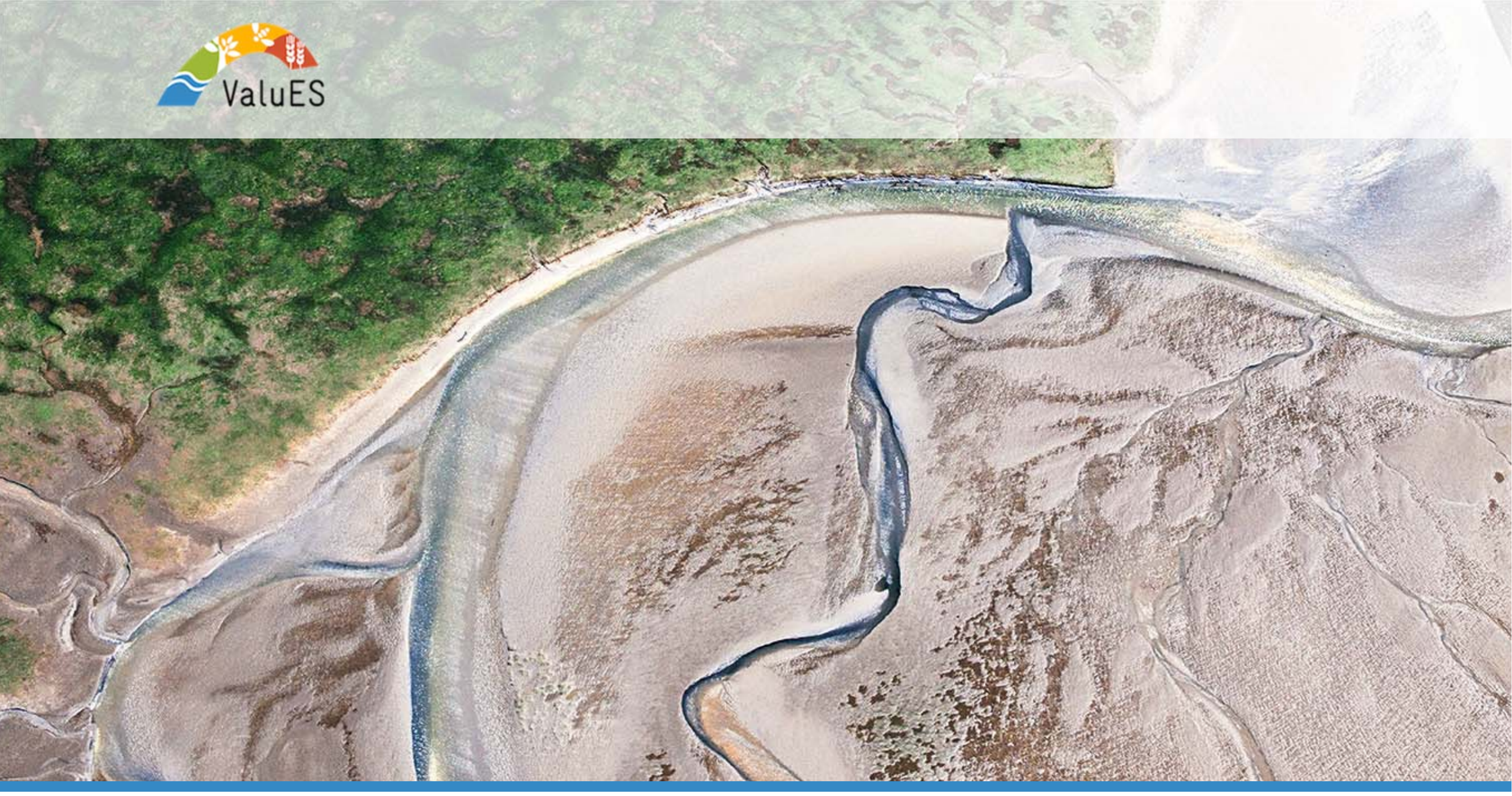

Indicators for Managing Ecosystem Services – Options & Examples

Guidance for seeking information that supports the integration of ecosystem services into policy and public management

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Contents

Part A: Finding Indicators for Ecosystem Services

The idea of 'ecosystem services' can help bridge the divide between development and conservation. Adopting an ecosystem services perspective means to look at nature in terms of the many benefits it provides to society. This perspective reveals that in most places on earth, maintaining well-functioning ecosystems should be part of a resilient development strategy. We cannot afford to disregard that ecosystems sustain much of our economy, culture, health and well-being.

This is not a mere claim. Looking at ecosystem services can reveal the details. What often matters in policy and public management is to get the causal connections sorted between a (planned) specific action, its impacts on the environment, and the further consequences this may have on (parts of) society (van Oudenhoven et al. 2012). For determining these impacts, the 'ecosystem service lens' indicates who benefits from (or depends on) nature, where, and in which ways.

An 'ecosystem service lens'

If we adopt such an 'ecosystem service lens', we look at water not primarily as a hydrologist, ecologist, engineer, or farmer, but try to combine these views. The added value of such a perspective is that 'supply'-'demand', or, in less economic terms, the 'provision' and 'use' or 'appreciation' are being considered jointly. It is their relationship which matters for policy and public management: If the societal need for one service increases, its stable provision is much more important, than in the case of a fading need.

> For example, in case of a growing population in a municipality, water provision has to satisfy growing needs. This can be ensured by enhancing overall water availability (e.g. better protection of the catchment area), or by introducing measures to increase the efficiency in water delivery (e.g. modernization of infrastructure), or by reducing per capita water demand (e.g. outreach and introduction of water saving technologies at household level). Whether these measures become urgently required depends on the overall ratio of water supply and (expected) water use.

In practice we often look closely at one side (either the ecosystem, or the society), and implicitly assume the other side to be stable or sufficiently known. Effective policy responses are those which take both sides into account.

Indicators play a key role for adopting an ecosystem service perspective in policy and public management. They tell us about what is happening 'on the ground' or 'in the field', as opposed to 'in the plans'. They inform us about conditions, trends, and pressures in a comprehensive way.

Ecosystem service indicators are not substantially different from other environmental indicators, but they focus on the environment in a slightly different way: Beyond biophysical data, they seek to capture how this information can be interpreted with regard to nature's benefits to humans. In practice this implies, ecosystem service indicators are often composite indicators, i.e. those which combine various measurements of the supply and the use/demand of a benefit provided by an ecosystem.

> For example, a 'water stress indicator' combines measurements or approximations of (i) water availability and (ii) water demand and describes their ratio.

Finding ecosystem service indicators

A principal challenge is to find those indicators, which meet the specific information needs in a situation. This means, understanding what needs to be known, and then choosing a suitable combination among the plethora of potential indicators.

Important guidance on developing and using ecosystem service indicators has been prepared under the lead of the UNEP World Conservation Monitoring Centre:

- The CBD Technical Series 58 presents experiences, issues and challenges from sub-global assessment processes, following the Millennium Ecosystem Assessment.
- More detailed guidance, including a stepwise procedure for developing ecosystem service indicators, has been proposed by Brown et al (2014) in the report Measuring Ecosystem Services .

We seek to complement this guidance, by presenting for each ecosystem service a succinct selection of literature and further sources, which describe example indicators for approximating

- its (bio-physical) condition or supply, and
- its appreciation in socio-cultural or economic terms.

This collection of indicators (Part B) should not be understood as an exhaustive list, but rather as a representative sample of typical applications.

The 10 steps proposed by Brown et al (2014) and illustrated with an example in this introductory section invite to carefully reflect on what knowledge is needed and how this can be obtained amidst the site-specific constraints regarding time, resources and capacity. The focus on policy cycle and political entry points emphasizes the need and the opportunity to align indicator efforts with a clear understanding of actual knowledge needs: Who needs which kind of information about ecosystem services?

What makes a good ecosystem service indicator?

Ecosystem service indicators have been defined as information that efficiently communicates the characteristics of ecosystem services, making it possible for policy-makers to understand the condition, trends or rate of change in ecosystem services (Brown et al. 2014). Good ecosystem service indicators are:

- **relevant to the issue**, i.e. they capture the changes we are concerned about
- **transparent and understandable**, i.e. their logic and methodology can be properly explained
- **scientifically robust**, i.e. they reflect current scientific understanding about the issue
- **practically feasible**, i.e. they do not imply huge additional efforts if the monitoring budget does not allow for it.

Furthermore, the indicator should be geared to its purpose and its audience: There are **different purposes for using indicators**. One can draw on their information for planning and decision-making, or in order to raise public awareness about environmental conditions. Indicators can also serve to strengthen accountability, e.g. measuring compliance with resource use rules or conservation contracts. Indicators can function as benchmarks for performance and results-oriented management; they are used for reporting progress on objectives e.g. for sustainable development and conservation.

Indicators are also needed for implementing policy instruments, e.g. for PES schemes. For example, in Indonesia, sediment load in streams was measured to monitor the effectiveness of riverine land-use change for reducing the sediment load in a hydro-electric dam. This allowed identifying communities to be encouraged to participate in a PES scheme which compensates for riverine protection. It later allowed tracing compliance with the PES contract, and helped track the overall effectiveness of the scheme in lowering sediment accumulation in the dam - and thereby its maintenance costs. (see ValuES case).

Specifying information needs to gear indicators to purpose

Different purposes may require different kinds of information, and therefore different indicators: Which depth, format, metric, and degree of certainty is appropriate, in the specific context and for the specific purpose? Delineating this knowledge gap is a prerequisite, for the subsequent indicator search. Such 'needs-driven indicator development' means, that actual information needs serve as starting point. Once, the information needs are clear, the task is to identify those indicators which correspond to this gap and tell us what we want to know, in the degree of detail and of certainty which we need this information to be in.

> For example, monitoring water availability can be done in many different ways, e.g. by analysing satellite images, measuring a river's streamflow, by looking at ground water tables, or by doing surveys with water users.

Each indicator emphasizes different aspects, captures some issues better than others, builds on a potentially different explanation about how things work, and has different practical implications for data gathering.

> For example, if a forest cover indicator uses low resolution satellite data, it may not be able to distinguish between different forest types, and would therefore ignore the set-up of planted forests in a natural growth forest. Such an indicator may still be used to approximate overall forest cover trends, but cannot grasp the changes for example in species diversity, water pollution, erosion control or pollinating services that the conversion of a natural growth forest into a forest plantation typically brings along.

Finding the right indicator combination (or composite indicator) is therefore an exercise of comparing and skilfully combining data options and practicalities with specific information needs. The necessity for new pieces of information (e.g. measurements), and their added value compared to their additional monitoring costs can only be cross-checked in light of such a comparison.

Indicators shape how we see reality

Indicators are not merely technical: they also shape how we view or frame an issue. The Human Development Index (HDI) resulted from the conviction that the GDP is a poor descriptor of a country's welfare. The HDI frames a country's development situation as a combination of three indices, describing life expectancy, education and income, each drawing on several sub-indicators. It could be conceived in quite different ways as well and the HDI has been continuously evolving in the attempt to better express, describe and measure what people mean by 'development'.

What does this imply for ecosystem services? Finding the right composite indicator also requires to cross-check each candidate: Is this the way we want to see, describe, and manage the issue at stake?

Indicators along the ecosystem service cascade

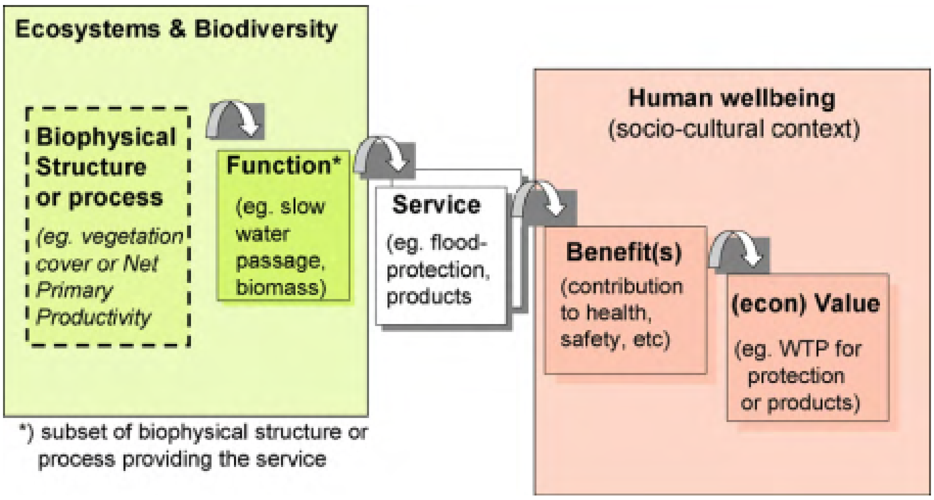
Indicators about ecosystem services can take different angles. Depending on what should be measured or which data is available, they can e.g. more directly relate to the bio-physical conditions within which service provision takes place. At the other end of the spectrum they can examine demands, needs or appreciation of the benefits that are being enjoyed.

A so-called 'cascade' has been widely used, to clarify the meaning of ecosystem services (Haines-Young & Potschin 2010). This concept usefully depicts ecosystem services at the interface between the bio-physical and social system – showing that various aspects can be examined, and used as indicators for ecosystem services.

The Ecosystem Service Cascade makes a distinction between ecosystem structures und functions and the benefits that people eventually obtain (Haines-Young & Potschin 2010). Ecosystem structures are thereby the result of complex interactions between biotic (living organisms) and abiotic (chemical and physical) components of ecosystems. Ecosystem functions result form these structures of an ecosystem, which are at the end potentially useful for people.

> For example, the vegetation cover in a tropical rain forest (as ecological structure) influences the runoff conditions and the discharge into a river as a natural process. The ecosystem function in this case is water regulation (slowing the passage of surface water). If people derive a benefit from this function then that ecosystem function is regarded as a service (e.g. flood protection). People or society will value this function differently in different places at different times. Beneficiaries of this ecosystem service are, for example, different downstream users or communities, which profit from a mitigation of flood peaks. The value of this service can be described as the protection of people, fields or properties and can be defined, for example, by the calculation of costs avoided.

A hands-on overview of ecosystem services, their importance and typical management instruments can be found here: http://aboutvalues.net/ecosystem_services/



Ecosystem Service Cascade (Haines-Young & Potschin 2010)

The ecosystem service cascade has been criticized for not including social processes which enable their use or drive their enjoyment. Taken on its own, the cascade seems to suggest that nature's benefits are 'flowing effortlessly from nature to people' (Spangenberg et al 2014). Issues of access and distribution, as well as incentives/regulations driving service use are not part of the cascade. Thus, the actual benefits people receive from well-functioning ecosystems, especially regarding the provisioning services (e.g. fish from the sea), also highly depend on who has the rights and the means to enjoy them.

A focus emphasizing the supply-side of ecosystem services (e.g. actual fish stock) can risk hiding the conditions for access to them, and (changes in) their distribution among different beneficiary groups. Whether this bias is a problem, or not, depends on how indicator information is intended to be used.

The ecosystem service cascade and the example indicators from Finland (below) show that there are various ways of looking at environmental and economic data and to interpret them through the lens of the ecosystem service concept. Again, which data to consider for an indicator on ecosystem services depends on the combination of available data and on actual information needs.

It is therefore useful, to consider ecosystem service indicators as a specific interpretation of socio-economic and environmental data rather than as a completely new category of indicators. Thus, in the later section with examples of ES indicators you will find many indicators already well-known from environmental or socio-economic statistics.

In principle, indicators can be identified for each box of the cascade, the question is, where do they make most sense? The Finnish Ecosystem Service Indicators database uses four categories of the cascade (structure, function, benefit, value), but not 'services' itself, to classify indicators. The table below provides descriptions of each category, which illustrate the different angles which indicators for ecosystem services can adopt.

Finnish classification of ecosystem service indicators, following the 'cascade metaphor'

Category	Definition	Example indicator for timber provisioning service
Structure	These indicators define the biophysical features that ecosystems need to be able to function and provide ecosystem services.	Total area under forestry in Finland. Share of productive forest land in total area under forestry.
Function	Function indicators define the ability of the ecosystem to produce ecosystem services in a certain time frame. Also spatial units can be involved when the indicator represents the productivity of an area in a certain time unit (e.g. kg/ha/a).	Estimated annual increment of round wood in cubic meters/ha/year
Benefit	Actual benefits are considered as the used share of the total yield of ecosystem services.	Annual roundwood removals in cubic meters/ha/year.
Value	Value indicators are separated to four categories of economic, social, health and intrinsic values. The purpose is to present thoroughly the importance of ecosystem services from different perspectives.	Economic value: Income for forest owners for felled wood. Social value: number of regular employments in timber value chain Intrinsic value: 'Forests are green gold', and wood production is a central element in Finnish identity. No specific measurements for changes in this value have been proposed.

The Finnish example also raises the frequent question whether ecosystem services are better measured in terms of stocks or flows. In the above table, the function is described as an ecosystem service supply flow: Estimated annual increment of round wood in cubic meters/ha/year. Alternatively, the amount of tree biomass in a forest is a stock indicator; it supports several potential ecosystem service flows, such as the annual harvest of wood or an annual uptake of carbon dioxide.

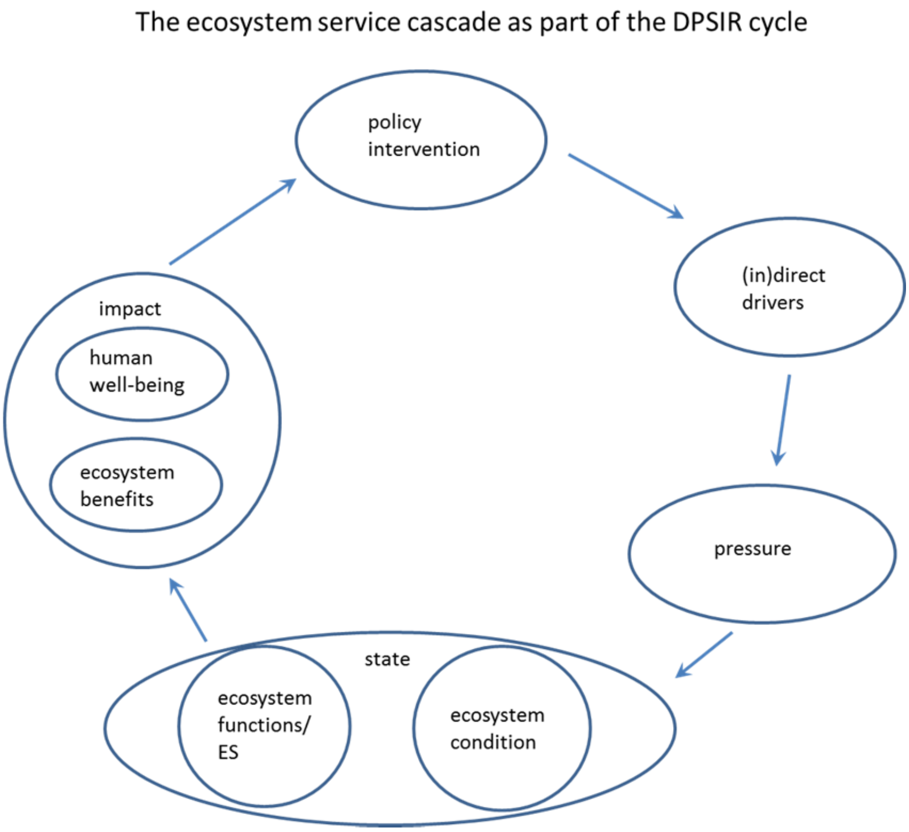
Stocks and flows need to be balanced: if the annual Roundwood removal exceeds the annual wood growth, the Roundwood stock will be reduced – and possibly depleted at some point. It is usually helpful to monitor ecosystem services in both flow and underlying stock terms. The significance of a particular flow is hard to judge unless the size of the stock (and its natural replenishment rate) is known (Scholes et al. in: Ash et al 2010).

Indicators and the policy cycle

For enhancing the practical relevance of the ecosystem service concept, the cascade has been combined with a policy or management cycle (as e.g. proposed by Müller & Burkhard 2012). This illustrates the varied options for indicators, and it shows that **indicator information can feed into decision making at different entry points**.

The graphic below places the ecosystem service cascade inside the so-called 'DPSIR' cycle. DPSIR stands for:

- **Drivers**: social, demographic and economic developments, consumption or production patterns in societies and the corresponding changes in motivations and lifestyles. Drivers create pressures.
- **Pressures**: can be described as environmental inputs including dismissals of substances, physical and biological agents as well as the concrete utilization of land and resources by human activities. Pressures produce a certain environmental state.
- **State of the environmental systems**: State refers to the environmental, physical, biological and chemical conditions in a defined area, Here, 'state' is further broken down into ecosystem condition and functions, of the ecosystem service cascade (see above). Environmental states have impacts.
- **Impacts on natural and human systems**: They can be understood as changes in the provision of ecosystem services, benefits and associated human-wellbeing. Impacts can motivate a policy or management response.
- **Response**: Policy strategies and interventions are carried out to respond to the negative impacts imposed on the human-environmental system. They can comprise mitigation and adaptation measures. These address drivers, but can also be geared directly at 'pressures' or 'human well-being' (not depicted in the graphic).



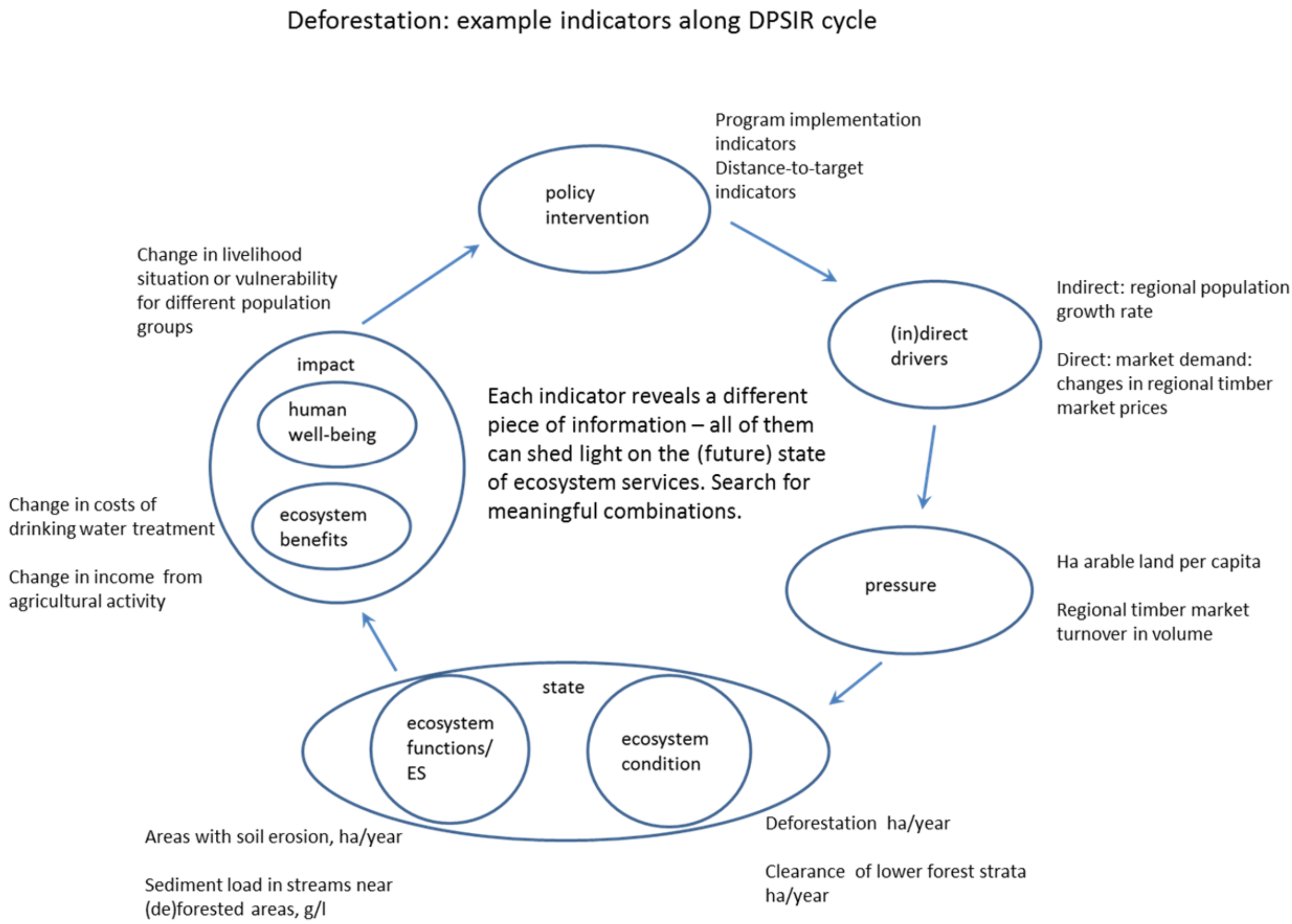
At each 'bubble' or step in the cycle, indicators can shed light on different aspects relating to ecosystem services.

Indicators relating to ecosystem services, along the DPSIR cycle

An example of forest conversion to agricultural areas:

- **Indicators for drivers**: Let us assume that in a tropical forest area, population growth is one of the indirect drivers of forest conversion, and improved market access due to a new road constitutes a direct driver. This can be approximated with local population data and national/regional timber market statistics.
- **Indicators for pressure**: With population growth, livelihood needs increase. With the road, marketing opportunities for timber also increase. As a result, demand for arable land and for timber also increases. This can be approximated e.g. in terms of a local poverty index or the ratio of arable land per capita. Timber export from the area can be monitored indirectly via number/size of timber companies or turnover at key transport locations along the new road.
- **Indicators for ecosystem condition** ('state') can be measured in terms of rate of forest conversion in ha/year. Methods include remote sensing data, or aerial photography. However, this may not reveal the ecosystem condition in lower forest strata (e.g. clearance below the forest canopy for shade grown coffee plantations). In that case, the indicator would have to be adapted to 'state of forest areas' and methods would include e.g. field visits.

- **Indicators for ecosystem function and ecosystem service supply** ('state'). The whole range of ecosystem functions and ecosystem services (i.e. those functions of benefit to humans) change in case of forest conversion. Typically, provisioning services increase (timber harvest, crop production), at the expense of regulating services (regional climate regulation including regular rainfalls, or loss of erosion control and increased sediment load in surface waters). For each function/service different indicators apply, for example sediment load in surface streams can be used as one measure for water quality.
- **Indicators for actual benefits** derived from these ecosystem services ('impact'): If for example the forest lies in the catchment area providing drinking water to a municipality, the reduced availability of good quality drinking water can be measured in terms of additional water treatments needed and costs associated with it. If the focus lies on livelihoods, the increased provision of food and cash crops due to agricultural activity on converted forest land can be monitored, using harvest quantities as an indicator.
- **Indicators for change in human well-being** ('impact'): How does the forest conversion impact on human well-being? Whether an environmental change positively or negatively affects livelihoods is often a matter of who exactly is being considered. Aggregate views on the local population can indicate overall increases in well-being due to forest conversion, if measured e.g. in terms of local/regional market turnover increases (as a proxy to for cash income). More detailed indicators, considering population subgroups separately, can reveal how different people benefit from conversion, or are affected by it.
- **Indicators for policy interventions**: Indicators for the government decision itself are rarely required, as these are typically one-off decisions – however, continued monitoring of the implementation progress of policies and programs is often used to track government performance. This can be measured in terms of activity indicators (how many hours of forest patrol per month? Or how many visits to farmers? How many outreach workshops?) Alternatively implementation can be monitored by means of more outcome-focused 'distance to target' indicators (e.g. rate of conversion lowered by 10%/per year).



It is not necessary to have indicators in place for every aspect, i.e. for every bubble (or arrow). Rather, the graphic shows the wide range of possible indicator options, and the need to carefully select according to what information is most useful or mostly needed in the specific situation.

> If the purpose is for example to understand the effectiveness of a new program promoting agroforestry (as opposed to slash-and-burn conversion to agricultural land), monitoring (i) program activities in comparison with (ii) harvest levels of multiple crops in one farm could be a suitable approach. Alternatively, if the purpose is to demonstrate the impact of deforestation on water availability, then (i) 'timber extraction' or other indicators describing deforestation and (ii) 'changes in sediment load of surface streams ' should be jointly considered.

At times, the distinction between function, service and benefit can be subject to interpretation, for example when it comes to less tangible 'cultural ecosystem services'. Here, other indicators which focus more on the interaction with the environment can be more appropriate, such as those describing use practices, use trends and accessibility (e.g. different forms of sports and recreational use patterns in parks and urban green spaces).

Where traditional forms of cultivating or harvesting are still in place, the cultural importance of a certain resource use pattern should not be neglected: Fish is a 'provisioning service', but 'fish' also allows 'fishing' which may be an important part of local culture. So with dwindling fish stocks, both, the local economy and the local identity are affected.

For monitoring, this interdependence of ecosystem services, their multiple values and their appearance in 'bundles' has important potential: It implies that well-chosen indicators can allow plausible conclusions with regard to various ecosystem services, provided the ecosystem service bundle has been well-understood. For example, water related indicators allow conclusions regarding the water provisioning service, but also concerning agricultural productivity, if water is the critical limiting factor in the production function.

Finally, indicators focusing on ecosystem services values (rather than their quantity or condition), require particular attention: They should be cross-checked with regard to the indicator's interpretation of the service.

> For example, the economic value of a beautiful national park may be better measured and monitored using 'visitor satisfaction' or 'visitor motives' as indicators (e.g. to be assessed by means of surveys), than 'travel costs incurred' to reach the park. The distance travelled to reach the place, and the costs associated with this travel distance, is a very limited proxy for assessing or monitoring its, aesthetic, recreational or didactic importance. Several pieces of information should be jointly considered if value assessments or value monitoring is required.

Steps for developing ecosystem service indicators

The following stepwise approach is adapted from Brown et al. (2014), who outline a process how such requirements can be met, and how the underlying concerns can be addressed. Brown et al provide detailed explanations and illustrations for how to apply this procedural guidance. Here we present a simplified version and, further down, an example illustrating its application.

Step 1: Identify the target audience:

- Who needs the ecosystem services indicators in your case? Typical users include national, sub-national and local governments, NGOs, media, research institutes and universities.

Step 2: Specify the intended indicator use and key questions:

- For which purpose will indicators be used? For example, they can be used for measuring progress, early-warning of problems, understanding an issue, reporting, and/or awareness-raising. From the purpose follows: What are the key questions that the intended user or audience have related to ecosystem services?

Step 3: Develop a conceptual model:

- The conceptual model describes a systemic functioning, e.g. a cause-effect relationship between human land-use decisions and ecosystem service flows. The conceptual model guides the selection/development of indicators. For example, if sediment load in rivers is an issue, indicators on upstream deforestation can be applied, based on a conceptual model that specifies how deforestation in upstream watersheds contributes to sediment load in streams. The conceptual model provides an explanation about linkages and thereby seeks to ensure that only those indicators are chosen which are relevant to the issue and can accurately describe it.

Step 4: Identify and select indicators:

- It requires a combination of scientific rigour and creative thinking to identify potential indicators. It builds on combining key questions/conceptual model with the data that is available and the resources/capacities to obtain additional data (e.g. by measurements). Data can be found in many different forms and at different scales, including: downloadable databases, statistical surveys, spatially mapped data, academic research and books.
- Several rounds of joint brainstorming and reflection among indicator users and providers may be necessary to identify those indicators which are technically/financially feasible and allow conclusions on exactly those aspects which need to be known. Presentation of draft indicators is useful for developers and users. It allows users to see if the indicator is suitable for their issues and to validate them.

Step 5: Apply and make use of indicators:

- The application or calculation of an indicator will depend on the rationale and underlying measurement method.
- Indicator results then need to be interpreted appropriately for their intended audience. The communication of indicators and the conclusions to be drawn from them can be designed in the form of a 'story' or narrative relating to the purpose for which the indicator was initially sought.

Step 6: Develop monitoring and reporting systems:

- Indicators that are chosen for use over time require an investment in the monitoring systems to produce the required data.
- The consistent production and reporting of an indicator over time requires one institution to have this responsibility, although it is not necessary for this to be the same institution as that which produces and uses the indicator.

Applying the stepwise approach to indicator selection – an example

For illustration, these steps are now applied to an example, inspired by an exercise conducted in November 2015 with representatives of the management of the Parque Nacional de Cabo Pulmo, a small marine protected area in Mexico.

Cabo Pulmo is renowned as one of the world's most outstanding destinations for diving. It is located in the Gulf of California and extends over an area of approximately 7.000 has. The coastal village of Cabo Pulmo is the basis of an active community-based tourism industry in the park, with some 20.000 dives per year and associated services.

While substantial biophysical and tourism-related monitoring data is available to the park management, the observed ongoing degradation of the park's coral reefs prompts the need for indicators to better monitor and understand the links between touristic dives and the ecological condition of the park.

Step 1: Identify the target audience

Primary user of indicator data is the park management. Key audience for conclusions from monitoring is the community of Cabo Pulmo and its tour operators.

Step 2: Specify the intended indicator use and key questions

The intended use of indicators monitoring the impact of diving activities on the park's coral reefs is twofold: (i) Guide decisions of the park management with regard to regulating and patrolling diving activities in the park. (ii) Provide scientific evidence to convince local tour operators of the appropriateness of such decisions.

Key questions include:

- Which areas are mostly affected by diving tourism?
- Which diving activities are most harmful to the reef?
- Which alternative diving activities generate the least harm?
- How can the expected further increase in annual dives be managed to limit further reef degradation?
- How can patrol activities be restructured to increase their effectiveness in preventing reef degradation?

Step 3: Develop a conceptual model

The conceptual model about the linkages between tourism and the park's ecological status comprises the following axioms:

- Reef degradation has been ongoing over the last decades.
- Diving tourism, ocean warming and ocean acidification are key drivers of reef degradation.

- The exact share of diving tourism in accounting for reef degradation is unknown.
- As large areas of the reef are already severely degraded there is an urgent need to reverse or at least slow down this trend, also in view of maintaining the basis for the local tourism industry.
- The environmental impact of diving not only depends on the number of dives in an area, but to a significant part on the rules complied with, while diving.
- Rule compliance depends on tour operators' willingness and on effective patrolling.

Step 4: Identify and select indicators

Given that the park's environmental monitoring programme already provides good insights in coral reef status, and diverse tourism related data is also available, any additional indicators should focus on the environmental impact of diving, i.e. of appreciating the ecosystem service 'opportunities for nature-based tourism'.

Instead of a single new indicator, the situation requires a more complex monitoring scheme. First, the indicators should be able to single out the impact of diving as opposed to other drivers of reef degradation (which is needed to convince tour operators). Second, the indicators should allow to innovate diving regulations, and third, the indicators should help optimize the use of the park's scarce resources for patrolling.

In a first round of brainstorming and reflection the following scheme was developed:

- Review literature on diving regulations and develop 2-3 different diving regimes. This concerns for example the maximum dive time allowed per dive, or a zoning system with less degraded areas only allowed for experienced divers.
- Discuss diving regimes with tour operators to obtain their buy-in and cross-check technical feasibility of the regimes.
- Subdivide the park in different areas according to wider biophysical conditions. Identify suitable sites inside each area where the different regimes can be tested under similar conditions. Include also no-dive sites for each area.
- Focus patrolling on these sites.
- Analyse dive data separately for each site.
- Analyse biophysical monitoring separately for each site.
- Then compare dive data and biophysical monitoring data separately for each site. Also compare the condition of dive and no-dive sites for each area.

Step 5: Apply and make use of indicators

- Once data becomes available from the above described monitoring scheme, conclusions can be drawn regarding the impact of each diving regime for each area. In consequence, some diving regime may be identified as most appropriate for areas and B, whereas another diving regime seems most suitable for areas C and D. The comparison of dive and no-dive sites helps single out the impact of diving as opposed to e.g. ocean acidification or other factors driving degradation.
- Conclusions need to be discussed with tour operators to (i) convincingly convey the need

for better diving management inside the park, and to (ii) cross-check acceptability of the preferred diving regimes for the different areas.

Step 6: Develop monitoring and reporting systems

Is further monitoring necessary, if tour operators and park management have agreed on which diving regime to follow in which area? It depends. Park management benefits from being able to repeatedly show the need for (and the benefits of) a sustainable dive regime, as compared to unsustainable ones. However, park management must also decide whether investment of its limited resources should not rather be directed towards other activities, once and if the dive regime issue has been settled.

What can this example show? Looking for suitable indicators for tracking conditions of ecosystem services can result in very specific questions being pursued. The answers to such questions often require a (re-)combination of diverse data sets, several of them may already be available. Thus, adopting an ecosystem service perspective on environmental indicators is less about new indicators, but rather about new interpretations of what is already known, and about what should usefully be known in addition to that.

Part B: Example Indicators for Ecosystem Services

In the following, we shortly outline for each ecosystem service some principal threats, and present example indicators, data sources and selected methods for their assessment. We use TEEB's categorization of ecosystem services.

Please note that the suitability of an indicator and an assessment method largely depends on the purpose and the context in the specific case. Therefore recommendations should always be critically reflected in the light of the site's circumstances.

Practical information on methods, and further guidance on assessment processes can be found at www.aboutvalues.net

1. Indicators for Provisioning Services

1.1 Food

In a nutshell

Virtually all ecosystems provide the conditions for growing, collecting, hunting or harvesting food.

1. Typical threats

The long-term capacity of (agro-) ecosystems to supply food is harmed by overuse and by unsuitable management practices. Where land use is not adapted to local ecological conditions, this can lead to degradation (e.g. soil acidification or erosion) and desertification of fertile land. The long term effects of heavy use of agro-chemicals are often disastrous.

A lack of sustainable fishing quotas and techniques can lead to the irreversible loss of fish species in freshwater and marine ecosystems. Sustainable aquaculture is a promising alternative. Conventional aquaculture is largely based on the input of wild fish for feeding and often has powerful adverse ecological and socio-economic impacts. See FAO report: The State of World Fisheries and Aquaculture.

In many developing countries the availability of food is negatively affected by climate change. Effects such as extreme events (e.g. droughts or heavy rainfall) and the long-term shift of regional rainfall regimes will worsen in the future. See, for example, the FAO report Managing climate risks and adapting to climate change in the agricultural sector in Nepal.

A major threat to small-scale and subsistence agriculture or extractive use can be uncertain land tenure or use rights. A shift from subsistence agriculture to cash crop production, such as coffee or cocoa, can significantly increase income from agriculture. However, typically most of the profit is not retained at farm level. Conversion to cash crops also brings the risk of threatening a region's food security or increasing malnutrition: as local food production declines, food prices rise.

Foreign investments in developing countries' agriculture, large-scale land use changes for intensive export-oriented agriculture or tree plantations, river diversions and the construction of dams are other factors that can threaten small-scale agriculture. Similarly, the establishment of protected areas or other conservation measures which prohibit local people from extracting the plants and animals important to their livelihoods can also diminish this service.

2. Example indicators

- Economic statistics often provide the volume of trade in goods or meat in an area ($/t) or the income per capita ($/capita) related to agricultural food production.
- Often statistical bureaus or departments of agriculture/environment provide indicators related to the provision of food, such as the harvest volume removed in an area (kg/ha/year) or the market price for extracted agricultural goods per area over time ($/ha/year).
- To assess the importance of subsistence use, it is necessary to look at production and consumption at household level (kg/household/year).

- To measure the contribution of food to human nutrition, total dietary intake of carbohydrates and proteins can be assessed in cereals (kilocalories/person/day) or in meat and fish. For further information see CBD TCS No 58, p. 87.
- To discover the extent to which production and harvesting is being maintained at a sustainable level, the indicator 'maximum sustainable harvest' (kg/ha/year) needs to be specified for local conditions.
- For wild plants or animals the stock of species (population density/ha) can give information on the sustainability of harvesting levels.
- The potential forage production for livestock can be assessed by the number of hectares required per large stock unit (LSU). For further information see CBD TCS No. 58, p 92.

Global available sources for national data:

- FAOSTAT offers a range of national statistics for the production and trade of food, e.g. yield/ha, quantity produced and food price/kg.
- GEOSS Portal offers agricultural data mostly related to remote sensing (hosted by GEOBON).
- The World Bank offers indicators such as agricultural value added per worker or threatened fish species.
- The FAO Fisheries and Aquaculture Department and FishBase provide data on fisheries especially.

3. Example methods

For **assessing the condition** of this ecosystem service:

- Models such as SWAT (Soil and Water Assessment Tool) can be useful to predict a wide range of biophysical variables under different types of agricultural land use.
- By assessing the areas under sustainable management, information is gathered on the extent of resource-conserving interventions with reported positive impacts on social, economic and environmental conditions.
- The Wild Commodities Index indicates whether wild terrestrial, freshwater and marine animals and plants are used in a sustainable way.
- The free software ADePT-Food Security Module was developed to analyse food security using household survey data. These indicators, derived at national and subnational levels, include the consumption of calories and macronutrients, the availability of micronutrients and amino acids, the distribution of calories and the proportion of people undernourished.

1.2 Raw Materials

In a nutshell

Ecosystems provide a wide diversity of materials for construction and fuel, including wood, biofuels and plant oils that are directly derived from both wild and cultivated plant species.

1. Typical threats

The threats here are similar to those described more detailed for the ecosystem service food provision. Local people's ability to harvest raw materials in forests or wetlands is adversely affected by land use changes caused by agricultural or infrastructure development. In many cases over-harvesting or a lack of integrated and balanced resource management may have a powerful negative influence.

Furthermore, socio-economic changes such as the loss of traditional land use practices and site-specific knowledge can be a critical issue. Conservation measures can also prevent the extraction of plants and animals for use as raw materials.

2. Example indicators

- Statistical bureaus often provide indicators such as the total amount of useful substances (trees, plants) in m^2/ha or kg/ha or economic value in $/ha or $/t.
- The economic value of timber is typically measured in terms of sawn timber in $ and can often be measured based on available data. For further information see CBD TCS No. 58, p. 99.
- The time required to collect and transport raw materials (e.g. fuel wood) can be measured (time/household).
- Measuring total annual wood production (tonnes/km^2/year) and comparing it with fuel wood demand enables gaps to be identified; see CBD TCS No. 58, p. 91.
- For evidence on the long term availability of this service, useful indicators are the maximum sustainable harvest (kg/ha/year) or the stock of species used (population density/ha/year).

Global sources available for national data:

- FAOSTAT provides data on the production and trade of raw materials such as relevant crop, timber or fuel wood production.

3. Example methods

For **assessing the value** of this ecosystem service:

- Direct market price
- Production approach
- Factor income
- Surveys or questionnaires focusing on the importance of plants and animals as raw materials, such as the protocol for social valuation of ecosystem services.

For **assessing the condition** of this ecosystem service:

- Changes in land use or land cover can be measured on the basis of available land use maps or other remote sensing data, e.g. orthophotos. With both methods, GIS software and mapping are crucial for a spatially explicit calculation.
- To predict future trends based on spatially explicit data, models such as InVEST timber production can be used.

- The webpage Global Forest Trends offers a global map of forest cover change, and satellite data per area can be downloaded. The Global Forest Observation Initiative is developing a similar map and database for selected countries.

1.3 Fresh Water

In a nutshell

Ecosystems play a vital role in providing humans with drinking water. They influence the flow and storage of water. The extent of vegetation and forests has an impact on the quantity and quality of water available locally.

1. Typical threats

Water quality and availability are directly influenced by human activities:

Agricultural activities such as water usage for irrigation upstream or other changes in watershed management may impair the amount of available fresh water for downstream water users during the year. The use of pesticides, herbicides and fertilizers in intensive agriculture pollutes ground and surface water bodies and can lead to their eutrophication.

Unsustainable forest management, especially clear cutting, impacts on the availability and quality of fresh water by increasing sediment load, dissolved organic carbon content, nitrification and evaporation.

Sewage from human settlements or industries that is discharged into rivers harms their ecology and also worsens conditions for fresh water provision downstream.

Climate change will alter rainfall regimes and can cause extreme events. For the links between climate change and freshwater provisioning see the CBD issue paper: Dealing with too much, too little and both.

2. Example indicators

- See the UN-Water set of key indicators for 15 quantitative 'key indicators' at national level (some are suitable for the regional, basin or local level) which provides a snapshot of the water sector.
- Annual surface water availability (km^3/year, m^3/capita, m^3/year) can be assessed using the indicator 'water availability'. For further information see CBD TCS No. 58, p. 88.
- The indicator 'water yield' is based on the contribution of different parts of the landscape to annual water yield (mm/year). For further information see CBD TCS No. 58, p. 95.
- Demand for water by all sectors (million m^3/year) can be measured using the indicator 'potable water use'. For further information see CBD TCS No. 58, p. 97.
- Potential water flow regulation can be measured in millions of m^3 of groundwater recharge per 1 km^2 grid cell. For further information see CBD TCS No. 58, p. 105.

- The indicator 'water flux' (e.g. rainfall, evapotranspiration and river flow) can be used to assess the condition, status and trends of the water cycle, an important supporting ecosystem service. For further information see CBD TCS No. 58, p. 115

Global available sources for national data:

- AQUASTAT (FAO) hosts comprehensive water related national statistics such as water use for most countries.
- The UN-Water portal provides maps, tables and charts for indicators at country or global level, as well as additional geographic information.
- The GEOSS Portal hosted by GEOBON is producing comprehensive sets of data and further information products.
- UNSD Environmental Indicators provides indicators related to inland water resources and use of fertilizer per ha.

3. Example methods

For **assessing the condition** of this ecosystem service:

- Spatially explicit models such as InVEST, ARIES or SWAT can help to predict future changes in fresh water provision under different scenarios.
- A questionnaire to enable a better understanding of dependence on water based ecosystem services deriving from a specific site and how these services could be affected under different scenarios is provided in the TESSA toolkit, p. 217 ff.
- The method `assessing water supply services´ helps you where to find existing water supply data and how to calculate water usage. See TESSA toolkit, p. 215.
- The web-based spatial modelling system WATERWORLD helps to estimate the quantity of water at a given site. For a detailed description see TESSA toolkit, p. 223 ff.

1.4 Medicinal Resources

In a nutshell

Biodiverse ecosystems provide a variety of plants and mushrooms used in popular or traditional medicine. They offer effective cures for many kinds of health problems and provide raw materials for developing or producing pharmaceuticals.

1. Typical threats

A vast number of wild plant species worldwide is estimated to be threatened with extinction. Over-harvesting or uncoordinated management puts the provision of medicinal resources (and their lucrative trade) at risk. Poverty and the breakdown of traditional control systems within e.g. local communities are an issue. The major challenges for sustainable wild collection include: lack of knowledge about sustainable harvest rates and practices, poorly defined land use rights and lack of legislative or policy guidance. The loss of traditional medicinal knowledge also directly impacts this ecosystem service.

With respect to the commercial use of traditional medicinal knowledge, there have been a number of prominent cases where powerful corporate actors have applied for patents granting them exclusive rights, thereby disrespecting traditional knowledge holders and disadvantaging them economically ("bio-piracy"). See, for example, Third World Network Briefing Paper 5.

2. Example indicators

- The indicator 'biodiversity for food and medicine' is a combination of the Red List Index and Accessibility Index. It shows the use of wildlife for food and medicine and the impacts on ecosystem integrity and ecosystem goods and services.
- The value of this service can be indicated in economic terms by the trade volume of medicinal resources extracted from an area ($/ha).
- An indirect indicator can be the income (profit, employment, livelihood) obtained from sending traditional medicinal products to markets.
- Different public health indicators can be useful in many cases.
- An inventory of medicinal plants used in a region for self-medication (or by doctors and traditional healers) can be compiled.
- The occurrence of medicinal resources is to a large extent dependent on the distribution of plant species. Maps of plant species distribution can be coupled to their different uses, such as plants for medicines.
- For evidence relating to the long-term availability of this service, the indicators 'maximum sustainable harvest' (kg/ha/year) and the 'stock of species used' (population density/ha/year) are useful

Global sources available for national data:

- The GBIF database offers an open data infrastructure where information on species used for medicinal purposes can be found.

3. Example methods

For **assessing the condition** of this ecosystem service:

- Bio-physical assessments, e.g. of the population density of a species used for medicinal purposes over time per hectare
- Questionnaires and surveys focusing on changes in the availability of resources used for medicinal purposes
- (Changes in) the amount of time required to collect and transport medicinal resources can be measured (time/household)

2. Indicators for Regulating Services

2.1 Local climate regulation

In a nutshell

Trees and green spaces moderate the temperature (e.g. in cities) while forests influence rainfall and water availability both locally and regionally. Trees and other plants also play an important role in regulating air quality by removing pollutants from the atmosphere.

1. Typical threats

Land cover changes can affect local and regional climates in many ways. If forests in tropical areas are cleared, the rainfall regime can shift and the temperature rise. Threats to rainforests stem mostly from economic development including agricultural expansion or infrastructure projects such as dams. In and around cities increasing urbanisation is the most pressing issue.

Trees that provide shade or green spaces that serve as corridors for fresh air are lost through a lack of awareness of their necessity or through the need for housing (e.g. green spaces compete with infrastructure building areas or dwellings). As global temperatures are expected to rise in the medium term, both the threats to this ecosystem service and its importance for human well-being will increase.

2. Example indicators

- The air quality index indicates how clean or polluted the air is (g/m^3/day). This indicator can be directly linked to human well-being through the associated health effects which might arise.
- The indicator forest fragmentation can be used to indicate specific changes in forest configuration that can be associated with changes to the local climate.
- The canopy of a forest can be measured using the leaf area index.
- The effects on temperature of green spaces and trees in cities can be measured by thermal mapping to detect overheated or cool areas. By calculating the effects on health or cooling costs, this information can be converted into socio-economic terms.
- Differentials in the number of people with respiratory disease can also indicate the socio-economic importance of this service.
- The capacity of ecosystems to extract aerosols & chemicals from the atmosphere can be measured using various indicators including the following:
  - The fine dust captured by vegetation (kg/ha) and/or NOx fixation (kg/ha).
  - The change in atmospheric fine dust concentration (PPM, g/m^3)

3. Example methods

For **assessing the condition** of this service:

- The descriptions of essential climate variables by the Global Terrestrial Observing System provide a good overview of how to measure the leaf area index or current land cover.
- InVEST (Integrated Valuation of Environmental Services and Tradeoffs) in general

- ARIES
- MARXAN
- In urban areas tools such as CITYgreen or i-tree Eco are useful to measure e.g. summer energy savings or air quality. See, for example, the case study from Barcelona.

2.2 Carbon sequestration and storage

In a nutshell

Ecosystems regulate the global climate by storing greenhouse gases. As trees and plants grow, they remove carbon dioxide from the atmosphere and effectively lock it away in their tissues ('sequestration'); thus acting as carbon stores.

1. Typical threats

The ability of ecosystems to serve as a sink or store for CO_2 (and other greenhouse gases) depends largely on the current and/or historical use and management of land and resources. The conversion and degradation of forests, wetlands and peat lands lead to high CO_2 emissions. Conversion is mainly driven by the spread of commercial agriculture for pastures or monoculture systems (e. g. soya, palm oil etc.).

According to the report Deforestation and forest degradation drivers: synthesis report for REDD+ policymakers the carbon stored in forests is diminished by unsustainable logging used mainly for timber and (especially in Africa) for fuel wood and charcoal production. The overuse of non-forest timber products along with unmanaged small-scale agriculture – mainly for subsistence purposes – can also emit large amounts of CO_2. Additional factors are mining and conversion for urban expansion and infrastructure development.

Carbon emissions from peat lands are caused by the drainage of large areas of organic wetlands and other events such as peat fires. Intensive industrial agriculture emits huge amounts of CO_2. Cattle ranching, rice production and emissions from unsustainably managed soils are the main causes. By contrast, soil-friendly extensive agricultural management can store C and capture CO_2.

The oceans lose sequestration potential when the water temperature rises. Moreover, high concentrations of CO_2 result in the dying of coral reefs, thereby causing additional emissions.

2. Example indicators

- A widespread indicator is the total amount of living and dead C stored in an ecosystem biomass, measured in above-ground vegetation, roots and soil. However, roots are often excluded from assessments as they are difficult to measure.
- Amount of sequestered C in marine ecosystems. A proxy can be the abundance of sea grass meadows and other marine/coastal ecosystems important for carbon sequestration.
- In the MoorFutures project in Germany the amount of C stored is indicated on the basis of the ecological condition and vegetation cover of peat lands.

- The economic value of carbon storage can be expressed by the current market price of stored carbon per hectare or per ton ($/ha; $/t).
- In most countries, carbon stocks and fluxes of greenhouse gases are monitored. Countries which are parties to the UN's climate change convention are obligated to establish a balance of emissions – including emissions/removal per land use type. See: unfccc.int/di/DetailedByCategory.do.
- Net balance between ecosystem carbon gains and losses (annual carbon fixation in million tons carbon per year).

Global available sources for national data:

- FAO and IPCC have estimated geographically the comparative sequestration of carbon among national ecosystems.
- UNSD Environmental Indicators and the World Bank provide information on agricultural emissions by country.

3. Example methods

For **assessing the condition** of this ecosystem service:

- Measuring forest carbon for carbon certification and soil carbon measurement
- InVEST Carbon Storage and Sequestration model
- See the overview in the TESSA toolkit (p.50) for assessing the contribution to global climate regulation of a current and alternative state of an area.
- The TESSA toolkit provides methods for calculating carbon storage, carbon sequestration, carbon dioxide emissions, methane emissions, nitrous oxide emissions and overall greenhouse gas fluxes as well as for calculating carbon stocks in different habitat types (grassland-dominated, tree-dominated and crop-dominated habitats).
- Methodologies and data available for quantifying GHG emissions from peat lands and organic soils are summarised in Peatlands – guidance for climate change mitigation by conservation, rehabilitation and sustainable use (FAO and Wetlands International). The report includes practical solutions on measuring, reporting, verification (MRV) and accounting.
- A Technical guide from the LEAF project provides guidance on the stratification process for developing accurate and statistically rigorous estimates of forest carbon stocks based on available National Forest Inventory (NFI) data.
- The webpage Global Forest Trends offers a global map on forest cover change; satellite data per area can be downloaded. The Global Forest Observation Initiative is developing a similar map and database for selected countries.

2.3 Moderation of extreme events

In a nutshell

Ecosystems and living organisms create buffers against natural disasters. They reduce damage from natural hazards including floods, storms, tsunamis, avalanches, landslides and droughts.

1. Typical threats

Due to population growth and infrastructure development the beneficial impacts of this service are decreasing. People's vulnerability to natural hazards is increasing worldwide. This is due partly to an increased use of 'high-risk' areas that are exposed to extreme events and partly to the conversion of ecosystems that otherwise serve to prevent or moderate extreme events. Conversion or structural changes in natural ecosystems are leading directly to a decline of this service, for instance in mountainous regions (landslides), in watershed areas and along rivers (floods and droughts) or coastal regions (storms).

Moreover, depositions of man-made waste products (such as chemicals) in ecosystems diminish the ability of ecosystems to provide protection against natural disasters over the long term. Ecosystems crucial to the moderation of extreme events have thresholds. If so called tipping points are passed, they collapse and lose their ecological capacity to deliver the service. Restoring ecosystems or devising and implementing man-made alternatives require substantial investments. People often recognise their dependence on properly functioning ecosystems only when a natural disaster has already occurred and the loss of this service becomes obvious.

In the Philippines, the 2004 tsunami contributed to a wider understanding and appreciation of the value of mangroves for disaster risk reduction and not just for shrimp farming. It is difficult to predict when an extreme event will happen. However, climate change models indicate that in many regions the frequency of extreme events is likely to increase.

2. Example indicators

- The social value of this ecosystem service can be assessed by the number of households at risk or the population protected by natural ecosystems (households/ha).
- Avoided damages in terms of property or health and avoided costs of man-made alternatives (e.g. for dams) are other socio-economic metrics.
- The frequency of extreme events (e.g. abundance/50 years) and their extent (e.g. hectares flooded) can be measured by gathering existing local or regional data. This can indicate the vulnerability of communities to natural hazards and shows the socio-economic importance of natural habitats in protecting communities.
- The capacity of ecosystems to store water (in m^3/ha or biomass/ha) and the spatial extent of riparian zones available for retention (in hectares) can show the importance of an area for flood protection.
- Land cover/land use maps or aerial views are helpful: Information on the extent of current land cover can indicate the state of protection against extreme events. One example is the indicator 'extent of marine habitats'. This indicator assesses global trends in mangroves, seagrass beds and coral reefs, which in many coastal areas are linked with the moderation of extreme events.
- For protection against landslides, the total size of deforested slopes in ha and the share of area required to protect human communities can serve as an indicator.

Global available sources for national data:

- The website PreventionWeb provides disaster and risk profiles for different hazards and regions/countries.
- FAO's Global Land Cover Network (GLCN) and the USGS provide extensive databases relating to different remote sensing land cover issues.

3. Example methods

For **assessing the condition** of this ecosystem service:

- Assessing various forms of vulnerability
- The TESSA toolkit, p.199 provides a set of methods to assess flood protection services. These methods are based on stakeholder meetings and are focused on wetland sites. Different methods can be used depending on access to hydrological data. See also the related ValuES Method Profile
- In addition, the TESSA toolkit, p.213 gives examples of possible alternative state contexts for assessing flood prevention in order to give some idea of how hydrographs are likely to change in the future.
- The description of essential climate variables provides a good overview of how to measure land cover changes.

2.4 Waste water treatment

In a nutshell

Ecosystems such as wetlands filter effluents. Most waste is decomposed by the biological activity of microorganisms.

1. Typical threats

In most developing countries water quality is declining. Various factors diminish the limited capacity of ecosystems to purify polluted water. One is the drainage of large areas of wetlands for agricultural or other uses. The input of nitrates into the water has increased rapidly over the last few decades.

Excessive discharges of waste water, pesticides or insecticides and other depositions also have negative impacts. The overuse of water, e.g. for irrigation, reduces the available water in ecosystems and therefore has a destructive effect. Ecosystems that are under pressure from other human impacts are especially vulnerable to negative climate change effects in many regions. Of course it is also crucial to keep in mind that there are limits to the capacity of ecosystems to provide natural waste water treatment and that ecological thresholds should not be exceeded.

If so called tipping points are reached, this can lead not only to the loss of ecosystems and species but also the capacity to further provide waste water treatment is lost. Restoration efforts or the search and implementation of man-made alternatives may require considerable investments.

2. Example indicator

- To understand the socio-economic importance of waste water treatment, the number of households not connected to the waste water system can be assessed to show their dependence on natural waste water treatment.
- Avoided treatment or damage costs can indicate the economic value of this service.
- In some cases the total input of waste water can be measured – e.g. the total amount of waste water deriving from households (l/person/day) or industrial production (l/factory/day).
- The indicator water quality shows the current condition of a water body.

Energy and food production releases a large amount of ammonium and nitrogen oxides into the atmosphere. A variety of indicators are relevant when assessing the capacity of ecosystems to infiltrate nitrogen from the water:

- The indicators nitrogen deposition (kg N/ha/year) and loss of reactive nitrogen to the environment (kg N/person/year) show the rates of nitrogen input (N) to the ecosystems on different levels.
- To ensure the sustainable provision of this ecosystem service, it is crucial to measure changes in the capacity of ecosystems to reduce organic content and extract chemicals from the water. Suitable indicators to understand the state of this service are e.g. total nitrogen bound (N mg/l), total nitrogen removed (N mg/l), total organic content (mg/l) and total oxygen content (mg/l).

3. Example methods

For **assessing the condition** of this ecosystem service:

- Assessing water quality improvement services: Direct measurement method to find out if the wetland has an impact on improving water quality (TESSA toolkit, p.242).
- The WaterWorld PSS web-based tool (TESSA toolkit, p.247) estimate water quality improvement
- InVEST Nutrient Retention
- InVEST (Integrated Valuation of Environmental Services and Tradeoffs) in general
- ARIES
- SWAT

2.5 Erosion prevention and maintenance of soil fertility

In a nutshell

Vegetation cover provides a vital regulating service by preventing soil erosion. Soil erosion is a key factor in the process of land degradation, loss of soil fertility and desertification.

1. Typical threats

The type of land use and the agricultural or forest management practices applied heavily influence soils and therefore this ecosystem service as well. Many practices can lead to increased water run-off, loss of nutrients and sediments as well as the destruction of habitats that are home to beneficial soil organisms. In forest management, clear cutting and especially slash and burn have led to soil degradation and erosion.

The input of reactive nitrogen for agricultural and energy production is causing nitrification which can have negative effects on soil organisms. Soil compaction due to the usage of heavy machines leads to the long term destruction of soils, especially in areas with fragile soil types. In agriculture, not only is unsustainable management of crop production an issue, livestock waste or overgrazing can also have negative impacts. Climate change impacts such as shifting rainfall patterns and extreme events increase the vulnerability of soils to degradation.

2. Example indicators

- A variety of indicators are useful for assessing the state of erosion or soil fertility. Biophysical information, such as rain intensity, topographic type and soil type, is relevant; so too are management practices, e.g. soil preparation, fertilizer and irrigation, and societal aspects, e.g. characteristics of dams and human made water canals.
- The potential erosion control of high, medium and low categories of erosion hazards can be a suitable indicator. For further information see CBD TCS No. 58 p. 103.
- The indicator 'sediment retention' measures the capacity of land cover to retain sediment (tons/hectare/year). For further information see CBD TCS No. 58 p. 110.
- The indicator loss of reactive nitrogen to the environment shows the loss in different regions of the world as a result of the production and consumption of food and the use of energy.
- Changes in land use or vegetation cover are often associated with a negative impact on soil cover and thus on soil erosion and fertility. Examples include the indicators forest fragmentation and the extent of forest and forest types.
- The canopy of a forest can be measured using the leaf area index.

Global sources available for national data:

- Among others, FAO's Global land cover network and the USGS provide a huge database relating to different remote sensing land cover topics.

3. Example methods

For **assessing the condition** of this ecosystem service

- InVEST Nutrient Retention

- The LADA toolkit provides various useful methods such as soil assessment based on direct measurements or on visual estimation and a vegetation assessment tool
- ARIES
- SWAT

- Measuring sedimentation rate of rivers and streams
- The descriptions of essential climate variables by the Global Terrestrial Observing System provide a good overview of how to measure the leaf area index or current land cover.

2.6 Pollination

In a nutshell

About 80% of the world's species of food plants relies on pollinators for reproduction, mainly by insects and birds.

1. Typical threats

Interaction between human activities and pollinators are difficult to assess and to understand. In many regions a lack of adequate data on the abundance and diversity of pollinators leads to population losses (up to 50%) before evidence to indicate a decline becomes available. However, there is a consensus that land use changes are a major threat, as they lead to (semi-) natural habitat destruction and reduced habitat diversity (e.g. monocultures). A major driver is increasing (industrial) agricultural intensification, which is causing pressure on wild pollinators.

Large-scale pesticide input and the introduction of invasive species and pathogens can impact negatively on pollinator species. Other threats are environmental pollution in general and changing environmental conditions caused by climate change. Honeybees – which are not only an important pollinator but also an indicator species – are in an alarming state of decline. UNEP (2010) reports that especially in regions with high agricultural production, such as North America and Europe, but also in China and Egypt, beekeepers have faced inexplicable colony losses.

2. Example indicators

- To better understand the condition of pollinator species their abundance (individual or population/ha) in an area can be assessed. Mean species abundance is an indicator of naturalness or biodiversity intactness. It is defined as the mean abundance of original species relative to their abundance in undisturbed ecosystems.
- Changes in habitat quality can be indicated by changes in area cultivated crop species (field crop/ha) and density or changes in land use or land cover type around areas in agricultural use.
- Coverage of ecosystem border zones important for pollinators (e.g. forest-agriculture).
- Human dependence on crops pollinated by animals in an area can be assessed in surveys. This indicates the socio-economic importance of the pollination service.

- Indicators such as the following can be measured in order to understand pollination capacity: the number of species needed to be pollinated by animals (field crop/ha), the number of pollinator species (species/ha), the number of ecosystems important for pollinators (spatial extension), and days available for flying.
- Agricultural and environmental statistics can be a helpful source of existing indicators relating to the ecosystem service 'pollination'.
- Increased yield of crops attributable to pollination (Crop dependency x Annual production (ton/year)).

Global sources available for national data:

- The Global Biodiversity Information Facility offers background information on pollinator species. Some countries also have their own biodiversity information facilities e.g. www.tanbif.or.tz/.
- A study by Lauterbach et al. (2012) (free of charge) provides maps on the spatial and temporal trends of global pollination benefits.

3. Example methods

For **assessing the condition** of this ecosystem service

- InVEST Pollination
- Survey for local assessment of benefits provided by insects
- FAO – Guidelines for rapid assessment of pollinators' status

2.7 Biological control

In a nutshell

Predators and parasites play an important role in ecosystems by regulating pests and diseases that are harmful to plants, animals and people.

1. Typical threats

A major threat to species that are crucial for biological control is the destruction of (semi-)natural habitats and reduced habitat diversity. In agricultural landscapes, increasing agricultural intensification and the use of pesticides are major drivers of declining predator species. Pesticide use not only leads to resistant pest species; it also degrades the capacity of agro-ecosystems to provide biological control. Further pressure on pest control species results from the introduction of pathogens and invasive species. Other threats include environmental pollution and changing environmental conditions caused by climate change. The loss of indigenous/traditional knowledge of agro-ecological interactions and potential pest-control species may also compromise this ecosystem service.

2. Example indicators

- Measuring the abundance of both pest species and pest controlling species can aid understanding of the current state of the latter. Trophic interactions among insects, birds and bats should be considered as well as effects from different management types on relevant species.
- Proxies for diversity/abundance of pest controlling species: Frequency of pest outbreaks, observed new alien species with possible harmful impacts.
- The areas in which diseases or pests occur can be studied along with spatial changes over time.

- Changes in habitat quality can be indicated by the heterogeneity of habitats or the percentage of natural habitats in agricultural landscapes that sustain the lifecycle of pest control species.
- Human dependence on biological control for agricultural production or the control of human diseases and vectors in an area can be assessed using qualitative surveys. This is an indicator for the socio-economic importance of the biological control service.
- Health, agricultural and environmental statistics can be a helpful source for existing indicators related to the biological control service.

Global sources available for national data:

- The Global Biodiversity Information Facility offers background information related to the species important for biological control, and some countries have their own biodiversity information facilities e.g. www.tanbif.or.tz/.

3. Example methods

For **assessing the condition** of this ecosystem service:

- The instruments typically used to measure biodiversity related aspects include assessing the richness or diversity of the relevant species and linking the results to changes in land cover or land use (e.g. structural changes in ecosystems, ecosystem fragmentation). Mapping is useful for this purpose.

3. Indicators for Habitat or Supporting Services

3.1 Habitats for species

In a nutshell

Habitats provide everything an individual plant or animal needs to survive: food, water and shelter. Each ecosystem provides different habitats that can be essential for a species' lifecycle.

1. Typical threats

The loss of habitat leads directly to a loss of species. An article by IUCN reports, for example, that habitat loss is the single biggest threat to European butterflies and may lead to the extinction of several species. Habitat loss has been said to occur most often as a result of changes in agricultural/forest management practices, climate change, forest fires, and the expansion of infrastructure and tourism. Further issues include large-scale land use changes for intensive export-oriented agriculture or tree plantations, river diversion and the construction of dams.

The introduction of invasive species can also impact negatively on habitat quality. Endemic species which are unique to a specific location are extremely vulnerable to all these threats. If they become extinct their loss is irreversible.

Changes in agricultural/forest management practices can also be driven by a loss of traditional knowledge such as local adapted land use practices. Migratory species including birds, fish, mammals and insects depend upon different ecosystems for their migratory movements. If natural ecosystems crucial to their life cycle are lost, they often come to depend on habitats provided by extensive land use practices.

2. Example indicators

Habitat or supporting services are generic, which it makes difficult to find suitable indicators to describe their relative condition. In several cases data on habitat services are available nonetheless.

Possible **indicators related to structural and qualitative changes in habitats**:

- The extent of native vegetation or of high nature value farmland.
- The water quality index for biodiversity indicates the impact of water quality on species dependent on clean water.
- Structural changes in habitats and other characteristics related to this ecosystem service can be assessed via remote sensing.

Possible **indicators related to changes in populations or biodiversity as a whole**:

- The number of indicator species measures the average population trends of a suite of representative wild birds, as an indicator of the general health of the wider environment. See, for example, the Wild Bird Index.

- The number of keystone species – species that play a disproportionate role in structuring a habitat relative to their numbers, such as beaver – per habitat.
- Mean species abundance is an indicator of naturalness or biodiversity intactness. It is defined as the mean abundance of original species relative to their abundance in undisturbed ecosystems.
- The Red List Index provides a standard and repeatable method for assessing the overall extinction risk of a species and the rate of biodiversity loss.
- A possible proxy for monitoring biodiversity change in different habitats is the Living Planet Index.
- Trends in population of endemic species or species extremely threatened shows how irreversible their loss will be.
- Trend in Invasive Alien Species measures plants, animals or micro-organisms outside their natural geographic range and thus the threat to biodiversity and regional habitat.

Global available sources for national data:

- The Group on Earth Observation is establishing a worldwide observation network to collect, manage, share and analyse the status and trends of the world's biodiversity and is also developing a comprehensive ecosystem monitoring capability.
- The Global Land Cover Network promotes the distribution of base datasets in support of land cover mapping programmes around the world.
- The National Red List (IUCN) is the most respected and robust inventory of global species conservation status.
- The Global Biodiversity Information Facility is the biggest biodiversity database on the internet

3. Example methods

For **assessing the condition** of this ecosystem service:

- See the report land cover for an overview of how to assess changes in land cover and for information about available data.
- GLOBIO is a modelling framework used to calculate the impact of environmental drivers on biodiversity in the past, present and future.
- InVEST (Integrated Valuation of Environmental Services and Tradeoffs) in general
- ARIES
- MARXAN
- ToSIA – Tool for Sustainability Impact Assessment

3.2 Maintenance of genetic diversity

In a nutshell

Genetic diversity (the variety of genes between and within species populations) distinguishes different breeds or races from each other, providing the basis for locally well-adapted cultivars and a gene pool for developing commercial crops, livestock, as well as commercial products (e.g. pharmaceuticals, cosmetics and flavourings).

1. Typical threats

The main reasons for the loss of genetic diversity are the loss of forest cover, coastal wetlands and other 'wild' uncultivated areas with high biodiversity and the destruction of the aquatic environment.

The FAO reports that the state of agro-biodiversity is alarming: since the beginning of the 20th century, the world has lost 90% of agro-biodiversity for 20 of its major staple food crops. Genetic resources in agriculture have mainly been lost through the loss of traditional cultivars of crop species (due in part to the adoption of industrial farming practices and varieties) and through species extinction, see Greenfacts.

Further issues in agriculture are the promotion of commercial (genetically modified) seed varieties and the exclusion of genetic variations via patent procedures. Additionally, patents taken out by life science companies can prevent local people from benefiting financially from the commercial use of plants or animals for medicine and at its worst exclude them formally even from subsistence use.

The introduction of invasive species into ecosystems is another growing threat. In many cases – especially in most developing countries – climate change will have a negative impact on wild and cultivated genetic diversity. This implies a need for new crop varieties that can withstand the regional or local effects of climate change in order to ensure food security.

2. Example indicators

- The dependence of households on local adapted crop species is an indicator of their value.
- Genetic diversity of crop products. For example, in Germany the indicator genetic diversity is used to show the endangerment of genetic resources for food and agriculture, initially using selected indigenous breeds as examples.
- Ex-situ crop collection indicates the dynamics of the bio- and geographical diversity contained within ex-situ collections over time.
- The indicator genetic diversity of terrestrial domesticated animals shows the rate of genetic or breed diversity of farmed or domesticated animals, which in turn offers vital options for adapting livestock production to future challenges.
- Status of habitat and species diversity (Hectares of land in traditional varieties; Number of

breeding females/animals within each species).

- Trends in invasive alien species measures plants, animals and micro-organisms outside their natural geographic range and thus the threat to genetic diversity.

Global available sources for national data:

- The Global Biodiversity Information Facility is the biggest biodiversity database on the internet.
- See the Crop Wild Relatives Global Atlas and Vincent et al. (2013) for a prioritised crop wild relative inventory to help underpin global food security.

3. Example methods

For **assessing the condition** of this ecosystem service:

- Mean species abundance is an indicator of naturalness or biodiversity intactness. It is defined as the mean abundance of original species relative to their abundance in undisturbed ecosystems.
- Using participatory research methods such as questionnaires, conducting interviews with key informants, focus group discussions etc., a wide range of relevant information can be collected. Such as the identification of used crop landraces based on morphological characteristics; traditional knowledge, beliefs and bio-cultural heritage associated with all aspects of crop cultivation and identify the custodians. See for example:
  - Documentation of yam diversity and associated traditional knowledge systems in Yap state, Federated States of Micronesia (FSM)
  - Participatory Methods to assess traditional breeding systems.

4. Indicators for Cultural Services

4.1 Aesthetic appreciation and inspiration for culture, art and design

In a nutshell

Many people enjoy the beauty of natural landscapes and are fascinated by animals, plants and ecosystems. Nature has also been the source of inspiration for much of our art and culture as well as for technological innovations.

1. Typical threats

Changes in land use and degradation caused by unsustainable land use reduce the attractiveness and scenic beauty of a natural area. They also compromise the environmental conditions that are crucial for all cultural ecosystem services.

Cultural landscapes are especially vulnerable to social and economic changes and loss of traditional knowledge. Many world heritage sites, e.g. the Rice Terraces of the Philippine Cordilleras, reflect a harmonious relationship between humankind and the natural environment and are of great aesthetic appeal. The Philippine rice terraces have been created by more than a thousand generations of local small-scale farmers. Due to rapid socio-economic changes, traditional land use patterns are being lost, resulting in degradation, conversion or the abandonment of cultural landscapes.

2. Example indicators

Different indicators shed light on different aspects:

- Number of scenic sites or distance between human habitations to landscape in an attractive condition.
- Database of handicrafts or other arts products based on nature.
- Direct economic value of nature related arts and popular culture origins from the price of the artworks.
- Public recognition of and support for traditional land use practices in cultural landscapes, as expressed in programmes, subsidies, communications, regulations.
- The indicator VITEK - Vitality Index of Traditional Knowledge has been developed for measuring the vitality of traditional environmental knowledge across generations in e.g. local communities.
- The indicator status and trends of linguistic diversity and numbers of speakers of indigenous languages helps towards an improved understanding of the links between land use changes and loss of local/regional culture.

3. Example methods

As with the ecosystem service 'spiritual inspiration', 'aesthetic appreciation' should first be described in qualitative terms prior to any attempts to quantify its components. A qualitative description reveals the different facets of the cultural service and enables the integration of perhaps very different aspects important to the relevant groups. A major challenge to properly identifying and assessing cultural values is a Western perspective and related concepts (including the notion of ecosystem services itself), which may not necessarily capture the essence of value for local communities, including indigenous people.

A qualitative assessment can be conducted by means of semi-structured interviews, focus groups, mapping exercises or anthropological field methods. To assess aesthetic inspiration, it should be clear how a given cultural expression is linked to a landscape, species or natural phenomenon.

Another approach is to ask participants directly to voice their aesthetic appreciation for specific sites or natural characteristics. This could be done by using questionnaires or structured interviews with local people/visitors. For initial scoping, one could ask:

- Which landscapes or places are most beautiful to you?
- What are beautiful landscape features and land cover forms?
- Where in your community do you enjoy the beauty of the landscape?

For further information regarding the challenges involved in measuring cultural services, see TEEB Ecological & Economic Foundation Ch. 3 p. 24 & 32 (p. 131 & 137 in book version).

For a review of the current state of knowledge about measuring cultural services, see the article Contributions of cultural services to the ecosystem services agenda by Daniels et al. 2012.

4.2 Spiritual experience, sense of place and identity

In a nutshell

Nature is a common element in all major religions. Natural heritage, traditional knowledge, and associated customs are important for creating a sense of belonging.

1. Typical threats

Land use changes and degradation caused by unsustainable use are particular threats to sacred places. A case study from Gunung Lumut, Kalimantan Indonesia (p. 117-119) highlights how the forests of the Lumut Mountains were integrated in the traditional belief system of the indigenous people there. However, the forests are threatened by illegal loggers and gold miners. Semi-natural areas such as cultural landscapes are also vulnerable to land use changes and degradation. Changes in socio-cultural conditions, e.g. the decline of religious influence, as occurred with the sacred Gumpa Forests, Eastern Himalayas (p. 91-92), can also lead to the degradation of sacred places.

2. Example indicators

It is difficult to measure and quantify the non-material benefits of cultural services, which is based on subjective perceptions. Nevertheless, attempts can be made to assess the ecosystem service 'spiritual experience' based on the following indicators:

- Number and area of sacred sites. Presence of UNESCO classified sacred sites (global only); number of UNESCO classified spiritual sites; state of sacred sites.
- Species diversity (since this is often higher at sacred sites). Species relevant to performance of rituals.
- VITEK - Vitality Index of Traditional Knowledge is a new indicator developed to measure the vitality of traditional environmental knowledge across generations in communities or populations.

For further information regarding the lack of measures and insufficient data availability on cultural services see TEEB Ecological & Economic Foundation Ch. 3 p. 24 & 32 (p. 131 & 137 in book version).

3. Example methods

For **assessing the condition** of this ecosystem service:

- Maps showing land use changes in combination with questionnaires, as mentioned above.
- The VITEK - Vitality Index of Traditional Environmental Knowledge methodology has been developed for gathering and analysing traditional environmental knowledge (TEK) data and for building a locally appropriate indicator of trends in the retention or loss of TEK over time.
- See Social assessment of conservation initiatives - A review of rapid methodologies for the strengths and weaknesses of methods and for guidance on how to select appropriate indicators.

4.3 Tourism

In a nutshell

The cultural ecosystem service 'Tourism' is defined here as the nature-based opportunities which attract travellers to a place to enjoy nature. This includes the benefits that accrue to visitors and the income opportunities that accrue to service providers of nature-related tourism.

1. Typical threats

Land use changes reduce the attractiveness of a natural area for tourism when scenic beauty or environmental conditions are compromised. Cultural landscapes such as terraced hill slopes become degraded when traditional land use practices change. In some cases, too many tourists can reduce the overall attractiveness of a site and endanger the sustainability of the tourism destination (e.g. by leaving waste behind).

Unregulated access for tourists can also harm ecosystems (e.g. the impacts of un-managed diving on coral reefs in Hawai´i), disturb wild animals, or conflict with traditional lifestyles of local communities. Equally, a very rigid protection status may thwart opportunities to generate nature-based tourism income by restricting broad access. Appropriate rules can be established if local conditions are duly considered and if stakeholders participate in the process, as occurred in the Mohéli Marine Park in Comoros.

2. Example indicators

It is difficult to measure and quantify cultural services, as they provide non-material benefits and are often based on subjective perceptions. For further information regarding the lack of measures and insufficient data availability on cultural services see, see TEEB Ecological & Economic Foundation Ch. 3 p. 24 & 32 (p. 131 & 137 in book version). Nevertheless, the following indicators may be useful in assessing the ecosystem service 'tourism':

- Gross profit from nature-based tourism [$/area/year] and factor income from nature-based tourism [$/year/person] are two typical indicators.
- To assess the economic importance of tourism as an ecosystem service in the Maldives, the indicator 'total employment in the tourism sector' was used – 58% of the country's total workforce is employed in this sector.
- In Cape Town the economic importance of the city's natural areas and biodiversity for tourism were assessed using the average of total travel costs plus entrance fees paid by tourists to access key natural areas.
- For information on how to measure the number of visitors to a site over time (no. of visitors/area/ year) see CBS TCS No. 58 p. 113.
- Indicators for monitoring the natural features particularly appreciated by visitors help prevent their degradation, e.g. water quality at beaches, condition of hiking trails, proportion of area in an attractive condition, or sightings of charismatic species. To understand what aspects visitors value in their nature-based tourism experience, questionnaires and interviews are useful.
- Number/area of national parks, presence and abundance of key features for nature based tourism, or number and abundance of flagship, rare, attractive, etc. species can indicate the tourism potential of a region.

3. Example methods

For **assessing the condition** of this ecosystem service:

- See CBD Good Practice Guide: Tourism for Nature & Development p. 29 & CBD Guidelines on Biodiversity and Tourism Development for information on how to gather necessary baseline information (Ch. 1) and on monitoring & reporting (Ch. 9).
- See the concept of tourism carrying capacity.
- For a review of methodologies and recommendations for developing ecotourism impact monitoring programs in Latin America, see the: Ecotourism Technical Report No 1.
- For information on monitoring tourism in protected areas, see WCPA: Sustainable Tourism in Protected Areas: Guidelines for Planning and Management p.151ff.

- The Vitek - Vitality Index of Traditional Environmental Knowledge methodology has been developed to gather and analyse traditional environmental knowledge (TEK) data and to create a locally appropriate indicator of trends in retention or loss of TEK over time.

4.4 Recreation

In a nutshell

The cultural ecosystem service 'recreation' is defined here as the role nature-based recreation plays in maintaining humans beings' mental and physical health, e.g. for walking, hiking, climbing, or playing sports in green spaces or natural landscapes.

1. Typical threats

As people often choose where to spend their leisure time based on the characteristics of available (semi-) natural spaces, any changes that reduce the attractiveness of those areas play a role here. Urban planning, especially in and around cities, should take account of the importance of (semi-) natural areas for recreation. Urbanisation can lead to a loss of green spaces and can hinder access to parks and other sites. As green spaces in cities are often scarce, entrance restrictions such as fees can exclude people on low incomes.

Furthermore, land use changes can decrease the scenic beauty or environmental conditions required for recreation. Cultural landscapes such as terraced hill slopes degrade when traditional land use practices change. Rapid increases in tourism can lead to a degradation of natural recreation assets if these are left unmanaged.

2. Example indicators

The value of natural landscapes or green spaces for recreation usually needs to be assessed by ascertaining people's subjective perceptions e.g. via questionnaires. Nevertheless, attempts can be made to assess the value of the ecosystem service 'recreation' based on the following indicators:

- The indicator 'access to green spaces for city inhabitants' (parks, forests etc.) shows the value of green spaces for recreational activities. See, for example, a map displaying park access for children of color living in poverty with no access to a car in Los Angeles.
- In some areas, public investment or the subsidies used to support traditional cost intensive land use practices necessary to preserve the scenic beauty of a semi-natural area could be used as a proxy for high recreational value.
- The indicator 'visitor numbers' can be used to measure the importance of a site for recreational activities over time (number of visitors/ year). For further information see CBS TCS No. 58 p. 113.
- Indicators for monitoring natural features that are particularly appreciated by visitors help prevent their degradation, e.g. water quality at beaches, condition of hiking trails, proportion of an area in an attractive condition, or sightings of charismatic species.
- Questionnaires and interviews are useful to gain an understanding of the aspects and areas valued by visitors for recreational purposes.

For information regarding the lack of measurements and insufficient data availability on cultural services, see TEEB Ecological & Economic Foundation Ch. 3 p. 24 & 32 (p. 131 & 137 in book version).

3. Example methods

For **assessing the condition** of this ecosystem service:

- Issues such as availability, accessibility, quality and security of public green spaces are relevant
- Maps of land use changes in combination with information on areas people value for recreation
- Assessing the availability of access to areas important for recreation
- See also the relevant section in the ValuES ecosystem service factsheet: Tourism.

ANNEX

Guidance documents on selecting, developing and using ecosystem services indicators

1. Measuring ecosystem services: Guidance on developing ecosystem service indicators (UNEP-WCMC, CSIR, Sida and SwedBio 2014)

This report describes ten steps that may be used as a guideline for building an individual ecosystem services indicator or for a suite of ecosystem service indicators brought together to answer a specific policy question. In addition, various examples of indicator developments are provided as well as practical guidance for mainstreaming indicators.
http://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/303/original/1850_ESI_Guidance_A4_WEB.pdf?1424707843

2. Convention on Biological Diversity Technical Series No. 58 (Secretariat of the Convention on Biological Diversity 2011)

This report presents the results of a project conducted by the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), together with a wide range of international partners. The project examined the methodologies, metrics and data sources employed in delivering ecosystem service indicators, so as to inform future indicator development. The annex provides "Fact Sheets for Selected Ecosystem Service Indicators used in Sub-Global Assessments".
http://www.bipindicators.net/LinkClick.aspx?fileticket=QxjjDuqt2Qk%3d&tabid=155

3. Guidance for National Biodiversity Indicator Development and Use (Biodiversity Indicators Partnership 2011)

The report is designed to help the development of biodiversity indicators at the national level for uses such as reporting, policy-making, environmental management, and education. The annex provides an "Indicator Development Fact Sheet" and a complete example.
http://www.bipindicators.net/LinkClick.aspx?fileticket=PDjcfjlI-ik%3d&tabid=429

4. 'Developing Biodiversity Indicators' e-learning module (Biodiversity Indicators Partnership)

This module is designed as a resource for practitioners across the world, working to develop and use biodiversity indicators. It builds on the BIP's publication 'Guidance for National Biodiversity Indicator Development and Use'. This module focuses on developing biodiversity indicators at the national level, but is relevant for developing indicators at other scales.
http://www.bipindicators.net/nationalindicatordevelopment/elearning

5. Good Practice Guidelines for Indicator Development and Reporting (Short paper by Denise Brown 2009)

This guideline presents five main stages in the development and reporting of indicators in New Zealand. This paper summarises the characteristics of good practice associated with each of these stages in indicator development and reporting, and illustrates them with case studies of indicator initiatives in New Zealand and Australia.
http://www.oecd.org/site/progresskorea/43586563.pdf

6. A framework for developing urban forest ecosystem services and goods indicators (Dobbs, C., Escobedo, F.J., Zipperer, W.C. 2011, Landscape and Urban Planning)

This paper presents a framework for developing indicators using field data, an urban forest functional model, and literature. Urban tree and soil indicators for groups of ecosystem functions were used to statistically analyze the effects of urban morphology and socioeconomics on urban forest ecosystem services and goods (ESG). The indicators presented in this paper allow for non-monetary valuation of urban forest ESG and can be used to develop urban forest management goals and to monitor the effects of urban greening policies on human well-being.
http://www.sciencedirect.com/science/article/pii/S0169204610002793

7. National Indicator Development Toolkit (Biodiversity Indicators Partnership 2013)

The 'Indicator Toolkit' provides help for indicator practitioners, offering easy access to guidance and support. For any question or help in developing biodiversity indicators, the toolkit aims to direct the user to the right part of the website quickly and simply.
http://www.bipindicators.net/nationalindicatordevelopment

8. Integrating Ecosystem Services into Development Planning (GIZ 2012)

Recommendations for developing ecosystem services indicators are provided as a check list in the annex of this report.
http://www.conservation-development.net/rsFiles/Datei/giz-2012-en-integr-ecosys-serv-in-dev-planning.pdf

9. UK National Ecosystem Assessment Follow-on Work Package Report 5: Cultural ecosystem services and indicators (Church et al. 2014)

This report highlighted the need to develop quantitative indicators for cultural ecosystem services. The measurement of cultural ecosystem services is difficult because their qualitative and interpretative nature and the lack of easily accessible datasets. A range of potential new indicators was identified and evaluated. The four indicator types considered in detail focused on the measurement of cultural ecosystem services in a range of environmental spaces in terms of supply, accessibility, demand, and quality.
http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=2&ProjectID=18081#Description

Further resources on ecosystem services indicators

1. Finnish ecosystem service indicators (Finnish Environment Institute; latest update 2015)

This is a work in progress site of Finland's national set of ecosystem service indicators. At the moment the collection includes 112 indicators. This site provides a detailed overview of provisioning, regulating and cultural services and their indicators. They use the Cascade model on ecosystem service flows as a conceptual background model. Indicators were developed for four steps (structure, function, benefit, value) of the Cascade models.
http://www.biodiversity.fi/ecosystemservices/home

2. Global Indicators of the Biodiversity Indicators Partnership (2012)

This website (http://www.bipindicators.net/globalindicators) provides an overview of global biodiversity indicators developed by the Biodiversity Indicators Partnership monitoring progress towards the Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets.

3. Workshop report with lists of possible Ecosystem Service Indicators (UNEP-WCMC 2009)

This report presents key findings from the workshop on ecosystem service indicators "Developing and mainstreaming ecosystem service indicators for human wellbeing: Gaps, opportunities and next steps" as well as lists of ecosystem service indicator.
http://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/122/original/EcosystemServiceIndicators_Workshop_Report_Final.pdf?1398681607

4. Measuring Nature's Benefits: A Preliminary Roadmap for Improving Ecosystem Service Indicators (World Resources Institute 2009)

This report provides a compilation of Ecosystem Services Indicators used in the Millennium Ecosystem Assessment (MA) as well as Sub-Global MA's (SGMA), an assessment of each indicator's capacity to support policy as well as their data availability and recommendations for next steps toward improving ecosystem services indicators and data compilations, and their application in decision-making processes.
http://srv2.lemig.umontreal.ca/donnees/geo2312/A%20toolbox%20%28Double%20click%20on%20BFD.exe%20not%20available%20for%20Mac%29/Resources/CD%20Resources/Monitoring/ES_Indicators_WRI_measuring_natures_benefits_09.pdf

5. UK Biodiversity Indicators (Department for Environment, Food and Rural Affairs 2014)

This report provides a set of biodiversity indicators developed and used for report on progress towards meeting the "Aichi targets". The assessment of each indicator shows trends over time. http://jncc.defra.gov.uk/pdf/UKBI2014.pdf

6. Socio-economic importance of ecosystem services in the Nordic Countries (Nordic Council of Ministers 2012)

This report provides a list of identified direct indicators and proxies for nordic ecosystem services, with a view to creating the most comprehensive and informative basis for gathering further knowledge for future assessment and monitoring of services. Additionally, there is a detailed description of each ecosystem service and how to measure the status of this service.
http://www.teebweb.org/wp-content/uploads/2013/01/TEEB-Nordic-Synthesis-Report.pdf (p.91)

7. Corporate-level reporting on ecosystem services - Incorporating ecosystem services into an organization's performance disclosure (Global Reporting Initiative 2011)

This publication features a table exploring example corporate-level indicators based on the principal key threats to ecosystems. These indicators could be options for an organization to report on its pressures, impacts, dependence on and responses to ES. Many of the example indicators listed do not directly measure ES, but are used as proxies that could reveal information on the actual ES.
https://www.globalreporting.org/resourcelibrary/Approach-for-reporting-on-ecosystem-services.pdf

8. A European atlas of ecosystem services (European Commission 2011)

The report collected spatially explicit indicators for 13 ecosystem services. For each service the study identify indicators for service capacity and service flow. The different indicators for ecosystem service capacity and flow are presented including detailed information on the data sources, a presentation of EU ecosystem service maps and a discussion on possible limitations and recommendations for further research and development of each of these services.
http://publications.jrc.ec.europa.eu/repository/handle/JRC63505

9. Review of indicators and JRC-data for mapping ecosystem services (European Commission / JRC-Ispra, Institute for Environment and Sustainability 2012)

This report gives an overview of spatial information used for mapping and modelling ES according to the scientific literature and evaluates the potential contribution of the JRC in supporting such initiatives at global, continental, and national level. This includes: i) identify spatial indicators that have been used to map and quantify ES; ii) inventory the currently available spatial data on indicators in the JRC; and iii) identify the possible contribution of the JRC to ES mapping initiatives.
http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26749/1/lbna25456enn.pdf

10. FAO Indicators on genetic diversity and biocultural innovation systems (Methodology Coordination Workshop, Cusco Peru 2013)

This report presents the usage of some indicators provided by the FAO Commission on Genetic Resources for Food and Agriculture (GRFA). http://pubs.iied.org/pdfs/G03618.pdf

11. Indicators for measuring biodiv gains in IKI-projects on forests/wetlands (UNEP-WCMC technical report 2014)

Indicators for the criteria are measures based on verifiable data that convey information about how projects will perform/are performing against the biodiversity criteria.
http://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/220/original/IKI_report_1_accessible_version_20140530.pdf?1401884816

ValuES

About the ValuES Methods Navigator

Assessing ecosystem services has been widely recommended for showing the many ways how humans depend on intact nature. It has also been criticized for paving the way for further commodification of nature. Whether ecosystem service assessments can live up to their promise depends on how they are being done. How are they designed? And how are assessment processes connected to decision making processes?

At www.aboutvalues.net users find assistance for developing their own case-specific responses to whether an assessment makes sense, and if yes, in which form.

The site hosts a database with more than 60 method profiles with practical information on how a method works, and what its requirements are with regard to e.g. time and data. To make best use of these method profiles, a navigator guides users through various steps. The site also hosts a hands-on introduction to ecosystem services for those new to the topic.

About the project

ValuES is a global project that aids decision-makers in our partner countries in recognizing and integrating ecosystem services into policy making, planning and implementation of specific projects. We do this by developing instruments and training courses, providing technical advice and facilitating planning and decision-making processes. We also promote knowledge-sharing via regional workshops and participation in global discussion forums.

On behalf of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) as part of the International Climate Initiative (ICI), the ValuES project is implemented by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in close collaboration with the Helmholtz Centre for Environmental Research (UFZ) and the Conservation Strategy Fund (CSF).

About GIZ

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH GIZ is a German federal enterprise that operates in more than 130 countries worldwide to support the German Government and other donors in achieving their objectives in the field of international cooperation for sustainable development. The conservation and sustainable use of biodiversity for human well-being is one of the priority areas of German development policy. GIZ implements projects around the globe that support partners in implementing the CBD Strategic Plan for Biodiversity.

About UFZ

Scientists at the Helmholtz Centre for Environmental Research (UFZ) in Leipzig, Germany, study the complex interactions between humans and the environment in all its facets. They develop concepts and processes to help secure the natural foundations of human life for future generations. For further information on the UFZ's role in the ValuES project see: here

About CSF

The Conservation Strategy Fund (CSF) sustains natural ecosystems and human communities through strategies powered by conservation economics. Our trainings, analyses and timely expertise make development smarter, quantify the benefits of nature, and create enduring incentives for conservation. CSF has offices in the US, Bolivia, Peru and Brazil and additional staff in Costa Rica, Colombia and Uganda. Our training faculty includes instructors from Harvard, Duke, University of Brasilia, University of the Andes (Colombia), University of Concepción (Chile), Oregon State University, University of Cape Town and Makerere University (Uganda), among others.

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

HELMHOLTZ ZENTRUM FÜR UMWELTFORSCHUNG UFZ

CSF

On behalf of:
Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
of the Federal Republic of Germany