Market-based valuation of biodiversity in Luang Prabhang, Laos.
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CHAPTER 4

Quantifying and valuing ecosystem services

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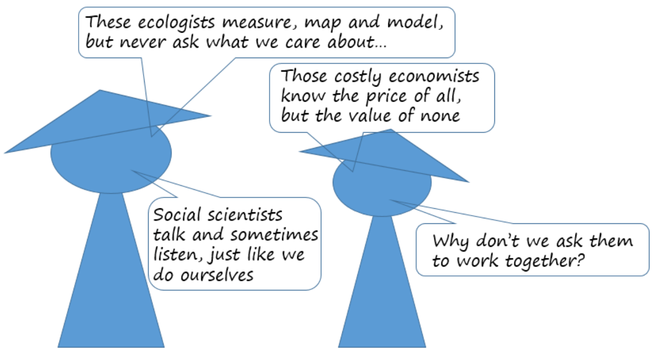
Highlights

- ES quantification is contextual and requires an understanding of the location-specific data, data needs and stakeholder interests.
- Lack of data on differences in social-ecological contexts and stakeholder preferences are key factors that complicate ES quantification across scales.
- ES quantification is currently driven more by economic than by social and cultural valuation.
- There is need to invest in developing Integrated ES quantification and valuation approaches that take into account the social, economic and ecological values of ecosystems.



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4.1 Introduction

Ecosystem Services (ES) depend on natural capital in interaction with human and social capitals[1]. Natural capital, including vegetation and belowground biodiversity supporting soil formation and nutrient enrichment, is important for producing the supporting, regulatory and provisioning services used by humans for economic, social and cultural benefits. Mainstreaming economic development in most developing countries is usually accompanied by a decrease of natural capital and shifts in the social fabric, both affecting ES. Concerns triggered by this change have led to quantification and valuation of ecosystem services often applying globally standardized financial metric as that used for economic progress, so that the genuine economic growth can be monitored [2,3,4]. As such, global and national environmental laws and policies now recognize the need for ES quantification and valuation for very many reasons.

Quantification and valuation of ES is a key step in deciding remedial actions for emerging environmental problems such as climate change. For instance, the change of carbon dioxide and fluxes of nitrous oxide and methane expressed in carbon-equivalent units and multiplied with the market price for a unit of certified emission reduction has been used to prioritize climate change remedies and climate change investments. This way, carbon sequestration by forests, agricultural and other natural systems can be expressed in financial terms. Through quantification, it is also possible to link a particular share of greenhouse gasses to particular actors e.g. national governments[5,6], industries and local farming communities) or particular activities such as deforestation, manufacturing industry, transport etc.

Quantification and valuation also inform the rights to use and invest in natural capital based on value to various beneficiaries including governments, multilateral markets and farmers. For instance, governments are motivated to protect biodiversity when the value of this biodiversity in terms of economic, environmental and social contribution is clearly articulated. Similarly, local communities have often been motivated to engage in sustainable forestry based on quantified economic, social and ecological value of certain tree species. However, this often requires the recognition that quantified ES and associated values have varying appeal to different people, institutions and ecologies[1,7]. An ES value attached to global consumers, e.g. carbon credits (or not feeling guilty about tropical deforestation) may not appeal to a local peasant interested in firewood to cook a meal. As such, the Millennium Ecosystem Assessment Framework[8] emphasized the need for ES quantification to consider the full value of an ES to various stakeholders.

There has been progress in the development of methods and standards to quantify ES[9], and the trade-off between them (Table 4.1)[10]. Strict definitions[11] of Payment for Ecosystem Services (PES) suggest that payments for an ES will only be made on condition that a given amount (quantified) of ES is delivered by the seller to the buyer. Some value in the range between what buyers are willing to pay (WTP) and the price for which providers are willing to accept contracts (WTA) indicates the current market value per unit of ES. However, this may be a poor estimate of the real value to humanity, given the many market failures involved[12].

Quantification of value implies assigning numbers to a particular ES[13]. For instance, tons of carbon stock change per hectare of agricultural or forest landscape, or the percentage of indigenous tree species in a forest. The ES 'value' refers to the worth or usefulness of a particular ES in relation to other equivalence[14]. Despite the difference between quantification and valuation, the two are closely linked in the sense that quantification often is a major prerequisite for valuation. However, certain methods for valuation exclude quantification step[15]. For provisioning services and C-stock change a simple multiplication of total area and value per area unit may work, but regulating and cultural services generally have more complex scaling rules where the value per unit area depends on the area involved[16,17].

While ES quantification and valuation are still relatively new in informing ecosystem management decisions and economic development globally, there is little information on progress in the developing world, where associated challenges may be different[18]. This chapter reviews existing ES quantification and valuation methods, as a next step beyond the typology and quantification discussed in the preceding chapters[9,10]. The discussion addresses two propositions[1]: (1) that ES provision in the land use sector is influenced by the existing combination of factors including practices, spatial distribution and interactions over time and (2) that ecological intensification and restoration are necessary for restoring ES in landscapes but not sufficient unless social issues of equity, gender and culture are accounted for as well. We use case studies to illustrate these propositions.

Table 4.1 Typology of ES quantification methods, values, data sources and scale of measurements. The + signs indicate the level of emphasis on a particular aspect, i.e. most (+++), moderate (++) and least (+). The typology was developed from the Millennium Ecosystem Framework and literature.

Method	Main ES measured	Main data	Values measured	Scale of applications	References
Mathematical models combining pattern and process understanding and information to predict ES	Provisioning (+) Regulating (+++) Cultural (+)	Primary biophysical (+) Secondary biophysical (+++) Primary social (+) Secondary social (++)	Ecological (+++) Economic (+++) Social (+)	Global (+++) Regional (+++) Local (+)	[13,25,19,20,33]
Extrapolation of field data and databases weighted by cartographic data	Provisioning (++) Regulating (++) Cultural (+)	Primary biophysical (+++) Secondary biophysical (++) Primary social (++) Secondary social (++)	Ecological (++) Economic (++) Social (++)	Global (++) Regional (+++) Local (++)	[8,33]
Look-up tables. Use of existing land-cover classes to summarize ES values from the literature	Provisioning (++) Regulating (+++) Cultural (+)	Primary biophysical (+) Secondary biophysical (+++) Primary social (+) Secondary social (++)	Ecological (+++) Economic (+++) Social (+)	Global (++) Regional (+++) Local (+)	[21,32,33]
Expert field measurements of parameters associated with ES through instrumentation or surveys	Provisioning (+++) Regulating (+++) Cultural (+)	Primary biophysical (+++) Secondary biophysical (++) Primary social (++) Secondary social (+)	Ecological (+++) Economic (+++) Social (++)	Global (+) Regional (+) Local (+++)	
Expert knowledge of ecosystems and associated services	Provisioning (+) Regulating (++) Cultural (++)	Primary biophysical (++) Secondary biophysical (++) Primary social (++) Secondary social (+++)	Ecological (++) Economic (+++) Social (++)	Global (+++) Regional (++) Local (+++)	[8,22,32,33]
Participatory indigenous approaches. Involves assigning quantities based on deliberative stakeholder negotiations	Provisioning (+++) Regulating (++) Cultural (+++)	Primary biophysical (++) Secondary biophysical (+) Primary social (+++) Secondary social (++)	Ecological (++) Economic (++) Social (+++)	Global (++) Regional (++) Local (+++)	[**Error! Bookmark not defined.**,23,24]

4.2 Unpacking ES quantification methods

4.2.1 Overview

The preceding chapters[9,10] summarized many measurement tools for ES quantification that involve direct measurements using calibrated equipment and instruments that record or project numbers. A range of methods, data sources, scales, value systems on ES quantification exist and continue to emerge. In this section, we compare various ES quantification methods, drawing on the Millennium Ecosystem Framework and a host of ES quantification studies, to code and rank the various ES quantification methods, the values and services they measure, as well as scale and data applied (Table 4.1). The ES quantification methods include mathematical models, look-up tables, expert knowledge and participatory approaches[25].

4.3 Models, secondary and primary data

Mathematical models used to relate measured quantities to the value-at-scale desired for informing target audiences include regression equations, remote-sensing projections and GIS interpretation. Mathematical models are mainly applied in quantifying regulating services and depict causal relationships with other ES, e.g. provisioning services[26]. The era of climate change discourse has seen the development and application of various mathematical models to account for carbon in various agricultural[27,28,29], forest and other landscapes[26,30]. These methods provide a low-cost overview of wide areas, quick estimations and general projections of different scenarios, but they require ground-truthing and expert technical input to improve accuracy. The level of effort depends strongly on the scale at which precision is needed[31].

Look-up tables (LUT)[32] with standard values for recognized land-use types and ES categories represent interpretive databases developed from literature and various studies. They serve as a reference to assign ES quantities based on system characteristics, e.g. land cover characteristics[32,33]. LUTs were, for example, used[34] to map biodiversity in southern Africa and identified trade-offs between biodiversity and other ecosystem services such as biomass and water regulation.

Both LUT and mathematical models mainly utilise secondary biophysical data where available. Secondary data costs less and their use enables quantification of ES for large areas where standardization is comparatively accurate[8]. Globally standardized land cover maps[35] have gained wide support and usage in global ES policy decisions such as climate change[36].

In terms of scale, a survey of ES mapping studies[33] revealed that most published ES quantification relates to regional scales with little focus on local scales. The choice of scale tends to largely depend on the data types and forms available. Wider scale quantification such as regional levels tend to utilise secondary data. Secondary data are relatively easy to access and are less costly. On the contrary primary ES quantification data at finer scales provides contextual insights about the ecological, economic and social values of ES to a particular community, household or system in a manner informative to effective policy choices. However, collecting primary data for ES quantification is associated with higher costs[37]. Additionally, it is cumbersome to standardize contextual ES information across various regions, especially where certain ES that are valuable in specific contexts are not necessarily cherished in other contexts.

4.4 Participatory methods

Participatory methods exploring expert opinion and stakeholder knowledge systems and preferences have as of yet received little attention in ES quantification[25]. Yet, it is increasingly recognized that valuation of ecosystem services is highly context specific, and has to be guided by the perspectives and requirements of beneficiaries[38,39] if the ES definition based on 'benefits people derive' is to be taken seriously. Participatory methods are therefore increasingly likely to be used to improve the reliability of data, and to ensure the relevance of outcomes to decision makers. These methods are mainly applicable for quantifying provisioning and cultural (social) ES such as local-livelihood-based forest uses, quantities of traditional medicines and local social networks around ES. In some studies, participatory quantification is equated to group deliberation[24]. Such methods are derived from social and political theory on deliberative democracy through public debates that promote inclusion and equity of various interests in ES. Participatory methods have been applied in various parts of Africa, e.g. in southern Africa[40], to quantify mainly diverse cultural services such as aesthetic and social values. A key experience with participatory methods is that most deliberations are steered towards individual wellbeing, thus making the process highly context-specific and cumbersome to scale-out. In addition, the mapping and deliberations in participatory approaches are usually done in a bottom-up manner (techniques), i.e. taking stakeholder perceptions and views as starting points[41].

Participatory methods have also been applied successfully for biophysical measurements in carbon systems in Tanzania[42] and Southeast Asia[43,44]. In Asia, participatory ('negotiation support') approaches have contributed to local landscape management, with or without explicit PES mechanisms[45,46].

4.5 Challenges to ES quantification

This section highlights some of the ecological and social factors influencing ES quantification by example of agricultural landscapes, which are key sources of ecosystem services in most African and Asian countries (through such processes as soil structure and fertility, nutrient cycling, erosion, pest control and soil retention).

First, the applicability of a particular ES quantification method is limited to regions with similar climatic, edaphic, geographic and taxonomic variables. Agro-ecozones (AEZ) determine the various processes responsible for generating ES. In cases where equations developed in one AEZ are applied to another AEZ, the resulting ES estimates may contain errors that can misinform decisions. For instance, methods used to estimate the biodiversity index in elevated humid zones with altitudes between 2000–2500 m above sea level may not be applicable at lower elevations[47].

Scaling ES measurements geographically and across actors' interests remains a daunting task in ES quantification[48]. ES quantities must be standardized to harmonize the differing measurement units from various ecosystems and to scale up the values. ES preferences also differ between stakeholders at different institutional scales. Evidence reveals that ES that are easily scaled up to a global level (e.g. carbon stocks and biodiversity) often draw the attention in developing quantification methods[49]. This is driven by internationally legitimized PES schemes which seek to harmonize ES quantification nationally and globally. Highly context-specific ES, such as cultural services or social services, are reportedly difficult to upscale[50] and have therefore received little attention in global policy instruments aimed at managing ecosystems. To provide useful information for decision makers, ecosystem services studies should be supplemented by investigations of interactions between ecological processes and societal valuations[41].

Land-use changes over time also complicate ES quantification by altering the chemical and biophysical characteristics of particular landscapes either resulting in difficulties in sampling or new ecosystems that do not resonate with certain methods. For instance, continuous land management practices such as external inputs and removal of land cover types that provide key ecological functions in the landscape may degrade or alter the features of important ES. In Uganda, a study from sub-humid areas in Soroti region[48] revealed that land left fallow generated the highest amounts of carbon stocks compared to areas where grazing and annual crops were intensified. Further evidence from Africa reveals that ES composition and structure decline especially in areas where agricultural landscapes are faced with disturbances such as deforestation, overgrazing and overexploitation[51,52]. Soils of African agricultural landscapes have over time experienced overexploitation and subsequent input intensification, degrading soil nutrients and associated ES[53]. This ultimately impedes the re-application of quantification methods initially applied in such landscapes due to changes in sampling intensity and sample characteristics.

The varying socio-ecological contexts further complicate ES quantification across scales and across various stakeholders' valuations of ES. The challenge of scaling ES across global, national and local levels is that the process does not transform linearly. Various global agreements on ES quantification (e.g. Aichi agreements), land restoration and carbon-emission reduction under the UNFCCC are often broad and require standardized values across regions. While national and global ES quantification needs include green accounting targets for human welfare especially at the local level, this often remains a complex task[12]. Harmonizing ES quantities across scales as well as time factors that determine ES accumulation also complicates quantification. Furthermore, the commonly-used method of GIS and remote sensing for ES quantification for measuring at such scale gives indication of ES structure from which function can be judged. How this transforms into benefits that people get from nature depends on a number of social and economic factors.

Overall, ES quantification in the developing world still faces various challenges, some of which are both technical and institutional and are exacerbated by the complex nature of ecosystems. These ecosystems are highly depended on for social, economic and cultural services resulting in intense use, alteration and preferences in a manner that complicates systematic quantification over time. Thus, there is need to further understand and standardize ES quantifying methods in the changing trends of ecosystem landscapes to inform resilient and adaptive lifestyle development.

4.6 Linking ES quantification to valuation

ES encompass complex relationships that link ecosystems to human and ecological wellbeing across local, regional and global scales. The main approaches to ES valuation are economic, ecological and social[13,33]. ES valuation is interlinked so that the value of one approach depends on the integrity of the other. While the three valuation approaches are recognized and interlinked, the ultimate goal of most ES quantifications is to link various ES to an economic value[54]. Apparently, economic ES value is widely recognized in policy instruments, but there are key concerns about the implications for sustainable ecosystem management.

Policy focus on economic valuation is mainly supported by emerging markets for ecosystem services involving direct or indirect economic rewards. Direct market value refers to the exchange value that an ES has in trade and is mainly applicable to the 'goods', e.g. monetary value attached to the carbon sequestered by forests, to easement of watershed services to a water plant that would pay for the utility of the watershed or even wetlands trading programs that allow owners to sell fishing services to fishermen at specific prices[55].

However, many ES do not have direct market value. In this case, indirect market valuation approaches have been proposed that involve willingness to pay. Economic measures that assign monetary value often provide a more convenient means to make choices than social and ecological values that are context-specific. For instance, the economic value of wildlife reflects the utility value that tourists from other regions would prefer to pay to visit the conservancy, compared to the spiritual (social) value that is confined to localized beliefs and traditions. This perhaps explains why at the international level, policy instruments for ecosystem management are dictated by economic identity and requirements of service beneficiaries[56]. For example, economic ES values are now legitimate as part of carbon markets in the global fight against climate change.

While such economic instruments of ES valuation can be praised for spurring a new wave of public-private partnership in ecosystem management and creating incentives for landowners to manage ecosystems[57,58], questions have been raised on the extent to which economic value represents the real value of ES.

A key inquiry remains on the extent to which economic valuation is useful or even valid. A recent ICRAF study[59] under UNEP-TEEB on valuing ecosystem services in agroforestry systems in Africa found that economic valuation of ES is just indicative at best because of gaps and methodological inconsistencies in quantification of biophysical entities (e.g. soil nutrients and carbon stocks) and uncertainties in time-dependent economic parameters such as price and discount rates.

Additionally, the extent to which economic value accounts for the full range of ES values (ecological, cultural and social) remains widely contested. The relevant ecological information that markets gather and apply tends to be contingent and particularly marginal. Focus has mainly been on the end product, i.e. the ultimate ecological service, with little attention to the intrinsic ecological functions generating these services. For example, market forces (demand and supply) may determine the economic value of a 20-ft timber at $50, reflecting the price people would be willing to pay for the timber. This price mainly reflects the marginal value of the timber plus (perhaps) the costs of delivering it to the market. However, the price likely does not reflect the full extent of ecological value in terms of functions, e.g. soil stabilization, filter functions, flood prevention and microclimate effect of the tree from which the timber is made[60].

This concern is also raised in the ICRAF UNEP-TEEB study[59], which further reveals that economic valuation cannot be used to reflect key ecological functions in agroforestry such as pollination, disease and pest control, resilience, species diversity, habitat enhancement/connectivity and synergy and trade-off in ecosystem service interactions. In other words, the full ecological value of an ecosystem may not be satisfied by money or time. Ideally, market forces that are largely driven by individual preferences are poorly positioned to capture the full value of ecosystems. As markets for environmental services take precedence in steering environmental change, they rarely reflect the ‘reproductive value’, i.e. the ecological functions that are crucial in sustaining these services, and this signals negative implications for ecosystem management for sustainable development (see next section).

Further, the social value of the ES is often unrepresented in the economic measure, yet these social values, e.g. livelihood dependence, cultural services are key in defining ecological quantities for payments.

Social values such as rights, cultural attachments, communal value, spiritual values, indigenous and communal identity, livelihood sharing/networks[47] have received the least attention in ES quantification. These social and evolutionary values lack price tags that could be captured in the economic framework. Social values are complex, sometimes deeply rooted in traditions and beliefs that are difficult to define. While this complexity of social values is often emphasized and used to justify the exclusion of market value of such services, the institutional setting of markets for ecosystem services also tends to constrain opportunities for assigning markets to social values.

For instance, markets for ecosystem services are mainly designed to work effectively with private goods where owners can exclude others in order to deliver the service for payments[1]. Yet, most of the social values of ES are public. For example, the social value of agricultural post-harvest residues that are freely accessed by village members to graze their livestock may not be captured by the market system targeting carbon from such landscapes. Indeed, there is rising recognition that the social values remain an important impediment to design and implement economic policy instruments because the ES that deliver economic returns are vulnerable to social usage by (mostly) poor people who heavily depend on ES for livelihoods[4,61].

Social values such as equity, inclusivity, recognition, ownership and institutional development are crucial for generating ES. Ecosystems management options largely informed by a narrow economic perspective may therefore not effectively deliver. Poverty parameters have been well studied and some level of quantification has been assigned to them, for instance numerous case studies are presented in a review[62] of the empirical link between ES and poverty alleviation. Other social parameters measured with non-economic values include attitudes[48], behaviour[63], local knowledge and norms (decision-making capacity and representation, ownership rights etc.) The empirical case study below provides some insights[64].

4.7 Empirical case of land-based ES valuation

We focus on two projects in Kenya that have been designed to reduce emissions in the land-use sector to illustrate how various ES values are interlinked. first, the *Kasigau Corridor REDD+* project works in Kenya's coastal area to protect over 500,000 acres of dryland forests and valuate the carbon stocks for climate change mitigation. The project proponent is a United States-based private company and engages the local community in conservation and development activities[65].The other case project is the *Kenya Agricultural Carbon project (KACP)*. KACP is one of the first projects initiated by the World Bank to showcase climate-smart agriculture in Africa. Supported by the Bio Carbon Fund (BioCF), the project has worked with 60,000 smallholder farmers in western Kenya since 2008 to implement sustainable land management practices such as agroforestry and soil, water and residue management, all aimed at generating the triple wins[66] of economically valuable carbon, improved yields and climate resilience.

In both projects, ecological (carbon sequestration), economic (carbon credits) and social (livelihoods and rights) values were recognized, but ES quantification was largely driven by economic valuation. For instance, the main quantification was done on carbon through established international standards—the voluntary carbon standards (VCS)—that allow the quantified carbon to be assigned economic values in terms of USD/tonne CO_2. The main driver of this quantification is carbon markets where these projects have to deliver carbon credits to be paid. In this, there is no market value assigned to social services e.g. communal livelihoods, rights, spiritual values (even though they are recognized), thus no deliberate efforts were made to quantify these services because their economic values have gained little institutional support. According to project proponents, the main impediment to quantifying the social and cultural ES is the lack of standardized methods and data for doing so to allow the values to be scaled up to the global level as in the case of carbon.

The paradox is that projects' experiences revealed that social values were most critical in supporting the delivery of the much-needed carbon for economic valuation. The KACP generates carbon from individual household fields where farmers are expected to undertake ecological intensification through climate-smart technologies such as residue incorporation, conservation agriculture, mulching and agroforestry. However, communal use of this land is common practice (social value). This has raised intense conflicts over whether farmers should allow free grazing of land during the dry season or instead conserve residues for carbon sequestration and individual benefit. Such social realities may be overlooked as the commoditization of ES potentially locking out landless tenant farmers and even women and the young (who have no traditional land inheritance rights) from access to and ownership of land resources.

Indeed, the generation of carbon in these landscapes will depend significantly on the social practices that drive ecological processes. On the other hand, the Kasigau project, which has embraced the diverse social values of land ownership systems, is knitting these social values into a trust fund supporting community groups. This has yielded apparent success in delivering carbon from communal lands including group ranches and communal hills because the social cohesion in forest protection (social value) provides a framework for inclusive community participation, simplified negotiations and more inclusive benefit sharing. In the Kasigau case, supporting social values such as communal water projects enhanced the delivery of carbon as more peasants were dissuaded from encroaching on the forests, thus allowing for carbon replenishment for the global market. This indicates that social value is a prerequisite for ecological ES quantities from which economic values are derived.

4.8 Discussion and conclusions

It remains challenging to reconcile economic and ecological criteria for identifying, measuring, and evaluating ES[67]. The implications of ES quantification and valuation are diverse but can be viewed in the context of sustainable development. Sustainable development provides the basis for ecosystem management with collective efforts to spatially and temporally harmonize development with environmental and human wellbeing in a manner cognizant of future needs and ecological limits to economic growth[68]. However, we have shown that ES quantification is driven by economic rewards that do not fully reflect the full ecological and social value of ecosystems. Specifically, the ecological functions that regenerate ecosystem services are not fully captured in the existing quantification methods and subsequent valuations[69]. This has negative implications for managing the regeneration of ES required to serve the needs of current and future generations as envisaged in the sustainable development principle. While ES quantification driven by economic rewards spurs efficiency in ecosystem management, this approach subdues prospects for sustainable development. A narrow focus on ES quantities and valuation may not dramatically alter the ecological functions of a system in the short term but, if sustained, such approaches may push the ecological functioning to the limit.

Box 4.1 What is the value of an Asian elephant?

In the history of Asia, the value of elephants has traditionally depended on the colour of their skin, with 'white elephants' notorious for having high cultural values, but also being expensive in their maintenance costs, if you were given the honour of having to take care of them. Global biodiversity value depends on taxonomic interpretation of elephant diversity. On the island of Borneo a few hundred elephants exist, most likely as feral populations, escaped from captive court elephants of the Sultan of Suhu, a few hundred years ago. These elephants do considerable damage to forests and oil palm plantations, and are negatively appreciated locally. As feral animals (escaped 'invasive exotics') their global biodiversity value was seen as negative as well. Until, DNA analysis showed that these populations are different from both the mainland Asian and Sumatran subspecies of the Asian elephant, and sufficiently different to be named as a third species (beyond African and Asian elephants): pygmy elephants. The species is highly endangered (only a few hundred individuals remain) and represents the highest conservation value. They may well be the only *ex situ* survivors of a Java elephant, that became extinct in the 15th or 16th Century. Their local value has not (yet) changed by this taxonomic reinterpretation – but there are now new options to make them part of 'ecotourism' efforts. Value partly depends on what these animals do, but much more so on how they are portrayed.

From the analysis and the empirical examples, we have seen that the development of ES quantification methods in PES is mainly influenced by institutional conditions. Existing PES efforts usually structure ES quantification prioritizing services with internationally-supported economic values. The ease of quantification, availability of data and scaling up are critical in supporting ES quantification and subsequent assignment of values that can be reasonably applied across local, national and international levels. Methods must be developed to quantify social and cultural services[70] if they are to gain legitimacy in international and national policy agendas.

This is critical, given that the successful delivery of marketed services depends largely on the social value that people who depend on these services place on ecosystems. Such value can be enhanced through partnerships in ecosystem management projects and through research institutions that can enhance the accessibility of existing data, methods and capacity.

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