# Nature-Based Solutions for Hydropower Companies

## Monetizing Ecosystem Services to Finance Upstream Conservation: Lessons Learned from Two Colombian Pilots

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## Nature-Based Solutions for Hydropower Companies

### Monetizing Ecosystem Services to Finance Upstream Conservation: Lessons Learned from Two Colombian Pilots

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**Abstract**
While forest ecosystems provide invaluable services to water users, conservation efforts have fallen short of needs. Spending on nature is negligible compared to the $800bn invested annually by the water sector.

To bridge the conservation funding gap, one solution could be the monetization of ecosystem services such as sedimentation and water flow regulation, which can be measured, priced and paid for by hydropower companies. This approach creates a financial incentive for the private sector to positively impact biodiversity, human well-being and energy security, while decreasing the need to build additional hydroelectric plants.

To explore this hypothesis, Conservation International (CI) and The Nature Conservancy (TNC) have developed the Blue Energy Mechanism (BEM).

BEM is an innovative way to engage hydropower companies in upstream conservation. Inspired by project finance techniques, it is conceptualized as a pay-for-success scheme that reduces the implementation and financial risk to hydropower companies by avoiding upfront investment costs and making payments based on the actual volume of ecosystem benefits they receive from a set of nature-based solutions.

For the two selected Colombian pilot projects, the proposed portfolio of nature-based solutions proved to be effective in reducing sediment export to reservoirs and in increasing their lifespans. However, this did not translate into immediate pay-for-success transactions, due to (i) uncertainty regarding future land-use scenarios and the associated actual volume of ecosystem services, (ii) competition from grey infrastructure alternatives that have been deemed by the pilots less risky both in terms of implementation and capacity to deliver the expected benefits, and (iii) implementation challenges associated with the size of the portfolio to be implemented.

Despite the above, the experience accumulated from the pilot projects presented in this report has generated important lessons learned that can be useful to future BEM candidates or similar pay-for-success schemes.

**Keywords**:
Nature-based solutions, energy, hydropower, sedimentation, flow regulation,

**Areas**:
Multi country, Colombia

# Soluciones basadas en la naturaleza para empresas hidroeléctricas

## Monetización de servicios ecosistémicos para financiar la conservación de cuencas abastecedoras: lecciones aprendidas de dos proyectos piloto colombianos


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**Resumen**

Aunque los ecosistemas forestales prestan servicios inestimables a los usuarios del agua, los esfuerzos para su conservación están lejos de cubrir las necesidades. Las inversiones en naturaleza son insignificantes en comparación con los 800.000 millones de dólares que se invierten anualmente el sector del agua.

Para colmar este déficit, una solución podría ser la monetización de servicios ecosistémicos como el control de la erosión y la regulación hídrica, que pueden ser medidos, valorados y pagados por empresas hidroeléctricas. Este abordaje crea un incentivo financiero para que el sector privado genere impactos positivos sobre la biodiversidad, el bienestar humano y la seguridad energética, al tiempo que disminuye la necesidad de construir nuevas centrales hidroeléctricas.

Para explorar esta hipótesis, Conservation International (CI) y The Nature Conservancy (TNC) han desarrollado el Mecanismo Energía Azul (BEM).

BEM es una forma innovadora de implicar a las empresas hidroeléctricas en la conservación de sus cuencas abastecedoras. Inspirado en las técnicas de financiación de proyectos, se concibe como un sistema de pago por éxito que reduce el riesgo financiero y de ejecución de las empresas hidroeléctricas al evitar los costes de inversión iniciales y realizar pagos basados en el volumen real de beneficios ecosistémicos que reciben de un conjunto de soluciones basadas en la naturaleza.

En los dos proyectos piloto colombianos seleccionados, la cartera propuesta de soluciones basadas en la naturaleza demostró su eficacia para reducir la exportación de sedimentos a los embalses y aumentar su vida útil. Sin embargo, esto no se tradujo en la implementación de mecanismos de pago por éxito, debido a (i) la incertidumbre respecto a los futuros escenarios de uso de la tierra y el volumen real asociado de servicios ecosistémicos, (ii) la competencia de alternativas de infraestructura gris que han sido consideradas por los proyectos piloto como menos arriesgadas tanto en términos de implementación como de capacidad para proporcionar los beneficios esperados, y (iii) los retos de implementación asociados al tamaño de la cartera de soluciones a implementar.

A pesar de lo anterior, la experiencia acumulada a partir de los proyectos piloto presentados en este informe ha generado importantes lecciones aprendidas que pueden ser útiles para futuros candidatos BEM o esquemas similares de pago por éxito..



**Palabras clave**:
Soluciones basadas en la naturaleza, energía, hidroelectricidad, sedimentación, regulación hídrica,

**Áreas**:
Multipaís, Colombia

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We are very grateful to all the Conservation International and The Nature Conservancy staff who shared experience and ideas to develop this concept.

Finally, we would like to thank the project team members at AES and ENEL Colombia for sharing the data necessary for this study and for making the time to think out of the box and explore new solutions to their operational challenges.

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# Introduction

The Blue Energy Mechanism (BEM) originated based on a premise that water regulation and sedimentation control ecosystem services can provide significant commercial value to the hydropower sector. Evidence suggests that high-mountain ecosystems, such as paramos or cloud forests, regulate water flows and also “harvest” additional water from moisture-laden air, so their protection and restoration might maintain or increase baseflows, especially during dry seasons, contributing to increased or optimized electricity generation. Also, given the protective cover effect of natural vegetation on the soil, erosion and sediment exports downstream would be reduced, resulting in the reduction in hydropower operating and maintenance costs (e.g., dredging, equipment wear) and increasing reservoir lifespans.

These benefits were perceived to be the foundation of a pay-for-success model designed to engage hydropower companies (HPCs) in upstream conservation and restoration activities and attract private sector financing. Replicating project finance structures, BEM would rely on cash flows from nature-based solutions (NbS) that would be sufficient to add financial value to the HPCs, finance watershed conservation and restoration activities, and provide adequate remuneration to debt and equity investors.

While CI and TNC still believe in this initial hypothesis, the experience from the two Colombian pilots has led us to reconsider our approach to three fundamental project parameters: (i) enabling conditions, focusing on how to generate sufficient ecosystem services while designing a realistic project from an implementation and financing perspective, (ii) engagement with HPC, to better understand their challenges, how they plan to face them and their perception of nature-based solutions (NbS), and (iii) typology of financial benefits, and how to generate the conditions for a bankable project from steady and recurring cash flows.

This document presents the lessons learned from the BEM pilots. It starts by introducing NbS most relevant to HPCs and potential monetization pathways. Section two describes how the BEM was designed as an innovative way to engage HPCs in conservation and restoration of natural ecosystems. In section three, it details the BEM pilot selection process. Section four outlines the methodology used to build a portfolio of NbS that maximizes impacts and optimizes implementation. A summary of the study cases for the two pilots is presented in section five. Lastly, section six concludes the document with lessons learned from the pilots that can be used by future project developers and facilitate the implementation of pay-for-success schemes.

# 1. Nature-based solutions for the hydropower sector

Nature-based solutions are defined by the International Union for Conservation of Nature (IUCN) as "actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits. They are underpinned by benefits that flow from healthy ecosystems and target major challenges like climate change, disaster risk reduction, food and water security, health and are critical to economic development" (Cohen-Sacham et al., 2016).

For the hydropower sector, natural ecosystem conservation and restoration as an NbS can specifically tackle challenges related to disruption in water flows, in terms of both overall annual volume and intra-year fluctuation, as well as issues related to soil erosion and sediment export towards production assets. Moreover, they provide a multitude of other benefits, such as carbon sequestration habitat for pollinators and biodiversity conservation in general, which is what sets NbS apart from more conventional grey infrastructure solutions. Lastly, they can also be beneficial to other stakeholders such as water utilities and irrigation boards, creating opportunities for HPCs to share the financial burden of their implementation.

## 1.1. NbS for the hydropower sector and how to monetize them

Under specific conditions, forest ecosystems may regulate water flows in streams and rivers, influencing volume availability as well as the timing of its delivery. This regulation is the result of complex processes such as water interception, evapotranspiration and infiltration (Ellison et al., 2017). A change in vegetation type and cover can have profound effects on water availability in streams and rivers. Forest ecosystems provide soil protection and, therefore, can function as "sponges" that accumulate water during the rainy season and release it during the dry season. They can thus play an important role in attenuation of extreme weather events such as floods and droughts (Peña-Arancibia et al., 2019).

Natural ecosystems such as paramos and tropical montane cloud forests , may have unique hydrological characteristics resulting in a positive water balance by being able to capture water from moisture-laden air in addition to rainfall precipitation (Sáenz and Mulligan, 2013).

For the hydropower sector, higher or better regulated water flows could translate into higher electricity production or sales optimization, especially if water volumes available for generation of electricity during the dry season can be maintained or increased (Sáenz et al., 2014b). Potential financial benefits are derived not only from the increased volume of electricity production generated, but also from higher sales prices during the dry season, which are typically seen in countries that rely heavily on hydroelectricity.

Regarding sediments export, natural ecosystems with multiple strata of vegetation are more efficient at reducing erosion (Wischmeier and Smith, 1978), which in watersheds might be translated into a reduction of sediment exports that impact downstream hydropower production assets (e.g., reservoirs).

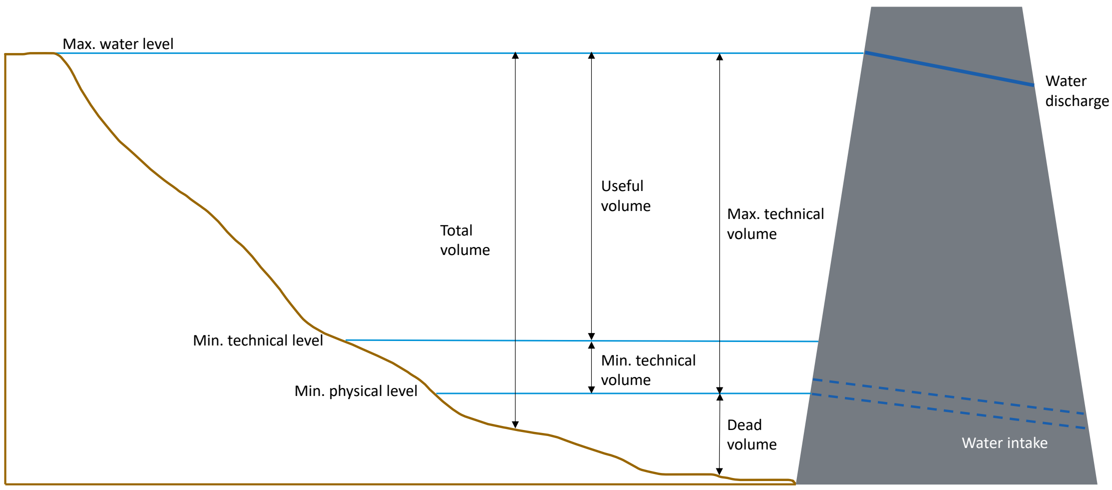
We identified four ways in which conservation or restoration of natural ecosystems can benefit HPCs:

- Reduction in dredging costs: decrease in sediments accumulation of certain hydropower assets (e.g., reservoirs), resulting in the reduction in removal and disposal costs.

- Savings on equipment and maintenance cost: principal pieces of equipment – mainly turbines and injectors– can be damaged when water with high sediment loads is processed. The presence of healthy natural ecosystems in watersheds results in a reduction of suspended sediments, thus limiting equipment wear and the subsequent maintenance and/or replacement.

- Extension of reservoirs' lifespan: to understand how NbS can increase the lifespan of a reservoir, it is important to first understand how different volumes are allocated.

**Figure 1.1 – Understanding the different volumes of a hydropower reservoir**




Source: BEM project, 2020.

As sediments reach the reservoir, they either flow through the water intake or deposit at the bottom of the reservoir, leading to a reduction of reservoir's volume. The 'useful' and 'dead' volumes are most relevant to consider when evaluating a reservoir's lifespan: if the useful volume is reduced dramatically and reaches the minimum technical volume –during the dry season for example–, the plant cannot operate (Figure 1.1).

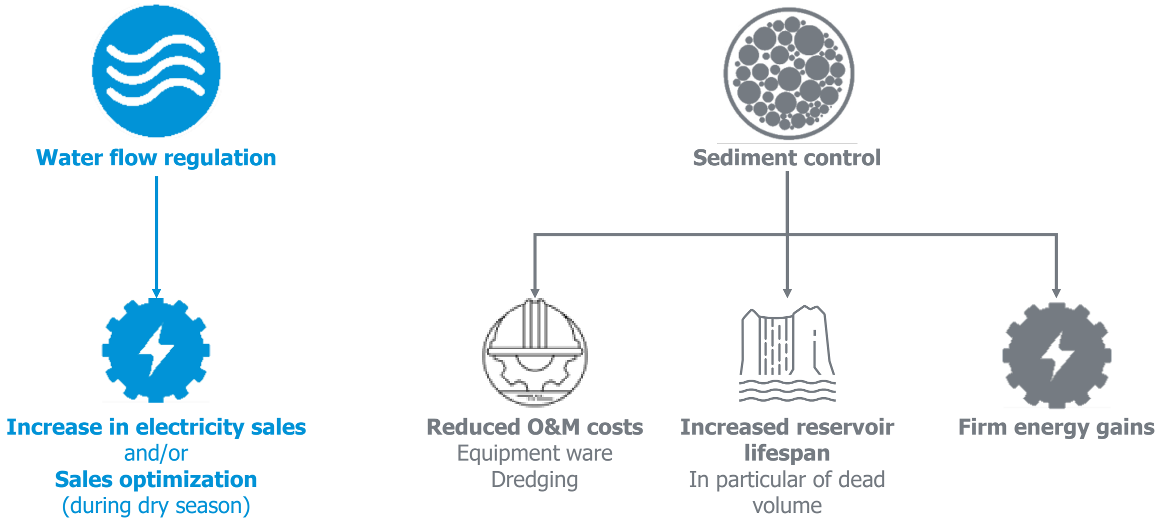
Likewise, if the dead volume is reduced to zero, sediments deposited at the bottom of the reservoir reach the water intake and are processed by the plant, which is not viable from a financial and operational perspective because of the subsequent damage to its turbines.

Extending the reservoir lifespan brings two monetary benefits for the hydropower plants: (i) the additional electricity generation that would have not been possible otherwise, and (ii) the financial benefit of postponing CAPEX, assuming that the corresponding amount is invested in risk free financial assets.

- Impact to firm energy generation: some electricity markets remunerate the ability of the producers to provide electricity during the dry season. It is typically based on the minimum production capacity during the dry season and – for hydropower plants – driven by the minimum useful volume. By maintaining the reservoir's useful volume (or slowing down its reduction), implementation of NbS could therefore have a positive impact on firm energy payments from the energy regulators.

Figure 1.2 summarizes how NbS to the hydropower sector can be monetized.

**Figure** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.1 – Monetizing NbS to the hydropower sector**



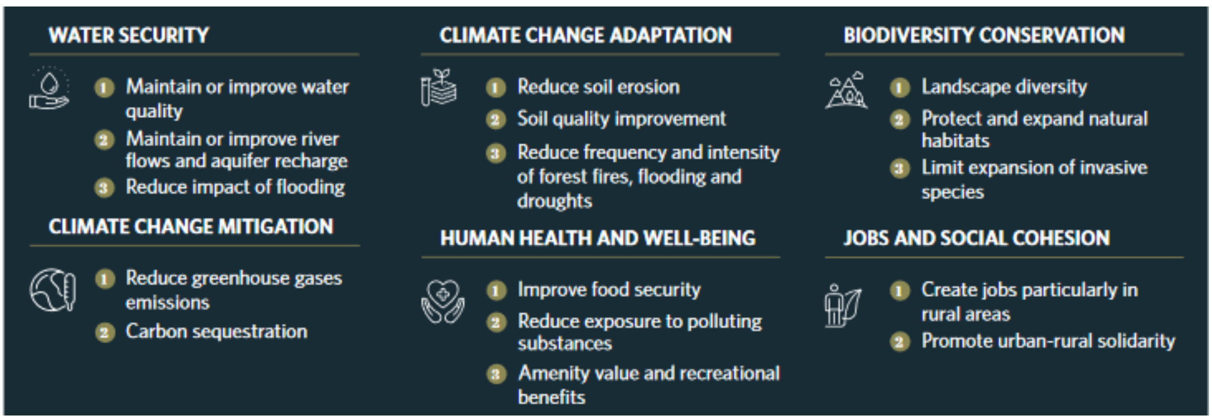

Source: BEM project, 2020.

## 1.2. Co-benefits

A key characteristic of NbS is that they are not limited to providing one specific solution. When comparing them with man-built grey infrastructure solutions, one must consider all the additional benefits that a natural ecosystem can potentially generate (Figure 1.3). At the landscape level, NbS can thus bring together a multitude of beneficiaries with different profiles and interests, such as water utilities, municipalities, local communities, the agricultural sector, water dependent industries (e.g., beverage companies).

For pay-for-success projects, the challenge lies in the monetization of some of these additional benefits (health and well-being, biodiversity, etc.), as well as in the complexity of structuring a project with multiple beneficiaries.

**Figure 1.3 – Selected potential benefits from NbS**




Source: Tremolet *et al.*, 2019.

# 2. Blue Energy Mechanism: an innovative way of engaging hydropower companies into watershed conservation and restoration

The Andean-Amazonian countries of Colombia, Ecuador, Peru and Bolivia rely heavily on hydropower production to meet growing energy demand. These countries also contain cloud forests which are some of the most biodiverse and threatened ecosystems on the planet, and which, as seen in section 1.1, can provide unique hydrological regulation through the capture of fog and cloud. As with other natural ecosystems, they can also reduce sediment exports that impact downstream hydropower production assets.

Despite all these benefits, forests continue to be cut down across Latin America at an alarming rate, primarily for agriculture and cattle grazing. The majority of original cloud forest cover has been lost—between 47-55% globally as of 2010 (Bruijnzeel, Mulligan and Scatena, 2011; Portillo-Quintero et al., 2012). This global rate of loss is disproportionately concentrated in Latin America. It is estimated that 90% of Andean montane forest cover was lost by 1995 (Hamilton, 1995). The remnants are often fragmented or degraded (Portillo-Quintero et al., 2012).

Yet, funding to conserve and restore critical ecosystems has fallen well short of the need (Anyango-van Zwieten, Lamers and van der Duim, 2019). To bridge this gap, one potential solution could be the monetization of ecosystem services such as sedimentation and water flow regulation, which can be measured, priced and paid for by HPCs. This approach creates a financial incentive for the private sector to positively impact biodiversity, human well-being and energy security, while decreasing the necessity to build additional hydroelectric plants.

Inspired by Project Finance techniques in which loans rely primarily on the project's cash flows for repayment, CI and TNC have designed an innovative pay-for-success model in which HPCs pay for sedimentation control and waterflow regulation ecosystem services as they materialize (Figure 2.1). The objective is to structure a project in which nature pays for itself and where the financial risk level for HPCs is reduced:

1. A Special Purpose Vehicle (SPV) is created to undertake the project;
2. Investors finance environmental conservation/restoration programs in the watershed where the hydro powerplant is located. The debt is assumed by the SPV;
3. These programs are implemented by local communities and/or specialized companies;
4. Actual services provided by ecosystems are measured by an independent third party; and
5. Once measured and priced, the HPC pays for part of the ecosystem services, which allows for debt repayment and financing of the project expenses.

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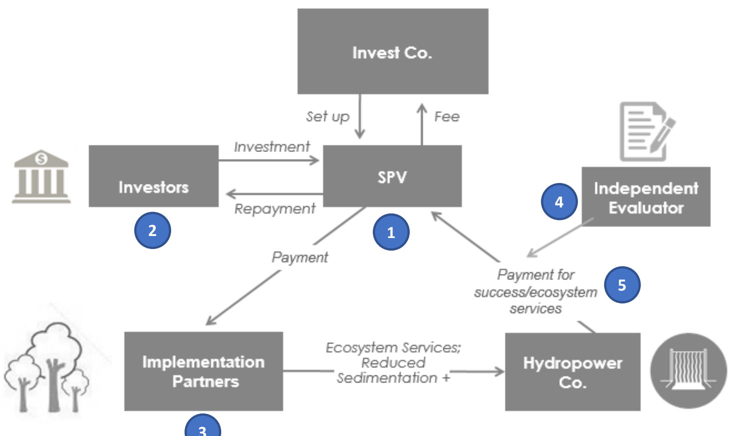



document..2 –

**Description of the Blue Energy Mechanism**

Source: BEM project, 2020.

This structure significantly reduces the implementation and financial risk of the HPC, which does not have to assume upfront investment costs and pays for the ecosystem services only if and when they materialize in the form and volume agreed with the project SPV. It should therefore incentivize HPCs to engage in upstream conservation activities beyond regulatory obligations and unlock much needed private sector funding.

However, pay-for-success models such as the BEM present significant challenges for conservation: ecosystem services need to be accurately modeled to generate trust and commitment from the HPC and investors; benefits must materialize within the expected timeframe and at a sufficient level to generate sufficient cash flows and match the project's financial needs; and the implementation scale must be realistic so that the SPV and local partners can reasonably commit to deliver the expected portfolio of NbS.

With the BEM, CI and TNC aimed to pilot this new concept in order to find ways to overcome these challenges and promote a model that could be adopted by the private sector and replicated at scale.

# 3. Pilot selection process

The first step to testing the BEM hypothesis was to select two pilots presenting the most promising enabling conditions. This pilot selection process combined biophysical and other criteria focused on the HPCs' profiles and the characteristics of their assets.

Overall, CI and TNC screened over 156 watersheds and 300 run-of-river or retention dam hydropower plants with a minimum installed production capacity of 20 MW, in Bolivia, Colombia, Ecuador and Peru.

## 3.1. Biophysical enabling conditions

TNC's science team used the Invest Sediment Delivery Ratio[1] and Waterworld[2] models, to assess the watersheds ecosystems' potential in terms of sedimentation control and waterflow regulation, respectively.

Other criteria considered were:

- watershed area: ideally neither too small nor too large to guarantee that there is enough ecosystem services potential but also that project implementation is realistic. The ideal area was set at 100,000 ha. Deviation from this target size was assessed and deemed acceptable depending on local conditions; and

- deforestation and remaining standing forest area: to assess the potential threats to the hydropower's operations and the potential for conservation type programs.

For each indicator, each asset was granted a point if its value was above the threshold defined by TNC's science team (typically the mean value of the portfolio of potential pilots). Each asset was hence attributed a total rating ranging from 0 (least potential) to 5 (highest potential). Assets were considered eligible as potential pilots if they presented a score greater or equal to 4.

The result of this work can be visualized online using this link to this Blue Energy Mechanism – Screening Arcgis map.

## 3.2. Pilot selection matrix

Meetings were organized with 15+ HPCs in the 4 targeted countries. 23 potential pilots were identified (Annex I) with the HPCs that showed interest in the project.

Each potential pilot was then tested against the 24 selection criteria of a more detailed Pilot Selection Matrix (Table 3.1). Each criterion was assigned a different weight depending on the level of importance for the project.

[1] See http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/sdr.html.

[2] See http://www.policysupport.org/waterworld.

The following 4 criteria have been considered as go/no go: the asset was not considered as eligible for the BEM in case of negative answer:

- project location is safe;
- reputational risk of HPC is not high;
- HPC is interested in the project; and
- asset prone to addressable sedimentation issue.

**Table** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.1 – Pilot selection matrix criteria**

| Criteria | Value | Metric | Points |
|---|---|---|---|
| Project location is safe | Go/No-go | Yes/No | 4 |
| Reputational risk of hydro power company is not high | Go/No-go | Yes/No | 4 |
| No major conflicts with local communities | Go/No-go | Yes/No | 4 |
| HPC is interested in the project | Go/No-go | Yes/No | 4 |
| Asset prone to addressable sedimentation issue | High | Yes/No | 3 |
| Existence of reliable and qualified local implementation partners | High | Yes/No | 3 |
| High sedimentation management costs (in relative terms) - Removal & disposal, turbine wear | High | % O&M costs | 3 |
| Potential to enhance future ecosystem services | High | Low/Medium/High | 3 |
| Reasonable watershed size | High | Ha. | 3 |
| Existing data on local weather conditions, hydrology, sedimentation, topography | High | Yes/No | 3 |
| HPC relationship: willingness to share information | High | Yes/No | 3 |
| HPC relationship: willingness & ability to pay | High | Yes/No | 3 |
| Asset prone to water regulation issue | High | Low/Medium/High | 3 |
| Effectiveness of sediment management technologies/procedures @ power plant level | Medium | Low/Medium/High | 2 |
| Old asset/reduced remaining project life | Medium | Years in operation | 2 |
| Supportive local government and communities | Medium | Yes/No | 2 |
| Operational improvement opportunity | Medium | Low/Medium/High | 2 |
| Existing conservation program at HPC level | Medium | No/Yes but modest/Yes significant | 2 |
| Relative size of plant vs. watershed | Medium | Small/Medium/High | 2 |
| $CO_2$ sequestration potential of local ecosystem and selected species | Medium | Low/Medium/High | 2 |
| Existing energy pricing mechanisms that could be used in favor of hydro power plants | Medium | Yes/No | 2 |
| Favorable production profile (seasonal production with dependence on peak prices) | Medium | Yes/No | 2 |
| Project easily accessible | Medium | Yes/No | 2 |
| Existence of monetizeable co-benefits (e.g. ecotourism) | Low | Yes/No | 1 |

Source: BEM project, 2020.

Note that lack of data (generally due to lack of cooperation from the HPC) penalized the project (0 points for the answer).

# 4. Methodology for building a nature-based solutions portfolio for the hydropower sector and analyzing its financial viability

The methodology developed for a BEM project is composed of 7 steps, with the objective of building a portfolio of NbS, assessing its financial and implementation viability and, eventually, negotiating the terms and conditions of a pay-for-success scheme with the HPC. This section describes each step of the process, which are also presented schematically in Figure 4.1.

## 4.1. Validate the HPC's priorities, define project metrics and gather data

The first step of the methodology is crucial as it conditions the whole technical and financial analysis. Getting it right will avoid rework later in the process and improve the quality of outputs, creating trust with the HPC.

The impact of sedimentation and/or water flow deregulation challenges on the plant's operational and financial performance should be clearly understood to make sure that the right NbS are selected. Is the priority issue dredging, equipment wear, reservoir lifespan or other? Is it specific to an area in the watershed or more applicable to the entirety of the river basin? Once this is done, an agreement should be reached with the HPC on the metrics that can both (i) be used as inputs to the financial model to convince management of the project's financial value and viability, and (ii) be properly modeled and monitored.

It is also very important to understand from the HPC what has been done in the past to manage these challenges (where, at what cost, with what results), and what are the plans for the future, especially if these include grey infrastructure. In such a case, detailed information should be gathered to analyze how NbS can complement grey infrastructure, or if these solutions are mutually exclusive.

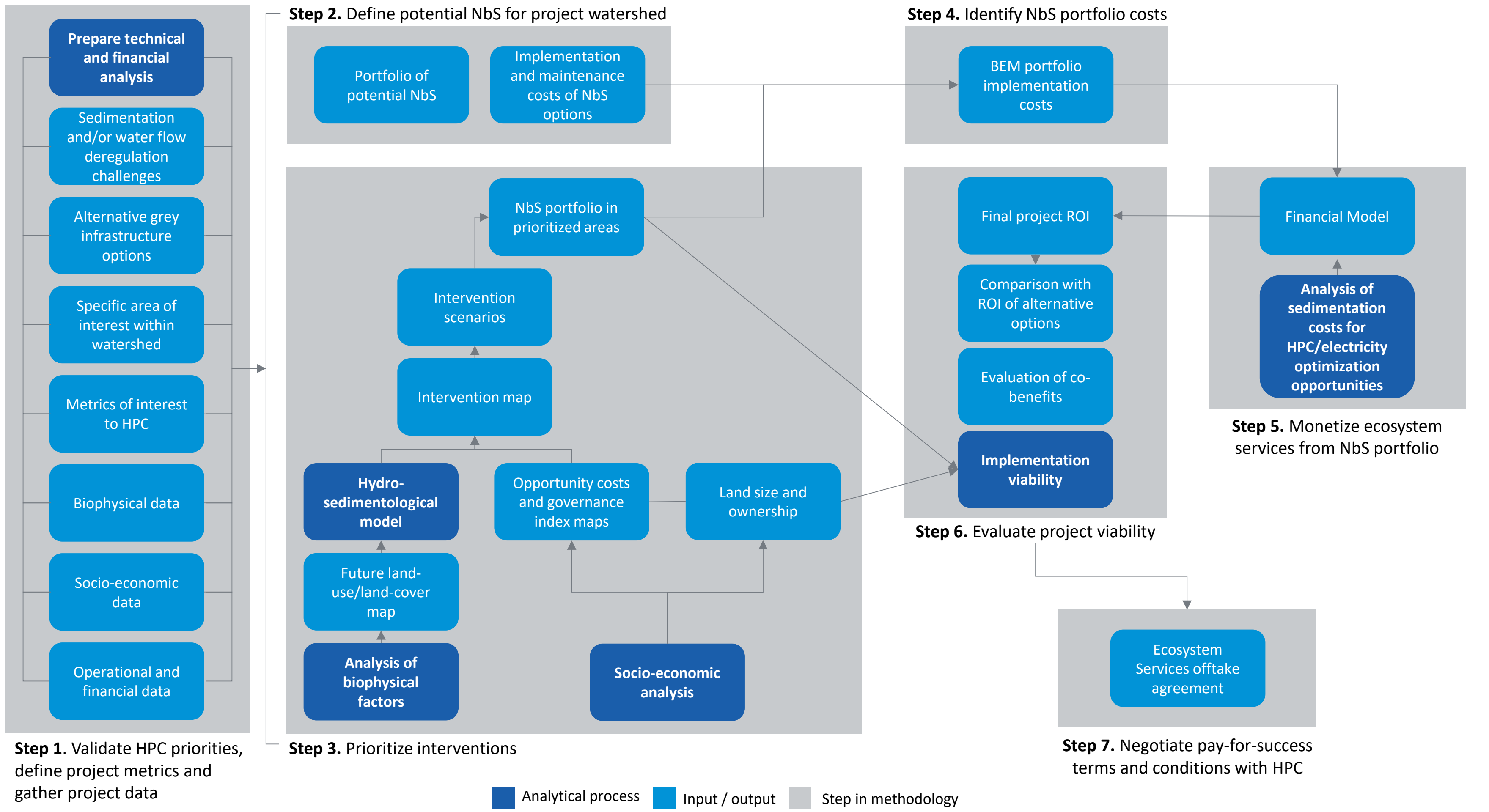
Lastly, the project team must gather all available technical, operational, financial and socio-economic data to feed the hydro-sedimentological and financial models.

## 4.2. Define potential NbS for the project watershed

Once operational challenges are understood, a list of potential nature-based solutions that could successfully be implemented in the project watershed can be devised.

Based on their expertise in similar contexts, in particular CI's large experience in Colombia's High Andean ecosystems, CI and TNC selected 6 potential NbS to generate sediment control and water regulation ecosystem benefits for the hydropower assets (Table 4.1). Even though broader categories should only marginally change from project to project, it is important to keep in mind that NbS should be carefully selected according to local specificities, and that the portfolio described in this study might not be relevant for every project.

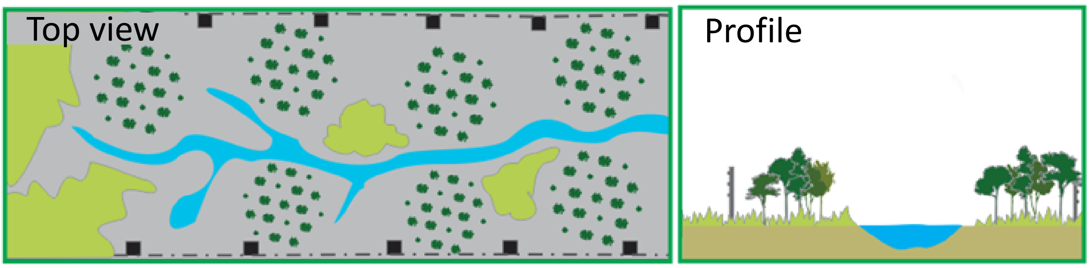
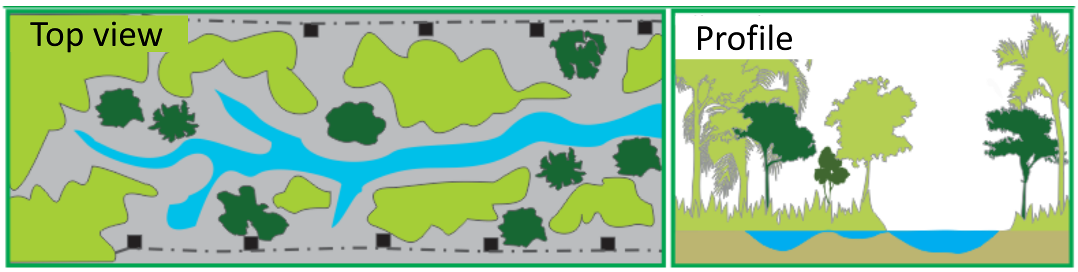
**Figure** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**3 – BEM methodology**




Source: BEM project, 2020.

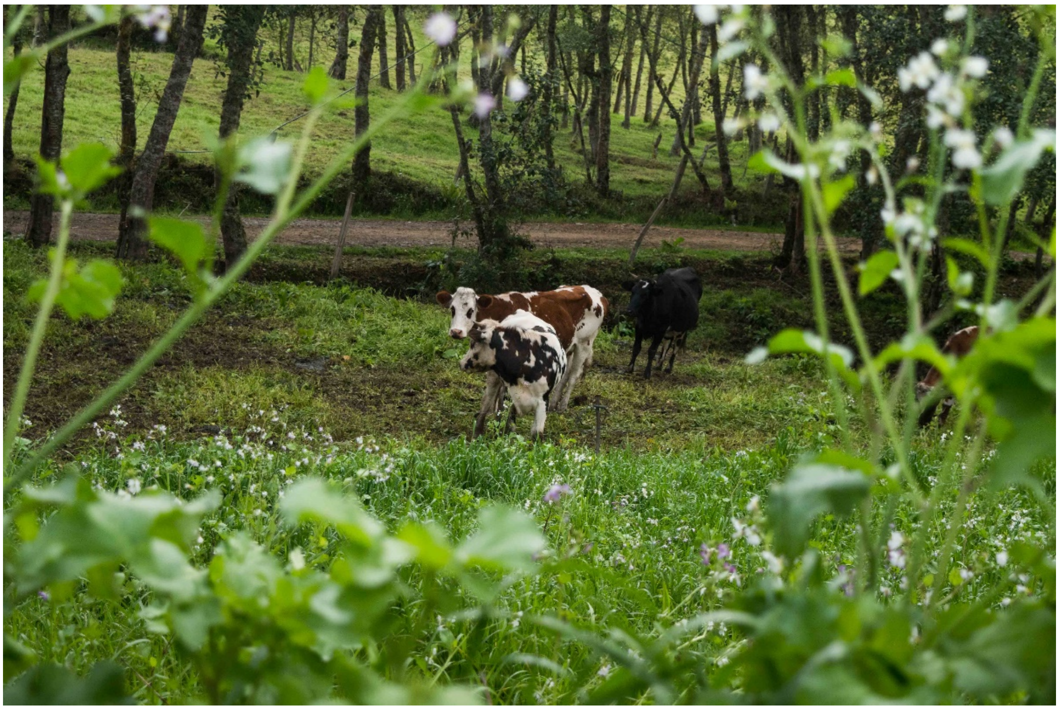
**Table** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.2 – Selected nature-based solutions for the BEM**

| | Key objectives | Description & associated interventions | Specific interventions for BEM |
|---|---|---|---|
| **Ecosystem protection** | | | |
| 1 | Targeted habitat protection<br><br>(conservation) | Conservation activities to protect target ecosystems.<br><br>Includes preventative measures (e.g., land rentals, fencing out cattle, funding of park wardens) to reduce future adverse land-use changes that can impact soil erosion and water regulation.<br><br>Crucial to maintain the ecosystem services that the existing ecosystems are already providing and given the difficulty and time for restoration activities to reach a similar level of benefits. | • Clear paths for / fencing out cattle, sheep or people from nature sites.<br><br>Land rentals and funding of park wardens were not considered as part of the project. |
| **Ecosystem restoration** | | | |
| 2 | Passive restoration | Also called natural regeneration, passive restoration means creating a suitable enabling environment for natural succession to occur in an ecosystem. May include removal of contamination, inappropriate grazing, restriction of natural water flows, and inappropriate fire regimes.<br><br>According to the Society for Ecological Restoration, it can be implemented "where damage is relatively low and topsoil retained, or where sufficient time frames and nearby populations exist to allow recolonization, plants and animals may be able to recover after cessation of certain types of degradation."<br><br>It can be the most cost-effective restoration measures if enabling conditions exist. | • Clear paths for / fencing out cattle and sheep to avoid grazing and allow for natural recovery. |

| Key objectives | Description & associated interventions | Specific interventions for BEM |
|---|---|---|
| Active restoration | Also called assisted regeneration or reconstruction. For sites of intermediate or greater degradation which require removal of the causes of degradation and active interventions to correct abiotic and biotic damage and trigger biotic recovery. It can take various forms. The BEM focuses on nucleation and enrichment. | |
| 3 Nucleation | Nucleation involves planting small patches of trees as focal areas for recovery. Once planted, these patches, or nuclei, attract dispersers and facilitate establishment of new woody recruits, expanding the forested area over time. It is an attractive option in that it mimics natural successional processes to aid woody plant recolonization and can be more cost-effective than traditional active restoration in some contexts. | • Fencing.<br>• Tree planting.<br>• Installation of perches for dispersers. |
| | <br>Design: GEF-Adaptación al cambio climático en la alta montaña, 2020. | |
| 4 Enrichment | Enrichment targets areas that have been degraded but retain some characteristics of the native ecosystem (selective logging, clearings....). It consists in reintroducing species from the center of the degraded area towards its border with conserved ecosystems, as well as planting faster growing species at the border to close the canopy. | • Fencing.<br>• Tree planting. |
| | <br>Design: GEF-Adaptación al cambio climático en la alta montaña, 2020. | |

| Key objectives | | Description & associated interventions | Specific interventions for BEM |
|---|---|---|---|
| **Land-use best management practices** | | | |
| 5 | Agroforestry | Simply defined as “agriculture with trees”, agroforestry seeks to incorporate trees in fields where tree and crops are grown together; on farms, where trees may provide fodder for livestock, fuel, food, shelter or income from products including timber; or in landscapes, where agricultural and forest land-uses combine in determining the provision of ecosystem services (Torquebiau, 2000).<br><br>In the case of BEM, planting is considered in fields or on farms, with species producing timber, fruits, or seeds. | • Tree planting and soil conservation |

| Key objectives | | Description & associated interventions | Specific interventions for BEM |
|---|---|---|---|
| **Land-use best management practices** | | | |
| 6 | Silvopasture | Refers to the practice of incorporating trees in pastures for domesticated animals, to reach an equilibrium between soil, plants, animals and biodiversity.<br><br>Silvopasture provides shelter and shade to cattle and can improve milk production and quality as a result of better cattle farming conditions. | • Soil preparation, grass and tree planting, fencing. |



© GEF-Adaptación al cambio climático en la alta montaña, 2020.

### 4.3. Prioritize interventions

To define the NbS portfolio and prioritized areas of intervention, two processes are done in parallel. A hydro-sedimentological model is developed to calculate changes in sediment export and water flows of different land-use land-cover scenario. At the same time, a socio-economic analysis is performed to analyze opportunity costs and governance.

#### 4.3.1. Hydro-sedimentological model

Given the importance of accurate cash flow modeling in pay-for-success transactions, the challenge presented by the BEM to the science team was to elaborate a tool capable of answering the following five fundamental questions:

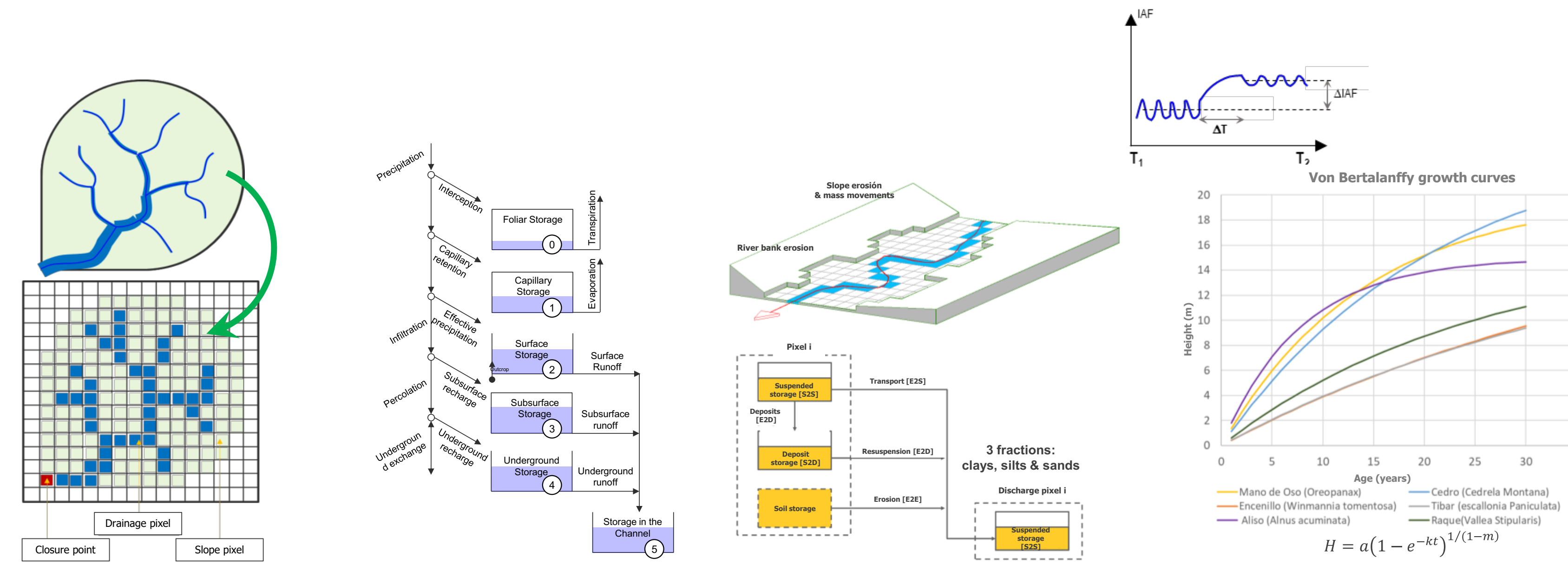
- Which activities? Which of the possible project activities should be implemented to maximize ecosystem benefits for different objectives –sediment control or water flow regulation?
- In what order? How to prioritize areas of intervention to maximize ecosystem benefits?
- How much? What is the volume of measurable benefits that can be expected from the project's portfolio of interventions?
- Where? The definition of success, which is a cornerstone of the Blue Energy pay-for-success model, depends on where benefits materialize. The model must provide results anywhere in the watershed to adapt to specific pilots' problematics and needs.
- How long? How long will the project's portfolio of interventions take to generate the expected ecosystem benefits?

SIGA, the biophysical model specifically developed by the consulting company, Gotta for BEM under the supervision of TNC, is a state-of-the-art tool. It is not only capable of answering these questions over a 30-year horizon with a daily resolution for each pixel of the watershed, but it also represents all the sediment and waterflow processes needed to do it accurately. It is the only model that we know of that includes 15 different key processes. In particular, it takes into account vegetation growth rates for restoration, agroforestry and silvopasture activities, which was very important to estimate yearly benefits and corresponding cash flows and avoid "all or nothing" results that are typical of less sophisticated models (Figure 4.2).

In that respect, BEM greatly contributes to the science of modeling ecosystem services critical to a large variety of watershed stakeholders, from hydropower plants to water utilities and beneficiaries of irrigation systems.

Annex II compares it to other models typically used to represent sediments and water flows.

**Figure** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.4 – Main characteristics of the SIGA hydro-sedimentological model**




**Distributed model**: **where** and **how much** (output for each pixel)

**Main water processes** including horizontal precipitation

**Main sediment processes** including mass movements

**Vegetation growth processes when** and **how much**

Source: Developed by Gotta for the BEM project, 2020

.

Gotta devised 4 different land-use, land-cover scenarios that are used to assess the potential benefits of the selected NbS:

- Base Line: static scenario[3] that does not contemplate any project activities and uses the watershed land-use land-cover state at the date of the study as reference for the whole modeling period. It is used for comparison purposes with the Total Intervention or Improvement and Prioritization scenario.
- Dynamic Trend: a dynamic scenario that does not contemplate any project activities and models different watershed land-use for each period based on historical degradation trends. It is used for comparison purposes with the Total Intervention or the Improvement and Prioritization scenario.
- Total Intervention: static scenario that models the implementation of a mature portfolio of selected project NbS in the entire watershed since day 1.
- Improvement and Prioritization: a dynamic scenario that models a progressive implementation of selected interventions in the whole watershed.[4] This scenario is run for 2 different project priorities: maximization of sediment control and maximization of water flow regulation.

SIGA assesses, in each scenario and for every 1-hectare pixel (100 m x 100 m) of the watershed, which of the 6 NbS described in Table 4.1 is better suited:

- to the pixel's specific land-use conditions. For example, targeted habitat protection can only be applied to a pixel presenting native ecosystems. Similarly, nucleation cannot be implemented in pixels that are too distant from native ecosystems, and land-use best management practices can only be implemented on agricultural land; and
- to generate the expected ecosystem service (sediment might be prioritized over water flow, or vice-versa) at an optimized cost.

#### 4.3.2. Socio-economic analysis

The purpose of the socio-economic analysis is to complement the biophysical modeling with aspects that are of great importance from an implementation standpoint: opportunity cost, governance and land size and ownership.

Although it cannot replace field work and engagement with local communities, it can be used at pre-feasibility stage to estimate the value of the financial incentives that might need to be paid to landowners to engage them in conservation activities, and to assess the viability of implementation given governance and land-tenure characteristics.

The opportunity cost reflects the financial value of the resources that a landowner accepts to give-up when protecting or restoring ecosystems instead of expanding cultivated area, or when transitioning to more sustainable agricultural practices.

Using the methodology described in Figure 4.3, and considering variables such as land-use, type of crops (for agricultural land), nearest type of crops (for natural ecosystems), or distance to roads (as a proxy for evaluating access to markets), net-agricultural earnings have been calculated for each pixel of the watershed.

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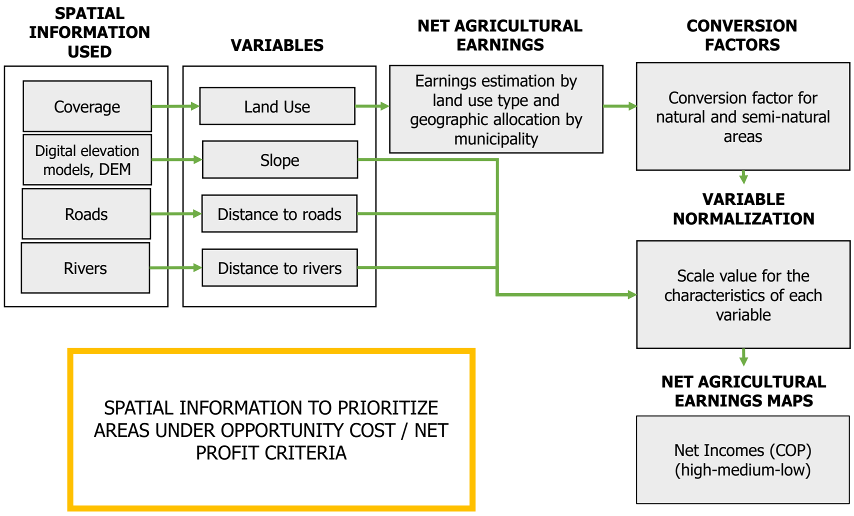
[3] In this context, static means that inputs do not vary during the whole modeling period (e.g. land-use does not change as it would in a dynamic scenario that accounts for the influence of relevant variables and uses different values for each period).

[4] Each year, selected project activities are implemented over an area equal to the total intervention area divided by 30 (modeling period).

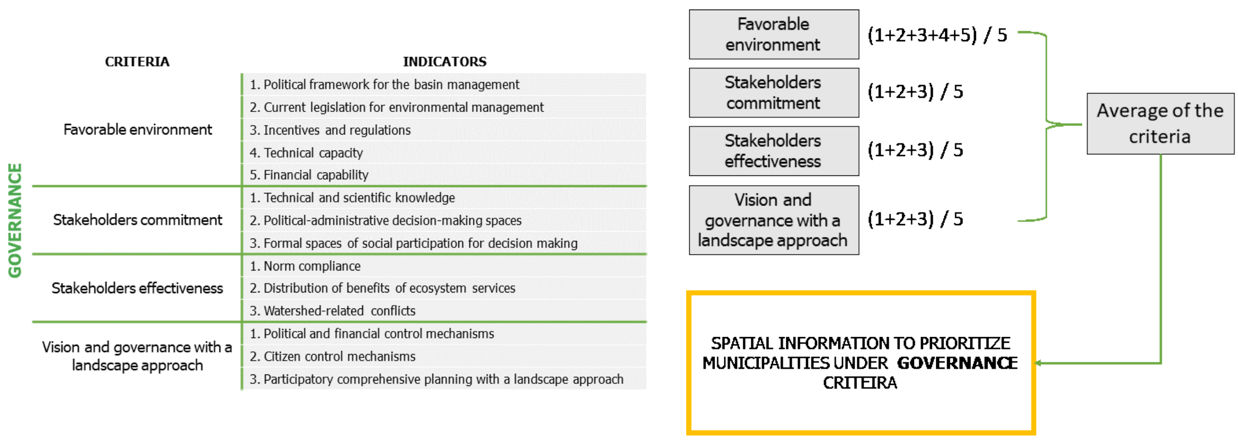
**Figure** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.5 – Methodology for calculating opportunity costs**




Source: BEM project,2020.

Governance is defined as structures and processes through which decisions are made and create conditions to establish rules and collective actions or participatory platforms (Schulz et al. 2015). In the context of the BEM, an analysis was conducted at municipality level to identify the main stakeholders and to create an index that could be used as a proxy to assess how complex implementation might be if local stakeholders are not well organized. As shown in Figure 4.4 below, it is based on 4 criteria assessing how favorable the political and regulatory environment in each municipality is; the level of commitment of local stakeholders and their decision-making capacity; their compliance with existing norms; and their capacity to establish a governance with a landscape approach.

**Figure** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.6 – Methodology for calculating the governance index**




Source: BEM project, 2020.

Land size and ownership regimes should be carefully analyzed to assess how realistic the implementation of an NbS portfolio is. A highly fragmented landscape increases implementation complexity and costs, both in terms of logistics and engagement with landowners.

Likewise, implementation is a greater challenge when people cultivating the land are not the owners and cannot guarantee permanence of the results generated by the NbS.

#### 4.3.3. Identify NbS portfolio costs

Implementation and maintenance costs of NbS are very context specific and should as much as possible be obtained from local stakeholders with actual field experience. The costs presented in Table 4.2 below and used for the two pilots have been calculated based on data gathered from the CI and TNC Colombian offices as well as the environmental authorities active in the watersheds.

**Table** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.3 – NbS 2020 implementation and maintenance costs**

| Project type | CAPEX (USD/ha.) | | | 1st year OPEX (USD/ha.) | | |
|---|---|---|---|---|---|---|
| | Min. | Average | Max. | Min. | Average | Max. |
| **Ecosystem protection** | | | | | | |
| Targeted habitat protection | 788 | 1,126 | 1,704 | 98 | 143 | 155 |
| **Ecosystem restoration** | | | | | | |
| Passive restoration | 788 | 1,126 | 1,704 | 98 | 143 | 155 |
| Enrichment | 1,460 | 3,280 | 4,930 | 722 | 983 | 1,239 |
| Nucleation | 2,803 | 3,416 | 4,028 | 926 | 1,238 | 1,551 |
| **Land use best management practices** | | | | | | |
| Agroforestry | 1,896 | 2,426 | 2,956 | 436 | 436 | 436 |
| Silvopasture | 2,851 | 3,944 | 5,038 | 681 | 699 | 718 |

Source: BEM project, 2020.

Note: implementation costs decrease to 50% and 25% of the first-year value in years 2 and 3 respectively to reflect the reduction of the activities to be performed as trees grow.

#### 4.3.4. Monetize ecosystem services from NbS portfolio

The benefits that NbS can provide to the hydropower sector and the different ways to monetize them have been presented in section 1.1. This section presents the "cost discovery" process that has been conducted with the pilot HPCs to assess the actual financial impact of sediment on their operations.

The first step consists in detailing the different type of impacts sediments can have on the operations of a hydropower asset (Table 4.3) and to estimate an average yearly cost based on historical expenses.

The next step focuses on identifying historical and future investments engaged by the HPC to manage sediment issues:

- Grey infrastructure such as modifications to production process (e.g., increase of water intake level), sediment traps, repairs to damaged infrastructure (e.g., water tunnels), riverbanks reinforcements, etc.
- Green infrastructure, like protection of reservoir banks, restoration work, sediment traps, etc.

An average yearly cost was again calculated based on their financial costs and expected lifespan.

The final step estimates the volume of sediment reduction achieved by these costs to obtain a dollar value per cubic meter for each cost type. In the case of the pilots, this was the most challenging part of the process given the absence of historical data on sediment load at the specific points where costs were incurred. Some assumptions, detailed in each business case below, had to be made in agreement with the HPCs.

**Table** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.4 – Impact of sedimentation on hydropower plants operations**

| Cost type | Detail |
|---|---|
| Dredging | Cost of removing and disposing sediments. |
| Equipment wear | Damages to production equipment, mainly turbines and injectors.<br>Costs associated with preventive and/or corrective maintenance. |
| Impact on electricity production | Unscheduled maintenance.<br>Forced change in operations rules: e.g., need to maintain a higher minimum technical reservoir level due to increased water intake level.<br>Plant shut down (if increase of water intake level is not possible) due to impossibility to process sediment dense water (equipment ware is too high). |

Source: BEM project, 2020, based on discussions with hydropower companies.

### 4.3.5. Evaluate project viability

The analysis of the project viability is a mix of financial and operational considerations.

The return-on-investment analysis examines project cash flows and net present value, based on the costs and benefits calculated according to the methodology described in the previous sections. A project presenting a negative net present value or a cost/benefit ratio inferior to 1 should not, in strict financial orthodoxy, be deemed viable. When competing with grey infrastructure, the cost/benefit ratio of the NbS portfolio should also be compared to the one for these alternatives. However, the absolute value of these ratios is not sufficient to decide financial viability. The timing of cash inflows (revenues) should also, as much as possible, match the one of cash outflows (expenditures). The gap, if any, should be reasonable enough to be possibly filled by bridge funding, should it be in the form of public grants, subsidies or commercial loans.

Nevertheless, in the case of NbS and contrary to the decision-making process that typically applies to grey infrastructure, a cost/benefit ratio slightly lower than one or than the ratio of alternative solutions, should not necessarily translate into a no-go for investment. As explained in section 1.2, natural ecosystems can generate many co-benefits that cannot be monetized and still be of great interest to HPCs, compensating for lower cash flows.

Another consideration with regards to financial viability is the diversity of project cash flow sources from different financial benefits to the HPC. The dependence on one specific source (e.g. reservoir lifespan expansion) can deter the HPC and potential funders if they deem the associated risk to be too high.

Beyond financial considerations, the feasibility of project implementation should also be considered, based on criteria such as project area and number of landowners to be involved, social environment and governance, topography and logistical challenges and availability of vegetal material.

#### 4.3.7. Negotiate pay-for-success terms and conditions

The definition of success and the legal terms and conditions are two of the most important topics to be negotiated with the HPC should it be interested in entering into a pay-for-success scheme.

Defining success is obviously key in a pay-for-success transaction. However, many different scenarios can be envisioned. The SPV will want to measure success based on successful implementation of project activities or NbS impacts close to the implementation points. This provides the SPV with greater certainty of achieving success since the measures of success are largely within the SPV's control and the SPV does not assume that risk relating to the uncertainty of implementation translating into actual financial benefits to the HPC. This will make it easier for the SPV to raise investment capital, since the investors will better be able to evaluate the risk of achieving success.

On the other hand, the HPCs will prefer to define success as the impact directly measurable at production point. This provides them with greater certainty that success will lead to financial gain for the HPC.

To prepare for future negotiations, CI and TNC have considered the following definitions that focus on different points in the watershed and could be used as starting points:

- <u>implementation</u>: defined as "the successful implementation and maintenance, within the expected schedule, of the forecasted conservation and/or restoration activities". This is extremely important to reduce risk for the project SPV and to lower debt needs as implementation success can be achieved relatively quickly, resulting in earlier cash flows to re-pay the cost of implementation

- <u>impact at implementation site</u>: defined as "the positive impacts of conservation and/or restoration activities at the implementation site, calculated by the biophysical model and validated by the hydropower company". The model can be updated and recalibrated on an annual basis with actual measures of project impacts; In this scenario, 1) the SPV takes a) implementation risk and b) the risk of whether implementation will result in the anticipated level of success at implementation site, as predicted by the model, and 2) the HPC takes the risk of a) whether the actual level of success at implementation site will translate into anticipated levels of success further downstream (at the reservoir and electricity production point) and b) whether levels of success downstream will ultimately result in the expected operational benefits, all as predicted by the model. This will result in somewhat later cash flows to the SPV, since it may take a few years for implementation to lead to impact, especially where implementation involves restoration;

- <u>impact at reservoir</u>: defined as "the positive impacts of conservation and/or restoration activities on the hydropower reservoir as calculated by the biophysical model and validated by the hydropower company". The model can be updated and recalibrated on an annual basis with actual measures of project impacts. In this scenario, 1) the SPV takes the risk of a) implementation success b) whether implementation will result in the anticipated level of success at implementation site and c) whether the anticipated level of success at implementation site will also translate into anticipated levels of success at the reservoir and 2) the HPC takes the risk of a) whether the actual level of success at the reservoir will translate into anticipated levels of success at the electricity production point and b) whether anticipated levels of success at the electricity production point will ultimately result in the expected operational benefits, all as predicted by the model.

This will result in later cash flows to the SPV, since it may take a few years for implementation to lead to impact at the implementation site, especially where implementation involves restoration, and it will take more time for impact at the implementation site to lead to impact at the reservoir, especially in larger watersheds where there may be a significant time lag to sedimentation reduction upstream to ultimately result in sedimentation reduction downstream; and

- impact at electricity production point: defined as "the positive impacts of conservation and/or restoration activities at the point of electricity generation as calculated by the Biophysical and validated by the hydropower company". The models will be updated and recalibrated on an annual basis with actual measures of project impact. In this scenario, 1) the SPV takes the risk of a) implementation success b) whether implementation will result in the anticipated level of success at implementation site c) whether the anticipated level of success at implementation site will also translate into anticipated levels of success further downstream (at the reservoir and electricity production point) and 2) the HPC takes the risk of whether the actual level of success further downstream (at the reservoir and electricity production point) will ultimately result in the expected operational benefits, all as predicted by the model. This will result in even later cash flows to the SPV, since it may take a few years for implementation to lead to impact at the implementation site, especially where implementation involves restoration, and it will take more time for impact at the implementation site to lead to impact further downstream (at the reservoir and electricity production point), especially in larger watersheds where there may be a significant time lag to sedimentation reduction upstream to ultimately result in sedimentation reduction downstream.

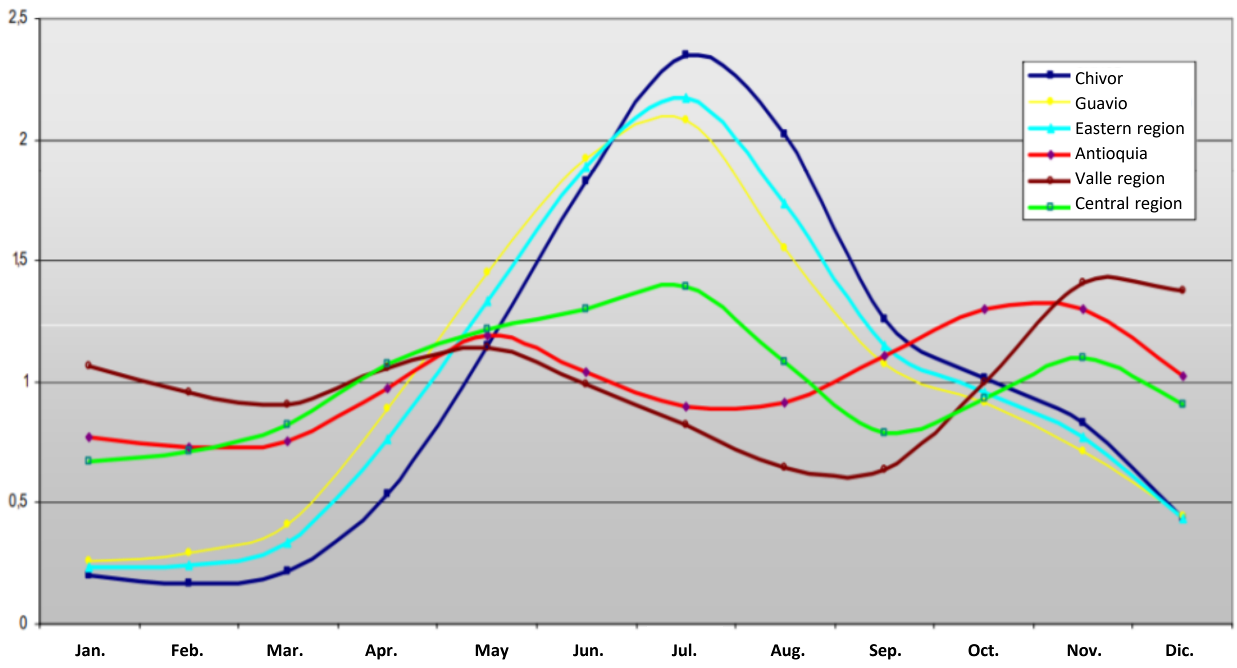
Please see more details on these definitions in Annex V. Items highlighted in red indicate the need for discussion/validation with partner HPCs.

CI and TNC, with the *pro-bono* support of the international law firm, Reed Smith LLC, have drafted a tentative Term Sheet of Ecosystem Services Purchase Agreement that could be the basis of discussions with any HPC interested in the Blue Energy Mechanism. It is presented in Annex VI.

# 5. Summary of Colombian pilots business cases

Located in adjacent watersheds, the Chivor and el Guavio plants share very similar characteristics. They have a very large production capacity (1,000 and 1,250 MW respectively, accounting jointly for approximately 16%-18% of Colombia's production – Annexes III and IV) and source their water from retention dams. Both are a key asset for the Colombian electricity grid because of their unique production profiles. Due to watersheds rainfall patterns, influenced by the Amazon, they are unimodal and produces mainly between June and September, when generation from hydropower plants located in other regions is low due to drier conditions (Figure 5.1), thus providing year-round continuous supply of cost-effective energy all year round.

**Figure** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.7 – Hydrology profiles of areas in the Colombia's national interconnected system**

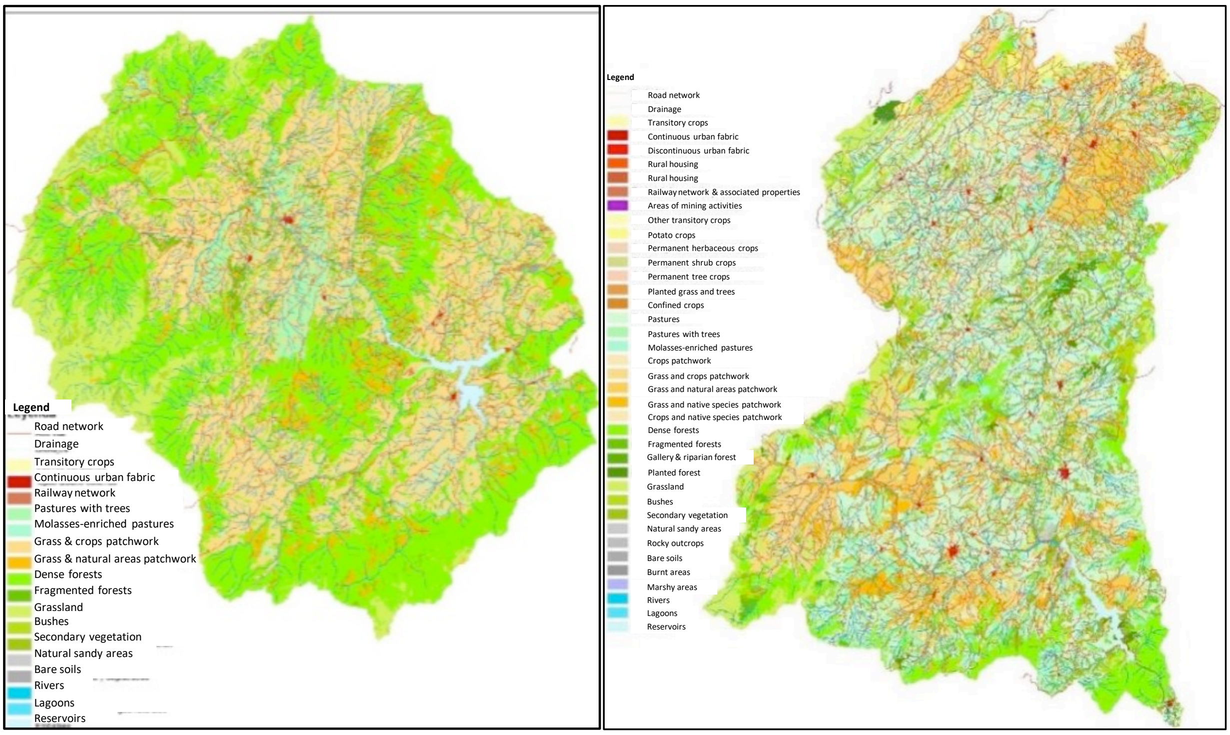



Source: AES Chivor, 2011.

Both reservoirs are affected by a high volume of suspended sediment originating from runoff and riverbanks erosion (about 80% of exports in both cases), which results in the reduction of the dead volume and threatens operations.

Both watersheds have been severally degraded by human activities over the past decades —even though the Guavio watershed still presents more than 50% of natural ecosystems. However, they have seen an improvement in forest coverage over the past decade, probably due to the exodus of a rural population that represents more than 65% of the total, is very young, uneducated, and highly vulnerable. In both cases, land ownership is very fragmented, with farms under 5 hectares representing more than 80% of the properties.

**Map** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.1– Land-use in the Guavio and Chivor**




**watershed**

Source: Consorcio Río Garagoa, 2018..

The results of the biophysical modeling process were found to be disappointing for water flow regulation. The portfolio of interventions would not generate any increase in base flows and would therefore not have any impact on electricity generation. It is interesting to note however that base flows would be maintained despite the significant increase in evapotranspiration from the newly introduced vegetation. This suggests that nature-based solutions can sustain base flows through modification and improvement of infiltration patterns in the watershed as degraded land are restored. This is an important finding to demystify some common beliefs amongst hydropower companies that restoration activities might be detrimental to their operations.

As for sedimentation, results greatly depend on the land-use land-cover (LCLU) scenario selected as basis for comparison with the scenario modeling the implementation of the BEM portfolio of NbS. The Base Line (LCLU as at the date of study maintained for 30 years) is more favorable than the Dynamic Trend scenario, which projects LCLU based on historical trends of increasing vegetation coverage. The reduction in sediment export to the reservoir ranges from 21% to 56% in the case of AES Chivor and 8% to 31% for el Guavio, translating into a potential extension of reservoir lifespan of 1.2 to 7.2 years and 1.7 to 2.8 years, respectively.

**Figure 5.2 – Summary of NbS portfolios benefits for BEM Colombian pilots over 30 years**

| Type of benefit | AES Chivor | | ENEL el Guavio | |
|---|---|---|---|---|
| | Min. | Max. | Min. | Max. |
| Change in water flow | 0.1 $m^3/s$ (0%) | 0.1 $m^3/s$ (0%) | 0.1 m3/s (0%) | 0.1 m3/s (0%) |
| Change in sediment export to reservoir | -9.9 $Hm^3$ (-21%) | -48.3 $Hm^3$ (-56%) | - 5.6 Hm^3 (-8%) | - 28.6 Hm^3 (-31%) |
| Change in sediment export to dredging points | n/a | n/a | - 0.3 Hm^3 (-8%) | - 1.5 Hm^3 (-31%) |
| Additional reservoir lifespan based on dead volume | 1.2 year | 7.2 years | 1.7 years | 2.8 years |
| Change in sediment turbines flow-through | -0.5 $Hm^3$ (-21%) | -2.6 $Hm^3$ (-56%) | - 0.2 Hm^3 (-8%) | - 0.9 Hm^3 (-31%) |
| Note: negative value is a benefit | | | | |

Source: output from Gotta's SIGA model.

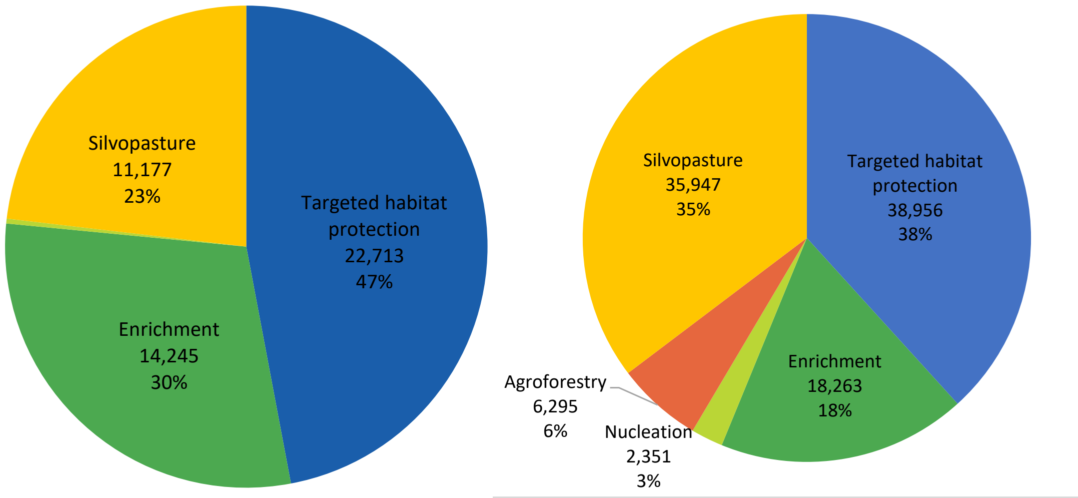
To monetize these benefits, CI and TNC have engaged in a "cost discovery" process with the pilots to assess the actual financial impact of sediments on their operations. Costs are in both cases mostly driven by investments in grey infrastructure (repairs to damaged water tunnels for ENEL el Guavio, increase of water intake level to manage loss of dead volume for AES Chivor). It is interesting to note that neither plant have suffered production losses directly related to sedimentation issues. Sediment dredging is only a concern for ENEL el Guavio, while AES Chivor is the only asset for which impact on equipment wear could be estimated. Overall, the analysis concluded for both assets that the main value generated by the proposed portfolio of NbS lies almost exclusively on extension of reservoir lifespan.

In the case of AES Chivor, which is a smaller asset located in a larger watershed, the different scenario present contradicting conclusions in terms of financial viability: positive when comparison is made with the Base Line (cost/benefit ratio of 2.0x), negative when Dynamic Trend is used as reference (cost/benefit ratio of 0.3x). This level of uncertainty is too high to make a decision that would be a bet on the future forest degradation trend.

For ENEL el Guavio, results are interesting in both scenarios despite lower relative sediment reduction than AES Chivor, thanks to the combination of a smaller intervention portfolio and larger volume of electricity produced during each additional lifespan year. The project's cost/benefit ratio ranges between 1.7x and 3.0x.

However, in both cases, the project is faced with two seemingly impossible challenges. First, the size of the portfolio to be implemented to generate the required level of ecosystem services and cash flows: 101,800 hectares (42% of the watershed) over 13 years for AES Chivor; and a more reasonable but still unrealistic 48,290 hectares (35% of the watershed) over 10 years for ENEL el Guavio.

**Figure** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.3– Breakdown of ENEL el Guavio (left) and Chivor (right) NbS portfolios by type of NbS**




Source: output from Gotta's SIGA model.

Second, the competition with grey infrastructure, with AES having already decided to invest in civil work to increase the level of the water intakes, and ENEL el Guavio strongly considering following the same path. These grey alternatives are deemed less risky both in terms on implementation and capacity to deliver the expected benefits. Their implementation *de facto* rule out NbS by expanding reservoir lifespan beyond the timeframe of the project (34 years in the case of AES Chivor, to be determined for ENEL el Guavio).

For these reasons, CI, TNC and the pilots mutually agreed to not proceed further with the project. Nevertheless, the BEM study is arguably the most comprehensive hydro-sedimentological analyses ever made of the pilots's watersheds. These resources could be put to good use to optimize compulsory or voluntary green investments that both companies make. They could also be used by the local environmental authorities to refine and enhance their interventions.

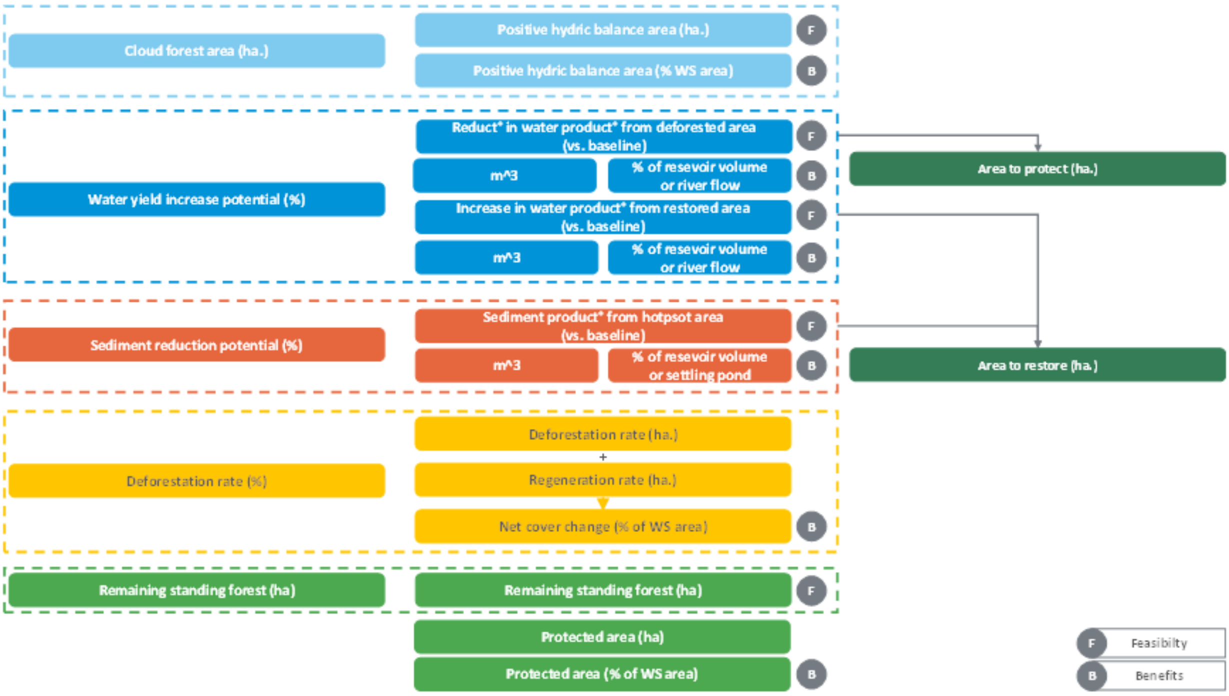
# 6. Lessons learned from Colombian pilots

Even though the two BEM Colombian pilots did not turn into actual pay-for-success transactions, many lessons have been learned regarding biophysical enabling conditions, how to select the right HPC partner with the right assets, how to better guarantee financial viability, and the best approach to commit HPCs to large scale NbS projects.

## 6.1. Revised project screening methodology

The experience gained from the Colombian pilots led to a revision of the biophysical criteria for project screening, with the aim of better capturing both the potential benefits provided by NbS, and the project's feasibility (Figure 5.1).

**Figure** Erreur ! Il n'y a pas de texte répondant à ce style dans ce document.**.8 – Revised biophysical criteria for project screening**




To create a practical tool that could allow for systematic screening of a large number of watersheds around the world, CI and TNC have partnered with Professor Mark Mulligan from the King's College of London and AmbioTek. They have brought together a series of 39 existing WaterWorld metrics (www.policysupport.org/waterworld) to assess the following properties, and tested this new methodology for dams in Brazil:

- Current state of green infrastructure. The current status of hydrologically influential upstream green infrastructure (GI). This metric is intended to define the proportion of the dam watershed under key GI land uses. High values indicate much upstream GI. It is useful in understanding the natural state of the catchment. The metric is a compound variable of 3 inputs.

- Overall contribution of green infrastructure. The overall contribution of upstream nature to dam operation. This metric is intended to define the influence of upstream green infrastructure on hydrological ecosystem services supplied to the dam. High values indicate GI in areas producing most water or GI hydrologically close to the dam. The metric is a compound variable of 5 inputs.

- Contribution of specific investable natural assets. The contribution of specific investable natural assets to dam operation. This metric is intended to capture the influence of specific assets that could be better protected or enhanced. It identifies key assets that are influential to the dam. The metric is a compound variable of 8 inputs.

- Risk to green infrastructure contributions. The current and future risk of upstream land use changes to dam operation. This metric is intended to identify current and future risks associated with land use and land use change that may already or may soon influence the dam negatively, including a specified deforestation scenario. The metric is a compound variable of 9 inputs.

- Benefits of green infrastructure restoration. The magnitude of beneficial outcomes for the dam of restoration of upstream green infrastructure. This metric is intended to understand the magnitude of benefits that might accrue to a dam through a specified restoration scenario. The metric is a compound variable of 4 inputs.

- Overall priority for investment. Combines state, contribution, investment potential, risk and benefits into an overall investment priority.

Together, these metrics cover all the factors identified in Figure 7.1 and more. The metrics are now brought together in WaterWorld for ease of application to dam data downloaded from GlobalDamWatchKB (www.policysupport.org/globaldamwatch). Individual maps are written for all of the contributing variables and for the compound indices. All metrics are to the same scale (0-100%) for ease of comparison. In addition, maps of the greatest contributing index to each compound index are also written.

A detailed presentation of the methodology and training videos are publicly available in this document: https://docs.google.com/presentation/d/17k1IsOhcNpUYWnJlers6IbVCKtqX9w4hcHOBjw-DfUA/edit?usp=sharing.

## 6.2. Land-cover land-use projections have important implications for financial viability

The project's modelled ecosystem and financial benefits are the result of the estimated changes generated by the implementation of NbS in the watershed. However, which scenario should the improved land-cover and land-use (LCLU) situation be compared to? Our first reaction was to compare it against the current situation, or baseline, which would be maintained throughout the modeling period. However, wouldn't it make more sense to use a business as usual (BAU) approach, which defines the most probable future LCLU, based on historical trends, or foreseeable changes (changes in regulations, planned infrastructure, etc.)? Both positions have strong arguments. The baseline approach presents the benefit of evaluating the potential change against measured data, while BAU only relies on modelled data, thus increasing uncertainty.

On the other hand, one could consider that the BAU methodology, which compares two possible futures, is a more dynamic approach reflecting the reality of changes that will inevitably occur in the catchment.

For the two selected pilots, the historical trends showed an actual increase of the tree cover in the river basin, probably due to the work of the local environmental authorities and socio-economic factors such as rural exodus and abandonment of agricultural lands. This leads to a BAU scenario that predicted further cover improvement based on historical trends, which limits opportunities for conservation activities and has a negative impact on the project by reducing the volume of ecosystem services, and thus project cash flows, generated by the proposed BEM portfolio. We decided to devise another BAU scenario that would model a more progressive and realistic improvement in vegetation cover, but the volume of ecosystem services from the BEM NbS portfolio was still very low compared to the baseline scenario.

There are three lessons learned from this:

- A deforestation criterion is interesting but not enough. The Global Forest Change database used for the analysis does not consider recovery processes. The adequate criteria should be the net change in forest coverage, relative to the total watershed area, to avoid a situation in which the deforestation rate indicated favorable project conditions while the reality of improving LCLU change is averse to the project.
- The size of protected areas relative to the watershed size should also be accounted for since biomes with the highest potential in terms of ecosystem benefits might be under some kind of protection status. This was the case for example for paramos in the Guavio watershed. Even though deforestation might be high in some areas of the catchment, the systems responsible for most of the water regulation are protected by law. Even though there can be localized threats from extension of cattle ranching and potatoes crops areas, large changes in LCLU affecting these ecosystems are not expected.
- Using both baseline and BAU methods is necessary. This rigorous approach provides confidence to HPC and allows for the definition of a shared vision of the watershed's future. Moreover, the results of both methods will provide a good understanding of the range of potential benefits to the HPC.

## 6.3. Sedimentation reduction is the safest bet to generate benefits to HPCs

Water related ecosystem services are very complex to apprehend and highly context dependent. The potential both in terms of volume and regulation depends on several factors such as evapotranspiration, soil texture, antecedent humidity, topography and altitude. A variety of ecosystems promote baseflow and/or infiltration. However, only a few biomes, such as cloud forest and paramos present a positive water balance as they capture more horizontal precipitation than they consume water through evapotranspiration. These biomes typically have low overall productivity, making them slower to respond to environmental changes and a challenge for the project due to long response time to restoration processes. Identifying a pilot with such conditions can be a challenge, which explains why the Blue Energy concept was extended to forest ecosystems beyond cloud forests.

In the case the two Colombian pilots, restoration activities would have had a positive water regulation impact as base flows were modelled to be maintained or slightly improved despite a significant increase in evapotranspiration.

However, should improved baseflow benefits have been more significant, their conversion into actual project cash flows would still have been impaired by size of the reservoirs, which are designed to act as buffers and absorb unpredictable changes such as long dry seasons.

The initial intuition that revenues can be generated by water regulation ecosystem services must be tempered and restricted to specific cases, such as reservoirs with operating issues during the dry season or run-of-river assets, which are by design more vulnerable to changes in river flows. These conditions need to be confirmed early in the engagement process with the HPC.

Last, the transformation of water related ecosystem services into project cash flows also depends on the reservoir/plant operation rules and the HPC's electricity sales strategy, which can complicate negotiations with the HPC very much.

For the BEM to be viable, the HPC would have (i) to acknowledge that the BEM NbS portfolio does generate water volume and/or regulation benefits, but that these benefits are not transformed into actual cash flows for reasons outside of the control of the BEM project (i.e. operating decisions from the HPC), and (ii) still agree to pay for these ecosystem services to cover the NbS portfolio implementation costs. This seems quite difficult to negotiate in a pay-for-success scheme.

By contrast, sediment ecosystem services are much less context dependent, and benefits such as reduced dredging or equipment wear can be materialized even in the case of large reservoirs.

Things are more complex regarding reservoir lifespan as the relationship between sediment load and additional reservoir useful life is not straightforward. A high volume of sediments reaching the reservoir (in absolute or relative terms) does not guarantee the possibility to transform the ecosystem service into financial value. The impact of sediments on the HPC's operations –or to put it differently opportunities of costs savings and/or increased lifespan– very much depends on the topography of the reservoir and the location of sediment deposit areas. It needs to significantly affect the useful and/or dead volume during the project time window. For assets that are close to the end of their useful life, the impact of an NbS portfolio might not materialize quickly enough. Conversely, for other assets with a very long remaining lifespan, the benefits might materialize too far away in the future, resulting in an insufficient net present value for the project to be financially viable. Nevertheless, it is impossible to systematically perform this type of analysis on a large number of potential sites. The conclusion from the sediment yield analysis will therefore need to be confirmed with the HPC during the engagement process.

## 6.4. Selecting the right partner with the right asset(s)

### 6.4.1. HPC profile

Identifying an HPC with the right profile to suit the BEM is probably as important, if not more, than the biophysical characteristics of the watersheds in which its assets are located. Early in the engagement process, key issues must be validated, such as the existence of a significant opportunity for NbS, the compatibility of NbS with the action plan defined by the HPC to mitigate problems or enhance opportunities, and the willingness to share confidential data and enter into a cost discovery process.

#### a) Early validation of actual sedimentation and/or water flow deregulation issues

Theoretical scientific work to assess the potential benefits of NbS is very important, in particular because it facilitates the engagement process with HPCs, showing rigor and good understanding of local conditions as well as making things more concrete for the HPC than mere conceptual benefits.

However, the conclusions of the high-level preliminary analysis must be confirmed by the HPC itself. Does it face sedimentation or water deregulation issues? Are these outside of the range expected by the initial reservoir/plant design? For how long have the issues materialized and what are the HPC's expectations for the future? Which part of the watershed/which assets are being most affected?

Have the causes of these issues been identified (nature and localization)? What are the main operational and financial impacts? What has been done so far to mitigate these risks and what is the action plan for the future? What is the remaining reservoir lifespan and what type of investment is contemplated to extend it?

Very early in the engagement process, the project team must receive clear answers to these questions to have a good understanding of the challenges faced by the HPC and if NbS could be a credible and cost-effective solution.

**b) Understand the HPC's proposed solutions to water regulation and sediment challenges and how NbS could fit in it**

If water deregulation and/or sedimentation are significant enough issues for the project to be successful, the HPC is very likely to have an action plan already designed in response, or will have at least a rough idea of what solutions it could implement.

Based on our discussion with 15+ HPCs in the Andean region, we found that this plan might typically rely mostly on grey infrastructure, including but not limited to dredging, sediment traps and/or deviations, civil work for slope stabilization, channeling of riverbeds, and modifications to water intake design to increase dead volume and expand reservoir lifespan. However, all the aforementioned grey solutions, with the exception of water intake design for the reasons explained in section 5.4.2 b), could be efficiently complemented or replaced by NbS under the right conditions.

In that context, it is crucial to:

- clarify the HPC's level of understanding of NbS, how they work, their difference with corporate and social responsibility (CSR) investments, and the benefits they can bring to its business. In particular, it is important to understand why investments were made and the perception of management on their results. In several cases, we have heard comments such as "planting trees is nice but cannot be a solution" regarding projects conducted by the environmental and social responsibility department that were not initially designed to provide ecosystem services. The outcome of these CSR investments, as well as those made to comply with regulatory requirements (e.g. protecting water sources as part of water concessions) are often not sufficiently monitored and measured to prove their benefit to the company's operations. Explaining how the design and objectives of NbS projects differ from CSR or mandatory investment can greatly contribute to overcome internal investment barriers;

- understand the timing of existing the grey-infrastructure plan, for both implementation and benefits. This is key to assess if there is enough time to include NbS in the overall strategy; if bioengineered infrastructure might need to be considered to complement NbS in the early stages of the project to provide quick answers to the HPC's problems; and if the benefits of NbS will be significant enough during the project time window; and

- understand the design, costs and expected benefits of the proposed grey infrastructure and the reason(s) for their implementation. Ideally, detailed information should be available on the expected impacts on operations, especially on O&M costs, assets lifespan and electricity generation. Objective grey infrastructure expert advice should be sought to evaluate if NbS can optimize their design, for example by maintaining optimal water intake level for maximized electricity generation, or by reducing the maintenance costs of sediment traps. This could also provide comparative cost-benefit ratios that can be useful in determining return on investments and provide useful information for decision making regarding investments.

### c) Validate willingness to dedicate human resources, share data and engage in a cost discovery process

To be successfully implemented, the BEM requires a significant amount of sensitive/confidential data, including:

- biophysical data such as water flows and sediments monitoring;
- reservoir bathymetries;
- reservoir and plant operating rules;
- historical and projected sediment management CAPEX and OPEX;
- historical and projected maintenance costs;
- environmental and social strategy and investments, including details on any community-related issues;
- historical and projected electricity production;
- historical and projected contractual engagements and electricity prices; and
- details on any other source of cost and/or revenues that could be affected by NbS.

It is crucial that the HPC understands that without this information, the analysis might not be conclusive or present high uncertainty risks.

Although the BEM might not be looking for financial support during the design phase of the project, in-kind contribution, especially with dedicated human resources, will be needed. The amount of time necessary to gather this information and the number of people to be mobilized to help with its analysis and cost discovery process should not be underestimated.

## 6.4.2. Asset(s) characteristics

### a) Reservoir vs. run-of-river

There has been a lot of internal discussion on the profile of the asset that would fit the BEM best. We initially decided to focus on larger plants, which typically rely on large reservoirs, because of their financial potential: they have greater O&M costs and sell more electricity, both of which are the basis for the project's pay-for-success scheme. Run-of-river assets were not prioritized because of the smaller financial opportunity and the fact that conservation effort would be the same as for reservoirs, when considered in cost per hectare. Preliminary engagement with a Bolivian HPC operating this type of asset seemed to be confirm these issues.

In retrospect, both type of assets could be considered for the mechanism, but with a different focus.

- <u>Assets with large reservoirs are likely to benefit more from sediment ecosystem services</u> than from water regulation. Hydropower facilities are designed with much care, since the financial, reputational, and environmental costs are high. Reservoirs are created to serve as a "shock absorber", so the system resists unpredictable changes such as long dry seasons or massive landslide events, and is still able to function. Additional electricity generation or sales optimization might only be possible in a very specific context such as significant impacts of water scarcity on production during the dry season.

  On the other hand, even though reservoirs might have the capacity to receive large sediment loads, a viable business model might still exist if there is a conjunction of dredging and equipment wear issues, and if the reservoir faces long-term issues with dead-volume clogging. On paper, we proved with the ENEL el Guavio pilot that NbS could create a lot of value by extending lifespan.

- Focus might be on water regulation for run-of-river assets. Benefits from sedimentation control might be hard to materialize as these assets are typically equipped with sediment settling ponds which are both efficient and relatively cheap to maintain. However, they are directly exposed to changes in river flow and could very much benefit from the natural ecosystems' capacity to regulate flow during extreme weather events: attenuate peak flow during the rainy season that might cause production stops, and maintain base flow during the dry season, improving the plant's load factor.

#### b) Presence of other assets upstream

In hydropower dense watersheds, analyzing the whole electricity production system is key to target the right asset. Downstream assets might not be incentivized to participate in upstream watershed conservation if other plants "filter" the water they process.

## 6.5. Guaranteeing financial viability

### 6.5.1. Willingness from HPC to engage in a pay-for-success scheme

The whole BEM relies solely on the payments made by the HPC to the project SPV to raise debt and equity capital. A strong and committed HPC acting as ecosystem services off-taker is therefore key to the project bankability. The HPC needs to perfectly understand the financial scheme and the nature of its commitment and be ready, once it is comfortable with the ROI analysis and tentative terms and conditions of the offtake agreement, to sign a letter of intent that will be used to attract financing.

Most of the HPCs we have engaged with were interested in the BEM because it should significantly reduce both the financial (initial CAPEX investments) and execution/implementation risks.

However, depending on its financial profile and strategy, some HPCs might prefer to assume CAPEX rather than generating new OPEX, to optimize the presentation of its profit and loss statements. As for other key project components, the HPC's strategy and preferences in that regard will need to be validated early on.

### 6.5.2. Generate steady and recurring cash-flows

#### a) High cost/benefit ratio does not necessarily guarantee a bankable project

Experience has shown that a cost/benefit ratio superior to 1 does not necessarily translate into a bankable project. Projects that rely solely on reservoir lifespan extension will present a challenging cash-flow profile where cash flows available for debt service are negative or very low during most of the project, and very high during the extended lifespan period.

In such cases, it might take some challenging negotiations to convince the HPC to make the early payments necessary for debt sculpting. In theory, this might not be an issue if parties agree on the adequate discount factor.

In practice, it will depend on the HPC's confidence in (i) the biophysical model and its outputs, (ii) the capacity of NbS to actually generate the expected impacts, (iii) the capacity of the SPV and local partners to implement the NbS program in a timely fashion with the requested level of quality.

The ideal project would incorporate some dredging costs or equipment wear issues to generate recurring cash flows, or better still, have a direct impact on electricity production and/or sales optimization. It would also be scalable over time rather than require large immediate implementation thresholds, so as to avoid binary outcomes early on (no revenues and significant cash flows) and generate trust iteratively between the BEM project SPV and the HPC.

### b) How to measure and monitor benefits? The importance of trust in model outputs

Most of the project decisions will be made based on the outputs of the biophysical model and the prioritization tool.

The HPC and potential investors' trust and confidence in the model is an absolute pre-requisite for project success, as payments from the HPC under the ecosystem services offtake agreement will have to be agreed upon based on modeled benefits. To guarantee such trust, the selected model needs to be able to answer, with reasonable accuracy, key questions that the HPC will necessarily ask, and which have been detailed in section 4.3.1: which NbS should be implemented? In what order of priority and in which area? How many benefits can be expected? Where and when will they materialize?

Actual data will be important to allow for comparison with modeled benefits and to update future expected payment. Monitoring might however be a challenge if sufficient data to build a relevant baseline is not available from the HPC or other sources. In this case, it will be important to validate the HPC's willingness to make payments strictly on modeled benefits while the project builds a baseline that will be later be used to adjust the model.

### c) Engage with other stakeholders?

NbS identified for the hydropower sector are also very relevant to other catchment beneficiaries. Mitigation of irregular flows due to extreme weather events such as flood and droughts or the improvement of water quality through the reduction of sediment in suspension are services that could be of interest to water utilities, the agriculture sector and municipalities.

At pilot level, engaging in a pay-for-success scheme with multiple stakeholders seemed too big of a challenge. In retrospect, it might not only be relevant but the only solution to widen the project's financial basis and generate sufficient cash flows.

Ideal assets would thus be multi-purpose reservoirs, that are used for one or more of electricity generation, potable water consumption and irrigation.

## 6.6. A step-by-step approach to commit HPCs to large pay-for-success transactions

Even though ROI analyses might demonstrate the relevance of NbS to an HPC's business –at least on paper, depending on the HPC's profile and familiarity with NbS, structuring a large transaction straight away might be overly challenging. To overcome the HPC's hesitations, it can be useful to take a step-by-step approach that gradually builds confidence in NbS and pay-for-success schemes.

- Demonstrate how NbS could be integrated into grey infrastructure investment plans. A first step to building trust from the HPC could consist in analyzing how NbS could fit into the HPC's grey infrastructure program and their potential to reduce O&M costs and/or optimize design. See section 7.4.1 b) above for more details.

- Optimize existing conservation/restoration investments. Arguably, all HPCs invest in some sort of watershed conservation activities, be it to comply with environmental regulations, to meet concessions requirements, or as part of their corporate social and environmental responsibility strategy. However, chances are that these conservation activities are not designed to optimize ecosystem services and that their impact on the HPC's operations are not adequately evaluated nor measured.

  The biophysical and socio-economic prioritization tool designed by Blue Energy can be used to optimize investments by targeting hotspots for sediments and water flow regulation and identify the most effective NbS. It can help the HPC to comply with its obligations while optimizing impacts on its operations, therefore creating trust and interest in NbS and paving the way to future transactions.

- Design a smaller scale project. The magnitude of the conservation efforts to be made to generate durable and material changes in a watershed can be daunting, not only to the HPC, but also to implementing parties and investors. Focusing on a smaller scale project might be wise to test and refine the different processes necessary for a successful project: engagement with local communities; sourcing of vegetal material and implementation logistics; ecosystem services evaluation and monitoring; and legal and financial arrangements for pay-for-success payments.

  However, it should be clear to all parties that a smaller scale project cannot have the same impacts as a full-fledged conservation program. This is obvious but will have repercussions on how success is defined and where benefits are measured. For example, benefits might not be material enough at reservoir level to extend its lifespan and would be better measured at the implementation sites or sub-watershed levels.

  Thanks to proven implementation capacities, tested processes and actual cash-flows generation, larger projects will be much easier to structure and finance.

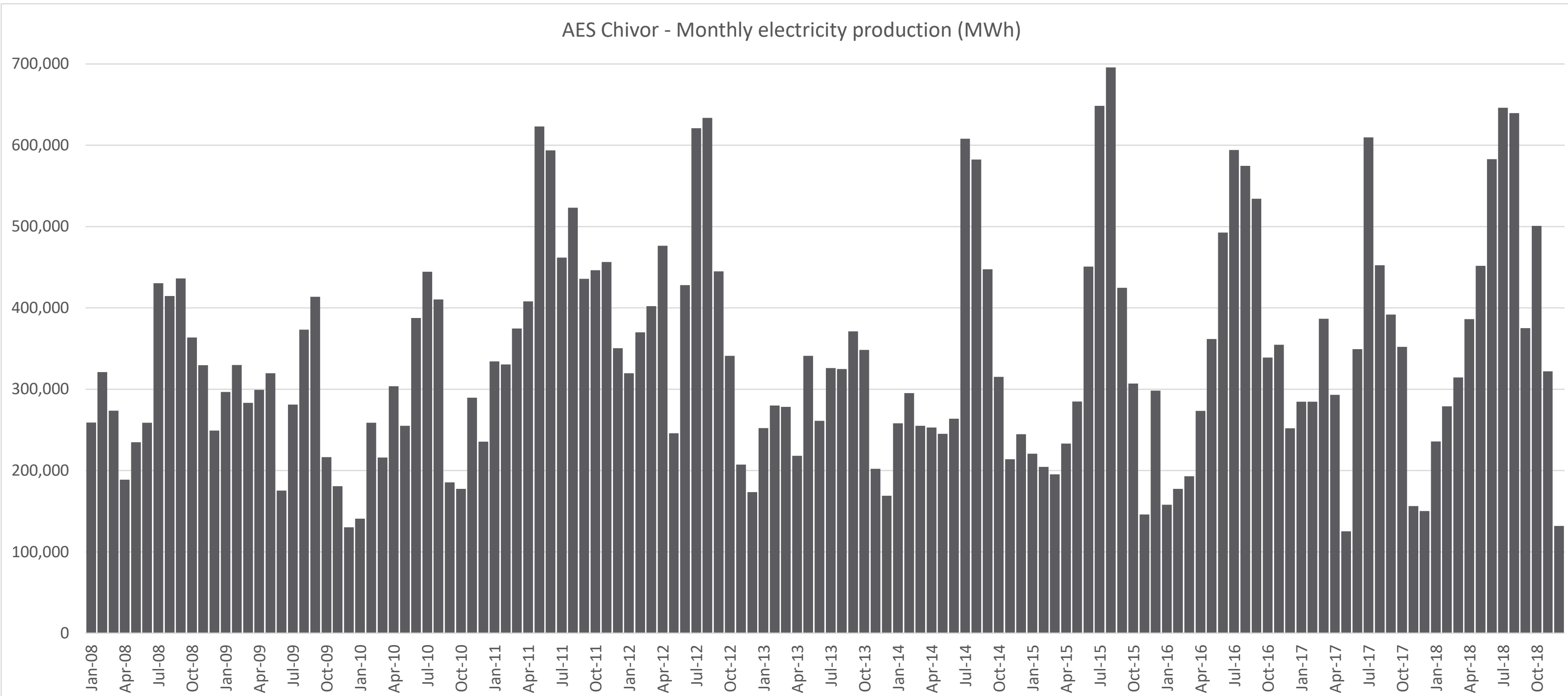
# Annex I – Potential pilots identified with interviewed hydropower companies

| Country | HPP Name | Owner | Type | Capacity (MW) |
|---|---|---|---|---|
| Bolivia | Huaji | COBEE | Run-of-river | 30 |
| Bolivia | Cahua | COBEE | Run-of-river | 28 |
| Bolivia | Harca | COBEE | Run-of-river | 26 |
| Bolivia | Chururaqui | COBEE | Run-of-river | 26 |
| Bolivia | Cuticucho | COBEE | Run-of-river | 21 |
| Bolivia | Santa Rosa | COBEE | Run-of-river | 13 |
| Bolivia | Sainani | COBEE | Run-of-river | 10 |
| Bolivia | Zongo | COBEE | Run-of-river | 10 |
| Bolivia | Tiquimani | COBEE | Run-of-river | 10 |
| Bolivia | Botijlaca | COBEE | Run-of-river | 7 |
| Bolivia | Santa Isabel | ENDE | Run-of-river | 93 |
| Bolivia | Corani | ENDE | Storage | 54 |
| Bolivia | Yanacachi Norte | Hidrobol | Run-of-river | 51 |
| Bolivia | Chojlla | Hidrobol | Run-of-river | 38 |
| Colombia | Chivor | AES | Storage | 1 010 |
| Colombia | Punchiná (San Carlos) | ISAGEN | Storage | 1 240 |
| Colombia | El Popal | HMV | Run-of-river | 20 |
| Colombia | San Miguel | HMV | Run-of-river | 42 |
| Colombia | El Guavio | ENEL | Storage | 1 250 |
| Ecuador | Paute Molino | CELEC | Storage | 1 100 |
| Ecuador | Cardenillo | CELEC | Storage | 596 |
| Ecuador | Mazar | CELEC | Storage | 170 |
| Ecuador | Ocaña | Elecaustro | Run-of-river | 26 |
| Peru | Huinco | ENEL | Storage | 268 |
| Peru | Chimay | ENEL | Run-of-river | 155 |
| Peru | El Platanal | Celepsa | Storage | 223 |
| Peru | Mantaro | Electroperú | Storage | 679 |
| Peru | Restitución | Electroperú | Storage | 219 |
| Peru | Carhuaquero | Kallpa | Storage | 95 |
| Peru | Gallito ciego | Statkraft | Storage | 35 |
| Peru | Cheves | Statkraft | Storage | 176 |
| Peru | Yaupi | Statkraft | Run-of-river | 114 |

# Annex II – Comparison of SIGA to other hydro-sedimentological models

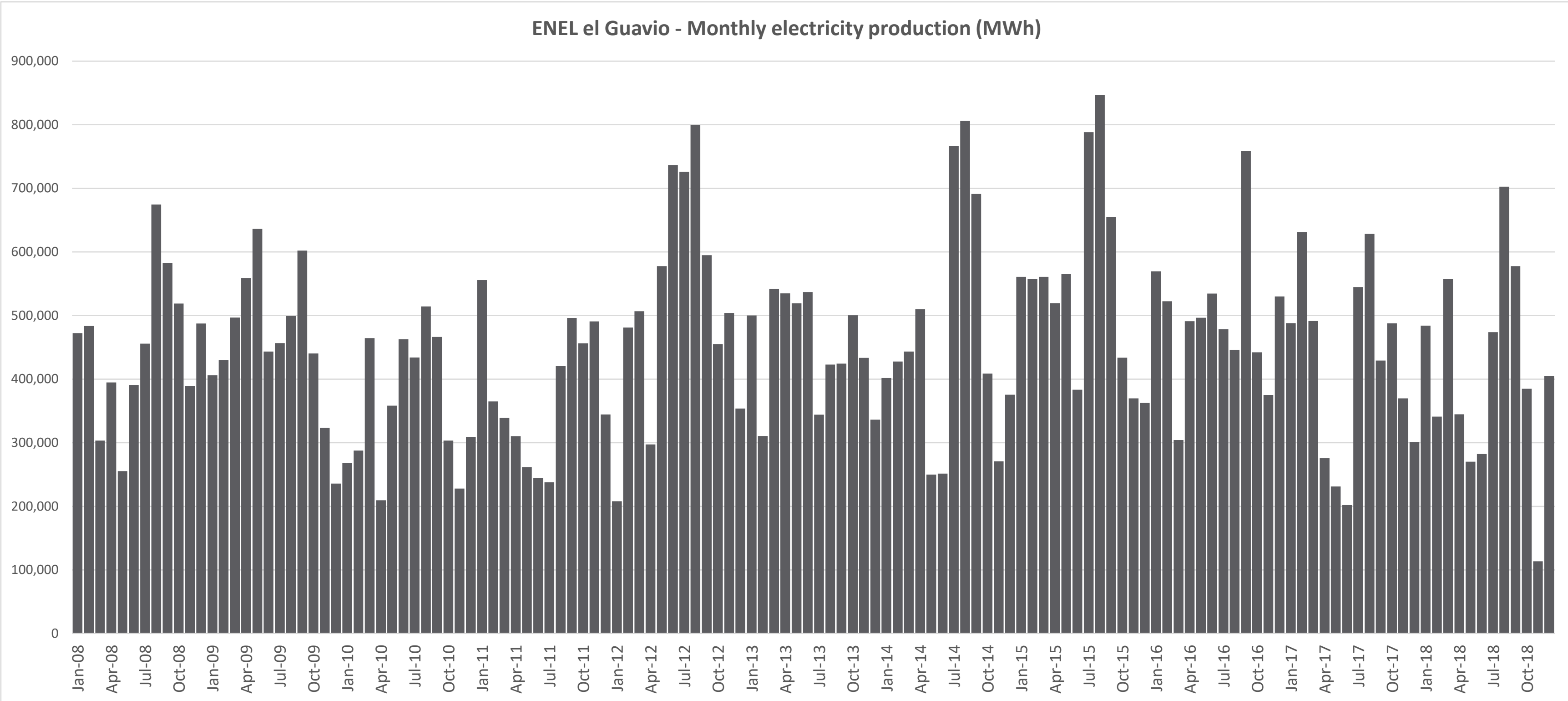
| Model | Rainfall Runoffs | Spatial structure | Time resolution | Water processes | | | | | | | | | Sediment processes | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Intercep. | Fog/Hp | Evapo, | Infiltrat° | Percolat° | Superficial flow | Subsurface flow | Base flow | Rout | Slope processes | | | Riverbed processes | Riverbank processes | Mass movements |
| | | | | | | | | | | | | | Generat° | Transport | Deposits | | | |
| AGNPS | Yes | Distributed | Event | ≈ | ✗ | ✗ | ≈ | ✗ | ✓ | ✗ | ✗ | ✓ | ✓ | ✗ | ✗ | ✓ | ✗ | ✗ |
| ANSWERS | Yes | Distributed | Daily | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| CREAMS | Yes | Aggregated | Event/Daily | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| EMSS | Yes | Aggregated | Daily | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ | ✓ | ✗ | ✗ |
| GUEST | Yes | Aggregated | Event | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✗ | ✗ | ✗ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ |
| HSPF | Yes | Semi-Distributed | Minutes per day | ✓ | ✗ | ✓ | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ |
| IHACRES-WQ | Yes | Aggregated | Daily | ✗ | ✗ | ✓ | ✗ | ✗ | ✓ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✓ | ✗ |
| IQQM | Yes | Semi-Distributed | Daily | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |
| LASCAM | Yes | Distributed | Daily | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ | ✗ | ✗ |
| LISEM | Yes | Distributed | Event | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✓ | ✗ | ✗ |
| MIKE-11 | Yes | Distributed at section scale | Event to monthly | ≈ | ✗ | ≈ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ |
| PERFECT | Yes | Plot | Daily | ✗ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ | ✗ |
| SEDNET | Yes | Distributed | Long term | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✗ | ✗ | ✓ | ✓ | ✗ |
| D-SEDNET | Yes | Distributed | Daily | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ | ✗ | ✗ | ✓ | ✓ | ✗ | ✗ | ✓ | ✓ | ✗ |
| SWAT2000 | Yes | Distributed | Daily | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ |
| FIESTA | Yes | Distributed | Hourly/Daily | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |
| SHIA | Yes | Distributed | Event/Daily | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ | ✗ | ✗ |
| TETIS | Yes | Distributed | Hourly/Daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | |
| SHIA-SED | Yes | Distributed | Event/Daily | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ |
| SHIA-LANDSLIDES | Yes | Distributed | Daily | ✓ | ✗ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✗ | ✗ | ✗ | ✗ | ✗ | ✓ |
| SIGA-GOTTA | Yes | Distributed | Daily | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

# Annex III – AES Chivor monthly production 2008-2018




Source: XM.

# Annex IV – ENEL el Guavio monthly production 2008-2018




Source: XM.

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# List of acronyms

**BEM**: Blue Energy Mechanism.

**CAPEX** : Capital Expenditure (i.e. long-term investments capitalized on balance sheet rather than expensed on the income statement).

**CI**: Conservatión International Foundation.

**GEF**: Global Environment Fund.

**HPC**: Hydropower Company.

**IUCN**: International Union for Conservation of Nature.

**LCLU**: Land-cover and land-use.

**NbS**: Nature-based Solutions.

**OPEX**: Operating Expenses.

**ROI**: Return on Investment.

**SER**: Society of Ecological Restoration.

**SIGA**: *SImulación Geocientífica Abierta* (modeling tool).

**SPV**: Special Purpose Vehicle.

**TNC**: The Nature Conservancy.

**USD**: United States Dollars.

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