Ecosystem Services (ES) in river basin management – background information and discussion document

Authors	Suzanne van der Meulen & Jos Brils (both TNO)
Contact	Jos Brils, jos.brils@tno.nl

Deliverable Nr.	Not applicable
Document status	DISCUSSION document
Version d.d.	18 September 2008

Dissemination level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Contents

Preface, guide to the reader and acknowledgements

Preface

This report contains an overview of available information about ecosystem services (ES), where possible specifically in the context of (risk-based) river basin management. The report is the result of a brief exploration of readily available knowledge and practical experiences on this topic. Both scientific and other information sources were used. This study was not intended to be all embracing, but to provide some basic input for further discussion in the European Commission 6th Framework Programme project RISKBASE (www.riskbase.info) as well as in the Dutch Living with Water project AquaTerra the Netherlands (www.levenmetwater.nl). In these projects it is discussed whether the ES concept could be used in these projects, and in case so, how.

This report may be used publicly as a discussion paper.

Guide to the reader

The first chapter gives an introduction about ecosystem services. Chapter 2 to 5, provide information from several information sources on four questions:

1. Which ecosystem services (ES) are relevant for risk based river basin management?
2. How to assess threats/risks to these ES?
3. How to prioritise the assessed risks/threats at a basin scale?
4. What practical threat/risk reducing/mitigating measures are available?

Chapter 6 contains a synthesis of the information from literature about the answers to these questions, including some remarks of the authors. Chapter 7 closes this report with recommendations for actions within the framework of RISKBASE.

Acknowledgements

The authors would like to acknowledge several persons for their suggestions and contributions: Joop Vegter (Vegter Advice), Wim Salomons (IVM), Claudia Pahl-Wostl (USF), Nicoletta Toniutti (WWF), Frans Cleassen (Deltares), Philippe Pypaert (UNESCO) and Joke van Wensem (TCB).

Summary

Ecosystem services are the benefits that people get from nature. The services can be goods (provisioning services) or regulating services, cultural services and supporting services. Some ecosystem services that have been identified during studies in river basins are: nutrient removal, temperature regulation, carbon sequestration, habitat, flood protection, food and goods, biomass for renewable energy, water supply, recreation, hydroelectric power, transportation, fish production, aesthetic, fiber and fuel, hydrological flows (groundwater recharge), pollution control, educational services (opportunities for formal and informal education and training), soil formation, pollination, nutrient cycling and biodiversity.

The importance of ecosystem services and their protection is being mentioned in several EC communications and strategies. Applying an ecosystem services approach in management and decision making means:

- Raising awareness with public and policy makers about the value of nature conservation and sustainable use of the ecosystem and its services and the value of nature conservation.
- Involvement of stakeholders and knowledge owners from different blood groups
- Community spirit about ecosystem services values and conservation measures increases the likelihood that measures will be accepted and implemented in an effective manner.
- A better understanding of the value of ecosystem services will make it easier to raise funding for protection of the ecosystem and its services.
- Boundaries of sectors and ecosystems are crossed and integrated management is possible.
- Showing (unexpected or unintentional) consequences of policies and actions at different temporal, spatial and socioeconomic scales.
- Consider the complete system of biophysical and socio-economic factors and the many related processes and values within en between these systems. Hereby, prioritization and the development of effective protection measures is possible.
- A less static, defensive approach of ecosystem conservation.

Changes in ecosystems and their services are mostly gradual, detectable and predictable but nonlinear or abrupt changes exist as well. Prediction of thresholds is a problem and some changes are irreversible.

The relevance of ecosystem services depends on the scales that are considered. Literature provides assessment frameworks that assume either of the following applications:

- The protection of desired ecosystem.
- The assessment of ecosystem services within the context of a decision.

In this report, methods are described for identification and prioritization of ecosystem services, monetary and non monetary valuation of services and assessment of state, trends and risks/threats to ecosystem services. The methods are mainly based on or focusing on participatory approaches and expert opinion, mapping, assessment of ecosystem service providers, scenario analyses, monetary and/or non-monetary valuation of ecosystem services, indicators for system quality, thresholds and comparison of provision and demand. The prioritization of threats to ecosystem services could be done by considering the following aspects:

- Relevance of the ecosystem service(s);
- State of the relevant ecosystem service(s);
- The impact of irreversible change or slow recovery of the ecosystem service.

Prioritization of risks is depending on temporal, spatial and social/political scales. In order to prevent from missing important aspects of ecosystem services, all the mentioned assessments should be focussed on different scales.

Prioritization of measures can be based not only on the prioritization of the risks they aim to prevent for or the damage they need to repair, but also on the negative and positive side–effects (both monetary and non-monetary) that they will generate. When measures need to be chosen, a broad spectrum of both soft and hard measures should be considered.

Five categories of responses to enable sustainability of ecosystem services were given within the framework of the Millennium Assessment:

- Measures concerning *institutions and governance* are mainly focussing on enabling implementation of an ecosystem services approach in management structures.
- E*conomic measures* such as subsidies, rewards for positive actions, penalizing measures for negative actions and payment for ecosystem services.
- *Social and behavioural* responses are focussing on information distribution and empowerment.
- *Technological responses* such as measures to increasing efficiency with which resources are being used and reduction of impacts of drivers, alternatives for lost or impaired ecosystem services, and development of monitoring and warning systems to enable better management of ecosystem services.
- *Knowledge and cognitive responses* are referring to gathering knowledge and adequate use of knowledge and information.

1. Introduction

1.1. Definition of ecosystem services

Ranganathan et al. (2008):
‘Ecosystem services are the benefits that people get from nature’. Ranganathan et al. define an ecosystem, following CDB (1993), as ‘a collection of plants, animals, and micro-organisms interacting with each other and with their non-living environment’.

Daily (1997):
‘Ecosystem services are the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfil human life’

Millennium Ecosystem Assessment (2005a):
‘Ecosystem services are the benefits provided by ecosystems’. In figure 1, the linkages between ecosystem services and human well-being is depicted.

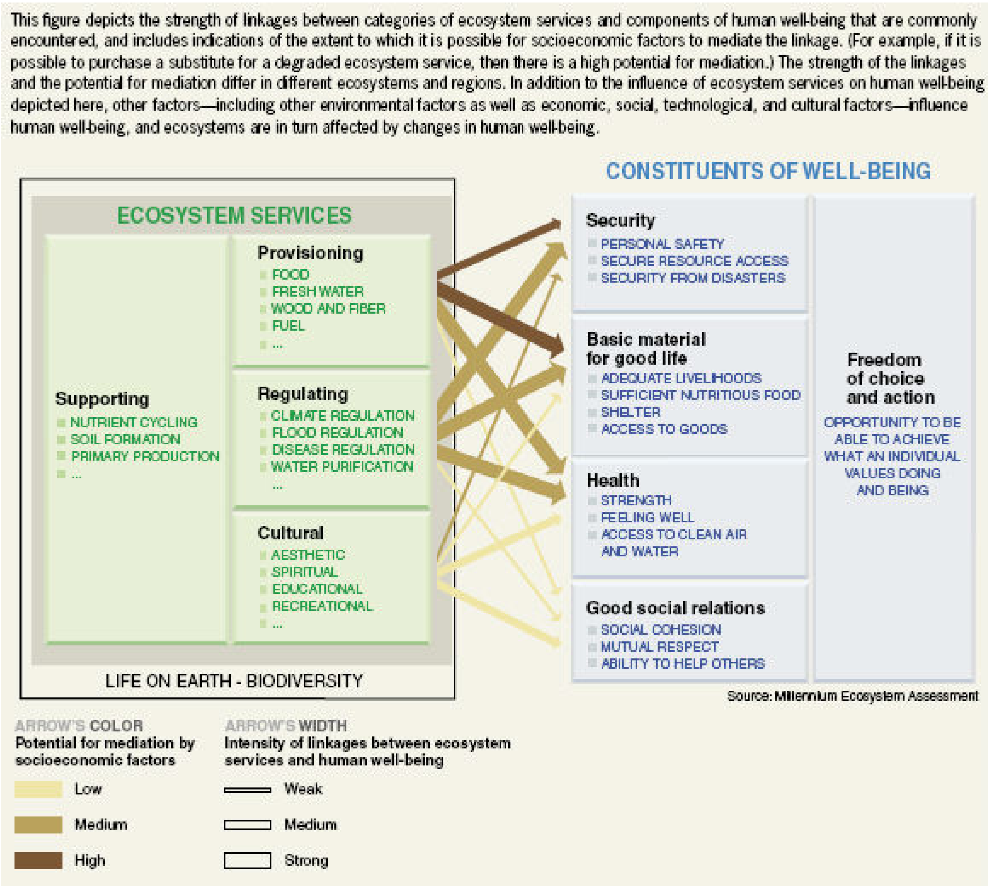

Figure 1: Linkages between ecosystem services and human well-being (Millennium Ecosystem Assessment, 2005a)

Development goals such as adaptation to climate change and health depend on ecosystem services. For example, vegetation provides regulating services by capturing carbon dioxide which contributes to climate change adaptation and the ecosystem services food production and water purification are important for human health (Ranganathan et al., 2008).

1.2 Types of ecosystem services

Ecosystem services can be divided into four categories (Millennium Ecosystem Assessment, 2005a):

- **Provisioning services** are products obtained from ecosystems;
- **Regulating services** are the benefits obtained from the regulation of ecosystem processes;
- **Cultural services** are nonmaterial benefits people obtain from the ecosystem;
- **Supporting services** are services that are necessary for the production of all other ecosystem services. Their impacts on humans are often indirect or occur over long time periods.

The synthesis report Ecosystems and human well-being (Millennium Ecosystem Assessment, 2005a) describes examples of those types of services and the condition of the services at a global scale. Table 1 lists examples of ecosystem services.

1.3 The value of an ecosystem services approach

Salomons (2008) states that risk assessment at the river basin scale needs to cut across existing frameworks of legislation and directives in order to serve as a basis for the management of risks resulting from propagation of local and regional adverse impacts. An ecosystem services framework integrates biophysical and social dimensions of environmental protection (Daily, 2000).

Beaumont et al. (2007) state that the use of goods and services framework reduces the chance that managers will overlook certain goods and services when making decisions and raise the profile of services compared to the much better understood and documented goods.

The EU White paper on adaptation to climate change that is under development, mentions that the EU adaptation strategy should aim to maintain ecosystem services in order to increase natural resilience and decrease vulnerability of ecosystems and society (WWF comments on the EU White Paper on adaptation to climate change).

The 2006 Biodiversity Communication and its detailed Action Plan set out a detailed agenda for action to halt the loss of biodiversity by 2010 and beyond. The objectives of the plan among others are to conserve and restore biodiversity and ecosystem services in the wider EU, to substantially strengthen effectiveness of international governance for biodiversity and ecosystem services (Commission of the European communities, May 22, 2006).

Vihervaara et al. (2008) in a presentation during the Ecosystem Services Workshop at Salzau Castle of May 13 - 15th, 2008 show how the ecosystem services approach has been used to find new, objective perspective for the question of optimal land use.

Table 1: Examples of ecosystem services (based on Millennium Ecosystem Assessment, 2005a)

Provisioning services	Food
	Fibre
	Fuel
	Genetic resources
	Biochemicals, natural medicines, pharmaceutics
	Ornament resources (for example skins, shells and flowers)
	Fresh water (fresh water is also a source of energy and a supporting service because it is required for life)
Regulating services	Air quality regulation (ecosystems contribute to and extract chemicals from the atmosphere)
	Climate regulation (for example land cover can influence temperature and precipitation)
	Water regulation (timing and magnitude of runoff, flooding and groundwater recharge can be influenced by changes in land cover)
	Erosion regulation (for example vegetation cover)
	Water purification and waste treatment
	Disease regulation (changes in ecosystems can alter the abundance of human and animal pathogens or disease vectors like mosquitoes)
	Pollination
	Natural hazard regulation (for example the presence of mangroves can reduce damage caused by hurricanes)
Cultural services	Cultural diversity
	Spiritual and religious values
	Knowledge systems
	Educational values
	Inspiration
	Aesthetic values
	Social values
	Sense of place
	Cultural heritage values
	Recreation and tourism
Supporting services	Soil formation
	Photosynthesis
	Primary production
	Nutrient cycling
	Water cycling

In 2003, the Dutch Soil Protection Technical Committee (TCB), a scientific advisory body created by the Dutch Soil Protection act, brought out an advice on ecologically sustainable land use (TCB, 2003). In the advise it is indicated that many forms of land use in the Netherlands are not sustainable. The committee states that land use can be made more sustainable when an ecosystem approach is adapted in soil management. Such an approach will make it easier to identify and anticipate adverse effects of present land use, to change land use and reduce costs to society. Besides, an ecosystem approach clarifies which parties should be involved in land use planning and development. The health of an ecosystem can be deduced from properties like activity levels, stability, resilience and organisation. Since these properties cannot be expressed in well-defined and measurable indicators, the functioning of ecological services can be a good proxy for the health of an ecosystem. TCB writes that an ecosystem approach in soil management is based on three principles: sustainable use of soil and water, multisectoral approach and an integrated management structure. Within the framework of long term objectives, all parties/persons with a management functions and other stakeholders need to be involved in the planning process (multisectoral approach). Responsibilities for the ecosystem management should be assigned and coordinated at policy, planning and operational levels (integrated management structure). Ecological services need to be managed at the appropriate level. Services that are relevant to the local land use need to be managed at the local level; ecological services that are relevant at a larger scale, for example water, should be managed at the catchment level.

In 2005, the Dutch Soil Protection Technical Committee (TCB) advised the Dutch Minister of Agriculture, Nature and Food Quality specifically on more sustainable use of agricultural land (TCB, 2005) from a soil protection viewpoint. Sustainable land use is defined by TCB as 'preventing present land use from having adverse impacts elsewhere and in the future, the ability to maintain the land use in the long term, ensuring that the other land uses can be practised in future and preserving the ecological services of general benefit'. The committee has set objectives in which ecological functions of the land play a predominant role.

EPA applied the ecosystem services approach in the Willamette-Ecosystem Services Project (EPA, 2007a and 2007b). The aim of the program was to transform the way decision makers understand and respond to environmental issues by making clear the ways in which their choices affect type, quality and magnitude of the services we receive from ecosystems. In the case study, river restoration priorities were set. EPA is also carrying out projects in Tampa Bay and North and South Carolina (EPA case Tampabay, EPA case Carolina).

According to EPA (EPA, 2007b), 'ignoring or undervaluing ecosystem services can and has apparently resulted in failure to implement necessary environmental regulations to protect them'. EPA traditionally evaluated measures that are taken to protect the environment by cost-benefit analysis, mostly focussing on single issue problems with little multi-scale (temporal and spatial) understanding of the effects of a decision on the aggregate of ecosystems and human well-being. The Science Advisory Board of EPA therefore criticised EPA for 'dramatically undervaluing' improvements to ecosystems that will result from proposed regulations. Technology and knowledge will not be fully utilized to protect the environment as long as ecosystem services are considered free and limitless an their value is not taken into account.

Luisetti et al. (2008) used an ecosystem services approach within the framework of a cost-benefit analyses of an alternative coastal protection policy in England.

In 2000, Turner et al. described a case study in which an ecosystem functions and services framework is used for the environmental evaluation. A decision support system was developed for the evaluation of a wetland ecosystem management strategy.

Economic activities strongly affect the hydromorphological, hydrological and ecological value of an ecosystem. The other way around, loss of ecosystem services affects the economic value of an ecosystem. For example, the value of an estuary is about 22.000 dollar per year based on functions such as nutrient cycling and regulating physical disturbance (communication with Frans Cleassen). This shows economic relevance of ecosystem services conservation.

During the Dutch conference Kennisconferentie Water 2008 (http://www.kennisconferentiewater.nl/?mn=4&paginatype=2 *in Dutch*), one of the major issues of the discussion about the Water Framework Directive in the coming 10 years was to develop clear concepts and options for sustainable use of ecosystem services.

1.3.1 The value of a ecosystem services approach in relation to biodiversity conservation

Chan et al. (2006) assessed the opportunities and trade-offs of expanding a conservation plan based on conservation of biodiversity, with goals for ecosystem services protection. During a study in the Central Coast Region of California, USA, six ecosystem services were considered. For four different conservation network designs (ranging from only considering biodiversity to only considering ecosystem services and combinations of the two), the degree to which biodiversity and the flow of the six services were protected have been compared. The results showed that a network only based on biodiversity would protect a considerable part of the desired supply of ecosystem services. The conservation network based on ecosystem services only or biodiversity and all selected ecosystem services, would decrease the ability to protect biodiversity. If a network in which both biodiversity and part of the selected ecosystem services targets were protected is compared to a network only based on biodiversity conservation, biodiversity conservation is somewhat lower and achievement of the targets for the protected services is higher. Chan et al. also assessed what additional land is needed for the conservation network to meet the targets for individual ecosystem services (targets that will not be achieved with the chosen network). Analyses of the costs and benefits (for biodiversity) involved, can help decision-makers in choosing a conservation approach and additional measures. The adding of ecosystem services goals to biodiversity plans can potential pay-off tremendously for biodiversity conservation and human well-being.

Goldman et al. (2008) compared 26 traditional biodiversity projects and 34 projects that in part focussed on ecosystem services. The aim of the project was to assess whether ecosystem services projects attract new and more diverse financial support and to find other differences between the two types of conservation projects. The research showed that ecosystem services projects attracted on average four times more funding than traditional biodiversity projects. This was the result of greater corporate sponsorship and use of a wider variety of financial tools. The ecosystem services projects do not take away financial resources from biodiversity projects, but engage a more diverse set of funders. It is not possible to assess the effectiveness of ecosystem services and biodiversity projects because monitoring of conservation goals achieved is to infrequent.

Naidoo et al. (2008) compare ecosystem services maps with the global distribution of conventional targets for biodiversity conservation. Preliminary results of this research show that regions that were selected for biodiversity conservation do not provide more ecosystem services than other, randomly chosen, regions. Despite a general lack of concordance between services and between ecosystem services and conservation priorities, win-win areas can be identified. These areas are important both for ecosystem services and biodiversity.

The RUBICODE project held the workshop Habitat management and conservation policy – Strategies for a new dynamic approach focused on ecosystem service provision' (RUBICODE, 2008). In the key messages of the workshop it is stated that traditional conservation policy, in which networks of protected sites are being used to protect biodiversity, leads to two problems: 1) this approach ignores the huge contributions of biodiversity outside the protected areas to human welfare and economic activity; 2) conservation works are mostly static and not well fitted to achieve their aims in the fact of climate change. An ecosystem service approach can act as an communication tool and a framework to structure thinking about the relationship of humans and natural systems. The ecosystem services approach is not replacing conservation but complementary to and a basis for it. Key challenges in managing relationships between human societies and ecosystems:

- Mismatch of management at spatial scales (with landscape and other ecosystem service boundaries), at time scales (short term / sustainability);
- Improving cooperation over boundaries, disciplines and governance levels;
- Uncertainty, including variability in ecosystem services;
- Integration of nature conservation with climate change and integration of ecosystem services into adaptation and mitigation policy design.

Through case studies, the participants of the workshop explored the potential for an ecosystem services approach, for instance within the framework of the Water Framework Directive. The results of this workshop are presented in the workshop report (RUBICODE, 2008).

1.4 Direct and indirect drivers for changes in ecosystems and their services

Indirect drivers are demographic, economic, socio-political, cultural and religious or science and technology based (figure 2). The drivers can magnify or diminish the effect of others (Millennium Ecosystem Assessment, 2005a). For example, science and technology can increase efficiency by with ecosystem services are used while economic growth is increasing the demand for services.

The most important direct drivers of change for freshwater ecosystems and their services in the past 50 years are modification of water regimes, invasive species and pollution (Millennium Ecosystem Assessment, 2005a). Regarding pollution, particularly high levels of nutrients lead to eutrophication of water bodies and high levels of nitrate in drinking water. The increase in nitrogen fluxes in rivers to coastal oceans due to human activities compared to the fluxes before industrial and cultural revolutions is 3,7-fold in Western-Europe and 17-fold in the Republic of Korea. Other causes of contamination are non-point sources of pollution such as storm water runoff in urban areas, poor sanitation facilities in rural areas and flushing of livestock manure by rainfall and snowmelt and point sources such as mining. For terrestrial systems, the most important direct drivers of change in the ecosystem in the last 50 years have been land cover change, especially the conversion to crop land, and new technologies, which resulted in increased supply of provisional services.

In the last 50 years, climate change has led to changes in species distributions, population sizes, timing of reproduction or mitigation events, an increase in the frequency of pest and disease outbreaks and the growing season in Europe has lengthened (Millennium Ecosystem Assessment, 2005a).

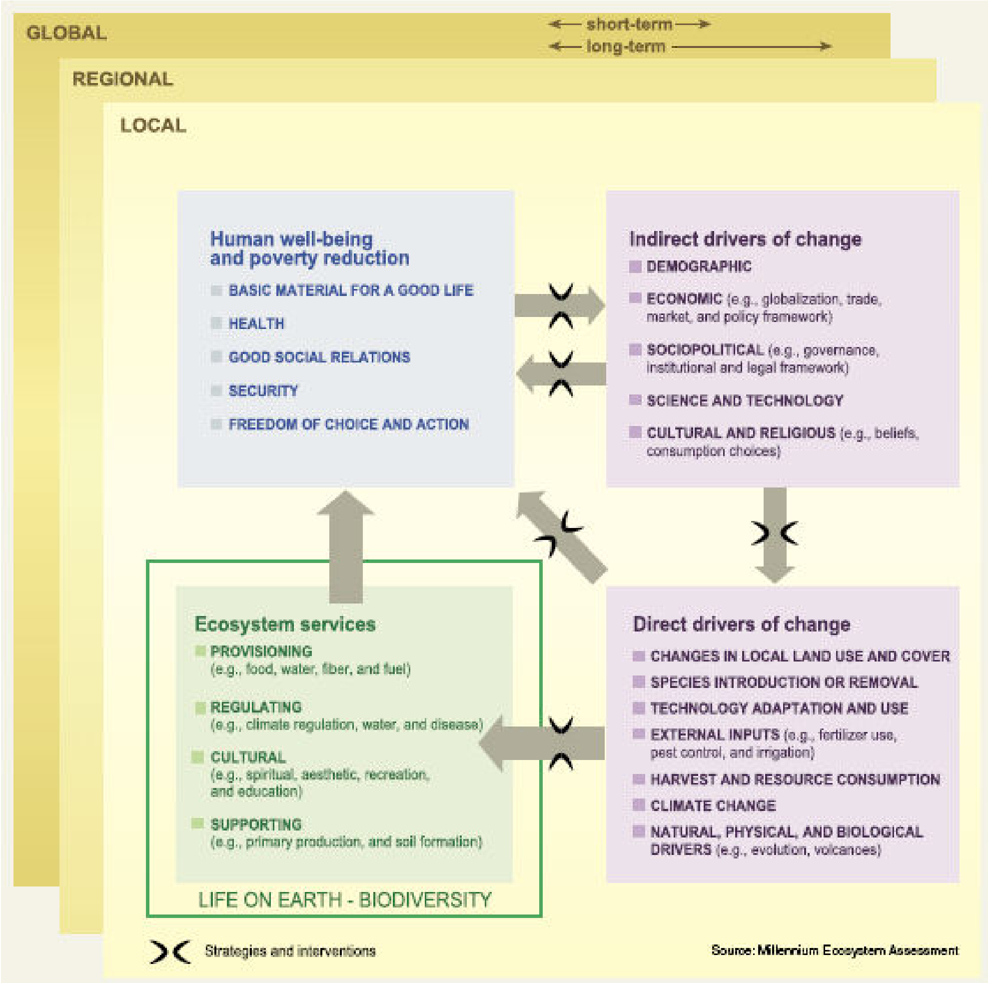

Figure 2: The interaction between biodiversity, ecosystem services, human well-being and drivers of change. Changes of indirect can lead to changes of direct drivers (Millennium Ecosystem Assessment, 2005a).

1.5 Changes in ecosystem services

The Millennium Ecosystem Assessment (2005a) reports that human use of ecosystem services is growing rapidly and that approximately 60% of the services are being degraded or used in an unsustainable manner. Some services are used at an unsustainable rate, others are altered by human activities. Despite local resource depletion global gains in the supply of certain services like food have been achieved in the past century by shifting production or harvest to other regions. The options for such practices are decreasing at the moment. The total demand of ecosystem services is growing but the demand for particular services in specific regions can decline as well. For example, the demand for fuel wood is being displaced by the demand for other energy sources.

The ecosystem services both support and depend on biodiversity (Kremen and Ostfeld, 2005). When a species that offers certain ecosystem services is lost or introduced to a certain location, the ecosystem services are changed as well. Changes in biodiversity also affect ecosystem services indirectly over longer time by changing ecosystem processes (Millennium Ecosystem Assessment, 2005a). Measures to affect one ecosystem service (for example to enhance food production) will generally modify other services as well and can have both positive and negative trade-offs.

1.6 Future changes in ecosystems and their services

The Millennium Ecosystem Assessment (2005a) explored changes in ecosystems and their services under four scenarios with different global development paths and ecosystem management. The changes in direct and indirect drivers, including climate change, changes in ecosystems and changes in ecosystem services and human well-being were projected under the four scenarios. The degradation of ecosystem services could grow significantly worse during the coming 50 years.

2 Relevant ecosystem services for risk based river basin management

Some ecosystem services that have been identified during studies in river basins are: Nutrient removal, temperature regulation, carbon sequestration, habitat, flood protection, food and goods (EPA, 2007a), biomass for renewable energy, water supply (WWF), recreation (Millennium Ecosystem Assessment, Glomma river basin study), hydroelectric power, transportation, fish production, aesthetic values (National Research Council (U.S.)., 2004), fiber and fuel, hydrological flows (groundwater recharge), pollution control, educational services (opportunities for formal and informal education and training), soil formation, pollination, nutrient cycling and biodiversity (Lellouch et al., 2007).

In the Willamette case of EPA (2007b), a list of ecosystem services is divided into four categories: Regulation, Habitat, Production and Information. Services that were expected to be the most relevant in the Willamette river basin are gas regulation (UVB-protection, air quality, influence on climate), disturbance prevention (storm protection, flood diminishing), water regulation (irrigation, transport), water supply (for consumptive use), soil retention (arable land, erosion and siltation prevention), nutrient regulation, refugium (living space for wild flora and fauna), nursery, food and recreation.

3 How to assess threats/risks to ecosystem services: indicators and assessment tools

3.1 Threats to ecosystem services

Ecosystem services are severely threatened through (1) growth in the scale of human enterprise (population size, per-capita consumption, and effects of technologies to produce goods for consumption) and (2) a mismatch between short-term needs and long-term societal well-being (ESA, 1). Human activities threat ecosystems by pollution, introduction of non-native species, overharvesting, destruction of landscapes such as wetlands, erosion of soils, deforestation and urban sprawl.

The Ecological Society of America (ESA) provides information on providing land types for and threats to the ecosystem services water purification, pollination and carbon storage. For example, threats to water purification are paved roads, altered waterways, loss of riparian vegetation, invasive species and pollution. For flood damage control a fact sheet is in preparation (ESA, 2).

3.2 Assessing changes in ecosystem services: thresholds and targets

Mostly, changes in ecosystems and their services are gradual, detectable and predictable (Millennium Ecosystem Assessment, 2005a). However, nonlinear or abrupt changes exist as well. When a certain threshold is reached, gradual changes suddenly become more rapid and the system moves to a new state. It is possible to predict gradual changes and warn when risks of change are increasing, but prediction of thresholds is a problem.

3.3 Frameworks for the assessment of ecosystem services

3.3.1 Ecosystem Services Framework

Daily (2000) describes the four key elements of the Ecosystem Services Framework:
1. <u>Identification of ecosystem services</u> at different scales and assessment of ecosystem service flow. Ecosystem service area maps could be used for this purpose.
2. <u>Characterization of the services</u>: An ecological characterization of ecosystem services in which is described how ecosystems generate services, how services are interdependent and the extent and time scale over which the ecosystems are able to repair. The characterization can be used to the importance or value of the services.
3. <u>Establishing safeguards</u>. Determine the desired mix of ecosystem services, especially where exploitation of one service hampers the delivery of another and create the institutional means of securing the desired range of options.
4. <u>Monitoring</u> of the ecosystem services / evaluating the safeguards. For some services, clear and well monitoring is possible and taking place, for example fish stocks or water quality. For most services, however no systematic monitoring exists. Monitoring is essential to evaluate the efficiency of institutional safeguards to protect ecosystem services.

Daily treats the implementation of the Ecosystem Services Framework in management. It is suggested that priorities should lay in starting with the ‘low hanging fruit’; the assessment of safeguards for well-known ecosystem services (such as water purification and flood control).

Secondly monitor the results of safeguards and learn from these experiences. Third experiments and innovations are needed. And finally, models of success should be promoted.

3.3.2 Assessment of risks and opportunities related to ecosystem service

In 'Ecosystem services, a guide for decision makers', Ranganathan et al. (2008) present a method to assess the risks or opportunities that ecosystem services put to a specific decision (or policy, plan, project). The method is schematically presented in figure 3.

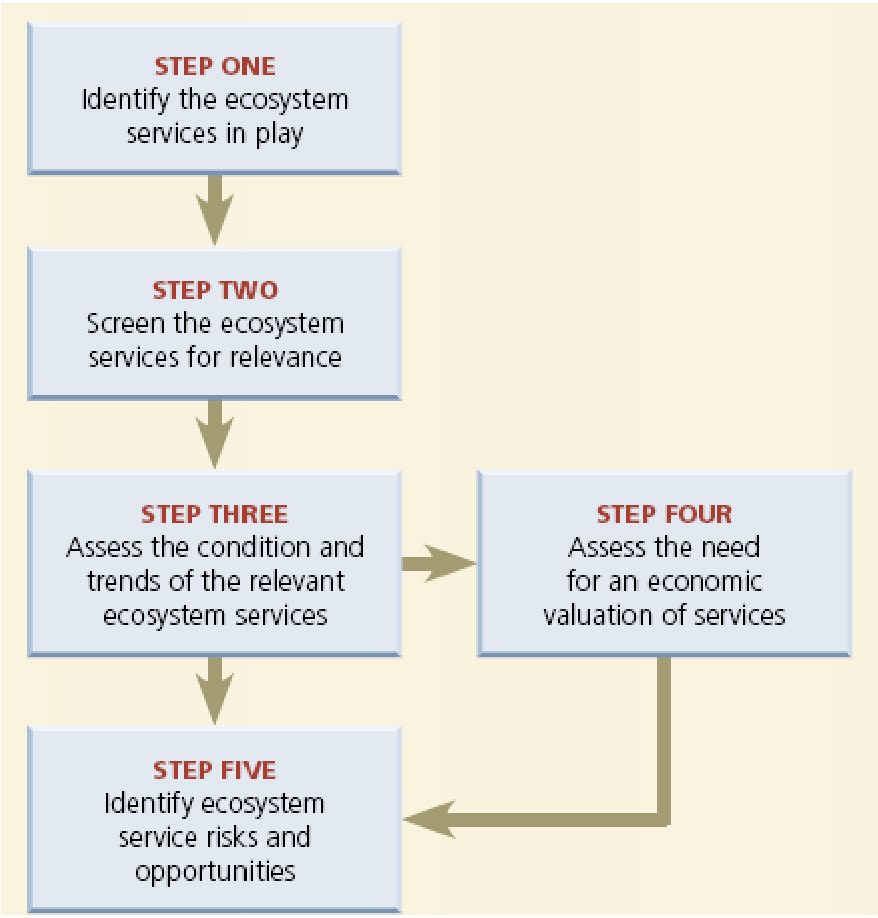

Figure 3: Steps in assessing risks and opportunities related to ecosystem services (based on Ranganathan et al., 2008). In practice, it will be necessary to move back and forth among the steps.

1. **Identify the ecosystem services in play; systematic dependency/impact analyses.**
   'A decision *depends* on an ecosystem service if the service serves as an input or if it enables, enhances or influences the conditions necessary for a successful outcome in relation to the decision.'
   'A decision *affects* an ecosystem service if actions associated with the decision alter the quantity or quality of a service.'
   To indentify ecosystem service dependencies and impacts, a list of ecosystem services is provided in the guide, as well as a list with common ecosystem services

and drivers by ecosystem type. It can be helpful to consider whether the decision will contribute to the drivers of ecosystem change. It is important to include indirect effects and impacts at different landscape levels and time frames.

2. **Screening ecosystem services (as selected in step 1) for relevance**
   The dependence of a decision on the ecosystem service is relevant if no cost-effective substitute for the service exists.
   The impact of a decision on an ecosystem service is relevant if the impact limits or enhances the ability of others to use or benefit from the service. The ‘others’ may be located at different spatial or temporal scales.

3. **Assess the condition and trends of the relevant ecosystem services**
   Useful questions to answer during this step include:
   - What are the conditions and trends of the selected ecosystem services?
   - What are the major drivers affecting the ecosystem services?
   - What thresholds or irreversible changes have been observed in the ecosystem services?

   Different methods exist to asses the condition and trends of ecosystem services. Table 2 shows the methods that were used by the Millennium Ecosystem Assessment. Since many ecosystem services can not be measured directly, indicators are often used. However, there are major gaps in monitoring systems for example for fresh water resources, groundwater and standard water quality which makes it difficult to develop indicators needed by decision-makers to assess state and trends (Millennium Ecosystem Assessment 2005b). The report on state and trends concerning ecosystems and their services (Millennium Ecosystem Assessment 2005b) provides indicators and references to other information sources about indicators.

Table 2: Methods used by the Millennium Assessment (table based on Ranganathan et al., 2008)

Method	Description	Sample uses	Example
Remote Sensing	Data obtained from satellite sensors or aerial photographs (LANDSAT, MODIS)	Assessment of large areas, land cover/land use, biodiversity	The India sub-global assessment team tracked deforestation using satellite imagery.
Geographic Information Systems	Software that spatially maps and analyzes digitized data (ArcGIS, ArcView, IDRISI)	Analysis of temporal changes in ecosystems; overlaying social and economic information with ecosystem information; correlating trends in ecosystem services with land use change	The Southern Africa sub-global assessment used GIS to analyze where human demand for water existed and where that service is supplied.
Inventories	Lists	Tally ecosystem services and natural resources	An assessment in the Mekong wetlands of Vietnam developed an inventory of all the ecosystem services that are important in the region (to people, the economy. and ecosystem functioning).
Ecological Models	Simplified mathematical expressions that represent the complex interactions between physical, biological, and socioeconomic elements of ecosystems (SWAT, IMAGE, IMPACT, WaterGAP, EcoPath, Ecosim)	Filling gaps in existing data; quantifying the effects of management decisions on the condition of ecosystem services; projecting long-term effects of changes in ecosystem condition; assessing the effects of individual drivers and scenarios on ecosystem condition and the supply of ecosystem services; exploring the links between elements in a system	The Western China sub-global assessment used the Agroecological Zoning model to estimate the carrying capacity of land (i.e., the maximum number of individuals that can be supported by ecosystem services in a unit area assuming sustainable development). The Southern Africa sub-global assessment used the PODIUM model to assess trade-offs between food and water provisioning services.
Participatory Approaches and Expert Opinion	Information supplied by stakeholder groups, scientific experts, workshops, traditional knowledge	Collection of knowledge not available in scientific literature; fills gaps in the literature; adds new perspectives, knowledge, and values to assessment	Assessments in Norway and Portugal made use of participatory ranking and scoring for the condition and trends of ecosystem services and biodiversity.

4. **Assess the need for an economic valuation of services**
   This assessment should be carried out for services that are valued in markets and those that are not. Sometimes it is more important to consider health or poverty impacts. However economic valuation can be valuable for:
   - communication about the value of ecosystem services by highlighting economic values to societal goals;

- cost-effectiveness of an investment;
- evaluating impacts of policies;
- creating markets for ecosystem services.

In Ranganathan et al. (2008), limitations of valuation and practical considerations are explained, as well as methods for valuation and some practical examples. Table 3 summarizes economic valuation methods. In Appendix 2 of Brouwer et al. (2003) most of these methods are described, including their advantages and disadvantages and references to literature. Contingent Valuation is carried out by opinion polls, For Travel Costs and Hedonic Pricing market data are being used (costs that people paid to travel to for example a nature park and differences in housing prices).

Chan et al. (2006) in their case study follow the approach of Davis et al. (2003) by avoiding the most problematic valuation methods like the contingent valuation and the question of a common currency for disparate preferences and principles.

Cowling et al. (2008) provide references on economic valuation of ecosystem services. It is emphasized that that nonmonetary values can also be used to valuate ecosystem services, for example cubic metres of water, jobs created and lives saved. Cowling et al. recommend that stakeholders are encouraged to reach consensus on assigning subjective values to ecosystem services and cite Starbuck: 'Acceptance by people is crucial, because knowledge is what people say it is'.

Danièle Perrot-Maître, during the Seminar on environmental services and financing for the protection and sustainable use of ecosystems Geneva, 10-11 October 2005 provides the following reasons to valuate ecosystem services:
- Understand how much an ecosystem contributes to economic activity or society;
- Understand what are the benefits and costs of an intervention that alters the ecosystem (conservation investment, development project, regulation or incentive) and make ecosystem goods and services comparable with other investments;
- How are costs and benefits of a change in ecosystem distributed?
- How to make conservation financially sustainable?

The presentation contains methods for valuation (box 1) and advantages and limitations of the methods are shown. A toolkit and other valuation products can be found on: http://www.waterandnature.org/value.

Brouwer et al. (2003) describe the assessment of benefits of water (policy) within the framework of cost-benefit analyses of water projects. For the cost-benefit analyses, monetary valuation of benefits is necessary. By expressing both priced and non-priced effects in monetary values, environmental changes will gain importance in decision making. Economic valuation will show that for environment and nature the same scarcity principle counts as in economics.

Monetary valuation or payment for ecosystem services are merely tools that help thinking and decision making (RUBICODE, 2008).

5. **Identify ecosystem service risks and opportunities**
   Questions that are relevant to answer:
   - Does the decision depend on ecosystem services that were previously unrecognized or in poorer conditions than previously known?
   - Could the goals of the decision be endangered because users are competing for

ecosystem services in limited supply? And if so, are cost-effective substitutes available?
- Are there unforeseen impacts of the decision on ecosystem services that others depend on for their well-being? Table 4 shows some examples of trade-off effects and box 2 gives an overview of tools for the analyses of trade-offs.

Table 3: Common economic valuation methods as described in the Millennium Ecosystem Assessment (after Ranganathan, 2008).

Method	Approach	Applications
Effect on productivity	Trace impact of change in ecosystem condition on the produced goods	Any impact that affects produced goods (e.g., declines in soil quality affecting agricultural production)
Cost of illness, human capital	Trace impact of change in ecosystem services on morbidity and mortality	Any impact that affects health (e.g., air or water pollution)
Replacement cost	Use cost of replacing the lost good or service	Any loss of goods or services (e.g., previously clean water that now has to be purified in a plant; shoreline protection once provided by mangroves or reefs)
Travel cost	Derive demand curve from data on actual travel costs to estimate recreational use value	Recreation, tourism
Hedonic prices	Extract effect of environmental factors on price of goods that include those factors	Air quality, scenic beauty, cultural benefits (e.g., the higher market value of waterfront property, or houses next to green spaces)
Avoided damages	Model comparison of the damages avoided by having protection against natural disaster events such as earthquakes, hurricanes, and flooding	Shoreline protection services, erosion reduction, etc.
Contingent valuation	Ask respondents directly their willingness to pay for a specified service	Any service (e.g., willingness to pay to keep a local forest intact); can be used to estimate consumer surplus (the benefit above actual expenditure), social value, and existence value
Choice modeling	Ask respondents to choose their preferred option from a set of alternatives with particular attributes	Any service
Benefits transfer	Use results obtained in one context in a different context (e.g., estimating the value of one forest using the calculated economic value of a different forest of a similar size and type)	Any service for which suitable comparison studies are available

Methods for valuation of ecosystem services

- **Assigning market prices** (people's actual willingness to pay);
- **Productivity method** (the economic contribution of ecosystems to other production and consumption activities);
- **Travel costs** (how much people spend to use or benefit from using ecosystems for recreational purposes / people's implied willingness to pay);
- **Replacement costs** (the costs of replacing an environmental good or service; a minimum estimate of money saved);
- **Costs of mitigating ecosystem degradation** (the costs of mitigating or averting the effects of the loss of an environmental good or service; a minimum estimate of money saved);
- **Damage costs avoided** (the costs avoided from the destruction of ecosystem; a minimum estimate of money saved);
- **Contingent valuation** (the amount people would pay/accept under the theoretical condition that biodiversity could be bought and sold; people's stated willingness to pay);
- **Hedonic pricing** (difference in - property or wage - prices that can be ascribed to the existence or level of nearby environmental goods and services) ;
- **Conjoint Analysis** (obtains information on preferences between various alternatives of environmental goods and services, at different price or cost);
- **Choice Experiments** (present a series of alternative resource or use options, each of which are defined by various attributes including price).

Box 1: Methods for the valuation of ecosystem services (Perrot-Maître, 2005)

Table 4: Examples of ecosystem services trade-offs, based on Ranganathan et al., 2008. For references, see Ranganathan et al.

Decision	Goal	Example winners	Ecosystem services decreased	Example losers
Increasing one service at the expense of other services				
Draining wetlands for farming	Increase crops, livestock	Farmers, consumers	Natural hazard regulation, water filtration and treatment	Local communities including farmers and some downstream users of freshwater
Increasing fertilizer application	Increase crops	Farmers, consumers	Fisheries, tourism (as a result of dead zones created by excessive nutrients)	Fisheries industry, coastal communities, tourism operators
Converting forest to agriculture	Increase timber (temporarily), crops, livestock, and biofuels	Logging companies, farmers, consumers	Climate and water regulation, erosion control, timber, cultural services	Local communities, global community (from climate change), local cultures
Converting ecosystems and their services into built assets				
Coastal development	Increase capital assets, create jobs	Local economy, government, developers	Natural hazard regulation, fisheries (as a result of removal of mangrove forests or wetlands)	Coastal communities, fisheries industry (local and foreign), increased risks to coastal businesses
Residential development replacing forests, agriculture or wetlands	Increase capital assets, create jobs	Local economy, government, developers, home buyers	Ecosystem services associated with removed ecosystems	Local communities, original property owners and downstream communities
Competition among different users for limited services				
Increased production of biofuel	Reduce dependency on foreign energy	Energy consumers, farmers, government	Use of crops for biofuels instead of food	Consumers (rising food prices), livestock industry
Increased water use in upstream communities	Develop upstream areas	Upstream communities, industries	Water downstream	Downstream communities, industries

Tools for analyzing trade-offs

Poverty and ecosystem service mapping overlays geo-referenced statistical information on poverty with spatial data on ecosystem services. The resulting maps can highlight important relationships, such as how the location of poverty compares with the distribution of services; which areas provide critically important services to the poor; who has access to natural resources; who benefits; and who bears the cost of changes to ecosystem services. Such overlays do not show causality, but suggest focus for further analysis (WRI et al. 2007).

Economic valuation assigns an economic value to ecosystem services that do not have a value in the market place, such as regulating and certain cultural services. The resulting information can draw attention to the value of ecosystem services that might otherwise be ignored when making decisions that affect ecosystems. In general, economic valuation is effective in persuading decision makers of the value of ecosystem services by highlighting their economic contributions to societal goals; comparing the costs and benefits of ecosystem service protection versus engineering alternatives; and building markets for ecosystem services, such as global carbon markets or stewardship incentive programs for farmers.

Alternatives to Slash and Burn (ASB) Matrix is a tool to assess the multi-scale impacts of alternative land uses at the margins of tropical forests. Different land uses are scored against criteria that reflect the objectives of different interest or use groups. The ASB matrix can be adapted for other ecosystems, but should always comprise indicators for a range of ecosystem services at different scales. This might include indicators for one or two regulating services that have global additive effects (carbon storage), indicators of national significance (development indices), and indicators of significance to local populations (agronomic sustainability and the availability of credit, markets, and technology) (Tomich et al. 2005).

Action Impact Matrix assesses the two-way interactions between development goals and ecosystems by exploring the effects of development goals on ecosystems as well as the effects of ecosystems on development. It can be used to determine economic, environmental, and social priorities that facilitate management and restoration of ecosystem services. The tool is best used as part of a participative process (Munasinghe 2007).

Irreplaceability mapping can be used to assess trade-offs between food services and biodiversity. Food production is divided into two types: calorie production (cereal) and protein (meat). Based on targets for calories, protein, and biodiversity, irreplaceability values are assigned to map grid cells. In the Gariep Basin in Southern Africa, these ranged from 0 (many options in other locations to achieve goals) to 1 (totally irreplaceable). While no site was found to be irreplaceable for protein and calorie goals, several sites were irreplaceable for biodiversity. This information supports a land use plan that guides protection of sites with a high degree of irreplaceable biodiversity, while steering grazing or cultivation to other sites (MA 2005b; Bohensky et al. 2004).

Box 2: Tools for analysing trade-offs, based on Ranganathan et al., 2008. For references, see Ranganathan et al..

3.3.3 RUBICODE

During the international Workshop at Salzau Castle, northern Germany May 13 -15th, 2008 about ecosystem services, Pam Berry of the Environmental change institute of the University of Oxford, presented the RUBICODE project. It provides a framework for assessment of ecosystem services (figure 4).

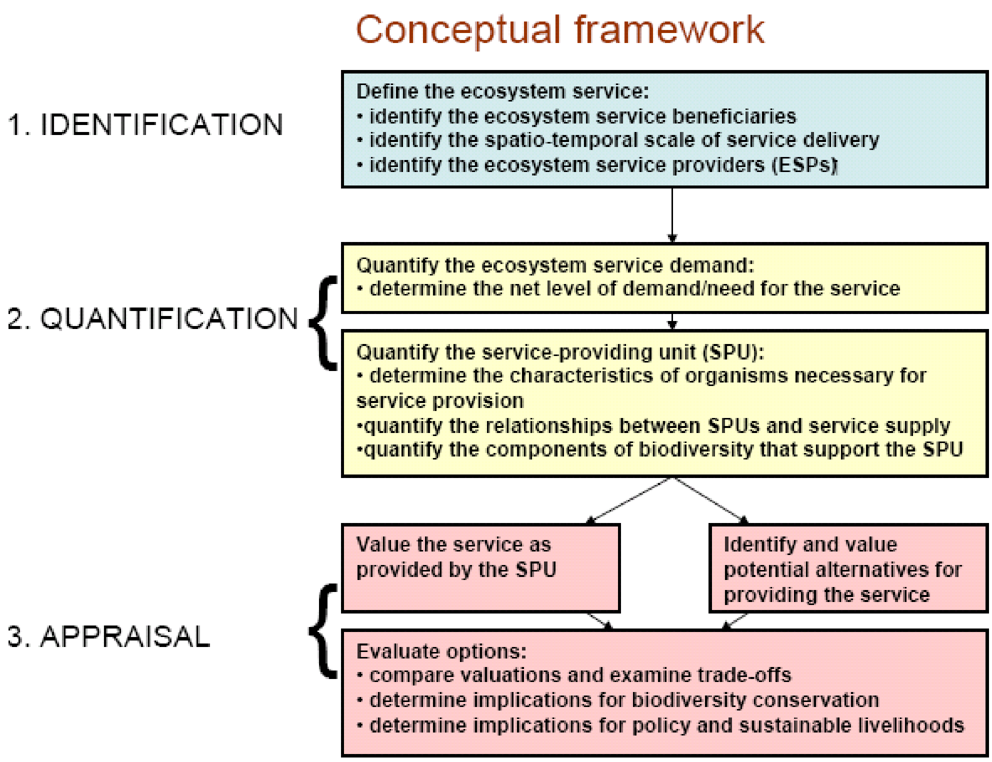

Figure 4: RUBICODE provides a conceptual framework for the assessment of ecosystem services (from workshop presentation of Berry et al., 2008)

3.4 Case study: Identifying ecosystem services and their relevance in a marine ecosystem

Beaumont et al. (2007) identified marine ecosystem services for seven case study sites. During a two-day workshop with twenty one experts from different disciplines the goods and services that are provided specifically by marine biodiversity were identified and defined. The goods and services were categorized in a similar way as the Millennium Assessment categories. For each case study site, an inventory was made to assess whether the specific services are present/not present/not known and whether monetary value is available for the services. Quantitative monetary value was known for some services, especially for food, but the figures tended to underestimate the total benefit of the service because revenue and employment were not included in the value.

The case studies showed that most definitions of goods and services were comprehensive and workable, but for some services, confusion existed about the precise meaning of the services. It should be kept in mind that the benefits or the system depends on the ecosystem as a whole and that the different goods and services are intrinsically related. When the data for different services is available in different quantities or not available at all for some services, the assessment is likely to be biased towards the services for which the most information is available. There is a risk that services for which more data is available, seem to be more important then the ones that are less well monitored. Especially ecosystem services tend to be undervalued compared to the better understood and clear value of ecosystem goods. The identification of ecosystem sources and consumers should be carried out for different levels, for example locally and globally and import and export of services should be considered in order to assess flows of ecosystem services (Daily, 2000).

3.5 Valuation case study; an ecosystem services approach to assess economic gain and losses of a policy

Figure 5 shows how ecosystem services in a wetland were classified and valued in a study of Luisetti et al. (2008).

The report of the case study describes how monetary valuation was established through market prices and peoples willingness to pay (WTP). In order to determine WTP, a choice experiment was carried out (see box 3).

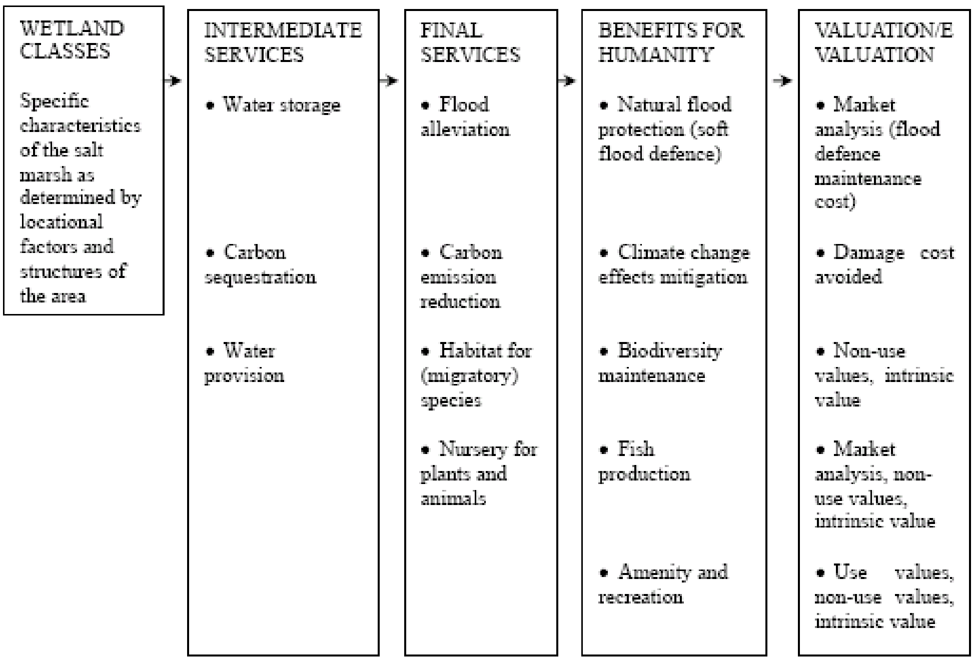

Figure 5: Classification of wetland services in case study and valuation methods (Luisetti et al., 2008).

Assessing willingness to pay: a choice experiment

Aim: finding a value of wetlands (salt marsh), expressed by people's willingness to pay (WTP).

1. Through group investigations with policy makers, stakeholders, public members a set of attributes that affect WTP was identified:
   - AREA: the area of new salt-marshes to be created
   - BIRDS: the number of protected species
   - DISTANCE from respondent's home to the nearest site
   - ACCESS: binary variable to assign whether the salt-marsh will be open-access or not
   - TAX: increase in respondent's annual local tax to pay for the option.
2. Respondents answered eight questions, each consisting of two options: status quo/alternative option(salt marsh) in which the attributes values are variable.

In their report, Luisetti et al. describe in more detail how the survey was conducted and which statistical analysis of the results were used.

Box 3: Case study example (summary) of the design of a choice experiment, carried out in the cost-benefit analyses for the creation of wetland as a new coastal protection scheme (based on Luisetti et al., 2008).

3.6 Assessment of ecosystem service providers (ESP)

Kremen and Ostfeld (2005) describe two methods for the assessment of ecosystem services providers. The methods can be used to predict functional response to changing community composition (Kremen, 2005).

3.6.1 Functional inventory

Identify key ecosystem service providers (EPS) in a landscape at an ecological level that is suitable for the service. It is possible form there to calculate the service provided by a community or ecosystem under different management scenarios (Kremen and Ostfeld, 2005). Based on the functional inventory, it is possible to:

- Identify key species for management (Power et al., 1996);
- Correlate functional traits to each other, including (Larsen et al., 2005);
- Assess the level of redundancy in the system (Memmott et al., 2004);
- Analyse interaction effects that affect function (Cardinale et al., 2003);
- Prediction of the functional effects of alternative management or disturbance scenarios (Balvanera et al., 2005).

Examples of such inventories can be found in Kremen, 2005.

3.6.2 Functional attribute diversity

This method is complementary to the functional inventory. A guild or community that provides a service is characterised by the 'ecological distance' that separates each ESP within the community (Walker et al., 1999; Petchey and Gaston, 2002). Ecological distances can be based on different attributes of species that are likely result in functional differences, for example root depth for plants. With this method, the community can be divided into groups that are functional similar, which makes it possible to predict functional resilience with species loss (Walker et al, 1999) or identify guilds that are complementary to each other. The relationship between aggregate function and the contribution of each ESP in the community is not clear.

! ESP is being used in literature as abbreviation for both *Ecosystem Service Provider* and *Ecosystem Services Profile* !

3.6.3 Assessment of how environmental factors that affect the magnitude and variability of ecosystem services vary across the landscape

Two approaches exist:

- Focus on the abundance of an important ecosystem service provider (ESP);
- Focus on the function as a whole; irrespective of fluctuations in individual ESPs.

If the functional inventory (see §3.4.1) shows that individual ESPs are highly uneven in their functional contributions, a focus on ESP should be applied. If little differences between ESPs exist in their functional contribution, then a focus on the function is appropriate. In case interactions among ESPs are expected to influence the function strongly, the function-centred approach can be practical, or maybe both approaches should be used (Kremen, 2005).

3.7 Thresholds and targets

The LOICZ-Basins approach uses three approaches to identify targets and indicators for coastal processes (Crossland et al., 2005):

- The most simple “policy-oriented” approach is taking the critical values for a parameter as load which has been agreed upon in international treaties;
- The “ecosystem” approach uses historical data on the response of the system to changing loads and identifies indicators. This approach will incorporate an attempt to discriminate between natural state and an anthropogenic altered state;
- The “regional management” approach is based on consultation with local authorities and identifies their criteria for indicators or critical loads. It is envisaged that this encompasses the incorporation of other indicators than those based on scientific arguments alone.

3.8 Indicators for system ecological quality

Brouwer et al. (2003) describe two types of indicators:

- Quality indicators: plants or animal species that are desired to be present in a system because their presence means that the system meets goals for the system. For assessment, information about their presence and eventually their quantity or trait is required.
- Pressure indicators: are objects that are undesired to be present because they indicate a pressure on the system. For assessment, information about their presence and eventually their quantity or trait is required.

3.9 Objectives for sustainable use of (agricultural) land from the soil viewpoint

TCB has set objectives for the soil quality parameters organic matter, nutrients, other substances, functional biodiversity and physical soil quality. TCB (2005) suggests to adopt minimal and desired quality of those parameters. A central role is given to the principle of standstill and ALARA. ALARA admits that emissions to the environment are inevitable and that emissions are stopped at a level that is enabled by technology.

When discussing sustainability, the time frame of interest needs to be defined. The timescale over which an ecosystem undergoes major impacts is about 10 to 100 years, while for farmers and national and regional economies much shorter time frames are relevant. With regard to spatial scales, TCB distinguishes between local scale (the farm) and the environment (beyond the farm, catchment). Differentiation should be made between interests of local land users (farmers) and of society as a whole when regarding duty of care for the land.

For sustainable agricultural land use, six objectives are proposed by TCB:

1. Use of an ecological function should not lead to its exhaustion or destruction locally;
2. When one ecological function is used, the others should as far as possible remain intact locally;
3. The recovery capacity of the soil remains unimpaired; this means that the functions temporarily absent, possibly for a protracted period, must be able to return. This requires that all the organisms important for the soil ecosystem must be kept available;
4. The rate of recovery should be commensurate with the rate at which the use is being changed. A recovery period of centuries is too long where the changes took place over 30 years.
5. All ecological functions must have the requisite space; this limits the scale on which use can occur.
6. The use of the soil ecosystem must not harm the environment, such as the groundwater and adjacent ecosystems.

3.10 Exploring future trends in ecosystem services: scenario planning

'Scenarios are stories about the future, told as a set of "plausible alternative futures" about what might happen under particular assumptions' (Ranganathan et al., 2008). The use of scenarios can help decision-makers to foresee unintended consequences of policies. Looking into the future in a structured way can help to choose the policies that are most likely to achieve goals and to alert decision-makers to possible thresholds.

Within the framework of the Millennium Assessment, four scenarios were developed to assess future changes in world ecosystems and services over the next 50 years and beyond, to assess the consequences for human well-being and to inform decision-makers about these potential developments and possible response strategies and policies to adapt to or mitigate the changes (Millennium Ecosystem Assessment, 2005c). The report describes the state of the art for forecasting changes in land use and land cover, impact of land cover change on local and regional climates, change in food demand and supply, change in biodiversity and extinction, changes in phosphorus cycling and impacts of water quality, changes in nitrogen cycle and their consequences, fish populations and harvest, impacts on coastal ecosystems, impacts on human health and integrated assessment models. The report also provides a description of drivers of change in ecosystem condition and services.

The scenario building process has three primary benefits:

1. Participants can gain better understanding of interactions, assumptions about the future and ecosystem services trade-offs;

2. A platform is created for communication;
3. Building trust and cooperation and resolving conflicts among stakeholder groups in relation to ecosystem services and the choice of policies for sustaining ecosystem services.

3.11 Assessment of ecosystem services by mapping

In an atlas of ecosystems and human well-being for Kenya (WRI, 2007), WRI describes the assessment of ecosystem services at a national scale in Kenya. For the assessment of water based ecosystem services, for example, maps have been constructed to show the main uses and users of water in Kenya: drinking, industrial, and other uses in urban areas; energy generation; crop production; livestock production; and wildlife demand. Comparison of maps of supply (water sources) and demand and poverty and human well-being, provides a view of the relevance of ecosystem services related to water and their state.

Overlaying maps can provide indicators of ecosystem services. For example, if surface water seems to be the main source for drinking water in an area, surface water can be used as indicator for the ecosystem service ‘drinking water’.

The maps can provide insight of spatial relationships between ecosystem services that can point out competition or synergies.

3.12 Mapping ecosystem service values

Troy and Wilson (2006) carried out three case studies to assess the challenges and opportunities in linking GIS and ecosystem values transfer. The results show that variability is related to initiations in the available spatial data and economic valuations studies, differences between site characteristics, spatial and temporal scales and management objectives.

3.13 Participatory approaches

Participatory approaches are considered the most promising data collection methods by the Millennium Assessment. Especially Participatory Rural Appraisal (PRA) is mentioned as valuable method. ‘PRA is an alternative to unstructured visits to communities, which may be biased toward more accessible areas, and to costly, time-consuming questionnaire surveys’ (Millennium Ecosystem Assessment, 2005b). With PRA, research activities such as interviewing, transects, mapping, measuring, analysis, and planning are done jointly with local people over longer time periods. Limitations of participatory methods are 1) they produce certain types of information, which can be brief and superficial; 2) the information collected can be subjective; 3) possible unequal power relation among participants and between participants and researchers. Besides PRA, the Millennium Ecosystem Assessment used other methods as workshops, semi-structured interviews, forum theatre, free hand and GIS mapping, pie charts, trend lines, timelines, ranking, Venn diagrams, problem trees, pyramids, role playing, and seasonal calendars. The report on current state and trends (Millennium Ecosystem Assessment, 2005b) provides references to these methods.

3.14 Ecosystem Service Profile (ESP)

Paetzold et al. (2008) present the concept of a Ecosystem Services Profile (ESP), see figure 6. “ESP is the match between the societal demands for a set of ecosystem services and the realized sustainable provision of those services, in terms of both quality and quantity”.

After selection of the most relevant ecosystem services in a management context based on stakeholder participation and legislation, demand and provision of the services are compared.

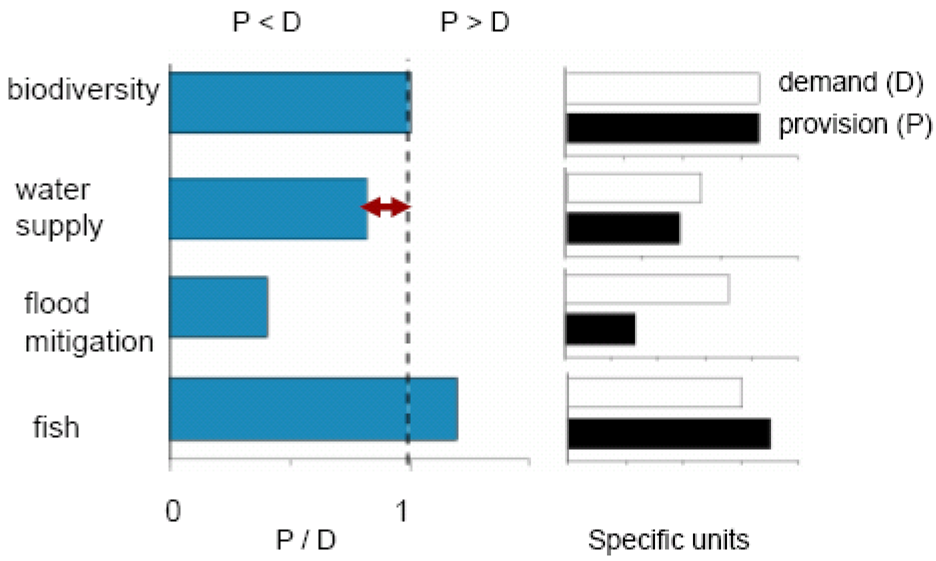

Figure 6: Ecosystem Service Profile (ESP), comparing demand and provision (based on Paetzold et al., 2008).

4 How to prioritise threats/risks to ecosystem services at a basin scale?

4.1 Effect of scales: time, spatial, social

The scale at which the importance of (changes in) ecosystem services is assessed influences the problem definition and the assessment results (Millennium Ecosystem Assessment, 2005a). Factors at different scales have influence on other scales as well and there are inequities in the distribution of costs and benefits of ecosystem services between places and time. As a consequence of those different scales, trade-offs are difficult to evaluate. The incorporation of several scales in the assessment provides results that would otherwise be missed and prevents inaccurate conclusions.

<u>Spatial</u>
In some cases, local assessment showed worse or better conditions than was expected from global assessment. Threats observed at a large scale may be mitigated by innovative responses at a smaller scale. On the other hand, local actors can tend to neglect treats that are beyond their reach of immediate influence.

Changes in one region can lead to higher or lower pressures on ecosystem services in another. Increase of population growth in urban areas for example increases pressures on services in rural areas.

<u>Temporal</u>
The overuse of services today can lead to lower capacity of ecosystem services in the future and the increased use of provisioning services can lead to changes over much longer time scales in supporting services. For some drivers, impacts can be minimized or halted within a short period of time, while for others long time frames are needed In the process of species extinction as a result of habitat loss, significant inertia occurs.

<u>Social</u>
Stakeholders at different scales perceive different values in ecosystem services, which is important to acknowledge in the development of policies. Including multiple knowledge systems (like non-scientists) increases the relevance, credibility and legitimacy of the results for some users. The assessment needs to be adapted to the specific needs and characteristics of the groups incorporated in the assessment.

More details about multiscale assessment can be found in the working group reports that are listed in Appendix E of the report ‘Ecosystems an human well-being’ (Millennium Ecosystem Assessment, 2005a).

4.2 Propagation principle

Riverbasin-wide management should only have to deal with pressures that are propagated in the system and have negative effects on other compartments. Non propagating threats should be dealt with at the local scale (Salomons, 2008).

If the impairment of ecosystem services is due to present propagation, then priority is on the sources (the source is the result of pressures on the system). If the impairment of ecosystem services is due to past propagation it might have a low priority. The question then arises whether natural processes do lead to a recovery or active intervention is needed.

4.3 Setting priorities for protecting biodiversity and ecosystem services: GIS-based case study

Chan et al. (2006) assessed the opportunities and trade-offs for aligning of goals for biodiversity conservation and ecosystem services protection in a GIS-based study. During a study in the Central Coast Region of California, USA, six ecosystem services were considered (carbon storage, flood control, forage production, outdoor recreation, crop pollination, water provision). For four different conservation network designs, the degree to which biodiversity and the flow of the six services were protected have been compared. These three issues were addressed:
- For each land parcel, the provision of each ecosystem service was determined;
- Spatial associations between the lands required for protecting biodiversity and supplying the ecosystem services;
- The amount of each ecosystem service provided by a network of lands that is prioritized for biodiversity, compared to networks designed for multiple services.

Terrestrial biodiversity and the ecosystem services were characterized and mapped to develop networks of conservation areas for each service. The networks were assembled by using MARXAN. By using this algorithm, priority conservation areas that collectively form networks for biodiversity and ecosystem services can be selected and a measure of the irreplaceability of a planning unit can be gathered as well. The spatial correlation between biodiversity and the provision of ecosystem services was assessed by two methods: service correlation and network overlap. The ecosystem services forage production and crop pollination seemed to correlate in a negative way with biodiversity.

To analyse trade-offs of the incorporation of ecosystem services in a conservation plan, four types of networks were assessed, based on protection of:
- Biodiversity only (‘Biodiversity’);
- Ecosystem services (‘Non-biodiversity’);
- Biodiversity and ecosystem services (‘All’);
- Biodiversity and four ecosystem services (‘Strategic’). Forage production and crop pollination excluded because of their negative correlation with biodiversity.

For each network, the proportion of ecosystem services targets and biodiversity targets achieved was assessed (figure 7).

To analyse the benefits, MARXAN-runs were used to calculate the amount of the additional land that is needed to meet individual ecosystem services targets (assuming that biodiversity is already being protected) when using the four different networks. Next, the costs of this additional land and the benefits of it for biodiversity were determined (table 5).

The spatial association between ecosystem services and between ecosystem services and biodiversity was found to be low. However, figure 4 shows that the biodiversity network would protects a considerable amount of ecosystem services provision. Incorporating protecting ecosystem services into the network, leads to higher achievement of ecosystem services goals and lower achievement of biodiversity conservation, depending of the types of ecosystem services involved.

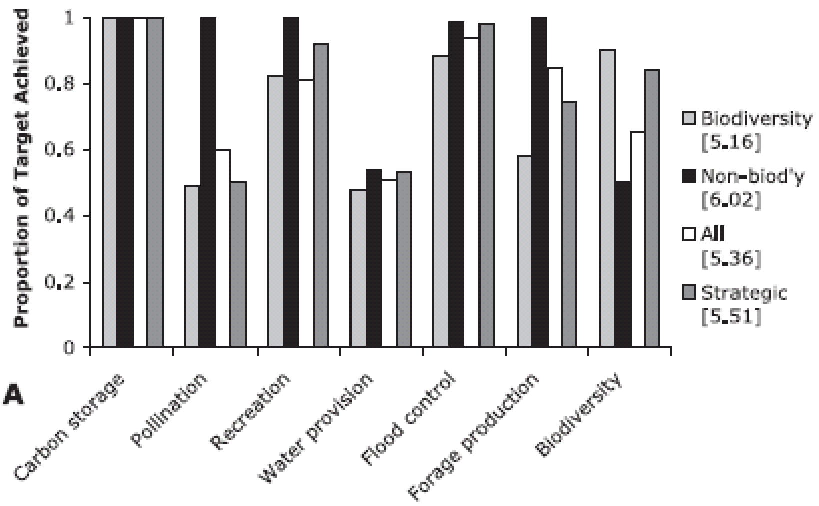

Figure 7: The achievements of targets for ecosystem services and biodiversity by four different networks based on conservation of biodiversity, ecosystem services or both (based on Chan et al., 2006)

Table 5: Results form adding individual ecosystem service targets to the existing biodiversity network, from Chan et al., 2006)

Service	Needed Service Contribution	Additional Land	Added Cost	Biodiversity Benefit	Biodiversity Benefit Ratio
Carbon	0	0	0	0	n/a
Pollination	51%	10%	10%	0.6%	0.06
Recreation	18%	9%	13%	1.5%	0.11
Water	52%	21%	21%	5.4%	0.26
Flood	11%	12%	12%	1.3%	0.11
Forage	42%	27%	20%	1.7%	0.08

The following are displayed: the percent of each ecosystem service's targets left unmet by biodiversity network; the additional land required to meet these targets; the additional constraint (from the service's suitability); the added benefit to biodiversity (already at 90.2%, as measured by rarity-weighted richness index; see Methods); and the ratio of this benefit to the added constraint. The benefits of flood control to biodiversity as a whole are likely to be enhanced considerably relative to these values by inclusion of aquatic biodiversity features.
n/a, not applicable.
DOI: 10.1371/journal.pbio.0040379.t002

5 Measures to reduce or mitigate threats/risks to ecosystem services

5.1 Selecting measures

A broad palet of measures to mitigate problems or to deal with inevetable changes is available. Measures are practical if they are (RISKBASE-presentation Jos Brils):

- Technically feasible;
- Cost-effective (work with nature …);
- Social/political acceptable (sustainable, at least in 2012 at 2nd RBMP phase …);
- Showing clear cause-response relationships.

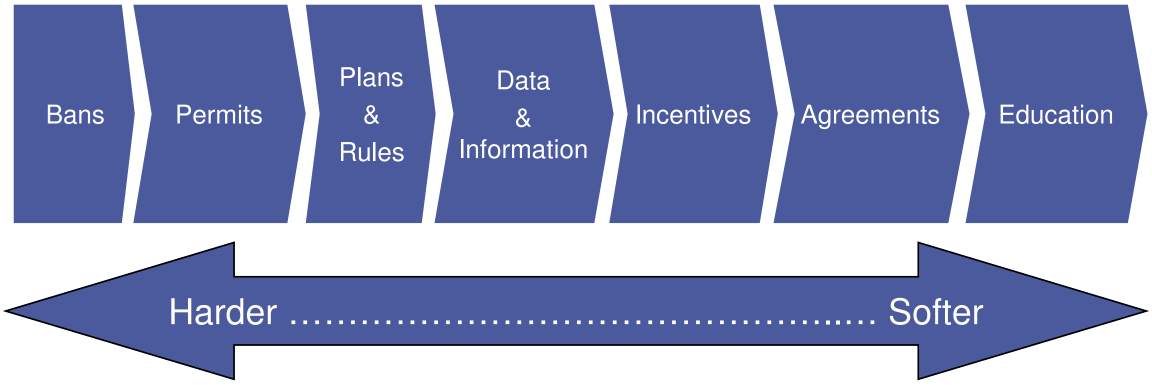

Figure 8: The spectrum of measures. (Damian Crilly, UK EA, RISKBASE WP5 WS1, 2007).

Measures can be ‘hard’, like bans or permits or ‘soft’ such as education or agreements (figure 8).
Several methods exist to assess measures. Morselt and Nijwening (2006) describe a toolbox of micro-economic instruments that are helpful during the development of policy and measures: force field analyses (attitude of and relations between stakeholders), impact assessment, cost-benefit analyses, cost-effectiveness analyses, business case (financial feasibility) and market scan (to assess whether market-involvement during development and planning phase is desired).

5.2 Categories of responses

The Millennium Ecosystem Assessment - MA - (2005a) recognizes five categories of responses to enable sustainable ecosystem management and thereby ensuring the sustainability of ecosystem services. Appendix B of the MA-report lists assessed responses and their effectiveness. MA considered a response effective when assessment indicated that it enhanced a particular ecosystem service and contributed to human well-being without significantly harm other ecosystem services or other groups of people. Responses are considered promising if they are likely to success but don’t have a long track record to assess.

The categories responses are described in section 5.2.1 – 5.2.5. Information of the MA is complemented by other information sources. More details about promising interventions concerning ecosystem services can be found in the working group reports that are listed in

Appendix E of the report 'Ecosystems an human well-being' (Millennium Ecosystem Assessment, 2005a).

5.2.1 Institutions and Governance

Existing institutions may have mandate to address degradation of ecosystem services but they cannot always enable cooperation across sectors and coordinated responses at multiple scales. Therefore, changes of institutions or new institutions may be necessary. Promising instruments include (Millennium Ecosystem Assessment, 2005a):

- Integrate ecosystem management with other sectors. The most important decisions affecting ecosystems are often made by parties that are not involved with ecosystem protection.
- Increase coordination among multilateral (environmental) agreements and institutions.
- Involvement of stakeholders in decision making leads to institutions and instruments that are more likely to be effective. Public participation also leads to better understanding of impacts and vulnerability, costs and benefits of trade-offs, response actions and increases accountability.
- Ecosystem management problems have been exacerbated by both overly centralized and overly decentralized decision-making. This can be prevented by development of institutions that carry out decision-making based on effective coordination across scales and management needs.
- Development of strong institutions that regulate interaction between markets and ecosystems.
- Develop institutional frameworks that promote a shift from highly sectoral resource management to integrated approaches. Since in most countries separate ministries are in charge of different aspects of ecosystems and drivers of change, there is seldom political will to develop effective ecosystem management strategies.

5.2.2 Economics and Incentives

Economic and financial measures are powerful instruments to regulate the use of ecosystem services. Many ecosystem services are not traded in markets and people are not compensated for providing services or sanctioned for reducing them. The Millennium Ecosystem Assessment (2005a) describes the following promising interventions:

- Resource tax against overexploitation.
- Subsidies that promote overuse of ecosystem services should be eliminated. For example production subsidies in the agricultural sector lead to increased food production and promotes excessive use of water, fertilizers an pesticides.
- Creation of markets for ecosystem services that have been treated as free resource will increase efficiency of the use of the service. This intervention can however have harmful effects on particular groups who may be unevenly be affected by this measure.
- Payment of ecosystem services (PES) can for example stimulate land owners to produce ecosystem services like the sequestration of carbon or biodiversity. Another mechanism is biodiversity offsets which means that perpetrators of negative effects on biodiversity as compensation pay for conservation practices.
- Mechanisms to enable consumer pressure in markets, such as certification schemes.

5.2.2.1 Economic valuation of ecosystem services and economic tools

The Economics of Ecosystems and Biodiversity (TEEB) initiative aims 'to promote a better understanding of the true economic value of ecosystem services and to offer economic tools that take proper account of this value'. Better understanding of ecosystem (services) economics will support the creation of cash flows for protection of ecosystem services, gain political support for protected areas, improve policy making and improve governance structures.

In Phase I of TEEB, the huge significance of ecosystems and biodiversity and the threats to human welfare if no action is taken to reverse current damage and losses is demonstrated (TEEB, 2008). Phase II will show how to use this knowledge for the development of the right tools and policies. During Phase I some good policies were already observed and the four main conclusion that can be drawn from those examples are:

1. Rethink today's subsidies to reflect tomorrow's priorities

Method's that were proven to be promising are:

- The removal or change of subsidies, for example the agricultural subsidies in the USA and EU;
- Replacement of subsidies by private resources to sustain financial flows for certain land use practices, for example the landscape auction in the Netherlands, where people pay for conservation of a specific element of a landscape.

2. Reward unrecognised benefits, penalize uncaptured costs

- This can be done by policies and by encouragement of appropriate markets, for example by payment for ecosystem services.
- Another measure is the principle 'polluter pays' which implies that the polluter pays for damage caused to the ecosystem services by bearing clean-up or restoration costs or by paying fines.
- The creation of new 'compliance markets' that reward ecosystem services and biodiversity. Governments can help to solve difficulties in such markets by providing an appropriate institutional framework. An example of such a market is the EU-ETS (a trading scheme for carbon credits).
- Several financial products and mechanisms exist to deal with liability, such as environmental credits, which can be used to offset a companies or person's negative impacts on the environment. The TEEB-report provides some references for literature about his subject.
- If risks to a business of losing ecosystem services are high enough, the business will be willing to invest in ecosystem management. An examples of this is that insurance firms and shipping companies finance reforestation along the Panama Canal because floods, erratic water supply and heavy silting are imposing increasing problems to their business. Another example is the Vittel mineral water company that pays farmers in the catchment to make their practices more sustainable because Vittel is concerned about nitrate contamination.

3. Share the benefits of conservation

Local communities can bear costs without receiving benefits from conservation. This mismatch can be corrected by sharing revenues, for example from tourism in protected areas, or by tax transfers between local, regional and central governments. In Europe, intergovernmental tax transfers to communities exist for the conservation network Natura 2000 (that is related to the EU Birds and Habitat Directives).

4. Measure what you manage

National accounts are based on financial transactions and as a result, they are not accounting for nature. During the conference Beyond GDP conference in November 2007, consensus was made that we need more than GDP as a measure of what society values. The target of GDP growth cannot solve many of today's problems. Not only governments, but corporations as well recognise that corporate success needs to be redefined. The Global reporting Initiative (GRI) provides guidelines for sustainability reporting. Consumers can incorporate sustainability factors in their choices when purchasing goods, especially food, only when the ecological footprint is clear.

5.2.2.2 Experiences with payment for ecosystem services (PES)

Practical WWF examples of projects that promoted payments for ecosystem services (PES)
In the comments on the EU White Paper on adaptation to climate change, WWF presents projects in which the organisation used ecosystem services and payment schemes. Some examples include:

- In the Tisza catchment (tributary of the Danube river), farmers replace native plants on floodplains and harvest them sustainably. A local power company buys the biomass as source of green energy.
- A Water Fund collects payments from local industries and pays upstream communities for watershed conservation activities that will result in better water availability and water quality for downstream users.

The development of PES schemes requires three steps (WWF at http://www.worldwildlife.org/science/projects/ecosystemserv/item1987.html):
1. An assessment of the range of ecosystem services that flow from a particular area, and who they benefit.
2. An estimate of the economic value of these benefits to the different groups of people.
3. A policy, subsidy, or market to capture this value and reward landowners for conserving the source of the ecosystem services.

Countries experiences with payment for ecosystem services
On the website
http://www.unece.org/env/water/meetings/payment_ecosystems/seminar.htm#pres
of the Convention on Protection and Use of Transboundary Watercourses and International Lakes experiences with payment for ecosystem services from different countries within and outside of Europe can be found.

For example in Estonia, environmental fees have to be paid for the right to use all the main natural resources belonging to the state and for releasing pollutants and waste into the environment. To stimulate environmentally friendly land-use practices, compensation systems exist.

In the report of the Dutch Ministry of Agriculture, Nature and Food Quality, three preconditions for payment for ecosystem services (PES) are given:

2. Ecosystem services should be considered valuable or indispensible;
3. Ecosystem services should be used by consumers;
4. Ecosystem services should be more or less owned (managed) by providers.

The report describes instruments to determine the impact of a project to ecosystem services. Some of those instruments are obligatory for developers and/or decision makers.

More
Jack et al. (2008) provide more lessons learned for PES from previous experience with incentive based mechanisms.

On the internet, see http://www.fao.org/docrep/006/y5305b/y5305b01.htm for information on payment schemes for environmental services in watersheds.

5.2.3 Social and Behavioural responses

Promising interventions include measures to reduce consumption of unsustainably managed ecosystem services (Millennium Ecosystem Assessment, 2005a):

- Communication and education actions by governments or educational institutions can for example raise public awareness.
- Industry can take action by improving product labelling or the use of certified sustainable resources.
- Empowerment of social groups, like women, indigenous people or young persons, that particularly depend on ecosystem services is also a promising response to the degradation of ecosystem services.

5.2.4 Technological responses

Technologies can increase the efficiency of resources use or reduce the impacts of drivers. However, since these technologies can have negative impact as well, they need to be assessed very carefully before implementation. For the reduction of nutrient pollution, technologies already exist, but for these tools to be applied a broad scale, new policies are needed. Examples of promising response are (Millennium Ecosystem Assessment, 2005a):

- Promoting technologies that increase crop yields without any harmful impacts related to water, nutrient and pesticide use.
- Restoration of ecosystem services by restoring ecosystems. However, not all ecosystem services of the original ecosystem can be restored.
- Promoting technologies that increase energy efficiency and reduce greenhouse gasses. To reduce emissions fuel switching, increased power plant efficiency and the use of renewable energy are needed, complemented by more efficient use of energy in buildings, transportation and industry.

5.2.5 Knowledge and Cognitive responses

A lack of knowledge and the ignorance to adequately use the available information hampers effective management of ecosystems and their services. Major knowledge gaps exist, for example about the economic value of ecosystem services in most regions or about the likelihood of nonlinear changes in ecosystems and thresholds. Models of future environmental and economic conditions have limited capacity to incorporate ecological feedbacks, including nonlinear changes. Promising instruments include (Millennium Ecosystem Assessment, 2005a):

- Incorporation of nonmarket and market values of ecosystem services in resource management and investment decisions. Nonmarket values then may exceed market values, for example for the use of water supply and recreation.
- Use all relevant forms of knowledge and information in assessments and decision-making concerning ecosystems and their services. Traditional and practitioners' knowledge can be of equal or greater value than scientific knowledge.
- Enhance and sustain capacity for assessment of changes in ecosystem and services. There is limited experience with the assessment of ecosystem services. Especially in developing countries expertise is limited about monitoring changes in and health of ecosystem services and economic valuation.

6 Synthesis

6.1 The value of a ecosystem services approach

The importance of ecosystem services and their protection is being mentioned in several EC communications and strategies such as the EU White Paper on adaptation to climate change and the Action Plan accompanying the Biodiversity Communication.

The concept of ecosystem services makes it easier to raise awareness with public and policy makers about the value of nature conservation and sustainable use of the ecosystem and its services. It becomes clear from literature that for the assessment of ecosystem services it is necessary that stakeholders and knowledge owners from different blood groups are involved in the assessment. Community spirit about ecosystem services values and conservation measures increases the likelihood that measures will be accepted and implemented in an effective manner.

A better understanding of the value of ecosystem services will make it easier to raise funding for protection of the ecosystem and its services.

With an ecosystem services approach boundaries of sectors and ecosystems are crossed and integrated management is possible. The assessment of ecosystem services will show consequences of policies and actions at different temporal, spatial and socioeconomic scales. Measures that are being taken in favour of the goals of one policy (or Directive) can be conflicting with conservation of ecosystem services that are protected by another policy. Or, measures taken by one institution are conflicting with measures to be take by another institution. The assessment of ecosystem values will provide a method that will more likely warn for unexpected negative side effects.

An ecosystem services approach forces to consider the complete system of biophysical and socio-economic factors. It leads to an understanding of the many related processes and values within en between these systems. Hereby, prioritization and the development of effective protection measures is possible.

Identification and protection of supporting ecosystem services and assessment of ecosystem services providers can support the concept of resilience of the natural system. This enables a less static, defensive approach of ecosystem conservation.

The ecosystem approach can be helpful when assessing whether climate change or change of land use or water use will affect the functionality of an ecosystem.

The question now is, how to apply the ecosystem services approach in practice. Is it necessary and feasible for policy makers and managers to carry out an extensive ecosystem services assessment for every step they take? In paragraph 6.3 and 6.4 this issue will be further discussed.

Without explicitly label it an ecosystem services approach, the concept is probably being used by many environmental managers and policy makers. Certain components of the frameworks and assessment methods described in this report will be well known concepts. For example, in the Netherlands, societal cost-benefit analyses are being carried out using monetary valuation methods that were used by the Millennium Assessment as well, environmental impact assessment and social impact assessment.

6.3 Assessing the relevance of ecosystem services

The relevance of ecosystem services depends on the river basin that is considered. In principle all conceivable services can be relevant for river basins in general. Ecosystem services that are relevant for management of a particular river basin are the services that are provided by or used within the basin scale or that are influenced by drivers and pressures at a basin scale at present and in the future. Also provision and demand cross-border, regarding other management scales or biophysical units needs to be considered when assessing the relevance/value of ecosystem services. It should be emphasised that ecosystem services can be interrelated and supportive to other services.

Literature provides a number of assessment frameworks that assume either of the following applications:

- **The protection of desired ecosystem services** (such as in Daily, 2000).
- **The assessment of ecosystem services within the context of a decision**. How does socio economic development affect ecosystem services? What opportunities are provided by ecosystem services? This is a proactive position which takes the full interaction between socio economic development and ecosystem services into account (in terms of opportunities and threats). Ranganathan et al., 2008 suggest that identification of relevant ecosystem services when considering a decision can be based on an inventory of *dependence* of the decision on ecosystem services and the *impact* of the decision on ecosystem services. This can be assessed in advance of taken the decision, but assessment of risks after taking the decision is possible as well.

In literature several methods for identification and valuation (both monetary and non-monetary) are provided, see chapter 3, that could be used supplementary. Many of the described approaches are more or less similar in essence. The following (types of) methods could be extracted form this first literature study:

<u>Participatory approaches and expert opinion</u>
Besides (scientific) literature, valuable information can be gathered from stakeholder groups, traditional knowledge and scientific experts (Millennium Ecosystem Assessment). For example in a workshop, experts from different disciplines can identify ecosystem services and assess the availability of monetary values (Beaumont et al., 2007).

<u>Ecosystem service area maps</u>
Mapping can provide insight of ecosystem services provision and demand, indicators of ecosystem services and interrelationships (WRI, 2007), flows of ecosystem services (Daily, 2000) and ecosystem service flow values (Troy and Wilson, 2006).

<u>Ecological assessment of ecosystem service provision by an ecosystem</u>
Clarify how ecosystem services are generated, how they are interdependent and assess the resilience mechanisms of the system (Daily, 2000; Berry et al., 2008). Kremen and Ostfeld (2005) provide a method to assess the species and communities of species that provide ecosystem services.

Assessment of potential alternatives for the ecosystem service
Ranganathan et al. (2008) state that the dependence of a decision on an ecosystem service is relevant if no cost-effective substitute for the service exists. Berry et al., (2008) suggest to value not only the service that is subject of the assessment but also to identify and value potential alternatives.

Valuation of ecosystem services
For monetary and/or non-monetary valuation of ecosystem services most authors advise some level of involvement of stakeholders and/or different expert groups (Beaumont et al., 2007; Cowling et al., 2008.; Perrot Maître, 2005; Millennium Ecosystem Assessment). The involvement of many different stakeholders and different types of knowledge owners asks for very good leadership. Cowling (2008) emphasises that teamwork is difficult and rewarding and that the required emotionally intelligent leadership hard to find is.

Valuation can be based on financial data, interests of people or companies, legislation and so on.

Basically, monetary/economic valuation is based on 1) prices of economic services, 2) benefits to production of goods or services and 3) damage costs when the ecosystem service disappears or becomes in worse condition. Non-monetary values of ecosystem services can be for example jobs created or lives saved.

Comparison of values is very difficult when monetary values and non-monetary values are compared, or when goods are compared together with services. The values are then projected at different scales and one type of value is easier to understand than another. Even when only one type of value is chosen to be relevant for decision making, the value is the result of many factors that could be given different weights and maybe some factors are overseen. The definition of an ecosystem value has to be clear when several sources are used to identify and value ecosystem services.

Identification of spatio-temporal scales of relevance
In order to prevent from missing important aspects of ecosystem services, all the mentioned assessments should be focussed on different scales (Daily, 2000). Identifying the scale(s) at which an ecosystem service is provided (Berry et al., 2008) and demanded can be helpful in the assessment of the relevance of a service.

6.4 Assessing the threats/risks to ecosystem services

This section describes methods to determine *if* an ecosystem service is threatened or *which threat/risks* to an ecosystem service exists now or in the future.

Assessing state and trends
Both current state and past or predicted future undesired trends in ecosystem services can be an indication of threats to ecosystem services. Methods to assess those state and trends are given by several authors. Methods are explained below.

Methods for assessment of condition and trends of ecosystem services are Remote Sensing, GIS, inventories, ecological models and participatory approaches/expert opinion (like workshops). Actually these are the same techniques as the techniques that can be used to identify and value ecosystem services, only now they are being used to clarify changes over the past until now. The change of a ecosystem services quantity or quality into an undesired direction indicates that the service might be under threat. Analyses of past trends can also identify indicators and thresholds.

Several authors mention the gaps in monitoring data and lack of indicators for a lot of ecosystem services. As Beaumont et al. (2007) mentioned, this lack of information also leads to the risk that well documented ecosystem services may unjustly seem to be more relevant than those that are less well monitored or valued.

Scenarios can be used to explore future trends in ecosystems and their services. If drivers of change are known, different scenarios can be developed to assess potential impacts of those changes on ecosystem services provision.

Mapping

Overlaying maps can provide insight in competing ecosystem services (WRI, 2007).

Quantitative analyses of Provision and Demand

Berry et al. (2008) describe the quantification of Service Providing Units and ecosystem service demand. Paetzold et al. (2008) adopt the provision/demand principle in their Ecosystem Services Profile (ESP). Comparison of provision and demand provides insight in shortage of ecosystem services and services for which shortage is possibly soon to expect.

Drivers affecting ecosystem services

If drivers of changes in ecosystem services are known, changes of the drivers can predict changes in ecosystem services. The ecological characterization that was described in paragraph 6.2. can be helpful to detect or to predict how possible changes to ecosystem service providers, affects the delivery of ecosystem services. Kremen and Ostfeld (2005) provide an explanation of techniques that can be used to unravel the species and groups of species that provide ecosystem services.

Thresholds and targets

Ecosystem services can be classified to be threatened when certain thresholds or target values are overcome. The LOICZ-Basins project provides three approaches to identify targets for coastal processes (Crossland et al., 2005). These approaches should be suitable for other systems, like a river basin, as well.

We suggest that the three types of critical values that are named by the LOICZ-Basins could be regarded in a wider context and lead to the following types of critical values:
1) Policy oriented values: critical values in legislation, treaties, policy or directives.
2) Ecosystem based values (this would be a pure scientific approach): critical values based on historical data. The assessment of trends might provide this information.
3) Management based values. LOICZ uses this term for the criteria of local authorities including those that are not only based on scientific arguments alone. We define these values as critical values that are not only based on scientific values or targets that are fixed in policy.

Models and scenarios can also be used to determine thresholds although it was already mentioned in the Millennium Assessment report (2005a) that nonlinear and abrupt changes are hard to predict.

6.4 Prioritizing threats and risks to ecosystem services

The prioritization of threats to ecosystem services could be done by considering the following aspects:

- Relevance of the ecosystem service(s), based on its (monetary or non-monetary) value, including the value to other services, and potential alternatives.

- State of the relevant ecosystem service(s); the degree of possible damage the risk has already caused or the distance to irreversible change or slow or uncertain recovery. Salomons (2008) states that impairment of ecosystem services due to present pressures should have higher priority than impairment as a result of former pressures. This seems quite obvious because when no present pressure is causing damage to an ecosystem service, the service is not expected to degrade further. However, the ecosystem service may affect other ecosystem services in such a way that the duration of a bad condition of the service or low quantitative provision of the service can further damage the other ecosystem service.

- The impact of irreversible change or slow recovery of the ecosystem service. This will mainly depend on the relevance of the ecosystem service and the resilience of the system.

Prioritization is depending on temporal, spatial and social/political scales and the likelihood of propagation of issues from small to large scale in space, time and socio/political dimensions.

6.5 Measures

Prioritization of measures can be based not only on the prioritization of the risks they aim to prevent for or the damage they need to repair, but also on the negative and positive side–effects (both monetary and non-monetary) that they will generate. When measures need to be chosen, a broad spectrum of both soft and hard measures should be considered.

Troy and Wilson (2006) describe how different conservation networks result in different benefits for biodiversity and ecosystem services.

Five categories of responses to enable sustainability of ecosystem services were given within the framework of the Millennium Assessment. Measures concerning *institutions and governance* are mainly focussing on enabling implementation of an ecosystem services approach in management structures. *Economic measures* could be taken at different scales. Literature provides many examples of economic instruments to protect ecosystem services and practical experiences with application of these instruments. Main types of instruments are subsidies, rewards for positive actions, penalizing measures for negative actions and payment for ecosystem services. *Social and behavioural* responses are focussing on information distribution and empowerment.
Technological responses can be used in various ways. The Millennium Assessment report mentions for example increasing efficiency with which resources are being used and reduction of impacts of drivers. One could however think of more possibilities like finding alternatives for lost or impaired ecosystem services, and development of monitoring and warning systems to enable better management of ecosystem services.
Knowledge and cognitive responses are referring to gathering knowledge and adequate use of knowledge and information and especially using <u>all</u> available information. This means

using market and nonmarket values, scientific and practitioners knowledge. Great challenges lie in combining these types of information and enlargement of experience and knowledge.

Measures need to focussed on the proper scale. Local issues need to be addressed by local managers for river basin management to be successful.

7 Recommendations for RISKBASE

The following topics could be addressed by the RISKBASE working groups, in cooperation with stakeholders.

Relevance and applicability

1. How can incorporation of an ecosystem services approach improve river basin management in general?
2. What kind of problems exist in traditional policy and management of river basins? How can an ecosystem services approach provide solutions to these problems or difficulties in specific situations?
3. What kind of difficulties arise concerning existing Directives and legislation when focussing on ecosystem services in river basin management?
4. How does the ecosystem services approach relate to other approaches that are being used in river basin management?
5. What are the drawbacks/risks of focussing only/mainly on ecosystem services in river basin management?
6. When is it necessary and feasible to conduct an extensive assessment of ecosystem services and which methods should be used? How can the concept of ecosystem services be used in 'small' projects in which an extensive assessment might be too expensive or takes too long.

Scale and location

7. What issues related to ecosystem services should be treated at a basin scale and what needs to be done at a broader or a smaller scale? How do the ecosystem service relate between different locations in a river basin?
8. What are the relevant ecosystem services in different types of river basins?
9. What are the correct scales for assessment and which groups need to be involved in the assessment ecosystem services?

Measures

10. Different types of measures exist to prevent impairment of ecosystem services. How can decision makers choose form those measures that are different in principle and in practice?

Practical experience

11. Detailed description of methods for assessment of ecosystem services.
12. Comparison of methods for assessment of ecosystem services (pro's and con's; suitability for different situations).
13. Lessons learned from previous experiences, also in other management units (other than river basins, for example marine systems).
14. Case studies.

References

Balvanera, P., Kremen, C., Martinez-Ramos, M., 2005. Applying community structure analysis to ecosystem function: examples from pollination and carbon storage. Ecol Appl 15: 360–75. In: Kremen, C., Ostfeld, R.S., 2005. A call to ecologists: measuring, analyzing, and managing ecosystem services. Front Ecol Environ 2005; 3(10): 540–548.

Beaumont, N.J., et al., 2007. Identification, definition and quantification of goods and services provided by marine biodiversity: Implications for the ecosystem approach. Marine Pollution Bulletin 54 (2007) 253-265.

Berry, P., Harrison, P.A., Bugter, R., Luck, G. 2008. A new approach to ecosystem service provision. Presentation during the Ecosystem Services Workshop at Salzau Castle of May 13 - 15th, 2008. Available at: http://www.ecology.uni-kiel.de/salzau2008/

Brouwer, R., de Boer, J., van Ek, R., Hisschemöller, M., 2003. Baten van Water in Geld, Groen en Gevoel. Uitgave Waterverkenningen, Opdrachtgever Hoofdkantoor Rijkswaterstaat. *In Dutch*

Cardinale, B.J., Harvey, C.T., Gross, K., Ives, A.R., 2003. Biodiversity and biocontrol: emergent impacts of a multi-enemy assemblage on pest suppression and crop yield in an agroecosystem. Ecol Lett 6: 857–65. In: Kremen, C. and Ostfeld, R.S., 2005. A call to ecologists: measuring, analyzing, and managing ecosystem services. Front Ecol Environ 2005; 3(10): 540–548.

Chan, K.M.A., et al., 2006. Conservation planning for ecosystem services. 4(11): e379. DOI: 10.1371/journal.pbio.0040379.

Commission of the European communities, May 22, 2006. Halting the loss of biodiversity by 2110 – and beyond ; Sustaining ecosystem services for human well–being, Annex 1 action plan to 20101 and beyond. Ref: SEC(2006)621.

Cowling, R.M., et al., 2008. An operational model for mainstreaming ecosystem services for implementation, PNAS, july 2008, vol. 105, no. 28, 9483-9488.

Crossland, C.J.; et al. (Eds.), 2005. Coastal Fluxes in the Anthropocene ,The Land-Ocean Interactions in the Coastal Zone Project of the International Geosphere-Biosphere Programme. Series: Global Change - The IGBP Series, ISBN: 978-3-540-25450-8, Chapter 4.

Daily, G.C. (Ed.), 1997. Natures Services: Societal Dependence on Natural Ecosystems. Washington, DC: Island Press.

Daily, G.C., 2000. Management objectives for the protection of ecosystem services. Environmental Science & Policy 3, 333-339.

Davis, F.W., et al., 2003. A framework for setting land conservation priorities using multi-criteria scoring and an optimal fund allocation strategy. Santa Barbara (California): University of California, Santa Barbara, National Center for Ecological Analysis and Synthesis. 72 p. In: Chan KMA, Shaw MR, Cameron DR, Underwood EC, Daily GC, 2006. Conservation planning for ecosystem services. 4(11): e379. DOI: 10.1371/journal.pbio.0040379.

EPA, 2007a. Ecological Research Program: Willamette-Ecosystem Services Project. Presentation during NAS Sustainability R&D Forum October 17-18, 2007. Available at: http://dels.nas.edu/sustainability/pdfs/EPA_Goodman.pdf

EPA, 2007b. Willamette ecosystem services project (W-ESP) research plan. September 19, 2007.

ESA, 1. http://www.esa.org/ecoservices/comm/body.comm.fact.ecos.html

ESA, 2. http://www.esa.org/ecoservices/comm/body.comm.fact.wate.html

Goldman, R.L., Tallis, H., Kareiva, P., Daily, G.C., 2008. Field evidence that ecosystem service projects support biodiversity and diversify options. PNAS, July 8, 2008, vol. 105, no.27, 9445-9448.

Jack, B., K., Kousky, C., Sims, K.R.E., 2008. Designing payment for ecosystem services: Lessons learned from previous experience with incentive-based mechanisms. PNAS, Julu 15, 2008, vol. 105, no. 28, 9465-9470.

Kremen, C., 2005. Managing ecosystem services: what do we need to know about their ecology? Ecol Lett 8: 468–79. In: Kremen, C. and Ostfeld, R.S., 2005. A call to ecologists: measuring, analyzing, and managing ecosystem services. Front Ecol Environ 2005; 3(10): 540–548.

Kremen, C. and Ostfeld, R.S., 2005. A call to ecologists: measuring, analyzing, and managing ecosystem services. Front Ecol Environ 2005; 3(10): 540–548.

Larsen, T.H,, Williams, N., Kremen, C., 2005. Extinction order and altered community structure rapidly disrupt ecosystem functioning. Ecol Lett 8: 538–47. In: Kremen, C. and Ostfeld, R.S., 2005. A call to ecologists: measuring, analyzing, and managing ecosystem services. Front Ecol Environ 2005; 3(10): 540–548.

Lellouch, M., Hyun, K., Tognetti, S., 2007. Ecosystem Changes and Water Policy Choices: Four Scenarios for the Lower Colorado River Basin to 2050, Island Press, Washington, D.C.

Luisetti, T., Turner, K., Bateman, I., 2008. An ecosystem services approach to assess managed realignment coastal policy in England. CSERGE Working Paper ECM 08-04.

Memmott, J., Waser, N.M., Price, M.V., 2004. Tolerance of pollination networks to species extinctions. P Roy Soc Lon B Biol Sci 271: 2605–11. In: Kremen, C. and Ostfeld, R.S., 2005. A call to ecologists: measuring, analyzing, and managing ecosystem services. Front Ecol Environ 2005; 3(10): 540–548.

Millennium Ecosystem Assessment, 2005a. Ecosystems and Human Well-being: Synthesis.
Island Press, Washington, DC

Millennium Ecosystem Assessment, 2005b. Ecosystems and human well-being, Current state and trends, volume 1. Island Press, Washington, DC

Millennium Ecosystem Assessment, 2005c. Ecosystems and Human Well-being: Scenarios, Volume 2. Island Press, Washington, DC

Millennium Ecosystem Assessment, Glomma river basin study. Available at: http://www.millenniumassessment.org/en/SGA.Norway.aspx

Morselt, T., Nijwening, S., 2006. Een beschrijving van een zevental economische beleidsinstrumenten bij het tot stand brengen van waterbeleid. DGW. *In Dutch*

Naidoo, R., et al., 2008. Global mapping of ecosystem services and conservation priorities. PNAS, July, 2008. Vol. 105, no. 28, 9495-9500.

National Research Council (U.S.)., 2004. Committee on Assessing and Valuing the Services of Aquatic and Related Terrestrial Ecosystems, Valuing Ecosystem Services: Toward Better Environmental Decision-making. National Academies Press.

Paetzold, A., Warren, P., Maltby, L., 2008. An ecosystem service centred approach to assess ecological quality. Presentation during the Ecosystem Services Workshop at Salzau Castle of May 13 - 15th, 2008. Available at: http://www.ecology.uni-kiel.de/salzau2008/

Perrot-Maître, D., 2005. Valuing ecosystem services-advantages and disadvantages of existing methodologies and application to PES. Presentation during Seminar on environmental services and financing for the protection and sustainable use of ecosystems Geneva, 10-11 October 2005. Available at: http://www.unece.org/env/water/meetings/payment_ecosystems/seminar.htm

Petchey, O.L., Gaston, K.J., 2002. Extinction and the loss of functional diversity. P Roy Soc Lond B Bio 269: 1721–27. In: Kremen, C. and Ostfeld, R.S., 2005. A call to ecologists: measuring, analyzing, and managing ecosystem services. Front Ecol Environ 2005; 3(10): 540–548.

Power, M.E., et al. 1996. Challenges in the quest for keystones. BioScience 46: 609–20. In: Kremen, C. and Ostfeld, R.S., 2005. A call to ecologists: measuring, analyzing, and managing ecosystem services. Front Ecol Environ 2005; 3(10): 540–548.

Ranganathan et al., 2008. Ecosystem Services, A Guide for Decision Makers. World resources institute. ISBN 978-1-56973-669-2.

RUBICODE, 2008. Workshop on habitat and conservation policy – Strategies for an new dynamic approach focused on ecosystem service provision, workshop report. Workshop 29/30 April 2008, report July 2008.

Salomons, W., 2008. Linking Soils, Sediments and Catchment Ecosystems. J Soils Sediments 8 (2) 67–68.

TCB, 2003. Advice towards a more ecologically sustainable land use. 4 June 2003.

TCB, 2005. Advice on the more sustainable use of agricultural land. To the Minister of Agriculture, Nature and Food Quality. S16(2005), 29 April 2005.

TEEB, 2008. The economics of ecosystems and biodiversity, an interim report. ISBN-13 978-92-79-08960-2.

Troy, A., Wilson, M.A., 2006. Mapping ecosystem services: Practical challenges and opportunities in linking GIS and value transfer. Ecological Economics 60, 435-449.

Turner, R.K., Brouwer, R., Georgiou, S., Bateman, I.J., 2000. Ecosystem functions and services: an integrated framework and case study for environmental evaluation. CSERGE working paper GEC 00-21.

Vihervaara P., Kumpula T, Tanskanen A., Burkhard, B., 2008. Ecosystem services – a new tool for land use planning. Case study of Forest Lapland, northern Finland. Presentation during the Ecosystem Services Workshop at Salzau Castle of May 13 - 15th, 2008. Available at: http://www.ecology.uni-kiel.de/salzau2008/

Walker, B., Kinzig, A., Langridge, J., 1999. Plant attribute diversity, resilience, and ecosystem function: the nature and significance of dominant and minor species. Ecosystems 2: 95–113. In: Kremen, C. and Ostfeld, R.S., 2005. A call to ecologists: measuring, analyzing, and managing ecosystem services. Front Ecol Environ 2005; 3(10): 540–548.

WRI (World Resources Institute), 2007; Department of Resource Surveys and Remote Sensing, Ministry of Environment and Natural Resources, Kenya; Central Bureau of Statistics, Ministry of Planning and National Development, Kenya; and International Livestock Research Institute. *Nature's Benefits in Kenya, An Atlas of*

Ecosystems and Human Well-Being. Washington, DC and Nairobi: World Resources Institute.

WWF comments on the EU White Paper on adaptation to climate change (available at WWF).