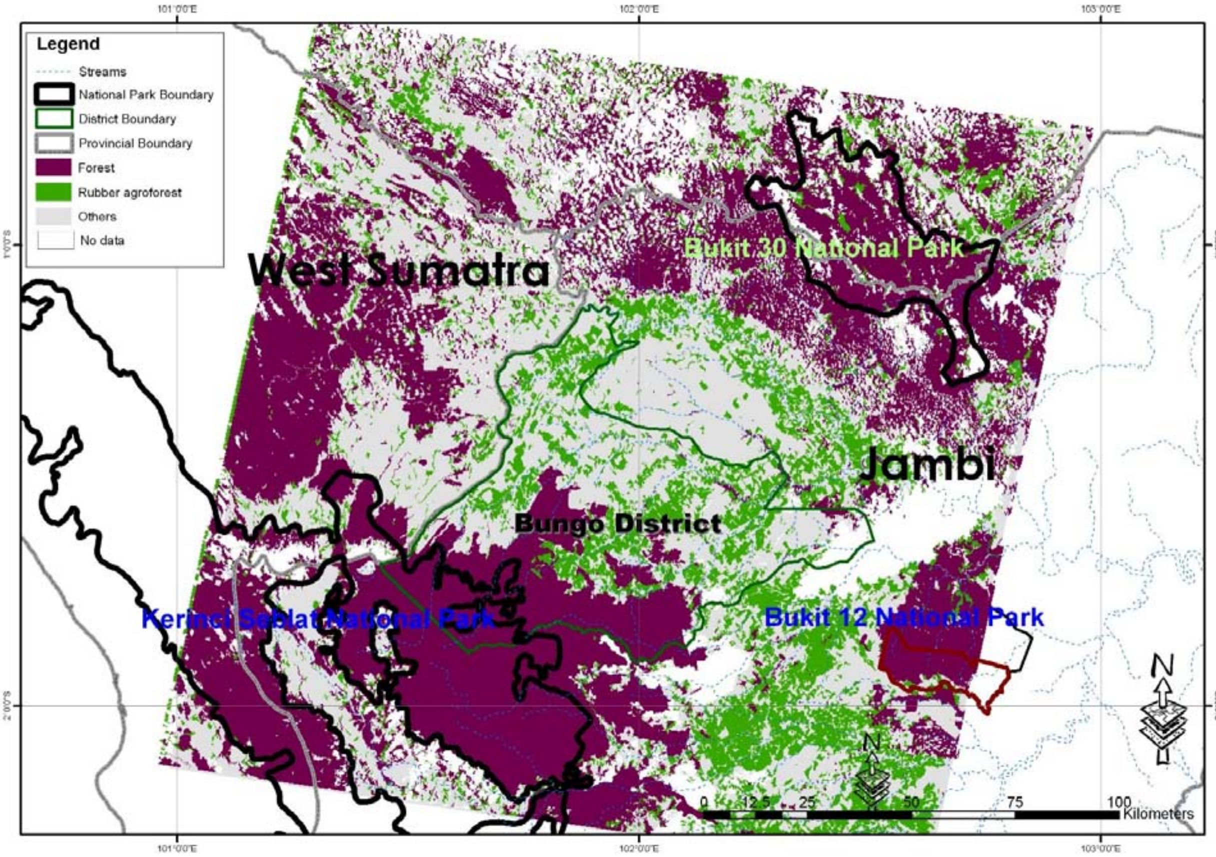


Figure 7. Tentative interpretation of the landscape corridors through rubber agroforests connecting the three main protected areas of lowland and mid-altitude forest in Jambi (Sumatra, Indonesia): Kerinci Seblat National Park, Bukit Tigapuluh (30) National Park and Bukit Duabelas (12) National Park ; the yellow corridor provides remnant of natural forests, the red one a series of stepping stones in rubber agroforest; for Bukit Duabelas the rubber agroforest corridor is the only one left (Ekadinata et al., 2004)

2.2.2 Local importance of flora, fauna and ecosystems

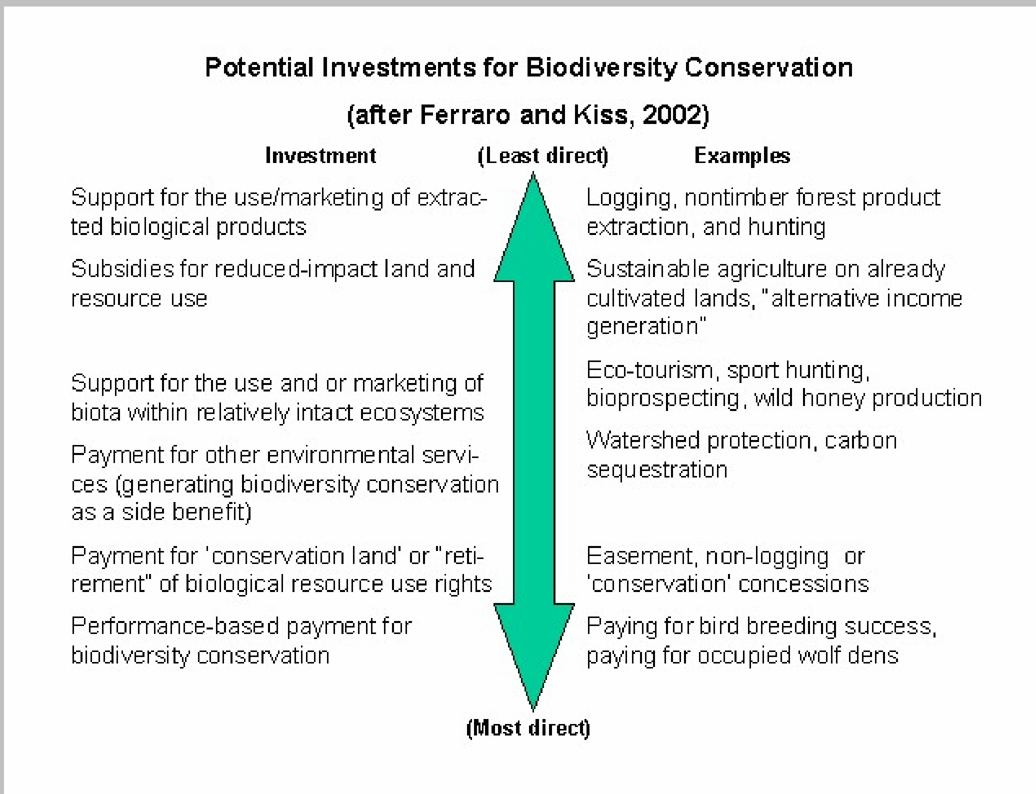
The distinction between 'protected areas' where the dominant objective is conservation and the agricultural lands where production and economic gains dominate has been questioned. Function B2 recognizes that lands and landscapes used for agriculture can have conservation value as well. There have been efforts to reconcile human resource exploitation with conservation in the realm of protected areas (B1) as well. Yet, the experience with this integration of functions is subject to debate, with a general sense that the 'integrated conservation and development' (ICDP) formula has not delivered on the expectations (Box 6).

In the words of Ferraro and Kiss (2002), four issues need be examined in relation to direct and indirect approaches to conservation and development:

1) *Institutional complexity*. Indirect and direct approaches require institutions that can monitor ecosystem health, resolve conflict, coordinate individual behaviour, and allocate and enforce rights and responsibilities. A system of conservation payments, however, allows practitioners to focus their energies on designing the requisite institutions. Existing direct payment initiatives have estimated administrative costs from 5% to 25% of the operating budget, whereas ICDPs have administrative costs at least as high, and often higher. A developing nation may not have the institutional capacity to make contractual agreements and to manage money in a direct payment initiative. If, however, it lacks such capacity, it would not likely have the institutional capacity to implement a more complex indirect intervention.

Box 6. Direct Payments to Conserve Biodiversity

In a recent paper in Science under this title, Paul Ferraro and Agnes Kiss from Georgia State University and the Worldbank argued that direct payments for conservation deserved more attention in developing countries. This direct approach to 'pay for what you expect to get' is the emerging trend in the USA and Europe. These payment approaches are based on a willing buyer–willing seller model. Sellers deliver conservation outcomes in exchange for a negotiated payment in cash or in kind. Payments are conditional on conservation outcomes. By contrast, in developing countries the emphasis is (as yet) on indirect methods by supporting extraction and use of biological products in 'integrated conservation development projects' (ICDP's) and Community-Based Natural Resource Management. Such projects encourage rural communities to maintain biodiversity by helping them to use it sustainably. They may also provide alternative sources of products, income, or social benefits (schools, wells, clinics, etc.) as a means of encouraging communities to cooperate. These kinds of efforts have been referred to as "***conservation by distraction***".



After decades of global efforts to conserve biodiversity through indirect approaches, there is a growing recognition that such initiatives rarely work as the technical, economic, social, and political conditions needed for an indirect approach to succeed are difficult to find in the real world. A recent review of ICDPs declared that there was "a notable lack of successful and convincing cases where people's development needs have been effectively reconciled with protected area management."

"People will generally do what is in their own interest, particularly their short-term interest. If they can receive more benefits from clearing an area of habitat than they could from protecting it, they will clear it. A society would never think to provide a public good like national defence through indirect means. The conservation community must reconsider its attempts to provide biodiversity through indirect means. If we want to get what we pay for, we must start tying our investments directly to our goals. "

2) *Costs*. In general, a direct payment approach will be more cost-efficient than any indirect approach. For example: an analysis of a conservation intervention in south-eastern Madagascar indicates that, were the nearly $4 million of available conservation funds invested in annual payments conditional on the protection of forest, about 80% of the original forest could have been protected into perpetuity, whereas only 12% could have been protected through support of indirect incentives. Furthermore, rural residents receiving conservation payments would have received incomes two times those that could be generated through an indirect intervention. Another example: the middle-income nation of Costa Rica pays rural residents about $35 annually per hectare of forest protected, and excess demand for conservation contracts suggests that these payments are higher than necessary. Even cheaper, Conservation International is protecting 81,000 hectares of rain forest in Guyana through a conservation concession that costs $1.25 per hectare per year.

3) *Development benefits*. The indirect approach is attractive to many stakeholders because it seems to achieve conservation and development objectives simultaneously (despite evidence suggesting it achieves neither in most cases). However, direct payments benefit poor farmers by improving cash flows, providing a fungible store of wealth, and diversifying sources of household income. Furthermore, under a payment approach, the land holders/resource users decide how best to meet their own goals and aspirations, rather than being subsidized to carry out predetermined activities, as is the case under the indirect approach. Paying an individual or community for "not doing something" might be seen as a form of social welfare rather than development. However, the idea that conservation payments are a form of welfare belies what conservationists have been arguing for decades: Biodiversity is a valuable commodity and biodiversity protection is an alternative land use.

4) *Sustainability*. The Holy Grail for the international conservation community is the self-financing conservation activity. Direct payments are seen as undesirable because they require an ongoing financial commitment to maintain the link between the investment and the conservation objectives. Like the legendary Holy Grail, however, the self-financing conservation activity is elusive. Indirect approaches are also likely to require a sustained flow of funds over time. A recent World Bank analysis of ICDPs *(16*) argued that conservation initiatives "based on simplistic ideas of making limited short-term investments in local development and then hoping this will somehow translate into sustainable resource use and less pressure on parks need to be abandoned."

Local perspectives on flora, fauna and ecosystems may differ substantially from those of external stakeholders interested in global conservation. Sheil et al. (2002) documented a methodology developed for one of the last forest areas of southeast Asia. Local perceptions differ from the 'scientific' one in the underlying taxonomy (where plants and animals of low 'importance' tend to be lumped in local languages, finer distinctions (beyond the biological 'species' level) are often made in plants and animals of local use and importance), classification of habitats (often involving distinctions that cannot be easily recognized in remote sensing imagery) and assignment of importance for various use and non-use categories. Local ecological knowledge can be explicit in recognizing the threats to various biota. Sheil et al. (2002) found that 'low impact logging' that makes use of ridge tops for extracting logs rather than rivers in order to protect water resources, can have strong negative impacts ion the sago palms that tend to grow on ridges. In working with the local communities such effects can be easily identified, where a full biological inventory might not pick it up.

2.2.3 Belowground biodiversity a special case?

Where much of the public debate on biodiversity is focused on tigers, elephants, rhino's, panda's and orang utans, or medicinal plants, in the research community the interest has grown in less visible aspects: belowground biodiversity. The soil harbours an amazing variety of life forms, that play essential roles in the ecosystem as a whole. The impacts of land use change on this diversity are not as easily evaluated as the changes aboveground (Williams et al., 2002).

In the CSM-BGBD project, we aim to address both of these challenges, by going beyond the 'survey' stage into an exploration of the functional value of soil biota for farmers (pest and disease control, soil structure, C and nutrient cycling) and external stakeholders, and by using an operational version of the 'land use intensity' concept. The data in figure 8 refer to plant species richness in plots of standard size. Plants live both above and belowground, so plant species richness can be a first indicator of both parts of the ecosystem. However, aboveground parts of plants provide both the structure and primary production of food sources for all other parts of the ecosystem, and may thus be used as first indicator. Belowground, however, plant roots are only one of the contributing elements to the structure of the ecosystem, and provide only part of the energy basis for the food web. It is likely that changes in above- and belowground biodiversity can at least be partially uncoupled (Fig. 8). Again, there is little consistent data on this topic, so the data collection of the CSM-BGBD project may become a benchmark in the discussion on the topic (Bignell et al., in press; Gillison et al., in press). If the relation is as depicted in figure 8, we may tentatively conclude that hypothesis 3 holds for BGBD even in situations where aboveground biodiversity changes according to hypothesis 2.

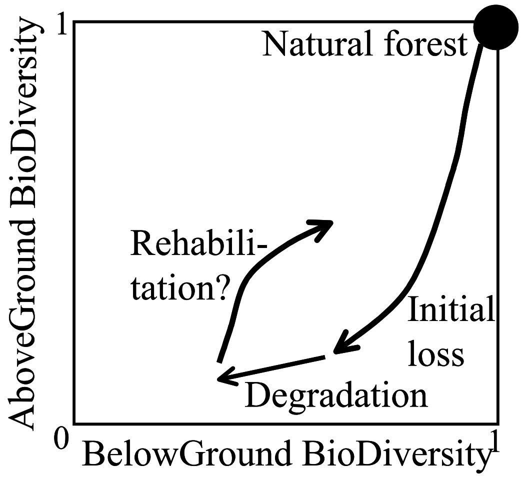


Figure 8. The dynamics of above- and belowground biodiversity may be partially uncoupled, as aboveground losses can be more rapid, but may also be more easily reversible

2.3 Carbon stocks

While the cumulative historical increase in the concentration of CO_2 in the atmosphere is due to 'deforestation' (or loss of terrestrial carbon stocks to be more precise) and use of fossil fuels in approximately equal shares, current emissions are dominated by the release of CO_2 from fossil fuel. These fossil fuels were formed in geological history, at times that green plants captured more CO_2 from the atmosphere than was released back by decomposition. At a geological time scale the concentration of CO_2 and the overall 'greenhouse' effect on global climate has fluctuated widely, and the current change, although rapid, will not make the planet earth unsuitable for any form of life – but the changes will be very disruptive for anything we currently know. The international convention on climate change has thus formulated targets for reducing global net emissions below the level of 1990.That target will not prevent measurable and substantial global climate change, but it was seen as the best result negotiators could achieve. As modest as the target in fact is, it will not be met in the agreed time frame. The key instrument of the 'global convention' is the so-called Kyoto protocol, ratified by nearly the officially required number of countries, but with the country responsible for the largest emissions no longer subscribing it.

The terrestrial biosphere was largely neutral with respect to net carbon exchange during the 1980s, but became a net carbon sink in the 1990s (Schimel et al., 2001). This recent sink can be largely attributed to northern extratropical areas, and is roughly split between North America and Eurasia. Tropical land areas, however, were approximately in balance with respect to carbon exchange, implying a carbon sink that offset emissions due to tropical deforestation. The evolution of the terrestrial carbon sink is largely the result of changes in land use over time, such as regrowth on abandoned agricultural land and fire prevention.

Forests in the humid tropics store more carbon in the woody stems of the trees than in the soil – but under wetland conditions the amounts may be equal and in peat swamp forest the aboveground portion is minor. Carbon stocks in wood can be destroyed overnight, while changes in soil carbon tend to be slower. The issue of whether soil or tree carbon is the primary concern thus vary with the situation and the time frame of consideration. Basic data on the carbon stocks associated with the major land use types on the tropics exist (Hairiah et al. 2001a; Palm et al., 2004). Values range from 350 Mg (megagram (10^6 g) or ton) of carbon per ha for old growth forest, via approximately 200 for forest under a 'sustainable logging' cycle, 50-150 Mg ha^{-1} for various forms of agroforest or tree crop plantations and crop/fallow rotations, to 0 – 20 for annual crops and perennial grasslands. Changes in soil carbon stocks that can be related to land use change are usually less than 30 Mg ha^{-1}.

The main positive impacts people can have on the amount of carbon stored in the terrestrial agro-ecosystem (and thus kept out of the atmosphere) are:

- C1. Protecting forest area
- C2. Protecting above- and/or belowground carbon stocks in areas used for forestry and/or agriculture
- C3. Restoration, increase in tree cover (in a 'sustainable harvest' regime the time-averaged C stock does not depend on the growth rate, but on maximum stock at time of harvest)
- C4. Accumulating wood and other products derived from recent plant production in, for example, the form of houses, furniture, paper, organic waste dumps.

Unfortunately, only C3 is currently recognized in the Kyoto protocol as a positive contribution to the global C problem that warrants 'rewards' (under a further set of conditions that will be discussed below).

Carbon sequestration by actively growing plants can be considered at 'process' scale. This brings about the need, however, to consider all the return flows of CO_2 to the atmosphere. If one wants to claim credit for the trees and other plants, one needs to take responsibility for the bacteria and worms involved in decomposition as well. So, the simplest way is to look at changes in 'stored carbon stocks' over periods of time that involve at least one yearly cycle of seasons. Still, with multiyear cycles of cyclones, earthquakes and natural fire cycles of 10 – 50 years, there is still a major conceptual challenge to balance the gradual increases in C stocks under 'normal' conditions from the 'abnormal' losses that form their counterpart. OK, forests may from that perspective not continue to sequester carbon – but if we harvest wood and preserve it outside of the forest we can claim an increase in the amount of carbon stored in the terrestrial urbo-agro-ecosystem. In principle this is a valid idea, although the proposed global book keeping systems for wood products are full of assumptions that are hard to check. The simplest way would be to measure the amount of stored carbon in houses, furniture, libraries and town refuse dumps, similar to the way we can measure C stocks in a forest. An interesting question in this regard is who is actually providing the carbon storage function: the forest manager who sells the timber, or the buyer who decides not to use the teak garden chair as firewood as yet.

As the forest manager has no control over the after-sale fate of wood, it is not logical to claim 'carbon credits' for such wood.

Adapting the generic scheme of figure 1 to the 'terrestrial carbon storage' issue in the context of mitigating climate change (Fig. 9), we have two main types of 'services': a change in the actual net

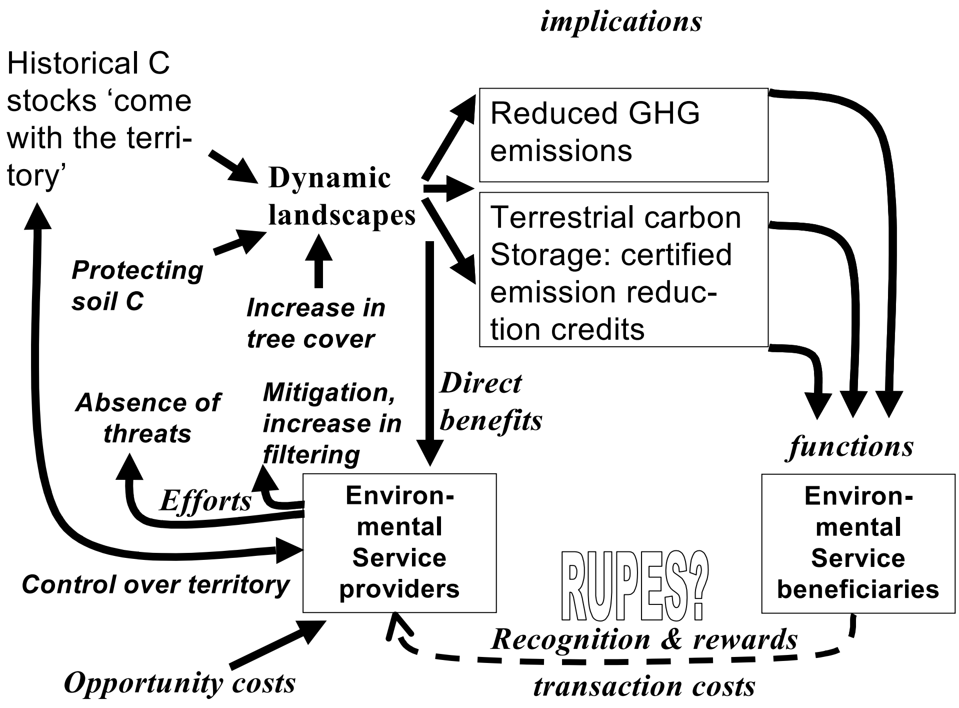


Figure 9. As Figure 1, but specific to the 'terrestrial carbon storage' function

Box 7. Rewards destroying the service

A major issue in deciding whether or not terrestrial carbon storage is a service that warrant rewards is the expectation that the 'reward' will actually be used to destroy the service and that thus the public at large may be better off without a reward system. In one form of the 'rewards destroying the service' syndrome the 'sellers of the service' use the rewards to destroy the service. An example can be found in the 'ecotourism' range, where additional income in the village is used to invest in loudspeakers and buildings that destroy the sense of quiet and aesthetic aspects that the 'ecotourists' appreciate. In another form of the syndrome it is the buyers of the service who 'consume' the service and destroy it from a global public goods perspective. With carbon credits the destruction of the service is done by the 'reward' givers. They 'buy' the certified carbon emission reduction amounts to meet their obligations to the global convention to reduce their net emissions – so they will continue to emit fossil fuel carbon to the amount stored in the new forest that was the basis for the certification. Is there any global benefit in this? Will there be less or more CO_2 emitted to the atmosphere as a result of this trade in certified carbon emission reduction amounts? Many critics of the system fear that this type of 'environmental service rewards' does represent a 'moral hazard', and that the net effect on global warming is negative or neutral at best. In fact this concern has been part of the design of the Marrakech implementation of the Kyoto protocol; most of the emission reductions have to be achieved through other means than increased terrestrial C storage. The 'additionality' criteria that were developed for the selection of Clean Development Mechanism activities largely derive from this concern.

emissions of greenhouse gasses from the landscape, and storage of carbon in terrestrial systems certified by international standards and used to comply with commitments emission reduction. Increasing tree cover and protecting soil carbon pools are the two main instruments for which ES providers can be rewarded. Fears over a 'rewards destroying the service' syndrome of C trade (Box 7) have led to a series of additional criteria in the global protocols. Terrestrial carbon storage can only be recognized if one finds a way to show '***additionality***', adequately deals with the 'risk' of a return flow of the stored carbon into the atmosphere and addresses the concern for '***leakage***' (increases of carbon stocks within the project domain that are directly linked to reductions in carbon stocks outside the project boundary, as may occur if people are simply moved out of a forest area). The 'additionality' concern is particularly tricky: one has to show that the increases in carbon stocks would not have occurred without additional incentives or project activities. Slightly exaggerating, this means: if the activity makes sense it would occur anyway, so only if it does not make sense will be provide rewards… The 'clean development mechanism' (CDM) is aimed at providing 'development benefits' to the countries where such projects are implemented in a way that is 'neutral' to the global environment (as the local gains by C sequestration will be used to offset commitments to reduce emissions elsewhere – hence the nickname 'chase dirty money'). Many political leaders in the (over)developed world still perceive that the measures required to reduce emissions will burden the economy; at time scales beyond a political election cycle, economists have argued that most of the adjustments required to meet the climate change agenda will pay back for themselves, but this view is not yet widely accepted. Given the complexities that surround

Box 8. Oxygen supply a 'forest function'?

The counterpart process of carbon sequestration is the release of oxygen to the atmosphere. Decomposition of the sequestered carbon will tend to re-use the same amount of oxygen as was produced. Popular accounts of 'forest functions' and benefits of having trees around, tend to include production of oxygen as a 'service' that should be included in 'valuing' trees and forests. People can't live without oxygen, so any increase in oxygen supply should be welcome.

Counter arguments are:

With over 20% of the atmosphere consisting of O_2 there is no shortage of oxygen, except in locations with poor atmospheric contact (in water, in wet soils, in closed air spaces), so only local supply within locations with shortages are relevant, not additions to the global atmosphere,

A doubling of atmospheric CO_2 concentration due to the oxidation of stored carbon (biomass or fossil fuels) will be linked to a change the atmospheric O_2 concentration of only 0.03%, which is negligible.

the issue of 'rewards for increased carbon stocks', it is understandable that the expectations for managers of tropical forests remain high – but hardly any actual reward has been provided, and none that has directly benefited the rural poor…. Carbon stocks are relatively easy to measure and assess, but translating this 'outcome' to a 'service' is not straightforward, and finding effective rewards for real efforts is marred with institutional and administrative complications.

A few words on the absence from our list of an 'environmental service function' of forests and trees that is often mentioned ion popular discourse: provision of oxygen (Box 8). There is no global shortage of oxygen and the impacts of vegetation on oxygen supply, though numerically equivalent to those on carbon dioxide, are negligible in view of the much larger atmospheric stocks.

Filter functions of removal of dust and aerosols from the air around places where people live can, however, be included in a list of 'filter functions' that provide real tangible benefits (along with filter effects for noise and light pollution)

2.4 Watershed functions

2.4.1 General

The broad category of 'watershed functions' may well be the first 'environmental service functions' that has been recognized as such, and it continues to be the one with the largest immediate relevance for people, especially for poor people who don't have the opportunities of the better-off to shield themselves from the impact of droughts, floods and poor quality of water. With strongly increasing demand for water and a constant supply, the prediction that conflicts over water are likely to increase is easily justified. Perceptions in the public and policy domain tend to differ from current science (Agus et al., 2004; Bruijnzeel, 2004; Calder, 2002; Swallow et al., 2001; Van Noordwijk et al., 2004a) as well as from local ecological knowledge (Joshi et al., 2004).

Watershed functions can be analyzed by following the flows of water through a landscape, with overland flow, subsurface lateral flow and (deep) groundwater flows (Fig. 10) having substantially different impacts downstream.

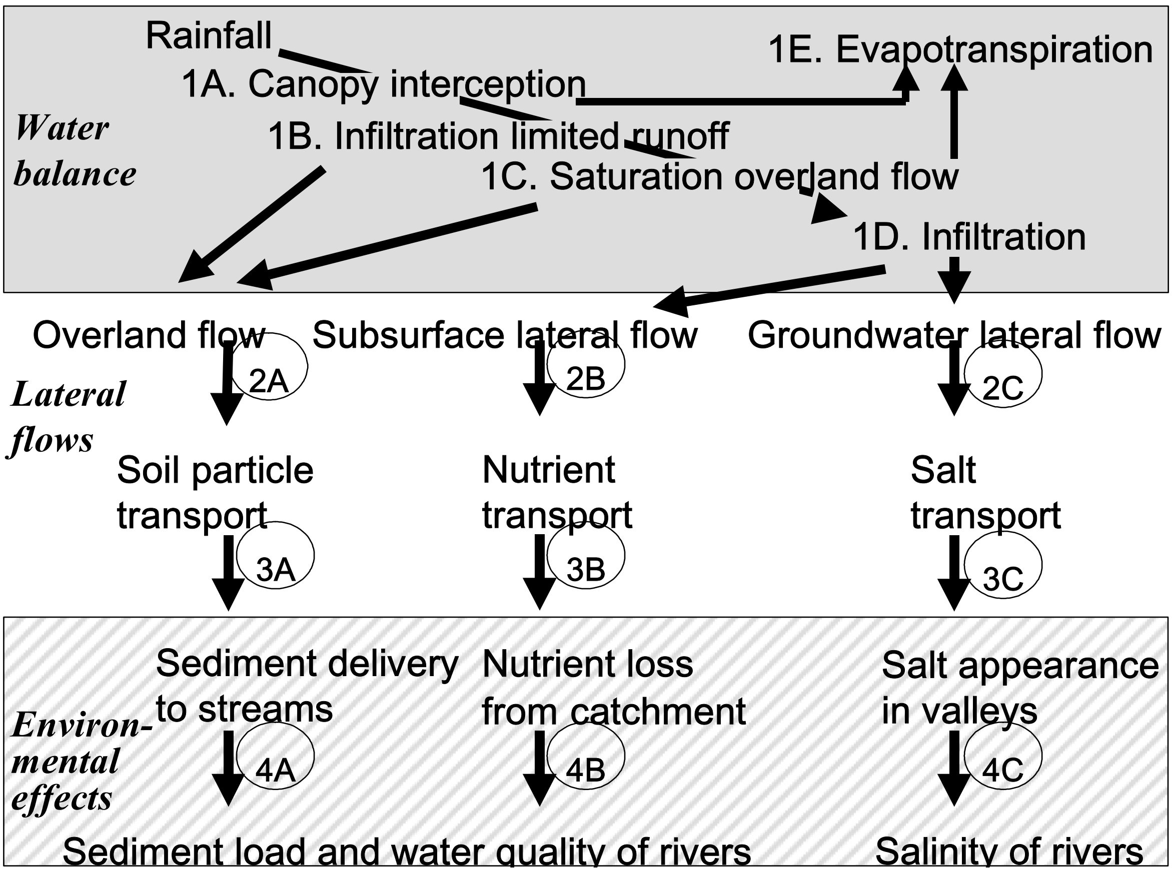


Figure 10. Relationships between the components of the water balance (at plot level), lateral flows of water, soil, nutrients and salt (at landscape level) and downstream environmental effects (modified from Ranieri et al., 2003).

A simple way to explore the overall concept of 'watershed functions' is first of all to look at the hydrological 'outcomes', in this case the flow of water coming bout of an area in rivers, and sometimes in subsurface groundwater flows. We can distinguish (Susswein et al. 2001; Van Noordwijk et al., 2004b) between the

- Quantity or total water yield

- Evenness of flow, which implies high flows in the 'dry' season and an absence of strong peak flows in the set season

- Quality of water, with respect to its use as drinking water, other domestic uses, industrial use, irrigation or as habitat for fish and other water organisms

These three aspects are influenced by land use to different degrees, and this has consequence for possible 'reward' mechanisms.

2.4.2 Total water yield

Rainfall varies between different parts of the earth, from approximately 0 to over 10 m of rainfall per year (that means that if rainfall would not infiltrate the soil or runoff laterally a lake of up to 10 m depth could be formed in a year, in the absence of evaporation at the surface of the lake).

Rainfall is usually expressed in mm rather than m, and is broadly linked to the type of natural vegetation: evergreen tropical forest usually requires rainfall amounts of more than 1500 mm year^{-1}, deciduous (= shedding leaves in an 'off' season) forest and savanna may grow in the 800 – 1500 mm year^{-1} range, and various forms of scrub or open vegetation in the 300 – 800 mm year^{-1} range. Below 300 mm year^{-1} very few crops can be grown without irrigation, and the natural vegetation will consist of short grass or desert specialists. As forests are associated with high rainfall, it may come as no surprise that the cause-effect relation has been confused: do forests cause rainfall? Or does rainfall allow forests to grow?. The perspective that deforestation will lead to a reduction of rainfall has a long history (elegantly reviewed by Williams in his book 'Deforesting the Earth'), but most evidence indicates that effects are hard to prove against a considerable 'background' variability of rainfall; effects are likely larger in 'continental' areas such as the Amazone domain (and even there likely to be less than 10% of annual rainfall) than in 'insular' areas wit a large influence of the sea despite the large scale at which the 'experiment' of deforestation has been implemented, first in Europe, than in north America and currently in the tropics.

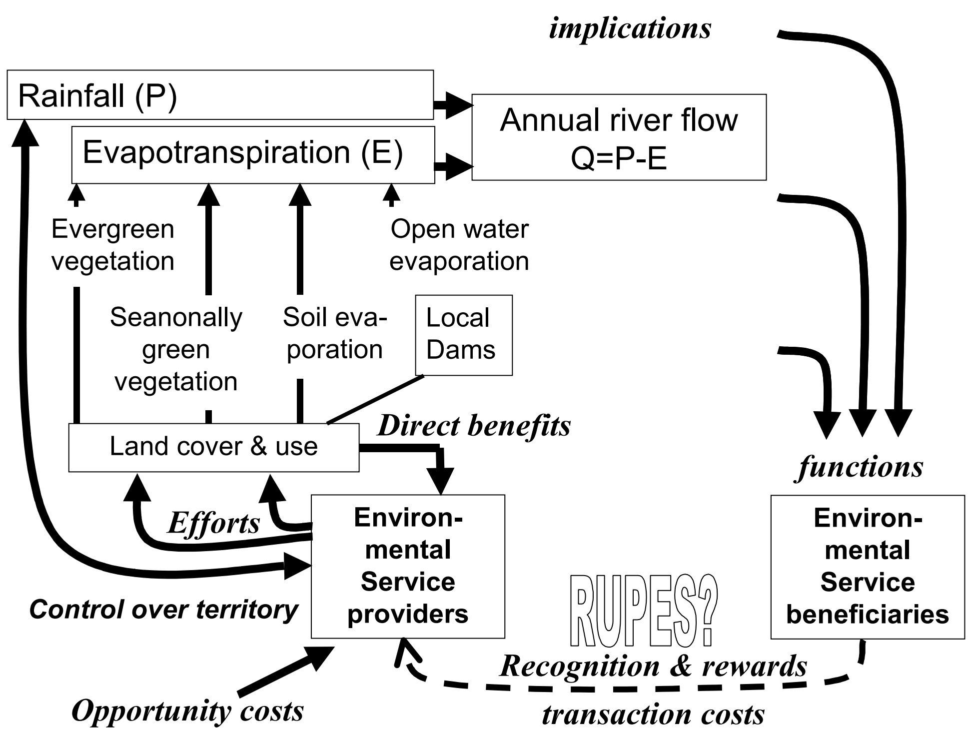


Figure 11. As Figure 1, but specific to the 'water quantity' function

Current evidence points to clear relations at global scale, with atmospheric circulation and thus rainfall zones shifting even if the total rainfall may not change much Some places definitely have become wetter, others drier, and future changes may add to variability, even if the direction of change for specific locations is not clear yet. These real changes in climate have coincided in many parts of the tropics with real changes in forest cover – even though the causal link is indirect, via global climate change. The continued perception of a direct link between local land use change and local climate is thus understandable, but real effects at this scale are unlikely to be large, if they exist at all. There is significant although still not definitive evidence of sub-global climate change linked to land use changes ('tele-connections'), related to atmospheric circulation patterns, between for example the Amazon basis and an area to the northeast of the Caribean islands. If we take for granted that effects of local land use on total annual rainfall are small, the main effect on total water yield of a catchment area is a change in the rate of evapotranspiration, or the return flow of water molecules to the atmosphere. In a simple equation: Q = P – E, or the total water yield (surface rivers+ groundwater flows) equals precipitation (rainfall plus snow and ice, which in most parts of the tropic can be ignored) minus evapotranspiration. That leads to the scheme in figure 11.

Four classes of land cover can be distinguished from the perspective of evapotranspiration:

- open water bodies, where water loss is determined by the relative humidity of the air and the presence of a stagnant boundary layer of air that reduces the transport of water vapour,
- open soil, which may have a rate of evaporation similar to open water bodies when the surface is wet, but where evaporation may rapidly become limited by the rate of transport to the soil surface; soil cover with a litter layer provides a stagnant air zone, further reducing transport opportunities and mixing with the atmosphere
- seasonally green vegetation: most plants are able to provide their leaves (evaporating surfaces) with the amount of water that is needed for evaporation similar to an open water surface, during most of the rainy season; during periodic dry spells, plant transpiration is likely to drop below the value of open water, but stay above that of open soil,
- evergreen vegetation such as evergreen trees (e.g. pines, eucalypts, trees such as grevillea), irrigated rice paddies or vegetable crops will have a rate of transpiration equal to that of open water, or higher if lateral flows of dry air drive the evapotranspiration per unit area to higher levels.

Efforts of land users that will reduce evapotranspiration and thus increase total water yield may thus be found in ***not*** planting evergreen trees (especially fast growing ones), or ***not*** irrigating rice paddies or vegetable crops in the dry season.

The differences in total water use between different types of vegetation (deciduous or evergreen) are often less than 300 mm year^{-1}. In a climate zone with a n annual total of 1500 mm year^{-1}, such a difference is likely to be noticeable (and many villagers complain that reforestation with pine trees or eucalypts reduces dry season flow or total water yield – even though the public and forest service tends to believe that such trees will increase water yield….). In climates with higher rainfall the same absolute difference will be smaller relatively speaking., and may drop below the threshold of what people can notice and care for.

Overall we can say that the total water yield of any 'catchment' area is largely determined by rainfall and thus outside of the control of any local land users. The difference that land cover can make is fairly well bounded (less than 300 mm year^{-1}), and rewards for efforts may have to focus on this difference against baseline, rather than at the total volume that actually comes out of a watershed (unless we attribute a greater influence to 'human rainmakers' than most of them would subscribe to themselves).In areas with an annual rainfall below 1500 mm year^{-1} the additional water use by early stages of plantations of fast growing trees may be a valid concern.

2.4.3 Evenness of water flow

Floods alternating with droughts – that is the general picture of 'disturbed watershed'. When we make a comparison across the tropics, however, we see that not only the total amount of rainfall per year varies over more than two orders of magnitude (i.c. from 0.1 – 10 m year^{-1}), but also the variability: the number of dry and wet months can vary quite independently of total rainfall (giving rise to various climate classification schemes that use the number of dry and wet months rather than total rainfall). Evenness of river flow, in the sense of a continuation of flow during dry months and an absence of high peaks and floods in wet months, may thus be largely attributed to the local climate – and thus to the 'natural capital'. Land cover, and thus the decisions of local 'actors' will influence the degree of 'buffering', but we need to carefully tease out the part that can be influenced, if we want to get a clear basis for 'rewards'.

A straightforward way to define 'buffering' is to compare the total quantity of river flow at above-average rates, with the total quantity of rainfall at above-average rates. Buffering equals 1 minus the ratio of these two quantities, both expressed in mm year^{-1}. As daily rainfall data are most widely available, we can take this time step as a basis for the calculations of what is above average river flow or rainfall. A fully 'asphalted' watershed where river flow directly follows rainfall may have a buffering of 0, a watershed that provides constant river flow regardless of the rainfall pattern has a buffering of 1. Real watershed will be in between these two extremes.

With this definition of buffering, we can further analyze a range of influences. Land cover is important, especially where it influences the rate of infiltration of rain into the soil, by maintaining a good soil structure (one can argue whether it is the earthworms that do this, the trees that feed the earthworms, or the farmers that plant the trees, but that is another story). But the basic make-up of the landscape, the depth of soil over bed-rock, the slopes, and the type of soil (soil texture, specific soil horizons that don't allow water to penetrate all influence the degree of 'buffering'. A further influence on 'buffering' is the degree of spatial correlation of rainfall: where rainfall is dominated by 'fronts' large areas may receive rainfall on the same day; where (convective) thunderstorms dominate, a strong 'patchiness' of rainfall may cause different streams to carry water at different days and a river that integrates across these streams to be relatively stable – even without forest cover.

If, hypothetically, rainfall would be a constant amount every day, the watershed will not be able to express any 'buffering', and the buffering would be zero. With this definition we can explore 'buffering' as the resultant of:

Site

- local rainfall regime (and its temporal autocorrelation)
- underlying landscape and geology that determines release of groundwater

Scale

- size of the catchment (upstream of the observer/stakeholder) relative to the spatial autocorrelation of rainfall

Land Use

- infiltration and supply to groundwater as potentially influenced by vegetation and land use
- the properties of the riverbed (and temporary storage) that dominate pulse transmission

Engineering

- any regulating structures or dams in the river

We can thus separate the 'buffering component' that is attributable to land use (and thus to ***human*** '***environmental service providers***') from those that '***come with the territory***' but do not reflect any specific effort (and thus form no basis for ES function rewards…). Figure 12 specifies the relations for 'evenness of flow'.

Buffering, according to our definition, will thus depend on the location of the observer relative to the watershed. The further away, the more even the river will tend to be, and the less obvious effects of land use change may be. Current research is trying to quantify these relations, but empirically good evidence for changes of land use on evenness of flow exists for catchments up to 100 km^2 and little or none for catchments of more than 1000 km^2.

With current hydrological models it is possible to determine which part of the overall degree of 'buffering' that an observer at a certain distance from a 'catchment area' will perceive can be directly related to the land use in the catchment, with a specific role for the riparian vegetation in and around the riverbed. Slow transmission of water, linked to trees and dead wood in the channel, may cause local flooding, but increases the evenness of flow of a downstream observer (again clarifying that we need to be explicit about the point of observation or the location of the stakeholders before we can quantify 'evenness of flow').

2.4.4 Water quality

Water from forests streams can be directly suitable for drinking, if one can be sure no people live upstream. Otherwise, surface water is hardly ever directly suitable for drinking – even if many people in rural areas are in fact relying on it.

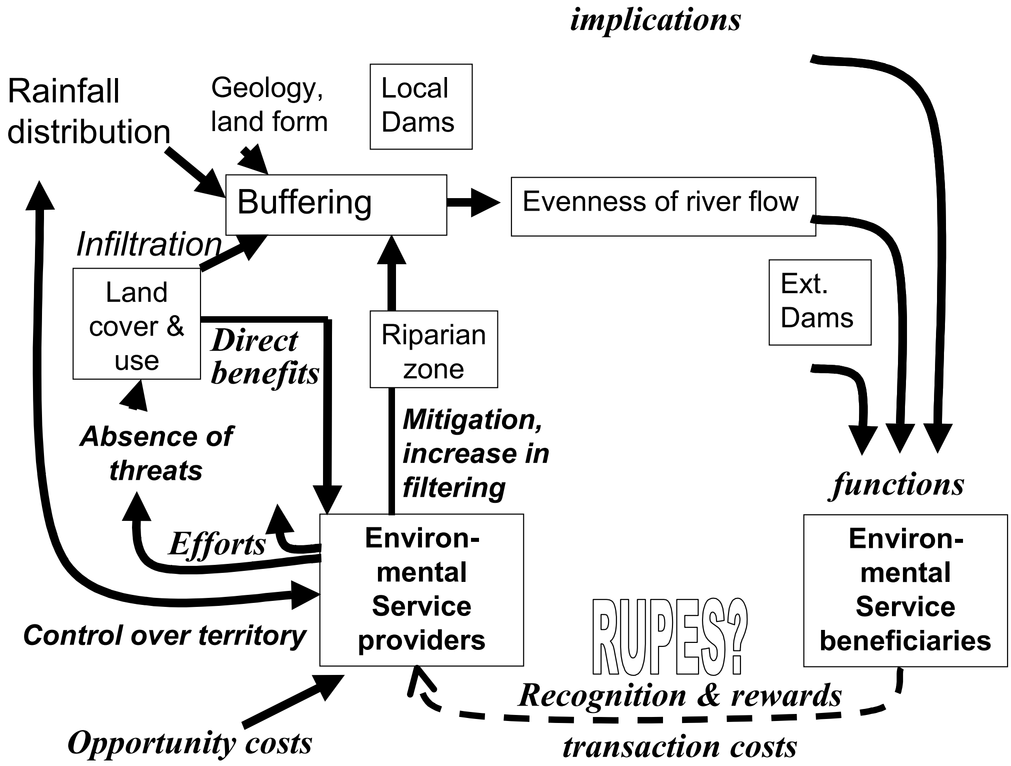


Figure 12. As Figure 1, but specific to the 'evenness of water flow' function

Water from wells that tap into subsurface flows of water or groundwater may be safe, as long as the filter effect of the soil surrounding the well is not overcharged and the distribution pathway of the water is kept clean. Below the standards for safe drinking water, a range of other uses have less stringent criteria for quality:

- other domestic use
- fishponds and drinking water for domestic animals
- industrial processes
- irrigation
- cooling systems
- filling a reservoir for future use (but allowing sedimentation and other changes in water quality to occur)

Where water from watersheds with natural vegetation may meet the criteria for all, human activity in watersheds may decrease water quality before it has any substantial effect on the other watershed functions (Fig. 13). Where point sources of water pollution can be many orders of magnitude above the detection capacity, it is understandable that long range effects of land use on water quality have been recorded, at least to catchments of 10^5 km^2.

Pollution of water can be a consequence of mining (especially where mercury (Hg) or cyanide (HCN) are used for gold mining in riverbeds…), use of pesticides and fertilizer (especially in the quantities often used on vegetable crops) and people living around streams and using the streams for personal hygiene. More directly linked to land use, erosion in its various forms (sheet erosion, gully erosion and collapse of river banks) can increase the 'sediment load' of rivers. Disturbance of groundwater flows by agricultural crops that use less water than the native vegetation that they replaced can bring salt into circulation, especially in drier climates with deep salt deposits.

'Absence of threats' is thus the key way to provide the 'watershed function' of delivering clean water. For some forms of pollution, especially where 'sediment loads' are due to sheet erosion, vegetation around streams and rivers, in the riparian zone, can perform a (partial) filter function and reduce the load of the river. Increasing the effectiveness of such filter vegetation can thus, under specific circumstances, be seen as 'enhancing watershed functions'.

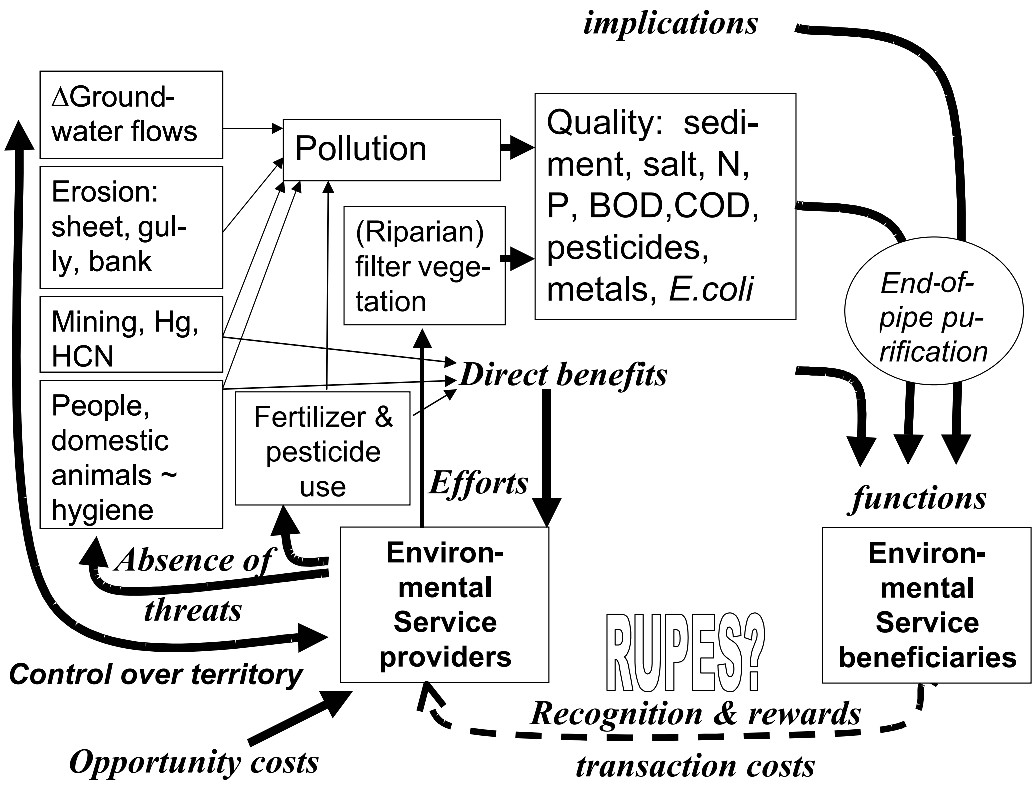


Figure 13. As Figure 1, but specific to the 'water quality' function

A wide range of measurable indicators of water quality is available and mostly used for testing the safety of drinking water. River water of very low quantity can still be made suitable for consumption by technical means, relying on filtration in sandbeds, aeration and specific chemical processes. This 'end of pipe' solution can be used as a point of reference for the economic valuation of the provision of clean water (that requires less intensive or no treatment).

2.4.5 Watershed protection

The general public and policy perception of 'watershed protection' does not rely on the previous three outcomes, but rather specifies a desirable condition within the watershed (usually 'forest') – with all reductions in forest cover associated with a loss of 'watershed functions'. A recent declaration of forests and water (Box 9) appears to imply that 'non-forests' cannot meet any of the 'forest watershed functions'. In that sense it seems that the debate has not progressed much since De `Haan (1936) wrote in his 'contemplations on the issue of forest reserves' in Indonesia:

> "There has been too much emphasis on the contrast between "forest' and "non-forest". One often supposed that as long as a certain percentage of an area was reserved as 'protection forest', agriculturalists outside of that area could do as they wished. Nothing is further from the truth. The difference in hydrological behaviour between a montane forest and for example a rubber garden is certainly much smaller than that between this rubber garden and the cropped fields of a smallholder."

Maybe the clearest functional relation between trees (especially deep rooted ones) and the integrity of watersheds is found in the prevention of superficial ***landslides***. Landslides can occur on any slope if the weight of a soil column after heavy rainfall is greater than the 'sheer strength' or the resistance to movement.

Deep rooted trees can provide 'anchoring' of the top 1 – 2 m of soil layers and prevent their movement. When the trees are cut (especially in a 'clear cut' affecting all trees on a slope) the propensity for landslide will increase – especially when after a few years, the deep roots decompose and loose their anchoring function.

Box 9. Chambéry Declaration on "Forests & Water " in the International Year of Fresh Water 2003

The following declaration was adopted at the International Workshop on Forests and Water, Chambéry, France, 5 and 6 June 2003, with a view to reinforcing collaborative and supportive mechanisms among all related actors in the sustainable management of forest and water resources, taking into account international initiatives related to forests and water.

Background

Supplies of fresh water are unevenly distributed and increasingly in demand. Sustainable forest management is considered a key to water resources management in particular and to upland resources development in general. It is tightly linked to watershed development. Forested catchments supply water for domestic, agricultural, industrial and other needs in downstream areas. Forests and forested watersheds play essential roles in sustaining and protecting water supplies. Well-managed forests have a ***direct*** impact on the quality of ***water yields*** from watersheds and on the ***regulation of flows***. They also ***mitigate the effects of soil mass movements, rock falls and avalanches*** and contributes to soil erosion control, and consequently to reducing ***downstream sediment transfers***. All these forest services related to water may be better identified within a watershed framework, linking upstream and downstream areas. Although forest and water resources are inextricably linked, they are rarely managed in an integrated way.

A growing number of factors influence forest and water resources, including: climatic variability, local- or larger-scale pollution and fires, deforestation and changes in land use, demographic trends, conflicts, market and short-term economic factors, the development of infrastructure and tourism, insufficient participation of local actors, lack of political vision, and shifts in societal expectations.

Recommendations

A major conclusion of the Workshop is that continuous and determined efforts are needed to integrate the management of these vital resources for sustainable development.

In order to reach such an objective, participants highlighted the following:

1) The watershed perspective is best suited to achieve this integration, which often implies the need to ***overcome administrative and political divisions*** and compartmentalization.
2) Participative and cross-sectoral mechanisms, as well as exchanges of experiences, are needed to provide ***beneficial interactions among stakeholders***.
3) The ***full value*** of water-related services derived from the management of their forests by owners (private and municipal) and local populations should be recognized.
4) It is critical to develop and implement national and sub-national policies, programmes and strategies for ***integrated management of forest and water resources***. Such policies and strategies could benefit from international initiatives such as those referred above.
5) ***Solidarity*** among countries in this area should be developed in the financial, technical, educational and training fields.
6) ***Relevant data*** should be made available to facilitate assessment of the results of ongoing initiatives. Pilot sites, such as those identified within the joint UNESCO-World Meteorological Organization (WMO) Hydrology for the Environment, Life and Policy (HELP) initiative are effective means to these ends.

Under specific conditions large trees, e.g. growing on riverbanks, can be a cause of 'mass wasting', as they become unstable and fall over, lifting a considerable amount of soil still attached to their roots.

Many landslides, however, are linked to road construction cutting into slopes and interfering with the mechanical stability. Landslides are common in natural vegetation on steep slopes (and geologically young or volcanically active mountain areas), but are usually interrupted by vegetation downhill that can act as a 'filter'. During earthquakes or extreme rainfall for several days, such filters may loose their effectiveness. After forest clearing, landslides can more easily increase in size, and lead to major mudflows destroying everything in their path. Reducing human damage by landslides can be achieved first of all by not building houses in vulnerable sites. In general, avoiding clear felling of forests on slopes will reduce landslide risk. A substantial length of time of observation may be needed, however, to actually proof changes in 'landslide risk'.

'***Erosion control***' is often included in lists of watershed functions, and as positive attribute of forests. In evaluating this as an 'environmental service function', we need to be careful. Erosion tends to reduce the future fertility of the eroding site – but this will be the immediate concern of the farmer on the site, rather than outside stakeholders. In the longer run, however, erosion may increase the 'land hunger' that drives further forest conversion, along with population growth and increased demands for per capita production. Similar to the 'existence value' in the biodiversity function, one can argue that knowledge of the preservation of topsoil has value to outside stakeholders. Further rationalizations of such value can be derived from the need for farmers to clear further forestlands as a consequence of loss of on-site productivity. The causal chain in these cases is rather complex. In the absence of filter vegetation surrounding the plot, or in the pathway between plot and stream, erosion can increase sediment load of the river and thus reduce water quality.

While erosion rates under most types of forests are low, there are some notable exceptions in forests that do not have an understory or permanent litter layer. Drips falling from a tree canopy after rainfall can actually have a higher splash impact on the soil and lead to greater erosion than would have occurred without (plantation) forest. A simple criterion for absence of erosion is the presence (throughout the year) of a litter layer. This works in two ways: it is an indicator that there is little overland flow (otherwise the litter would be washed away) and it contributes to the activity of soil iota that maintain soil structure and infiltration rates for water. The watershed function 'prevention of erosion' may thus be better linked to the litter layer than to the presence of trees as such.

Overall, we can conclude that the holistic concept of 'watershed functions' that require 'intact forest' and 'absence of human activity' refers to only one way of maintaining measurable outcomes in the range that is acceptable to downstream stakeholders. Depending on the rainfall, landscape properties and the distance to the watershed area, quantity, evenness and quality of the water in the river can be maintained in landscapes that are used for forms of agricultural production. Key locations for maintaining forest cover are:

- around springs,
- tops of the ridges and hills, and above main groundwater flow pathways if clean groundwater is important ,and
- riparian forests for filter functions and slow pulse propagation.

Outside of these three 'keystone' locations, we may need enough tree cover to maintain a permanent litter layer and thus infiltration conditions, but the need for this depends on soil type (propensity to loose its structure and infiltration capacity) and rainfall distribution.

2.4.6 Environmental flows

In the discussion so far we have focussed on 'services' provided by a part of the landscape to human stakeholders downstream. There is, however, an equivalent concern over the impacts of human water use and hydrological alteration of rivers on aquatic and marine ecosystems 'downstream' of human systems (agricultural, urban). These concerns over the quantity and quality of water required for ecosystem conservation and resource protection may be expressed in terms of the 'normal' functioning' of these systems and/or in the human implications of a change in function. The issue is often discussed under the heading 'environmental flows'. Tharme (2003) provided a global perspective on 'environmental flow assessment' and discussed emerging trends in the development and application of environmental flow methodologies for rivers.

3 The classification system used for Millennium Ecosystem Assessment

The global Millennium Ecosystem Assessment (MA) aims to analyze the relationship between the ecosystems of the world and human welfare at the start of the third Millennium. The typology of 'ecosystem services' starts from a human perspective: provisioning, regulating and supporting are the high level concepts used (Table 2)

Table 2. Ecosystem service classification used for Millennium Ecosystem Assessment

	Equivalent in Table 1
PROVISIONING SERVICES	
Food: crops, wild fruit and vegetables, meat, fish	P1
Fiber: 1. fuel wood and charcoal 2. timber for construction and furniture 3. for textiles and paper	P1
Feed: fodder	P1
Fresh water, water supply	W1
Biological products 1. biochemical, medicines, pharmaceuticals 2. ornamental resources	B2 / P1
Genetic resources	B1
Minerals, sand and non-living resources	P2
Other	
REGULATING SERVICES	
Air quality	W7, H2
Climate	
1. water flow	W2, W3
2. water purification	W4
3. carbon sequestration	C3
Erosion control	W5
Regulation of pests and diseases in:	
1. humans	H1
2. their domesticates	P2
Detoxification	H2
Other	
SUPPORTING SERVICES	
Soil formation	P3
Nutrient cycling	P3
Pollination	P4
Primary production	P1
Other	
CULTURAL AND SPIRITUAL	
Spiritual and religious values	H3
Recreation and ecotourism	H4
Inspiration and aesthetic values	L1
Sense of place and culture: 1. cultural diversity and identity 2. cultural heritage value	L1
Knowledge systems: ecological knowledge	H5

The MA scheme can be reconciled with the ASB scheme of Table 1, as indicated in the right-hand column of Table 2, and illustrated in Fig. 14.

The analysis of the Millennium Ecosystem Assessment as well as others (Tomich et al., 2004) indicates a clear need to link the human impacts of changes in ecosystem (or environmental) services to the direct and indirect drivers (Fig. 15). This is in a nutshell what 'rewards for environmental services' tries to do. Before we explore the possible range of mechanisms, we need to have a clearer sense of the relationship between poverty and (lack of) environmental services.

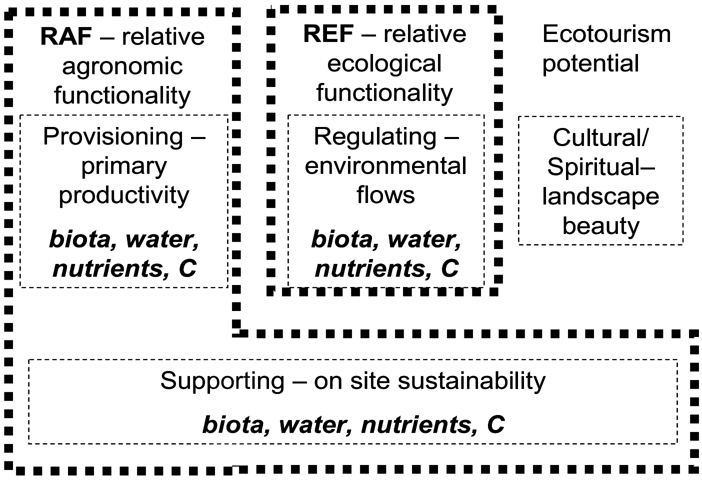


Figure 14. Tentative grouping of the four categories of environmental services as distinguished by the Millennium Ecosystem Assessment (Table 2) into 'relative agronomic functionality' or RAF and 'relative ecological functionality or REF, with the cultural/ spiritual values and landscape beauty linked to 'ecotourism potential'

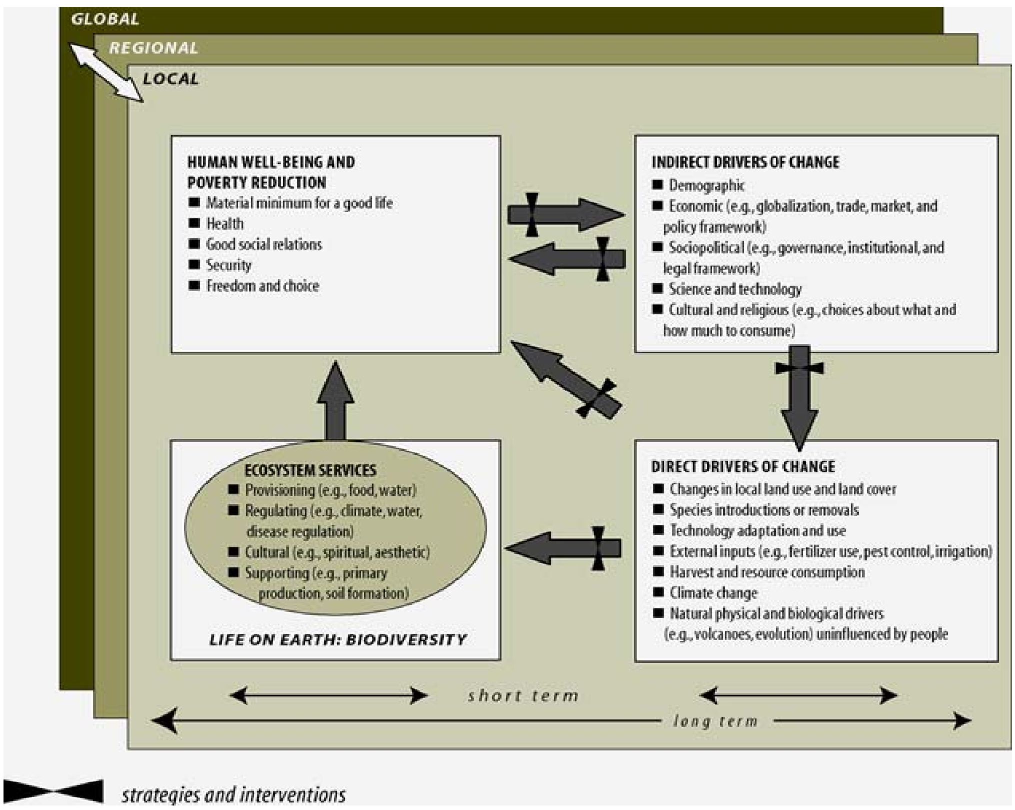


Figure 15. Relationships between the existing environmental service functions and the direct and indirect drivers of change in the conceptual scheme of the Millennium Ecosystem Assessment (Alcamo et al., 2002)

4 Poverty dimensions and environmental service levels

We follow the 'sustainable rural livelihoods' framework that was developed by DFID and recognize five types of 'capital' or assets. Poverty is defined as a critical lack of any of these five types of capital (Fig. 16).

In this context we may distinguish a number of 'syndromes' of poverty, linked to different parts of the landscape:

- ***Urban poverty*** – normally depending on the 'informal economic sector', urban poor tend to live in slums, often exposed to flooding risk, poor quality of drinking water, poor quality of air, soil pollution, unsafe food sources and other negative side effects of the 'development' that attracted them to move to the city in the first place; many of these environmental aspects of urban poverty can be addressed by local interventions (once a place for living is secured), but some require improvements outside the urban environment that enhance 'environmental services', especially in watershed functions.
- ***Poverty in high potential, intensive agricultural areas*** – landless labourers in landscapes with intensive agriculture may have a (seasonal) source of income from farm-work and may be relatively 'food secure', but their livelihood opportunities are constrained by a low quality of water (due to pollution of surface and groundwater), poor nutrition (due to loss of landscape level sources of vegetables and fruits); depending on the elevation these areas of intensive agriculture may specialize in irrigated rice (generally below 1000 m a.s.l.), vegetable production (highlands) or other enterprises
- ***Poverty in less intensively used or degraded agricultural areas (dry-land, upland)***. Linked to the lower value of land, landlessness is less common, but the inadequate production of food may lead to food insecurity, while income opportunities in off-farm labour are limited; use of fertilizer and pesticides is less of a concern for the quality of water and foods, but soil degradation and erosion may have a negative effect on surface water quality,
- ***Wetlands and small islands*** form a separate form of these less intensively used

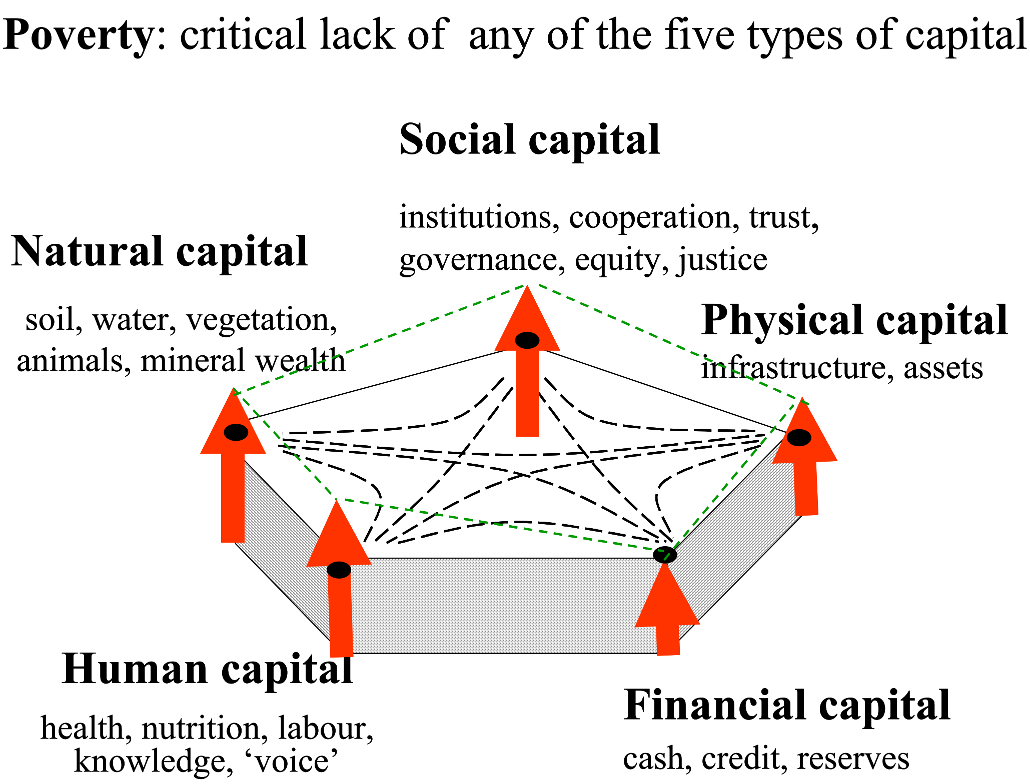


Figure 16. Five types of capital that can contribute to 'sustainable livelihoods' and, inversely, can define 'poverty'

areas, as poor physical accessibility restricts access to health and educational services, while they are vulnerable to changes elsewhere in the landscape affecting the regularity of river flow; they are specifically vulnerable to sea-level rise in response to global climate change; coastal forests and mangroves play specific roles in protecting the hinterland and for reproduction of fish, so coastline rehabilitation may qualify for environmental service rewards from interest groups in fisheries or (in specific areas) interest groups linked to coral-reef biodiversity.

- ***Core forest and/or mountainous areas*** have almost by definition low accessibility and low quality of education and health services, but people living here may still have a varied diet and may not be food-insecure. Many of the remaining forest areas represent areas of specific interest for global biodiversity protection, while they tend to have high rainfall and thus provide water to streams and rivers, usually of good quality.

In table 3 these 'poverty syndromes' are described with respect to the way that environmental degradation is a contributor to poverty (and hence environmental improvement can reduce poverty), and the degree to which the landscape can provide environmental services and thus qualify for 'rewards' of one form or another. These five 'syndromes' are points in a continuum, and at this stage it may not be particularly useful to define sharp boundaries between them.

Table 3. Poverty syndromes in different parts of the landscape and potential relevance of 'environmental service rewards' for reducing poverty (through the improvement of the environment that follows from these rewards, or directly from the rewards)

Syndromes of poverty	**Affected by environmental degradation – potentially benefiting from environ-mental improvement**	**Opportunities for 'environmental service' rewards'**
Urban areas (often recent migrants from low-opportunity agricultural areas)	Exposed to flooding risk, low air quality, soil pollution, poor-quality foods	'Food for work' type efforts in cleaning up river channels, rehabilitating urban environment
High potential agricultural areas	Low quality of drinking water, lack of nutritional balance	Reducing pollution of streams, rivers and groundwater
Low potential or degraded agricultural areas	Low reliability and quality of water supply	Kyoto-protocol based C storage rewards (if deforested before 1990), Improvement of water quality by restoration/ maintenance of riparian zones and infiltration Eco-labelling for premium product prices Public investment in 'reforestation' and 'watershed rehabil-itation' in 'critical lands' Under specific conditions: Eco-tourism opportunities
Wetlands and small islands	Vulnerable to sea-level rise (global climate change)	Inland wetlands as buffers in river flow and as sources of endemic biodiversity or stopovers for migratory birds Coastal protection reforestation for protection of hinterland, migratory birds, fisheries and coral reefs Eco-tourism opportunities
Remote core forest areas	Conversion of currently used forests to other land use (either protected forest or non-forest) will reduce access to forest resources	Biodiversity reservoirs, source areas of river flow, influencing regularity of flow and probability of landslides Eco-labelling for premium product prices Eco-tourism opportunities

Table 4. Major farming systems in East Asia and Pacific (source: Dixon et al. 2001); NB the data on area and population size include all of China and the Koreas

Farming system	Areal extent (% of land area in region)	Rural population, population density (% of total)	Principal livelihoods	Prevalence of poverty
1. Lowland rice/urban	197 M ha (12 %)	474 M 241 km^{-2} (42 %)	Rice, maize, pulses, sugarcane, oil seeds, vegetables, livestock, aquaculture, off-farm work	Moderate
4. Upland intensive mixed (***incl. major areas outside of the tropics***)	314 M ha (19 %)	310 M 99 km^{-2} (27 %)	Rice, pulses, maize, sugar cane, oil seeds, fruits, vegeta-bles, livestock, off-farm work	Extensive
5. Highland extensive mixed	89 M ha (5 %)	47 M 53 km^{-2} (4 %)	Upland rice, pulses, maize, oil seeds, fruits, forest products, livestock, off-farm work	Moderate
2. Tree crop mixed	85 M Ha (5 %)	30 M 35 km^{-2} (3 %)	Rubber, oil palm, coconuts, coffee, tea, cocoa, spices, rice, livestock, off-farm work	Moderate
8. Sparse (forest)	172 M ha (10 %)	23 M 13 km^{-2} (1 %)	Hunting, gathering, off-farm work	Moderate
3. Root – tuber (PNG)	25 M ha (2 %)	1.5 M 6 km^{-2} (< 1%)	Root crops (yam, taro, sweet potato), vegetable, fruits, livestock, off-farm work	Limited
***Others* (mostly non-tropical China)**				
6. Temperate mixed	6 %	14		Moderate
7. Pastoral	20 %	4		Extensive
9. Sparse (dry)	20 %	2		Extensive

Hadi and van Noordwijk (2005) combined four data sources: the FAO classification of agro-ecological zones ('agro-ecosystems' or 'farming systems'; Table 4), district level human population data, the IGBP land cover classification and a coarse digital elevation model. Overlays were used to estimate the number of people and area involved in combinations such as 'lowland rice below forest', 'lowland rice below upland crop mosaics' or 'lowland rice below tree crops', as well as the actual forest cover fractions in each of the agro-ecological zones. Overall, 80% of Indonesia's population is directly linked to the potential downstream – upstream conflicts associated with the land use in upland crop mosaics. The data suggest that 50% of Indonesia's population live in lowland rice agro-ecosystems (>700 persons km^{-2}) with 'upland crop mosaics' (~ 150 persons km^{-2}) as their upstream neighbours; 23% live in these mosaics and another 8% in tree crop systems downstream of the upland crop mosaics (Fig. 17). Area-wise the lowland side of the rice - upland combination covers only 7.1% of the total land area, and on Java involves 4.1 person in the lowland per person in the uplands. Lowland rice agro-ecosystem downstream of the 'forest' agro-ecosystem cover only 3.1% of the area and involve 3.2% of the population, but they have a lowland: upland person ratio of 33 which offers better (per capita) prospects for effective 'rewards' in the uplands for maintaining watershed functions.

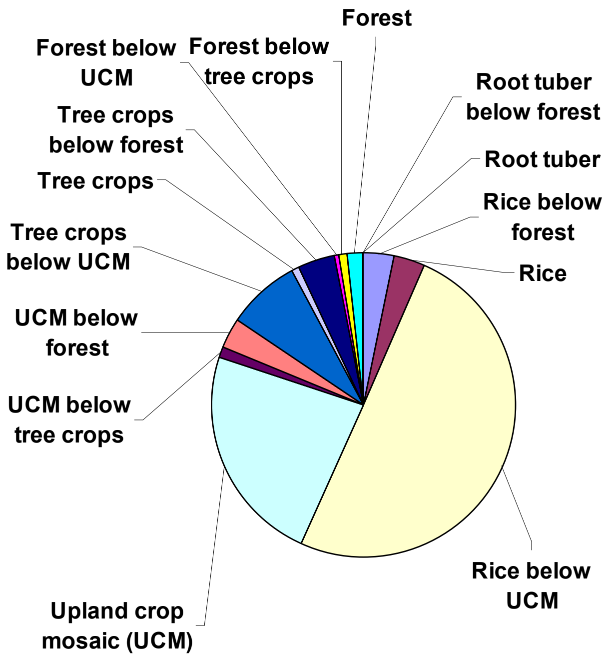


Figure 17. Distribution of Indonesia's population in 1995 over various 'upland' – 'lowland' combinations at the overall farming system level (Hadi and van Noordwijk, 2005)

From a biodiversity perspective, the combination of 'tree crops' and 'forest' in the same watersheds may be of specific interest. This involves 18.5% of the land area and 4.8% of Indonesia's population. Actual forest cover within the various agro-ecosystems varies from 35 % in the lowland rice agro-ecosystem, via 46 % for the upland crop mosaic and 48% for the 'tree crop' zone to 75 % for what is classified as the 'forest farming system'. At the smaller scale, these remaining forest areas within the agriculturally used and productive landscape may be the focus of 'environmental service function' analyses, focussing on 'landscape agroforestry'.

5 Environmental service reward syndromes

5.1 Protection or rehabilitation

When we compare the various environmental services we can see that all somehow vary from location to location, and depend on the 'natural capital'. However, the relative influence of human efforts (avoiding negative and stimulating positive impacts) differs substantially between the various services (Table 5).

Table 5. Indicative ranking of the various 'environmental services' to the degree they are based on 'natural capital', avoidance of negative human influence and opportunities for positive human effort

	Natural capital	- Human effort: avoid negative impacts	+ Human effort: opportu-nity for positive impacts
Biodiversity	+++++	---	+
Landscape beauty	++++	--	+
Clean air: absence of Smoke/Haze	+++	----	0
Landslide probability	++++	--	+
Total water yield	+++	-	+
Regularity of water flows	+++	--	++
Quality of surface water	++	----	+
Increased C storage	+	-	++

These differences may have important implications for the type of 'environmental service recognition and rewards' that are feasible. Where the service essentially depends on '***natural capital***' the '***owners of the land***' can claim the main credit. Where 'ownership' is often contested between different systems of '***legality***' (e.g. the nation state may claim ownership based on the constitution, while other groups have 'historical claims'), resolution of tenure conflicts may be needed before ES rewards for 'natural capital' are likely to have positive impacts (rather than aggravating conflict; Box 10).

Where '***avoiding threats***' is the dominant feature of the maintenance of the service, the basis of the rewards changes towards the '***guardians***' of local rules and institutions that regulate the behaviour of individuals. Paying individuals for not committing crimes is not a viable option; rewarding communities that maintain a social fabric ('social capital') in which crime rates are low is feasible and may be effective and efficient. Relying on local institutions and regulating mechanisms (the term 'social control' indicates the downside risks involved) rather than 'police men' working for the state is likely to include more checks and balances in the system.

Box 10. Environmental service use rights and 'environmental justice'

In different cultures we find different approaches to the rights to use environmental resources:

1. A right for the first users to continue their activities,
2. A concept of proportional access to the environmental service for all members of a certain community, with various degrees of exclusion of 'outsiders',
3. An equitable sharing of environmental resource use rights among all global citizens (this can be seen as a form of 2 but without restrictive definition of 'incrowd').

The first type of rule is typical of a 'frontier' or pioneer mentality, and can be justified from a 'development' perspective in that it provides incentives and reduces uncertainty for pioneers. Traditional water use rights in Sumatra, as documented in 1872 (anonymous, 1872), generally agreed that every member of a *marga* or inhabitant of a village had the right to use water from springs and streams that originate in their non-cultivated areas for domestic use. If necessary they could dig canals to transport the water, partially dam the rivers, install fishing gear etc, as long as this would not unduly hinder other people or 'rob' the downstream areas of their water supply. If some one is using a stream to irrigate paddy rice fields, no one is allowed to interfere with this water supply by opening up paddy rice fields upstream if this would reduce water availability downstream.

Internationally, such right of prior use has been the guiding principle in the former English colonies; an example that persists to this day is the Nile water agreement, in which Egypt maintains its claims to the major part of the Nile water for use in irrigation schemes in Egypt, largely because it had established such schemes before countries upstream on the Nile (Sudan, Ethiopia, Uganda) were ready to do so.

The concept of sharing of water between all landowners proportional to the length of the border between land and river has been in use on mainland Europe for several centuries. In South Africa the Dutch (proportional) and English (prior use) legal concepts of water use rights clashed in an environment where water is in short supply (Bate and Tren, 2002).

The international convention on climate change has started from a 'prior use' concept, where the countries agreed to a stepwise proportional change in their emissions relative to 1990 as baseline: countries with high per capita emissions in 1990 will continue with high per capita emissions of greenhouse gasses. Such an outcome of negotiations should not come as a surprise, as it is considered more 'pragmatic' than the more principled approach of equal rights to emissions by all people (the latter is complicated by obvious differences in climate and therefore in 'need' to use energy to regulate temperature by heating or cooling systems; agreements on per capita emissions are further complicated by differences in population growth rates, and issues of who takes responsibility for these growth rates).

These legal concepts have a direct bearing on RUPES mechanisms:

If customary or national laws put obligations on upstream land users not to disturb environmental services in the forms of water flows to downstream users who had settled earlier, the lowland people will not see any need to pay for continuation of the service, they rather see it as their '***right***'.

If one starts from an 'equal use rights' perspective it may be easier to agree on constructions where less-than-proportional use of the resource can be rewarded by stakeholders who benefit from a more-than-proportional share.

Where '***positive actions***' can be undertaken to enhance the 'environmental services' a form of direct reward, at individual level, for the efforts (***stewardship***) made is likely to work best (Fig.18).

The various environmental service functions differ considerably in this respect:

- ***Dominated by 'natural capital'; strong negative impacts, little opportunities for positive human effort other than 'avoiding threats':***
  - Biodiversity conservation
  - Landscape beauty
  - Landslide probability
  - Clean air: absence of Smoke/Haze
- ***Relatively small human impact:***
  - Total water yield
- ***Positive human effort can increase the 'environmental service', complementing the relevance of 'avoiding threats':***
  - Regularity of water flows
  - Quality of surface water
  - Increased C storage

5.2 How do rural poor affect environmental services?

The relationship between environmental degradation and poverty is much debated. The people wielding the axe or handling the chainsaw that cut the trees are often poor – but they may act on behalf of the not-so-poor who obtained *de facto* control over the forest resources. Poor people generally have less opportunity to shield themselves from the negative impacts of environmental degradation. The two-way interaction is often perceived as a downward spiral.

Rural poverty has many facets, such as:

- Material deprivation (low consumption of food, no access to clean water, poor housing),
- Low human development and lack of access to education and health services
- Lack of voice and ability to influence decision that affect their lives
- Acute vulnerability to adverse shocks (illness, economic crisis, natural disasters)

	Natural capital	Guardianship (prevent degradation)	Stewardship (stimulate rehabilitation)
W	Rainfall, geolo-gical substrate, landform	Riparian zone, drinking water source areas	Maintain infil-tration & redu-ce runoff
B	Flora and fauna, biotic accessibility	Integrity of pro-tected areas, On-site ('agro-forest')	Corridor restoration
C	Soil (peat!!) and vegetation C stocks	Not recognized under Kyoto protocol	LUCF CDM opportunities

Figure 18. Recognizing natural, social and human capital roles in the generation of environmental service functions (W = watershed functions, B = biodiversity conservation, C = terrestrial carbon storage)

The earlier definition of poverty as critical shortage of any of the five types of capital provides a short-hand way of categorizing these aspects.

In the same broad sweep approach as we applied to the environmental services, we may find that poverty indicators will vary across the land use intensity gradient (Fig. 19). There are stages where forest destruction provides the financial resources to reduce poverty and phases where environmental degradation becomes a determinant of poverty.

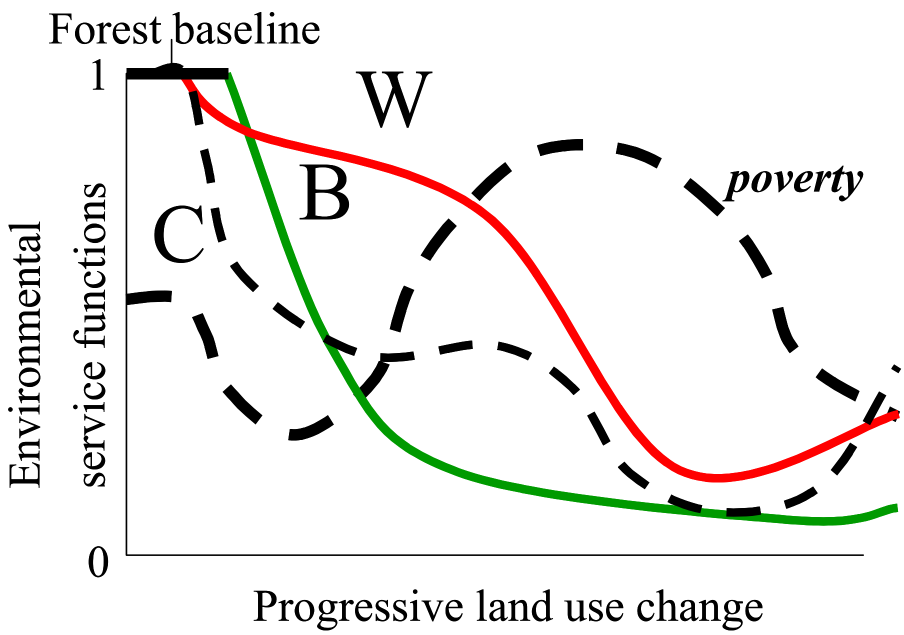


Figure 19. Tentative changes in poverty along a land use intensification gradient with its impact on environmental qualities

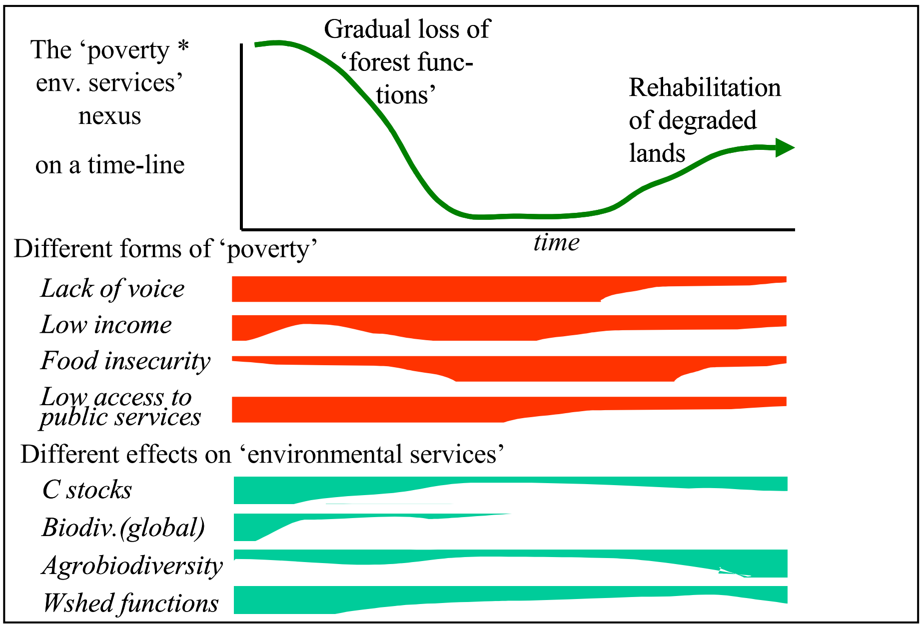


Figure 20. Schematic diagram of the relationship between 'environmental services' and dimensions of poverty along a forest – degradation – rehabilitation cycle

In this continuum of conditions, we can for the ease of our discussions recognize four major 'types' of setting:

1. Forest people ('indigenous') living in remote places in or close to the last remaining 'wilderness' areas of the world, rich in biodiversity of global significance, with high C stocks and intact Watershed functions, but poor access to markets, no voice in policy debates and poor access to public services (health, education etc.)
2. Local & migrant people living in active forest conversion zones or derived 'agroforests' that still have (potential) biodiversity of global significance, with fairly high C stocks under threat and Watershed functions that are ok (except for logging practices), but little voice in policy debates and low access to public services (health, education etc.)
3. Local & migrant people on degraded lands, often without tenurial security, with low productivity (food insecurity problems?), low C stocks and poor Watershed functions
4. People in landscapes that 'rehabilitate' with a partial restoration of agrobiodiversity, C stocks and watershed functions; various dimensions of poverty may be recovering, but a fall-back to stage III is possible

RUPES typology E S* Poverty

Type	Key e.s. to be conserved	Key e.s. to be restored	Key poverty aspect
I forest	Biodiv_glob C_stocks		Indig.pple rights access,services
II forest margin, agroforest	C_stocks AgroBiodiv Wshed fns	Biodiv_glob	Local pple rights income,services
III degraded lands, early rehabilitation		AgroBiodiv_ C stocks Wshed fns	Migrant tenurial rights,food insecurity, income,services
IV more advanced rehabilitation	C stocks Wshed fns	AgroBiodiv_	Income, public services

Figure 21. Draft typology of the environmental services that can be conserved or restored in the four stages of landscape evolution, with the dominant poverty aspects associated with these stages

5.3 Dependence of environmental services on land use and opportunities for ES rewards

A summary of the land use dependence of the various ES is provided in Table 6. The 'RUPES potential' relates to this dependence as well as the sphere of influence.

Table 6. Typology of specific environmental services in the context of ES rewards, indication of the degree of dependence of the service on land use (1 = weak; 2 = medium; 3= strong) and RUPES potential (indicated by the number of apteryx)

Watershed functions (W)		**LU dependent**	**RUPES potential**
W1	Water transmission (total water yield per unit rainfall)	1	
W2	Buffering (above average river discharge per unit above average rainfall)	2	*
W3	Gradual release of stored water supporting dry-season flows	1	
W4	Maintaining water quality (relative to that of rainfall)	3	***
W5	Stability of slopes, absence of landslides	2	
W6	Tolerable intensities of net soil loss from slopes by erosion	3	*
W7	Microclimate effects on air humidity and temperature	3	*
Biodiversity functions (B)			
B1	Protecting the integrity of conservation areas by preventing loss of habitat and threats at population level in the areas directly around core protection areas,	3	***
B2	Providing habitat for a sub-set of the original fauna and flora inside agriculturally used landscapes	3	*
B3	Maintaining connectivity between protected areas via corridors,	3	**
B4	Creating opportunities for local-level 'restoration', in landscapes where connectivity is still maintained.	3	*
B5	Various forms of ex situ conservation.	-	
Carbon stocks (C)			
C1	Protecting natural forest area, peat soils and other carbon storage areas	3	*
C2	Protecting above- and/or belowground carbon stocks in areas used for (agro)forestry and/or agriculture	3	*
C3	Restoration, increase in tree cover (in a 'sustainable harvest' regime the time-averaged C stock of a land use system does not depend on the growth rate, but on maximum stock at time of harvest)	3	***
C4	Accumulating wood and other products derived from recent plant production in, for example, the form of houses, furniture, paper, organic waste dumps.	1	*
Productivity and direct profitability (P)			
P1	Allowing extraction of potentially renewable resources	3	
P2	Non-renewable resource mining	1	
P3	Nutrient and water supply for agricultural crops, fodder and trees	3	
P4	Biotic relationships: pollination, pests, diseases and their control	3	
Human health & landscape beauty (H)			
H1	Regulation of pests and diseases	3	
H2	Detoxification of air, water, food	3	
H3	Spiritual, religious and aesthetic values	3	
H4	Opportunity for active recreation (ecotourism)	3	**
H5	Ecological knowledge	2	

5.4 Prototypes of environmental service reward situations

In view of the current experience with ES reward mechanisms in Asia, we suggest (Table 7) twelve 'prototypes' for further exploration of a comprehensive typology.

Table 7. Twelve prototype situations for ES rewards in upland agricultural systems

Environmental servi-ce	**Providers/ sellers**	**Users / buyers**	**Main issue**
1. Total water yield for hydroelectricity via storage lake (W_{cons}_1)	Impacts on total water yield small; reservoir sedimen-tation issue may dominate the debate; option for sediment traps and landscape filters	Consumer satisfaction depends on continued functioning; high project investment costs, little subsequent mana-gement flexibility	Intercepting sediment flows rather than avoiding them is generally easier to accomplish; sediment flows out of well-managed upper catchments may still be high because of geological and geomorphological processes
2. Regular water supply for hydro-electricity via run-off-the- river (W_{cons}_2)	A change from soil quick flow (saturated forest soils) to overland flow will have some effect on buffering of river flows and hydroelectric operation time		Interventions influencing the speed of drainage (linked to paths, roads and drains) have the most direct effect on buffering at larger scales
3. Drinking water provision (surface or groundwater) (W_{cons}_3)	Intensive agriculture and horticulture will cause rapid pollution of surface flows and slow but persistent pollution of ground-water flows with ni-trogen and pesticides; people residing around streams cause pollution E.coli and diseases	Willingness to pay for drinking water depends on quality assurance from me-dical perspective, as well as taste	Slow response of groundwater flows to changes in the pollutant status make 'regulation' a more effective solution than results based markets
4. Flood prevention (W_{cons}_4)	Land use effects strongest for flow buffering of small-to-medium sized events, with saturation dominating the large events	Relevance of upland land use depends on location ('floodplains') and engineering solutions (dykes, storage reservoirs)	Risk avoidance for the rare category of large events
5. Landslide preven-tion (W_{cons}_5)	Mortality of deep-rooted trees ('an-chors') causes tempo-rary increase in landslide risk	Relevance depends strongly on location in the flow paths	Deep landslides are little affected by land cover

6. General watershed rehabilitation and erosion control (W_{reh})	Promoting tree cover and permanence of litter layer protecting the soil is a good precaution	'Holistic' perception of watershed functions survives despite the lack of clear impacts on specifics	Communication gap with scientists who try to enhance clarity
7. Biodiversity buffer zones around protected area (B_{cons}_1)	Use value of buffer zones depend on hunting restrictions, presence of human-life threatening species	Flagship species still dominate the public perception of value	Push and pull factors in human land use; livelihoods operate at larger scales than most conservation plans acknowledge
8. Biodiversity landscape corridor (B_{cons}_2)	Still new concept in agriculture/forest land use mosaics in the tropics; use value of patches in the 'stepping stones' similar to the buffer zone case	Relevance depends on dispersion properties of the species of main interest; sometimes higher connectivity not desirable; relevance increases with climate change concerns	Ex ante impact assessment of effectivity is still difficult
9. C restocking degraded landscapes (C_{reh})	Options for profitable tree restocking primarily depend on policy reform	Demand is for Certified Emission Reduction (CER) rather than carbon	Additionality issues in CDM; high transaction cost
10. C protecting soil and tree stocks (C_{cons})	Road construction (accessibility) is main determinant of 'opportunity costs' for non-conversion		Not recognized as part of CDM
11. Guaranteeing production landscapes meet environmental standards (Ecolabel)	Where the 'ecolabel' process starts from the consumer side, there can be a substantial gap in communication and trust, leading to high transaction costs	Consumers with high sense of personal responsibility; gradually replaced by the introduction of standards and the raising of baselines of 'acceptable' behaviour	Relevance of global standards in the face of variation in local conditions; transparency of the standards and compliance monitoring; transaction costs
12. Providing guided access to landscapes of (EcoTourism)	The local and international appreciation for landscape beauty depends on culture and time (fashion); rewards are for roles as guide and provider of accommodation, food, transport and handicrafts ; gender aspects of provider roles may be prominent	The appreciation of landscape beauty and cultural traditions does not reduce the need to provide security and comfort to potential tourists	Global ecotourism is a highly volatile market where security and political concerns can interfere

Given this draft version of a typology, we can start to organize the 'lessons learnt' by type of situation. Some initial expectations of the poverty-reducing impacts are provided in Table 8.

Table 8. Table 8. Tentative ranking of opportunities for poor people in any of the five 'syndromes' to benefit directly or indirectly from environmental service rewards

Syndrome	**Number of poor people in this domain**	**Main opportuni-ty for ES rewards**	**Potential value (per capi-ta) of 'environ mental service rewards'**	**Opportunity costs that rewards have to exceed**	**Potential (per capita) for direct benefits *minus* opportunity costs**	**Potential for benefiting from environmen tal improveme nt**
Urban areas	*** (growing)	-	0/+	0/+	0/+	+ (improve)
High potential agricultural areas	**	Ecolabel?	0/+	++	0/+	+ (improve)
Low potential or degraded agricultural areas	****	C_{reh}, W_{reh}, Ecolabel?	+	0/+	+	+++ (improve)
Wetlands and small islands	*	C_{cons}, B_{cons}, W_{cons}, W_{reh}, Ecolabel, Ecotourism	+++	+	++	++ (maintain)
Remote core forest areas	*	B_{cons}, C_{cons}, W_{cons}, Ecolabel, Ecotourism	+++	++	+	++ (maintain)

References

Agus, F., Farida and Van Noordwijk, M. (Editors), 2004. Hydrological Impacts of Forest, Agroforestry and Upland Cropping as a Basis for Rewarding Environmental Service Providers in Indonesia. Proceedings of a workshop in Padang/Singkarak, West Sumatra, Indonesia. 25-28 February 2004. ICRAF-SEA, Bogor (Indonesia) http://www.worldagroforestry.org/sea/

Alcamo, J. et al. (2003) Ecosystems and Human well-being: a Framework for Assessment. Island Press, Washington (USA)

Anonymous 1872. Resumés van het onderzoek naar de regten welke in de gouvernements-anden op Sumatra op de onbebouwde gronden worden uitgeoefend. [Summaries of the rights on use of uncultivated lands in Sumatra]. Landsdrukkerij, Batavia.

Baillie, J.E.M., Hilton-Taylor, C. and Stuart, S.N. (Eds.) 2004. 2004 IUCN red list of threatened species, a global species assessment. IUCN – the World Conservation Union, Gland (Switzerland)

Bate, R. and Tren, R. 2002. The Cost of Free Water. The Global problem of water misallocation and the case of South Africa. The Free Market Foundation, Johannesburg, South Africa: 290 pp.

Bruijnzeel, L.A., 2004. Hydrological functions of tropical forests: not seeing the soil for the trees? Agriculture, Ecosystems & Environment, Volume 104(1): 185-228

Calder, I.R., 2002. Forests and hydrological services: reconciling public and science perceptions. Land Use and Water Resources Research No. 2, pp. 2.1–2.12. http://www.luwrr.com.

Dixon, J., Gulliver, A., and Gibbon, D., 2001. 'Farming Systems and Poverty: improving farmers' livelihoods in a changing world' by; FAO and World Bank)

Ekidanata, A., Widayati, A. and van Noordwijk, M. 2004. Sketch Map of Bukit 30-Bukit 12-Kerinci Seblat National Park, Jambi Province, Indonesia. ICRAF-Southeast Asia working paper, World Agroforestry Centre, Bogor (Indonesia)

Ferraro, P.J. and Kiss, A., 2002. Direct Payments to Conserve Biodiversity. Science 298: 1718-1719

Gribaldo, S. and Philippe, D.C., 2002. Ancient phylogenetic relationships. Theor. Popul Biol 61(4):391-408.

Hairiah,K., Sitompul, SM, van Noordwijk, M. and Palm, C.A., 2001a Methods for sampling carbon stocks above and below ground. ASB_LN 4B. In: Van Noordwijk, M, Williams, S.E. and Verbist, B. (Eds.) 2001.Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns. ASB-Lecture Notes 1 – 12. International Centre for Research in Agroforestry (ICRAF), Bogor, Indonesia. Also available from: http://www.icraf.cgiar.org/sea/Training/Materials/ASB-TM/ASB-ICRAFSEA-LN.htm

Hairiah, K., Williams,S.E., Bignell,D., Swift, M. and Van Noordwijk, M., 2001b. Effects of land use change on belowground biodiversity. ASB_LN 6A.. In: Van Noordwijk, M, Williams, S.E. and Verbist, B. (Eds.) 2001.Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns. ASB-Lecture Notes 1 – 12. International Centre for Research in Agroforestry (ICRAF), Bogor, Indonesia. Also available from: http://www.icraf.cgiar.org/sea/Training/Materials/ASB-TM/ASB-ICRAFSEA-LN.htm

Joshi, L., Schalenbourg, W., Johansson, L., Khasanah, N., Stefanus, E., Fagerström, M.H. and van Noordwijk, M., 2004. Soil and water movement: combining local ecological knowledge with that of modellers when scaling up from plot to landscape level. In: van Noordwijk, M., Cadisch, G. and Ong, C.K. (Eds.) Belowground Interactions in Tropical Agroecosystems, CAB International, Wallingford (UK). pp. 349-364

Landell-Mills, N. and Porras I., 2002. "Silver Bullet or Fools' Gold? A Global Review of Markets for Forest Environmental Services and their Impact on the Poor" IIED, London.

McNeely, J.A. and S.J. Scherr, 2003, Ecoagriculture. Island Press, Washington (USA)

Pagiola, S., Bishop, J. and Landell-Mills, N. (eds), 2002. Selling Forest Environmental Services: Market-Based Mechanisms for Conservation and Development. London: Earthscan.

Palm, C. A., Tomich, T., Noordwijk, M. van, Vosti, S., Gockowski, J., Alegre, J., Verchot, L., 2004. Mitigating GHG emissions in the humid tropics: case studies from the Alternatives to Slash and Burn Program (ASB). Environment, Development and Sustainability 6: 145-162.

Ranieri, S.B.L., Stirzaker, R., Suprayogo, D., Purwanto, E., de Willigen, P. and van Noordwijk, M., 2004. Managing movements of water, solutes and soil: from plot to landscape scale. In: van Noordwijk, M., Cadisch, G. and Ong, C.K. (Eds.) Belowground Interactions in Tropical Agroecosystems, CAB International, Wallingford (UK). pp. 329-347

Pascicolan, N. P., Udo de Haes, H. and Sajise, E. P., 1997. Farm forestry: an alternative to government-driven reforestation in the Philippines. Forest Ecology and Management 99: 261-274.

Schimel, D. S. House, J. I. Hibbard, K. A. Bousquet, P. Ciais, P. Peylin, P. Braswell, B. H. Apps, M. J., Baker, D. Bondeau, A. Canadell, J. Churkina, G. Cramer, W., Denning, A. S., Field, C. B. Friedlingstein, P., Goodale, C. Heimann, M. , Houghton, R. A., Melillo, J. M., Moore III, B. Murdiyarso, D. ,Noble, I., Pacala, S. W., Prentice, I. C., Raupach, M. R., Rayner, P. J. Scholes, R. J., Steffen, W. L. and Wirth, C.. 2001. Recent patterns and mechanisms of carbon exchange by terrestrial ecosystems. Nature 414, 169 - 172 (08 November 2001); doi:10.1038/35102500

Schroth, G., Da Fonseca, G.A.B., Harvey, C.A., Gascon, C., Vasconcelos, H.L. and Izac, A-M.N. (Eds.) 2004. Agroforestry and Biodiversity Conservation in Tropical Landscapes. Island Press, Washington (USA)

Swallow, B.M., Garrity, D.P. and van Noordwijk, M., 2001. The effects of scales, flows and filters on property rights and collective action in watershed management. Water Policy 3: 457 - 474. ftp://ftp.cgiar.org/IFPRItemp/Library/Effects%20of%20scales...pdf

Swift, M.J., Izac, A.M.N and Van Noordwijk. M., 2004. Biodiversity and ecosystem services in agricultural landscapes: Are we asking the right questions? Agriculture, Ecosystems and Environment 104: 113-134

Susswein, P.M., Van Noordwijk, M., and Verbist, B., 2001. Forest watershed functions and tropical land use change ASB_LN 7. In: Van Noordwijk, M, Williams, S.E. and Verbist, B. (Eds.) 2001.Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns. ASB-Lecture Notes 1 – 12. International Centre for Research in Agroforestry (ICRAF), Bogor, Indonesia. Also available from: http://www.icraf.cgiar.org/sea/Training/Materials/ASB-TM/ASB-ICRAFSEA-LN.htmTomich, T.P., van Noordwijk, M. and David E. Thomas, D.E., 2004. Environmental services and land use change in Southeast Asia: from recognition to regulation or reward? Agriculture, Ecosystems and Environment 104: 229-244

Tharme, R.E. , 2003. A global perspective on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. River Research and Application, 19: 397-441.

Tomich, T.P., Van Noordwijk, M., Budidarseno, S., Gillison, A., Kusumanto T., Murdiyarso, D. Stolle, F. and Fagi, A.M., 2001 Agricultural intensification, deforestation, and the environment: assessing tradeoffs in Sumatra, Indonesia. In: Lee D.R. and Barrett, C.B. (eds.) Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment. CAB-International, Wallingford pp 221-244

Tomich, T.P., de Foresta, H., Dennis, R., Ketterings, Q.M., Murdiyarso, D., Palm, C.A., Stolle, F., Suyanto,S. and Van Noordwijk, M., 2002. Carbon offsets for conservation and development in Indonesia? American Journal of Alternative Agriculture 17: 125-137

Tomich, T.P., van Noordwijk, M. and David E. Thomas, D.E., 2004. Environmental services and land use change in Southeast Asia: from recognition to regulation or reward? Agriculture, Ecosystems and Environment 104: 229-244

Van Noordwijk,M., Poulsen, J. and Ericksen. P., 2004a. Filters, flows and fallacies: Quantifying off-site effects of land use change. Agriculture, Ecosystems and Environment, 104: 19-34

Van Noordwijk, M., Agus, F., Didik Suprayogo, D., Hairiah, K., Pasya, G., Verbist, B. and Farida. 2004b. Role of agroforestry in maintenance of hydrological functions in water catchment areas. In: Agus, F., Farida and Van Noordwijk, M. (Eds), 2004. Hydrological Impacts of Forest, Agroforestry and Upland Cropping as a Basis for Rewarding Environmental Service Providers in Indonesia. Proceedings of a workshop in Padang/Singkarak, West Sumatra, Indonesia. 25-28 February 2004. ICRAF-SEA, Bogor, Indonesia. Pp 20-34

Van Noordwijk, F., Chandler, F. and Tomich, T.P., 2005. Introduction to conceptual basis of rewarding upland poor for the environmental services they provide. http://www.worldagroforestry.org/sea/Networks/RUPES/index.asp

Williams, S.E., Gillison, A.N. and Van Noordwijk, M., 2001. Biodiversity: issues relevant to integrated natural resource management in the humid tropics. ASB_LN 5. In: Van Noordwijk, M, Williams, S.E. and Verbist, B. (Eds.) 2001.Towards integrated natural resource management in forest margins of the humid tropics: local action and global concerns. ASB-Lecture Notes 1 – 12. International Centre for Research in Agroforestry (ICRAF), Bogor, Indonesia. Also available from: http://www.icraf.cgiar.org/sea/Training/Materials/ASB-TM/ASB-ICRAFSEA-LN.htm