Chapter 4
The Research Unit RU 816: Overall Approach in the Light of the Ecosystem Services Concept

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4.1 Introduction

Over the last decade, "ecosystem service" has become one of the most influential but also most controversial scientific concepts at the interface of biodiversity science and environmental policy. The most widely accepted definition of ecosystem service is provided by the Millennium Ecosystem Assessment (MEA, 2003), which highlights the role of ecological systems for the provisioning of benefits for human society. The establishment of IPBES (Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services) has recently underlined the steadily growing importance of the ecosystem service concept. Concurrently, RU 816 "Biodiversity and Sustainable Management of a Megadiverse Mountain Ecosystem in South Ecuador" strove to identify the characteristics of science-based sustainable land use management systems that should inform conservation decisions in the biodiversity hotspot of the South Ecuadorian Andes. Such management system(s) should at the same time

1. preserve biodiversity and the ecosystem processes underlying its evolution and conservation,
2. rehabilitate degraded biodiversity and lost land usability, and
3. improve livelihoods for the local population.

This triple reseach challenge poses the mein research question of RU816–a question directly related to the most urgent gaps of current knowledge requiring integrative research on the ecological/socio-economic science interface (Ehrlich and Mooney 1983; Daily 1997; Carpenter and Turner 2000; Farber et al. 2002; Heal et al. 2005). The required research is much facilitated if ecosystems with differing anthropogenic

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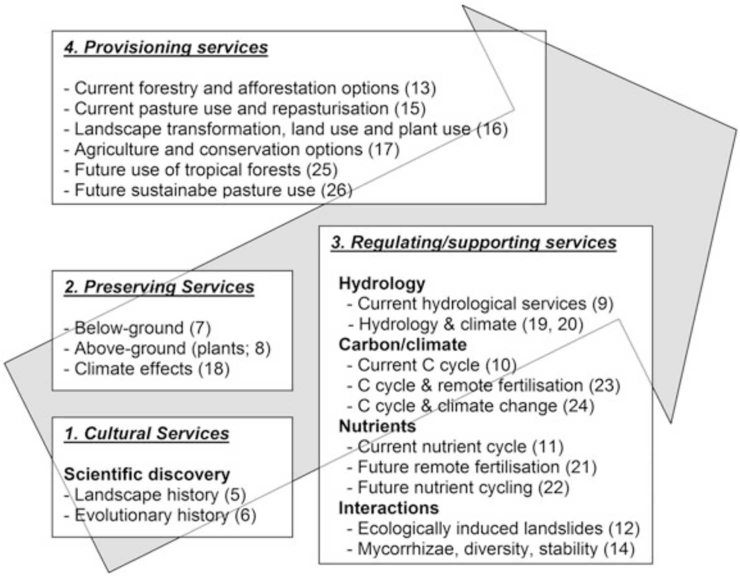

Fig. 4.1 The chapters of the book can roughly be arranged in four groups of ecosystem service categories that increase (*grey arrow* with respect to direct applicability to landscape management in the project area)

impact can be compared in direct spatial proximity. Comparative research can be based on field studies as well as on ecological experiments (refer to preface). Fortunately, the research area presents a dichotomy of protected natural forest and adjacent pasture ecosystems for which the forest had been cleared by slash and burn. Consequently, differences in the capacity of these two ecosystem manifestations to provide benefits to humans, i.e. ecosystem services, are at the analytic focus of this book.

When translating the main research question of RU 816 into a suitable research approach, it became apparent that all MEA (2003) categories of ecosystem services are covered to some degree by the investigations presented in this book. While the ecosystem service typology of the MEA provides the conceptual frame, the specific foci of the single projects suggest to place the chapters of this book into four groups that differ slightly from MEA ecosystem service categories: (1) cultural, (2) preserving, (3) regulating/supporting and (4) provisioning services (see Fig. 4.1). These four groups roughly indicate the differing relation of the chapters of this book to direct application in sustainable landscape management on the one hand and more basic research on the other.

In order to use an ecosystem services approach for the science-based design of sustainable land use management systems, ecosystem services need to be quantified in a suitable way. Many of the underlying ecological processes can be directly quantified such as water discharge and element leaching. With respect to benefits more directly appropriated by humans, ecosystem contributions—e.g. by soil quality or microclimate—to crop yields and farming income can also be quantified readily. For other ecosystem services, quantitative assessment is more difficult. For example, the usefulness of a preserved species for science or the more comprehensive importance of nutrient cycling or of a dampening of climate extremes is difficult to relate directly to human benefits. Contrary to a widespread belief, cultural ecosystem services including those based on aesthetical and ethical motivations pose no specific challenge to quantification in economic benefit terms (see e.g. Cerda et al. 2012; Barkmann et al. 2010).

The utilisation of an ecosystem service approach does not prescribe a specific valuation and/or decision-making method. Quantified data on the provisioning of ecosystem services can be input into multi-criteria methods, which do not monetise ecosystem services, as well as into cost-effectiveness or cost–benefit analysis. In cost–benefit analysis, for example, data on the effect of vegetation on the frequency of landslides is translated into a monetary estimate of avoided damages. Likewise, the contribution of a fascinating landscape to tourism profits can be assessed. Comparison of two or more differing manifestations of an ecosystem facilitates such valuation tasks considerably because the natural ecosystem can be used as a reference.

4.2 The RU 816 Approach in the Light of the Slightly Modified MEA Ecosystem Services Concept

Cultural services refer to the fact that ecosystems possess cultural value. Among other aspects, ecosystems serve as an object for research—including ecological research on ecosystem compartments, components and functionality. Understanding of landscape history and an evolutionary approach to speciation are further aspects of ecosystem research that tap cultural ecosystem services. With the generated information, ecosystem traits can be assessed and the conservation value of an ecosystem addressed. Plant, animal and fungal communities of the natural forest have been investigated during the past one and a half decades. The studies document that the research area is one of the "hottest" biodiversity hotspots worldwide (Liede-Schumann and Breckle 2008).

Preserving services are a specific manifestation of cultural ecosystem services, and refer to the maintenance of biological diversity irrespective of any specific ecological function. Preserving services provide benefits because many people assign a high value to the existence of species and to high biological diversity. Consequently, the research area deserves a high degree of conservation and protection from an existence and bequest value perspective (see Sect. 4.3). The existence value of the natural forests—as well as of the high altitude subpáramo vegetation—is underscored by the uniqueness of these ecosystems and by the irreversibility of ecosystem degradation: The systems will not restore themselves once converted to agricultural land, and then abandoned. The forests have, however, the potential for slow recovery after moderate disturbance that removes or destroys part of the trees

(Martinez et al. 2008). This knowledge might be transferable to other tropical forests. Thus, desiderata listed under (1) and (2) of the main research question can be materialised by the conservation of the natural forest manifested by its status as a national park.

Supporting services play a major role for desiderata (1)–(3) of the main research question because they are the fundament for the generation of ecosystem services from all other categories. Supporting ecosystem services range, e.g., from primary production via seed set and dispersal to soil formation, nutrient cycling and regional hydrology. As such the processes constituting supporting services can be quantified, but the importance of these quantitative figures for sustainable land management is difficult to assess.

Regulating services are necessary for the stabilisation of other services and, thus, often provide insurance services (Rajmis et al. 2010). Consequently, they are also inherently related to (1–3) of the main research question, addressing the capacity of the ecosystem to mitigate hazardous events by regulating climate extremes, erosion as well as water flow and nutrient cycles. Of particular importance is the question how changes of the environment affect the regulating capacity of the ecosystem, or how resilient the ecosystem is against changes of climate and/or of land use. A change of land use, e.g. conversion of the forest to pastures, may affect the single regulating services differently although the whole ecosystem changes.

Regulating and supporting services of an ecosystem are closely intertwined ecologically. Thus, the joint investigation of topics relating to *regulating and supporting ecosystem services* constitute the main focus of RU 816 research. The relevant book chapters are weaving around four themes essential for the valuation of the ecological basis (supporting services) and ecosystem stabilisation (regulating services) of provisioning services. The selected topics are highly relevant for Ecuadorian society. The four themes mainly address:

- Hydrological services, where the influence of the ecosystem and its changes on the water cycle with special reference to the soil–vegetation–atmosphere interface are investigated. This is a precondition for assessing the provision services potable water supply and water supply for hydropower generation.
- Nutrient services, where the current situation, regulation and stability (towards environmental change) of nutrient cycling are analysed, primarily supporting not only the provisioning service of agricultural production but also growth of the natural forest.
- Carbon/climate regulation services, whose investigation generates urgently needed knowledge on how to mitigate global climate change by carbon sequestration and how to prevent hazardous effects of climate extremes in the local climate due to land use change. Obviously, these services equally affect all other service categories.
- Interaction services that provide stability due to ecosystem interactions permeating the biotic and the abiotic spheres. One prominent example is the occurrence of landslides in the natural forest due to biotic–abiotic interactions, which at the same time enhances sediment transport in and fosters biodiversity of the natural system.

Provisioning services are a service category directly related to human needs (food and fibres, timber/non-timber forest products, potable water, hydropower, etc.), and thus to the livelihood of the local population. While provisioning services are obviously related to (3) of the main research question, the utilisation of provisioning services has feedbacks to (1) and is a precondition for achieving (2). The investigations of direct provisioning services in this book is related to current (non-sustainable) and potential future (sustainable) land use portfolios and thus, mainly related to agricultural production options including (a) forestry, (b) non-timber products, (c) pasture management and (d) indigenous home gardens. To answer the main research question of developing sustainable land use systems, benefits due to agriculture are investigated alongside other ecosystem services. One example is the design of Payment for Ecosystem Service schemes (PES) that foster afforestation of abandoned pasture land.

At this point it should be stressed that the perspective of investigating ecosystem services in a science-directed manner must not necessarily be in accordance with the priorities of the local population. However, reaching (1)–(3) without the acceptance and thus, the support of the local population is neither possible nor worthwhile. Therefore, the study presented in the next section was conducted to assess the preferences of the local population regarding selected ecosystem services.

4.3 Stated Preferences for Selected Ecosystem Services

Hillmann, Barkmann and Marggraf conducted a social science survey in order to estimate the economic preferences that the population of the project region holds with respect to a subset of the most important non-marketed ecosystem services. As the conservation of biological diversity in the Andean biodiversity hotspot is of global importance, we also estimated preferences of a German sample of respondents representing global stakeholders focusing on the conservation of "charismatic species" and of valuable habitats (see Fig. 4.2). While global stakeholders are expected to have only preferences with respect to the existence value of biological diversity of the research region—which relates to cultural ecosystem services-, local and regional respondents are expected to be interested economically also in other benefit classes. We report here briefly on results calculated form the two Ecuadorian samples using the Choice Experiment method (CE; Hensher et al. 2005). The design and wording of the CE instrument for these samples uses an ecosystem service approach specifically developed for the economic valuation of functional aspects of biological diversity (Barkmann et al. 2008).

During a qualitative pre-study, we tested several CE attributes, of which three were finally included in the main study. The number of moth species occurring in the project area was among the tested attributes. In the pre-study interviews, respondents did not indicate any economic preferences for the moths. The proximity

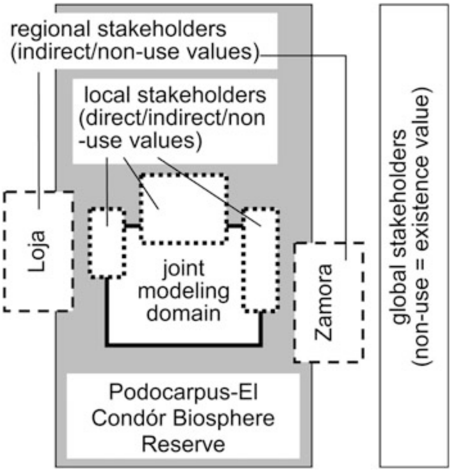

Fig. 4.2 Conceptual sketch of the spatial distribution of local, regional and global stakeholders valuing ecosystem services and biodiversity (for further explanations, see text)

of the forest to the home of respondents was initially included as a proxi for the provisioning services of regional forests. Averaged over interviewed local and regional stakeholders, preferences were very low in the pilot study, and the attribute subsequently dropped from the main study. Also, an attribute on the number of landslides (regulating service) was included in the qualitative interviews but not in the final valuation interviews as only low “demand” was recorded. In result, the main study addressed respondent preferences for changes (1) to endemic plant biodiversity at the species level, (2) to the quality of potable water supply, and (3) to offsets in average individual C emissions. We operationalised the carbon emissions attribute via an inquiry into the personal responsibility to mitigate the own C emissions of respondents by regional afforestation measures (cf. Rajmis et al. 2009). Current average annual C emissions stand at about 2 t C per capita in Ecuador.

For the Ecuadorian CE study, 310 of ~400 “local” rural households and 401 “regional” households from Loja and Zamora cities were sampled. Regional respondents were systematically selected from a stratified random sample of urban neighbourhoods. The local sample includes all households in the selected villages of the study area willing to participate (~78 %).

Positive preferences for the conservation of endemic plant species could clearly be detected ($p < 0.001$; see Fig. 4.3). However, this is the relatively least important CE attribute from the perspective of the Ecuadorian respondents. If scaled to a prevention of a loss of 20 endemic plant species, stated willingness to pay (WTP) is between ~1 US\$ year^{-1} and ~2 US\$ year^{-1}. WTP between 17 and 24 US\$ year^{-1} was estimated for a substantial reduction in infections brought about by hygienically cleaner potable water. Economic preferences for compensating 1 t carbon (C) emissions by regional afforestation ranged from 20 US\$ year^{-1} to 45 US\$ year^{-1}. In each case, the lower values are the mean of rural residents. As *willingness* to pay is restricted by *ability* to pay, lower economic preferences by rural respondents commanding lower average incomes were to be expected.

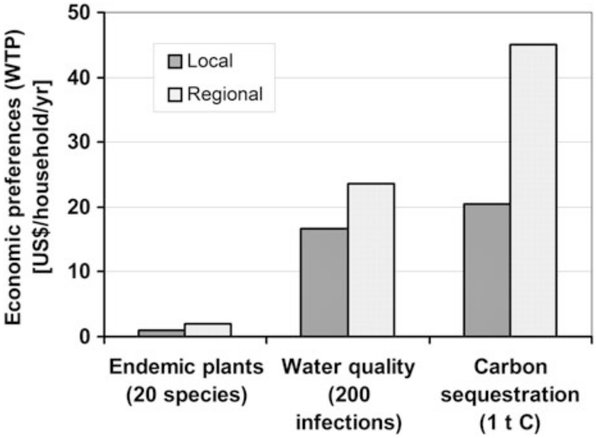

Fig. 4.3 Results of the local and regional Choice Experiment studies; WTP (willingness to pay) values are for changes in preserving, regulating and provisioning ecosystem relative to the status quo

Although direct benefits from offsetting individual C emissions by afforestation are low for any single individual, stated WTP is very substantial. Thus, respondents assign high importance to safeguarding global regulating services. High importance is also assigned to the direct "provisioning" benefits of cleaner potable water.

4.4 Conclusion

The ecosystem service concept was used as a tool to structure research at the interface of the natural and the social sciences. Thus, assigning a certain chapter to a specific part of the book should not be interpreted as a claim to the direct relevance of the ecological processes or functions investigated in terms of environmental assessment or decision making. Some of the proximity of the presented results in relation to their direct application in sustainable land management is captured by the used ecosystem service categories, though (Fig. 4.1). Within each category, however, there is substantial heterogeneity. This heterogeneity stems from the overall approach of RU 816 to advance the understanding of ecosystem structure and functioning at applied but also at more fundamental levels.

The social science results presented in Sect. 4.3 indicate that project area respondents clearly differentiate among different ecosystem services in terms of perceived benefits. For example, many respondents accepted a responsibility for offsetting their own contribution to climate change by local afforestation measures. Likewise, measures to improve the hygienic quality of potable water were strongly demanded. Without the demonstration of additional tangible benefits of biodiversity conservation—or without sufficient financial incentives-, local farming households are unlikely to forgo income opportunities even if income generation threatens plant species diversity.

The conservation of the exceptional biological diversity of the research area is a matter of potentially global concern. Results from the German sample indicate that international stakeholder preferences in the order of 130 € ha^{-1} $year^{-1}$ for the better protection of biodiversity hotspot areas such as the project area exist. Thus, there is substantial global demand for the protection of the "cultural" ecosystem services provided by biological diversity in southern Ecuador. Overall sustainable development of the project area and of the wider Andean biodiversity hotspot will require that synergies and trade-offs between potential development and conservation options be carefully examined—and that global WTP for biodiversity protection can actually be channelled into economically and ecologically sound conservation action.

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