In cooperation with:

Assessing the use of forest ecosystem services analyses as a national policy-making tool in Peru

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KEY MESSAGES

- We draw on an original study of forest ecosystem services in the Peruvian Amazon to assess the use of these types of analyses to guide national forest policy.

- The study used a land change model to project land use change in two watersheds for the year 2023 in three scenarios with differing degrees of ambition in environmental policy, and a biophysical model (InVest) to quantify three ecosystem services: water nutrient and sediment retention, and carbon sequestration.

- Results from the model suggest that deforestation and loss of ecosystem services are likely to occur in all scenarios, but that decisions about environmental policy and compliance do make a difference. Although no direct valuation of ecosystem services was attempted, secondary data suggests that the loss of ecosystem services in these two watersheds is likely to result in considerable economic losses both locally and regionally.

- The use of scenarios and models to quantify ecosystem services provides insights that can be valuable for land-use planning at local to regional levels to identify or prioritize critical areas for conservation. The use of these tools at the national level is constrained by time and data, but they could be usefully deployed in watersheds that involve several municipal or provincial jurisdictions.

- The economic valuation of ecosystem services is highly variable and context specific, and should therefore be used with caution. Rather than exact prices, valuation estimates can provide a sense of the magnitude of different policy options -including that of no action.

- For an individual user with short-term economic thinking, the conversion of forest land to agriculture in the Amazon basin appears to make economic sense in a hectare to hectare comparison. Only a valuation that captures the large-scale, long-term benefits of forest ecosystem services to society at large is likely to provide the correct incentives to reduce deforestation.

1. Rationale and purpose of this paper

"Ecosystem services" has become a common term in the world of environmental policy and research, and it's easy to understand why. It offers a simple way of understanding complex things. By using the language of economics and markets, the environmental agenda has been pushed much closer to the mainstream than ever before. An ecosystem services approach can help make visible the costs and benefits of human actions. Quantifying and valuating specific services such as water purification or carbon storage can help assess how much natural systems contribute to economic production or human welfare, and at the same time understand how human actions affects natural systems.

These characteristics make ecosystem services a potentially important tool for policy making. In fact, the quantification of specific services and the evaluation of their projected changes through time have been used successfully to inform decisions about land use and the establishment of payment schemes in some real-life cases.[1] However, the

[1] For examples, see Ruckelshaus *et al.* (2015). Notes from the field: Lessons learned from using ecosystem services approaches to inform real world decisions. Ecological Economics 115: 11-21. Available online at: http://www.sciencedirect.com/science/article/pii/S0921800913002498.

impact of ecosystem services quantification and 3 valuation on public policy is still rather limited: in most cases these assessments serve to inform the debate and raise awareness, but they are not used systematically for decision-making.[2] Moreover, quantifying and valuing ecosystem services is a data- and time-hungry enterprise that works best within a limited geographical area and a small number of well-known services–and the results are often good approximations at best.

So while the idea of ecosystem services is appealing for policy-makers, it's not clear whether or how an ecosystem services perspective may be useful to guide national-level policy making, including the development of broad strategies for the sustainable use and conservation of forest. We know that an ecosystem services perspective can be useful to inform relatively small-scale land use planning decisions; but can it be scaled up usefully? And if so, how?

In this paper we draw from an original study of ecosystem services in two watersheds of the Peruvian Amazon to assess if and how an ecosystem services perspective may be a useful tool for national-level policy making. Peru is a forest-rich and megabiodiverse country, but the forest sector (i.e. the production of timber and non-timber forest products) contributes less than one percent of the GDP, and deforestation is the leading cause of greenhouse gas emissions,[3] in addition to eroding natural capital and the ability to sustain the provision of goods and services. The ecosystems services perspective thus provides an attractive way to capitalize on the nation's forest resources while at the same time boost conservation efforts.

In this document we:

- Provide an overview of the key concepts and methods of ecosystem services approach, assessing its potential and challenges to its implementation;
- Discuss the motivations, interests and initiatives of the Peruvian national government to include ecosystem services in national policy, particularly in the context of the National Forest and Wildlife Plan (NFWP);
- Use a case study of physical quantification of ecosystem services in two watersheds in the Peruvian Amazon to assess changes in land cover and the provision of forest ecosystem services in three scenarios to 2023; and
- Draw from the case studies to evaluate the limits and uses of the ecosystem services approach, as well as to propose ways in which such an approach may be scaled up and used in national-level policy making.

Our main claim is that ecosystem services provide a useful concept for thinking about forest policy. The notion of ecosystem services is potentially very important as rough guide to the magnitude of costs and benefits of political decisions, rather than for the precise quantification of specific ecosystem

[2] Laurans *et al.* (2013). Use of ecosystem services economic valuation for decision making: Questioning a literature blindspot. Journal of Environmental Management 119: 208-219.

[3] MINAM & MINAG (2011). El Perú de los bosques. MINAM & MINAG: Lima. http://cdam.minam.gob.pe/novedades/elperudelosbosques2011.pdf;

SERFOR (2013). Perú Forestal en Números 2013. SERFOR: Lima.

PlanCC (2013). Actualización del Inventario Nacional de Gases de Efecto Invernadero al año 2009. http://www.planccperu.org/IMG/pdf/actualizacion_del_inventario_29-08-2013.pdf services, which is too tentative and context specific to be scaled up directly.

2. Understanding and accounting for ecosystem services

Ecosystems provide multiple services such as clean water, breathable air, pollination, and fertile soils, to name a few, which are essential for human economies and societies. These services are provided free by nature and are generally not accounted for in economic terms. At the same time, human activities have multiple impacts on the ability of ecosystems to function properly and to continue providing these services, which comes at a cost, even if these costs are not immediately obvious in our economic calculations. Economists refer to these unaccounted impacts and benefits as externalities, and there is a growing recognition that making these externalities visible is an important part of managing natural resources more sustainably. Showing the value hidden in the complex processes of ecosystems and the costs that we would have to incur to replace it may serve to create the right incentives to protect those ecosystems.

Forests ecosystems are a particularly important source of benefits to human society, both in the form of goods and services.[4] Forests provide goods like timber and are a host of other raw materials–many of them probably yet to be identified–as well as fuel for millions of people. In addition, they perform key functions such as water and carbon cycles regulation, and provide habitats for thousands of species. Forests also provide a space for tourism, recreation and many forested areas have cultural or religious value for local communities.

There are different approaches to including the costs and benefits of human activities on ecosystem services into economic practices.

One way is to value the natural capital, which means "the stock of natural assets that provide society with renewable and non-renewable resources and a flow of ecosystem services, the latter being the benefits that ecosystems provide to people".[5] The World Bank and the United Nations have established the System of Environmental-Economic Accounting (SEEA) to incorporate and systematize natural resources into country's national accounting through add-on or so-called "satellite accounts".[6] A similar initiative, Wealth Accounting and the Valuation of Ecosystem Services (WAVES) is working with a number of pilot countries to set up and mainstream environmental accounting.[7] Environmental accounting is most often used to tally stocks of non-renewable or renewable natural resources, such as coal reserves or fisheries, but more recently some attempts have been made at accounting the services, rather than only the goods, which are provided by ecosystems such as forests. Two examples for ecosystem services whose accounting has been receiving much attention are recreation and the provision of drinking water.

The accounting and valuation of natural resources has led, in some instances, to the possibility of set-

4 World Bank (2015). Trees: Not Just for Tree Huggers. http://www.worldbank.org/en/news/feature/2015/03/20/trees-not-just-for-tree-huggers.

5 Russi D. and ten Brink P. (2013). Natural Capital Accounting and Water Quality: Commitments, Benefits, Needs and Progress. A Briefing Note. The Economics of Ecosystems and Biodiversity (TEEB).

6 http://unstats.un.org/unsd/envaccounting/seea.asp

7 http://www.wavespartnership.org/en

ting up systems through which the beneficiaries of ecosystem services compensate those who ensure that those services can be provided–for example, the users of water downstream may compensate those who protect forests upstream. These payments for ecosystem services (PES) may also be made by those who exploit ecosystem services–for example through pollution–to try to redress some of the costs associated with their depletion. Currently PES can be based on market mechanisms–meaning that the market decides how much the services are worth, such as carbon exchanges–or through other means of payment such as direct transfers or subsidies for watershed protection. Reducing Emissions from Deforestation and Forest Degradation (REDD) is a wellknown PES mechanism through which payments are made to compensate for carbon sequestration through avoided deforestation.

The ability to incorporate the value of ecosystem services into national accounting or through incentives for conservation has been buttressed by the development of better and more accurate ways to quantify and monitor ecosystems and the products and services they provide. The Millennium Ecosystem Assessment,8 the first comprehensive survey of global ecosystems, was in good part possible due to the existence of land cover data for all corners of the planet from satellite images. Ecosystem services approaches such as the one described above require measuring and quantifying stocks and flows of natural resources, such as the biomass of a forest or the amount of carbon released by decaying matter. Our understanding of ecosystems services is necessarily partial: to quantify them, we need to simplify things that are complex. A simple stock and flow view of ecosystems misses interactions and feedbacks between different parts of the system, and between different services.

Even as we have become better at tracking and quantifying ecosystem services, assessing their economic value is a different thing altogether. The economic valuation of ecosystem services hinges on their relationship to human activities. The old conundrum "If a tree falls in the middle of a forest where no one is present–does it make a noise?" applies here too. For an ecosystem to provide a service there must be a beneficiary, and the size of the benefit must be measurable. An additional layer of complexity lies in the geographic distribution of beneficiaries: while some services, such as water retention, can be clearly assigned to a specific user group in a watershed, other services, such as carbon sequestration, benefit the international community as a whole. Moreover, religious and cultural values are particularly difficult to estimate in economic terms.

There is a wide range of economic valuation methods to quantify ecosystem services. Because most ecosystem services are not (commonly) traded in the market, and hence have no market price, most valuation methodologies involve assessing how much people are willing to pay for a certain service, or how much it would cost to replace a service that is provided free by nature. Much of the current knowledge about the values of ecosystem services has been systematically collected and synthesized by TEEB–the Economics of Ecosystems and Biodiversity– project[9] (See Box 1). As we will discuss below, it is important to understand that the values of a specific ecosystem service in a specific geographical area are highly context-specific and cannot be simply extrapolated to other areas.

8 http://www.millenniumassessment.org/en/index.html

9 http://www.teebweb.org/

In addition to the actual quantification and valuation of ecosystems, there is a debate about how to use that information, and how useful it is to inform policy. For example, some fear that because it reduces complex systems to simple models, the ecosystem services approach must focus on single services–such as carbon sequestration–to the detriment of a more comprehensive view of the ecosystem. For example, carbon sequestration goals may be met by destroying biodiversity. The economic valuation of some services is also neutral to distribution issues, that is, it does not take into account the distribution of the costs and benefits of ecosystem services and their depletion.

In sum, although there have been a lot of advances in understanding and valuating ecosystem services, the current data is at best a very gross estimate, and should be used with caution. Rather than using the quantification and valuation of ecosystem services as a means to creating fully functioning markets, there is more promise in using them instead as tools to nudge the market towards more desirable outcomes.[10]

Box 1. Ecosystem service valuation: data from the Economics of Ecosystems and Biodiversity (TEEB)

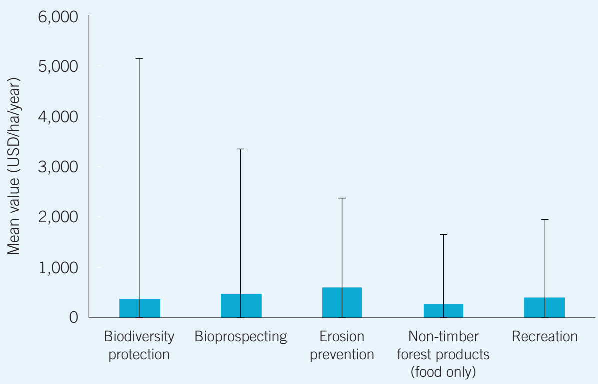
TEEB has compiled data from a large number of studies worldwide, using several different methodologies for ecosystem valuation. The TEEB data shows that there are great differences in the values assigned to ecosystems, owing to discrepancies of the benefits estimated, as well as the definition and physical quantification of the ecosystem service itself. For example, some services are calculated in money by hectare by year, while others use different spatial and time scales.

To illustrate the challenges of using ecosystem valuation data, we consider the estimates of the values of tropical rainforest ecosystems. Of the 1492 data entries in the TEEB database, only 237 are for this type of biome. Although more than a dozen ecosystem services are included, most of them only have one or two estimations for each service.

In Figure 1 below we present the estimates of five ecosystem services for tropical rainforest ecosystems. We have included only services for which there are at least 10 estimations, and for which those estimations are comparable because they use the same units.

Two things are evident from the TEEB data: first, the definitions of different services and the methods for quantification are quite different from one study to the other, which make comparisons across countries and studies difficult. Second, even when the data is broadly comparable, there is a very wide variation in estimates, ranging from only a few cents to thousands of dollars per hectare per year. Such differences suggest that the data must be used cautiously.

Figure 1. Mean values of selected tropical forest* ecosystem services in TEEB database**



* Van der Ploeg, S. and R.S. de Groot (2010). The TEEB Valuation Database – a searchable database of 1310 estimates of monetary values of ecosystem services. Foundation for Sustainable Development: Wageningen. http:// www.fsd.nl/esp/80763/5/0/50.

** Included are only services that have 10 or more data entries in the TEEB database; values are in 2007 US Dollars; brackets show maximum and minimum values.

[10] Muradian, R. and Rival, L. (2012). Between markets and hierarchies: The challenge of governing ecosystem services. Ecosystem Services 1 (2012): 93-100. Op. cit.

3. Forest ecosystem services in Peru

Peru is a particularly interesting case to study forest ecosystem services. With over 73 million hectares of forest, Peru has some of the largest reservoirs of tropical forests in the world.[11] Furthermore, the topic of ecosystem services has been receiving increasing attention by policy-makers over the past years, and a number of pilot projects on payment for ecosystem services have already been established. However, deforestation is slowly but steadily eroding the country's forest resource: between 2000 and 2013, Peru has lost an average of some 113 thousand hectares of forest a year, especially through conversion of forests to agricultural land.[12]

The loss of ecosystem goods and services to deforestation, although widely acknowledged, is difficult to quantify. And while some progress has been made in recent years, an ecosystem services approach has not been yet systematically used to inform forest policy. There are at least three reasons to explain this. First, a lack of adequate data of the physical variables, which does not allow for a very systematic way to monitor or track ecosystem services at large scales. When ecosystem services have not been quantified, it is impossible to determine their economic value and establish payment schemes. An ecosystem service which has received more attention than others is forest carbon storage, an initiative fueled by a variety of state and non-state initiatives on REDD+. Therefore, the data availability on forest carbon is arguably better than on most other ecosystem services in Peru.

Secondly, the valuation of natural resources tends to focus on direct, short-term benefits, and this works against large parts of Peru's forest resources. The country's main economic and population centers are separated from the Amazon basin by the Andes, a mountain range with altitudes of over 6,700 meters which divides the country from North to South. Thus the direct beneficiaries of the services provided by forests in the Amazon region are either less obvious–for example, the climate regulation of the Amazonian biome probably benefits everybody in the world–or less central to Peru's economic growth–this includes a considerable part of the 3.6 million Peruvian living in the five Amazon regions, and in particular over 300,000 indigenous people in the Amazon who depend on forest resources.[13]

Thirdly, even though the government is interested in the ecosystem services approach and concrete steps have already been taken, the policies and institutions to implement it are still work in progress. A Law on the Mechanisms of Payment for Ecosystem Services was passed in 2014; while it has yet to be fully implemented, it has already opened important possibilities for implementing initiatives involving ecosystem services, particularly water-related ones. Moreover, the Ministry of the Environment (MINAM) has established a Directorate General of Evaluation, Valuation and Financing of Natural Assets, an information hub and catalyst for public and private initiatives on ecosystem services which seeks to eventually establish a national environmental accounting system. In addition, the recently created National Forest Service (SERFOR)

[11] MINAM & MINAG (2011). El Perú de los bosques. MINAM & MINAG: Lima. http://cdam.minam.gob.pe/novedades/elperudelosbosques2011.pdf

[12] MINAM (2014). Mapa de bosque y no bosque del año 2000 y mapa de pérdida de bosques húmedos amazónicos del Perú 2000-2011; MINAM & MINAGRI (2014), según MINAM (2014). Informe de consultoría: Estrategia Nacional de Bosques y Cambio Climático (Documento Base). Inédito.

[13] MINAM & MINAG (2011). El Perú de los bosques. MINAM & MINAG: Lima. http://cdam.minam.gob.pe/novedades/elperudelosbosques2011.pdf INEI (2015). Población total según departamentos. http://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib0015/cap-51.htm

has showed interest in considering payment for ecosystem schemes in complementary norms to the Forest Law Regulation as well as the National Forest Plan, but the objectives and procedure have not been defined at this stage.

In conclusion, the political climate has created a demand for an ecosystems services approach at the national level in Peru, but the supply side–in the form of actual quantitative evidence on the physical and economic values of ecosystems–is still quite thin.

4. Forest ecosystem services in two watersheds in the Peruvian Amazon: data and methods

Our work was carried out in the context of our support to the Peruvian government for the development of the National Forest and Wildlife Plan (NFWP), which is being led by the Peruvian National Forest Service (SERFOR). This plan is the last in a series of new instruments, including the Forest Law (issued in 2011), aiming to update and improve the legal framework for the sustainable use and conservation of forests in Peru. Central to our support for the development of the NFWP is a broad diagnostic of the forest sector economy, including an assessment of production in natural and planted forests, tourism, REDD, timber value chains, deforestation, smallholders on the forest frontier and social inclusion in the forest sector. The objective of our analytical work is to enhance the information base of key topics of Peru´s forest sector, and thereby enable that informed decisions on the NFWP can be taken. Our work is thus not focused narrowly on ecosystem services, but rather aims to assess how an ecosystem services perspective may enrich the view of the forest economy, and how it may be useful to inform forest policy in a comprehensive way.

For the purposes of our diagnostic, full examination of forest ecosystem services at a national scale was not possible due to data and time constraints. On the other hand, we wanted to avoid the so-called benefit transfer method, which is to use average per-hectare values–such as those in TEEB–calculated elsewhere and simply transferring them to the Peruvian context. We thus settled for an intermediate option: detailed case studies of forest that are representative of a large part of the forest surface and its development patterns in Peru, and that illustrate rather different stages in their colonization and deforestation histories. Our studies used much of the available physical data, so we could capture specific geographical details without losing view of the general type of ecosystem.

We partnered for the analysis with The Nature Conservancy (TNC), which has been part of a group of institutions developing a model for quantifying ecosystem services called InVest, a tool that was also recently used in an regional-level study of ecosystem services and natural capital in the island of Borneo.[14] Our analysis assesses changes to the land cover and provision of ecosystem services in two watersheds under three future scenarios. The focus is on quantifying the flows of ecosystem services rather than on economic valuation, largely due to the limited amount of data. As we shall see below, we use some economic valuations to illustrate the magnitude of ecosystem services loss due to land use change rather than to provide precise monetary measurements.[15]

[14] Van Paddenburg *et al.* (2012). Heart of Borneo: Investing in Nature for a Green Economy. WWF Heart of Borneo Global Initiative, Jakarta.

[15] The methods and results reported here are a summarized version of a report prepared by TNC. The full project documentation is available at http://www.gggi.org

4.1. Selection of ecosystem services

The study focuses on three forest ecosystem services: water purification, filtering of sediments, and carbon sequestration (Table 1). The selection of these three services, among the many others that are provided by forest ecosystems in Peru, was made for two reasons. First, because they are essential services which have a considerable current or potential impact on the economy. And secondly, because they are measurable in a more reliable way than others. Some other ecosystem services–such as the contribution of pollination to crop production– are a lot more difficult to measure than the ones we use.

4.2. Selection of the study areas

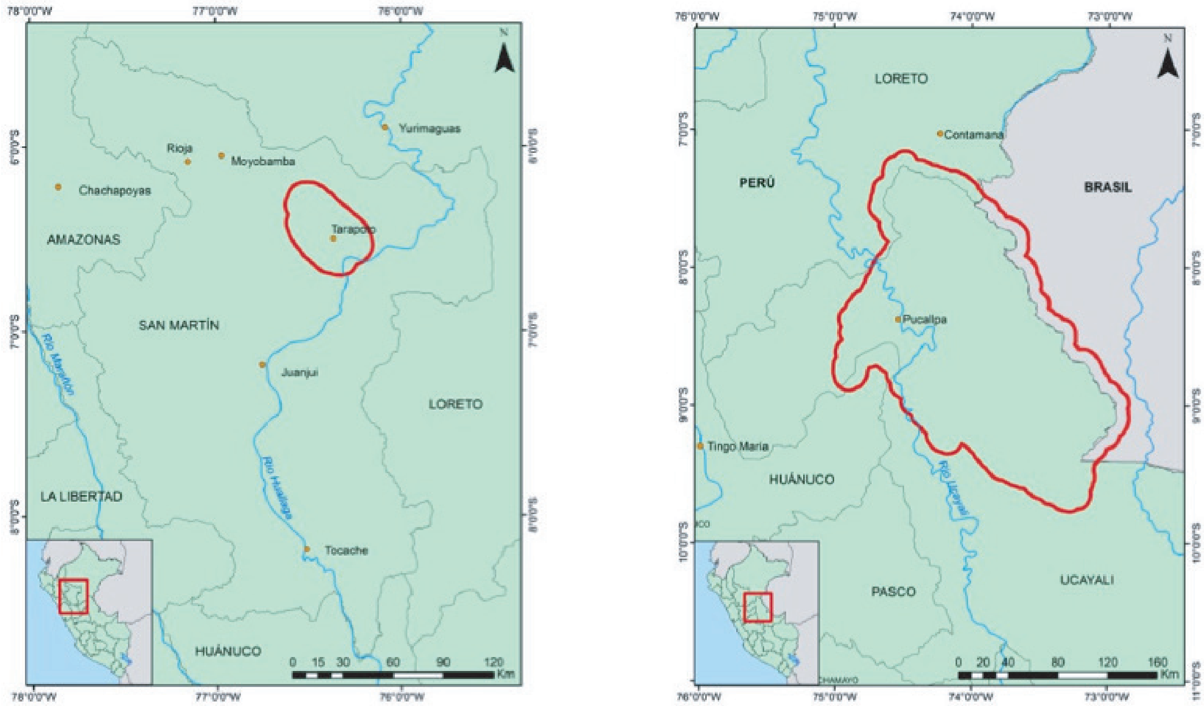
The research was carried out in two watersheds of the Peruvian Amazon region (Figure 2) which exemplify two types of typical trajectories in the Peruvian Amazon. The study areas have some broadly similar characteristics, but also enough differences in the type of vegetation, geography, colonization history and environmental management to make them distinct from each other. The selection also responded to practical reasons: enough physical data to carry out the modeling exercise is available for both areas, and TNC has well established networks of local support and information.

The first study area is the Cumbaza River watershed (hereafter “Cumbaza”), which is located in the San Martín province. It is a relatively small (200,000 hectares) area but it has significant population of farmers, indigenous communities, and urban dwellers – all of which depend on the ecosystem services provided by the watershed, particularly water for agriculture and domestic use. Furthermore, a part of the Regional Conservation Area (ACR) Cordillera Escalera is located in this basin. This area has long been colonized, and large parts of the watershed have already been converted to agricultural land. The second study area includes the much larger Sierra del Divisor Conservation Area (hereafter “Sierra del Divisor”), spanning some 3 million hectares over the watersheds of the Lower Ucayali River and the Tamaya River. This area provides various ecosystem services to indigenous populations and smallholder farmers, as well as water for the city of Pucallpa. Although the area of Sierra del Divisor is relatively well preserved, there are currently several infrastructure projects such as roads or railways which aim to link the region to national and regional markets, as well as increasing pressure on forests from the expansion of commercial agriculture.

Table 1. Description of the ecosystem services analyzed for this study

Ecosystem service	What is it?	How is it measured?	Why is it important?
Water purification	Removal of the nutrients nitrogen and phosphorous which enter the waterways	Quantity (kg) of nutrients per year	Excessive nitrogen and phosphorus can lead to water eutrophication, which affects fish stocks and may be harmful to human health
Filtering of sediments	Removal of solid particles in the water runoff which flows from higher altitudes	Quantity (ton) of sediments per year	When accumulating, sediments may increase the costs of treating drinking water, damage hydropower turbines, reduce reservoir capacity, or affect fish stocks
Carbon sequestration	Removal of carbon from the atmosphere to convert it to organic matter	Quantity (ton) of carbon captured per year	The excessive accumulation of atmospheric carbonis one of the major causes of climate change

Figure 2. Study areas: Cumbaza (left) and Sierra del Divisor (right)



4.3. Methods for quantifying ecosystem services

The quantification of ecosystem services was done through the use of two models (Figure 3). The first is a land use change model which projected the trends of changes in vegetation cover–mainly deforestation–to the year 2023. To make the projection, the land change model used several inputs: a) land use change patters for the period 2003-2013, quantified using satellite images for the two years; b) the state of different physical variables such as the gradient and altitude; and c) the distance to the centers of human intervention such as cities, roads, infrastructure projects, as well as other variables that were shown to have a direct effect on land use change for the period 2003-2013. The impact of these variables on deforestation was studied under three possible future scenarios: business as usual (BAU), sustainable development, and non-sustainable development (see Section 4.4 and Table 2).

The second model is InVest, a biophysical model which calculated the flow of ecosystem services in the study areas for each of the projected scenarios for 2023. The model is spatially explicit: this means that it produced maps showing the concentration of the different variables within each of the two watersheds for the three scenarios, as well as quantitative summaries of the changes to the state of the variables. InVest uses the following inputs: a) data on land use change (from the land change modeler described above); and b) physical data of the watershed, including, slope, soil composition and precipitation, among others. The more detailed the physical data, the more precise the quantification of the ecosystem service.

4.4. Developing the three different land use scenarios for future projections

The projections of land use change (mainly deforestation) and the flows of ecosystem services are based on assumptions about the variables which are known to drive deforestation, such as the construction of roads. For our study we defined three future scenarios based on different levels of ambition and com-

Figure 3. Diagrammatic summary of the two models used to quantify ecosystem services

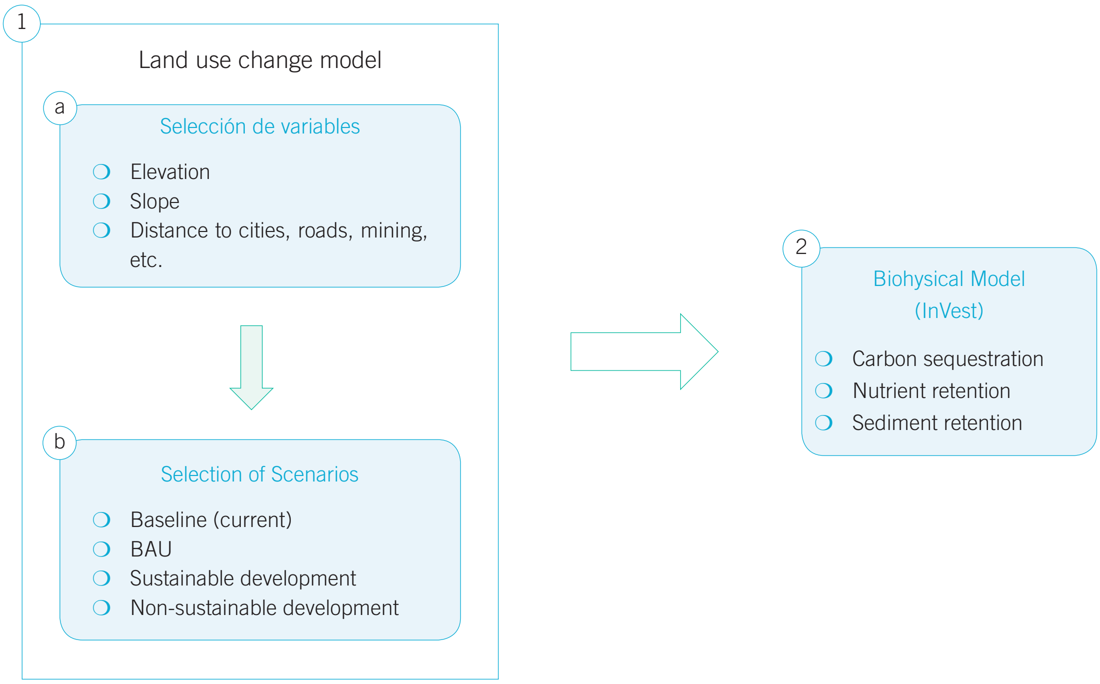


Table 2. Description of the three future scenarios used for this study

Topic	Current environmental policy (“Business as usual”)	Ambitious environmental policy and compliance (“Sustainable development”)	Lack of ambition and compliance in environmental policy (“Non-sustainable development”)
Agricultural policy	Continuation of current policy	Agricultural policy is fully in line with environmental laws	Promotion of oil palm and other crops that aggravate the deforesta-tion of primary forests
Environmental laws and environmental governance	There are partial deficiencies in the effectiveness of the state, and environmental laws are partially met	There is compliance of current environmental laws, and in addition, supplementary rules apply	There are critical gaps in environmental governance, and current environmental laws are not complied with
Spatial planning tools	Non-binding	Binding	Non-binding
Guidelines for payment forecosystem services	Do not exist or have not been approved	Have been approved and are functioning	Do not exist or have not been approved
Large-scale infrastructure projects	Neither the exploitation of oil in Cumbaza nor the construction of roads such as the Pucallpa-Cruzeiro do Sul Highway are implemented	Neither the exploitation of oil in Cumbaza nor the construction of roads as the Pucallpa-Cruzeiro do Sul Highway are implemented	Oil is exploited in Cumbaza, and roads such as the Pucallpa-Cruzeiro do Sul Highway are constructed
Deforestation in protected areas and indigenous communities with land titles	Low compared to other areas	Low compared to other areas, and the probability of deforestation is 50% lower than in the BAU scenario	Low compared to other areas, but the probability of deforestation is 50% higher than in the BAU scenario

pliance with environmental policy: one that follows current trends in environmental policy ("business as usual", or "BAU"), one that assumes ambitious environmental policy and good compliance ("sustainable development"), and one that assumes both low levels of ambition in environmental policy and poor compliance ("non-sustainable development") (Table 2). The scenarios are projections about the future state of those variables, and different projections result from assigning different probabilities of change from one type of land cover to another. For example, the probability that some forest area will be converted to agriculture is assumed to be lower in the sustainable development scenario than in the non-sustainable development scenario because a stricter environmental regulation may prevent the expansion of a particular access road. These probabilities were based on the consultation of existing literature. In addition, we carried out two workshops with regional governments and stakeholders to better understand local drivers of land use change. Further discussions with national-level government officials allowed us to complement and refine the policy components of the different scenarios.

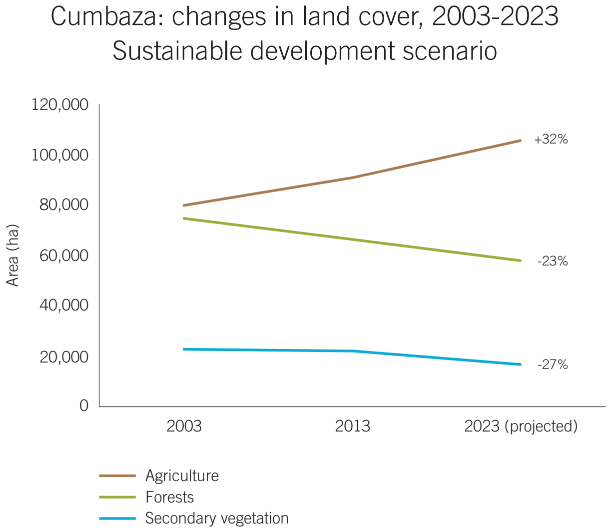
5. Main findings

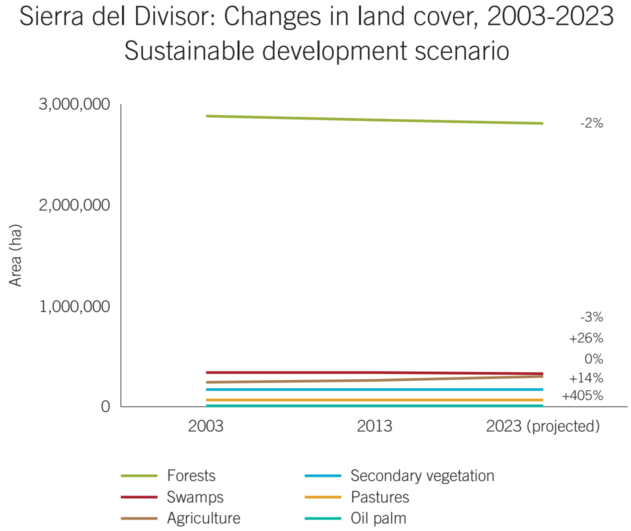
According to the projections of the land use change model, by 2023 deforestation will increase in both watersheds in all three scenarios. The InVest analysis shows that, as a result, the provisioning of forest ecosystems will be deteriorated, namely: the amount of nutrients and sediment exported by the system will increase, and the amount of carbon sequestered will decrease (Figure 6). Policy changes, represented in the future scenarios, have an important influence on the future provision of ecosystem services. We elaborate on these main findings below.

With regard to land use change patterns, we found that in both Sierra del Divisor and Cumbaza forest cover is mainly lost as a consequence of an increase in agricultural area. This loss occurs under all three future scenarios (Figure 4).

In absolute terms, deforestation is higher in all scenarios in Sierra del Divisor (between 43,000 and 75,000 hectares deforested) than in Cumbaza

Figure 4. Land cover change patterns in the two study areas under the sustainable development scenario, showing the projected percentage change from 2003 to 2023. *Even though the deforested area is larger in Sierra del Divisor, the deforestation rate is much higher in Cumbaza. It is notable that in both areas, the forest area reduces even under the sustainable development scenario.*





(approx. 9,000 hectares deforested), which is expected given that Sierra del Divisor is more than ten times the size of Cumbaza. However, in relative terms, deforestation is much higher in Cumbaza (approx. 13%) than in Sierra del Divisor (2%) over the 10-year period. This is possibly due to the high historic deforestation rates which have occurred in Cumbaza. Figure 5 shows that already in 2003 agriculture covered a larger area than forests, and that trend has increased in 2013 and 2023.

The difference of the three land use cover change scenarios is more pronounced in Sierra del Divisor than in Cumbaza (Figure 4). The reason for this is that the main loss of projected forest cover in Sierra del Divisor in the non-sustainable scenario occurs along the proposed route of the Pucallpa – Cruzeiro do Sul highway and railroad. Roads are projected to be the main drivers of deforestation in the Peruvian Amazon,[16] so it is likely that this infrastructure project explains the observed differences between BAU and sustainable development (which have no road) and non-sustainable development (which has a road).

Deforestation patterns vary according to different land use categories. For example, even though Protected Areas account for more than 20 percent of the surface area in both Cumbaza and Sierra del Divisor, they contribute only 1% to the total projected deforestation of these watersheds in the three scenarios (Table 3). This could be taken as evidence of the effectiveness of protected areas in stopping deforestation, but the underlying explanation would not be so transparent with regards to land titled to indigenous communities–why is deforestation in indigenous lands so high in Cumbaza but almost inexistent in Sierra del Divisor?–or set aside for timber production. In these cases factors other than land use planning, such as the effect of existing infrastructure or the different historical trajectories of indigenous communities in both areas, might play an important role. What does appear to be the case in both watersheds and for all three scenarios is that deforestation is consistently lower in areas that have been assigned a land use category, and conversely, higher in unassigned areas. This result is consistent with other studies suggesting that deforestation in Peru is relatively low in areas whose land use category is clearly defined.[17] The mere existence of a clear land use definition might be a powerful tool to incentivize forest conservation.

The results of the InVest model show that by 2023 there is a projected net loss of the three ecosystem services studied in all three scenarios. As expected, the largest loss in the provision of ecosystem services occurs under the non-sustainable development scenario, and the smallest loss under the sustainable development scenario; the BAU scenario gives intermediate results (Figure 6). As was the case for the land use change, the differences between scenarios tend to be higher in Sierra del Divisor than in Cumbaza, owing largely to the likely impact of the Pucallpa-Rio do Sul road.

The loss of ecosystem services reflects–but doesn't replicate–the patterns of land use in the two watersheds. The InVest model shows that the same amount of deforestation in two areas can have very different effects on the provisioning of ecosystem services de-

[16] Dourojeanni, Marc et al. (2009). Amazonía peruana en 2021. Explotación de recursos naturales e infraestructura: ¿Qué está pasando? ¿Qué es lo que significa para el futuro? Lima: ProNaturaleza; SPDA; DAR; ICAA.

[17] BID. (2012). Plan de Inversión Forestal, Componente III: Elementos para la identificación de áreas con mayor potencial para reducir emisiones de GEI en el sector forestal. Lima, Perú / Helsinki, Finland: Banco Interamericano de Desarrollo - Fondo Estratégico sobre el Clima.

Gráfico 5. Change of area of the different land cover types of the two study areas projected for 2023 under three scenarios (BAU, sustainable, non-sustainable). *The difference between the two scenarios is much stronger in Sierra del Divisor.*

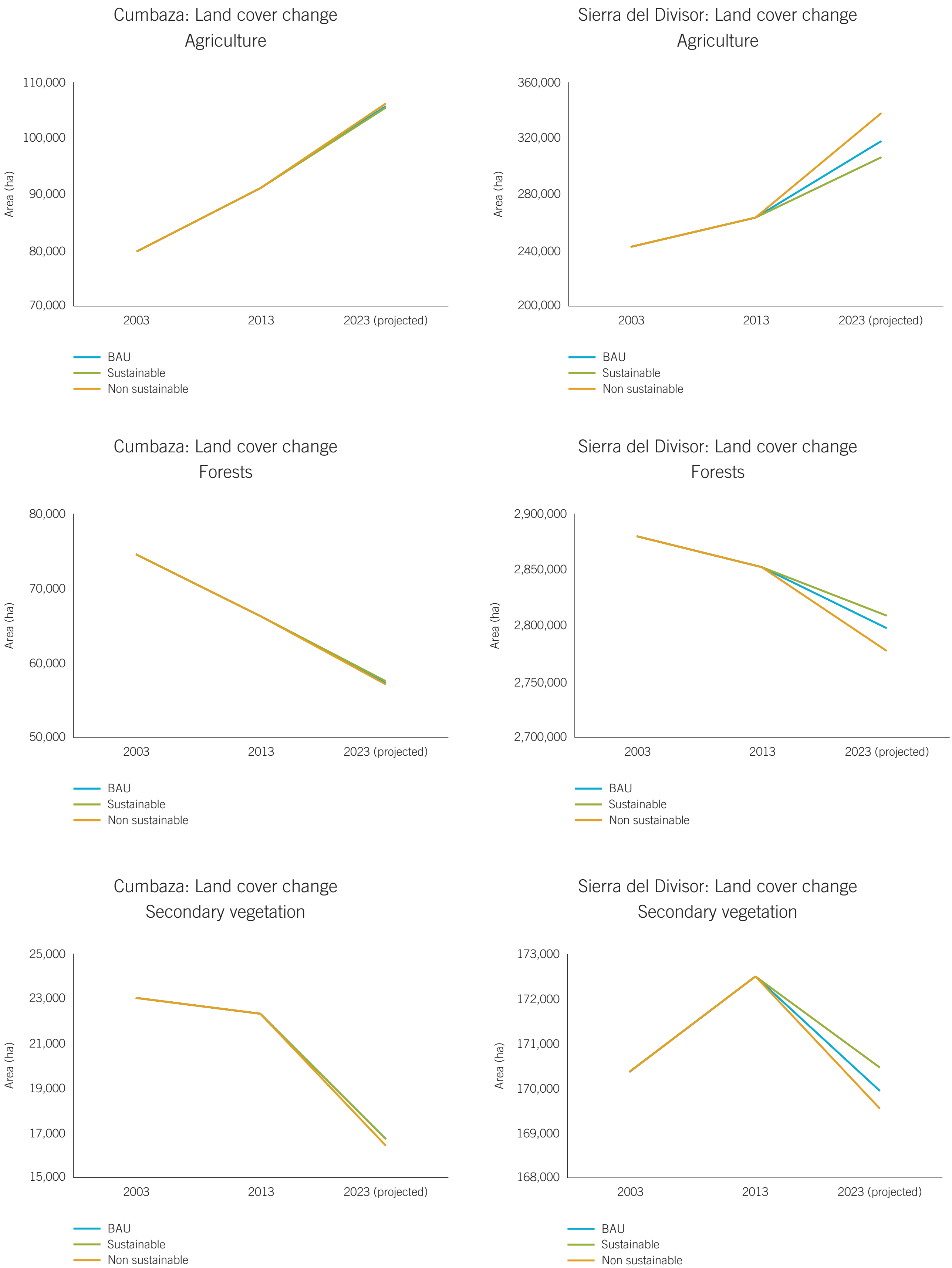
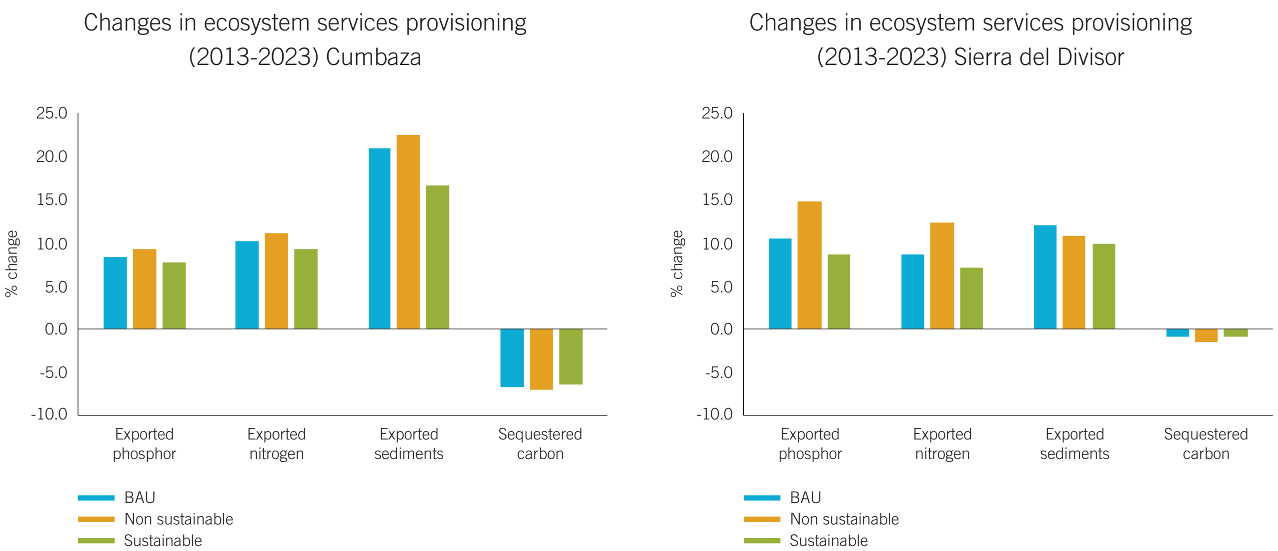


Table 3. Deforestation rates in different land use categories under the three scenarios 2013-2023*

Land category	Cumbaza				Sierra del Divisor			
		% of total deforestation				% of total deforestation		
	% land in this category	Sustainable	BAU	No sustainable	% land in this category	Sustainable	BAU	No sustainable
Protected areas	23%	1%	1%	1%	21%	0%	0%	0%
Native communities	15%	37%	44%	47%	8%	0%	>1%	>1%
Production forests	-	-	-	-	42%	19%	21%	37%
Total Assigned Areas	38%	39%	46%	48%	71%	19%	21%	37%
Total Non-assigned areas	62%	61%	54%	52%	29%	76%	74%	63%

* "Non-assigned areas" refers to areas that do not have an official land use category such as protected areas or native communities.

Figure 6. Percent change in ecosystem services provisioning, projected for the period 2013-2023 over the 2013 baseline, in three different scenarios



pending on the location of those areas. For example, the loss of the forest's ability to retain sediments is exacerbated when deforestation takes place in areas with steep slopes, relative to flatter areas.

The scenario modeling exercise suggests that there are measurable differences in the effects of alternative policy decisions. In both study areas, the non-sustainable development scenario accelerates the process of loss of ecosystem services, while the sustainable development scenario slows it down regarding business as usual (Table 4). For example, the quantity of phosphorous exported in ten years from the watershed of Sierra del Divisor under the BAU scenario would be exported in only seven years under the non-sustainable development scenario.

Table 4. Number of years in which the same amount of ecosystem services lost in the BAU scenario in 10 years would occur under the sustainable and non-sustainable scenarios

Study area	Ecosystem service	Non-sustainable	Sustainable
Cumbaza	Phosphorous exported	9.1	11.0
	Nitrogen exported	9.2	11.1
	Sediments exported	9.3	12.5
	Carbon captured	9.8	10.4
Sierra del Divisor	Phosphorous exported	7.1	12.3
	Nitrogen exported	7.0	12.3
	Sediments exported	11.0	12.1
	Carbon captured	7.3	12.4

Inversely, the sustainable development scenario would delay the export of this amount of phosphorous to 12 years.

5.1. Economic consequences of deforestation andecosystem services loss

Even though we did not perform a valuation of the ecosystems services provided by the two study areas, we can use existing data to get a sense of the economic consequences of projected ecosystem services loss. The magnitude of the economic consequences can be tentatively explored in two ways. Firstly, using the data of the relative acceleration and deceleration of ecosystem services in the watersheds (Table 4), we can estimate the annual costs to maintain or recover these services in the next decade. For example, under the non-sustainable development scenario in Sierra del Divisor, sediment loading which would normally occur in ten years would take place in seven years. This means that under the non-sustainable development scenario, the loss of ecosystem services translates into additional costs of increasing capacity of current water treatment facilities in the city of Pucallpa. Similarly, the benefits of the sustainable development scenario would imply saving water treatment costs at current capacity.

The results also allow an approximation of the economic costs of the loss of the capacity of ecosystems to capture carbon. In Cumbaza, the loss of non sequestered carbon over the next 10 years (i.e. the 2013 baseline versus the future scenarios) is around 2.7 million tons of carbon. If we use the prices from the InVest manual –between 66 – 130 USD per metric ton[18]– the loss of this service could cost between 187 million – 368 million USD in the course of the next ten years. Using a much more conservative figure, such as the price of carbon obtained in the voluntary market (about 5 USD per ton) the missed opportunity adds up to 13.5 million USD. In Sierra del Divisor, the numbers are much higher: the 8 to 14 million tons of carbon which would no longer be captured due to deforestation could cost between 920 and 1,820 million USD (using the social cost price), or 40 to 70 million USD (using the voluntary market price) in the next decade. To put these numbers in context, it is worth noting that the Norwegian and German governments have pledged some 300 million USD to the Peruvian government for reducing emissions from deforestation,[19] and that the value of Peruvian timber exports in one year is about 270 million USD.[20]

A second approach to assessing the economic impact of ecosystem services loss is to use the estimates of economic valuation of ecosystems compiled in TEEB. As noted, the TEEB data is highly variable and should be used carefully. Moreover, TEEB provides value estimates on a per hectare basis, whereas in this study we quantified ecosystem services at the watershed level. To assess the magnitude of potential economic loss due to deforestation, we used the data on projected deforestation generated by the land use change model, and combined it with a range of estimated values of selected ecosystem services in tropical rainforests found in the TEEB database. Only services for which there are 10 or more data entries were considered combined with the estimated values on ecosystem services found in literature (Table 5). While obviously not all deforested hectares provide

[18] This is called the “social cost” of carbon, i.e., an estimation of the harm which is caused at a global level.

[19] https://www.regjeringen.no/nb/aktuelt/Peru-Germany-Norway-launch-climate-and-forest-partnership/id2001143/.

[20] Dirección General Forestal y de Fauna Silvestre (2012). Perú Forestal en Números 2012.

the same value across the landscape, this exercise illustrates that, even using conservative estimates, deforestation may represent considerable forgone economic opportunities.

Table 5 also shows that only under generous estimations do tropical forest ecosystems like the ones studied yield more direct economic value per hectare in terms of ecosystem services, than when these are converted into common crops like coffee and cocoa. The calculations in Table 5 show how much value the deforested area in Cumbaza and in Sierra del Divisor would yield if it was wholly converted to either coffee or cacao, using relatively conservative estimates of production yields, costs and sale prices. The estimate is for a period of 10 years, and accounts for the time during which the crops are not producing fruit.[21] These are two commonly planted crops in the study areas, and they are both much less profitable than a third, albeit illegal crop that also drives deforestation in the Peruvian Amazon: coca. Obviously these numbers are based on local, short-term returns, and do not take into account the overlapping long-term, large-scale benefits of ecosystem services. However, as we discuss in section 6.3 below, they do help explain why the current structure of economic incentives pushes towards deforestation.

Table 5. VPotential value of some ecosystem services lost until 2023 due to deforestation under the three future scenarios, compared to potential value gained by conversion to cash crops*

			Cumbaza			Sierra del Divisor		
			Lost value 2013-2023 (1,000 USD/year)			Lost value 2013-2023 (1,000 USD/year)		
Ecosystem services		Estimated value (USD/ha/año)	Sustainable	BAU	Non-sustainable	Sustainable	BAU	Non-sustainable
Timber	Min.	10.99	95	98	100	477	593	819
	Max.	440.51	3,809	3,946	4,010	19,131	23,776	32,814
Firewood and charcoal	Min.	46.83	405	419	426	2,034	2,528	3,488
	Max.	5,052.82	43,689	45,262	45,997	219,445	272,720	376,387
Non-timber forest products	Min.	0.48	4	4	4	21	26	36
	Max.	551.80	4,771	4,943	5,023	23,965	29,783	41,104
Water purification	Min.	0.40	3	4	4	17	22	30
	Max.	1,230.57	10,640	11,023	11,202	53,444	66,418	91,666
Erosion prevention	Min.	3.35	29	30	30	145	181	250
	Max.	2,377.02	20,553	21,293	21,639	103,235	128,297	177,066
Ecotourism	Min.	6.65	57	60	61	289	359	495
	Max.	471.16	4,074	4,221	4,289	20,463	25,430	35,097
Climate regulation	Min.	219.54	1,898	1,967	1,999	9,535	11,849	16,354
	Max.	760.56	6,576	6,813	6,924	33,031	41,050	56,655
Crops								
Coffee		1,433	12,386	12,832	13,041	62,215	77,319	106,710
Cocoa		533	7,432	7,699	7,824	23,146	28,766	39,699

* Ecosystem services data from the TEEB database, as explained in the graph in Box 1. Agricultural data from FAOSTAT (2014). http://faostat.fao.org/site/703/default.aspx#ancor

21 Personal communication with experts from public agricultural agencies and research centers (2014).

6. *Scaling up ecosystem services analysis to inform national forest policy*

The modeling exercise provides important insights about the possible outcomes of land use change and its impact on the provisioning of forest ecosystem services in two specific watershed in the Peruvian Amazon. The question we deal with now is whether and how these insights are useful for policy-making nationwide, and what we can learn from this for other cases and countries.

We divide the following discussion in three parts. First, we address the issue of the general use of modeling and scenario analyses. We then turn to the specific issue of economic valuation of ecosystem services, and lastly examine the policy implications of our study.

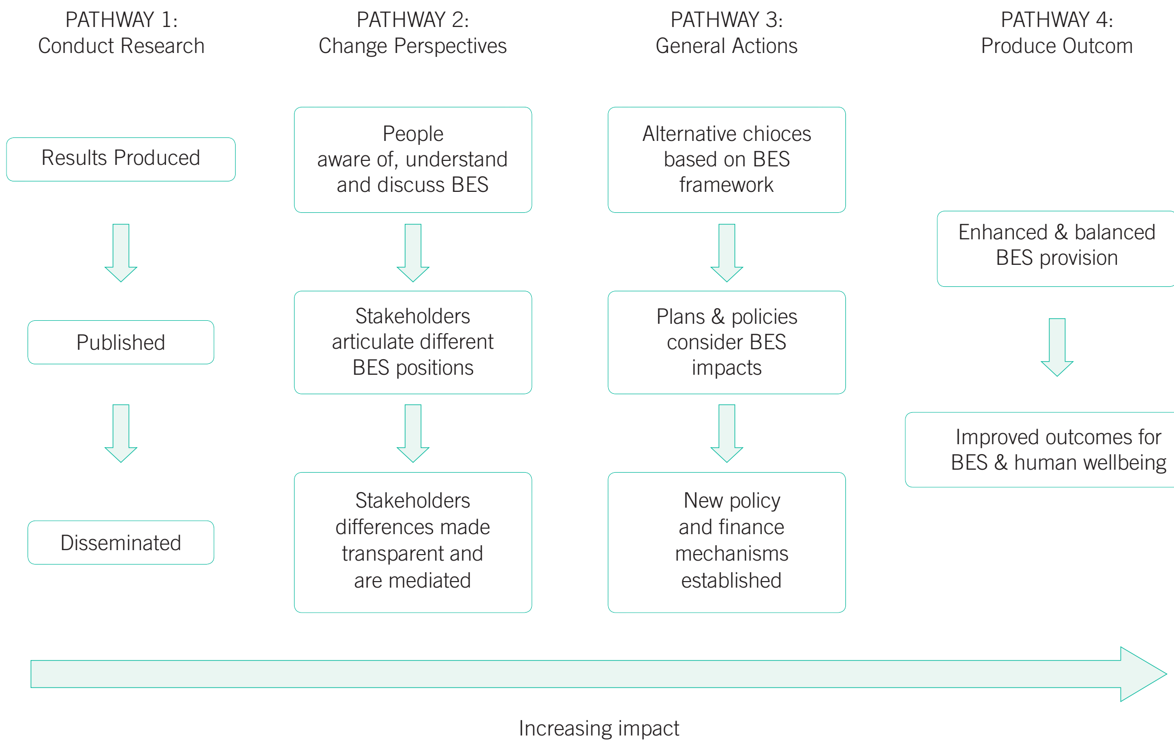
6.1. Using models and scenarios

The first point may be seem obvious, but it is worth stating: some quantification is better than no quantification. Ecosystem services can be measured–even if only roughly or partially–and this measurement provides potentially useful information for their management. The use of models to estimate the stocks and flows of important biophysical processes, and the possibility to assess their economic contribution, is a huge step forward for adequately accounting for people's impact on the environment and the environment's contribution to humans. If nothing else, a detailed study such as this one has provided data that until now has been unavailable for the Peruvian government. As Ruckelshaus *et al.* (2013) have argued, there are different levels of impact of an ecosystem services approach (Figure 7). The first one (pathway 1) is the impact of simply having knowledge that we didn't have before. This is the prerequisite of moving into other types of impacts, such as the direct use of those results in decision-making. Our own study, through socialization with our government partners at the national and regional level, is already having the types of impacts of pathway 2; in the context of our support to the National Forest and Wildlife Plan of Peru, it could eventually reach pathways 3 and 4.

But how indeed can studies like these make their way to policy-making? The maps and other quantitative outputs of the model, such as the quantification of sediment retention rates can be quite useful for local decision-making about land use and planning. The combination of land use and ecosystem services data can help identify potentially critical areas of the watershed that should be prioritized for conservation or restricted use, or test the potential impacts of alternative interventions. Given that land use planning is done at the local or regional level, the use of these types of studies at the national level could focus on large watersheds situated across the borders of municipal or provincial jurisdictions, where the central government could play a facilitating or brokerage role among different local stakeholders. Priority for these types of assessments can be given to those cross-jurisdictional watersheds in which major public or private investments are planned. Other specific findings of our study, such as the lower deforestation rates found in areas that have clear land uses assigned, appear to be consistent at a national level and could help to bolster the case for land use planning more broadly.

Future scenarios are only as good as the assumptions you use. While in this study we made the best possible effort to craft realistic, evidence-based scenarios, the end result is determined by the subjective process of assigning change probabilities and choosing the land use change variables. The problem is that assumptions are a bit teleological, i.e. they forecast things that you have previously assumed to be true, such as the lower probability

Figure 7. Different possible pathways for impact of biodiversity and ecosystem services (BES) modeling and valuation using InVest. Source: Ruckelshaus *et al.*, 2013*



* Ruckelshaus *et al.* (2015). Notes from the field: Lessons learned from using ecosystem services approaches to inform real-world decisions. Ecological Economics 115: 11-21. Available online at: http://www.sciencedirect.com/science/article/pii/S0921800913002498

of deforestation in protected areas. While this may have been the general pattern, it cannot be expected to apply to each specific situation. The quality of the scenarios can be improved by making these transitions' probabilities as accurate as possible by, for example, basing them on other experiences in similar places.

But ultimately all modeling exercises are particular. In this study the scenarios were useful because they showed the extent of path dependency and the likely minimum and maximum bounds of future forest cover change. The scenarios were less useful as sets of specific policies that could be implemented or avoided because they were defined in rather general terms. For example, the scenarios as defined differ on whether environmental laws are complied with or not, but they don't mention specific environmental laws; only a few specific sets of interventions, such as the construction of the trans-Amazonian highway, are mentioned. In sum, the more specific the scenarios, the more useful they are as tools to develop experiments about the likely impact of specific policies.

6.2. The limits of economic valuation

To the eyes of our government partners, one of the most appealing aspects of quantifying ecosystem services is the potential they offer to estimate their value, and eventually to set up payment mechanisms. A country with enormous forest resources like Peru is eager to realize some of its monetary value.

Our study points to two key problems with using ecosystem services valuation in policy making. The first is that sometimes the benefit provided by ecosystems to people is indirect or unclear, and this makes it much harder to put a value on their services. In the case of Peru, the bulk of the ecosystem services provided by the huge Amazonian tropical rainforest ecosystems doesn't appear to have a clear and present impact on the Peruvian economy – either because the benefit to human societies is indirect, or because they benefit less populated human settlements. As we noted above, the mountain ecosystems of the Andes provide direct economic benefits in the form of water storage and provisioning for the main centers of population, agriculture and industry in the Pacific lowlands,[22] but the Amazonian forests are separated from these hubs of economic activity by the Andes. Obviously this is not so say that there are no beneficiaries of the Peruvian Amazon forest ecosystem services. The agricultural industry in the coastal areas is entirely dependent on the rain that falls on the Andes, and the forests in the Amazon play a key role in regulating precipitation in this mountain range. Major tributaries of the Amazon River, which traverses through Colombia and Brazil, originate in Peru. Furthermore, the whole world benefits from the existence of the Peruvian Amazon for climate regulation, carbon sequestration and biodiversity and its potential future use. However, because these processes play out at such large temporal and spatial scales, it is difficult to assign specific beneficiaries–and hence, people to pay for them. REDD seeks to redress this problem concerning carbon sequestration and other so-called co-benefits.

There are indeed some economic activities that benefit directly from ecosystem services in the Amazon. About 3.6 million Peruvians live in the Amazon regions,[23] and cities like Tarapoto are important regional economic centers related to the production of coffee, cacao and rice. Rural residents in particular are highly dependent on forest resources such as timber, non-timber forest products and water for drinking and irrigation. In addition, the Amazon region is home to a significant indigenous population that is crucially dependent on forest ecosystems–and particularly vulnerable to their loss. However, in highly centralized Peru these areas and its people are often seen as marginal relative to the core of the country's economic and political life. Thus, from a national-level perspective, the direct beneficiaries of Amazonian forest ecosystem services are almost invisible from a strictly economic viewpoint because they do not–at least for now–take part in high-value economic activities.

The use of economic valuation for policy-making poses a second challenge. Due to the methodological complexities of actually valuating ecosystem services, decision-makers often have to resort to existing data, such as that in TEEB, using the benefits transfer approach. Using existing data can help to get a sense of the magnitude of the potential losses due to ecosystem service depletion, but not to precisely estimate the value of the services lost. As we have seen (Box 1), current values are highly variable, and are likely to be accurate only within the specific physical confines of the study in which they were originally measured. Using existing values does not account for the important geographical differences. As we have shown for the provision of water purification services, the localization of forests matter. Thus the contribution of a particular hectare of forest in one part of the watershed may be very different from that in another part. Moreover, TEEB values have been calculated for very specific services and in relationship to specific users. Although

22 Hajek, F & P. Martínez (Eds.). (2012). ¿Gratis?: los servicios de la naturaleza y cómo sostenerlos en el Perú. Lima: Servicios Ecosistémicos Perú.

23 INEI (2015). Población total según departamentos. http://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib0015/cap-51.htm

large forests such as the Amazon provide services that are beneficial across geographic regions (such as the contribution to climate regulation), these are precisely the ones that are harder to quantify.

6.3. Implications for policy

The lack of measurable direct or high value economic benefits in the types of ecosystems that we studied poses a difficult policy question: is there an economic case for conserving the Amazon forest? Unlike Andean ecosystems, Amazonian forests do not provide direct, critical services to the densely populated and economically active areas in the Pacific coast. Moreover, as we have seen (Table 5), in a hectare to hectare comparison, the potential economic value of converting forest land to certain agricultural land is much higher than conserving the forest. This calculus does not do justice to ecosystem services: many forest ecosystem services are additive–using non-timber forest products sustainably does not preclude carbon sequestration, and carbon sequestration can happen along erosion control–and other benefits are provided on time scales that transcend short-term profits. However, given the current markets (or lack thereof) and shortterm nature of the incentives, individual agents will find it much more lucrative in the here and now to convert forests to other uses, even if society as a whole is losing value.

This finding should help us reconsider the current use and application of payment for ecosystem services (PES) as a strategy to curtail deforestation.[24] If PES schemes are about allocating economic incentives to avoid deforestation, the sobering reality is that for those incentives to work we need to look beyond individual hectares. Payments to local land users must reflect the benefits provided by the watershed as a whole, not only to those living within the watershed (in the case of hydrological services) but also outside of it (in the case of carbon sequestration). The ecosystem services of the Amazon basin must therefore be considered in regional and global scales, and the political responsibility to ensure that those services continue to be provided lies with the national government and the international community.

On the road towards actual PES schemes, ecosystem service quantification like the one described here is only the first step. Unresolved are the technical and political aspects of assessing who are the beneficiaries, how much they should pay, and to whom. This is a technical process because it involves a socioeconomic characterization of local land users, as well as the estimation of the costs and benefits accrued by ecosystem services depletion and conservation. But it is also highly political because costs and benefits are relative, not absolute. In the absence of markets, questions such as who benefits, and how much, and by whom must be settled through normative decisions. And it is likely that those with greater power, those whose voice tends to be stronger may get a better deal.

Finally, policy-makers must confront head-on the difficult question of how much deforestation is acceptable. The results of our study suggest that deforestation continues even in the most sustainable of realistic scenarios. The question is then not whether deforestation will happen, but instead how much will be allowed to proceed. Peru has ambitious policies to curtail deforestation: the national government has committed to conserving 54 mil lion hectares of forests, and in the conference of parties in Poznan in 2008 pleaded to achieve net zero de-

[24] Nasi, R., Wunder, S. And J.J. Campos. (2002). Forest Ecosystem Services: can they pay our way out of deforestation? Discussion paper prepared for the Global Environmental Facility (GEF).

forestation by 2021.[25] Such commitments are laudable, but in view of current trends (e.g. regarding roads, agricultural development, and fossil fuel exploitation in the Amazon[26]) it is worth asking whether more modest, and perhaps more realistic, goals might lead to more constructive results. Tools for quantifying and valuating ecosystem services such as the ones described here could be very useful for taking the political decisions about how much to protect and where to concentrate the efforts with limited resources. In this sense, while an ecosystem services perspective is not the panacea to help stop deforestation, it can be very effective to help policymakers grasp the costs of inaction.

25 DS 008-2010-MINAM. http://www.minam.gob.pe/wp-content/uploads/2013/09/ds_008-2010-minam.pdf; MINAM (2014). Programa Bosques. http://www.bosques.gob.pe/programa-bosques

26 Cf. Dourojeanni, Marc *et al*. (2009). Amazonía peruana en 2021. Explotación de recursos naturales e infraestructura: ¿Qué está pasando? ¿Qué es lo que significa para el futuro? Lima: ProNaturaleza; SPDA; DAR; ICAA.

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