



# Quantification of management measures and ecosystem service provision

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# The Provision of Forest Ecosystem Services

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and designing economic instruments for  
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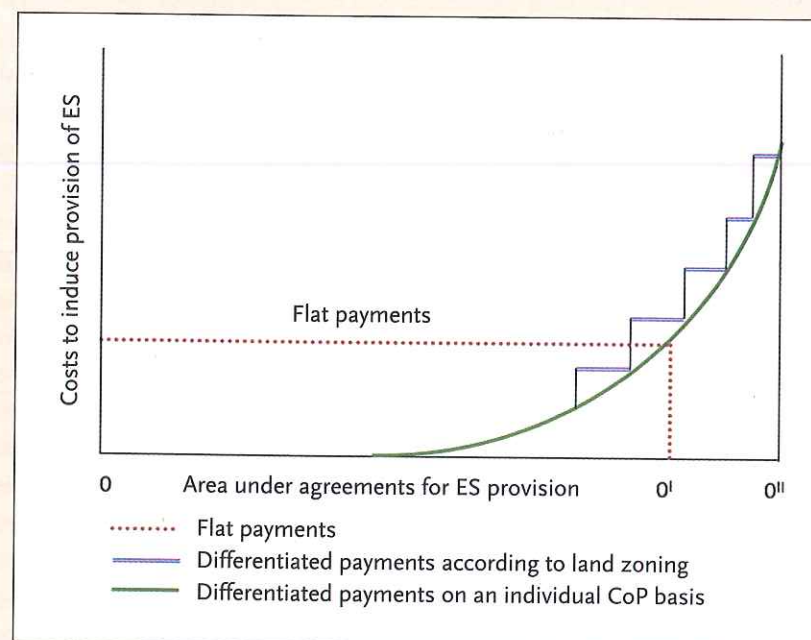


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**Box 2. A supply curve of ES as a function of CoP and related payments.**

Work published by Whitby and Saunders in 1996 has explored compensation under economic instruments. In the figure, the green curve represents a supply curve for a specific ecosystem service. Instruments based on flat levels (red horizontal dotted line in the figure) under- or over-compensate the ecosystem service providers. Differentiated payments calibrated along the step function in blue better approximate the supply curve. Payments negotiated with individual providers so as to cover the precise amount of compensation needed by each provider to accept the change (thus following exactly the supply curve as in a market transaction) can induce provision in all of the OO" area. Thus, both farmers' rents resulting from excess payment as well as the risk of forcing provision levels with costs above benefits, leading to failure in the medium-long term, could be avoided – ideally. To achieve that, the negotiation process should approximate the payment to the marginal cost incurred by the farmers, plus the costs needed to incentivize the farmer to enter the agreement. A compromise solution between the payment to single ES providers and the flat payment could be e.g. differentiated payments according to land zoning, if that can take into account site-specificities at least to some degree.



Source: modified from Whitby, M. and Saunders, C. 1996. Estimating the supply of conservation goods in Britain: A comparison of the financial efficiency of two policy instruments. *Land Economics* 72: 313–25.

## 2.2

## Quantification of management measures and ecosystem services provision

Sven Wunder, Jens Abildtrup and Bo Jellesmark Thorsen

In the design and implementation of policies enhancing ecosystem services provision two practical issues get very important. First, how is the provision measured? Measurement is important for enforcing and evaluating a given policy measure. Secondly, what measures will insure a given provision of services? Measurement and the identification of measures are in many cases two closely related questions as service provision is often measured by the implementation of specific actions. In this chapter we discuss measurement and the identification of measures (or management actions) to ensure the service provision.

### Should we measure ecosystem services or actions?

Environmental policies and interventions usually target a better provision and higher value of (some pre-defined bundle of) ecosystem services. But how will decision makers be able to know to what extent they have made the hoped-for difference? In a world without transaction costs (e.g. monitoring costs) and perfect knowledge it would be preferable to base policies on a given level of provision of the service of interest. For example, a forest owner could be paid for a certain number of rare species present in her forest. This would allow the individual forest owner to choose the least costly measure to insure the demanded provision in her specific case, as the least cost measure may depend on the forest characteristics and the forest owner type. Basing the policy on the output of the management actions ensures that forest owners may choose cost-effective measures for the specific forests, provided they know the relation between action and output. This is what is often called output based regulation. However, in many situations this is not an applicable approach since measurement costs are very high and/or we do not have perfect knowledge about the relation between action and outcome. For example, it will be expensive to assess the number of species in a forests every year to obtain a measure of biodiversity provision. A second issue is to what extent we will be able to measure the actual service within our targeted time frame. There may be a long time span between implementation of a provision measure and the desired outcome. Therefore, policies of environmental service provision are often based on proxies of outcome (changes in land use) or on specific management actions (also termed input-based regulation). Furthermore, management actions are less affected by hazardous third



factors (e.g. drought followed by increased non-anthropogenic fire risks). It will often be unacceptable and inoptimal to let individual forest owners carry this risk or the risk associated with lack of knowledge. However, specifying a policy based on management actions will reduce forest owners' flexibility and will typically increase their costs, as the implementing environmental principal (e.g. a government agency) would have less information than the forest owner about the cost-effective measure in individual forests.

Assessment of a baseline

Whether or not a policy is input or output based, it would always be necessary to assess a baseline: what would likely have happened to the targeted ecosystem service(s) without our intervention? And what would have been the management choice? The difference between the baseline and the actually observed service trend represents the incremental ecosystem service gained, and is often termed the "additionality" of the measure.

Normally we will look to history to construct a service baseline. For instance, if we want to avoid carbon losses from future deforestation, we have to predict a "business as usual" (no intervention) deforestation scenario, which we will often base on some simple extrapolation of past deforestation trends (e.g. the last five years' average) or a model that integrates determinants of our target land use (e.g. road building and agricultural commodity prices). Similar methods may be applied for losses of biodiversity at relevant scales. Modeling can to some extent bridge over the lack of good historical data. Hence, the reliability of our baseline also comes to depend on the quantity and quality of ecosystem service and land use data available. Note, however, that the implementing environmental principal will only be able to make qualified guesses about what actions individual agents (e.g. different landowners) would have taken under a 'business as usual' scenario without the intervention. This is usually referred to as the problem of 'asymmetric information' in measuring environmental additionality and service providers' costs. When policies have long time horizons it is important to account for potential climate and socio-economic changes which may have a significant impact on provision actions effectiveness as well as having an impact on the cost of provision.

Identification of management actions

As policies are often based on specific management actions and not directly the on the change in the ecosystem service which is the aim of the policy, it is important for the implementing principal to identify relevant and cost-effective measures. This may be a complicated task as many different measures may provide the same ecosystem service.

As an example, Table 1 reports four different management actions which have been identified as measures to increase the supply of biodiversity protection in Atlantic (deciduous) forests. In addition to a large set of potential measures affecting one ecosystem service, each measure may have impacts on more than one ecosystem service. For example, changing from conifers to broadleaved tree species in Denmark (Table 1) is normally considered to have a positive impact on biodiversity protection status in the long run. At the same time surveys have shown that most forest visitors prefer to visit forests with broadleaved species. This is an example of positive feedback between two services (joint production). If the supply of biodiversity increases the provision of recreational

Table 1. Example of how management actions (measures) may affect several services – here affecting the provision of biodiversity protection and recreational services in Denmark (the list is not exhaustive).

Examples of actions	Impact on biodiversity	Impact on recreation
Change from conifers to broadleaves	Increase in biodiversity due to more native species linked to broad-leaved forest	In general, more attractive forest for recreational users
Leaving a number of trees when doing final harvest	Increased number of insects, fungi, birds and small animals	Uncertain effect. Some users will benefit from increase in biodiversity – other will have disutility of seeing decaying trees
Leaving larger areas untouched by management	Increased number of insects, fungi, birds and small animals	Uncertain effect. Some users will benefit from increase in biodiversity – other will have disutility of seeing decaying trees and "messy" new forests
Allow public access on foot in all forest and everywhere in the forest	Potentially negative impact on biodiversity (disturbing larger animals and forest floor fauna and flora) in forests with many visitors	Increase the attractiveness of forest recreation

services increases too. However, such feedback effects may also be negative. For example, opening up for public access, i.e. increasing the recreational service this may have a negative impact on the big game population. This is an example of a negative feedback in the provision of recreational services. In Table 1 we have only considered two services. However, the considered measures may also have impacts on other services. For example, changing tree species may also have impacts on carbon sequestration and watershed protection.

Measurement of environmental service provision: Examples

In the following, we will briefly exemplify these matters for each of the four main targeted forest ecosystem services of these volumes. We refer the reader to the corresponding and more detailed chapters in Volume I of this publication.

a) Forests and watershed protection from

Hydrological ecosystem services from forests are among the most difficult to measure and predict, due to a strong variability in time and space. Important year-to-year variations in precipitation and temperatures cause natural fluctuations in service provision over time. Similarly, the complex interplay between vegetation cover and its management, soils and slopes is spatially highly heterogeneous, and long lags may occur between management changes and measurable service output (e.g. between soil restoration and stabilized water flow). Finally, many targeted watershed services refer to the mitigation of serious risks (e.g. floods, landslides, silting of water infrastructures), which by their very nature only occur in large time intervals, so that an improvement over a risk-mitigation baseline only can be reliably evaluated perhaps decades after the intervention has occurred.

Progress towards improved services is thus best measured in terms of promotion of those land uses that are likely to promote service provision (e.g. forest conservation on



slopes with fragile soils). Modeling changes explicitly in space can thus under such circumstances also become quintessential, for instance using a Soil and Water Assessment Tool, to quantify the linkages between changing land management, likely service amounts provided, and the corresponding costs to service providers and benefits to service users, respectively.

#### b) Forests and carbon services

How do we measure changes in forest carbon stocks, and the “additionality” of any improved management? Forest carbon services – within the forest – are easier to quantify in the sense that linkages between the “action” and the “service” are more stable in time and space than for watershed services. However, there are some exceptions. For instance, forests that in normal years act as carbon sinks can during El Niño Southern Oscillation (ENSO) years become net carbon emitters. Similarly, afforestation in some high-altitude areas with fragile soils can release accumulated soil carbon to an extent that at the extreme could outweigh the gains in above-ground biomass.

As a simple accounting point of departure, forest carbon stocks depend on two factors: forest area size and carbon densities. Many assessments of forest carbon stocks thus start out from ground-based forest inventory data, supplemented by biome-wide density averages for extrapolation in space. This information they combine with remote sensing (radar, laser, or air-borne optical sensors) based estimates for area size and its changes over time.

#### c) Forests recreational services

Recreational services differ substantially from water and carbon services in that the end service quantity is not biophysically measurable, but instead determined by ranked human preferences for different landscape attributes. Measurements of these ecosystem services are typically based on observations in the form of frequencies, length and site of recreational visits, which form the basis for e.g. travel cost based estimates of recreational values. Forest management changes affecting recreational visits depend on the specific context of the recreational landscapes, and the preferences of the relevant populations. Forest tree ages, species, open areas, track availability, the presence of other forest guests and many other factors affect the quality of the recreational ecosystem services to the individual.

#### d) Forest biodiversity services

Biodiversity services are linked to a stock of forest resources (species, landscapes, etc.) that humankind derives intangible, often non-use benefits from, such as ‘option’ (or ‘bequest’) values of future generations possible yet so far unknown resource uses, and the ‘existence’ values current generations attribute to the survival and thrive of species that they may never see in situ. Hence, while these values may change with human preferences and technology, the underlying stock of diversity has, unlike recreational services, a well-defined biophysical dimension. However, the exact measurement of biodiversity can be cumbersome and expensive, so that proxies are also often used. This could be certain keystone species (e.g. bird diversity) or land-use proxies (e.g. near-natural forest area preserved). The latter can provide fairly good approximations of changes in biodiversity under the well-known species area relationship, predicting that habitat size is the key determinant for biodiversity levels.

#### Key messages

The measurement of ecosystem service provision is costly and therefore the quantification for policy measures is often based on proxies or on management actions.

- For assessment of the additionality and cost effectiveness of policies it is important to assess a business as usual scenario which can be based on historical data or/and modeling.
- Changes in the provision of a given ecosystem service can typically be achieved by several different management measures, and the most cost-effective measure should be chosen.
- The relevant measures will depend on local conditions, and the identification of relevant measures should be case or region specific.
- Management actions would typically have impacts on the provision of more than one ecosystem service. This should be considered when assessing the cost-effectiveness of measures.

#### Recommended reading

- Quintero, M., Wunder, S. and Estrada, R. D. 2009. For services rendered? Modeling hydrology and livelihoods in Andean payments for environmental services schemes. *Forest Ecology and Management* 258: 1871–1880.
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