

Preliminary Intervention Assesment NBS

Espirito Santo & Yucatan Peninsula

1. Introduction

This document provides a preliminary assessment of the potential ecosystem service gains from restoration activities across five study areas. The current focus is on **Espirito Santo (Brazil)** and **Yucatán Peninsula (Mexico)**, with Peru (Madre de Dios), Madagascar (Diana Northen), and Vietnam (Northern Amannites) following.

1.1 Purpose

Estimate the potential ecosystem service value gains if restoration is distributed across target areas.

1.2 Objectives

1. Identify high-value pixels for restoration.
2. Estimate total ecosystem service provision (ES) gains under random distribution.
3. Represent uncertainty with confidence intervals and spatial distributions.

1.3 Theoretical Assumptions

- All ecosystem services are equally valued.
- Restoration likelihood is uniform across intervention areas.
- Pixel values are independent; no spatial autocorrelation considered.
- Confidence intervals provide robust estimates under random distribution scenarios.

2. Study Areas

2.1 Brazil - Espírito Santo

Espirito Santo represents a priority intervention area for restoration activities. The target area spans **30,200 hectares**.

2.2 Mexico - Yucatán Peninsula

The Yucatán Peninsula analysis includes two main intervention areas: the Jaguar Corridor and adjacent restoration polygons. The target intervention area spans **15,000 hectares**.

2.3 Additional Intervention Areas.

- Peru - Madre de Dios

- Madagascar
 - Vietnam
-

3. Methods

3.1 Data Sources

- **Ecosystem Service Data:** Chaplin-Kramer et al. (2022) Mapping the planet's critical natural assets (<https://www.nature.com/articles/s41559-022-01934-5>).
- **Restoration Potential:** Adjusted Griscom restoration data.
- **Raster Processing Tools:** `terra`, `dplyr`, and `sf` packages in R.

3.2 Evaluated Services

The data asseses here is expressedin terms of the potential gain in units of the provided services if the targeted areas is restored to a natural/seminatural state.

1. Coastal Protection. Unit less measure, refers to a vulnerability index. **InVEST Coastal Vulnerability Model** (https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/coastal_vulnerability.html)
2. Nitrogen Export. Derived from the Nitrogen retention modeled using the **InVEST Nutrient Delivery Ratio** (<http://data.naturalcapitalproject.org/invest-releases/3.5.0/userguide/ndr.html>). Expressed in kg/pixel/year
3. Sediment Retention. Derived using **InVEST SDR: Sediment Delivery Ration** (<https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/sdr.html>). Values in ton/pixel/year
4. Pollination. Derived from **InVEST SDR: Pollinator Abundance Model** (<https://storage.googleapis.com/releases.naturalcapitalproject.org/invest-userguide/latest/en/croppollination.html>). Units expressed on *equivalent people feed*. More information in **Chaplin-Kramer, et al. 2022** (https://static-content.springer.com/esm/art%3A10.1038%2Fs41559-022-01934-5/MediaObjects/41559_2022_1934_ESM1_ESM.pdf)
5. Nature Access represented as *the number of people within 1 hour travel of natural and semi-natural lands* (Chaplin-Kramer et al, 2022).

3.3 Data Preparation

3.3.1 Normalization of Ecosystem Service Rasters

This formula was used to normalize the raster values:

$$\text{Normalized Value} = \frac{\text{Raster Value} - \text{Min Value}}{\text{Max Value} - \text{Min Value}}$$

Where: - Raster Value is the value of a given pixel. - Min Value and Max Value represent the minimum and maximum observed values across the raster dataset.

This step ensures that services with different units (e.g., tons, kilograms, or people) can be aggregated without bias toward any single service.

Once normalized, the ecosystem service rasters were summed to create a composite raster that represents the aggregated value of all services. This approach assumes equal importance of all ecosystem services, meaning no weighting was applied at this stage. **Note**. Next iteration will include population-based weights.

3.3.2 Prepare Environemnt

Load libraries, functions and prepare template data

3.2.3 Load Templates

This loads and prepares template data used to align

4 Run Data Extraction

4.1 List the Restoration Layers

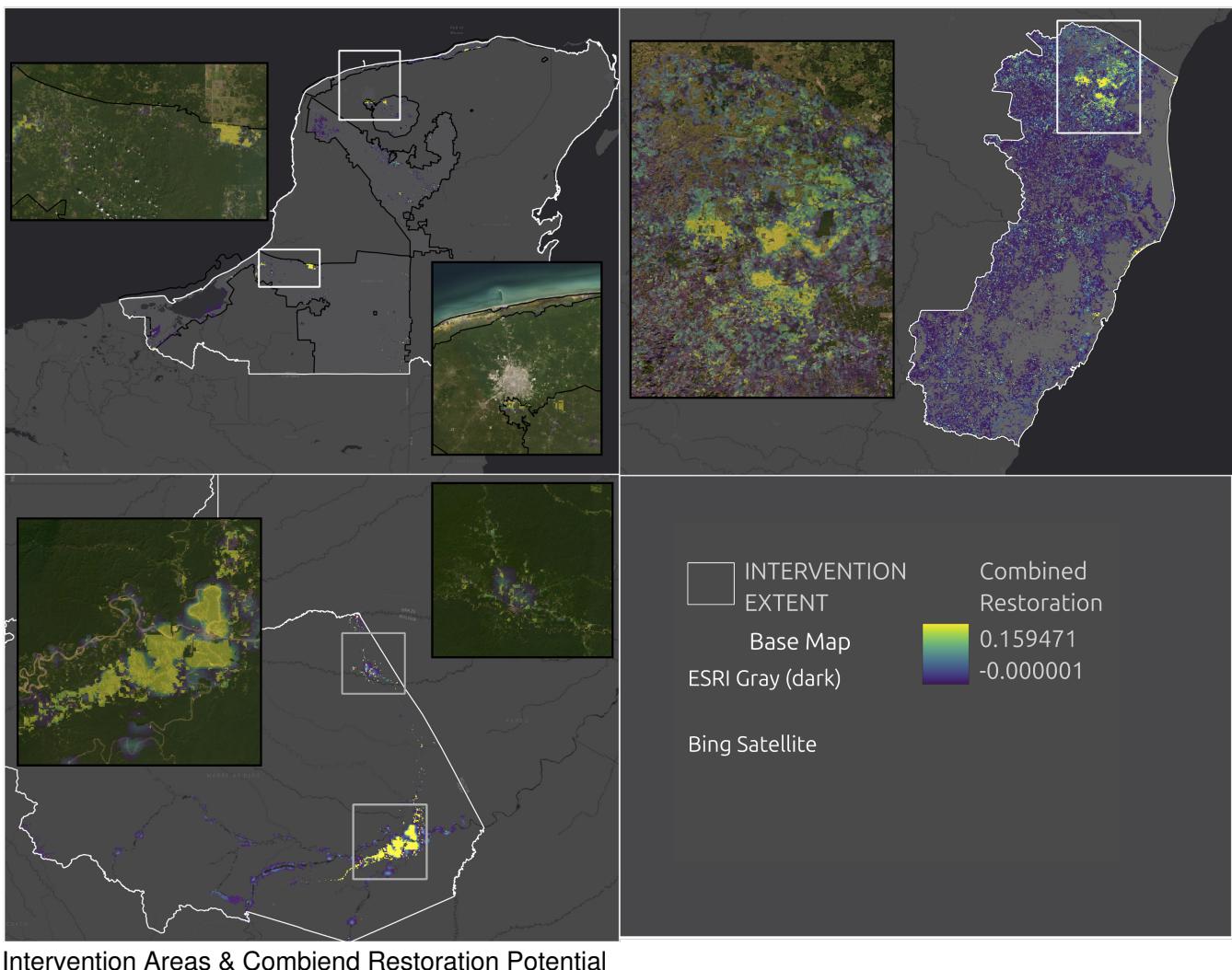
```
#Restoration:  
tiffes <- file.path(here("cropped_raster_data" ), list.files(paste0(here("cropped_  
raster_data")),pattern= '.tif$'))  
tiffes <- tiffes[c(1:5,51:55,71:75,81:90,106:110)]
```

4.2 Normalize and combine data layers

The combined raster is a proxy for the total ES provided (with some assumptions that need to be eventually reviewed and refined).

4.3 Load Adjusted Griscom Restoration Data and apply mask

Use the adjusted Griscom restoration data to extract the pixels includes as Restoration Potential in Griscom's Dataset on Global priority areas for ecosystem restoration (https://www.ksfire.org/woody_encroachment/documents/Global%20priority%20areas%20of%20ecosystem%20restoration.pdf).



Intervention Areas & Combiend Restoration Potential

5 Calculate Restoration Potential output.

5.1 Brazil Espiritu Santo

5.2. Mexico Yucatan

5.3 Peru Madre De Dios

Here, make sure that the intevention area is correct. Need to confirm with the new data provided

5.4 Vietnam & Madagascar

Pending...

6 Sampling and Extracting values

Model the estimated values of ES gains for the services based on a random sampling. This second part has implicit a couple of assumptions:

- We are not considering any spatial configuration (landscape metrics) aspects affecting the total value
- Eventually, the model can be refined by incorporating additional parameters (e.g minimum distance to boundaries, distance between points, topography or inhabited areas (some of it is implicit in the input data, but needs to be confirmed).
- Coastal risk protection only occurs at the coast, any random sampling performed will have to consider this. This can be adjusted using weights.

We run a stratified random sampling to estimate the mean values of different bands in a multi-band raster dataset. Stratified random sampling is a probability sampling method where the population is divided into homogeneous strata, and random samples are taken from each one.

Methodology

Define the Area of Interest: The first step is to define the area of interest (AOI) within the raster dataset. This AOI represents the spatial extent from which the samples will be drawn. In this specific case, the AOI is defined as 30,000 hectares for Espírito Santo and 15,000 for Yucatán.

Calculate the Sample Size: Based on the resolution of the raster and the desired AOI, the required number of pixels to be sampled is calculated. This ensures that the total area covered by the sampled pixels corresponds to the defined AOI.

Perform Stratified Random Sampling: The `spatSample()` function from the `terra` package in R is used to perform stratified random sampling. This function allows for random sampling of pixels within the defined AOI, while also excluding pixels with "NA" values in all bands, ensuring that only valid data points are included in the analysis.

Repeat Sampling: To reduce potential sampling bias and improve the accuracy of the estimates, the random sampling process is repeated multiple times (in this case, 30 times). This is analogous to the concept of bootstrapping, where repeated sampling with replacement is used to estimate the sampling distribution of a statistic.

Calculate Summary Statistics: For each repetition, the mean, standard deviation, and 95% confidence intervals are calculated for each band in the raster dataset. This provides a measure of the central tendency and variability of the sampled data.

Synthesize Results: The results from all repetitions are combined to calculate an overall mean and confidence interval for each band. This provides a more robust estimate of the expected values, effectively correcting for potential outliers and reducing the influence of individual sample variations.

Theoretical Justification

The use of stratified random sampling is justified as it ensures that the sample is representative of the entire population (i.e., all pixels within the AOI). By dividing the population into strata and sampling from each stratum, this method reduces the variability of the estimates compared to simple random sampling. This is particularly important when dealing with spatial data, where there may be inherent spatial autocorrelation or heterogeneity.

The repeated sampling approach further enhances the robustness of the estimates by providing a distribution of possible values. This allows for the calculation of confidence intervals, which provide a measure of the uncertainty associated with the estimates. By synthesizing the results from multiple repetitions, the overall estimates are less susceptible to the influence of individual sample variations and provide a more accurate representation of the true population values.

References

Cochran, W. G. (1977). Sampling techniques (3rd ed.). John Wiley & Sons. Lohr, S. L. (2010). Sampling:

Design and analysis (2nd ed.). Brooks/Cole. 1

1. Bivand, R. S., Pebesma, E. J., & Gómez-Rubio, V. (2013). Applied spatial data analysis with R (2nd ed.). Springer.

6.1 Espirito Santo

6.1.1 Prepare Data Esp Santo.

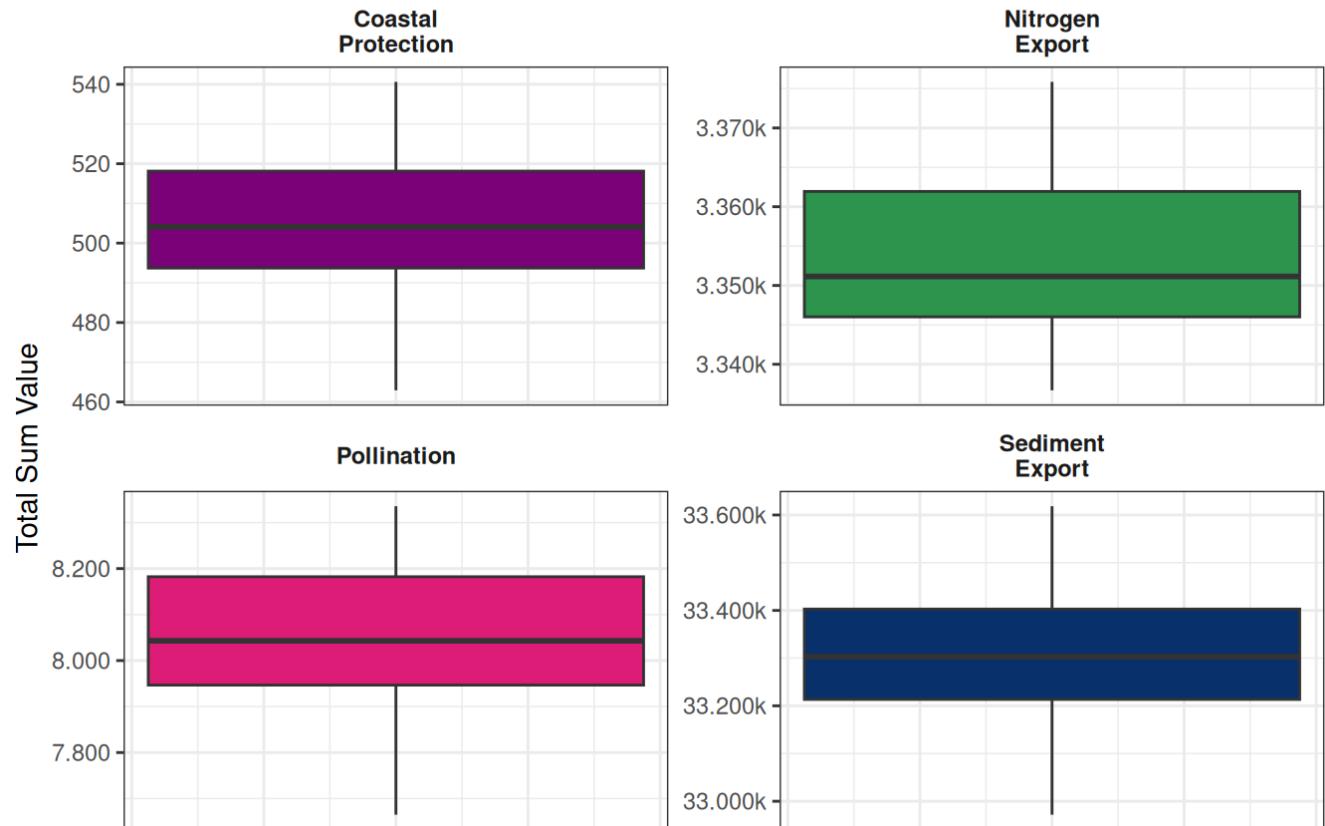
Align and resample all the raster datasets to the same crs and origin.

6.1.2 Run Sampling and Syntetize results - Espirito Santo

Here, we are sampling the data for obtain estimate of the expected restoration gains assuming randomly selected pixels extracted form the potential restoration areas. Again, some assumptions will have to be reviewed, but this is an initial assessment. The targeted intervention area is 30.200 ha.

6.1.3 Plot Results Espirito Santo

Total estimated service change in units for the target intervention area - Espirito Santo



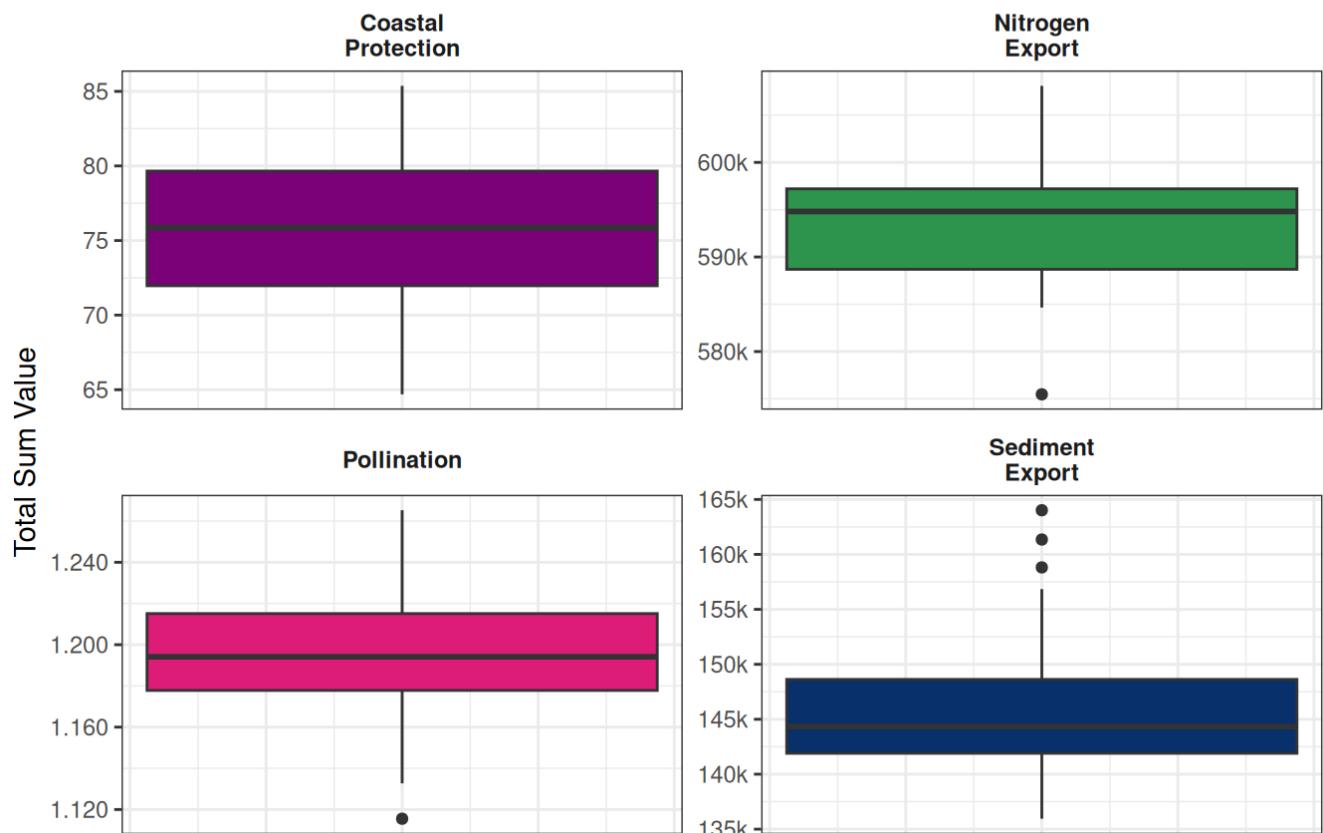
6.2 Yucatan

The approach is the same as in Brazil. Two main intervention areas were used tro build the final polygon: the jaguar corridor and # 4.2.1 Prepare Data Yucatan. Align and resample all the raster bands to the ame crs and origin.

6.1.2 Run Sampling and Synthetize results - Yucatan

6.1.3 . Plot Results Yucatan

Total estimated service change in units for the target intervention area - Yucatan



7. Next Steps:

Run the Analysis for Madre de Dios, incorpporate beneficiaries/population related data, as the target metric is not the sum of the values.

3.2 Madagascar (Not Necessary To Mask for te Interventions)