Supply and Demand for Ecosystem Services in Mountainous Regions

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While ecosystems deliver goods and services of enormous value to the human society (Pearce and Moran 1994, Daily 1997), intensive land and water use, extraction of natural resources, and chemical emissions into the environment are leading to a worldwide loss of biodiversity and degradation of ecosystem functioning (Hooper et al. 2005, Millennium Ecosystem Assessment 2005). Climate change has intensified the dynamics of this human-environment interaction, which is more severe in mountain regions compared to the lowlands (see Körner this volume). Because of topographical complexity and altitudinal gradients mountain ecosystems are particularly sensitive to global change compared to the lowland (Becker et al. 2007, Bugmann et al. 2007). However, the lowlands are also heavily influenced by undesired changes in mountain areas, because of their importance for biodiversity and for providing ecosystem services. Downstream actors benefit from clean water, flood control, reduced sedimentation, scenic beauty and many more positive mountainous ecosystem services.

By definition ecosystem services are functions of nature with value for the human wellbeing.[1] This polarity between nature and human well-being implies that it is essential to understand the interdependences between the ecological system and the socio-economic system (Figure 1). We use the concept of human-environment systems in sensu Scholz (2003) as the rationale for the research program. This allows studying the supply and demand for ecosystem services in an integrated manner.

1 This simple definition is not completely in line with that of the Millennium Ecosystem Assessment (MA), which defines ecosystem services as the "benefits people obtain from ecosystems". The difference in the two definitions is that the MA claims that food, water, timber and fiber are also ecosystem services. I would rather say it is not the commodity from forestry and agriculture, which is the service, but the function of nature to *produce* such commodities. Anyway, currently there is much confusion around the exact definition of ecosystem services (see Boyd 2007, Boyd and Banzhaf 2007, Wallace 2007, Costanza 2008).

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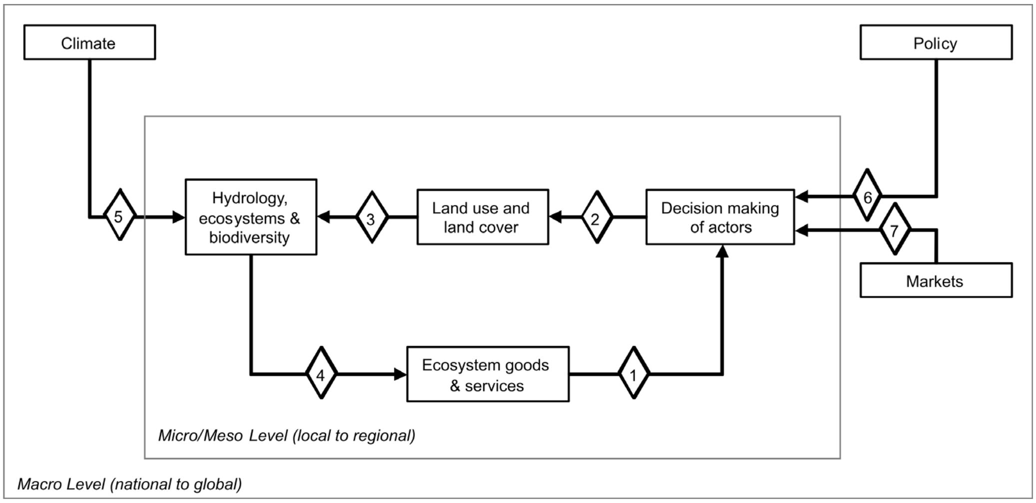

Figure 1: Conceptual framework of a research program on supply and demand for ecosystem services. (1) Effects of changes of ecosystem goods and services on the decision-making of actors demanding ecosystem services in a regional socio-economic system. (2) "Decision-making" of actors implies changes in land use and land cover. (3) Effects of changes to land use/land cover on regional hydrology, ecosystems and biodiversity. (4) Effects on the ecosystem goods and services supplied. (5), (6) and (7) describe exogenous variables, which influence the modeled system, especially (5) effects of changes in climate on regional ecosystems, (6) Effects of developments in policy on decision-making and (7) effects of developments in (financial and trade) markets on decision-making.

Within this general framework for human-environment systems three main objectives of the research on *Ecosystem Services* would be

A) to model land and water use and its impact on biodiversity and ecosystem services regionally, given scenarios of global change (i.e., changes of climate, markets and policies);

B) to analyze the decision-making that drives supply and demand for ecosystem services, and

C) to explore national and international payments for ecosystem services (PES) and their linkages to the financial sector.

Improving knowledge related to these three objectives is important to develop strategies for the adaptive and sustainable management of ecosystems services. The research results of such a program should inform and support policy-makers and ecosystem managers. For example, probabilistic and spatial models that quantify land use/land cover, levels of biodiversity, and intensity of ecosystem services for various global change scenarios can be implemented as decision support tools by ecosystem managers or decision-makers in policy and industry. Similarly, the factors (cost-benefit expectations, norms, and behavioral control), which influence the decisions made by supply and demand side actors should be understood and taken into account in designing new policy instruments like PES schemes as well as "green" financial products.

A) Modeling land use, biodiversity and ecosystem services facing global change

Many ecological economic models exist to understand the complex interdependencies between land use, biodiversity and ecosystem services under global changes of climate, markets and policies. They were developed to investigate ecological factors, economic decision-making and land use/land cover change on a landscape scale (see review in Baker 1989, Irwin and Geoghegan 2001, Bell and Irwin 2002, Heistermann et al. 2006) and the interdependency of trade, land use, biodiversity and environmental impacts on a global scale (Polasky et al. 2004, Mayer et al. 2005, Würtenberger et al. 2006).

Complemented with knowledge on hydrology, ecological economics models were used to investigate land use, (forest) ecosystem status and hydrological services in watersheds (Voinov et al. 1999, Bergh et al. 2004, Bruijnzeel 2004, Hörmann et al. 2005, Wattenbach et al. 2005). In the field of impact assessments of climate change and land use on ecosystems and economies such models considered the impacts from changing climatic variables on vegetation pattern and biodiversity (Ostendorf et al. 2001, Parmesan and Yohe 2003, Thomas et al. 2004), impacts of land use on biodiversity (Gaston et al. 2003), impact of global change on ecosystem services (Alcamo et al. 2005, Schröter and et al. 2005, Metzger et al. 2006), and the cascading effects from changing climatic variables, to land use, ecosystem impacts, economic consequences and policy implications (e.g. MINK model Dowlatabadi and Morgan 1993, Rosenberg 1993, Krysanova et al. 1999). Reversely, also the impact of policy interventions on farm level income and the environment in watersheds was modeled (Barbier and Bergeron 1999, Lant et al. 2005), however, not yet the link to ecosystem services.

In those models land-users' decision-making and behavior is normally explained with economic rationality based on expected profits and opportunity costs (e.g., Nieuwenhuyse et al. 2000), but neglect other factors, which explain behavior of land users. The People and Landscape Model (PALM) has made effort towards full integration of human decision-making and biophysical simulation models (Mathews 2006).

Meanwhile the idea of ecosystem services has also reached environmental accounting tools, which support decision makers. Two prominent tools are the Life Cycle Assessment, which quantifies environmental impacts of products and companies, and Green National Accounting, which puts the value of natural resources on the accounting sheets of nations. In the past, Life Cycle Assessment did focus mainly on land use impacts of biodiversity (Koellner and Scholz 2007, Koellner and Scholz 2008), but impacts on ecosystem services will be quantified soon[2] (see Koellner 2003 for conceptual framework). With respect to Green National Accounting it is currently discussed how ecosystem services can be taken into account (Weber 2007, Mäler et al. 2008).

B) Analyzing the actors' decision-making related to ecosystem services

In recent years many market based instruments to the management of ecosystem services emerged. Little is however understood about the decision-making process of suppliers and demanders of ecosystem services. The work of Sell (Sell et al. 2006, Sell et al. 2007, Sell et al. submitted) has filled this gap and has analyzed the expected benefits and market potentials of ecosystem services from tropical forestry, particularly focusing on the perception of international market actors. The three surveys suggest that the decision-theoretic combination of criteria, preferences and expected benefits is a useful approach to analyze the decision making of market actors. The surveys indicate that the perspective and decision making differ between market actors of tropical and non-tropical countries, with the former having a business and the latter tending to have a sustainability focus. Yet, similar studies for the relationship of lowland and mountains are missing.

Because the private sector is a beneficiary of such ecosystem services a large survey of over 900 international and Costa Rican companies was implemented to investigate their demand for ecosystem services from tropical forests (Koellner et al. in prep.). The results showed that international companies are interested in buying

2 Current project under the UNEP/SETAC Life Cycle Initiative entitled Operational Characterization Factors for Land use Impacts on Biodiversity and Ecosystem Services in the Life-Cycle Impact Assessment. LULCIA

certificates mainly for carbon sequestration; Costa Rican companies, for all four ecosystem services in the following order: watershed protection, biodiversity conservation, carbon sequestration, and scenic beauty. This information about factors driving demand was used to develop concepts for marketing ecosystem services (Gähwiler 2004, Gähwiler et al. submitted).

C) Exploring the links between ecosystem services and the financial sector

It is of the highest relevance for sustainable ecosystem management to link the provision of biodiversity and ecosystem services (being a positive externality) to public and private payments. For that reason much work was done on Payments for Ecosystem Services (PES) in the past (see the special issue on that topic by Engel et al. 2008). Especially, in Costa Rica–the birthplace of the PES idea-research did focus on identifying spatial priorities for ecosystem services in order to support national authorities to distribute payments more efficiently (Chan et al. 2006, Wünscher et al. 2007, Imbach et al. submitted). PES schemes are explicitly designed around ecosystem services, however, payments for biodiversity and ecosystem services can be also implement in existing fiscal instruments (Koellner et al. 2002, Ring 2002). Another current trend is that Payments for Ecosystem Services are put into an international context (Koellner and Engel 2008). On the one hand this clearly is relevant for "global" ecosystem services like carbon sequestration, but also for services like flood regulation, which can cross national borders, when beneficiaries downstream are situated in the next country. On the other hand, this concept allows integrating not only downstream users of ecosystem services in a physical sense, but also foreign beneficiaries, which financially benefit from ecosystem services in a given region. For example, regions with intact ecosystem services potentially can have a price advantage in the production of agricultural commodities (e.g., pollination services impacts coffee growing in mountainous regions). This price advantage can trickle through the global value chain linking producers and consumers internationally. However, this effect was not investigated yet.

Payments for Ecosystem Services can have a significant influence on global environmental change, but traditional financial markets have due to their sheer market volume the potential to even more strongly influence global ecosystems. For this reason Koellner (2008) reviewed financial market innovations, which integrate sustainability and natural resource management. Environmental commodities like biodiversity and ecosystem services were explicitly included in the analysis. The analysis embraced all types of financial markets ranging from conventional commodity markets, environmental commodity markets, capital (stocks & bonds) markets, real estate markets, to insurance markets. Actors in all those markets in fact proofed to be quite innovative in developing new financial products based on the sustainable production of soft commodities–like timber and food–as well as of environmental commodities–like clean water, clean air, biodiversity or ecosystem services. For example, small loans to farmers or forest owners, which comply with sustainability criteria and thus have positive influence on ecosystem services, can be securitized as micro credit funds and are traded on formal exchanges (e.g., in Costa Rica FONAFIFO was planning to issue a forest credit fund backed by the World Bank, http://www.fonafifo.com). Although this is a rather indirect influence on ecosystem services such instruments can have substantial impacts on ecosystems in a given region.

Conclusion

This by far not complete review of research covering the supply and demand for ecosystem services makes clear that the topic is widely covered and many facets are intensively investigated. However, especially when it comes to mountainous ecosystem services it becomes clear that there are still important research gaps. To identify this gap a workshop on supply and demand for ecosystem services was organized during the COST conference (see this volume). What is especially missing is that mountain ecosystems are not clear enough conceptualized in the relationship to their lowlands. For that reason analyzing disparities between mountain regions and lowland regions with respect to level and rates of change of ecosystem services as well as disparities in wealth and well-being of the people are an important research goal. This together with the modeling of impacts of global change needs to be the basis for adaptive land use planning and optimization. Until now much was done to model global *environmental* change, but the impacts of socioeconomic changes are still an open field. Only, when those factors are clearly understood it is possible to design instruments in the private and public sector to address unsustainable development. Such a research program clearly requires interdisciplinary and transdisciplinary research.

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