# The Ecosystem Services provided by Tropical Forests and a Proposed Framework to Assess Them

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On behalf of:
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of the Federal Republic of Germany

WINROCK INTERNATIONAL

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# 1 Contents



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# 1 Introduction

Natural ecosystems, such as forests, grasslands, and marine ecosystems, provide a variety of benefits to human beings. These benefits to humans are commonly referred to as ecosystem services. Many of these ecosystem services are not properly recognized or valued by society, leading to improper management, degradation, and destruction of the ecosystems and the services they provide. Costanza et al (2014) estimated that land use change (which usually implies the loss of natural ecosystems) has led to a global loss of ecosystem services valued at US $ 3-20.2 trillion/year. A key step to reversing the harm done to ecosystems and preventing future damage to ecosystems is by recognizing the importance of these services and assessing how different management practices are affecting them.

The Government of Colombia is currently in the process of developing a Nationally Appropriate Mitigation Action (NAMA) focused on reforestation and forest restoration. This NAMA explicitly recognizes one ecosystem service: the forests' capacity to capture carbon from the atmosphere, thereby helping to mitigate climate change. However, the newly reforested areas or restored forests may provide several other ecosystem services as well. Identifying and valuing these services could help bolster the case for implementing this NAMA and raise awareness about the importance of restoring forests and reforesting.

During meetings between the Ministry of Environment and Sustainable Development (MADS) and Winrock International (Winrock), MADS requested support in evaluating ecosystem service benefits that forest restoration and reforestation could produce. In particular, they requested that Winrock help identify the different potential ecosystem services resulting from these actions as well as a list of indicators – biophysical and if possible, socio-economic - they could use to measure these services. While this would be an important step to assessing the benefits of different actions, more in-depth assessments are necessary to identify and possibly quantify the *site-specific benefits and harms of current and potential actions*.

This paper presents an overview of the ecosystem services that tropical forests provide. A conceptual framework is also introduced that designers and implementers of the forestry NAMA can apply to systematically identify changes in ecosystem services in geographic areas of interest as result of management actions (e.g., reforestation of X hectares). Based on this proposed framework, a list of biophysical and socio-economic indicators is presented for each potential ecosystem service provided by tropical forests.

## 2 Types of ecosystem services

One of the most widely used classification systems is provided by the Millennium Ecosystem Assessment (MEA) (2005), which identifies four different categories of ecosystem services:

1. **Provisioning services** are the tangible products human receive from ecosystems, such as wood, water, and food.
2. **Regulating services** are derived from the regulation of ecosystem processes, such as the regulation of climate, hydrology, and certain diseases.
3. **Cultural services** are the nonmaterial benefits that people obtain for ecosystems including recreation, aesthetic experience, spiritual enrichment, etc.
4. **Supporting services** are the foundation for the production of all the other types of services. Examples of supporting services include primary production, soil formation and retention, nutrient cycling, etc.

Figure 1 shows the relationship between these four classifications.

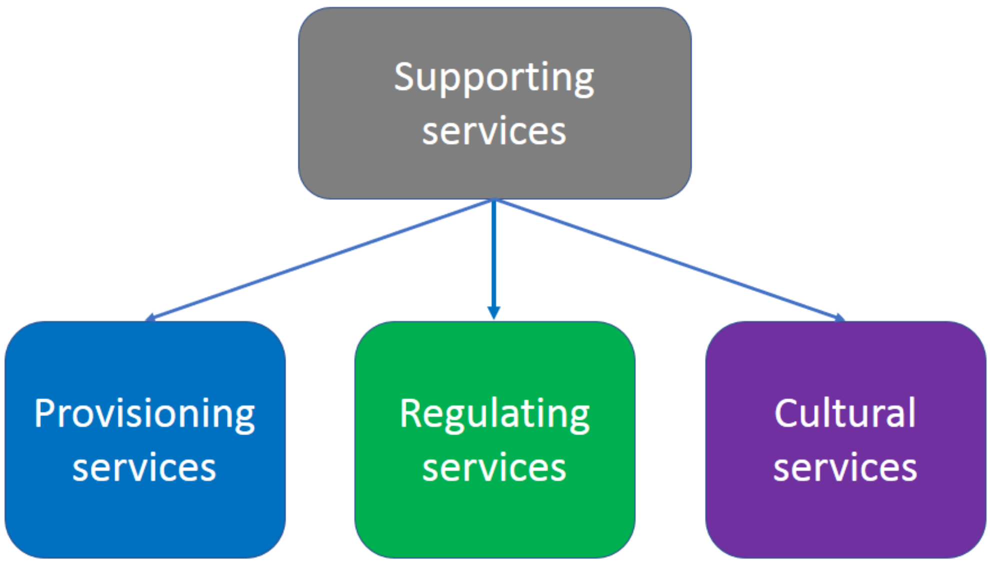


**Figure 1. Four classes of ecosystem services (modified from Figure A in the MEA (2005))**

Because of the widespread use of this classification system and the relative ease of understanding of the concepts versus other classification systems[1], the MEA's classification is applied in this paper. However, since supporting services are the inputs for all the other services, only provisioning, regulating, and cultural services are considered to avoid double counting.

[1] A variety of ecosystem service classification systems have been proposed as discussed in Fisher et al. (2009).

# 3 Overview of ecosystem services

## 3.1 Ecosystem services and disservices provided by native tropical forests

In 2014, the Center for Global Development (CGD) produced a report discussing that different ecosystem services that tropical forests can provide (Brandon, 2014). The findings from this report are summarized here and expanded upon when necessary. While the CGD report focuses on the provisioning and regulating service, we also present different cultural services. This list is intended to be as comprehensive as possible, although the authors recognize that there could be additional services provided by tropical forests.

Not every tropical forest provides all of the services listed below. The existence of these services depends on the particular biophysical and social circumstances in a given forest area and the area impacted. Further, some areas provide greater benefits of certain services than other areas.

The establishment of forests may lead to environmental disservices as well. We also discuss these disservices in the following sections. Changes in ecosystem services and disservices will depend on the specific human actions (e.g., reforestation, forest regeneration, selective logging, etc).

### 3.1.1 Provisioning services

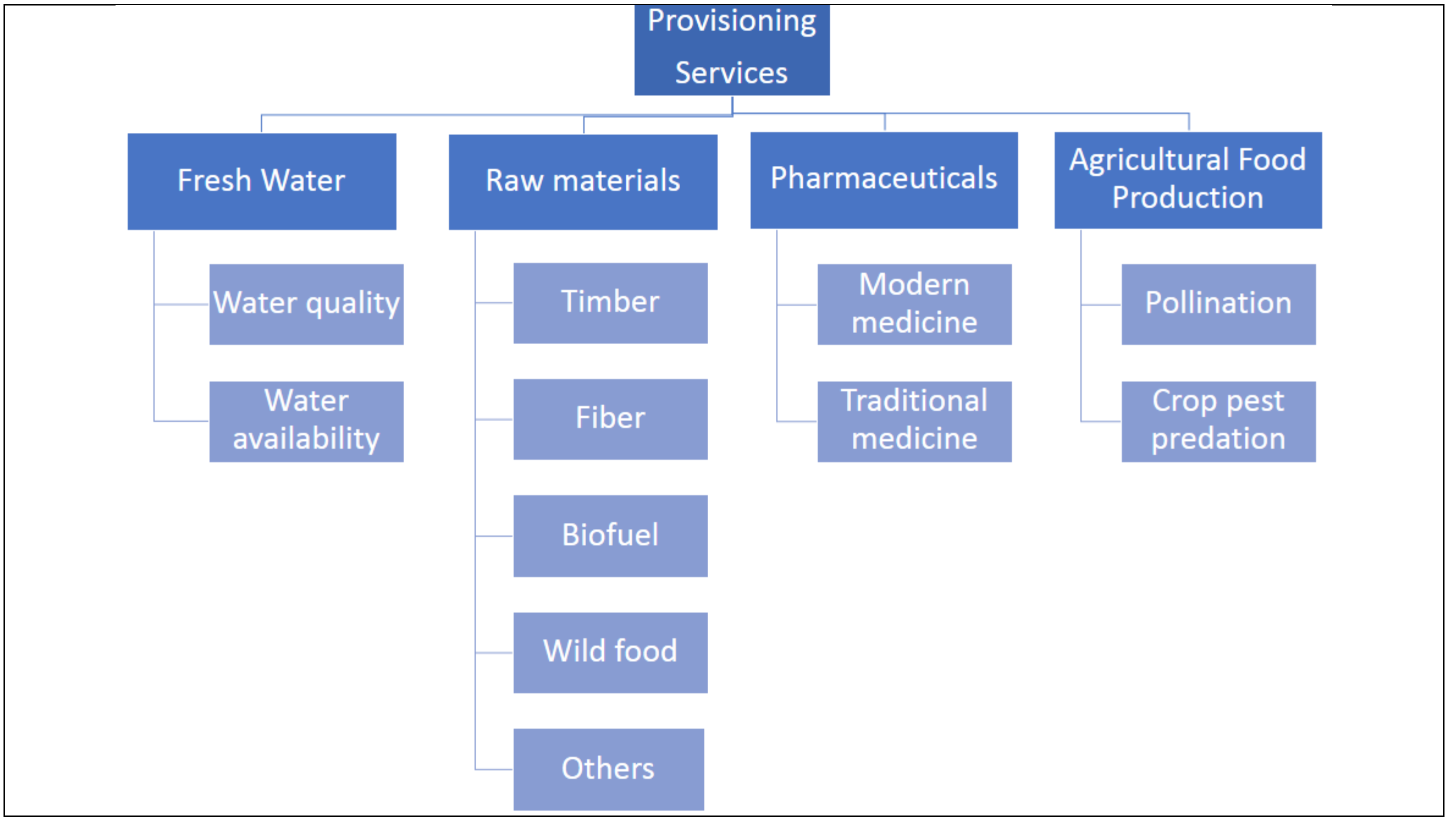


**Figure 2. Provisioning services provided by tropical forests**

- **Fresh Water**: Forest play an important role in maintaining and improving water quality and regulating water flow for human use.

  - **Water quality** - Healthy forests help prevent the contamination of nearby water bodies by preventing erosion and water run off containing a variety of pollutants such as excess nutrients from agricultural fertilizer, heavy metals, and pathogens. They also remove pollutants from water flowing through, and infiltrating into aquifers. Finally, trees and other plants remove pollutants from water returning to the atmosphere through transpiration.

  - **Water availability** – Compared to other land uses, forests may increase or decrease water availability. Forests have been shown to retain water and slowly release it during dry seasons, thereby mitigating the impacts of water shortages. Cloud forests also can intercept a significant amount of water from fog, thereby increasing surface water flow and groundwater infiltration. This service is not only vital for direct human consumption, but also for downstream hydroelectric dams and agricultural irrigation systems. However, Filoso et al (2017) found that forest restoration projects can reduce water yields, baseflow, and groundwater levels following interventions, although few projects analyzed focused on native species or studies done at large time and geographic scales.

Nonetheless, because tree cover increases soil infiltration, forests can increase groundwater recharge in the long term.

Finally, forests reduce erosion and, and as a result, reduce sedimentation rates in downstream water bodies, which improves the storage capacity of reservoirs for human consumption and hydroelectric dams as well as improves the functioning of navigation channels and irrigation systems.

- **Raw materials**

    - Forests are a primary source of **timber, fiber** and **biofuel** (e.g., firewood and charcoal), all of which play fundamental roles in local communities and, in the case of timber and fiber (i.e., pulp and paper), are important global commodities.

    - Forests are the source of a wide variety of **wild food,** including plants, nuts, fruits, and meat, for people. These wild foods are staples in poorer, forest-dependent communities. Forests also play pivotal roles in the health of freshwater, estuarine, and marine fisheries through a number of mechanisms. Riparian forests help reduce sedimentation, filter pollutants, and maintain water temperatures all of which benefit nearby and downstream **fisheries**. Leaf litter and seeds can also be a source of food for fish or serve as habitat for the food (different macroinvertebrates) for fish. Finally, mangrove forests serve as important nurseries for marine fisheries.

    - There are a number of other forest products including palm fronds, resins, oils, dyes, barks, etc that are important to local communities, for example to make arts and crafts that serve as an important source of income, and in global markets.

- **Pharmaceuticals:** Plants and animals in tropical forests have served as key sources for the development of modern medicine. According to Robinson and Zhang (2011), one-quarter of all modern medicine comes either from medicinal plants or from synthesizing compounds based on the chemical properties of these plants.

- **Agricultural Food Production:** Tropical forests also play important roles in agricultural production systems.
    - They serve as **habitat for species that are important pollinators**, such as bees, moths, bats, flies, rodents, etc. to commercial and domestic crop production.

    - They also can serve as **habitat for predators and parasitoids**, such as birds and bats, of crop pests.

### 3.1.2 Regulating services

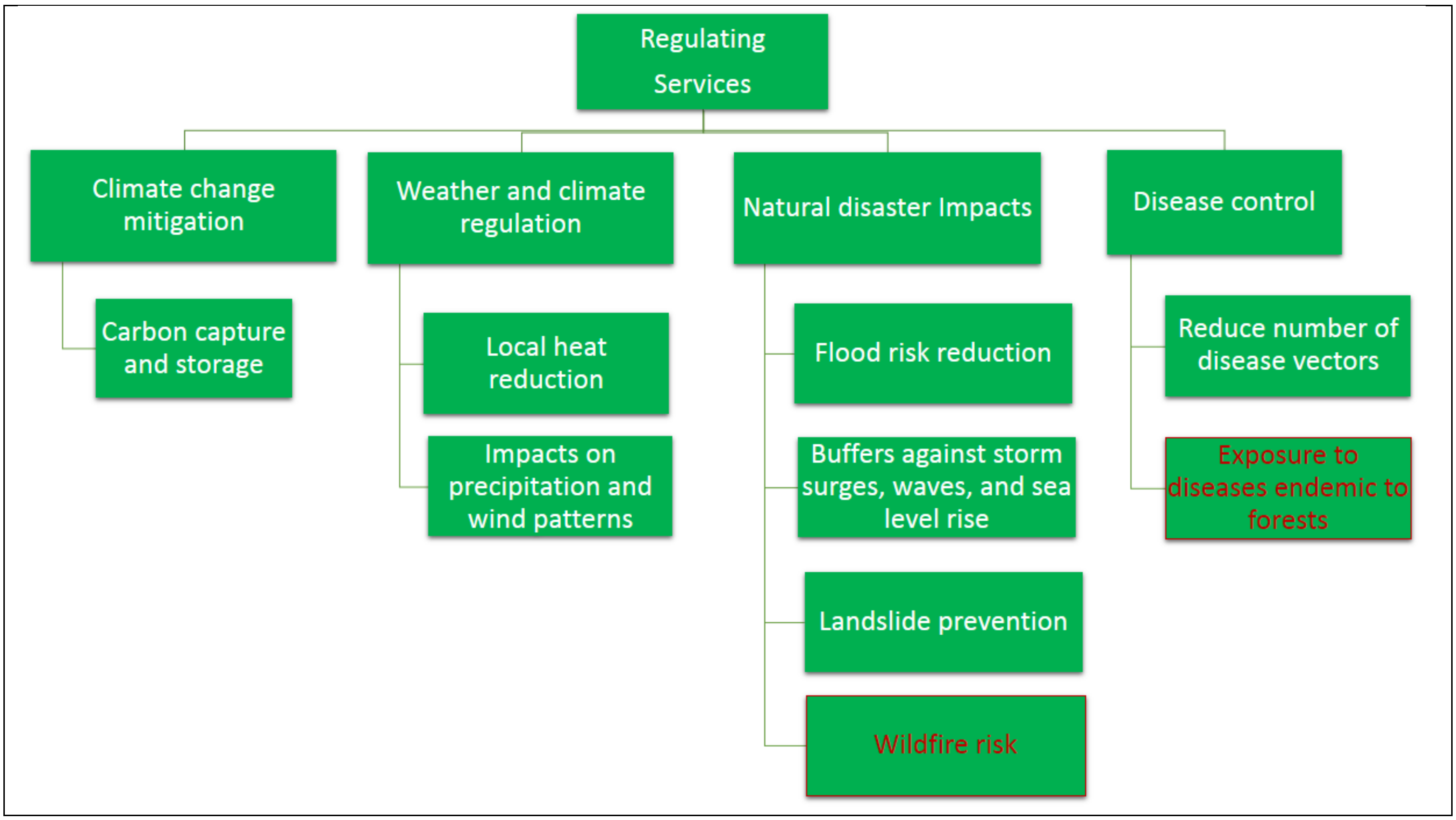


**Figure 3. Regulating services provided by tropical forests.**

*The boxes highlighted in red indicate that the forest may provide more harms than benefits with regards to this service as compared to other land uses.*

- **Climate change mitigation:** The trees and other plants in forests capture and store greenhouse gases through primary production thereby ameliorating climate change.

- **Weather and climate regulation:** through evapotranspiration, forests return moisture to the atmosphere which produces clouds and reduces heat in nearby areas. The process of evapotranspiration from so many trees also influences precipitation and wind patterns and the overall cycling of heat and moisture at local, regional, and global scales.

- **Impacts on Natural Disasters:** Tropical forests play a role in reducing the intensity, duration, and frequency of different natural disasters.

- Forest **reduce flooding risk** by slowing the water run off into rivers and streams, which in turn causese a greater proportion of precipitation to be absorbed by trees and other vegetation and released back into the atmosphere through evapotranspiration, or stored in the ground through soil infiltration. Forests also help prevent downstream water bodies from filling up with sediments and overflowing, by reducing erosion.

- Coastal forests serve as **buffers to mitigate storm surges and coastal waves**, since the trees reduce tidal and wave energy.

- Coastal forests also are **buffers against sea level rise** by maintain and enhance coastal elevations by trapping sediment and accreting peat.

- Forests also help **prevent landslides** in hilly areas since forest root systems anchor soil and promote water infiltration as opposed to water run off. Forests also remove excessive water through evapotranspiration. Furthermore, forest improve soil structure, increasing resiliency against the threat of landslides.

- The **presence of forests may increase wildfires** in comparison to other land uses due to the increased presence of biofuel. Intact tropical forests are generally not likely to burn as compared to degraded, fragmented forests because of high moisture levels and closed canopies in moist and wet forests, and fire tolerance in dry forests. Forest fires are much more common, in tropical forests that have experienced a high degree of degradation and fragmentation due to reduced canopy cover and evapotranspiration, the presence of invasive species more likely to burn, and the increase in forest edges which tend to be drier (Armenteras, González, & Retana, 2013; Brooks et al., 2004).

- **Disease control**: tropical forests have a mixed effect on disease transmission.

  - They can help **reduce the number of vectors of diseases**, such as malaria, schistosomiasis, west nile virus, hantavirus, among others. The exact reasons for this depend on the vector in question, but primary reasons include higher number of predators and competitors. For malaria, cooler temperatures (as opposed to deforested areas) lead to slower rates of maturation in mosquitos.

  - **People can become exposed to diseases, however, in these forests**. Yellow fever, for example, is endemic to forests. Consumption of forest animals have led to the spread of diseases such as Ebola and HIV/AIDS, among others.

### 3.1.3 Cultural services

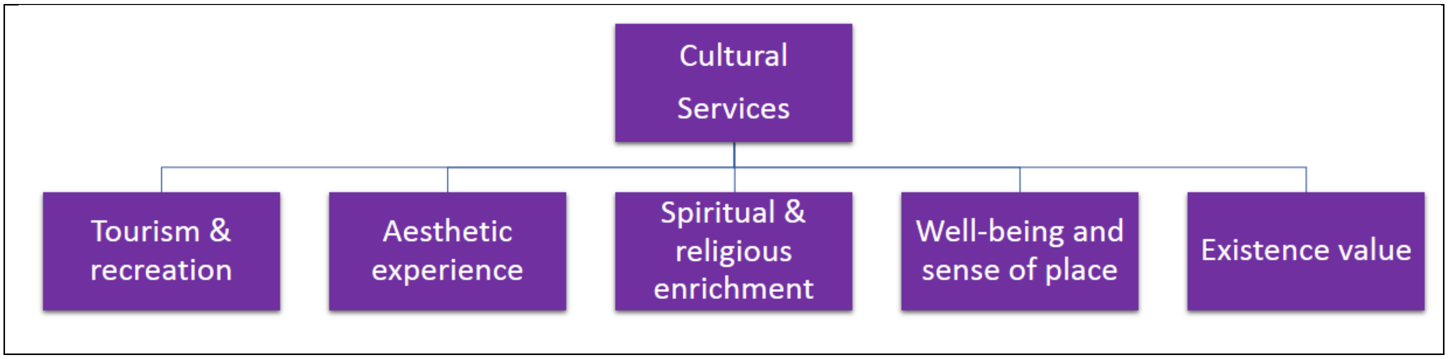


**Figure 4. Cultural services provided by tropical forests**

- **Tourism and recreation**: People from all over the world travel to experience tropical forests and engage in a number of recreational activities including hiking, kayaking, wildlife watching, hunting, among others. This tourism is a significant source of income and employment to local communities.

- **Aesthetic experience**: This includes appreciation of the beautiful scenery that tropical forests provide.

- **Spiritual and religious enrichment**: Tropical forests are source of spiritual and religious experience for many people and communities of people.

- **Well-being and sense of place:** Visiting or being in tropical forests can promote mental well-being in many people as well as promote a sense of belonging.

- **Existence value:** Many people value natural ecosystems, including tropical forests, and the species that live in them even though they never plan to visit these ecosystems or see the species. In other words, they receive satisfaction simply by knowing these forests and species exist.

## 3.2 Discussion on ecosystem services provided by tree plantations and agroforestry systems

Forest plantations and agroforestry systems provide some of the same ecosystem services that native tropical forests provide, especially when they are established in a previously degraded, non-native landscape.

They provide vital raw materials, such as timber and fiber, as well as agricultural products. They also help mitigate climate change through the capture of carbon from the atmosphere. Because plantations and agroforestry systems are established and maintained in order to maximize the production of these goods, it is much easier to quantify the benefits from these services as compared to those of native forests whose sole purpose is not the production of these good.

As compared to degraded, non-native landscapes, plantations and agroforestry systems can also be habitat to different species and therefore provide services related to biodiversity such as pollination, crop pest predation, and a variety of different cultural services. They can help mitigate natural disasters such as flooding, landslides, storm surges and waves, and sea level rise. These benefits of biodiversity and natural disaster mitigation services provided by forest plantations and agroforestry systems will likely not be as high as those provided by native tropical forests.

### 3.2.1 Forest plantation disservices

Because forest plantations generally only consistent of one tree species that often times is non-native, they can lead to additional problems, or disservices. Tree plantations are much more likely to catch on fire than native forests since they tend to be drier and have more open spaces conducive to the spreading of fires. The fact that most lack species diversity (indeed, many are monoculture) and may consist of highly combustible non-native species, such as Eucalyptus species, make the fire threat worse. The lack of diversity further makes tree plantations vulnerable to threats. Further, tree plantations have been shown to reduce water yields, especially when planted in areas without trees (afforestation as opposed to reforestation) (Jobbágy, Baldi, & Nosetto, 2011)

With regards to water quality services, tree plantations may have mixed effects. As with native forests, the presence of trees may help prevent erosion, remove pollutants through groundwater infiltration and through transpiration. On the other hand, the preparation of the plantation and the regular harvesting of trees can lead to more erosion. Tree plantations may also contribute to water contamination through the application of nitrogen- and phosphorus-based fertilizers which in turn run offs into nearby water bodies.

## 3.3 Colombian forests and the ecosystem services they provide

The forests in Colombia are well known for their high levels of biodiversity and the general ecosystem services they provide (Ministerio de Ambiente y Desarrollo Sostenible & Programa de las Naciones Unidas para el Desarrollo, 2014). However, there have been few studies to specifically evaluate these forest ecosystem services. For example, in the Colombian Amazon, Ramirez-Gomez et al (2015) found that demand has increased for the forest provisioning services wild food and raw materials due to socio-economic factors such as change in livelihood practices and consumption patterns. Vilardy et al. (2011) evaluated the ecosystem services provided by the Ciénaga Grande de Santa Marta, a coastal wetland system including mangrove forests, on the Caribbean coast. Among the most important services identified as vulnerable to environmental degradation was the mangroves' role as a nursery for fish.

The country is taking steps to incorporate the accounting of ecosystem services into national policymaking. Colombia is also a partner in the Wealth Accounting and Valuation of Ecosystem Services (WAVES) Initiative led by the World Bank, designed to mainstream the accounting of natural resources into development and economic planning. This includes work to establish national and subnational accounts to assess water assets, forest stocks and timber availability (WAVES, 2016). More work, however, is required on the evaluation of different ecosystem services to get a better context of the contribution of Colombia's forests to the well-being of humans and how different forest-related activities could impact ecosystem services at local, regional, and national scales.

# 4 Conceptual Framework for Ecosystem Services Assessments

As previously mentioned, not all forests provide all the ecosystem services (and disservices) to the same degree discussed in Section 3. For example, a forest close to a city will likely provide more recreational services than an equivalent forest far away from the city. Likewise, a coastal forest will provide more protection from coastal storms than an inland forest. To adequately assess the ecosystem services produced from reforestation and natural regeneration in a given site, it would be necessary to explicitly link the ecological changes in the geographic area of interest to changes in social benefits or harms.

An adaptation of the framework developed by Wainger and Mazzotta (2011) is proposed here (Figure 5). Before going through the steps of the framework, the project team must understand what ecosystem services will likely be impacted by the management actions. Throughout the explanation of these steps, we walk through an example, which is differentiated from the rest of the text by blue boxes.

**Box 1. Introduction to example of application of ecosystem service framework**

A project is promoting the natural regeneration of a certain area of native forest. It is expected that this will lead to benefits in the following two ecosystem services: 1) flood mitigation in downstream communities and 2) existence value for an endangered bird species native to the type of tropical forest being regenerated.

As discussed more in detail below, not all the steps proposed in this framework will be necessary for all services.

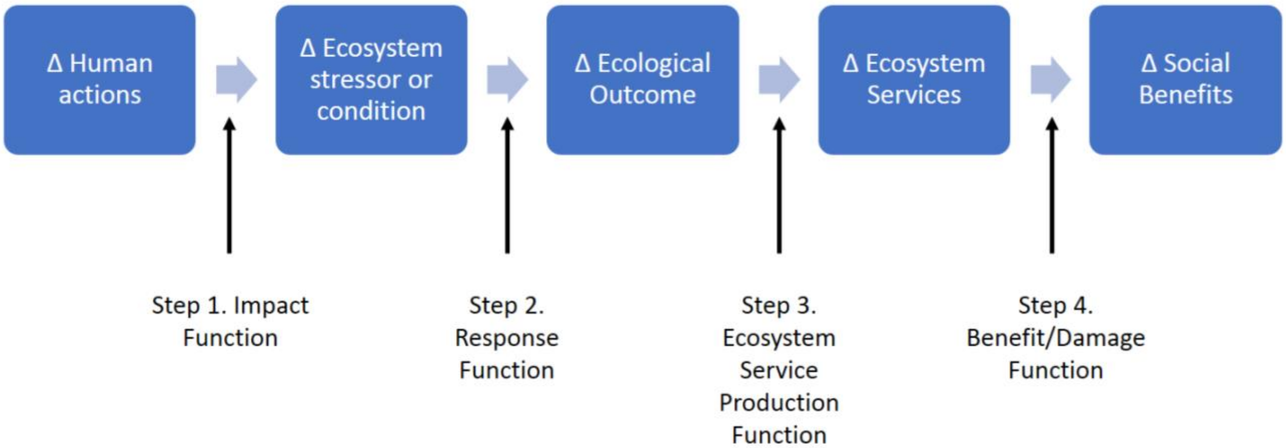


**Figure 5. Ecosystem services conceptual model: Steps in analyzing ecosystem service effects of project management measures. Taken from Wainger and Mazzotta (2011).**

The full implementation of this framework will require an interdisciplinary team of natural and social scientists, for example a team of ecologists, hydrologists, and economists, to connect the ecological changes resulting from the management action to clear benefits or harms to humans.

It will also require a thorough assessment of all the data, methods, and models available to quantify the different indicators in the 4 different steps. Data and model availability will inevitably be a limitation. However, as Wainger and Mazzotta (2011) stress, “managers cannot wait for perfect information; therefore, researchers can aim to synthesize the best information available… and use expert judgment in ways that minimize bias to fill gaps.” The methods for quantifying the different functions identified below and in Figure 5 may range from complex spatial econometric models to expert judgment.

## 4.1 Steps of the Assessment Framework

**Step 1. Impact Function.** In the Impact Function, changes in ecological stressors, i.e., the ecosystem’s processes and structures, resulting from the management actions are identified and quantified. The indicators used in this step, referred to as *ecological stressor indicators*, are traditional ecological indicators, such as nutrient loads, run-off coefficients, area reforested, etc.

**Box 2. Application of Impact Function in example**

In the case of natural forest regeneration in a certain area, the project team applies a hydrologic model to estimate that the regenerated forest will reduce surface run-off by a certain amount. The team also anticipates that the forest regeneration will lead to an increase in native forest by a certain number of hectares.

**Step 2. Response Function.** In the Response Function, the change in the ecological stressor is linked to changes in the ecological outcome that directly affect the ecosystem service in question. The indicator used to measure the ecological outcome, referred to as the *ecological outcome indicator*, is key as it should make it clear why these ecological changes are important to people.

**Box 3. Application of Response Function in example**

Flooding intensity and frequency are the ecological outcome indicators for the flood mitigation service. The hydrologic model results overlaid with population maps show that decreased surface run-off will lead to decreased flooding intensity and frequency in downstream communities.

For the endangered species ecosystem service, the indicator selected is the increased area of the bird species' habitat, which will be evaluated in this case by expert judgment from biologists on the team.

*In many cases, if the ecological outcome of interest is one and the same as the change in the ecological stressor, the impact function and the response function may also be the same.* For example, in the case of water quality for human consumption, the pathogen concentration in the water would be the indicator for both step 1 and step 2.

**Step 3. Ecosystem Service Production Function**. Once the response function has established that the natural conditions are in place to provide the ecosystem service, it is necessary to ensure that these actually provide ecosystem services or disservices by identifying whether these ecological changes have value to human communities. This step links the ecological changes to demand for the changes in social conditions.

**Box 4. Application of Ecosystem Service Production Function in example**

In the case of the flood mitigation ecosystem service, if the project team finds that there will be no human impacted by the change in flooding intensity and frequency, then the team can rule out flood mitigation as an ecosystem service. However, if the team finds that certain downstream communities would be impacted, then the magnitude of the impact should be assessed using the selected indicators. The indicator applied is the number of residences and businesses impacted by the change in flooding intensity and frequency, which the team identified using census data and local municipal data.

For the ecosystem service existence value for a bird species, the project team applies two indicators. The first indicator is the identification of the bird species as a conservation priority. The team finds evidence of several international conservation NGOs as prioritizing the conservation of the species. The

Government of Colombia has also identified as an endangered species required protection under the law. The second indicator is the expected abundance of the bird species in the restored forest.

**Step 4. Benefit/Damage Function.** In addition to identifying whether value exists or not for the ecological changes of a project, it is also possible to quantify these values in terms of changes in social welfare. These can be quantified through the monetization of values, for example by assessing people's willingness to pay, the market value of one tonne of reduced $CO_2$, flood damage costs avoided, etc. Alternatively, the project team may choose to use non-monetary indicators (e.g., number of people impacted) to indicate changes in social welfare, such as the indicators identified in the Ecosystem Service Production Function in Step 3. In this case, Steps 3 and 4 would be merged into one step.

Many techniques exist for valuing different ecosystem services in monetary terms (National Research Council, 2005). The team doing the assessment, however, should exercise caution when applying monetary values to changes in ecosystem services, as many ecosystem services are extremely difficult to monetize. This difficulty in turn could lead to an underestimation of the total benefits (or harms) resulting from a management action, especially when compared to more easily monetizable land uses such as agriculture or urban development. Furthermore, monetizing values may not capture true social value. For instance, monetizing the changes in ecosystem services to poor, forest-dependent communities may not adequately represent the high value these communities place on the services. In addition, a certain number of expensive homes in a well-off area will appear to be more important than the same number of inexpensive homes in a poor neighborhood, giving the impression that the benefits provided to wealthier people are more valuable than the needs provided to poorer people. This, in turn, may exacerbate issues of social inequality.

Steps 3 and 4 may also be merged if the best indicator to convey whether there is a demand for the service is monetary. For example, in the case of climate change mitigation, since it is difficult to link a specific amount of avoided carbon emissions to any distinct impact on human well-being, the most appropriate indicator for evaluating the demand for a reduction of carbon emissions is using the market value of a ton of carbon or the social cost of carbon[2].

If the team decides that changes in services should be monetized, experienced environmental or ecological economists should be involved in this analysis.

**Box 5. Application of Benefit/Damage Function in example**

For the flood risk service, the project team estimates the avoided damage costs to property from reduced frequency and intensity of flooding, which they estimate from recorded damage costs from previous floods. Because of the difficulty in adequately monetizing the additional benefits provided

[2] The estimated value of the total damages from emitting one ton of carbon dioxide into the atmosphere (Environmental Defense Fund, n.d.).

from the new habitat of the bird species, the team chooses not to monetize these benefits. Instead, they use the indicators derived from Step 4 to illustrate the social benefits provided by the forest regeneration project.

**Box 6. Summary of indicators applied to the different steps of the two ecosystem services evaluated**

| | Flood mitigation | Existence value for endangered bird species |
|---|---|---|
| **Step 1. Impact Function**<br>**Ecological stressor indicator** | • Surface run-off | • Area of native forests |
| **Step 2. Response Function**<br>**Ecological outcome indicator** | • Flooding intensity and frequency | • Area of the bird species' habitat |
| **Step 3. Ecosystem Service Production Function**<br>**Ecosystem services indicator** | • Number of residences and businesses impacted | • Identification of the bird as a conservation priority<br>• Expected abundance of the bird in the restored forest |
| **Step 4. Benefit/Damage Function**<br>**Benefit/Harm indicator** | • Avoided damage costs | N/A – not pursued |

# 5 Examples of indicators for different ecosystem services

A key to the implementation of the ecosystem services is the selection of indicators that clearly communicate the changes in each of the steps. Table 1 provides *examples* of indicators for each step. These examples should not be considered endorsements of particular indicators, however. The ultimate selection of indicators will depend on the specific ecosystem service being analyzed, particular circumstances of the study site as well as the data and methodologies available to analyze changes in ecosystem services.

**Table 1. Indicators to evaluate the changes in ecosystem services due to human actions**

| Ecosystem service | Examples of ecological stressor indicators | Examples of ecological outcome indicator | Examples of ecosystem service indicators | Examples of benefit/harm indicators |
|---|---|---|---|---|
| **Water quality** | • Pathogen concentration in water;<br>• Nitrate concentration in water. | • Pathogen or nitrate concentration in the water compared to the level deemed safe for human consumption. | • Number of incidences of waterborne illnesses;<br>• Avoided water treatment costs. | • Cost of potable water;<br>• Health costs from water-borne diseases. |
| **Water supply** | • Water flow during the dry season;<br>• Groundwater infiltration rates. | • Surface water availability;<br>• Groundwater availability. | • Use-to-resource ratio[3];<br>• Time it takes to find and extract water. | • Cost of water to different sectors. |
| **Supply of raw material** | • Change in area available for harvest;<br>• Change in number of species producing raw materials | • Amount of raw material available to be sustainably harvested. | • Amount of material sustainably harvested;<br>• Number of families/communities benefiting from the harvesting; | • Income produced from the sustainable harvesting. |
| **Pharmaceuticals** | • Change in area available for harvesting of | • Estimated number of species/amount of substance | • Number of local communities benefiting from the traditional medicine; | • Estimated value of additional area to modern medicine (via |

[3] Use-to-resource ratio is defined as the amount of water consumed by the amount available (Xu & Wu, 2017).

<table>
<thead>
<tr><th>Ecosystem service</th><th>Examples of ecological stressor indicators</th><th>Examples of ecological outcome indicator</th><th>Examples of ecosystem service indicators</th><th>Examples of benefit/harm indicators</th></tr>
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<tbody>
<tr><td></td><td>traditional medicine or area for researching modern medicine;<br>• Estimated species richness in new area.</td><td>to be used for traditional medicine or for research for modern medicinal use.</td><td>• Number of local communities benefiting from the traditional medicine.</td><td>literature review).</td></tr>
<tr><td>Climate change mitigation</td><td>• Reforested area;<br>• Size of forest carbon pools.</td><td>• Amount of carbon captured per year by forest;<br>• Amount of carbon stored per year by forest.</td><td>• See benefit/harm indicators.</td><td>• Market value of a tonne of carbon;<br>• Social cost of carbon.</td></tr>
<tr><td>Flood mitigation</td><td>• Run-off coefficient</td><td>• Flooding intensity<br>• Flooding duration<br>• Flooding frequency</td><td rowspan="4">• Number of properties and businesses impacted;<br>• Number of injuries avoided;<br>• Number of deaths avoided.</td><td rowspan="4">• Avoided damage costs</td></tr>
<tr><td>Sea level rise mitigation</td><td>• Soil accretion rates.<br>• Soil elevation</td><td>• Area converted from land to open water</td></tr>
<tr><td>Coastal storm mitigation</td><td>• Tree species composition;<br>• Forest size and density.</td><td>• Wave attenuation<br>• Storm surge amplitude;<br>• Storm tide amplitude.</td></tr>
<tr><td>Landslide prevention</td><td>• Land cover.</td><td>• Landslide intensity</td></tr>
</tbody>
</table>

| Ecosystem service | Examples of ecological stressor indicators | Examples of ecological outcome indicator | Examples of ecosystem service indicators | Examples of benefit/harm indicators |
|---|---|---|---|---|
| | | • Landslide frequency | | |
| **Forest fire risk** | • Quantity of combustible material | • Number of forest fires<br>• Severity of forest fires | | |
| **Disease control** | • Area of increased habitat for natural predators and competitors;<br>• Increased species richness. | • Presence of natural predators and competitors<br>• Abundance of natural predators and competitors<br>• Abundance of disease vector. | • Number of outbreaks | • Health costs from outbreaks |
| **Tourism and recreation** | • Species richness;<br>• Species abundance;<br>• Structure of forest. | • Natural area available for tourism;<br>• Catch per angler;<br>• Number and/or diversity of ecotourism activities supported. | • Number of tourists who visit per year;<br>• Catch per angler;<br>• Number and/or diversity of ecotourism activities supported. | • Amount of money spent per tourist per year;<br>• Amount of income generated from tourism;<br>• Consumer surplus for each tourist[4] |
| **Aesthetic experience** | • Change in area;<br>• Structure and | • Increased area of valued scenery. | • Number of residences or businesses (e.g., hotels) with a view of scenery; | • Real estate prices<br>• Willingness to pay for aesthetic experience. |

[4] Consumer surplus is the difference in the amount the consumer (in this case, the tourist) paid for the service and the amount they would be willing to pay.

| Ecosystem service | Examples of ecological stressor indicators | Examples of ecological outcome indicator | Examples of ecosystem service indicators | Examples of benefit/harm indicators |
|---|---|---|---|---|
| **Spiritual and religious enrichment** | composition of forest. | • Increased area of value. | • Number of individuals who value the forest for religious or spiritual reasons. | • Willingness to pay for spiritual/religious experience<br>• Willingness to accept to forego the religious/spiritual experience |
| **Well-being and sense of place** | | | • Number of individuals who derive well-being or a sense of place from the forest. | • Willingness to pay for well-being and sense of place derived from forest;<br>• Willingness to accept to forego well-being and sense of place derived from forest. |
| **Existence value** | • Change in area;<br>• Structure and composition of forest;<br>• Species richness and abundance. | • Change in area of valued ecosystem or habitat of a valued species<br>• Presence and abundance of valued species | • Identification of importance or value of ecosystem or species by conservation organization, government | • Willingness to pay to protect species or habitat;<br>• Willingness to accept to forego the protection of a species or habitat. |

# 6 Conclusions

The implementation of the conceptual framework to assess ecosystem services not only helps teams assess the benefits and harms resulting from different management actions, it also helps clearly communicate these linkages to decision-makers and local communities. For example, instead of arguing for the benefits of a forest restoration project in terms of reduced run off, the project team can clearly show the linkages between reduced run off to reduced flooding intensity on impacted properties in downstream communities.

This proposed conceptual framework is not just applicable to assessing additional benefits/harms of the NAMA forestry projects but could be used by other Colombian institutions when assessing the impacts of current and future natural resource-related management decisions.

# 7 References

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