Section II

Rural livelihoods in changing, multifunctional landscapes

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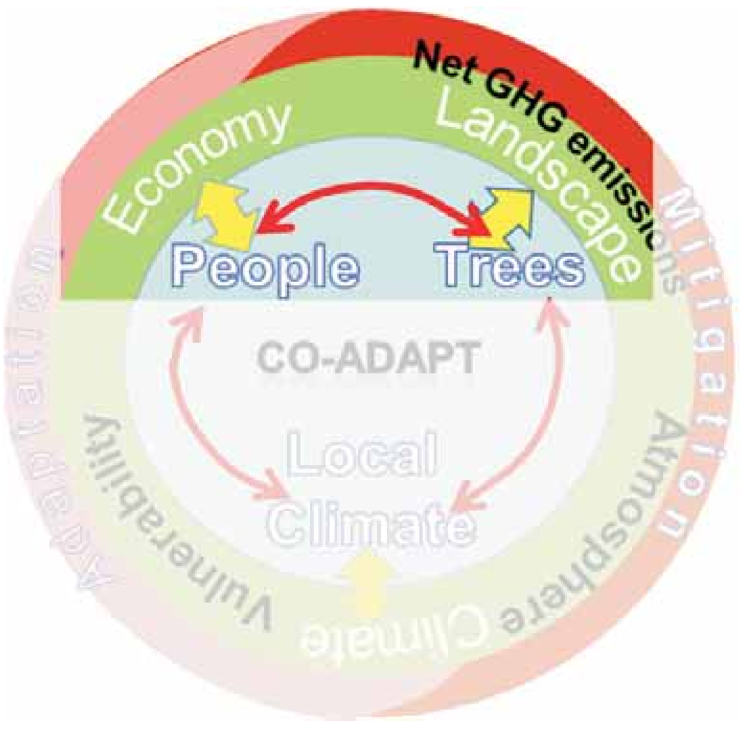
The main argument in this section is that changing (or 'transforming') landscapes and lives are mutually dependent on each other, as they are closely linked in time and space. Within the landscape continuum, the roles of landscape elements in supplying goods and services to local livelihoods, however, shift with the stage of development and substitution of traded and imported goods and services for those provided locally and potentially used as sources of income.



C. Rural livelihoods in changing landscapes

Livelihoods are dynamic and involve on-farm, off-farm-within-landscape and out-of-landscape ways of earning a living, often as part of a risk-sharing (reducing vulnerability) family network.

There are several key questions at the interface of livelihoods and climate change to be assessed in every local context.

1. Can development goals to end global poverty be combined with the required level of global net emission reduction to sustain life as we know it?

2. What are the causes, magnitude and characteristics of local climatic variability?
3. What affects and influences current local capacity to deal with climate variability?
4. What are the dimensions of, and constraints to, adaptive capacity (based on natural, human, social, physical and financial assets)?
5. Are short-term coping strategies conflicting with long-term adaptation?

Millennium Development Goals

Adaptation and mitigation are both closely linked with the Millennium Development Goals (MDGs). Goals numbers 1 to 6 probably require greater global resource use and access for the rural poor. Numbers 7 and 8 seek to achieve progress through 'sustainable development' (Figure C.1). Climate change can be interpreted as a symptom of the dominance of unsustainable development pathways: a high carbon-flow economy addicted to fossil fuels as energy sources while transforming landscapes from high to low carbon-stock conditions.

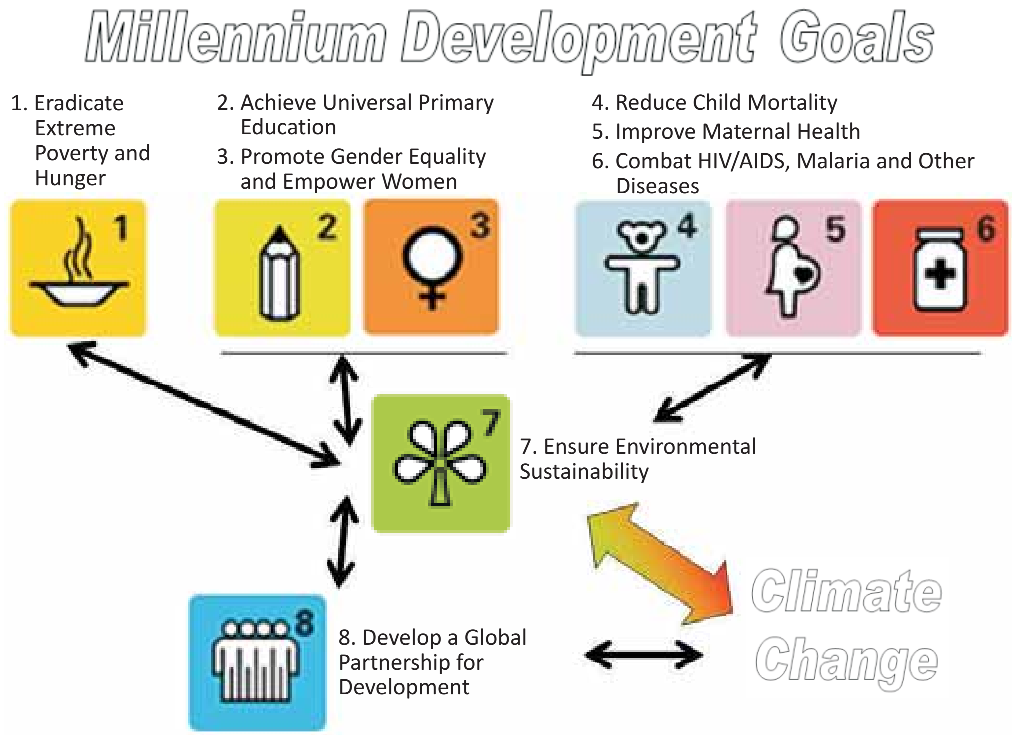


Figure C.1. The relationships between the eight Millennium Development Goals (http://www.mdgmonitor.org) and the challenge of climate change

A history of change

Since the peak of the last Ice Age, 20 000 years ago, human beings have by and large benefitted from global warming and have successfully adapted to an ever-changing and ever-variable climate (Figure C.2). They moved around, claiming nearly every type of habitat on earth and finding ways to use local resources. They brought their favoured plants and animals along, many of which 'naturalised' and became as invasive an exotic species as *Homo sapiens* proved to be. The one constant in the subsequent history of human success in conquering the world is change: *plus ca change, plus c'est la même chose*. Why be concerned about the current acceleration of climate change? Haven't we been able to deal with worse conditions and more rapid change? Yes, we have, but that response included substantial human migration and colonisation of previously sparsely populated continents. Now there is nowhere left to go and there is no Planet B. If a couple of small-island states disappear below sea level this will hardly affect humankind at large but it will cause political upheavals in a world carved into nation states. Previously, pastoralists could roam over large areas, looking for green pastures or sources of water; now all land within each country is divided by tribal, state-claimed or private property rights and social, economic and political upheaval follows transgressive mobility.

If there is anything remarkable about the last 12 000 years, which the geologists call 'Holocene' in contrast to the preceding Pleistocene, it is the stability of the climate. According to some, we're now entering the 'Anthropocene', the first geological period where climate is dominated by the activity of a single species. Starting with 'global warming' we may well get back to the climatic yo-yo of the Pleistocene.

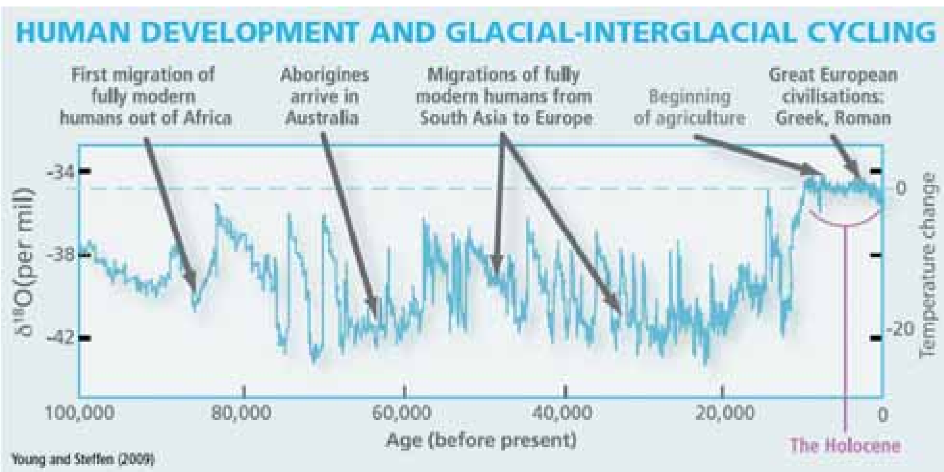


Figure C.2. Global temperature profile of the last 100 000 years with its various ice ages, as derived from the oxygen-18 isotope concentration in polar ice cores (based on Gaffney 2009)

Previously crops, trees and domesticated animals were the basis of integrated farming systems, involving considerable spreading of risk, with social networks of exchange and stockpiling as safety nets. Intensification and specialisation of agriculture increased the yields but also meant that markets and insurance schemes had to replace the old safety nets. Exposure to risk and the response options are very different now from what worked before. Many countries, regions and groups of people have been left behind while others increased their consumption per capita and draw on resources in a process called 'development'. Those left behind want to catch up but find that the resource base is already stretched and their political bargaining power to get a fairer share of the limited pie is small, regardless of past discourse, discussion, verbal commitments and evolving agreements. In other words: there is no risk of extinction for *Homo sapiens* from current and projected rates of climate change and at species level our adaptive capacity is fine. But there are countries and people within them that already are on, or over, the edge of 'carrying capacity' of their ecosystems at current technology and patterns of resource use and yet they want more resources, justified by the globally agreed Millennium Development Goals.

A 'livelihood' comprises the capabilities, assets (including both material and social resources) and activities required for a means of living (Carney 1998, Bebbington 1999). A livelihood is considered to be sustainable if it can cope with, and recover from, stresses and shocks and maintain or enhance its capabilities and assets, both now and in the future, while not undermining the natural resource base for further change.

In terms of vulnerability, small-island states and coastal zones (Dasgupta et al. 2009) plus farmers and pastoralists in areas of high variability in rainfall stand out. One option for them is to move to cities and/or to countries that enjoy higher standards of living. At individual level this probably is the preferred intergenerational adaptation strategy for the majority of the rural poor. While rich countries build higher walls at their borders and restrict migration, they realise that they have to support the emergence of local solutions in the rural areas affected, for reasons of self interest, justified by reference to moral standards. Climate-change adaptation cannot really be separated from concerns about, and approaches to deal with, current issues of health, exposure to natural hazards and loss of ecosystem services. Tinkering with a complex system without fully understanding it means that we have to be ready for surprises and be careful not to compartmentalise the issue for bureaucratic efficiency, with the risk of losing sight of reality.

This chapter will cover the impact of climate change and climate variability on rural livelihoods. Using examples, issues of sustainability will be covered and the need to incorporate 'sustainagility' (retaining/enhancing the resource base for, and ability of farming communities to adapt to, change). While there are many aspects of rural livelihoods, factors that are important to sustainable livelihoods in relation to climate change and climate variability will be highlighted.

Rural livelihoods and pressures at current climate variability

The UK Government's Department for International Development's 'livelihoods analysis' concept has effectively mainstreamed a perspective that livelihoods can best be understood on the basis of access to five or six types of assets: human capital, natural capital, financial capital, social capital (sometimes differentiated into 'within group' bonding and 'between group' bridging or political capital) and physical capital or infrastructure (Figure C.3, Carney 1998, Bebbington 1999, DFID 1999).

Poverty can be interpreted as a critical shortage of at least one of these assets. The livelihoods' paradigm differs from an economically driven one and from poverty definitions that refer to income (for example, 'USD 1 per person per day') by recognising that exchange between capital types can be slow and poorly reversible. That is, you can convert natural capital to money but it's not so easy the other way round: you can eat the chicken that laid golden eggs, but golden eggs don't hatch into the same type of chicken; access to clean drinking water can become reliant on technical infrastructure instead of on natural capital, but at considerable cost; social capital and trust can be rapidly destroyed, but only slowly rebuilt.

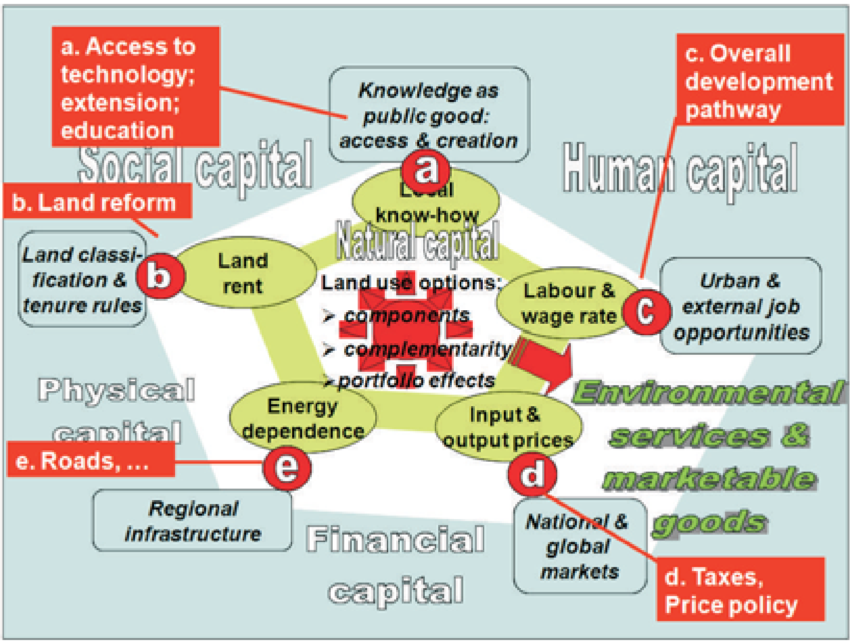


Figure C.3. The five capitals of livelihoods' analysis need to be understood across scales: from international down to village and rural households

Contrasting rural to urban livelihoods, there tends to be greater access to natural capital in rural areas (though this tends to decrease with progressive 'development'), but easier access to all other assets in urban areas, with the exception of 'bonding' forms of social capital. Political capital, healthcare, schooling and other determinants of human capital need specific efforts to be provided to rural communities.

Why and where is climate change and/or enhanced climate variability a problem? Compared to recurrent shocks such as war, conflict, illnesses, floods, storms, droughts, pests, diseases, bust-and-boom dynamics of commodity prices and urban employment opportunities, the additional challenge of climate change may be small. However, climate-change impacts can well manifest through an increase in conflicts and stressors on rural livelihoods.

Although this is an oversimplification, access to natural capital allows a first estimate of 'vulnerability': where assets and access are high, there are many options to cope with climatic variability and change. Where assets are already stretched and/or for groups who don't have access because of social exclusion and/or institutions aiming for resources conservation, vulnerability will be high. Initiatives to deal with the underlying causes of vulnerability rather than the symptoms include innovative approaches such as pro-poor rewards for environmental services that try to address equity-related issues, including resource access conditional to conserving environmental services.

Intermediate stage vulnerability hypothesis

Verchot et al. (2007) put forward the 'intermediate vulnerability' hypothesis. If we look at rural livelihoods along a conceptual, agricultural intensification gradient, we'll have remote places with high levels of natural capital in diverse landscapes, and usually with strong bonding capital, but low levels of access to other assets, including lack of voice in political forums. By most interpretations such people are poor, but they may not be specifically vulnerable to climate change, as their environment is diverse and offers multiple under-explored options. On the other end of the intensification spectrum we'll see intensive farms of low diversity in highly specialised landscapes. They may be relatively well off in terms of income and access to health, education and other services; they may also be part of insurance schemes to buffer them from risk, as their portfolio of options is very thin. They can afford low genetic diversity on farm and in the landscape because they have access to a 'germplasm delivery system' that has access to the diversity of many landscapes and is operated as a public/private partnership that matches supply and demand. A shift between crop varieties costs money but can be done quickly; a switch to another crop may lead to loss of capital in specialised machinery but maybe this can be resold to the farmers for whom the crop that is abandoned at one place becomes a new option. On both sides of this intensification continuum there are few reasons for specific concerns for vulnerability to climate change. Between the 'old' solution of local diversity and the 'modern' one of externalised sources of new options, there is a large domain where neither solution can be relied on. In landscapes where diversity has diminished, social institutions are stretched, resources of water overused and/or polluted, and market access and research/extension links are limited, climate change may be the straw that breaks the camel's back.

Sustainable livelihoods: operationalising a concept

Sustainability has many dimensions, all of which are important to a sustainable livelihoods approach. According to the Department for International Development's analysis (DFID 1999), livelihoods are sustainable when they a) are resilient in the face of external shocks and stresses; b) are not dependent upon external support (or if they are, this support itself should be economically and institutionally sustainable); c) maintain the long-term productivity of natural resources; and d) do not undermine the livelihoods of, or compromise the livelihood options open to, others.

Another way of conceptualising the many dimensions of sustainability is to distinguish between environmental, economic, social and institutional aspects of sustainable systems.

- Environmental sustainability is achieved when the productivity of life-supporting natural resources is conserved or enhanced for use by future generations.
- Economic sustainability is achieved when a given level of expenditure can be maintained over time. In the context of the livelihoods of the poor, economic sustainability is achieved if a baseline level of economic welfare can be achieved and sustained. (The economic baseline is likely to be situation-specific, though it can be thought of in terms of the `dollar-a-day' of the International Development Targets[12]).
- Social sustainability is achieved when social exclusion is minimised and social equity maximised.
- Institutional sustainability is achieved when prevailing structures and processes have the capacity to continue to perform their functions over the long term (IPCC 2001).

[12] http://mdgs.un.org/unsd/mdg/Host.aspx?Content=Indicators%2fOfficialList.htm

Range of options to include in climate-change adaptation and sustainagility analysis

The description of livelihoods as combining different assets needs to be linked with a broader perspective on the dynamics of land use, economic transformations reducing dependence on primary production and increasing jobs and value-addition service sectors (including food processing) and the back-and-forth shifts that can occur in a rural–urban continuum. Vulnerability implies not having options. Vulnerability assessments thus need to look across all options. Such options range from a new genotype for existing crops of farm animals to migration to another country. In between these extremes are switches to other crops, other cropping or husbandry systems, other ways of combining enterprises in a farming system, other ways of organizing agriculture-based value chains, and greater dependence on the urban side of integrated family networks. We can now describe each of these levels of response options as aspects of an integrated 'sustainagility' concept (Figure C.4, Verchot et al. 2007, Jackson et al. 2010) that complements a view on sustainability that is focused on persistence, on the ability to keep doing what has been done. The two concepts meet in the relevance of resource conservation. Sustainagility, however, will tend to put more weight on 'diversity' and sustainability more on resources such as soil and water.

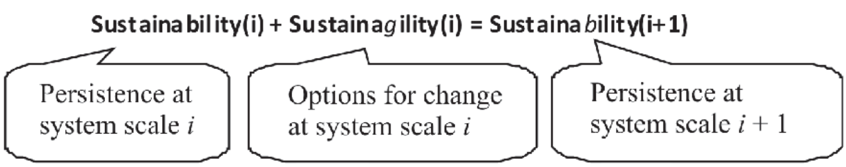


Figure C.4A. Basic rule for relating sustainagility and sustainability across system scales

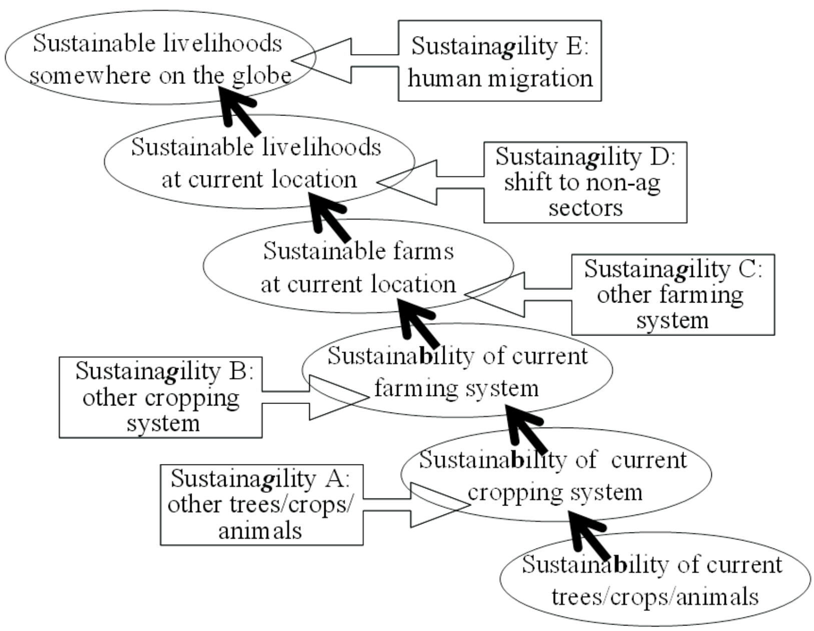


Figure C.4B. Multiple levels of adjustment that link 'persistence' and 'options for change' to higher levels forms of sustainability (Source: Verchot et al. 2007)

The politics of adaptation-resource allocation

The global debate on climate change went through the familiar stages of an 'environmental issue cycle' (Tomich et al. 2005): mavericks starting to talk, some non-governmental organizations picking up the early leads, governments and private sector in denial, while scientists in many different disciplines had their various theories and partially conflicting observations about separate aspects. The decision early on to establish an inter-governmental panel on climate change (IPCC) proved to be strategic: it provided a platform for the many different strands of science to be woven into fairly cohesive and compelling evidence that a) there was indeed a problem; b) that it had multiple causes but could be clearly linked to greenhouse gas emissions from use of fossil fuels and land-use and land-cover changes; and c) that it posed a great risk to current human welfare and development pathways. Then the phase of 'whodunit?' (who is the perpetrator?) started, as a lead up to the 'who pays?' debate. Developing countries were seen as the primary and innocent victims, not contributing much to the cause of the problem. Financial transfers, a form of compensation, were slowly put in place, alongside small steps to mitigate or reduce the severity of the issue (see the NAPA list in Table O.1). Since then, the 'victim' role has appeared attractive to many countries and groups within a country, as a way to ask for or demand part of the 'compensation'. Yet, many countries and groups asking for such may well aspire to the high-emission lifestyles that caused the problem. Climate-change adaptation became part of the politics of resource allocation familiar within the development debate. The dichotomy between villains (industrialised countries) and victims (developing countries) became untenable, as major developing countries rapidly increased emissions, partially through 'outsourcing' of the industries with high-emission levels. New arguments of 'fairness' based on 'per capita emission rights' came into the debate and attained moral, but no direct political, acceptance. While there is broad consensus that 'least developed countries' and small-island states are most worthy of support for adaptation, there is no clear sense of direction about which parts of their societies should be supported. 'Coming up with a good story' is still a major path to success in getting a piece of the pie. The examples of NAPAs in Table O.1 may give a sense of being selected on the basis of projects 'ready to go', rather than on an inclusive process of prioritisation.

Given their high per hectare carbon stocks and generally low population densities, forests and peatlands have become the primary topic for carbon-stock emission debates. As land ownership, government-regulated tenure and resource access are often most contested for forests, the debate on who has the right to enhance, avoid or decrease emissions came to be at the centre of the REDD discussion. Interestingly, the standards currently proposed for involving local communities' 'free and prior informed consent' on efforts to reduce emissions have not generally been applied to activities that enhance emissions.

Free and prior informed consent

After wide public consultation, a list of standards for REDD+ programs has been developed, that will consist of principles, criteria and indicators that define the issues of concern and the required levels of social and environmental performance[13]. It so far provides eight principles—the 'intent' level of a standard—that elaborate on the objectives of the standard and define the scope. They are fundamental statements about the desired outcome and are not designed to be verified. They are each linked to about five criteria, which set out the conditions which need to be met in order

[13] http://www.climate-standards.org/REDD+/docs/REDD+SE_Standards_draft_01-15-09_for_comments.pdf

to deliver a principle. The criteria are further elaborated by, on average, two indicators, which are quantitative or qualitative parameters that can be achieved and verified.

Principle 1: Rights to lands, territories and resources are recognised and respected by the REDD+ program.

Principle 2: The benefits of the REDD+ program are shared equitably among all relevant rights holders and stakeholders.

Principle 3: The REDD+ program improves long-term livelihoods' security and well being of indigenous peoples and local communities with special attention to the most vulnerable people.

Principle 4: The REDD+ program contributes to broader sustainable development and good governance objectives.

Principle 5: The REDD+ program maintains and enhances biodiversity and ecosystem services.

Principle 6: All relevant rights holders and stakeholders participate fully and effectively in the REDD+ program.

Principle 7: All rights holders and stakeholders have timely access to appropriate and accurate information to enable informed decision-making and good governance of the REDD+ program.

Principle 8: The REDD+ program complies with applicable local and national laws and international treaties, conventions and agreements.

Rights and resources: the tragedy of the commons

Much of the emissions and sequestration issues relate to land. And access to land (with or without forest cover) is hotly contested in many countries: between the state and local communities, between different communities that have historical claims on the same land, between households within each of those communities and even between household members in some cases. With expectations of new economic value linked to the maintenance, avoided disappearance or restoration of terrestrial carbon stocks, the issues of control over land obtained a new dimension. Especially where groups have unequal access to information, forms of speculation came into play, with some actors promising good prices to local governments and communities for unclear and poorly understood carbon rights: similar to logging rights and/or the expansion of supposedly promising tree crops and other plantations.

The atmosphere and the oceans, two key components in the interlinked Earth system that jointly dominate the carbon cycle and climate, are the ultimate 'commons', with benefits enjoyed by all but management effort by none. They can only be managed globally (Hare and Meinshausen 2006), by agreement on 'globally appropriate mitigation actions' (GAMA; see Figure C.5).

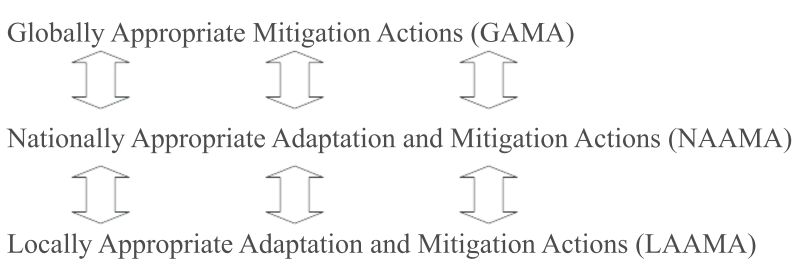


Figure C.5. Three interacting levels of climate-change adaptation and mitigation of emissions

Intermezzo 6.

Fruit tree portfolios in southern Africa

Nutritional concerns are heightened under climate change as food security decreases. This, however, provides an opportunity to make more use of indigenous fruit trees that are available for consumers and farmers to plant in the environments around them. If the right mix (or 'portfolio') of fruit trees can be cultivated then the availability of the key nutrients that fruits provide can be sustained throughout the year. An example of what a portfolio can look like—in this case for a range of mostly indigenous fruits found in Zambia—is shown in Figure C.6. Research on the propagation of these species, and their adoption by farmers, is the subject of ongoing work in southern Africa, and similar projects are underway in other parts of the continent such as Central and West Africa. What is needed is a strategic approach across countries in order to project the changes under climatic alteration in regional distributions of particular nutritional challenges (for example, vitamin A deficiency). Portfolios can then be tailored accordingly with the right species with the correct nutrient profiles at a local level.

Spreading production throughout the year is not only beneficial for the health of consumers, but for the businesses of farmers and processors, as it allows more efficient use of land and capital, and more regular and stable income. Portfolios can also be tailored in order that labour requirements focus on the times of year when farmers are not busy tending other crops. In addition, portfolios can be designed so that farmers are better able to service international markets. African smallholders should, for example, be encouraged to grow fresh fruit for export when other sources of the same fruit from alternative producers—such as large plantation growers in Brazil or Costa Rica—are unavailable because of seasonal differences of geography.

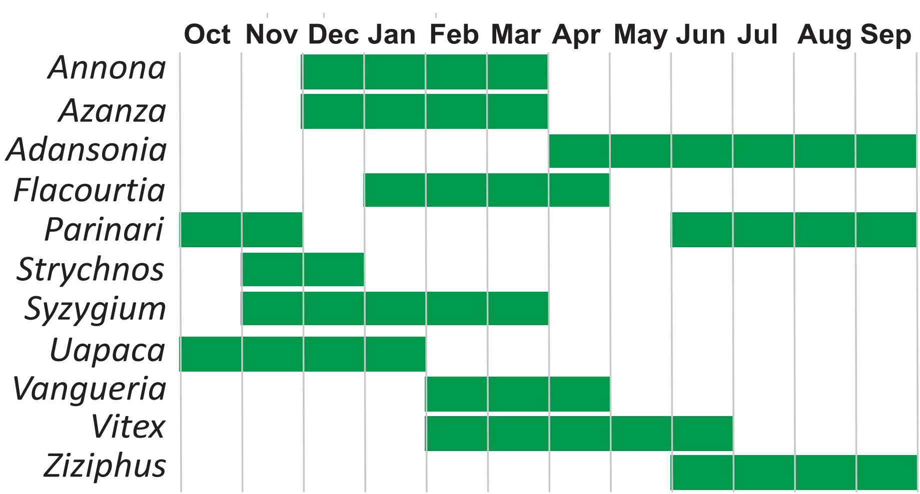


Figure C.6. A range of fruit trees found in Zambia that produce fruit in different seasons (indicated by green shading). Growing a diversity of species can provide a balanced nutrient supply year round

Intermezzo 7.

Bioenergy, fuelwood, charcoal and *Jatropha*

The current 'biofuel' debate is rooted in the concerns over global warming and the need to substitute current fossil-fuel use with renewable energy sources. With the relatively low net energy production per hectare of current technologies, once the production costs are accounted for, the contribution to the ecological footprint may be more than is affordable, while it already competes with the use of land for food production and provision of other ecological services.

The current debate on bio-energy is focused on 'biofuels' that can substitute for current use of fossil fuels. It pays little attention to the rural economies that have not got used to high fossil-fuel use and still largely rely on woody biomass to provide energy for household needs. The irony is that substitution of firewood and charcoal by subsidised fossil fuels has been (and still is?) part of environmental protection programs. Subsidised substitution of fossil fuels by 'new' forms of bioenergy is rapidly becoming part of 'climate change' policies.

Global warming can be seen as the 'spill-over' effect of human resource use that exceeds the capacity of planet Earth, or as the consequence of the ecological footprint that exceeds the size of land available. A breakdown of the components of ecological footprint in relation to the Human Development Index (HDI) at national scale shows that the area required for fuelwood production decreases with HDI (Figure C.7). At the same time, the land required to compensate for the fossil-fuel emissions increases, along with the area required to support the food and forest fibre products consumed. In balance, the ecological footprint rises exponentially with HDI and there are no current country-scale role models for sustainable development if we interpret the latter as achieving HFD > 0.8 as a globally affordable ecological footprint (a criterion that has been proposed for MDG number 7).

There are various terminologies in use as to 'generations' of bioenergy and biofuel. One version is:

Generation 1: Firewood/charcoal, manure and agricultural waste use for small-scale, static, energy use in cooking, heating and/or power generation. Firewood and charcoal have a long history as sources of bioenergy, with issues of 'overharvesting' largely owing to breakdown of local regulations in resource access and replacement by ineffective national authorities. Historical experience with wood-based electricity in periods and places of high fossil-fuel prices has raised concerns over nutrient depletion and/or loss of energy benefits when nutrient replacement is part of the system. Integrated systems in a plantation context are feasible.

Generation 2: Methane digestion of organic wastes for small-scale, static, energy use in cooking, heating and/or power generation. This has found application mostly where dairy cattle or pigs provide easily digestible manure, supported by 'appropriate technology' groups. Total energy substitution has remained low.

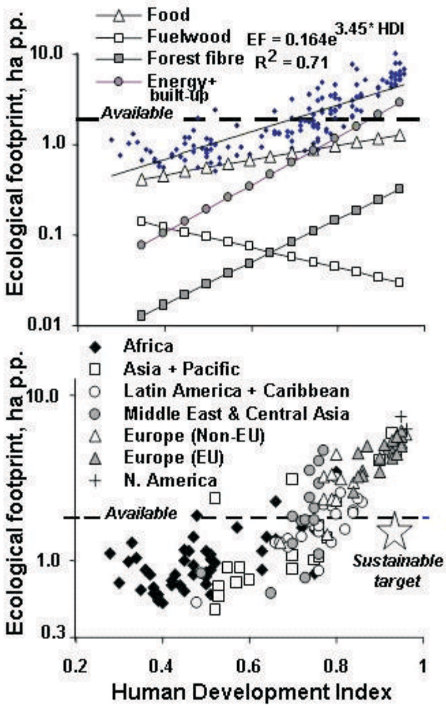


Figure C.7. Relationship between components of the total ecological footprint and the HDI (upper panel), and the total ecological footprint by HDI per geographical grouping of countries (lower panel)

Generation 3: Ethanol and biodiesel for mobile engines—substituting for gasoline and diesel—based on sugarcane, cassava, sweet sorghum, maize, soybean and other crops converted to ethanol, and oil-rich seeds (oil palm, coconut, *jatropha*, *ponghamia* and others) converted to biodiesel. Marketed as modern biofuels, the first decade of the 21st century saw a boom/bust cycle of public interest, with reality checks setting in after a hype phase. The low energy-efficiency of such fuels will lead to large area requirements and interference with global food supply, while productivity on 'degraded soils' is inherently low.

Generation 4: Large-scale, industrial, generic, biomass conversion to various fuel sources for static and/or mobile power use. Enzymatic digesters and various forms of biotechnology are in development to convert lower grade biomass, rather than starch/sugars and oils, into usable energy. The ecological consequences may be similar to first-generation bioenergy, in that large areas may be depleted of biomass without effective nutrient recycling. Whole-system approaches to see this as part of total land use are still scarce.

While any biomass can be used as fuel, woody perennials offer a number of advantages over annual crops: much lower energy and financial cost of establishment and maintenance and, in many climates, more resilience against variable rainfall patterns and co-benefits in soil protection. Wood has much lower nutrient content than leaves, fruits, seeds or tubers, and nutrient mining is less of a problem where wood is harvested (while other plant components are retained on site) than when energy is harvested through other plant components. Perennial grasses ('hay') may be second best in this respect.

D. Multifunctional landscapes and dynamic livelihoods

The main points covered in this section are that landscapes have a biophysical basis, including climate and biological richness, interacting with human management ('land use') by multiple actors. Some of the processes operating at landscape scale can be understood from the spatial distribution of landscape elements interacting through 'filters' on the lateral flows of water, soil, fire or plants and animals, such as riparian zone strips of vegetation intercepting sediment before it reaches the streams and making water quality less dependent on in-field erosion. Important other aspects of landscapes may be better seen as 'emergent behaviour', in the form of 'ecosystem services' that are the result of complex interactions that cannot be fully understood as yet. Land-use change tends towards specialisation and reduction of landscape complexity. But a turning point can be reached, beyond which there is a return to a more multifunctional optimisation. Rather than only providing harvestable goods, multifunctional landscapes are also buffers against climate change. The broad concept of 'ecosystem services' has to be teased apart into its various services and functions, however, to make management more rational and to open the experience up for more detailed analysis and progress of our understanding. Access, use and management of ecosystems and their associated services are often limited by the policies and the legislation that nations pursue. A good example is the impacts of the Sahelian Forestry Codes on the access, use and management of protected indigenous tree species (see Intermezzo 8).

Dynamic mosaics and gradients

The word 'landscape' refers to an area of land that is interconnected in its functioning through the lie of the land, the flows of water, the patterns in vegetation, the movements of animals, human livelihoods and systems of governance. There is no fixed size, but a landscape normally involves variation in height, geological substrate and soil types, multiple 'habitats' or 'vegetation types', multiple streams or rivers and multiple villages with variation in farming and other lifestyles, but connected through local markets, social networks, institutions and some of the lower levels of the nested systems of governance. The word came into use in English through 'landscape paintings' and has maintained an association with harmonious diversity, visualisation and beauty. Landscapes can change through the influence of many actors, reacting and responding to each other, with a relatively weak level of 'orchestration'. Yet, the interconnectedness makes the landscape a valid system-level of study and an important level between individual households and nation states.

Landscapes can be viewed as 'mosaics', internally homogeneous elements, and as 'gradients', gradual changes that reach across 'units'. Similar to the 'wave' and 'particle' duality of light in physics, both views may seem to be contradictory, but both add to our understanding of the patterns and process (Figure D.1). Ecologists can distinguish the 'arena' (conditions) from the 'actors' (organisms) and both are a target for conservation (Beier and Brost 2010).

Figure D.1. A visualisation of a landscape in northern Sumatra, Indonesia, as a gradient from open agricultural patches through a village and its surrounding agroforest, grading into natural forest. Orangutan that live in the forest come down to the agroforest zone of the landscape and people who live in the village and manage the parts of the landscape. The picture was created based on discussions with villagers. Artist: Wiyono

Lateral flows, filters, complex causation

A landscape gets its coherence from 'lateral flows'; from things, organisms and influences that move. Water and animals move, very fast in the air, rapidly over the soil surface and/or slowly through the soil. Soil moves slowly at geological time scales, eroding from hill slopes and aggrading along rivers and in floodplains (van Noordwijk et al. 2004c). Soil movement is slowed by vegetation, with roots holding the soil and groundcover reducing the direct splash impact of raindrops on soil. Removal of vegetation 'causes' erosion, but only in as much as it was a 'filter' before. Filters separate the materials transported from their carrier. For example, soil litter as a filter allows soil particles to become sediment while the water flows on; a wetland plant filter removes the nutrients from a water flow; and a windbreak or urban tree removes dust from air flows. Where filter functions are involved, the concept of causation becomes complicated: enhancing a filter reduces the impact of a 'primary cause' on its 'impact', but only as long as the filter lasts and isn't saturated. In human terms, the filter starts to share responsibility for the presence or absence of the 'final effect' of the 'primary cause'. When a filter is saturated or full, a breakthrough may occur that has more impact in a short time than the original flow might have had. This applies to the vegetation filter holding soil on steep slopes until a landslide occurs; it may apply to beaver or debris dams in a stream; or to vegetation temporarily storing carbon trapped (filtered) from the air, but released at the next wildfire. The role natural forests areas play in reducing flood risks appears to be restricted to relatively small catchments and riparian wetlands further downstream (van Dijk et al. 2009). Managing landscapes may often entail enhancing filter functions, but this shifts responsibility from the primary agents to those that control the fate and future of the filter, in a complex system with feed-backs and feed-forwards. Where complexity becomes too high it may be easier to describe and analyse the higher-level system on the basis of its emergent and more aggregate properties. Instead of a number of trees, we can start to see a forest.

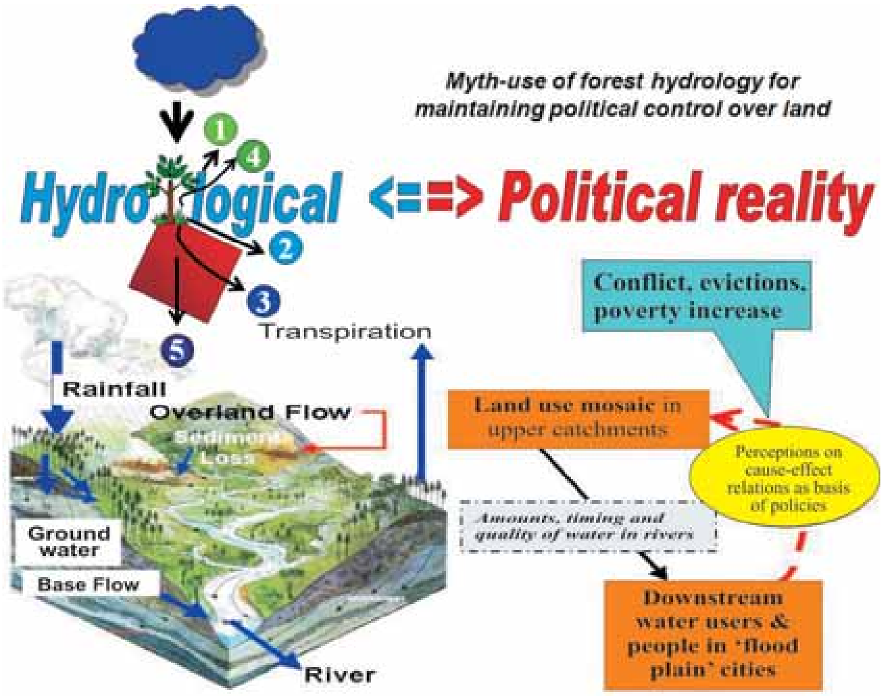


Figure D.2. The biophysical and institutional interpretation of landscape represent two sides of the same coin in the case of landscape-level water flows: institutional responses, and the public debate, attach a high importance to 'forest' as the only way to achieve good watershed functions and blame upland farmers for floods and droughts

Landscape institutions, rules and definitions

Where human beings settled, lateral flows of ‘harvested goods’ towards the settlement led to accumulation of nutrients in a few places and depletion over a large area: repeating on a larger scale what many savannah trees do in creating islands of fertility in an impoverished surrounding. Harvest of biomass as food, fuel and fibre tended to create concentric rings of modification of the vegetation around each settlement, the more so as more people lived together. The emergent pattern started to form a ‘typical landscape’. Wildlife and large trees tended to become restricted to places far from the villages. With the emergence of higher levels of political and military power, and associated state institutions, the concept of ‘forest’ arose: land controlled by the king or the state, for purposes of hunting, and later also for retaining the large trees needed for ships and marine power. The word ‘forest’ still refers to a boundary that was delineating the sphere of influence of the village, not necessarily to woody vegetation.

Control over parts of the landscape—regulating rights to use, harvest, modify or convert—have transformed the gradients into mosaics, with political struggle, negotiations and agreements. In 1215, when King John of England had to accommodate the ambitions of the local nobility to avoid being overthrown, he agreed to the Magna Carta, which includes a clause that substantial areas were to be 'deforested', that is, taken out of the royal hunting reserve and returned to local control (the 1297 version, had the long title (originally in Latin) of The Great Charter of the Liberties of England and of the Liberties of the Forest[14]).

The word 'forest', then, had political as well as environmental meanings, and has shifted these days more towards a description of woody vegetation, although much of the politics remains. Many local governance systems use multiple terms for different parts of the landscape that crudely translate to 'forest' in English. For example, there are more than 10 terms for forest in Northern Thailand, in the Karen language, that describe various functions such as protecting springs, modulating water flow into rice fields, acting as the umbilical cords and burials that mark the human cycle, as well as regulating hunting and use of tree products.

Intensification gradients

The term 'forest' can refer to a continuum (gradient) in tree cover or to an institutional dichotomy: 'yes' or 'no' under the control of 'forest authorities'. Much of current debate on trees, forests and climate is focused on the issue of political control versus observable and quantifiable processes. A broad view on the gradual intensification of land use may start with natural vegetation with minor modification of the natural succession by forming gaps and/or local fire events that allow pioneer plants (natural or planted) to grow and become domesticated as staple crops. From there on the domestication of 'commodities' and specialisation in fewer components, along with stronger modification of the environment (nutrient and water supply, control of other organisms that became labelled as pests, weeds and diseases), determined the trajectory of 'agriculture'. Parallel efforts in animal husbandry focussed on the animals as part of integrated farming but then branched off towards separate production systems. For trees, early domestication took place alongside that of annual crops and in a context of agriculture, with olives, coconut, coffee, cacao, tea, rubber, oil palm and a broad range of fruit or medical trees (including the cinchona that allowed human populations without genetic resistance to expand into malaria areas). The later domestication of timber trees took place mostly in an institutional context of 'forestry'. The current definitions of 'forest' span the full 'domestication' range, while terms for crop and animal husbandry focus on the endpoint of the intensification trajectory, seeing the more mixed and less specialised (more integrated) forms that include trees, as 'backward'. Coining the term 'agroforestry' for such systems in the late 1970s has lead to a solid research interest and gradual policy recognition of the relevance of such systems within 'agriculture', while forest authorities had to come to grips with 'community-based forest management' for similar forms of land use within the forest institutional domain (Figure D.3).

Tree cover on agricultural land

While global land-use statistics have accepted the 'forest' versus '0-forest' dichotomy, data on tree cover on what are considered to be 'agricultural' lands (Figure D.4) show that globally 50% of such lands contain at least 10% tree cover and, in Southeast Asia and Central America, 50% contain at least 30% tree cover (Zomer et al. 2009).

[14] Source: http://en.wikipedia.org/wiki/Magna_Carta

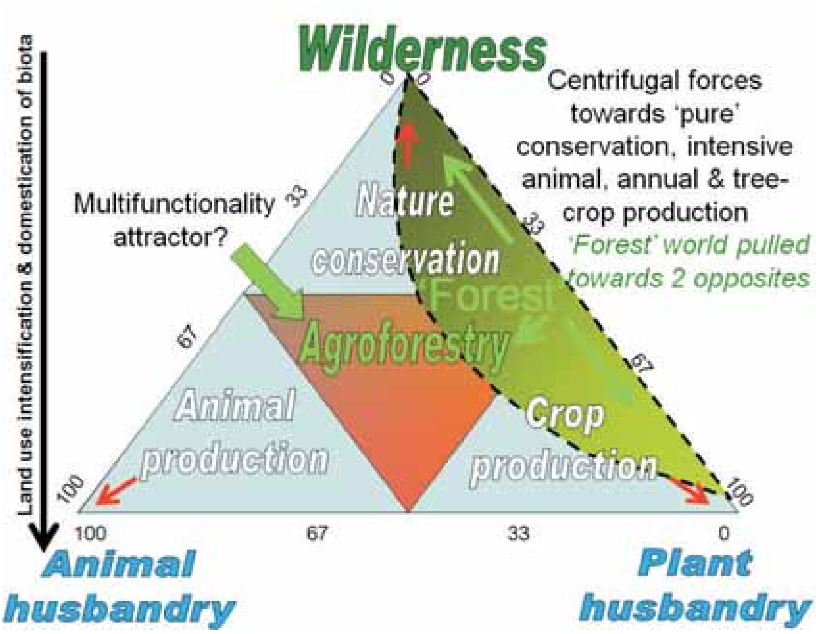


Figure D.3. Schematic interpretation of land use along a vertical axis of 'intensification' of land use and domestication of plant and animal resources, and a gradual differentiation into 'animal' and 'plant' husbandry; a similar gradient is found within the 'forest' institutional domain; the centre of the graph can be labelled as 'multifunctional agriculture', 'agroforestry' or 'community-based forest management', depending on perspective

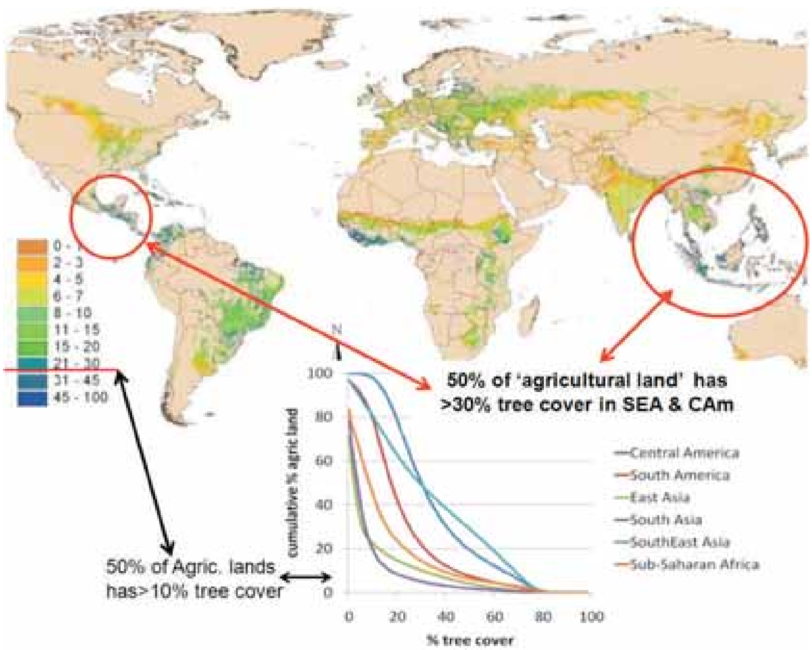


Figure D.4. Tree cover in what are classified as 'agricultural lands' in global databases. Source: Zomer et al. 2009

Mixed trees and crops or animal landscapes may actually be close to being the norm, rather than the exception. This raises three key questions.

1. What part of 'forest functions' can realistically be expected from such mixed landscapes?
2. Would a further segregation of functions into 'nature' and 'intensive production' systems be better from the perspective of overall societal goals?
3. Does that perspective change in the face of climate change?

Tree-cover transitions

Tree cover is variable in space and time and there usually is an institutional threshold above which a land unit is considered to be a 'forest'. Over time the fraction of a country (or any geographic domain) that is considered forest can both decrease ('deforestation') or increase ('re/afforestation') (Figure D.5). In practice, however, institutional interpretations of 'forest' dominate over ways of accounting for actual tree cover. Internationally accepted forest definitions allow for 'temporarily unstocked' types of forest without trees (van Noordwijk and Minang 2009), while tree cover in rural or urban areas is often not included in forest statistics, even though it exceeds the thresholds agreed in international definitions.

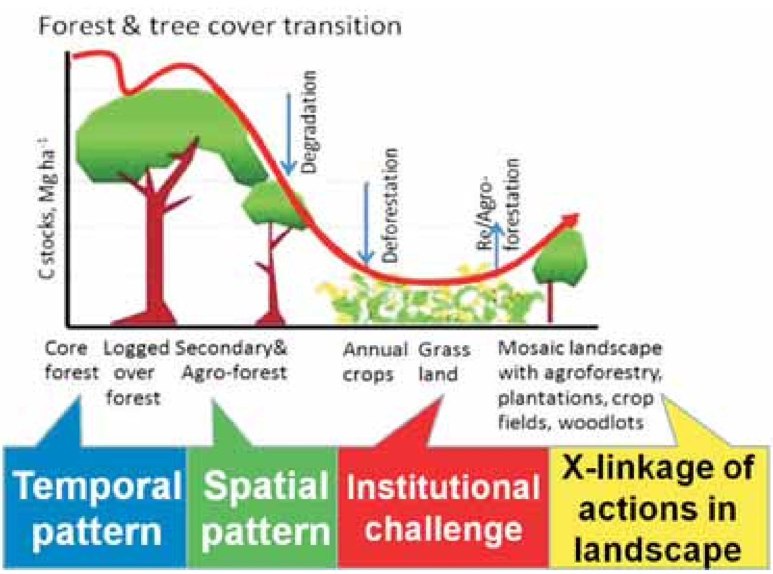


Figure D.5. Concept of tree cover (or 'forest') transition as a temporal, spatial or institutional pattern of change, with emerging interest in the cross-links across the landscape (van Noordwijk et al. 1995)

We prefer the term 'tree-cover transition' for descriptions of the two-way dynamics of tree cover, but the scientific literature refers mostly to 'forest transitions' (Lambin et al. 2001, Lambin and Meyfroidt 2010, Santos-Martin et al. 2011). Details of forest definition can have a large influence on 'deforestation rates' (Figure D.6) as well the increase or decrease of deforestation rates over time (Figure D.6). This is one of the key challenges for international climate rules that try to reduce emissions from deforestation.

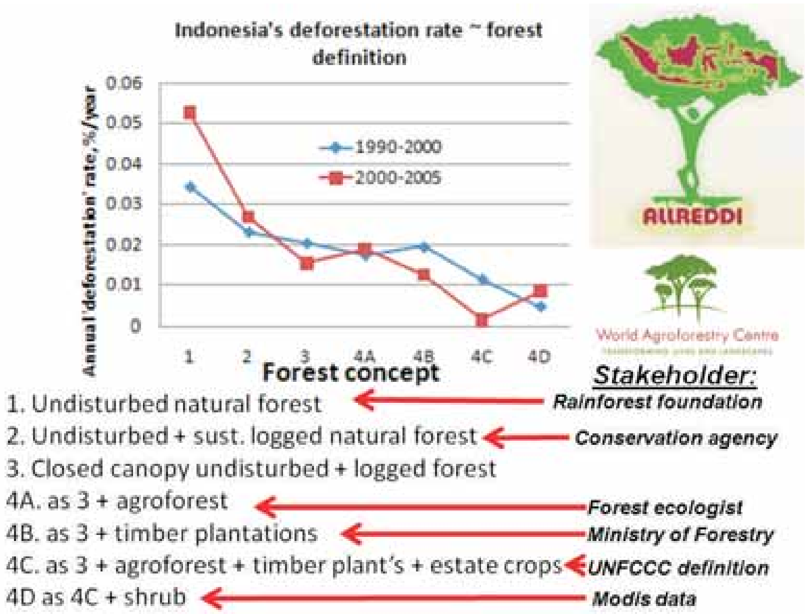


Figure D.6. Dependence of the 'deforestation rate' on the 'forest' concept that underpins forest definitions: data of land cover with various types of tree cover distinguished for Indonesia for the 1990–2000 and 2000–2005 periods were translated into a binary 'forest ⇔ non-forest' classification to derive these deforestation rates (expressed in %/year). Source: Ekadinata et al. 2010

Changes in tree cover, both positive and negative, can be linked to 'drivers' of change (Figure D.7), which tend to act in replicable sequences if we consider changes that start with the opening up of core forest areas. Interventions aimed at increasing tree cover will need to be fine-tuned to the local constellation of drivers in the specific stage of 'tree-cover transition'.

Beyond tree cover as aggregate statistic, the spatial pattern of trees matters as well. Policies to protect or restore (institutional) forests, in combination with intensification of agriculture, tend to transform a gradient of tree cover into a strong contrast between forest and non-forest. For example, Tran et al. (2010) documented such a pattern of land-cover change for the Huong River Basin in Central Vietnam. The resultant, much coarser pattern, where dispersed tree cover decreased while closed-canopy forest consolidated, appeared to be associated with an increase of flooding, while public perceptions of positive impacts of forest restoration expected the opposite effect. For watershed functions, the land use across the whole watershed is likely to be of greater importance than the percentage of forest cover (Verbist et al. 2010). However, policies in many countries remain focused on the forest condition and put targets such as 'at least 30% of any watershed must be forest' (as stated in the Indonesian spatial planning law). That figure of 30% has a long history, but little empirical support (Agus et al. 2004).

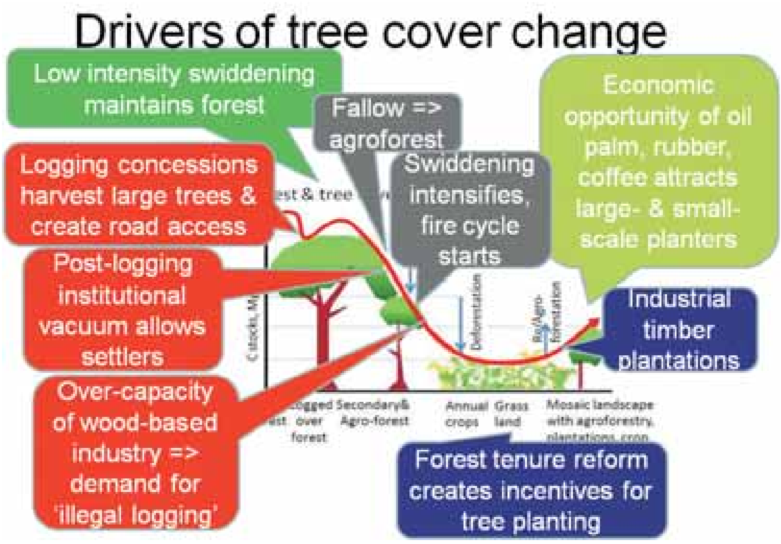


Figure D.7. Typical sequencing of 'drivers' of tree-cover change (compare with Figure D.5) that typically lead to reduced natural tree cover and its replacement by planted trees, selected for direct human utility

Dispersed trees in the landscape and strips of perennial vegetation in-between cropped fields can influence the overland flow of water and sediments and act as a 'filter' that protects downstream stakeholders from the direct impacts of land use in areas upstream (Figure D.8; van Noordwijk et al. 2004c). Inversely, if downstream stakeholders want to increase their supply of environmental services, it may be tempting to increase buffer functions, rather than seek solutions at 'root cause' level, as the latter may be more costly.

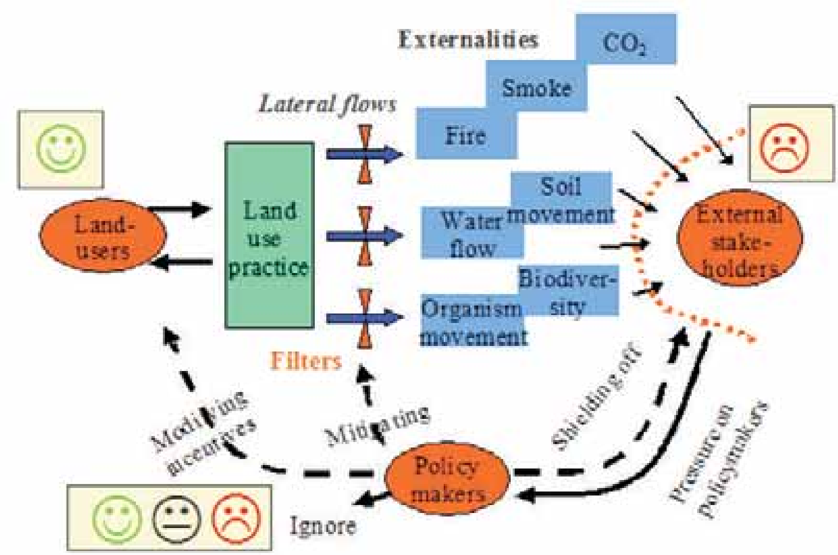


Figure D.8. Enhancement of buffer and filter functions that shield external stakeholders from negative impacts of land-use practices that affect environmental services may be more politically attractive than 'root cause' approaches, but the long-term effectiveness depends on buffer and filter dynamics. Source: van Noordwijk et al. 2004c

What part of 'forest functions' can be realistically expected from mixed landscapes?

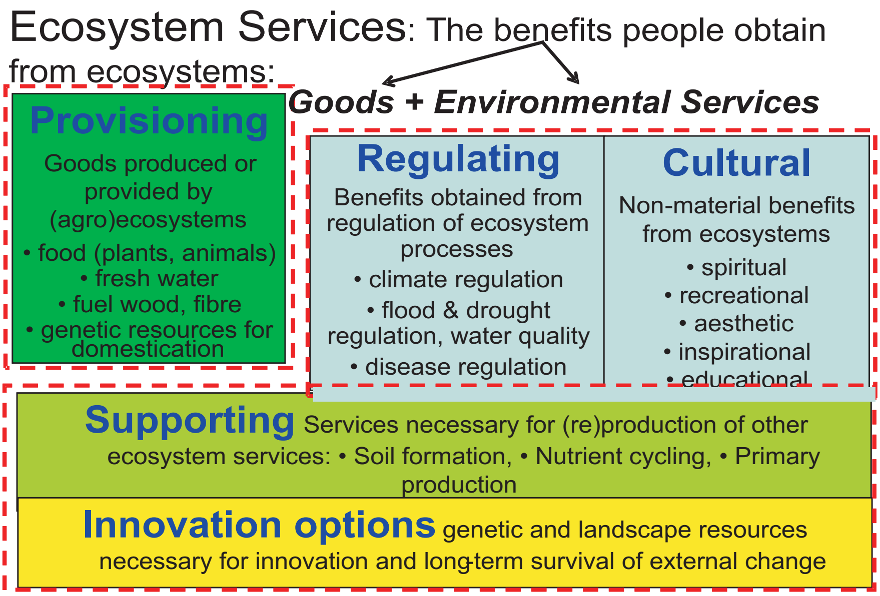


Figure D.9 Ecosystem and environmental services. Modified from MA 2005, van Noordwijk et al. 2004a and van Noordwijk 2005

Since the Millennium Ecosystem Assessment (MA 2005, Reid et al. 2010), the benefits that people obtain from ecosystems are conventionally discussed under four headings: 1) provisioning (or the supply of goods); 2) regulating; 3) cultural; and 4) supporting services. The first of these, the provisioning of goods, includes all agriculture and forestry and has readily developed markets and policies. The other groups are 'environmental services' that tend to be underrated in market valuation and to be treated as 'externalities' to decision making (Tomich et al. 2004, van Noordwijk 2005). Within the group of 'supporting' services, the maintenance of innovation options (sustainagility) is of specific relevance for adaptation to climate change. It depends more clearly on genetic diversity and landscape resources that may not currently have much utility but may prove to be crucial in the future. This group of 'services' requires specific attention, as it is poorly reflected in short-term utilitarian approaches. It can be treated as embedded in the 'inherent value' of nature.

When we compare agro-ecosystems with 'nature', we see clear trade-offs where management options that increase 'provisioning services' tend to reduce the others, especially the diversity that supports future innovation. Many of the regulating services can, in fact, still be provided by agro-ecosystems that are managed as multifunctional landscapes with trees.

Is segregation of functions better than 'integration' to achieve overall societal goals?

The aggregated term 'ecosystem services' may suggest that they all belong together. But within the landscape, with its gradients and spheres of human influence, the functions tend to be spread. Primary plant production takes place throughout the green space and regulation of water flows is needed throughout the landscape. Biodiversity functions, however, may be provided by maintenance of biodiversity-rich habitats on only part of the land. Strips and patches of natural vegetation and tree lines may harbour the birds that regulate, but also those that are, pests. Insect pollinators may nest in such patches, while the bat pollinators needed for several fruit trees can serve trees throughout a landscape as long as their caves or some dense groves of trees are retained intact. Depending on the scale and mode of movement of organisms, a distance from one metre to several kilometres may be critical in what still is a 'contiguous' landscape for them. Hence, overall ecosystem functions tend to vary along gradients of 'connectedness', usually without clear thresholds.

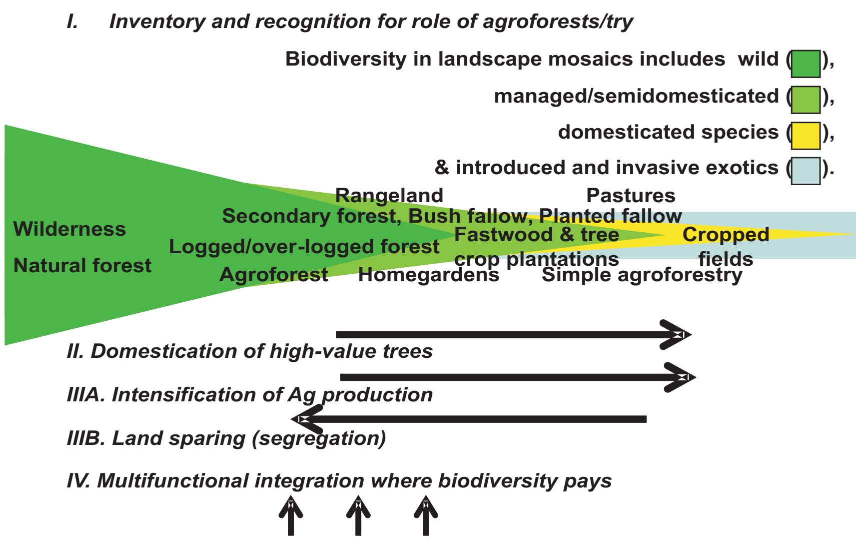


Figure D.10. Schematic representation of the species' richness across a gradient from wilderness to cropped fields, classifying the plants and animals as native to the original habitat and area, semi-domesticated, fully domesticated and introduced (invasive exotics)

Biodiversity functions are likely to be the most 'delicate' and dependent on the presence of at least some 'undisturbed' habitats. Many plants and animals, but not all, can survive in habitats that are used for low intensities of harvest and extraction and/or for recreational or religious functions. Many can still live in agroforest-type habitats, where planted and/or managed trees (for example, rubber, tea, coffee, durian, cacao) share the space with spontaneously established trees, in vegetation that retains some of the processes of a natural forest, including patch-level regeneration. A substantial loss of biodiversity occurs when such mixed agroforests are replaced by more intensively managed plantations of one or just a few species.

Does the segregate–integrate perspective change in the face of climate change?

At a rather high level of abstraction, seen from a greater distance, we can understand landscapes as evolving in a two-dimensional space, determined by the level of goods, biodiversity and closely related ecosystem services that they provide. A natural forest is low on the first and high on the second axis while an intensively managed agro-ecosystem may be the reverse (Figure D.11).

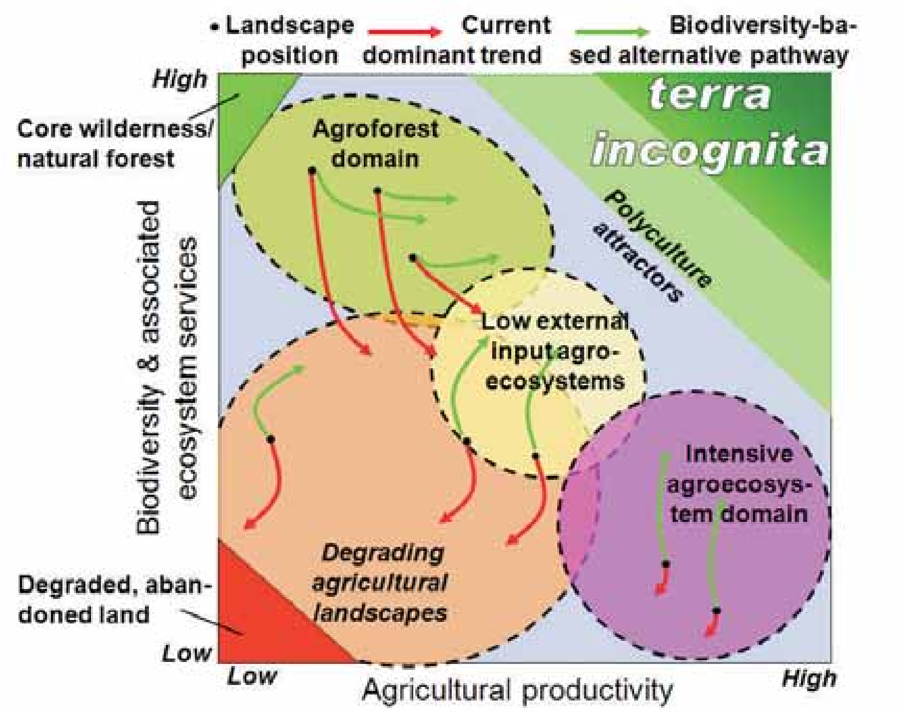


Figure D.11. Relationship between agricultural productivity and biodiversity and associated ecosystem services across the main diagonal from natural forest to intensive agriculture, with degraded lands in the lower left corner. This figure is used by the Agrobiodiversity group of Diversitas[15] for analysing the plausible trajectories of specific benchmark sites

The type of intensification of agriculture through specialisation in one or a few commodities that became known as the 'green revolution' has had to substitute for the loss of several ecosystem services. Chemical fertilisers rather than landscape-scale nutrient cycling became the primary source of plant nutrients, pesticides rather than reliance on natural predators and parasites became the main way to fend off organisms that have the same food preference as human beings. In the short run, this type of intensification seemed profitable, but with experience there also grew the awareness of its costs: financial as well as loss of natural capital and flexibility. More knowledge-intensive and integrated systems of managing pests and nutrients have since emerged, relying on better monitoring and advisory schemes based on extensive experimental data.

Climate change will change the opportunities for rapidly moving pest and disease organisms faster than those for their predators and control agents. It is a reasonable hypothesis to expect that more diverse and less intensively used landscapes have a greater resilience and more opportunity to deal with climate change than intensive agriculture. But this is as yet a hypothesis, and further critical data collection and synthesis is needed.

[15] Diversitas is an international program of biodiversity science with a dual mission: 1) to promote an integrative biodiversity science, linking biological, ecological and social disciplines in an effort to produce socially relevant new knowledge; 2) to provide the scientific basis for the conservation and sustainable use of biodiversity. Source: http://www.diversitas-

To make progress on the actual management of a landscape requires 'boundary work' that links multiple types of knowledge and multiple approaches to action (Clark et al. 2011) because the knowledge-based interpretations of reality are as often as contested as the actions they interpret, justify or see as culprits (Villamor and van Noordwijk 2011).

A number of recent studies have articulated the economic value of ecosystem services as a justification of the public policy interest in maintaining the landscapes that provide them (Leemans et al. 2009, TEEB 2010). Translating the theoretical value into action, however, is more easily said than done (Kosoy and Corbera 2010, Kumar et al. 2010, Pascual et al. 2010). What is commonly framed as 'payment for environmental services' (PES) (Wunder 2005), can be conceptualised in multiple ways (van Noordwijk et al. 2004b, van Noordwijk and Leimona 2010).

Intermezzo 8.

Sustainability analysis in West Africa

Sustainability appraisals promote planning and decision-making that makes local livelihoods more robust. It is an integrated assessment of environmental, social and economic effects of proposed actions at all levels of decision-making, from policy to plans to projects. It is undertaken under a national or international framework of sustainability principles, indicators or strategies (Dalal-Clayton and Sadler 2005). In many countries environmental impact assessment systems have been established to analyse development projects as part of the legal decision and approval process. The potential environmental impacts of policies, laws and plans, however, deserve a similar type of scrutiny. We can, therefore, say that sustainability appraisals try to link 'upstream' and 'downstream' parts of the decision cycle through integration of environmental objectives and considerations in natural resource policies and legislation at a strategic level. Such appraisals can be used in facilitating the review of policies through participatory assessment of the impacts of existing policies and legislation. They enable objectives pursued by different sectors to be assessed and reconciled. They also help to realise good governance of natural resources and promote inter-institutional relations in order to define priorities and build public trust and confidence.

It must, however, be noted that sustainability appraisal still remains a 'frontier' challenge in agroforestry. Scientists applied it for the first time in Mali and Niger to access the impacts of the Sahelian Forestry Codes on access, use and management of protected native tree species, using a three-point criteria with several basic aims and objectives. The sustainability criteria were 1) preservation of the environment; 2) social cohesion between those governing resource use and users at the local level; and 3) income generation. Under each criterion, basic aims and objectives were formulated with corresponding indicators as well as performance measures ranging from 1 to 5 with 1 being 'no relationship' and 5 being 'strongly supportive'. The reasons, issues or areas of improvement explaining the level of performance assigned to each basic aim or objective was recorded in a sustainability test record sheet. Each of the criterion was further sub-divided into a total of 15 basic objectives: 1) vegetation conserved and improved; 2) degraded land rehabilitated; 3) sustainable wood fuel harvesting; 4) achieving carrying capacity (balancing livestock numbers to available pastures); 5) promoting community cohesion; 6) improving health and wellbeing; 7) empowering women and vulnerable groups; 8) job creation;

9) promoting secure access to land; 10) promoting participation; 11) reducing vulnerability and risks; 12) increased incomes to farmers; 13) improved local economic conditions; 14) increased investment; and 15) improved agricultural production.

Closely examining the codes was the first step. This involved identification of the provisions of the codes that were conflicting and had the potential to work against the aims and objectives formulated to guide the sustainability appraisals. In order to determine the degree to which different policies/provisions of the codes supported or worked against each other at the local level, a compatibility analysis was undertaken using a compatibility matrix. This was accompanied by compatibility analysis record sheets (used as a record of all issues and reasons explaining either incompatibility or compatibility). In the Malian case, there were five incompatible provisions of the Forestry Codes that were subjected to the three-point criteria test.

- i) Current use of protected indigenous native tree species.
- ii) On-farm protection of native tree species.
- iii) Compliance with access, use and management rules.
- iv) Use of police to enforce the law.
- v) State ownership of land and protected indigenous tree species.

Foresters and other resource persons were trained on the sustainability matrices as well as in building a consensus on the significant determinants they considered as structuring the current forestry policy in Mali, Niger and Senegal. With resource persons and foresters, the researchers isolated the critical factors that seemed to have greater impacts on natural resources management, socio-cultural cohesion and local economic conditions.

To complement the sustainability appraisal other tools are also recommended. In the Sahelian case, researchers used participatory action research to: 1) enable communities to develop geospatial perceptions of landscapes by capturing geophysical features, locating different land uses, delineating access rights and defining their relationship to particular natural resources; 2) understanding the links between the provisions of the forestry law, practice and impacts on natural resource utilisation and management; 3) identifying roles through understanding the rights, responsibilities and benefits of different stakeholders and their relationships; and 4) establishing the potential or existing impacts of the critical provisions identified through the compatibility analysis. The participatory action research was useful in re-thinking, negotiating and re-evaluating the law.