TECHNICAL NOTE N° IDB-TN- 3216

Advancing Ecosystem Accounting for Financing Protected Areas in Colombia

Final Report

Authors
Héctor Angarita
Jesse A. Goldstein
Lisa Mandle
Jaime Moreno Miranda
Orlando Vargas Rayo
Carolina Díaz Giraldo
Fabián Darío Villalba Pardo
Camilo Andrés Díaz Campos
Lina Barbosa

Edited by
Vanessa Callau
Elana Kimbrell
Duval Llaguno
Mary Ruckelshaus
Gregory Watson
Zoë Wilson

Inter-American Development Bank
Climate Change and Sustainable Development Sector
Biodiversity and Natural Capital Unit

The Natural Capital Project
Stanford University

National Planning Department
of Colombia

IDB

Advancing Ecosystem Accounting for Financing Protected Areas in Colombia

Final Report

Authors
Héctor Angarita
Jesse A. Goldstein
Lisa Mandle
Jaime Moreno Miranda
Orlando Vargas Rayo
Carolina Díaz Giraldo
Fabián Darío Villalba Pardo
Camilo Andrés Díaz Campos
Lina Barbosa

Edited by
Vanessa Callau
Duval Llaguno
Elana Kimbrell
Mary Ruckelshaus
Gregory Watson
Zoë Wilson

Inter-American Development Bank
Climate Change and Sustainable Development Sector
Biodiversity and Natural Capital Unit

The Natural Capital Project
Stanford University

National Planning Department of Colombia

October 2025

Mainstreaming Nature in
Policy and Investment Decisions

Final Project Report
Advancing Ecosystem Accounting for Financing Protected Areas

Colombia

natural capital PROJECT

Departamento Nacional de Planeación

gef

IDB

Inside This Report

Acknowledgements

The authors would like to thank USOCHICAMOCHA, Veolia Aguas de Tunja, EMPO-DUITAMA, GENSA, *Parques Nacionales Naturales de Colombia*, CORPOBOYACÁ, the Tunja and Duitama municipalities, and *Departamento Administrativo Nacional de Estadística* (DANE) who provided valuable comments, observations, and inputs for the preparation of this report. Errors and omissions are the sole responsibility of the authors. The opinions expressed in this publication are those of the authors and do not necessarily reflect the views of the Inter-American Development Bank, its Board of Directors, or the countries they represent, including the National Planning Department of Colombia and the other co-author institutions.

Executive Summary

Overview

The pilot project in Colombia aimed at integrating natural capital assessments and economic valuation for the advancement of two policies: the strengthening of the National System of Protected Areas and the implementation of the System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA-EA)1 in Colombia. Results from this work are informing the design of an innovative, cross-sectoral eco-compensation scheme to support stewardship of the projected areas and equitable distribution of benefits from them.

The project evaluated the ecosystem services provided by Colombia's system of protected areas in the Northeastern Andes region to three higher-income, higher-population municipalities – Tunja, Sogamoso, and Duitama – and quantified nature's contributions to people as a percentage of Gross Domestic Product (GDP) and other societal benefit measures. This approach highlights the roles that benefits flowing from natural ecosystems and protected areas play in local economies, including maintaining water quantity and quality, which are essential for water-dependent economic sectors.

Novel analytical workflows were developed to characterize and value ecosystem services flows, aligning with SEEA-EA standards. These workflows integrated local data, biophysical models, and economic valuation techniques to implement Accounts 3 and 4 of the SEEA-EA, showing value in both physical and monetary units. This alignment with SEEA-EA standards enhances the legitimacy and relevance of the results, facilitating their incorporation into financial compensation mechanisms (such as payments for ecosystem services, in which beneficiaries of ecosystem services make payments to those protecting the ecosystems, thus internalizing the costs of nature protection) and planning processes, and furthering Colombia's SEEA-EA implementation. These data and modeling showing the connections from ecosystems to economic valuation also are applicable to other countries around the world.

The document also includes a series of policy applications and capacity development recommendations to support the next steps in integrating natural capital assessments into decision-making processes. These recommendations aim to strengthen the National System of Protected Areas and ensure that ecosystem services valuation supports financing for sustainable economic development.

This document outlines the activities and results of the Colombian pilot project under the Regional Technical Cooperation (TC), "**Transforming Policy and Investment through Mainstreaming Rapid Approaches for Natural Capital Assessment and Accounting**." This TC was funded by the Global Environmental Facility (GEF), implemented by the Inter-American Development Bank (IDB), and executed by Stanford University The main beneficiaries and co-designers of this TC are the Colombian Ministry of Environment and Sustainable Development, the National Department of Statistics (DANE), and the National Planning Department (DNP), and the technical work led by the Natural Capital Project team (Stanford University). This work also received funding from the Gordon and Betty Moore Foundation.

This pilot project in Colombia is also part of the **People, Planet, Prosperity (3Ps) project**, through which the Stanford University-based Natural Capital Project (NatCap) collaborates with IDB, the Asian Development Bank, and the World Bank on pilots in 16 countries, to scale up the use of natural capital approaches around the world.

1 https://seea.un.org/ecosystem-accounting

Glossary of Key Terms

Here, we use the following terminology:

Ecosystem services: Refers to the material, spiritual, cultural, communal, and other benefits that ecosystems provide to people. Formally, it refers to "the contributions of ecosystems to the benefits that are used in economic and other human activity."[2]

Beneficiaries: The specific people, groups, sectors, or organizations that receive ecosystem services. More specifically, these are all the socioeconomic units that benefit from ecosystem services.[3]

Users: These are the subset of beneficiaries that have a direct connection to the ecosystem service; in other words, they are the first beneficiary to receive the ecosystem service.[4]

Natural capital: The Earth's natural assets — its lands, waters, and biodiversity — upon which all life depends.

Natural capital approaches: Approaches that make explicit nature's benefits to people so they can be incorporated into decisions and can motivate investments in ecosystems, improving the well-being of both people and nature. This includes both natural capital assessments and accounting.

Natural capital assessments: Through close engagement with decision-makers, local experts, and stakeholders, natural capital assessments quantify and map both natural capital stocks (e.g., water-purifying wetlands) and the ecosystem services flowing to people (e.g., safe drinking water) to provide quantifiable — and often, spatially explicit – metrics of those services, whether monetary, biophysical, or social/cultural.

Natural capital accounting: Natural capital accounting measures stocks of natural assets and the flows of ecosystem services they provide to society and human activity, in monetary and/or biophysical terms, often aggregating this information nationally or regionally using a standardized, replicable approach that allows for monitoring change over time. This quantification is helpful for designing, monitoring, and evaluating policies and investments.

Valuation: A component of many natural capital assessments and accounting focused on providing estimates of values for the relevant ecosystem services. These values can be monetary or non-monetary. A natural capital assessment could evaluate the potential supply of ecosystem services (e.g., where water flows on the landscape); it can evaluate supply as well as quantify the service (e.g., how much water flows to specific communities); or it can estimate values (e.g., what is the monetary value created by that water for that specific community? Or how many people have changed access to drinking water?). This third step is the valuation component.

System of Environmental-Economic Accounting (SEEA): An international framework for natural capital accounting developed by the United Nations to integrate environmental data with economic national accounts. It provides a comprehensive and consistent set of principles, concepts, definitions, and classifications for recording the interactions between the environment and the economy. The framework includes two systems:

- **SEEA Central Framework (CF)** is an accounting standard for measuring the relationship between natural resources and the economy, characterizing resources availability, use, productivity and impacts.
- **SEEA-Ecosystems Accounting (EA)** is an accounting standard focused on the measurement of i. Ecosystem assets, and ii. Ecosystem service supply and utilization. SEEA-EA, also referred to in this report as ecosystem accounting, helps answer questions such as: How much do ecosystems contribute to the different sectors and beneficiaries of society? Where do the services come from in relation to the landscape? How have ecosystems and the benefits they provide changed over time, in both biophysical and monetary terms?

2 See Systems of Environmental-Economic Accounting – Ecosystems Accounting, United Nations, 2024, p.136
3 See Systems of Environmental-Economic Accounting – Ecosystems Accounting, United Nations, 2024, p. 140
4 ibid

Introduction

Colombia, one of the most biodiverse countries on the planet,[5] has for decades been advancing in adopting policies and strengthening its knowledge, institutions, and governance to integrate nature into its development decisions. In the Latin American region, Colombia has been a pioneer[6] in implementing integrated economic and environmental accounting frameworks, such as the United Nations System of Environmental-Economic Accounting (SEEA)[7], for forests, water, mining and energy resources[8] and conducting numerous studies on the valuation of the benefits of protected areas[9] to promote transparency and accountability in natural resource management. This information has allowed the adoption of various management mechanisms and instruments, including inputs for territorial planning,[10] incentives such as payments for environmental services,[11] and environmental rates,[12] which recognize and incorporate the benefits nature provides to society and individuals into management instruments.

These efforts demonstrate sustained and significant progress in the design and application of environmental policies; however, important challenges persist in aligning them with human development goals. The national assessment of biodiversity and ecosystem services for Colombia in 2021 indicated a decline in biodiversity and ecosystem conditions, and a reduction in nature's contributions to society's quality of life.[13] Therefore, Colombia has determined it is a priority to better understand the factors of environmental deterioration and to define paths aimed at achieving transformational changes in the social, economic, and cultural trends affecting biodiversity. These goals are also in line with global and national efforts to mitigate and adapt to climate change.

Facing these challenges, in 2024, Colombia presented its most recent National Biodiversity Strategy and Action Plan (NBSAP)[14], with proposed contributions to the targets of the Convention of Biological Diversity, outlined in the Kunming-Montreal Global Biodiversity Framework. This plan proposes goals for 2030 and a vision for 2050 to stop biodiversity loss and restore natural ecosystems.

Colombia's National System of Protected Areas (SINAP) was formally created in 2010. This system links public and private protected areas of the national, regional and local order, and currently protects more than 31 million hectares equivalent to 16.6% of the country's land surface and 13.4% of the marine surface. The "Consolidation of the National System of Protected Areas of Colombia," referred to as CONPES 4050,[15] is the central, binding policy to promote coordinated and long-term actions towards the objectives of the biodiversity agenda. The national parks system has historically been an effective way to maintain

5 See **Global Biodiversity Outlook 5, Convention on Biological Diversity**

6 See Ministerio de Ambiente y Desarrollo Sostenible, Programa de las Naciones Unidas para el Desarrollo. 2014. **Quinto Informe Nacional de Biodiversidad de Colombia ante el Convenio de Diversidad Biológica**. Bogotá, D.C., Colombia. p. 101

7 **https://seea.un.org/ecosystem-accounting**

8 **Departamento Administrativo Ambiental de Estadística (DANE) Cuenta satélite Ambiental de Colombia**.

9 Parques Nacionales Naturales de Colombia (2014, 2020). Estudios de valoración de servicios ecosistemicos de Parques Nacionales de Colombia. See review in Annex 7

10 **IAvH, 2019. Estructura Ecológica Principal para el Ordenamiento Territorial en Colombia.**

11 Ministerio de Ambiente y Desarrollo Sostenible, Programa nacional de Pago por Servicios Ambientales (2021). ISBN 978-958-5551-25-1.

12 **See regulations of the Environmental Management Sector, Ministry of Housing, City and Territory of Colombia**.

13 Gomez et al., 2021

14 Minambiente, 2017. **Biodiversity action plan for the implementation of the national policy for the integral management of biodiversity and its Ecosystem services 2016-2030**. Rojas, G. Paula; Mora, J. Emilce – Bogotá, D.C.(Colombia).

15 **Consejo Nacional De Política Económica Y Social (CONPES). Departamento Nacional de Planeación. Política Para La Consolidación Del Sistema Nacional De Áreas Protegidas - SINAP. (2021).**

ecosystems in good condition, restore degraded ecosystems, and prevent new impacts on natural habitats.To strengthen it, the CONPES 4050 policy sets a new strategy based on cooperation objectives between public, private, and community actors, to increase by 2030 the co-responsibility of productive sectors and compensation to local communities for biodiversity protection. An innovation of this policy is the implementation of mechanisms to involve strategic economic sectors (agriculture, energy, tourism, and forestry) and high-income municipalities (referred to here as "high-complexity municipalities") in financing conservation efforts. Specifically, CONPES 4050 seeks to secure the environmental investments required for more equitable and sustainable biodiversity management from the beneficiaries of the ecosystem services, thereby internalizing costs. To achieve this objective, Colombia sought to quantify the contributions of protected areas to strategic economic sectors and to design compensation mechanisms that factor this in.

As a parallel effort, through its 2021 Climate Action Law,[16] Colombia established a comprehensive framework to address the challenges of climate change mitigation and adaptation. A key action within this framework is the implementation of the recent United Nations' Ecosystem Accounting Framework[17] (SEEA-EA). This initiative aims to consistently measure and report the interactions between society and nature, integrating these metrics into the national accounts system by incorporating the systematic quantification and valuation of ecosystems. This approach facilitates cross-institutional coordination and provides a cohesive synthesis of knowledge that is essential for the standardized and systematic reporting of society-nature interactions.

These two sets of policies offer a unique opportunity to align inter-institutional efforts and advance in a coordinated manner between the implementation of biodiversity measurement frameworks and their benefits, and the use of this information by decision-makers in designing and implementing effective policies: the SEEA-EA offers a framework for measuring and reporting ecosystem benefits and institutionalizes the systematic and standardized monitoring of the economy and environment. For its part, CONPES 4050 demonstrates how to apply this information as input for the eventual design of financing mechanisms aligned with the policy objectives for the consolidation of SINAP.

This document describes the activities and results of the Colombian project to advance the implementation of two major components of the aforementioned public policies. These two components are: i) the valuation of contributions of protected areas to strategic sectors to high income municipalities, to inform the development of compensation mechanisms, and ii) the advancement of the implementation of ecosystem accounting under the SEEA framework.

The project team directly supported implementation of the CONPES policy and development of UN-SEEA-EA accounts through the application of natural capital assessments and accounting (hereafter, natural capital approaches), to provide estimates of the economic value of ecosystem service flows from protected areas to several municipalities with higher income and population. This valuation is a key input for adopting equitable compensation schemes and financing mechanisms as indicated under CONPES 4050.

Specifically, the project:

- Assimilates and validates natural capital assessment and accounting methodologies, based on SEEA-EA standards, for the economic valuation of protected areas' contributions to the energy, agriculture, forestry, and tourism sectors in municipalities with higher income and population, to inform compensation schemes under CONPES 4050.
- Implements a subnational-scale analysis to value the benefits of SINAP in the Northeastern Andes region towards the high complexity municipalities of Tunja, Sogamoso, and Duitama, considering the strategic sectors of sanitation, agriculture, and tourism.

16 **Ley de Acción Climática de Colombia. 2169 de 2021**

17 Ecosystem accounting is a recent addition to the **UN-SEEA Natural Capital Accounting frameworks**. The other accounting standard is the SEEA-CF framework, published in 2012, which focuses on accounting of natural resources like water, forests, and minerals.

- Generates lessons and methodological contributions for advancing the implementation of the SEEA-EA in Colombia, led by the National Statistics Department (DANE).

The first section of this report synthesizes the project's main activities, results, contributions, lessons, and next steps for the advancement of the mentioned policies. See separate technical appendices providing more information on the methodology and results. Where appropriate, the synthesis section references the technical documents to facilitate their consultation.

Process & Methodology

In general terms, the project's main objective was to develop a valuation of the flows of ecosystem services from protected areas to the productive sectors of several high-complexity municipalities in Colombia, adopting the methodological and conceptual standards of SEEA-EA. The process and activities undertaken were as follows:

- **Assimilation and application of the SEEA-EA:** International experiences show that effective adoption of the SEEA-EA in national accounts is a long-term effort that requires fostering interdisciplinary and inter-institutional collaboration, and strengthening technical capacity. Although the SEEA-EA provides a solid framework for quantifying and valuing ecosystem services, there are specific challenges that must be addressed to ensure its practical application and alignment with each country's particularities. This project implemented collaborative work with several institutions to advance and demonstrate the applications of SEEA-EA principles and standards. The team developed a series of novel workflows for characterizing and valuing ecosystem service flows in a way that aligns with both SEEA-EA standards and decision-making in the Colombian context – integrating local data, biophysical models, and economic valuation techniques to assess supply and utilization of ecosystem services based on SEEA-EA, showing value in both physical units (Account 3) and monetary units (Account 4).

- **Work with actors and beneficiaries of ecosystem services:** Using a natural capital-based approach involves an iterative engagement process of collaboration and interaction with a variety of individuals and sectors. In general, these collaborative work processes are an effective way to incorporate scientific information and local expertise and knowledge into policy and finance, as part of good governance carried out by governments and civil society. The project conducted a range of activities in order to identify and work with the relevant government agencies (including the municipal authorities of Tunja and Duitama) and beneficiaries of ecosystem services, with a focus on the agricultural and tourism sectors.

- **Develop a subnational valuation of ecosystem service flows from SINAP to high-complexity municipalities, in physical and monetary units:** This project linked the economic activities of three higher-income, higher-population municipalities with the ecosystem services provided by Colombia's system of protected areas. This activity was carried out at the subnational level, selecting a focal area that met the following criteria: i) include two or more high-complexity municipalities, ii) incorporate various kinds of dependencies

between municipalities and strategic sectors with SINAP's ecosystem services, and iii) align with the jurisdictional design of SINAP. These criteria were considered to enable alignment of technical results with the current governance of SINAP, and facilitate the eventual design of management instruments. The project quantified nature's contributions to people as a percentage of the Gross Domestic Product (GDP) of Tunja, Sogamoso, and Duitama, and using other measures of societal benefit. The results revealed nature's role in local economies, in particular in maintaining water quantity and quality. Supporting the ability of protected areas to maintain local watershed conditions, such as reducing soil erosion and maintaining the hydrological functionality of native páramo vegetation, constitutes a key strategy for the security of water-dependent economic sectors.

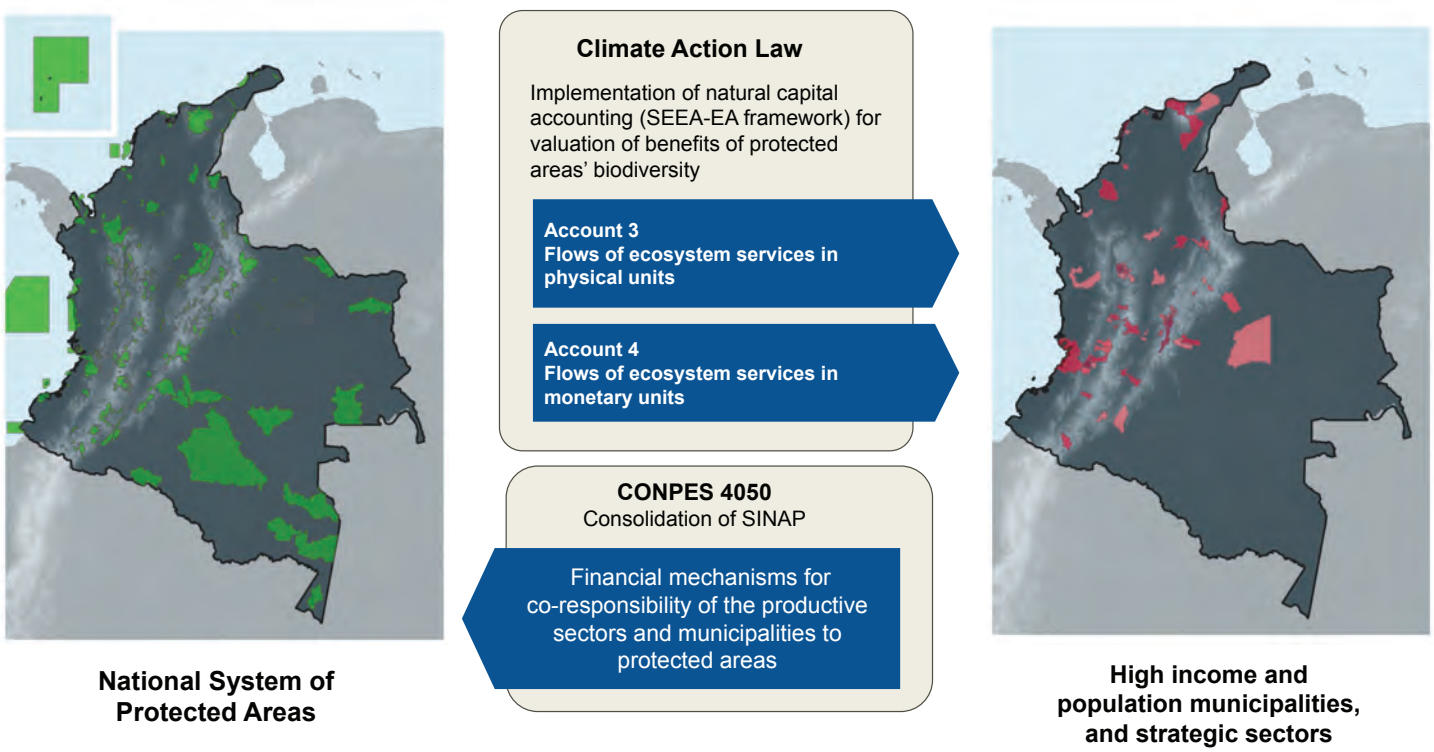


Figure 1: Project integrates actions of the Climate Action Law of 2021 and the Policy for the Consolidation of the National System of Protected Areas, CONPES 4050, through the advancement of ecosystem service flow accounts from protected areas to strategic sectors and high-complexity municipalities (darker red indicates higher complexity).

Technical Results

Subnational Assessment of Ecosystem Service Flows from SINAP to Municipalities

Focal area

The study focused on high-income and high-population municipalities (i.e., high-complexity municipalities) as units of analysis for the benefits of protected areas. This starting point significantly affects the definition of the biophysical units that should be considered to evaluate the sources of ecosystem services (i.e., which spatial domain, and which protected areas to consider?), since in many cases, jurisdictional boundaries can encompass multiple biophysical boundaries such as watersheds, ecosystems, or biomes. Conversely, a municipality can benefit from several protected areas, even distant ones, or the ecosystem services originating in a single protected area may concurrently benefit multiple municipalities. Therefore, to evaluate the provision of ecosystem services for the CONPES 4050, the team preferred to avoid defining a priori the biophysical analysis boundary (for example, a watershed) but rather, started by identifying the benefits perceived by ecosystem services users in each municipality. From there, the team identified a geographic scope that could reasonably encompass the sources of those ecosystem services.

A series of meetings, led by DNP with representatives of different entities in charge of SINAP coordination, was held to identify regions and municipalities to focus the subnational analysis, following the criteria stated in the previous section (see also Technical Appendix 2). A result of this process was the selection of the municipalities of Tunja, Duitama, and Sogamoso. These three cities are located in the Boyacá region of Colombia, nestled in and interdependent with Andes Mountain ecosystems such as Paramos and Cloud forest. Tunja, the capital of Boyacá, is situated at an altitude of 2,820 meters and has a population of approximately 200,000. Duitama, with a population of around 130,000, sits at 2,560 meters above sea level and is an agricultural and dairy production hub and industrial hub; Sogamoso, located at an elevation of 2,570 meters, has a population of about 120,000. Its name means “City of the Sun” due to its historical significance in the Muisca culture, and Sogamoso serves as a center for agricultural and dairy production.

Focusing on highly populated municipalities as beneficiaries, this project revealed the need to adopt a broad spatial domain to adequately capture the supply of ecosystem services and the biophysical or socioeconomic processes through which these benefits are transferred to the municipalities. In practice, this meant that the biophysical modeling domain required combining municipalities, nearby protected areas, watersheds, and other jurisdictional boundaries. As a result, the scope of analysis of the biophysical supply of ecosystem services included the departments of Cundinamarca, Santander, Norte de Santander, and Boyacá, extending to the piedmont of Orinoquia, shown in Figure 2. This delineation is adequate to evaluate ecosystem service flows, considering the areas where many of the benefits to Tunja, Duitama, or Sogamoso originate, and which biophysical (e.g., watershed areas, biomes, etc) or socioeconomic (e.g. reservoirs, transfers or other infrastructures) factors determine their transfer. This domain also includes a mosaic of protected areas, such as the emblematic Páramo de la Rusia, Páramo de Rabanal, Paramo de Oceta, La Cortadera y Pan de Azúcar, among many others.

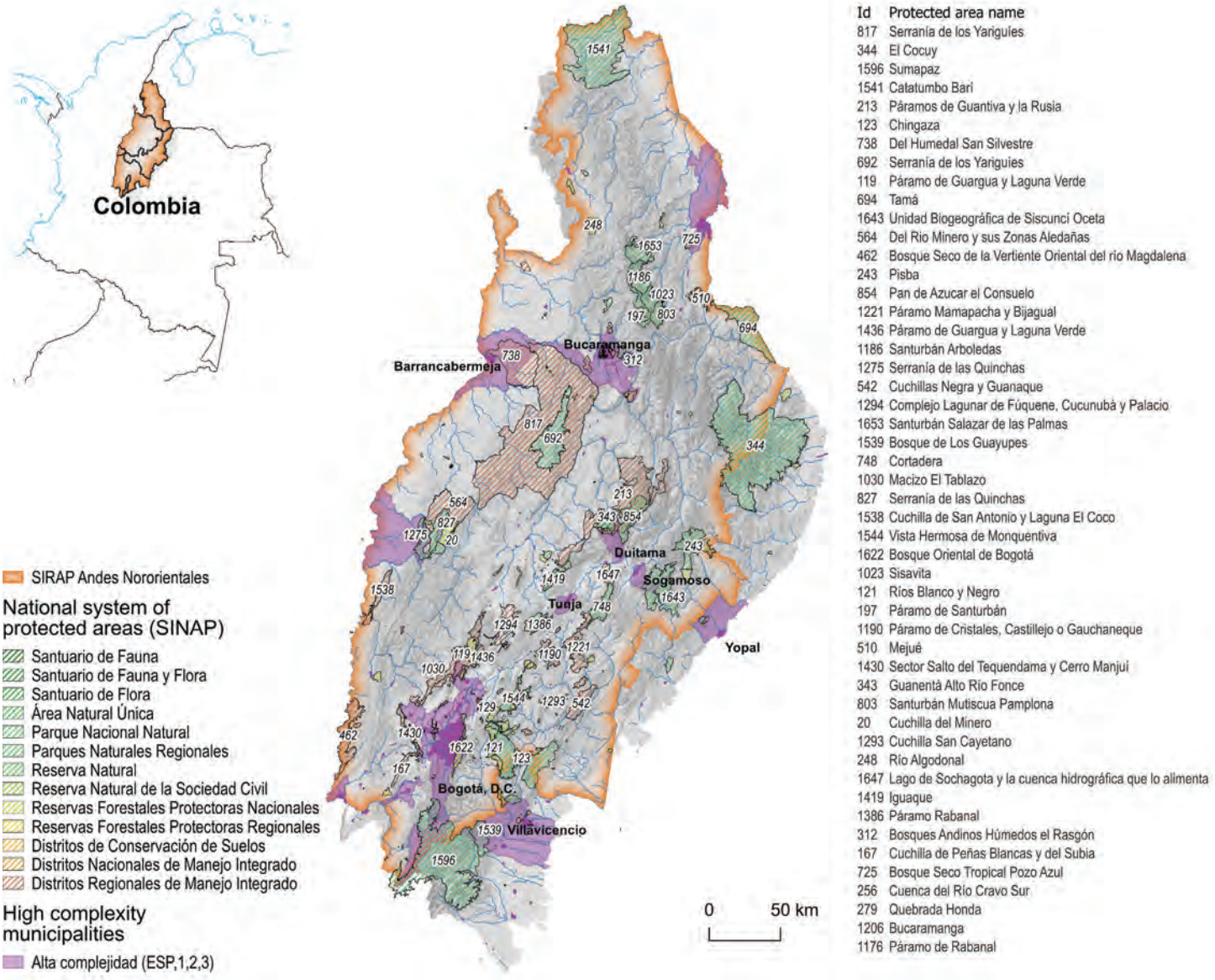


Figure 2: Protected areas and municipalities of high complexity that are located in the jurisdiction of the Northeastern Andes, and the biophysical boundary that contains the protected areas that benefit the municipalities of Tunja, Duitama, and Sogamoso.

Figure 3: Overview of landscape features of the focal area in the selected municipalities, highlighting native vegetation types, agricultural lands, and water infrastructure. The top-left image shows the Paramo de Cortadera, one of the protected areas assessed in the present study, and the top right shows the multipurpose Reservoir "Embalse La Copa" located downstream. The latter is the main water source for irrigation, domestic water use, and energy production in the area (bottom-left). The bottom-right image shows the Paramo de Rabanal and the Teatinos Reservoir, which provide water to the municipality of Tunja. Photo credits: Alejandro Quijano.

Engagement with local actors

The project identified the ecosystem services provided by SINAP for each potential beneficiary, outlining the connections between the supply of services and the municipalities, and the types of metrics required to measure the benefits within a specific context. These conceptualizations were validated and prioritized through discussions with representatives of different sectors. Several virtual and in-person meetings were held with different entities, including Veolia Aguas de Tunja, EMPO-DUITAMA (water utilities), ENEL, GENSA (energy), USOCHICAMOCHA (agriculture), Parques Nacionales Naturales de Colombia (Colombia's National Parks Administration), CORPOBOYACÁ (environmental authorities), and the municipalities of Tunja and Duitama (municipal authorities). During these meetings, project progress was presented, and the characteristics and challenges of each entity related to ecosystem services were discussed. Topics such as the operation and challenges of aqueduct, irrigation, and energy generation systems, as well as conservation activities, were discussed. These meetings allowed for the exchange of knowledge to validate the ecosystem services that are effectively used in the region. For further details, please refer to Technical Appendix 3.





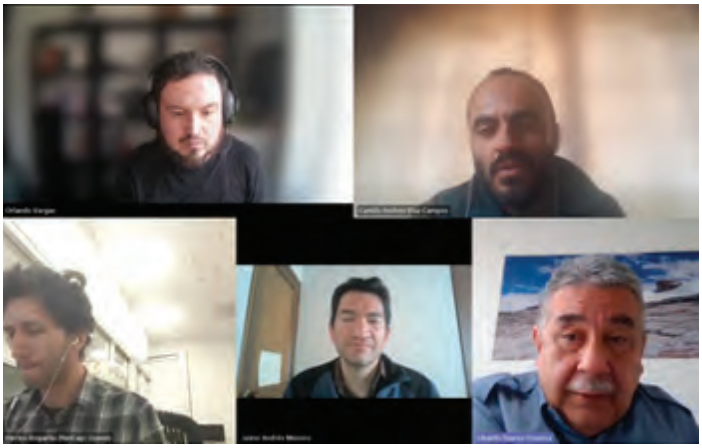
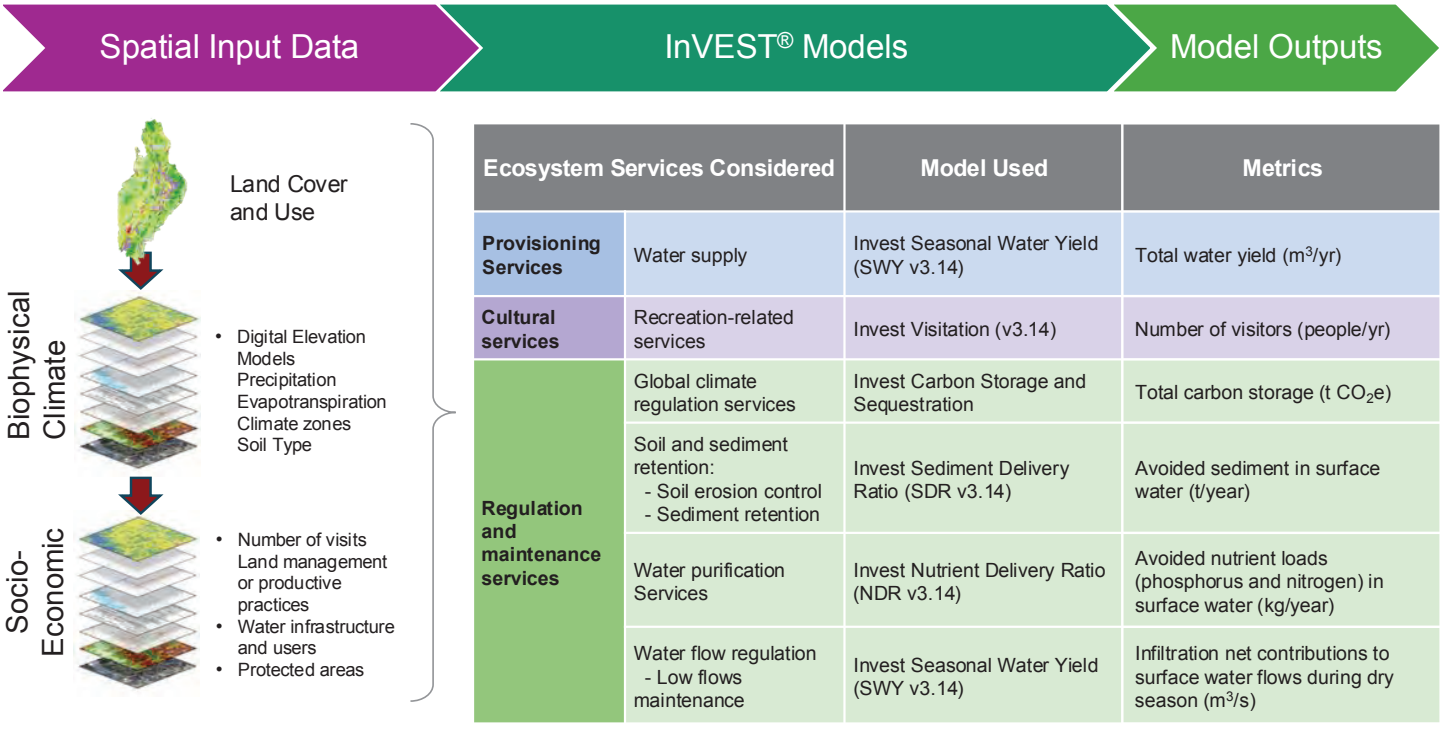



Figure 4: Various meetings held with representatives from entities and actors in the agriculture, sanitation, energy sectors, and municipal authorities, who supported validation of ecosystem services in the region. See Technical Appendix A3 for further details.

Assessment of ecosystem services flows

The project team assessed ecosystem services flows, characterizing two elements: i) the supply of different ecosystem services that originate from ecosystem functioning, and ii) the utilization of these services in human and economic activities in three high-complexity municipalities.

The first component consisted of an assessment using the InVEST (Integrated Assessment of Ecosystem Services and Trade-offs)[18] tool, a free and open-source software suite developed by the Natural Capital Project at Stanford University (see Invest Models on page 12 and Technical Appendix 4). We assessed and integrated geospatial information to generate maps of the potential supply of six different ecosystem services in the focal area. Figure 5 summarizes the ecosystem services considered, the InVEST models, and the unit of measurement of the ecosystem service in each case. This study prioritized ecosystem services for which information is available from institutional and public sources in Colombia, as well as from previous studies and research. Each of the services were quantified with respect to the baseline defined by SEEA-EA. These estimates compare the current provision of ecosystem services with respect to a reference level of ecosystem condition that will generate the minimum possible level of service provision, e.g. a degradation scenario.[19]



Ecosystem Services Considered		Model Used	Metrics
Provisioning Services	Water supply	Invest Seasonal Water Yield (SWY v3.14)	Total water yield (m^3/yr)
Cultural services	Recreation-related services	Invest Visitation (v3.14)	Number of visitors (people/yr)
Regulation and maintenance services	Global climate regulation services	Invest Carbon Storage and Sequestration	Total carbon storage (t CO_2e)
	Soil and sediment retention: - Soil erosion control - Sediment retention	Invest Sediment Delivery Ratio (SDR v3.14)	Avoided sediment in surface water (t/year)
	Water purification Services	Invest Nutrient Delivery Ratio (NDR v3.14)	Avoided nutrient loads (phosphorus and nitrogen) in surface water (kg/year)
	Water flow regulation - Low flows maintenance	Invest Seasonal Water Yield (SWY v3.14)	Infiltration net contributions to surface water flows during dry season (m^3/s)

Figure 5: Spatial analysis workflow for estimating potential ecosystem service supply, integrating biophysical and economic information to estimate metrics for each ecosystem service.

18 For more information see: **What is InVest? Natural Capital Project, Stanford University.**

19 In several ecosystem services, the baseline corresponds to zero. For example, the carbon storage service in an ecosystem is zero if vegetation biomass is completely lost and soils and organic matter are eroded and degraded. In other cases, such as services related to avoided erosion, the baseline corresponds to the absence of vegetation, i.e. bare soil. For services associated with the maintenance of water quantity, such as contributions to base flows (or aquifer recharge), the baseline reflects the condition of degraded soils and vegetation that prevents infiltration, recharge and storage of subsurface water, limiting its functioning as a natural reservoir that maintains flows in water sources during dry season.

InVEST: Open-Source Ecosystem Services Modeling Software

InVEST models are spatially-explicit, using maps as information sources and producing maps as outputs. InVEST returns results in either biophysical terms (e.g., tons of carbon sequestered) or economic terms (e.g., net present value of that sequestered carbon). The spatial resolution of analyses is also flexible, allowing users to address questions at local, regional, or global scales. InVEST models are based on production functions that define how changes in an ecosystem's structure and function are likely to affect the flows and values of ecosystem services across a land- or a seascape. The models account for both service supply (e.g., living habitats as buffers for storm waves) and the location and activities of people who benefit from services (e.g., location of people and infrastructure potentially affected by coastal storms).

For the second element, the project implemented a 'logic chain' analysis identifying and organizing the various components needed to describe and quantify the supply and use of ecosystem services. For an individual ecosystem service (e.g. low flows maintenance: see example in Table 1, and find a complete list in Technical Appendix 5), the logic chain describes a likely set of ecosystem types and provides an indication of the types of metrics that can be used for the measurement of ecosystem services and the benefits in a given context. Logic chains were elaborated and validated with representatives of the agriculture and drinking water sectors in the municipalities of Tunja and Duitama.

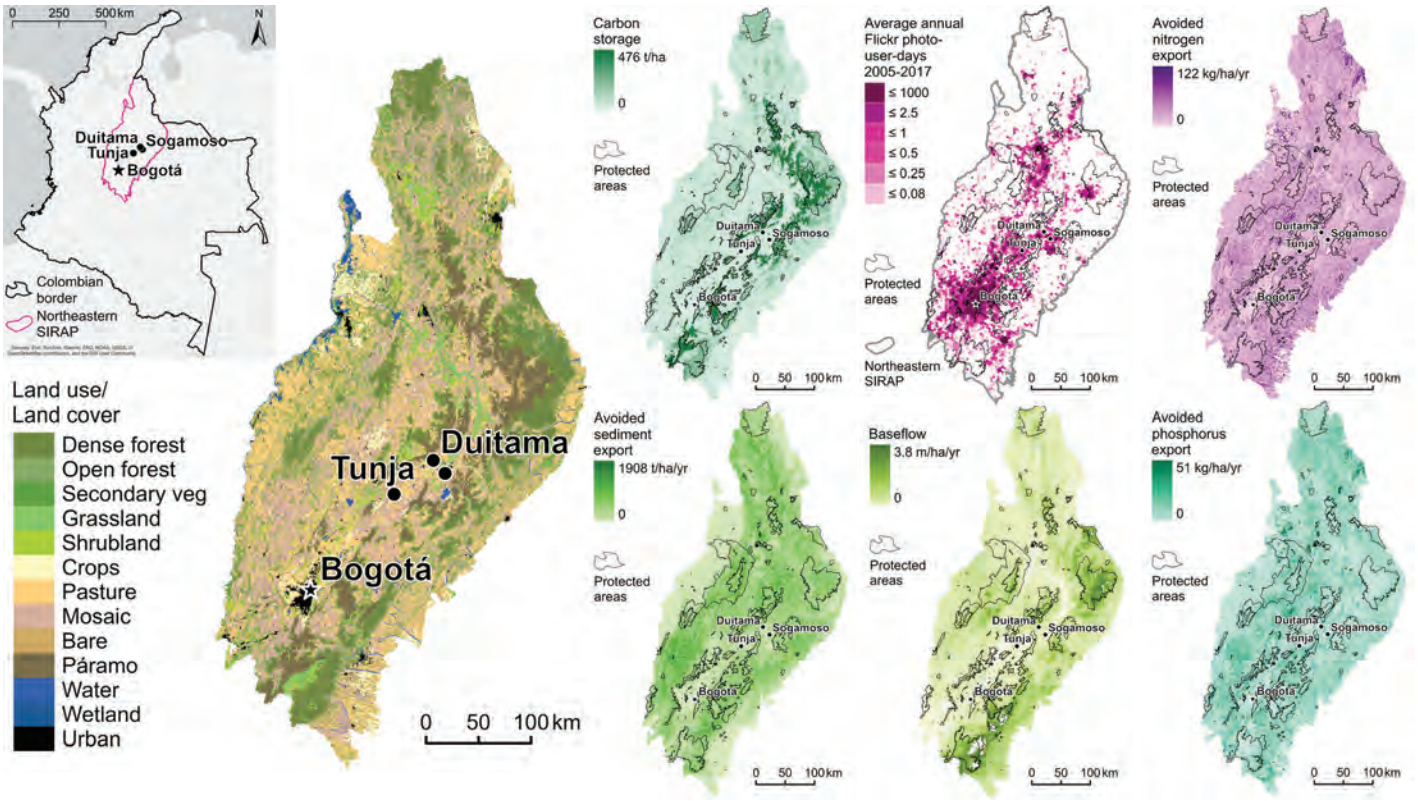


Figure 6: Land use and land cover in the study area (IDEAM, 2021), and the potential supply of different associated ecosystem services, developed through modeling with the InVEST suite. (A Flickr photo-user-day represents one unique photographer who took at least one photo on a specific day and uploaded it to Flickr).

Table 1: Extract from the logic chain analysis performed for the ecosystem services of water provisioning and low flows maintenance, in Duitama and Tunja. See complete list in Technical Appendix 5.

Ecosystem Service	Ecosystems	Factors determining the supply		Factors that determine use	Ecosystem service metric	Benefits	Beneficiaries and users
		Ecológical	Social				
Provisioning: Water supply	Paramos Native montane forests	Soil types, species present in the páramo, age of the páramo, and hydro-climatological variables such as temperature and precipitation Density of forest cover, species present in the forest, age of the forest, soils present.	Governance capacity and response to deforestation processes, occurrence of fires, expansion of the agricultural frontier and entry of the population into the drainage area of the reservoir. Maintenance and operation of the reservoirs.	**Tunja** • Use of water from the Teatinos Reservoir as the main source of supply for the municipality of Tunja • Location of treatment infrastructures • Higher treatment and distribution costs associated with alternative sources to the Teatinos reservoir (i.e., groundwater wells or, if the project is carried out, bringing water from the La Copa reservoir). **Duitama** • Use of water transiting and being allocated by the La Copa reservoir as a source of supply for irrigation, households, energy and water users	Average water yields (m3/yr) attributable to the low evapotranspiration rates of páramo and native old forests .	**Tunja:** • Greater continuity and coverage in the aqueduct system. • Lower operating costs of the purification and distribution systems. • Lower negative hydrosocial impacts such as: Need to anticipate the construction of the adduction project from the La Copa reservoir, or the need to withdraw greater flows from the Copa reservoir, and increase in possible conflicts associated with it. • Impacts associated with possible rationing of the water service, such as: conflicts over the use of water, illegality, increase in monetary poverty, among others **Duitama:** • Higher reliability in water supply from the La Copa reservoir • Increased productivity of agricultural areas downstream of the reservoir. • Reduced risk of crop and harvest losses due to agricultural droughts. • Reduced risk of domestic shortages for some municipalities. • Reduced risk for electricity generation in power plants such as TermoPaipa 1, 2 and 3. • Less conflict over water use in an area with high levels of pressure on water resources.	**User:** • Water utilities company of the municipality of Tunja • UsoChicamocha, as the reservoir manager **Beneficiaries:** • Households, commercial and institutional water users in the service area of the water utilities system of the municipality of Tunja • Water users downstream of La Copa reservoir (including the agricultural sector; irrigation district USOCHICAMOCHA, and other farmers) • Municipalities that draw water for domestic supply from the Chicamocha River. • Electricity generation sector (TermoPaipa 1, 2 and 3, TermoPaipa 4)

Ecosystem Service	Ecosystems	Factors determining the supply		Factors that determine use	Ecosystem service metric	Benefits	Beneficiaries and users
		Ecológical	Social				
Regulating: Low flows maintenance	Mainly Paramos	Soil types, species present in the páramo, age of the páramo, and hydroclimatological variables such as temperature and precipitation.	Governance capacity and response expansion of the agricultural frontier.	**Tunja:** • Water withdrawals from alternative sources to the Teatinos reservoir (i.e., groundwater wells) **Duitama** • Water withdrawals from sources originating Paramo headwaters	Seasonal low flows in water sources (m3/s) attributable to high infiltration of rainfall to soils	**Tunja** • Reduced risk of domestic shortages for some municipalities. **Duitama:** Less conflict over water use in an area • with high levels of pressure on water resources. Lower operating costs of the purification • and distribution systems.	**User:** • Water utilities company of the municipality of Tunja and Duitama **Beneficiaries:** • Households, commercial and institutional water users in the service area of the water utilities of Tunja and Duitama • Small scale farmers that make use of surface waters for irrigation

Economic valuation of ecosystem service flows to high-complexity municipalities

The project team performed a monetary valuation of ecosystem service flows for each logic chain, following SEEA-EA guidelines as well as the advances and recommendations made by previous studies in Colombia. We identified economic valuation methods appropriate to the characteristics of the benefits identified and reported by the beneficiaries and the availability of socioeconomic information in the region, shown in Table 2 and Technical Appendix 6. Results, summarized in Tables 3 and 4, indicate that the maintenance of riverine low-flow service has a significant contribution relative to the municipal GDP in Tunja, Duitama, and Sogamoso. In Duitama, this service alone accounts for 2.13% of the GDP, ensuring water availability for irrigation and water supply and its impact on agricultural productivity. In Sogamoso, the service represents 1.67% of the GDP, while in Tunja, it contributes 0.88%. Similarly, the nutrient retention service highlights the economic value of ecosystems in reducing costs for water treatment and improving water quality. In Duitama, this service totals $46,910 million COP/year, representing 1.67% of GDP. In Sogamoso, the combined value of nitrogen and phosphorus removal reaches $29,912 million, accounting for 0.82% of GDP. For Tunja, the absolute value is lower, at $4,521 million, equivalent to .10% of GDP. The economic valuation of cultural ecosystem services across the municipalities of Duitama, Tunja, and Sogamoso shows the role of protected areas in supporting recreation and tourism, with a total estimated value of $3,807 million COP. Of course, as additional ecosystem service benefits from protected areas are monetized, the estimated total contribution of ecosystems to GDP would increase.

Table 4 further illustrates these contributions by comparing ecosystem service values to municipal revenues. In Tunja, the total value of ecosystem services to maintain stable water supply in 2022 was equivalent to 10.93% of total municipal revenue and 22.94% of local tax revenue. In Duitama, stable water supply services represented 29.69% of total revenue and a substantial 111.57% of local tax revenue – indicating a financial susceptibility of the municipality on this service. For Sogamoso, water supply services comprised 27.45% of total revenue and 88.34% of local tax revenue.

The nutrient retention service also demonstrates the scope of the economic benefits of ecosystems in comparison to municipal income. Combined nitrogen, phosphorus, and sediment removal for Duitama is equivalent to 23.16% of total revenue and 87.05% of local tax revenue. In Tunja, ecosystem services contributed a value equivalent to 1.25% of total revenue and 2.62% of local tax revenue, and in Sogamoso constituted a value equivalent to 13.43% of total revenue and 43.21% of local tax revenue.

Table 2: Valuation methods selected for each of the ecosystem services

Ecosystem Service	Beneficiaries	Valuation Method	Metric of ecosystem service
Global climate regulation	• Society in general • Companies that emit greenhouse gases	Avoided costs, based on the avoided greenhouse gas emissions associated with land conversion. It includes annual adjustments reflecting marginal damages and the criterion of compensation through carbon credits, equivalent to Colombian carbon tax.	Tons of avoided CO_2e
Regulating: Low flow maintenance	• Farmers of Duitama, Sogamoso and Tunja • Society in general • Water Resource Managers	Revealed preferences based on water rates for irrigation and infrastructure maintenance. Rates reflect agricultural users' willingness to pay for stable and sufficient water resources to maintain stable production and minimize agricultural losses.	Water flows (m3/s) available during the dry season, attributable to ecosystem services' functions maintaining baseflow
	• Households • Local and regional authorities	Replacement costs calculated based on the reported use of tankers to transport water during extreme dry conditions. Costs include operating costs (fuel, maintenance, tank car rental) and cost overruns associated with emergency conditions.	
Cultural ecosystem services: Visitation	• Visitors to protected areas	Travel cost based on expenses incurred by visitors (fuel, tolls, travel time, vehicle maintenance). It includes a reverse distance model to distribute visitors based on the probability of visit based on the distance from the city to the protected area.	Number of visitors to protected areas
Regulating: Sediment retention	• Water utilities that operate and maintain reservoirs	Replacement costs, based on the capital costs of reduced lifespan of existing reservoirs, due to sediment inflows and entrapment.	Avoided of sediment inflow to reservoirs (ton/yr)
Regulating: N and P retention	• Different water users	Replacement cost, based on the equivalent capital cost required to maintain water quality in surface water sources above the threshold of eutrophication due to the loads of nitrogen and phosphorus in water bodies.	Avoided nutrient loads (kg/yr)

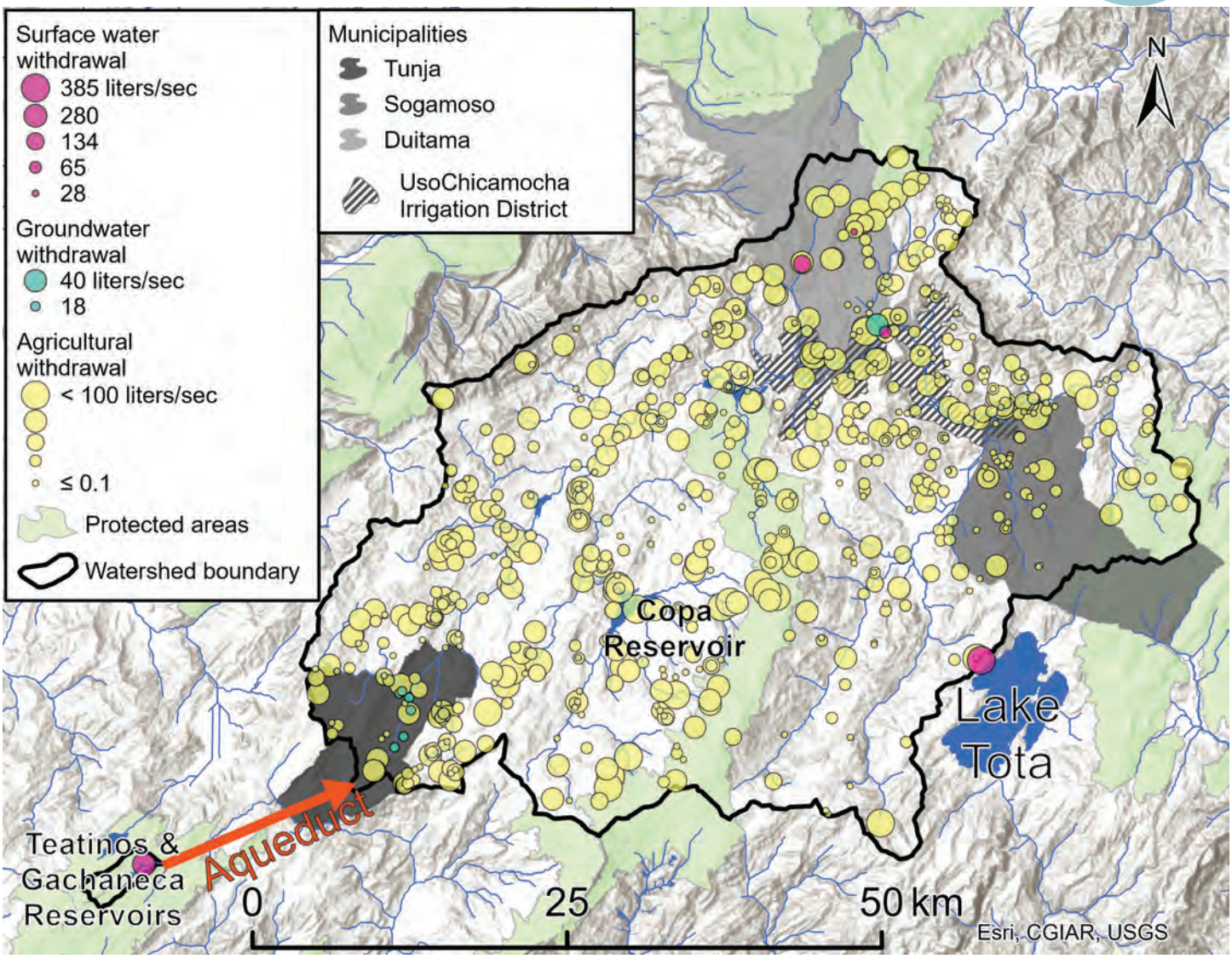


Figure 7: Water users by magnitude (liters per second) in Tunja, Sogamoso, and Duitama.

Table 3: Summary of results of the selected ecosystem service valuation for the municipalities of Tunja, Duitama, and Sogamoso. Figures in million COP $/yr.

Service	Tunja	Duitama	Sogamoso
Nitrogen retention	328	10,337	7,100
Phosphorus retention	347	29,076	22,812
Sediment retention	3,846	7,497	—
Low flow maintenance	39,523	60,125	61,153
Visitation	782	1,381	1,643
Total	**44,827**	**108,416**	**92,709**
Municipal GDP	4,489,000	2,827,000	3,670,000
% of municipal GDP	1.00%	3.84%	2.53%

Table 4: Comparison of the selected ecosystem service valuation and the total municipal income and local tax revenue for the municipalities of Tunja, Duitama, and Sogamoso. Figures in Million COP $/yr.

			Water quantity			Water quality				
				Ecosystem services proportion (%)					Ecosystem services proportion (%)	
Municipality	Total Municipal Revenue 2022	Local tax Revenue 2022	Water supply / low flows maintenance	Municipal Revenue	Local Tax Revenue	Nitrogen Removal	Phosphorus Removal	Sediment Retention	Municipal Revenue	Local Tax Revenue
Tunja	$361,504	$172,304	$39,523.29	10.9%	22.9%	$328	$347	$3,846	1.3%	2.6%
Duitama	$202,530	$53,891	$60,124.78	29.7%	111.6%	$10,337	$29,076	$7,497	23.2%	87.0%
Sogamoso	$222,749	$69,224	$61,153.48	27.5%	88.3%	$7,100	$22,812	NA	13.4%	43.2%

Note: Figures in current Colombian pesos (COP) as of 2022.

Capacity Development

The adoption of SEEA-EA in national accounts systems is a long-term effort that requires fostering interdisciplinary and inter-institutional cooperation and strengthening technical capacity for its effective implementation. In this project, our approach to capacity development was to serve as a bridge between policymakers — in this case, the DNP's efforts to implement CONPES 4050, data providers, DANE, and societal actors. The project fostered a series of technical discussions with entities relevant to the adoption of the SEEA-EA to co-develop specific methodological advances. By adhering to SEEA-EA principles and bringing in the users' perspective (i.e. focusing on CONPES and sectors in Tunja, Duitama, Sogamoso that benefit from protected natural areas), the team developed important insights and shared understanding across the institutions involved in the effort.

Specific co-developments for advancing SEEA-EA in Colombia derived from this work include key processes and recommendations for engagement to identify potential beneficiaries, methods for validating ecosystem services, valuation methods, and documented logical chains including ecosystems, drivers, metrics, users, and beneficiaries. These advances are relevant for inclusion in future curricula at local universities and more broadly across the international natural capital accounting community of practice to promote adoption of these approaches.

Outcomes

Policy and Finance Implications and Pathways for Mainstreaming Natural Capital Approaches

Contributions to the applications of the SEEA-EA in policy design

One of the main benefits of relying on the SEEA-EA framework for the project is increased legitimacy, repeatability, and integration across sectors.

Quantifying the contributions of protected areas to the municipalities of Tunja, Duitama, and Sogamoso does not constitute a national ecosystem accounting exercise, at least not at the scale of the national accounts DANE is evaluating and developing. Rather than accounting per se, evaluating the contribution of protected areas to different municipalities aims to establish financing measures for preserving the benefits of these areas. Adopting the SEEA-EA standards and validating their use by policymakers can contribute to generating win-win solutions.

Ecosystem services, first conceptualized over four decades ago, have seen progressive development with broad participation from academia, government, practitioners and NGOs. Over these four decades, possibly thousands of natural capital assessments have been developed in countries worldwide. Colombia has been no exception, with multiple evaluations conducted (see for instance Technical Appendix 7). These diverse evaluations have been valuable for reflecting the importance of ecosystems in the country. However, they have typically been based on different conceptualizations, classifications, terminologies, and approaches, limiting their reproducibility, replicability, comparability, and ultimately their commensurability. These aspects together often result in heterogeneous ecosystem service evaluations that limit the possibilities of establishing measures such as adoption of financing or economic mechanisms. Unified standards like SEEA-EA improve legitimacy and help establish acceptable financing mechanisms.

Additionally, specific conceptualizations, such as the idea that ecosystem services must be used by beneficiaries in order to be considered a service, further legitimize these financing instruments: in other words, at least one user must be identified. This often involves knowing, linking, and working with the potential users of the ecosystem service to conduct an objective evaluation. Involving the user in illuminating and identifying the service also contributes to building legitimacy around policies and financing.

Contributions to the scaling of the SEEA-EA in Colombia

This project developed a series of novel workflows for characterizing and valuing ecosystem service flows, aligned with SEEA-EA standards and policymaking in the Colombian context. The project demonstrated how to effectively integrate locally available data, biophysical models, and economic valuation techniques to advance the implementation of Accounts 3 and 4 of the SEEA-EA in Colombia.

One conceptual contribution among others was the identification of ecosystem accounting baselines[20] for several water ecosystem services in the Colombian context. Baselines are an important innovation within the SEEA-EA framework, as they help establish reference values against which it is possible to compare changes in the provision of ecosystem services over time. We developed specific modeling pipelines and criteria that should allow for replicating this quantification of baselines, and the attribution of the effects of ecosystems on perceived benefits by separating them from abiotic processes.

The project also provides a demonstration of modular and progressive implementation of SEEA ecosystem service flow accounts, considering sectoral and subnational policy priorities. The team validated data needs and capacities required to assess several key specific ecosystem services. As part of the process of adapting the SEEA-EA to the context of Colombia, the project also reviewed numerous previous studies on ecosystem service valuation in Colombia (see Technical Appendix 7). These studies demonstrate that Colombia already has a high capacity for and knowledge of these natural capital approaches/valuation and provide a foundation for valuing societal/economic benefits of protected areas.

Contributions for Designing Compensation Mechanisms for CONPES 4050

The analysis of ecosystem service values highlights the connections between protected areas, natural ecosystems, and multiple perceived benefits across different sectors in the evaluated municipalities.

Our comparison of the economic values of ecosystem services with respect to municipal GDP reveals their strategic role in local economies. Compared against GDP, ecosystem service flows represent a significant economic value in comparison with economic activity of municipalities, especially in Duitama, where it reaches 3.84% of the total municipal GDP in 2023. In Sogamoso, the economic value of the services equals 2.53%, and in Tunja, 1.0% of the municipal GDP. These values underscore the importance of ecosystem services in the local economy, particularly for the agricultural, domestic, and industrial sectors.

Our study provides an estimate of the economic dependency of sectors in high complexity municipalities to services provided by protected areas, enabling the design of innovative financing schemes. The maintenance of low flows, in particular, stands out in water provision for multiple economic sectors, while nutrient retention is also important for reducing costs associated with water treatment. In municipalities like Duitama, where both services represent a significant proportion of the GDP, the conservation of protected areas emerges as a key investment to sustain economic activity. The integration of ecosystem service values into local economic accounts would support the generation of innovative financing schemes for the

20 Most valuation studies in Colombia preceded the formulation of the SEEA-EA. An important result of this review is the understanding that in several cases, they have adopted methodological and conceptual approaches that are not compatible with the recent standardizations and refinements recently adopted by the SEEA. For example, to be able to quantify ecosystem services and ensure their comparability over time, the SEEA-EA developed the concept of baseline. This corresponds to a reference level of the ecosystem condition that will generate the minimum possible level of service supply.

management of protected areas. As more ecosystem service flows are quantified and valued economically, the compensation schemes can be adapted.

This project's results constitute a milestone in the adoption of the CONPES 4050 road map, fulfilling a prerequisite for designing a financial compensation mechanism. The quantification of economic benefits originating from protected areas to strategic economic sectors in a target geography provides concrete reference values for the flow of benefits currently perceived by users of ecosystem services. **More importantly, it offers a spatially distributed attribution of those benefits to landscape units, offering a clearer understanding of how to design payment mechanisms by helping to identify how much, where, and to whom compensation should go.**

As demonstrated, the ability of protected areas to maintain local watershed conditions, reduce soil erosion, and maintain the hydrological functionality of native páramo vegetation constitutes a key strategy for the security of water-dependent sectors. Economic instruments such as payments for ecosystem services and earmarked environmental investment in water fees can be implemented to internalize the costs of maintaining and improving watershed conditions, enhancing the mandate and management of protected areas.

Expanding applications based on SEEA-EA

DANE is the institution leading the adoption of ecosystem accounting under SEEA-EA at the national level. As part of this process, DANE will continue to define the implementation roadmap, including the selection of SEEA-EA accounts to be assessed, the prioritization of ecosystem services, the spatial units of analysis, the methodologies, the information sources, and the frequency of evaluations. In this sense, although the objective of this work was not strictly to carry out an accounting exercise under SEEA-EA, it does provide a series of lessons learned. For this reason, it may be helpful for DANE to closely monitor such exercises, as they can serve as references for decision-making regarding the implementation of SEEA-EA in Colombia.

The dialogue between entities designing or implementing policies, such as the case of DNP with the CONPES 4050, is a key input for the DANE approach of a modular implementation of the SEEA-EA in Colombia. Therefore, it is essential for DNP and other entities with similar missions to continue advancing in parallel with the adoption of these processes.

This study demonstrates other examples on how different entities can contribute to SEEA-EA implementation. For instance, the Special Administrative Unit of National Natural Protected Parks of Colombia (Parques Nacionales), as the administrator of protected areas, is uniquely positioned to advance the valuation of cultural ecosystem services such as ecotourism and recreational activities. Strengthening staff's skills in data collection and stakeholder engagement would help maximize this potential. This includes gathering detailed information from participants in tourism value chains, such as tour operators, local businesses, and visitors, to quantify the economic benefits derived from protected areas. Parques Nacionales can develop stronger capacities to implement surveys and visitor expenditure studies, enabling a robust understanding of tourism's economic contributions. Furthermore, by incorporating spatial analysis tools like GIS (Geographic Information Systems), staff could map out the cultural services provided by each protected area, linking them with conservation efforts. Capacity development in economic valuation techniques will ensure the integration of cultural ecosystem services into broader SEEA-EA assessments, facilitating informed decision-making and support for sustainable tourism practices.

Civil society actors are also relevant for advancing these efforts. For instance, USOCHICAMOCHA, an association of water users of the La Copa Reservoir, already maintains significant data regarding water consumption in the agriculture sector, which provides a strong foundation for advancing the process of ecosystem service valuation. However, developing additional skills and capacities would allow for scaling and improving the application of the SEEA-EA framework. Conducting periodic surveys about production technologies and water usage among different types of users will allow for a clearer understanding of the economic dependence on the

irrigation district. These surveys will highlight the role of protected areas in maintaining water provision, as they feed into the irrigation district's hydrological functionality. Furthermore, USOCHICAMOCHA's role as the administrator of water resources necessitates advanced data management and analysis skills to process and interpret information about water availability, uses, and costs. By strengthening its capacities in economic valuation methods, the organization could better communicate the importance of water-related ecosystem services to stakeholders, providing solid evidence for conservation investments and policy decisions.

As the regional environmental authority, CORPOBOYACÁ possesses substantial data on the current state of ecosystems, including biodiversity, land cover, and ecosystem conditions. SEEA-EA offers the opportunity to adopt novel strategies for partnering productive sectors, such as agriculture, industry, and tourism, which are key beneficiaries of ecosystem services. To address this, CORPOBOYACÁ needs to strengthen its capacity for inter-sectoral coordination and data integration. Developing skills in economic valuation methodologies will allow the authority to assess the economic benefits of ecosystem services and highlight their contribution to regional economies. Aligning its ecosystem monitoring efforts with the SEEA-EA framework will also enhance CORPOBOYACÁ's ability to explicitly include ecosystem service values in environmental accounts.

The municipality of Duitama, as a political authority, currently lacks much of the information and capacity needed to adopt the SEEA-EA framework. However, several municipal offices, such as agriculture, environment, and planning departments, hold significant potential to gather and analyze data related to agricultural users, water consumption, and local ecosystem services. The implementation of SEEA-EA depends on municipalities' capacity to collect and report information regarding agricultural production, water demand, and other ecosystem service dependencies. The municipality of Duitama should also focus on improving skills in economic valuation to assess the direct and indirect benefits that ecosystems provide to local economic sectors, such as agriculture and domestic water users. Encouraging interdepartmental coordination and fostering partnerships with organizations like USOCHICAMOCHA and CORPOBOYACÁ will help address information gaps and align efforts toward the integration of ecosystem service values into municipal policies and planning frameworks.

Implementation Strategy

To advance the implementation of the compensation mechanisms advanced through this work and outlined in CONPES 4050, DNP has planned two pathways to further apply the present findings:

1

Designing the compensation mechanism for the municipalities of Tunja, Duitama, and Sogamoso. Building on the present study, DNP has conducted a series of assessments to evaluate the fiscal and economic costs associated with nature protection within SINAP. By integrating these findings, and comparing the benefits and costs of protection, specific financial and institutional arrangements can be designed to create sustainable funding mechanisms connecting ecosystem services providers and beneficiaries. This comprehensive approach – linking both supply and utilization – can ensure that protection efforts are both economically viable to beneficiaries and entities that assume the costs and are supported by adequate institutional and management structures.

2

Scaling the application to other high-complexity municipalities. The biophysical analysis of ecosystem service supply developed in the present study covers an extensive area of Colombia's Northeastern Andes and can readily be applied to other municipalities, to fit other specific ecological and economic contexts, thereby broadening the impact and applicability of our findings. A modular approach can also enable the eventual design of larger scale compensation mechanisms that explore coordination between municipalities to enhance the impact of biodiversity financing.

Lessons Learned

While the evaluation and potential implementation of the SEEA-EA in Colombia are being led by DANE, efforts have been made to establish institutional synergies with DNP. In this sense, compiling reflections and lessons learned from quantifying the contribution of protected natural areas to the municipalities of Tunja, Duitama, and Sogamoso is useful.

These reflections and lessons learned can be organized into three blocks: i) methodological, which answers questions such as how to refine methods; assimilate principles, concepts, and definitions; assess data availability and gaps; and prioritize assessments in accordance with SEEA-EA concepts and principles, ii) viability, which addresses aspects essential to the application of SEEA-EA at the national level and within the framework itself and iii) capacity and inter-institutional coordination needs.

Methodological Aspects

The SEEA-EA framework places emphasis on the beneficiaries of ecosystem services. This approach requires a comprehensive description beyond the biophysical estimation of ecosystem service supply, one that includes societal, technology, and regulatory factors to quantify ecosystem services. For instance, existing regulation prohibiting sediment passing through reservoirs influences the actual value of the sediment retention service.

Objective attribution of the flows of benefits to specific users is key to enable applicability and equity in the design of financial compensation instruments. For example, natural areas that contribute to reducing sediments reaching the La Copa reservoir concurrently benefit domestic, agricultural, and energy generation sectors. Additionally, within these sectors, not all beneficiaries belong to the municipalities of interest – i.e., Tunja, Duitama, and Sogamoso. This situation implies that ecosystem services utilization depends on spatial interactions within sectors and municipalities of interest. In this project, these subdivisions were assigned proportionally to each sector's water quantity withdrawals. For cases like the agricultural sector, they were further weighted based on the proportion of the services area that includes irrigation infrastructure. However, given the multifold nature of ecosystem service flows between users and beneficiaries, in some cases to enable practical implementation of the financing schemes, the attribution will require further validation and dialogue between stakeholders.

Viability Aspects

Beneficiaries' collaboration: Beneficiaries' collaboration is key for an objective evaluation; however, this support is not always guaranteed. For example, in this project, while collaboration was obtained from several potential ecosystem service users, not all attempts were successful. Some potential users never responded to meeting requests, and others, despite initially offering information, never provided it despite multiple reminders. This situation affects the precision of the results and the verification of the service's existence. The beneficiaries' collaboration can, in some cases, determine the outcome of the ecosystem service evaluation.

The relevance of information: Information also plays a key role in the viability of ecosystem service assessments. In many cases, the necessary information and custody for certain evaluations is handled by national entities. However, despite multiple requests to such entities, the information was not always provided. Therefore, guaranteeing the viability of these evaluations requires support from various national institutions that produce and manage environmental information. Two aspects are crucial in this context: (1) identifying strategic information at the national, regional, and municipal levels to conduct ecosystem service assessment exercises, and (2) building inter-institutional partnerships to ensure the availability of such information in a timely manner.

Capacity development needs

To replicate, reproduce, and scale this type of evaluation, it is important for Colombia to continue to strengthen certain capacities. These are essential not only to conduct such exercises rigorously but also efficiently. In this regard, the following aspects are key:

Inter-institutional coordination: Many of the inputs needed to apply the SEEA-EA already exist within Colombian institutions. This includes elements such as environmental or socioeconomic information, knowledge, and engagement with potential beneficiaries. Therefore, capacity development can focus on coordination of the various entities that make up the Colombian Environmental Information System (SIAC). Representation from different economic sectors is crucial, including to:

- Facilitate cross-sectoral collaboration to ensure that information flows between public entities, environmental authorities, and productive sectors
- Address institutional barriers such as limited resources, workforce constraints, and lack of tools by promoting innovative financing mechanisms, capacity-building programs, and policy support

Professional training: Conducting the evaluation and assessment of ecosystem services requires professional skills across multiple dimensions. While the country and the institutions responsible for such exercises have professionals with solid training, it may be beneficial to strengthen certain skills in specific areas such as:

- Developing curricula to foster shared understanding of ecosystem services, their definitions, and their role in supporting local and regional economies

- Biophysical modeling, to enhance knowledge of the phenomena represented through modeling tools, as well as the various types of software (particularly important)
- Skills in economic and environmental valuation methods, enabling stakeholders to assess ecosystem service flows and their contributions effectively
- Data collection and analysis, including techniques such as stakeholder surveys, GIS mapping, and integration of environmental and economic datasets

Institutionalization in product generation: Ecosystem accounting relies on information produced by various entities. However, in many cases, multiple sources of information are available. This can influence the results of ecosystem accounting. For example, assessing a specific ecosystem service might allow the use of either the Land Cover Map or the National Ecosystems Map. However, the choice between these sources can, in turn, affect the outcome, resulting in a higher or lower valuation of the ecosystem service depending on the case. For this reason, it is important to define and institutionalize not only methodologies but also the information sources on which they are based. This may include aspects such as the source, scale, frequency, and others.

Adoption by local entities: The SEEA-EA application also has significant potential to inform decision-making in the three municipalities, integrating economic and environmental considerations; however, its full application faces several challenges. First, the system requires a broad set of technical and analytical skills among public servants across various municipal offices. These skills include data and spatial analysis and economic modeling, which are often absent or limited among local government staff. The effective assimilation of the SEEA-EA relies on access to comprehensive datasets such as information on users, economic value creation, ecosystem conditions, and service flows, which are not readily available to municipalities or environmental agencies due to limited data infrastructure or fragmented information systems.

Moreover, these challenges are compounded by the existing workload of municipal officers, who are already responsible for a broad range of tasks, leaving little room for new, resource-intensive initiatives. This situation is exacerbated by limited budgets that restrict the hiring of new personnel or the acquisition of advanced tools and technology needed to fully implement the SEEA-EA. Addressing these barriers requires strategic capacity development, funding allocation, and institutional support to bridge the gaps in skills, data, and resources, beyond current institutional budgetary constraints. To address these limitations, municipalities will require a modular approach for a progressive development and adoption of SEEA, focused on local priorities and capacities.

This project's results demonstrate the role of natural capital approaches in providing a common framework to integrate environmental, economic and societal objectives, and the coordination needed at institutional, sectoral, and strategic levels to achieve policy objectives in Colombia. By highlighting these interdependencies between nature, societal wellbeing, and economic activity, and between institutions, the study is a key contribution towards the adoption of novel and legitimate financing mechanisms for nature protection based on shared responsibility.

Read more and access the report appendices on this project page: https://bit.ly/3PsColombia.

Contact NaturalCapitalProject@stanford.edu for more information.

DOI: 10.18235/0013736


natural
capital
PROJECT


Departamento
Nacional de Planeación


gef


IDB

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Advancing ecosystem accounting for financing protected areas in Colombia: final report / Hector Angarita, Jesse A. Goldstein, Lisa Mandle, Jaime Moreno Miranda, Orlando Vargas Rayo, Carolina Díaz Giraldo, Fabián Darío Villalba Pardo, Camilo Andrés Díaz Campos, Lina Barbosa; editors, Vanesa Callau, Elana Krimbell, Duval Llaguno, Mary Ruckelshaus, Gregory Watson, Zoë Wilson.

p. cm. — (IDB Technical Note ; 3216)

Includes bibliographical references.

1. Protected areas-Economic aspects-Colombia. 2. Protected areas-Finance-Colombia. 3. Biodiversity conservation-Finance-Colombia. I. Angarita, Héctor. II. Goldstein, Jesse A. III. Mandle, Lisa. IV. Moreno Miranda, Jaime. V. Vargas Rayo, Orlando. VI. Díaz Giraldo, Carolina. VII. Villalba Pardo, Fabián Darío. VIII. Díaz Campos, Camilo Andrés. IX. Barbosa, Lina. X. Callau, Vanesa, editor. XI. Krimbell, Elana, editor. XII. Llaguno, Duval. XIII. Ruckelshaus, Mary, editor. XIV. Watson, Gregory, editor. XV. Wilson, Zoë. XVI. Inter-American Development Bank. Biodiversity and Natural Capital Unit. XVII. Series.

IDB-TN-3216

http://www.iadb.org