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A Cost-Benefit Analysis of Private Land Conservation: Measuring the economic cost and worth of TiME sites

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Abstract

Acquiring private lands to preserve them as Private Land Conservation (PLC) sites significantly contributes to global biodiversity conservation efforts. The monetary value of Ecosystem Services (ES) and other values provided by PLC sites for various beneficiary groups, is crucial for assessing their overall impact and effectiveness. However, a priori quantifying ES monetary value is often impractical due to time and cost constraints faced by PLC initiatives. To address this challenge, we propose a simple method that integrates an extensive ES valuation database with local socio-ecological knowledge of PLC sites. Applying this method to five PLC sites involved in This is My Earth (TiME) land acquisition, we estimated total costs, total values, and alternative total values over a century. Our findings reveal that when considering ES monetary values, the total value per hectare was on average 213 times greater than the total cost. Similarly, the mean benefit per unit area to the local community (the direct usage value) over a 100-year period was 54.39 times greater than the cost per unit area. Thus, we concluded that the total value of TiME's PLC sites significantly exceeds acquisition and operational costs, highlighting PLC as an economically efficient conservation strategy, both globally and for the local community. We further discuss avenues for enhancing the reliability of our protocol and how such information can support PLC decision-making processes and community engagement efforts.

Introduction

Anthropogenic pressures have been causing detrimental decline in diversity of species on Earth, that according to some researchers has initiated a sixth mass extinction in the planet's history (Ceballos et al., 2015). Land use change and habitat destruction are the leading causes for biodiversity decline (Barnosky et al., 2004; Haddad et al., 2015), and are expected to continue to exert their negative impact. Given the significant reduction in the available land for wild flora and fauna to thrive, the establishment of protected areas becomes crucial (Lovejoy, 2006; Naughton-Treves et al., 2005). In fact, as part of the global effort to protect biodiversity, Aichi target 11 set a goal to conserve 17% of terrestrial and inland waters and 10% of coastal and marine areas (Convention on Biological Diversity, 2010). Recent reports suggest this goal was almost met, with 16.64% and 7.74% protections respectively, covering a variety of governance regimes (e.g., government, private, governance by indigenous peoples and local communities, or any combination of these) (UNEP-WCMC & IUCN, 2021). Yet, understanding that this goal is too modest, the recent Kunming-Montreal Global Biodiversity Framework initiated the 30x30 goal aiming to protect 30% of Earth's land and water by 2030.

Most of the protected areas are established and maintained by governments in natural parks, biospheres, and reserves, ensuring statutory protection and long-term conservation. However, in recent years there is a growing trend of private land conservations, where landowners contribute portions of their land to conservation efforts. In the USA for example, federal, state or local government protected land covers a total of 119,973,528 ha, while only 3,189,198 ha are managed by private landowners or non-governmental organizations (U.S. Geological Survey (USGS) Gap Analysis Project (GAP), 2022). Motivations for private land conservation vary and can be broadly divided to involuntary participation and voluntary participation (Kamal et al., 2015). involuntary participation is done through compulsory acquisition of the site or through imposed restrictions and regulations (e.g., the Brazilian forest code). Voluntary participation is achieved through easements (a legally binding agreement between a landowner and an organization like a land trust or government agency), incentives (e.g., agri-environmental schemes), or through intentional purchasing of private land with the sole aim of preserving it in its natural state. Here we focus on the latter form of Private Land Conservation (PLC).

Conserving an important habitat in its natural state may entail considerable benefits to various stakeholders through the provision of Ecosystem Services (ES) (TEEB, 2010). It is customary to divide ES to five main groups, contributing to three main monetary value components - direct usage value, indirect usage value and non-use value (Table 1). ES exhibit differences in their most relevant scale, the beneficiary group, and the methods with which their monetary value can be quantified (Fremier et al., 2013; Gómez-Baggethun et al., 2016). For instance, provisioning ES typically offers resources at a local scale, benefiting the local inhabitants of the site or those from nearby towns and villages. The tangible nature of these goods allows for a relatively straightforward estimation of their value based on market prices. Conversely, habitat ES focus on the conservation of important species and habitats on a global scale. Identifying the beneficiary group for these services is challenging, and their value is not easily quantified using direct market prices. Since the success of PLC is likely to improve with enhanced stakeholder collaboration, pinpointing the potential beneficiaries of various ES and communicating the actual monetary value of these services is of paramount importance.

Table 1: General properties of the main Ecosystem Services groups (ES),

ES group	Description	Spatial scale	Beneficiary group	Monetary valuation	Valuation group
Provisioning	direct supply of material goods or resources that humans use, such as food, water, and timber	Local	Local communities	Direct, indirect, or simulated market valuation	Direct
Cultural	non-material contribution to human well-being through aesthetic / spiritual inspiration and through educational and recreational activities	Local / regional	Local communities	Opinion based methods	Direct
Regulating	the control of natural processes that impact the environment, providing benefits like climate regulation, disease control, and water regulation	Regional / global	regional	Ecological impacts methods	Indirect
Habitat	existence of living spaces for plants and animals, maintaining viable population and genetic diversity	Global	Unclear	Ecological impacts methods	Non-use
Existence / Bequest	the value individuals place on knowing that a resource exists and preserving it for future generations	Global	Global	Opinion based methods	Non-use

While numerous methods exist for the valuation of ES, the execution of such studies is often costly and time-consuming. Given the limited budgets under which most PLC initiatives operate, ES valuation is seldom conducted either before or after the purchase of a site. In fact, the selection of PLC sites typically hinges on the biodiversity they preserve. For example, the This is My Earth (TiME) initiative is an international conservation body that acquires lands in global biodiversity hotspots through crowd-funding. The lands purchased are managed and owned by local people or organizations, and various ecologically sustainable activities may be initiated for the benefit of local residents. All TiME donors partake in a democratic and egalitarian decision-making process regarding the allocation of funds. However, site selection primarily considers the species and habitats conserved, largely overlooking other factors such as the value of the provided ES versus the cost of site acquisition.

To address this gap, we propose a cost-effective and simple method for the valuation of ES. This approach integrates two primary sources of information: a harmonized repository of approximately 9,500 case studies that have estimated the monetary values of various ES, and comprehensive interviews with land managers. The ES valuation repository provides an estimate of the ES value per hectare per year, while the questionnaire yields information on the relevance of various ES to the site and additional financial details that facilitate the estimation of the site's cost and value. These elements collectively enable cost-benefit analyses and the calculation of the net value of the sites. Applying cost-benefit analysis in this way can guide decision-making processes, inform strategic planning, and optimize resource allocation in conservation efforts. This approach does not aim to validate our valuations, acknowledging that a universal 'true' valuation does not exist. Even when we set aside the differences between valuation methods, we recognize the inherent subjectivity in some aspects of ES, such as attributing a monetary value to a species that many believe to be priceless. Our focus is on pinpointing the fundamental elements necessary for developing an ES valuation protocol that can be applied in sites with limited resources and data and enables site-to-site comparisons.

Methods

General framework

We integrated in-depth interviews with site-managers, a detailed repository of approximately 9,500 case studies that estimated the monetary values of various ES and historical financial data. We estimated 3 main components- the total cost of the site, the total value of the site and the alternative total value of the site if it was not purchased for conservation (Figure 1). Net value is calculated as the difference between the total value and the total cost, while added value is the difference between total value and the alternative total value. The direct use value is also the benefit value to the local community since income (realized or potential) generated by these ES mostly remains in the local population.

The interviews provided information on land values, annual running costs, annual revenues, biodiversity, and types of ES provided by the site, as well as on the expected fate of the land if it was not purchased for conservation. The ES repository provided estimates of the monetary value of 23 ES, based on the TEEB framework, standardizes and harmonized to international dollar 2020. The historical financial data allowed accounting for inflation, convert currencies and accounting for future values of flows using discount.

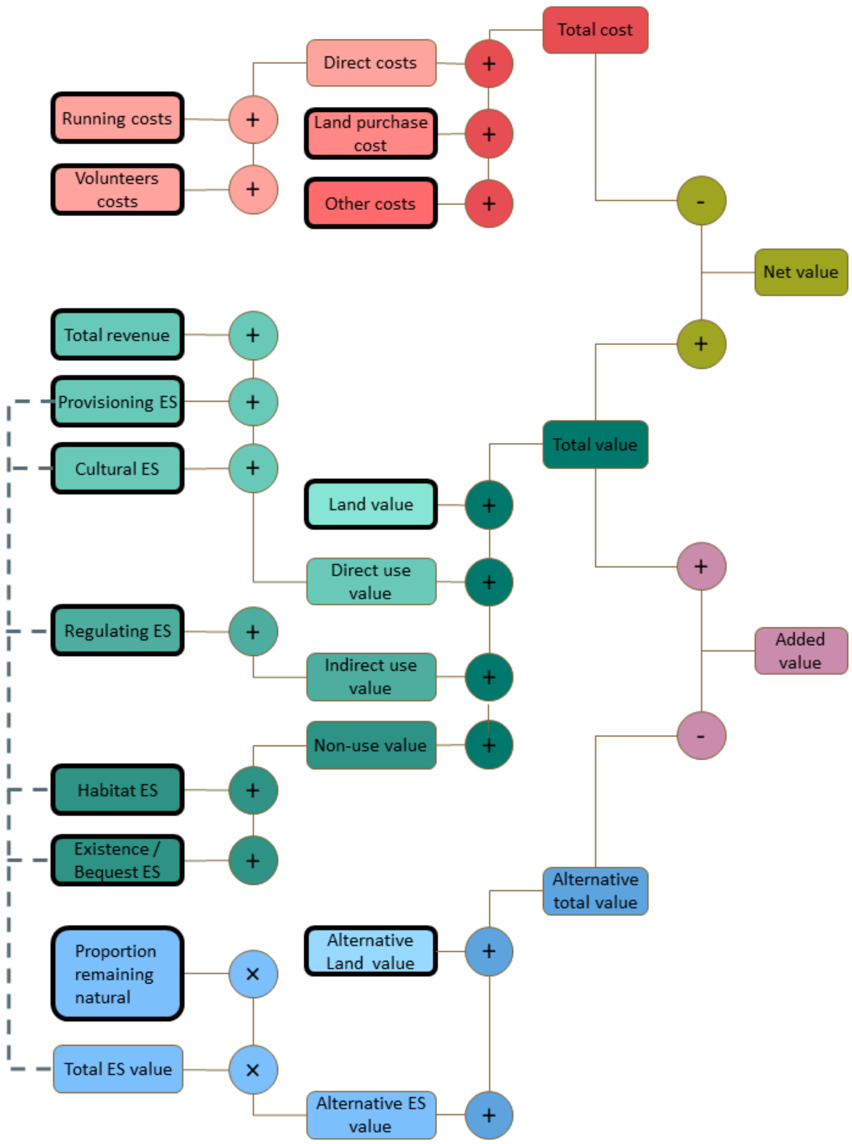

Figure 1: General framework of accounting used in this study. Boxes with thick black outline are inputs and their estimations are explained in the text. Mathematical notations near boxes represent the way the boxes to their left feed into the next level. For example, Direct cost = Running costs + Volunteers costs, while Added value = Total value – alternative total value. Total ES value is the sum of the five ES values (dashed connectors).

Study sites

Our analysis focused on four sites where a portion of their land was acquired through the TiME initiative and an additional site that was purchased through other funds. Among these sites, three are located in Peru, one in Brazil, and one in Colombia (Table 2):

- Brazil, Serra Bonita: located within the Atlantic Forest biome which is one of the Planet's highest priority areas for conservation. Most of the land is covered by primary montane forest, harboring many endemic species.
- Colombia, El Silencio: A biologically megadiverse Hotspot, located in the Tropical Andes. Pristine primary cloud forests, and a small parcel of land that was used in the past for cattle farming and was left abandoned years ago, which led to the natural recovery of the pastures.
- Peru, El Toro: Lies at the heart of the Tropical Andes Biodiversity Hotspot. The terrain is rugged with high ridges and steep valleys between 1,800 and 2,400 m.a.s.l.. The montane habitat holds a growing population of Critically Endangered yellow tailed-woolly monkeys.
- Peru, Jardines Angel del Sol: Harboring some of the last intact montane forests in the tropical Andes Biodiversity Hotspot. The geographical complexity of the site, including high mountains and deep valleys, allows for a variety of wildlife that doesn't normally share the same habitat.
- Peru, Pampa del Burro: Neighboring a Private Protected Area owned by the community of Yambrasbamba, the area protects rare white sand forest, home to many orchid species yet to be studied, and montane cloud forest, home to important species such as Andean bears, Peruvian night monkeys, and the Critically Endangered yellow-tailed woolly monkeys.

Table 2: the five sites explored in this study.

Country	Site	Area - total (Ha)	Area - TiME (Ha)	Total cost	Local benefit value	Total value	Alternative total Value	Net value	Added value
Brazil	Serra Bonita	3326.8	34	5236	179695	615592	114308	610357	501284
Colombia	El Silencio	3486	67	4857	623788	991910	4385	987053	987525
Peru	El Toro	100	0	657	11442	19259	18093	18602	1166
Peru	Jardines Angel del Sol	390	290	174	47479	80046	32026	79872	48019
Peru	Pampa del Burro	166	66	128	19219	32363	31070	32235	1293

Questionnaire

We devised a comprehensive questionnaire (SI1) tailored to obtain important information from site managers. This questionnaire first asks for general information about the site, exploring the site manager's familiarity with aspects such as the site's financial situation, historical background, biodiversity, ES, and the needs of local stakeholders. The subsequent section delved into financial details related to the site, including land purchase prices, annual running costs, additional occasional costs, and annual revenues. Next, we inquired about alternative land uses, aiming to estimate the percentage of land designated for various purposes if it had not been acquired for conservation, along with the anticipated timeframe and likelihood of such changes. Further sections focused on provisioning and cultural ES, addressing direct benefits associated with the site, as well as regulating ES that contribute towards indirect use value. The questionnaire also inquired into the biodiversity of the site, emphasizing charismatic and umbrella species, as well as those facing local and global risks of extinction. Lastly, we examined genetic and chemical resources within the site, identifying species with significant economic potential, such as wildtypes of essential crops, species used in various industries, and those with potential medicinal value. Some important details that were missing from the first questionnaire were added in a follow-up interview which was also used to clarify other sections (SI2).

The questionnaire was filled by their respective site managers, all with deep understanding of the site and the local environment and community. All three sites from Peru were evaluated by the same manager.

Ecosystem Services Valuation Database (ESVD)

We relied on the Ecosystem Services Valuation Database (hereafter, ESVD) as our main source of standardized monetary values (Brander et al., 2023). The ESVD is a comprehensive repository of more than 9,500 valuations from approximately 2000 studies, covering multiple ES from different biomes, geographical locations and valuation methods. Although the ESVD contains several ES frameworks, we relied on the TEEB framework (TEEB, 2010) that divides 23 ES into 5 categories: provisioning, cultural, regulating, habitat and existence / bequest value.

We accessed https://www.esvd.net/ on 6 December 2023 and downloaded the full database that included 9,500 ES entries, with 6635 of which reported valuation in int. US$ 2020 per hectare and the TEEB class. Additional data cleaning involved removing 38 cases with a valuation of 0 and 123 cases with valuation larger than larger than 100,000 int. US$ 2020. Valuations listed for more than 1 TEEB were unlisted and counted multiple times as separate (yet identical) estimates for different ES. Next, we calculated the mean value for each of the 23 ES for cases from the same country, the same combination of biome and continent, the same biome, the same continent, and the overall mean. We assigned each of the 23 ES the first mean value with sample size of at least 25 valuations, starting from the same country and moving along the listed order described above. If stratifying according to country, biome and continent did not retrain a large enough sample size we used the mean over all case studies.

Financial databases

Although all ESVD values were standardized to int. US$ 2020, values obtained from other sources (e.g., mean monthly income) or from site managers were from various years and currencies. Furthermore, some of the values represent stocks (e.g., price of the land) and some flows (e.g., 50 int. US$ 2020 per year of raw materials). Our general workflow was to first adjust the price for inflation to 2020 in the local currency, then convert from 2020 local currency to int. US$ 2020. Finally, if the value represented a flow, we accounted for the future value of money using discounting.

Accounting for Inflation

For inflation we downloaded (10 Dec. 2023) historical inflation rates from the International Monetary Fund data portal (International Monetary Fund, 2023b). Downloaded values are given as percent change per year. We used Eq1 to adjust for inflation and deflation:

$$GV = SV \times \prod_{i=1}^{n} \left(1 + \frac{R_i}{100}\right)^k \quad \text{Eq1}$$

With *GV* being the goal value, *SV* the start value, R_i the percent change rate between year *i* and year *i+1* (out of *n* inflation rates, recorded over *n*+1 years) and *k* being 1 when moving forward in time, e.g., from 2012 to 2020) and -1 when moving backward intime (e.g., from 2023 to 2020). For example (Eq2), if the starting value was 100 US$ in 2018 and the percent changes where 5 between 2018 and 2019 and 7 between 2019 and 2020, the goal value would be the multiplication (∏) of the starting price and the two inflation components:

$$100 \times \left(1 + \frac{5}{100}\right)^1 \times \left(1 + \frac{7}{100}\right)^1 = 112.35\ US\$ \quad \text{Eq2}$$

Currency conversion to Int. US$2020

After accounting for inflation in the local currency and bringing all values to their equivalent values in 2020, we converted the value to Int. US$ 2020 using exchange rates for Purchasing Power Parity (PPP) downloaded (10 Dec. 2023) from the International Monetary Fund data portal (International Monetary Fund, 2023a). The database contains conversion rates from 1980 until 2023, with projections until 2028 for 196 countries and regions. If the values were given in Euro, we took the mean PPP over all 20 countries that together form the Euro area (European Commission, 2023).

Applying discounting

After standardizing all values to Int. US$ 2020, we applied discounting to account for the opportunity cost associated with the delay in receiving or paying future amounts. The primary rationale for using discounting is rooted in the idea that a sum of money today holds greater intrinsic value than an equivalent sum in the future. This is because funds available today can be invested or utilized to generate returns or address immediate needs. This concept is especially relevant to conservation under limited funds where one conservation project comes on the expense of another conservation project. We used a discount rate of 1.043 (Goulder & Williams, 2012) for a period of 100 years. We used Eq3 when calculating the total discount value:

$$Value_{discount} = \sum_{i=0}^{Years} \left(\frac{Value_{start}}{DiscountRate^{i}} \right) \qquad \text{Eq3.}$$

With $Value_{start}$ being the initial value, *Years* the number of years over which discount should be calculated, *DiscountRate* the selected discount rate and $Value_{discount}$ the value after accounting for discount. Larger *DiscountRate* would results with lower estimations.

Calculations

In this section we provide the information on all the accounting calculations that feeds into the boxes with black outline in Figure 1.

Running costs

In the interview, we asked site managers to provide their annual budget for 2023. We first accounted for deflation to 2020 using Eq1 above (with k= -1) and if values were not supplied in US$, converted from local currency to Int. Us$ 2020. Finally, we applied discounting using Eq3.

Volunteers' costs

Beside paid labor accounted for in the annual budget, volunteers also contribute to the operation of the sites. Thus, the cost of replacing them with paid workers needs to be estimated and accounted for in the total cost of the site. To do so we downloaded (10 Dec. 2023) historic data on mean monthly wages from the International Labour Organization (International Labour Organization (ILOSTAT explorer), 2023), We applied the following filters on the database: Sex – Total only; Economic activity – Aggregate Total; Currency – US dollars; Year – 2012-2022. We first accounted for inflation to the year 2020 and converted to Int US$ 2020 (conversion factor being 1 since the data was downloaded in US$). We then calculated the mean monthly wage over all years ($Wage_{mean,month}$ in Eq4). In the interview we asked the site manager to estimate the number of hours per week (*HoursPerWeek* in Eq4) that various volunteers contribute to the ongoing maintenance and protection of the sites. We assumed that a full job is 40 hours per week and used Eq4 to calculate the value of volunteers work per year:

$$\text{Volunteers} = \frac{\text{HoursPerWeek}}{40} \times Wage_{mean,month} \times 12 \qquad \text{Eq4.}$$

We then applied discounting on this value to get the final estimated cost of volunteers.

Land purchase costs

In a follow-up interview we asked the site managers to provide details on the year in which various portions of the reserve was purchased, the area purchased, and the price paid. We first accounted for inflation using Eq1 above in the paid currency and then converted all purchasing costs to Int. US$ 2020. Since the purchase cost represents stock and not annual flows, we did not apply discounting. We summed the values over all portions purchased to get the total land purchase cost.

Other costs

Beside the costs that feeds into the annual budget, additional relatively large investments may be necessary occasionally. For example, buying expensive machinery for site maintenance, investing in infrastructure for protection, or renovations. To account for these costs, we asked the site managers about various large costs that occurred over the years and are not covered by the regular annual budget. We then accounted for inflation and converted to Int. Us$ 2020. We did not apply discounting since these are one-time costs similar to purchasing of land.

Land value

The total value of the site should include the value of the land itself if sold in the market, i.e., the land purchase cost. As part of the alternative land-use question (see below) we asked the site managers to estimate the current local market price per hectare of natural habitat. We then accounted for inflation from 2023 to 2020 and converted currency. If the value was not provided by the site managers, we used the price per hectare in Int. US$ 2020 paid by TiME as described in the land purchase costs above. We multiplied the price per hectare by the total area to get the land value of the site.

Total revenue

As part of their ongoing operation, nature reserves may generate revenue through various paths. For example, they can receive payment for services they provide to various stakeholders (e.g., offering activities on site) or from fund raising (e.g. donations). This revenue needs to be accounted for when estimating the total value of the site.

We asked the site managers to provide the amount of revenue generated through various funding sources. We focused on four funding sources (admission, activities on site, accommodation and selling of food and beverages), but accepted additional venues when specified. We also asked about additional funding sources such as research grants and donations, but have not included them in the revenue calculations since they were already accounted for in other calculations. For example, one of the cultural ES we estimated is the "Information for cognitive development" ES which included educational and research activities. Similarly, donations are accounted for when assigning value for existence / bequest ES values. As before, we first corrected for inflation and then converted to the common currency. Next, since the revenues are occurring annually, we applied discounting. Finally, we summed over all funding paths to get the total revenue value of the site.

Ecosystem services

As mentioned above, we estimated the value of 23 different provisioning, cultural, regulating, habitat and existence ES. We relied on Eq.5 to estimate the value of the service per unit area:

$$Value_{ES} = Score_{ES} \times ESVD_{ES} \times Area_{total} \qquad \text{Eq.5}$$

With $ESVD_{ES}$ being the mean value per hectare in Int. US$ 2020 as specified in the ESVD section above; $Score_{ES}$ being a numerical score in the range [0,1] that describes the relevance of this ES to the site according to the information provided by the site managers; and $Area_{Total}$ being the total area in hectares. We used this general equation for all subsequent ES calculations, yet the way the score was quantified varied. Since all ESVD outputs are already standardized to Int. US$ 2020, there was no need to apply any inflation of currency conversion. However, as the values are per year, we applied discounting of each $Value_{ES}$ that we quantified.

Provisioning ES

We focused on 6 provisioning ES covered by ESVD, including: (a) food, (b) water, (c) raw materials, (d) genetic resources, (e) medicinal resources and (f) ornamental resources. For provisioning ES, it is unclear if the ESVD estimates cover a single service or all similar services. E.g., if the mean value for the ES 'food' is for the harvesting of a single food source (e.g., honey) from the site or all potential food sources that can be harvested from the site (e.g., honey, game, fruits etc.). For simplicity and comparability, we assumed that they cover all services. For each resource mentioned by the site manager we assigned a score of 1 if the resource was used commercially and 0.5 if it is used for local consumption and summed over all resources up to a maximal value of 1.

Cultural ES

We focused on 5 cultural ES covered by ESVD, including: (a) aesthetic information, (b) opportunities for recreation and tourism, (c) inspiration for culture, art, and design, (d) spiritual experience, and (e) information for cognitive development. For (a) aesthetics information we assigned a score of 1 if the site manager specifically wrote that visitors come to see the site specifically for their aesthetic beauty and 0 otherwise. For (b) recreational and touristic opportunities, we assigned a maximum value of 1 if the site manager mentioned a few recreational activities carried on site (e.g., wildlife watching, hiking) but not accounted for in the revenue section (admission or payment for activities), a value of 0.5 if they were somewhat accounted for but the report indicated greater potential and 0 otherwise. For (c) inspiration for culture and for (d) spiritual experience we assigned a value of 1 if information related to such activities was provided by the site manager and 0 otherwise. For (e) cognitive development we assigned a score of 1 if considerable research was conducted in the site and/or if the site offers educational programs to nearby schools.

Regulating ES

We focused on 9 regulating ES covered by ESVD, including: (a) air quality regulation, (b) climate regulation, (c) moderation of extreme events, (d) regulation of water flows, (e) waste treatment, (f) erosion prevention, (g) maintenance of soil fertility (h) pollination, and (i) biological control. Since all these services are provided to a certain extent by all ecosystems, in the questionnaire we asked the site managers to assign each ES they mentioned a score between 0 and 1 that reflect the significance of each ecosystem service (0 being the lowest). We used these values as scored while reviewing the site managers' justifications for the given scores.

Habitat ES

We focused on 2 habitat ES covered by ESVD, including: (a) maintenance of life cycles, and (b) maintenance of genetic diversity. In the biodiversity section of the questionnaire, we asked site managers to list species that are unique and important to the site, along with their IUCN red list status and other relevant characteristics. We assigned (a) maintenance of life cycle score of 1 if the information provided by the site manger indicated that the site is an important population for these species (e.g., endemism, critically endangered, endangered, or vulnerable species according to IUCN red list status). For (b) maintenance of genetic diversity we asked the site manager to list species that are either important crops or wildtypes of important crops, important industrial species or wildtype of such species, and important medicinal species or wildtypes of such species. We assigned a score of 1 if the information provided by the site manager indicated that the site`s genetic diversity has value.

Existence / bequest value

This class of ES contained a single ES: Existence, bequest values. We assigned here a score of 1 if the species mentioned by the site manager in the questionnaire are subjected to extensive conservation efforts globally or locally. We have not used any systematic surveying methods or culturomics (Ladle et al., 2016) and instead relied on a relatively shallow online search for the species with various keywords related to conservation.

Alternative land value

The alternative land value is one of the components that contribute towards the expected total value of the site if it was not purchased for conservation. We asked the site manager to list the percent of the site that would be allocated to either agriculture, commerce, industry, residential, recreational, logging and natural habitat if the site was not protected. We also asked for an estimate of the local market value per unit area of each relevant land use. We accounted for inflation and converted currencies as described above and then calculated the weighted average of the value per hectare using the percentage of each land use indicated by the site manager as the weights. We multiplied the result by the total area to get the alternative land value in Int. US$ 2020.

Alternative ES value (proportion remaining natural)

As mentioned above, the site manager indicated the proportion of the area that would be allocated to each landuse if the site was not protected. In some sites, even after deforestation or other developments some of the area is likely to remain natural. For example, 17% of privately own land in the Atlantic Forest biome is required to be set aside for natural habitat cover by the Brazilian forest code. In other places, the remoteness or inaccessibility of the site may protect some of the area. Such remaining natural habitat would still provide some of the ecosystem services that we quantified above. Therefore, we assume that the quality of services is not affected by patch size and calculated the alternative ES value using Eq. 6:

$$Value_{AlternativeES} = \left(\sum_{ES=1}^{23} Value_{ES}\right) \times ProportionArea_{Natural} \quad \textbf{Eq.6}$$

With $Value_{ES}$ being the estimated monetary value of ecosystem service ES as quantified above and $PropotionArea_{Natural}$ being the proportion of the area that may remain natural under alternative ownership scenarios.

Additional information

As our sample size was only five, three of which were surveyed by the same manager, we did not conduct any in-depth statistical analysis of the results. Instead, we focused on qualitative comparison between sites. All computation were done in R version 4.3.2 (R Core Team, 2023).

Results

Total cost

The total cost of the site over a period of 100 years, after accounting for currency conversion, inflation/deflation and discounting was highest in the Serra Bonita site (5,235,597 Int. US$ 2020) and lowest in Pampa del Burro (127,649 Int. US$ 2020), with clear differences between Peru and the two other countries (Figure 2). Running costs accounted for 49.6% and 49.5% of the total cost in Serra Bonita and El Silencio (respectively), while volunteer work accounted for 69.2% and 66.1% of the total cost of El Toro and Jardines Angel del Sol (respectively). The total cost per unit area ranged from 0.446 to 6.57 Int. US$ 2020 / Ha in Jardines Angel del Sol and El Toro, respectively, with the Brazilian and Columbian sites having ratios of 1.574 and 1.393 Int. US$ 2020 / Ha, respectively.

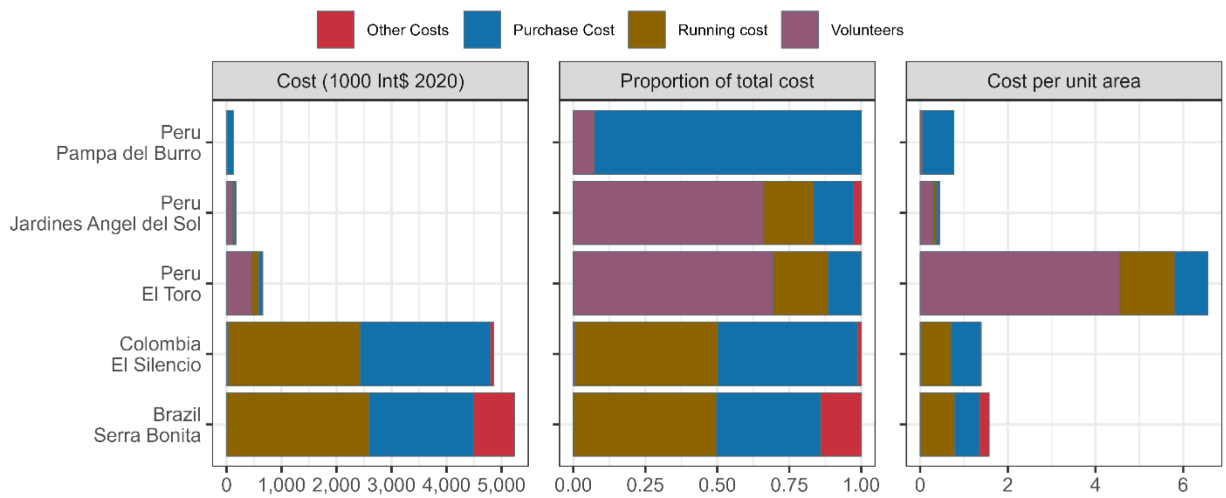

Figure2: The total cost of the sites and the breakdown to different contributing items. The left panel shows the values, the middle panel displays the relative contribution of the different items, while the right panel shows the cost per unit area (Int. US$ 2020 / Ha).

Total value

The total value of the site over a period of 100 years, after accounting for currency conversion, inflation and discounting was highest in the El Silencio site (991,910,347 Int. US$ 2020) and lowest in El Toro (19,258,830 Int. US$ 2020), with clear differences between Peru and the two other countries (Figure 3). Provisioning or Habitat ES dominated the values in most sites except El Silencio where Cultural ES accounted for 40.6% of the total value. In Serra Bonita regulating services accounted for 33.4% of the total value, similar to Habitat ES (34.2%). In the 3 sites from Peru, 59.4% of the total value was direct usage that remains in the local community (local benefit value in Table 1), with slightly higher values in

Colombia (63.1%) (Figure 4). In the Brazilian site direct usage accounted for only 29.4% of the total value but was still 34.32 times greater than the total cost. The total value per unit area was similar among sites, with El Silencio having the largest ratio (Figure 3).

Figure 3: The total value of the sites and the breakdown to different contributing items. The left panel shows the values, the middle panel displays the relative contribution of the different items, while the right panel shows the cost per unit area (Int. US$ 2020 / Ha).

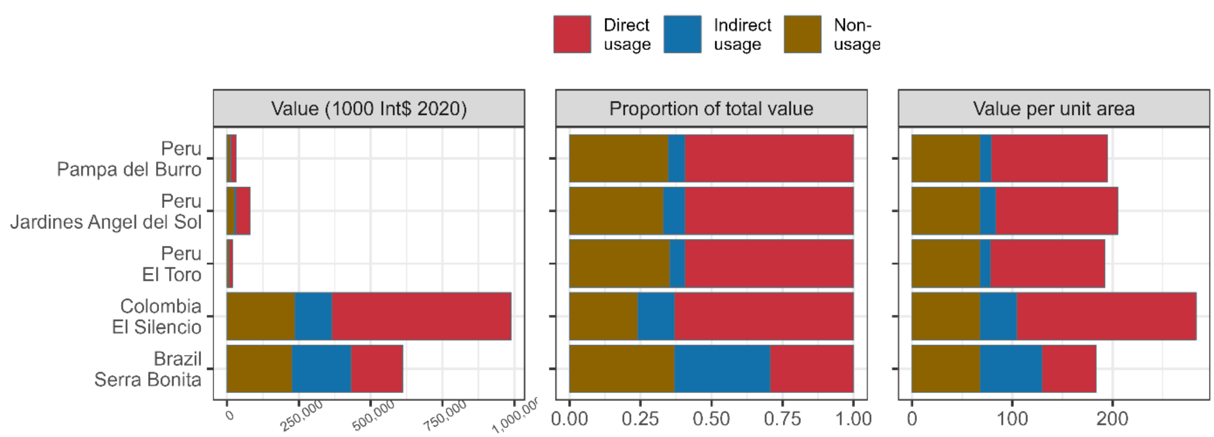

Figure 4: The partition of the total value to direct usage, indirect usage, and non-use values. The left panel shows the values, the middle panel displays the relative contribution of the different items, while the right panel shows the cost per unit area (Int. US$ 2020 / Ha).

Alternative total value

The alternative total value was largest in Serra Bonita (114,308,217 Int. US$ 2020), 96% of which accounted for by the alternative ES (Figure 5). Furthermore, the alternative ES accounted for almost all the total alternative value in the three sites from Peru. The site from Columbia, which received the lowest alternative total value (4,385,186 Int. US$ 2020) Is not expected to retain any natural area if not conserved. Site managers estimated a likelihood lower than 20% that the sites would remain natural if not conserved, El Toro being the exception with 50% likelihood to remain natural due to its remoteness (Figure 6). In El Silencio the site manager estimated that if not conserved, there is a 50% likelihood that the site loses all its natural area within a year.

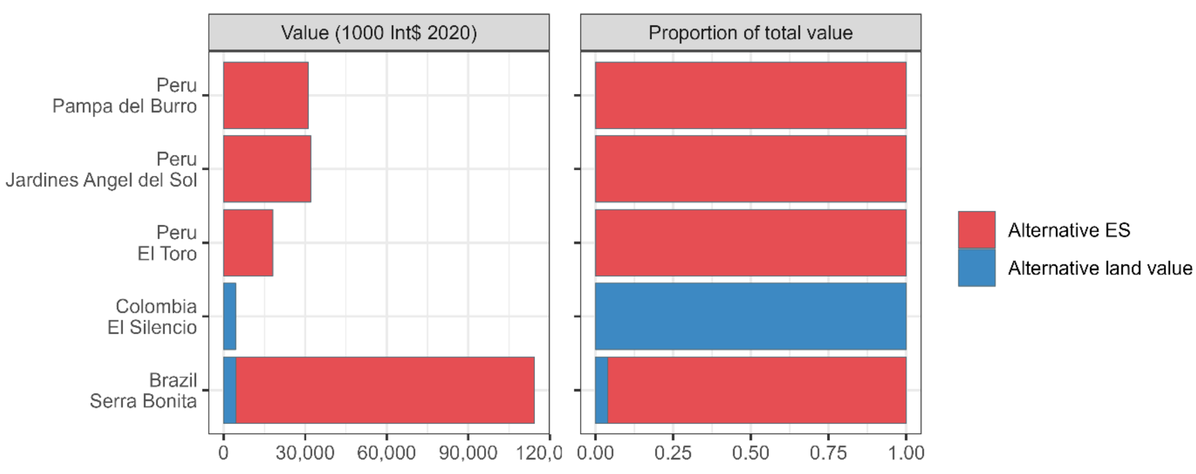

Figure 5: The alternative total values of the sites and the breakdown to different contributing items. The left panel shows the values, and the right panel displays the relative contribution of the different items.

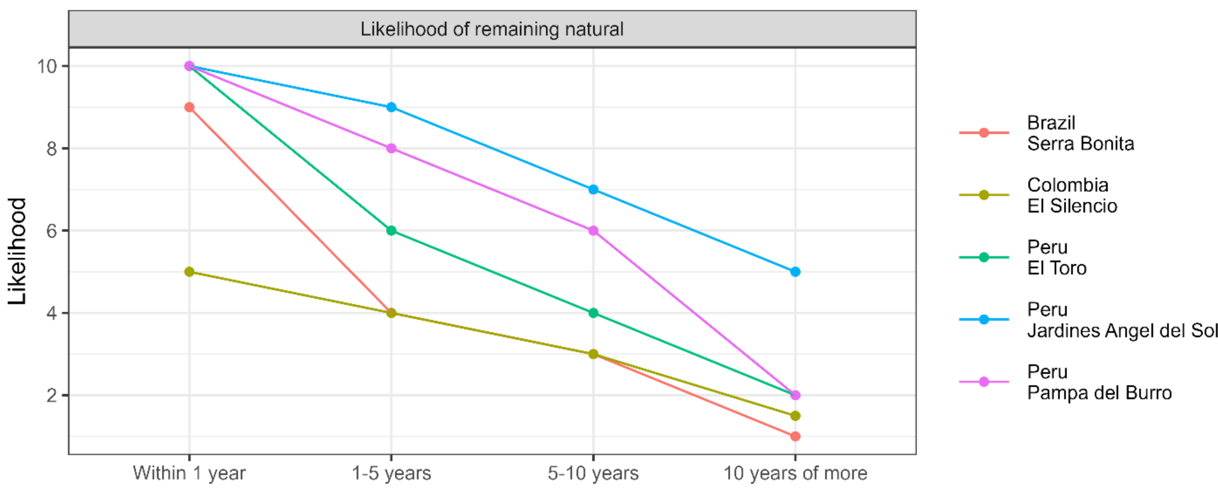

Figure 6: The likelihood of remaining natural if the site had not been protected along the years

Net Value and Added Value

In all sites, the total value was considerably larger than the total cost, such that the net values were almost identical to the total value (Figure 7). The added value was largest in El Silencio (Figure 7), where no natural area is expected to remain if not conserved (Figure 5). The smallest added values were calculated for the Pampa del Burro and EL Toro sites (1,293,125 and 1,166,020 Int. US$ 2020, respectively).

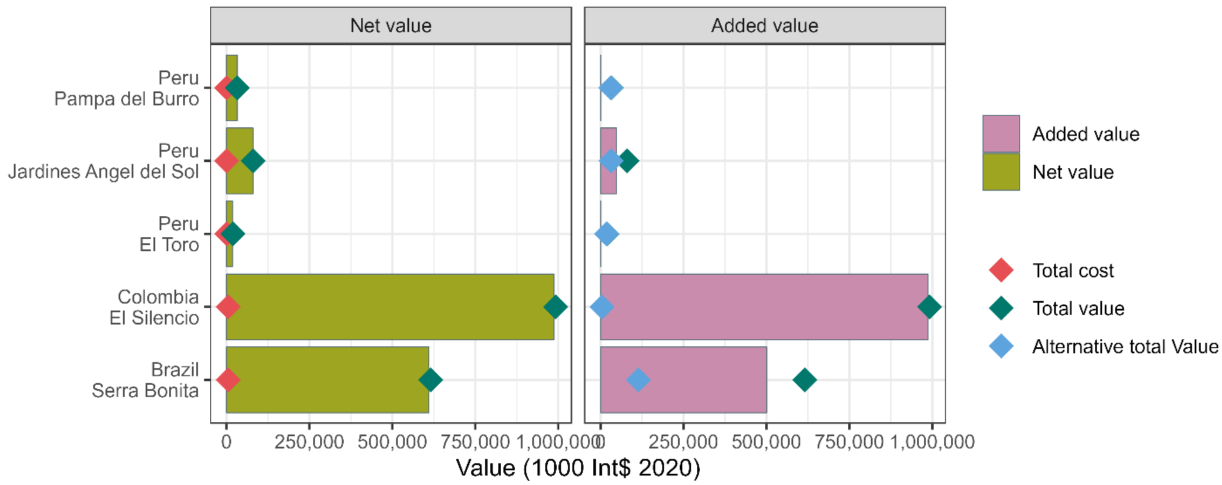

Figure 7: the net value (total value - total cost) and added value (total value – alternative total value) of each site.

Discussion

In this study, our aim was to estimate the monetary value of PLC sites for which formal monetary valuation is typically lacking, by integrating online repositories of ES monetary values and information gathered from local site managers. We observed considerable differences between countries in the estimation of total cost, total value, and alternative total value, with values in the substantially larger Brazilian and Columbian sites being several times higher than in Peru (Figures 2, 4, and 5). Note, however, that the values per unit area were relatively constant between sites (Figure 3), and were considerably higher than the cost per unit area (figure 2). Additionally, we found that the total value exceeded the total cost and alternative total values (Table 2 and Figure 7). The monetary values themselves were high, with the total value of 991,910,347 Int. US$ 2020 for the Colombian site, El

Silencio (with a total cost of 4,857,278 Int. US$ 2020). Even the site with the lowest estimate (El Toro, Peru) received a total value of 19,258,830 Int. US$ 2020 (with a total cost of 656,782 Int. US$ 2020). In Jardines Angel del Sol, the total value was 461 times greater than the total cost.

Determining the proximity of our total value estimates to the actual values of the sites presents a challenge. It is imperative to clarify that by "actual values," we refer to values that would have been estimated using valuation methods similar to those included in ESVD. The total value predominantly reflected the influence of the five ES, whereas the contributions from land value and revenue are scarcely discernible in Figure 3. Our estimations of the five ES hinge on various factors, including the accuracy of valuations within ESVD, our capability to identify sites resembling ours from ESVD, the scores we have used, and other methodological choices. The ESVD database encompasses representative cases from 18 distinct valuation methods, each applicable to different ES categories. Certain methods, particularly those associated with provisioning ES, are grounded in market prices and may be deemed more precise. Conversely, opinion-based methods might yield less accurate estimates, given that outcomes are contingent on population surveys – different stakeholder groups could yield different valuations. Delving into a comprehensive discussion of these variances falls outside the scope of this report.

Our valuations were also influenced by our capacity to select relevant case studies from the broader ESVD database that align with our sites. Essentially, due to budget constraints preventing on-site ES evaluation, it becomes necessary to pinpoint sites resembling ours. In our analysis, we prioritized estimates from the same country, and when sample sizes were insufficient, we expanded the spatial scale and included additional biomes until achieving a satisfactory sample size. This process could potentially be enhanced by retaining only a subset of the more reliable valuation methods from ESVD, incorporating supplementary criteria (e.g., GDP ppp), training a model to predict the most similar valuation based on site characteristics and the ESVD database, and utilizing alternative metrics instead of the mean value.

In relation to the scoring methodology, we utilized a range of [0, 1] for all five ES groups, but the methodology for assigning scores varied among them. In general, questionnaires may adopt a spectrum of options to survey each topic, with some questionnaires being highly specific and others allowing greater freedom for respondents. At one end of this spectrum, we could have requested managers to provide a direct single score within the range [0,1] for each of the 23 ES. Conversely, at the other end, we could have asked site managers to share all their knowledge on ES, deducing scores from their responses ourselves. We opted for an intermediate strategy, presenting general examples of each ES group, and prompting site managers to describe similar services in their own words. This approach led to some inconsistencies between ES and site managers. For future valuations, we recommend redesigning the questionnaire as a series of statements, with a few statements for each ES, and seeking concurrence on agreement scores within the range [0,1]. However, the more open questionnaire format allowed for a richer understanding of the unique characteristics of each site that is unlikely to surface with less fluid questionnaires. Additionally, we only administered a single questionnaire per site, and increasing the sample size of scores and/or involving additional local (e.g., nearby village) and global (e.g., TiME donors) stakeholders may provide more comprehensive valuations.

Finally, there were several other methodological choices whose impact on the valuation warrants further exploration. While we did not conduct a formal sensitivity analysis, the choice of discounting factor and the time horizon over which discounting was applied notably influenced the valuation outcomes. We utilized a discounting factor of 1.043, as recommended by Goulder & Williams (2012), over a 100-year period, resulting in a significant increase in total values (Figure S1). Employing a larger discounting factor would lead to lower overall estimations of total value and would place greater emphasis on present versus future values. Given the limited funds allocated to purchasing PLC sites, adopting a larger discounting rate over shorter timeframes may better reflect the urgency of conservation needs. Finally, incorporating the values generated by alternative land uses is essential for a more accurate estimate of the alternative total value and the added value. For example, if the alternative fate of a site includes commercial usage, we have incorporate the purchasing cost of a commercial property, but ignored the additional value generated through the commercial activity.

In summary, there are several avenues for potentially enhancing valuations without significant additional investment. Improving accuracy in valuation could lead to more effective engagement of local communities in conservation efforts, especially if benefits to the local communities are shared and publicized. In our findings, the mean benefit per unit area to the local community (the direct usage value) over a 100-year period was 54.39 times greater than the mean cost per unit area (116,979 and 2,150 Int. US$ 2020 / Ha, respectively). This approach may enable site managers to identify key ES that could potentially generate direct value and income for the site through sustainable management but are currently underutilized.

With further refinement, the proposed protocol has the potential to yield reasonable valuations for additional sites. This can be achieved by integrating insights from local site managers who possess detailed knowledge of the site's ecology and socio-economic context and oversee daily operations, with an expanding database of formal ES valuations. If executed effectively, ES valuations may facilitate conflict resolution among local stakeholders by conveying monetary benefits to the community. Furthermore, the accumulation of enough case studies may enable the mapping of ES values over wider geographical extents, providing valuable insights for conservation planning at regional or even global scales. Ultimately, grasping the net worth and added value of sites can strongly advocate for conservation efforts, especially when the future of the site is determined through formal decision-making processes. Introducing an easy-to-implement method for valuation may further strengthen global initiatives to acquire private land for conservation, thereby addressing the current biodiversity crisis.

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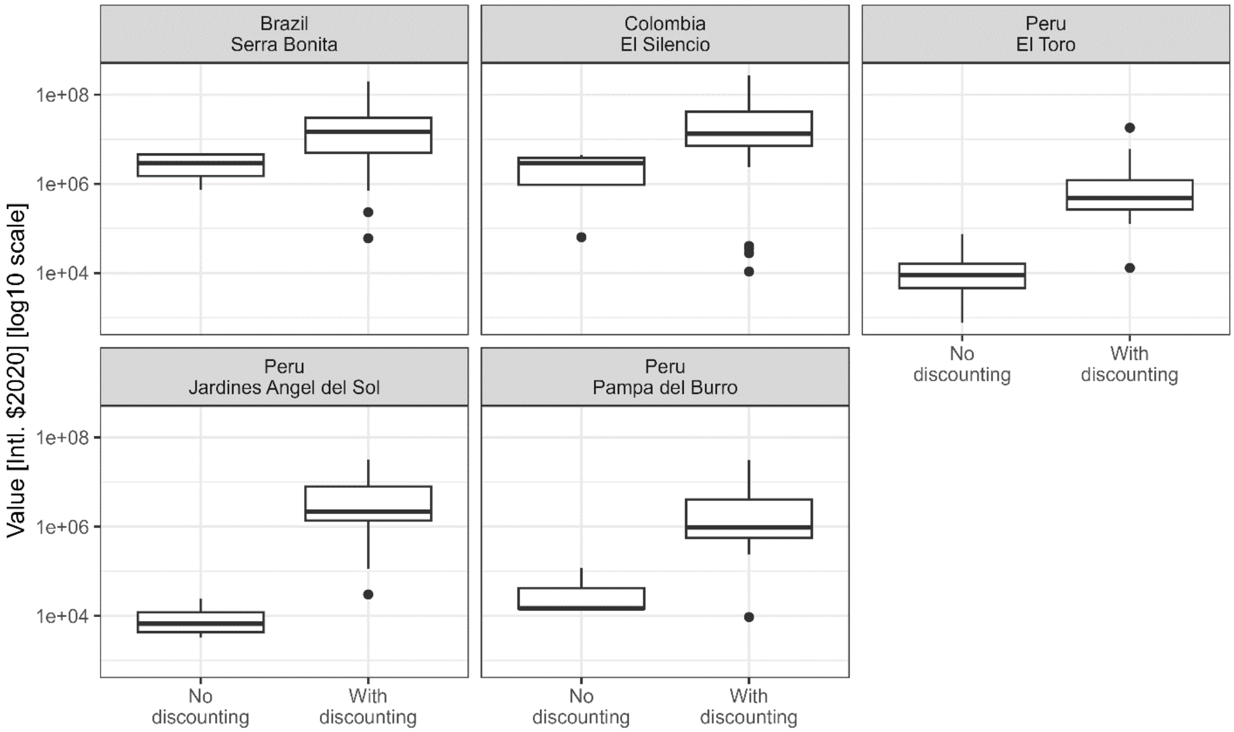
Supporting Information

SI1 – The questionnaire

SI2 – the follow-up questionnaire

Figure S1- boxplots of the estimated values for items that involve discounting vs. items with no discounting.

Figure S1: boxplots of the estimated values for items that involve discounting vs. items with no discounting.



Assessing the Cost-Effectiveness of Private Land Conservation:

A questionnaire designed to measure the economic cost and worth of TiME sites.

Prof. Uri Shanes and Dr. Yaniv Reingewertz

Dear partner,

Understanding the cost and benefits of purchasing land for conservation is essential if we are to mitigate current threats to biodiversity. Such understanding will promote better allocation of limited funds, yet it is restricted by our ability to translate land protection to monetary values. Here, we kindly invite you to participate in a research project led by Prof. Uri Shanes and Dr. Yaniv Reingewertz from the University of Haifa, in collaboration with TiME. Our research goal is to explore the optimality of conservation efforts via private land purchases, and how it depends on the type of land, the biodiversity it contains, its economic development value and its biodiversity conservation and ecosystem services values. The research is conducted in accordance with TiME's commitment to transparent, science-based, and cost-effective conservation.

We are reaching out to invite you to participate in a questionnaire that will help us gain valuable insights into TiME operation and ways we can improve it. Our aim is to use the information gathered in this questionnaire, along with earth observation data and other data from the public domain, to estimate the monetary value of candidate sites. We wish to do so both to reflect on TiME's past contributions and in the future, to provide additional information on candidate sites to our devoted voters.

We hope your expertise and knowledge on the site may aid in filling some of the knowledge gaps. Your participation in this survey is vital to the success of our efforts and we greatly appreciate your TiME and input. To further show our appreciation we would be happy to contribute 100$ to you, to the site, or to a charity of your choice.

Thank you in advance for your participation.

Prof. Uri Shanes and Dr. Yaniv Reingewertz

Instructions

The aim of this research is to estimate the cost associated with purchasing and running the site, alongside the revenues it generates and the monetary value of the various ecosystem services it provides. Together, the cost and worth may eventually allow cost-effective conservation, i.e., maximizing the worth gained for a given investment of funds. When doing so it is also important to estimate the fate of the site if no action was taken, i.e., if it would have remained in its current state or if it would have been used for other purposes.

After asking for some general information on the site and your responsibilities within it (section 1), we focus on estimating the running cost of the site and the revenues it generates (section 2). The third section explores the fate of the site if it was allocated to a different land-use, while sections 4-8 focus on estimating the monetary value of the various ecosystem services provided by the site to various beneficiary groups.

In fact, to reliably estimate the site's monetary values, it is important to account for the three main constituting components – direct, indirect and non-use values. ***Direct value*** (section 4) reflects the tangible goods and services that we receive from the ecosystem (e.g., food, logging), ***Indirect value*** refers to the benefits that we receive as a result of the ecosystem's functioning (e.g., pollination, section 5) or through its cultural significance to various stake-holders (section 6), and ***Non-use*** value is the value that we assign to the ecosystem simply because it exists (e.g., preserving biodiversity, section 7) or through potential usage by future generations (section 8).

It is important to note that our aim is to provide a reliable estimate of a feature which is very difficult to quantify. Thus, please include as many details as possible but retain from overstating the importance of the site. If you have any questions, please do not hesitate to reach out to us.

For further details please contact Dr. Yoni Gavish at: gavishyoni@gmail.com

Best regards,

The TiME team

Section 1: General information

Q1.1. Site name and location:

Q1.2. Your name:

Q1.3. What is your role in the site?

Q1.4. How long have you held this role?

Q1.5. Would you be interested in co-authoring scientific publications arising from this study?

Q1.6 Are you interested in being involved in future, more detailed, projects with a similar objective?

Q1.7. On a scale of 1-10 (1 being the lowest), how familiar are you with:

	Familiarity	Remarks
Site's financial situation		
Site's history		
Local residents' needs around site		
Local residents' opinions around site		
Land prices around site		
Biodiversity of the site		
Ecological functioning of the site		
Direct ecological services from the site (e.g., wood)		
Regulating ecosystem services provided by the site (e.g., soil preservation)		
Cultural ecosystem services provided by the site (e.g. spiritual or educational values)		

Q1.8 Do you know of any other personnel, volunteers, or local residents who could make a valuable contribution to this research? If so, kindly provide their name, email address, and relevant information in the table provided below.

Name	Email	Information

Section 2: Running costs and revenues.

Q2.1 What is the annual budget for the operation of the site (please specify the currency and the approximate breakdown of the budget).

Q2.2 How many volunteers operate on this site? What is the average time (in hours per week) which they dedicate to the site?

Q2.3. In the table provided, kindly indicate which funding sources are applicable to your site and the percentage and total revenue they represent. If not listed, please add in the available spaces.

Funding source	Percent revenue	Total revenue	Currency (e.g., $)
Site admission			
Activities on site			
Donations			
Accommodation in hotels or guest houses			
Dining or selling of food and beverages			
Governmental support			
Crowdfunding			
Carbon credit			
Grants			
Other:________			

Q2.4. Nature reserves have the potential to generate revenue through recreational activities and ecotourism. In the provided table, kindly rate the applicability of the following activities to the site on a scale of 1 to 10, with 1 being the least applicable. If a particular activity is already available, please indicate it in the last column. If there are additional activities that may be relevant to the site, please add them in the available space.

Activity	Applicability (1-10)	Currently available (yes/no)
Wildlife watching		
Botanical / wildflower viewing		
Fishing / Angling		
Hiking		
Camping		
Extreme sports		
Picnicking		
ATV and off-road vehicle touring		
Water sports		
Hosting researchers		
Other - please specify		

Section 3: Alternative land-uses

Q3.1. In the table provided, please indicate the estimated percentage of the land that would have been designated for each of the following land-uses if it had not been purchased by TiME. For applicable land-uses, kindly provide an estimate of the price per hectare, including the currency used. If a land-use is not listed, kindly add it in the additional rows provided. In the notes section, please indicate the source of the price (e.g., general estimate, asking price for similar properties etc.)

Land-use	Percent of site	Price per hectare	Currency (e.g., $)	Notes
Agriculture				
Commerce				
Industry				
Residential				
Recreational				
Logging				
Natural habitat (as is)				

Q3.2. On a scale of 1 to 10, with 1 being no chance at all, kindly estimate the likelihood of the site retaining its natural habitat if the land was not purchased in the following time scales. If possible, please provide information with your estimate.

Time scale	Likelihood	Information
Within 1 year		
1-5 years		
5-10 years		
10 years or more		

Q3.3. In the table below, please indicate if certain species were likely to face the following outcomes if the site was not purchased. If feasible, please provide a few examples of species (or groups such as invertebrates) that would experience these outcomes.

Outcome	Examples
Population growth	
Unaffected	
Population decline	

Section 4: direct (provisioning) benefits

Many ecosystems provide direct benefits that can be harvested and used by locals. These direct benefits may include the supply of fresh water, raw materials (e.g., wood), medicinal plants, game and fish. In some cases, the beneficiaries are locals, living within or in the surroundings of the site, while in other cases the beneficiaries may reside further from the site. If such ecosystem services are provided by the site, kindly list them in the table below. Please indicate who is the main beneficiary group and if possible, an estimate of the value per hectare (including currency). Leave the value blank if no estimate is available. If you list an estimate, please provide some rational for the value in the ***information*** column (e.g., based on the price of fish in the local market). For medicinal plants, if the service is provided by a specific species, please also list them in section 8 (Genetic and chemical resources).

Direct benefit	Beneficiary group	Value per hectare (+ currency)	Information

Section 5: Indirect (regulating) services.

Besides the direct benefits obtained from an ecosystem, it may also provide indirect regulating services that help to moderate natural phenomena within or around the site. Such services include pollination of crops, soil formation, soil erosion prevention, water purification, water flow regulation, climate regulation, and biological control. While many ecosystems offer these services to some degree, please only list in the table below the services that you believe make a significant contribution. For instance, include pollination only if there are crops in the site's vicinity and you know about the native pollinators that can provide the service. In the Score column, rate the significance of each ecosystem service on a scale of 1 to 10, with 1 being the lowest. Additionally, provide some justification for your answers in the ***Information*** column.

Ecosystem service	Information	Score

Section 6: Cultural services.

Apart from provisioning and regulating ecosystem services, nature reserves may also offer cultural services to the neighboring communities. These may comprise of plants, animals, or other elements of the ecosystem that serve as a source of spiritual inspiration or hold a special significance in the belief system of the local communities. Additionally, certain components of the ecosystem may have educational or scientific value. If there are any such elements in the ecosystem that provide cultural services, please list them in the table below. Please state the primary beneficiary group that utilizes the service and provide a rationale for including the ecosystem service in the table. Leave blank if this section is less relevant to the site. Note, that some species mentioned here may also fit section 7 (biodiversity). In case of overlap, please prefer listing important species in section 7.

Cultural service	Beneficiary group	Information

Section7: Biodiversity

Quantifying the monetary value of biodiversity is challenging. However, in many cases, it may be possible to estimate the value of specific species whose contribution is easier to grasp. For example, some species may be important from a cultural point of view, others may be an attraction that people wish to see. Other examples include critically endangered species that much effort is invested locally or globally in their conservation or species taking part in captive-breeding programs in zoos. If such species occur in the site, please indicate in the table below their names and why they are important. In the last column indicate the legal status of the species, i.e., if they are protected by local or international laws (leave blank if unknown). If there are other species that are important but not necessarily from a monetary perspective, please indicate them as well.

Common name	Latin name	Why is the species important	What is the legal status of the species?

Section 8: Genetic and chemical resources.

To justify biodiversity conservation, it is important to consider the preservation of genetic and chemical resources that can be utilized by future generations. For instance, some species may possess active compounds with medicinal properties, some may possess genetic diversity that can be utilized to enhance crop strains, and others may have potential for industrial applications. While all species have the potential to provide such services, here we are interested in specific species that are more likely to be significant. Therefore, in the table provided below, please only include species that fall into the following categories:

- ***Wildtypes***: close relatives of crops
- ***Industrial***: close relatives of species currently used in the industrial sector
- ***Medicinal***: species utilized by local populations for medicinal purposes.

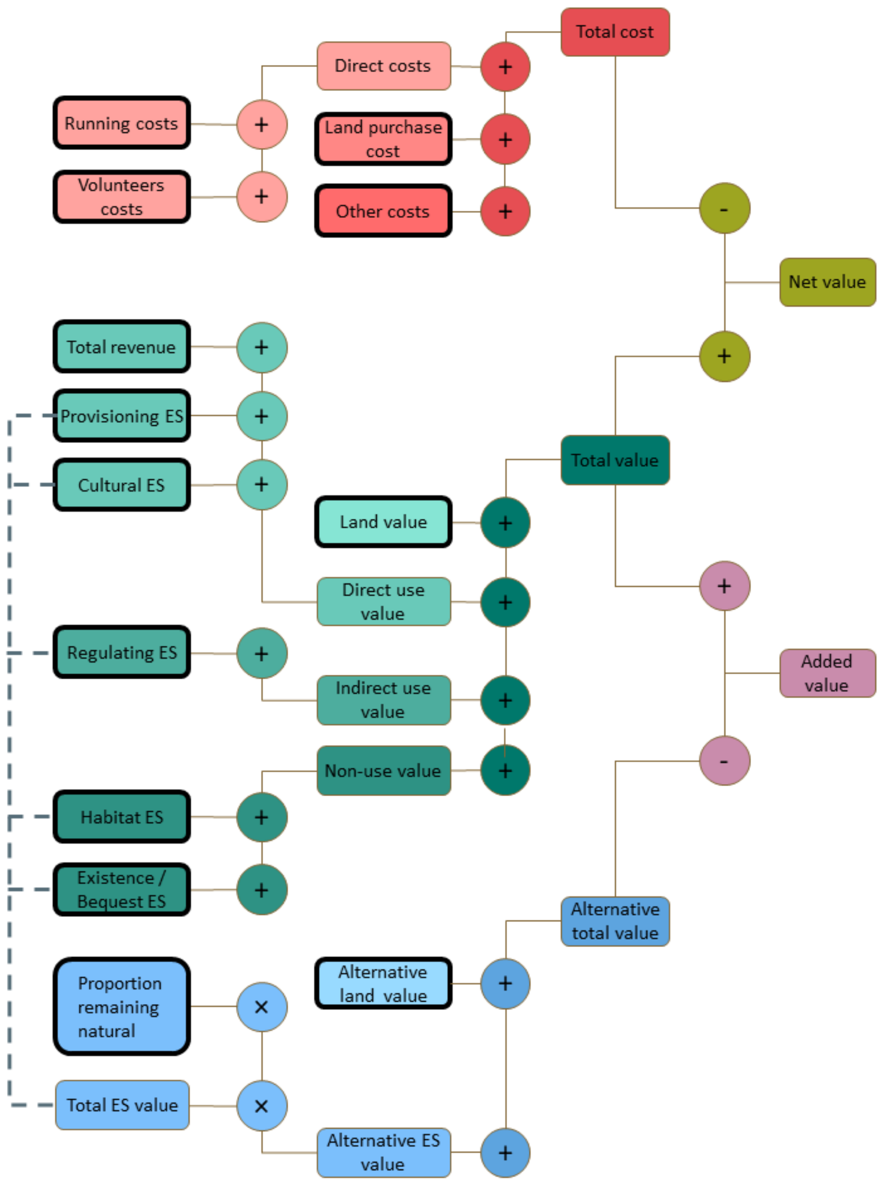
In the ***Group*** column indicate if the species is a wildtype, industrial or medicinal. As above, please provide the rational in the ***Information*** column. Leave the table blank if you are not aware of any species that meet the above criteria. You may include species that are listed in other sections of the questionnaire, but please mention that in the ***information*** column.

Species	Group	Information

Site: ______

Manager: ______

General framework:



purchase cost:

Fill in the following table with purchase cost. If the land was purchased over several steps, please indicate them as separate lines. In each line, fill in the year, the total number of hectares that were purchased, the total cost and the currency. If the area was purchased by TiME, please also indicate so in the last column.

Year	Number of hectares	Total cost	Currency	By TiME?

Other costs:

In the table below please fill in additional one time purchases that were made over the years that were required for running the site, but not accounted for in the annual budget. For example, purchasing a vehicle or machinery required for site maintenance, renovation of facilities etc.

Year	Description	Cost	Currency		