TREE RESTORATION MONITORING FRAMEWORK: FIELD TEST EDITION

PRICELESS PLANET COALITION

CONSERVATION INTERNATIONAL

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This tree restoration monitoring framework was developed through a partnership with the Priceless Planet Coalition, led by Mastercard. The framework was created independently by Conservation International and World Resources Institute and is being tested in on-the-ground projects funded by the Priceless Planet Coalition. After the period of testing closes, the final version will be published in 2023.

TABLE OF CONTENTS

DEAR READERS,

Conservation International and World Resources Institute created this tree restoration monitoring framework for the Priceless Planet Coalition initiative, which started restoring trees in 2021 and aims to restore 100 million trees around the world by 2030. We drew from best practices within and outside the organizations, adding new research products and tools. We are pleased to share it as a document that we are field testing, and welcome others to use, test, and help us improve it going forward.

Tree planting initiatives have been critiqued for a lack of transparency in monitoring. Martin et al 2021 found that only 18% of tree planting organizations mention monitoring on their websites, and only 5% mention monitoring survival rates. We hope that this product will be useful for the restoration community that is striving for standardized monitoring methodologies to track progress during the UN Decade on Ecosystem Restoration (2021-2030).

The **Tree Restoration Monitoring Framework: Field Test Edition** is 184 pages long- its length is due in part to its incorporation of suggestions from those working with it on the ground, and the high level of detail provided for practical use. It is broad, providing monitoring methods applicable to a diverse set of methodologies for tree restoration ranging from assisted natural regeneration (ANR) to tree planting, across many different landscapes. It is deep, describing how to measure indicators down to the field details and/or spatial analysis methods. Whereas its main focus is on methods to quantify the direct success of tree restoration, in terms of trees and hectares restored and changes in tree cover, it also provides methods for quantifying important co-benefits of tree restoration such as job creation, freshwater and biodiversity impacts, and improving ecosystem services. Finally, it is multi-purpose and modular - many of the protocols we have developed could be adapted for quantifying impacts of other types of restoration, conservation, and other land management.

We've combined data collected in the field with cutting-edge remote monitoring: the framework will allow users to evaluate whether investments in locally led tree restoration projects are achieving their expected impacts, to informing the adaptive management that will be crucial for all of us to succeed in the UN Decade on Ecosystem Restoration. We welcome all potential users to consider how they can apply it, in part or as a whole, to other initiatives. We note that quantifying the **number and species of trees restored** requires intensive field sampling methods and longer monitoring windows. Some initiatives may prefer to only monitor the number of hectares restored, or changes in tree cover, which can be done with remote sensing. Not all organizations will do household surveys or monitor faunal biodiversity- but these 'optional,' value-added methods are available in the document, should they be of interest.

We wish you well with your monitoring and would love to hear from you about your experiences interacting with this framework, and potential beneficial adaptations you might make to its applications. We plan to continue to improve it and issue an updated version in 2023.

On behalf of the authors,

Starry Sprenkle-Hyppolite

Footnote: Martin, Meredith & Woodbury, David & Doroski, Danica & Nagele, Eliot & Storace, Michael & Cook-Patton, Susan & Pasternack, Rachel & Ashton, Mark. (2021). People plant trees for utility more often than for biodiversity or carbon. Biological Conservation. 261. 109224. 10.1016/j.biocon.2021.109224. https://www.researchgate.net/publication/353092038_People_plant_trees_for_utility_more_often_than_for_biodiversity_or_carbon

INTRODUCTION

In January 2020, Mastercard launched the Priceless Planet Coalition (PPC) to focus the efforts and resources of its network, and accelerate positive impact on climate change. The Priceless Planet Coalition pledged to restore 100 million trees over five years as an initial goal. Guided by Conservation International and World Resources Institute, the PPC adheres to robust science-based best practices for project selection, implementation, and long-term monitoring of restoration efforts.

The PPC Program's **monitoring framework** was designed to track and measure the progress of the Program's interventions. The Framework focuses on monitoring changing ecosystem integrity, socio-economics, and carbon sequestration, directly related to the Program's Interventions (12 required indicators which is relatively few compared to 41 for the Atlantic Forest Reforestation Monitoring Guidelines PACTO[1]). assessment of progress will enable project developers to use adaptive management, and implement improved practices when necessary, therefore increasing the rate of success of this initiative. It will simultaneously allow for measuring the impact of the Program and maximize the potential scientific contributions of this ambitious reforestation initiative. The framework was crafted with the project developers in mind, while leveraging the best available science and technology. It provides **standardized procedures and metrics** to enable program-wide analysis to satisfy the needs of the Priceless Planet Coalition corporate members[2] seeking alignment with and potentially influencing global restoration monitoring[3]. The framework is complementary to overarching process-based frameworks such as the Climate, Community and Biodiversity (CCB) and Global Restoration Observatory's (GRO) 'Restoration Project Information Sharing Framework'. This document fleshes out the initial work on key indicators decided upon during the PPC Program proposal phase.

This document is the final update of the PPC Monitoring Framework. The core programmatic indicators have not changed since V1. The majority of the sub-protocols to guide baseline and first year monitoring for the PPC program were added in V2, and now this document includes the remaining protocols that were not completed for V2 as well as light revisions to previously developed protocols based on users' feedback. Optional indicators and protocols on biodiversity and freshwater have also been added.

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[1] https://www.researchgate.net/publication/304922549_Monitoring_protocol_for_forest_programs_projects_-_Atlantic_Forest_Restoration_Pact

[2] Including Global Evergreening Alliance, Rainforest Alliance, Zoos Victoria, Jane Goodall Institute, Motuihe Trust, UAE Ministry of the Environment, and others

[3] Climate, Community, and Biodiversity Standards (CCB) and the Global Restoration Observatory (GRO)

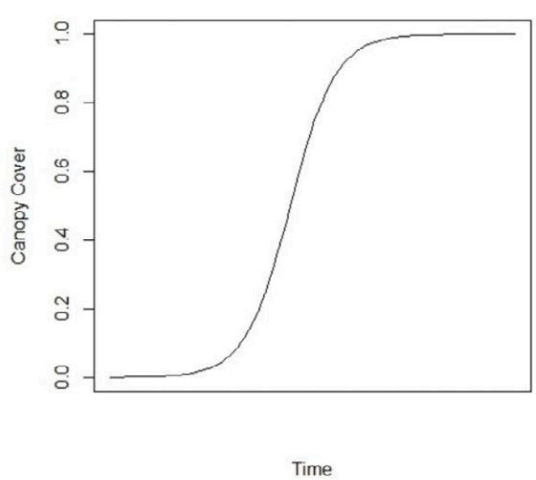
KEY CONCEPTS FOR ESTABLISHING BASELINES

Additionality: Evaluates the degree to which an intervention causes a benefit above and beyond what would have happened in a no-intervention baseline scenario.

Leakage (socioeconomic): Occurs when interventions displace emissions to other locations, times, or forms. For example, leakage occurs in forest carbon offset credit programs when a reduction in timber harvesting at a project site causes timber harvesting to increase somewhere else to meet demand.

From the Carbon Dioxide Removal Primer: https://cdrprimer.org/

The establishment of accurate baselines prior to project activities, and monitoring during the first year after planting is critical. **Programmatic safeguards** must be built into the project screening and selection process, which is described further in Annex 1. For example, it is of utmost importance to **ensure that the reforestation supported by the PPC Program is additional, does not contribute to leakage** (see box), **or unintentionally creates incentives for deforestation. We propose to ensure that restoration is taking place on land that was already degraded prior to 2010 (more than 10 years prior to the start of this program).** This 'look-back period' will be verified using satellite imagery during project consideration, creating a safeguard to ensure that the program does not restore recently cleared forests, since this could be interpreted as incentivizing deforestation. The program mitigates leakage by careful site selection (See Annex 1: Site Selection Criteria), and by not competing with or displacing extractive and/or income-generating land uses. Some PPC restoration interventions, such as agroforestry, will directly improve the productivity of agricultural landscapes and create additional, sustainable income sources. Further monitoring for leakage of the areas surrounding restoration sites may form part of the research agenda (Annex 4, Table 2) if resources allow.



To provide evidence for positive Program impact, restored sites should be compared to 'control' sites with no Program interventions (see box on p.5 for more on "counterfactuals", Annex 2: Impact Evaluation, and Sub-Protocol 2 on Control Sites).

The PPC approach to **restoring land,** not only planting trees, but also facilitating natural forest regeneration, requires **innovative monitoring approaches over longer time scales.** Even though it seems to be long, the PPC's 5-year monitoring window still represents a challenge for observing the results of tree restoration, especially natural regeneration which is an incremental process and could result in new tree growth after a multi-year time delay. We expect tree cover to follow a slow start – rapid increase – slow again as it approaches 100% canopy closure (logistic pattern) of increase (see figure at right). Achieving even 80% canopy cover (where the canopy closure rate starts to decrease) can take from three to more than thirty years, depending on the initial site conditions, climate, the actual tree species growth rates, and the management of the site. Unless there are exceptional conditions for growth, on most sites after five years, the canopy cover is likely to fall near the beginning of the growth curve (above), or in the exponentially increasing middle part of the curve[4]. Methods will need to be developed for projecting site-specific growth trajectories after the first 5 years, using site information and data collection from the first 5 years, in order to estimate the time required to achieve the project-specific target canopy covers and other expected long-term project results such as carbon fixation.

Additional funding should be sought, or other mechanisms established, to ensure longer-term monitoring, to document the full benefits of the Program. The monitoring done in years 1-5 will set the stage and build momentum for further studies, giving associated researchers great leverage. PPC partners should engage with local universities and research institutions to the maximum extent feasible, for long-term cost effectiveness and to increase in-country ownership. In addition, **Impact Evaluations** (IE) to assess the effectiveness and scalability of restoration interventions (i.e., strategies, activities, models) with climate mitigation as the primary outcome (as well as co-benefits), are critical. Impact Evaluations allow us to determine causal explanations about the effects on the outcome (causal attribution), investigate true additionality and potential leakage, and improve accountability. Evidence generated from IE can help policymakers and project developers practice adaptive management and identify and scale lower cost and more effective interventions. We propose PPC IE using both prospective and retrospective quasi-experimental evaluations and randomized evaluations for strategic restoration projects. More details can be found in Annex 2: Impact Evaluation.

This monitoring framework includes both **geospatial/remote** and **field-based** monitoring methods, combined to maximize accuracy and efficiency, while also minimizing the burden on implementing partners. Remote sensing data will be used to the maximum extent possible, with field data used for ground truthing, unless otherwise stated. Considering the PPC's ambition to reach large scale impact, and it's commitment to monitor that impact, methodological advances across the social and natural sciences and **innovations in geospatial and remote sensing,** make it possible to apply monitoring and impact evaluation methods to restoration projects; this approach plays a key role for learning and scaling the findings from the PPC sites.

While CI and WRI will share the majority of the monitoring workload when it comes to comprehensive reporting on indicators and processing remotely sensed data, **significant field-based work** is still required for some indicators (specified below), especially in the first years when saplings will be small (Annex 9). This will require careful coordination with implementing partners and project managers. Recognizing that PPC project developers may differ in their other organizational priorities, existing data collection methods,

[4] *Os indicadores de resultado na restauração da vegetação nativa [livro eletrônico] / [coordenação Rodrigo Lima]. – São Paulo: Agroicone, 2020.*

and staff availability, this framework contains both standard monitoring practices to be applied on all sites and approaches that can be implemented for more comprehensive monitoring (identified as optional).

A fundamental principle of this monitoring program is that it is site-based, requiring on-the-ground collection **of GIS shapefile boundaries (polygons) of the areas under restoration (sites)**, and control sites. These shapefiles will be used to delimit the **area of the intervention** and control sites, which is also an important stand-alone metric. Following the implementor's completion of **site baseline and establishment forms**, each site file will have associated attributes relative to the planting, including the date of planting and **number of each species of tree planted and the reforestation methods used** (specified in sub-protocol 3). The site polygons and files become the basis of the monitoring database upon which the CI and WRI teams and PPC implementors will gradually add information regarding survivorship, changes in tree canopy cover, costs, socioeconomic restoration partners, and carbon sequestration assessment, through the various monitoring methodologies described below, and presented in Table 2. Starting in 2022, the integrated monitoring platform[5] is the main data collection, aggregation, and reporting tool, except in cases where specialized additional tools are needed.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[5] The integrated monitoring platform is a web and mobile platform that facilitates the collection, aggregation, and distribution of data collected for the Priceless Planet Coalition. It is sometimes referred to as TerraMatch, but is a subset specific to PPC within the larger TerraMatch platform.

RESULTS FRAMEWORK

Outcomes and Objectives:

The overarching objective of the PPC Program is: "Restoring 100 Million Trees by 2025, by enabling sustainable, ecologically appropriate increases in tree cover, density, and biodiversity; sequestering carbon." In accordance with this overarching objective, four supporting objectives have been identified.

OBJECTIVE 1: Trees are restored so that their **density and crown** cover approach the maximum sustainable level for the related land use type (forest, agroforest, etc.) and climate of the restored area.

- **Outcome 1.1:** Restored forests have **biodiverse flora** supporting faunal biodiversity and critical habitats[6], with a majority of native tree species, except for when agricultural species are planted for agricultural purposes such as agroforestry, woodlots, and silvopastoral systems (specific targets to be set by individual projects). Invasive, non-native species are not planted.
- **Outcome 1.2: Tree survival rates**, both of planted trees and trees in nurseries, are within the acceptable margins for the restoration practices used. Information collected regarding species-specific survival rates is shared with the global restoration community.

OBJECTIVE 2: CO_2 is estimated to be sequestered over the project lifespan. The PPC Program-wide outcomes relative to estimated carbon sequestration – i.e. aboveground, belowground, and soil organic carbon, and expected sequestration rates per geography and restoration methodology, are still in development during 2022.

OBJECTIVE 3: PPC restoration activities benefit local communities and actively engage with them in planning, implementation, and management of project activities to ensure long term success. The majority of restoration partners are women and/or indigenous people.

- **Outcome 3.1:** Socioeconomic impacts including trainings (increased skills, knowledge, and/or understanding), increased productivity and market access generated.
  - **Sub Outcome 3.1:** Person-days of work generated in planning, implementation, and management.
  - **Sub Outcome 3.2:** Ecosystem service impacts (provisioning, regulating, cultural etc.) are improved for local populations.
    - **Sub Outcome 3.2.1:** People benefiting from improved freshwater quantity or quality.

OBJECTIVE 4: The extent of land area brought under restoration, directly[7] and indirectly[8], and the relative effectiveness of multiple **restoration interventions** is analyzed,

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[6] *CI is especially interested in tracking the PPC impacts to associated biodiversity and is working on additional optional monitoring modules for this purpose to roll out in 2022*

[7] *Land within the boundaries of the restoration site, shared in shapefiles, where restoration activities are taking place*

[8] *Land that benefits from restoration activities, but is not within the restoration site boundaries*

including but not limited to cost-effectiveness.

- **Outcome 4.1: Hectares of ecosystems** under restoration due to the PPC Program, direct and indirect.
- **Outcome 4.2:** Cost per tree grown by restoration intervention type doesn't exceed program parameters.

OBJECTIVE 5: PPC restoration activities benefit local biodiversity.

- **Outcome 5.1:** Restored areas have increased native faunal **biodiversity** (expressed as species richness, abundance, relative abundance, and community structure, where optional biodiversity monitoring is done).

COUNTERFACTUALS

The term 'counterfactual' refers to 'control' sites, matched with the same initial conditions, population pressures, surrounding landscapes, etc. as the restored sites. But nothing is done to them.

Counterfactuals are essential **to determine the additionality of PPC interventions** compared to a 'do nothing' scenario.

These sites should be **selected during the baseline period (time of restoration intervention),** and will be monitored with the same method and freqeuncy as the restored areas throughout the project, but, **they do not count as PPC Program intervention sites.**

Counterfactuals are strickly for monitoring purposes, and, will be primarily studied during the impact evaluation phase.

Although it requires some resources[9], counterfactual comparative research (see sidebar) is strongly encouraged for each intervention's context with rigorous impact evaluation and scaling analysis, including but not limited to:

- Effectiveness of restoration interventions used in terms of the main impact indicator of trees restored but also for expected co-benefits to Carbon, Socioeconomic Benefits for People, and Biodiversity (see Annex 2) and their relative costs, considering impact relative to counterfactual comparison sites
- Estimated cost models of RCT designs to be developed for consideration in proposal development
- Effectiveness of restoration interventions used and their relative costs, considering impact relative to alternative treatments implemented, where treatments may vary depending on both biophysical and/or social and/or logistical dimensions of project design.
- Individual vs collective efforts at four levels of adopters: (1) private landholders, (2) communities of smallholder farmers and (3) joint collaborations from 1 and 2 with governmental entities, as well as level of engagement by the implementing agency
- Protection status: work inside and outside of legally protected areas

Counterfactuals or control sites are strongly encouraged, but may not be feasible in all scenarios due to resource constraints. When counterfactuals are not possible, control areas within restored areas are strongly suggested. Sub-protocol 2 elaborates on the decision-making process for choosing between control sites and plots, and provides guidance for the monitoring of both.

[9] *Estimated cost models of RCT designs to be developed for consideration in proposal development*

PPC Program Indicators:

It is likely that each PPC project will monitor additional items in order to comply with national, regional, partner, and donor requirements. We welcome deeper monitoring work, and **encourage sharing of additional monitoring data, results and analysis amongst PPC project developers and with the general public,** for example through symposia and conferences, or publications (with complementary funding). Moreover, scientific design of projects, enhanced by scientific collaborations with restoration researchers, is strongly encouraged.

Additional guidance can be found in sub-protocol 2. If scientific research partnerships are sought by PPC Program grantees, we can facilitate matching with associated researchers (see Annex 4 on Associated Researchers). For example, Conservation International has experts in Restoration Science, Climate-Smart Forestry, Biodiversity, Freshwater, and Land Tenure, to name only a few, interested in assisting with experimental design and monitoring of PPC Program Projects. PPC Program research should always include local universities, to bring in invaluable on-the-ground expertise, while increasing local capacity building and buy-in.

The centralized PPC program monitoring is meant to feed into and **enable joined-up impact evaluation**, and should be enriched by additional program-wide studies and expansions, including rigorous impact evaluation. This requires at least setting up control plots at the time of baseline establishment, if it is not possible to adopt a Randomized Control Trial (RCT) design.

Remote sensing is integrated into the monitoring sub-protocols whenever possible, seeking to integrate the latest technologies and field sampling/ground truthing methods, rates and procedures, starting with the FAO standard sampling procedures developed for forest assessments[10]. Testing a range of methods will ensure comprehensive monitoring, that may later be refined/reduced/simplified as a result of testing, learning and statistical evaluation.

Because the success of this project hinges on being able to show that restoration in all its diverse methodologies, is measurable at

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[10] http://www.fao.org/3/a-i5601e.pdf

scale, the **PPC Program Metrics shown below in Table 1** should be monitored systematically across all PPC projects, using the standardized protocols in this document. The two programmatic impact indicators **bolded in Table 1** are:

A: The number (#) of trees restored (survived and crowded in[11]) after 5 years

B: The percent (%) attainment of target canopy cover for the restored area

Other important indicators, including three defined in the original PPC agreement (the # of trees planted, estimated amount of carbon sequestered by year 5, and cost per tree restored, and others around social, community and ecological benefits are detailed in Table 1 below. Carbon monitoring is a continually developing field. CI and WRI will continue to work actively to increase the precision and accuracy of their strategic carbon estimation, which will be reflected with gradual modifications to the PPC Program carbon monitoring protocols over time. CI's current global carbon estimating 'best practice' approach[12] via remote sensing is used as a

Table 1. PPC Program Metrics[13]

Metric Category	Indicator per intervention site	Objective(s) tracked
Forests: Tree density and diversity	**PPC Impact Indicator A: # of trees restored (survived and crowded in at year 5)** 1.1 # of trees planted 1.1.1 disaggregated by species 1.2 # of trees naturally regenerating 1.2.1 disaggregated by species (Optional) 1.3 # of trees grown in nurseries	1; 1.1
Forests: Tree cover	**PPC Impact Indicator B: % attainment of target canopy cover** 1.4 % change in tree crown canopy	1
Forests: Tree survival	1.5 % survival of planted trees 1.6 # of major disturbances observed	1.2
Carbon Benefits	2. Estimated # tons of CO2 sequestered (by year 5)[14]	2
Social/ Community Benefits	3.1. # of socioeconomic restoration partners 3.1.1. # of Person-days of work created 3.2. # of ecosystem service restoration partners (Optional) 3.2.1 # people directly benefiting from improved freshwater quality or quantity	3, 3.1–3.2
Management	4.1. # of hectares under restoration, by ecosystem type[15] and restoration intervention 4.2. $ cost per tree grown by restoration intervention type	4; 4.1; 4.2
Biodiversity	(Optional) 5.1. % change in species richness within class 5.2 Average % change in abundance within class 5.3 Occupancy Index 5.4 Community Similarity Index	5; 5.1

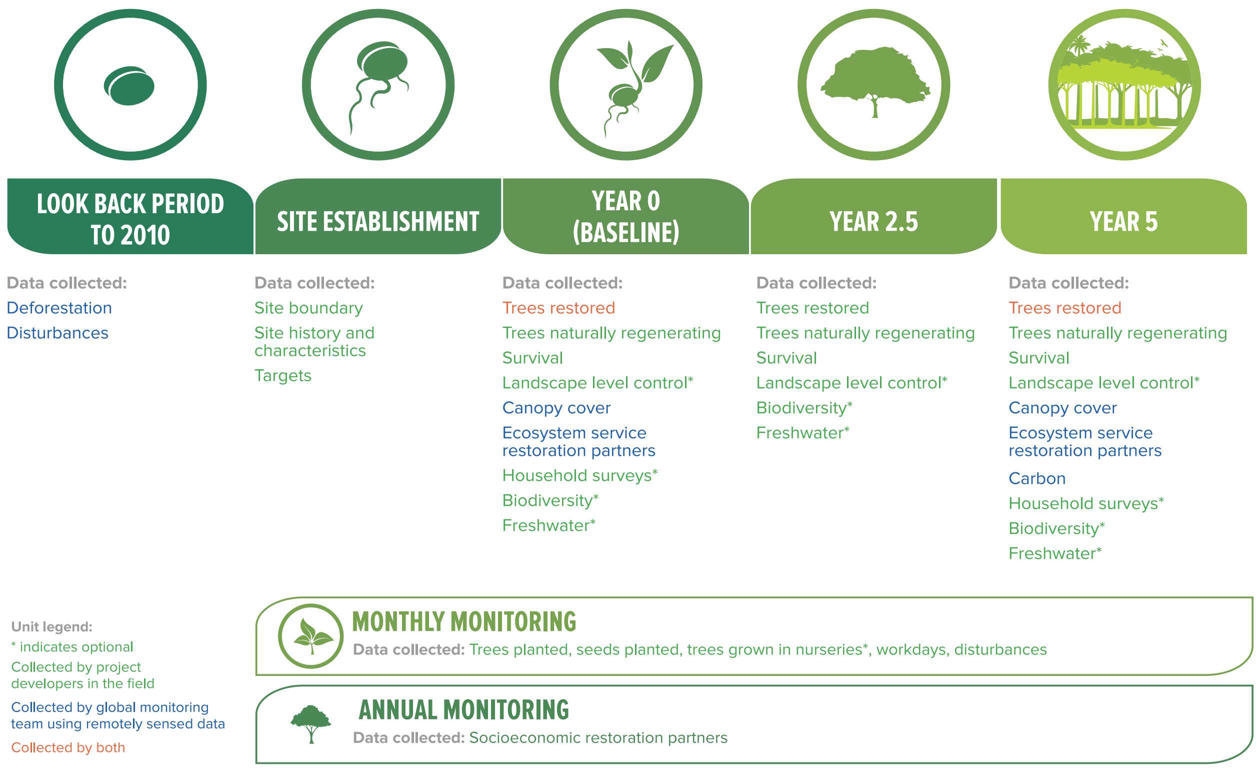
Monitoring for all indicators is required for all projects unless specifically designated as optional

starting point, with the understanding that it is subject to modification as new information and technologies come available. Integration of new technologies may also influence the way other indicators, including PPC impact indicators are calculated, and a similar process of including emerging best practices will be adopted for all indicators as possible.

Please note that all indicators below are required in all PPC projects unless specifically designated as optional.

The timeline of when data for each indicator is collected can be visualized using the diagram below. Additional detail is provided in Table 2.

MONITORING: WHEN DOES IT HAPPEN AND WHAT IS MEASURED



[11] 'crowded in' refers to natural regeneration and/or growth from planted seeds, as opposed to planted saplings which will 'survive

[12] These estimates of carbon stocks cannot be used to make carbon claims.

[13] *The abbreviation "/ area" is short for "per area under restoration" in the PPC Program- indicating that the information will be gathered for each specific area of PPC intervention, and then aggregated

[14] These estimates of carbon stocks cannot be used to make carbon claims

[15] Olson, D.M., E. Dinerstein, E.D. Wikramanayake, N.D. Burgess, G.V.N. Powell, E.C. Underwood, J.A. D'Amico, I. Itoua, H.E. Strand, J.C. Morrison, C.J. Loucks, T.F. Allnutt, T.H. Ricketts, Y. Kura, J.F. Lamoreux, W.W. Wettengel, P. Hedao, and K.R. Kassem. Terrestrial Ecoregions of the World: A New Map of Life on Earth (PDF, 1.1M) BioScience 51:933-938. https://ecoregions.appspot.com/

Table 2 below describes how the monitoring information will be collected and generated, from what needs to be collected in the field by the implementors, during what time intervals, and what processing will be done by CI and WRI for reporting. This table shows the site-based approach, where each PPC restoration site has a GIS shapefile, baseline, and establishment information. Some minimal additional information will be submitted monthly by partners, as well as an annual and final report.

CI/WRI's function of compiling and analyzing data is important for reporting, yet, it is also essential that the analysis of information flows back to the implementing partners for insights, learning exchanges and adaptive management. Key opportunities for adaptive management arise following the sharing of the quarterly reporting, and during the PPC symposia. The first PPC Learning Exchange, including CI, WRI, project developers, and associated researchers was held in early 2022 and stimulated interest in regular continuation.

Table 2. Reporting and Flow of Project Data Collection and Evaluation from Implementors to CI/WRI to Produce Compiled Program Metrics

Project Field Implementors Submit	CI/WRI Process and Compilation
Restoration Site Baseline Form (per site) Site shapefile and basic site information	Visual interpretation of high-resolution imagery for baseline tree count and deep learning algorithm for baseline tree crown cover from site shapefile, verify year of deforestation
Restoration Site Establishment Form (per site) Site shapefile confirmed, site photographs Specify restoration methods used and values for trees planted and socioeconomic restoration partners (1.1, 1.1.1, 3.1, 3.1.1)	Receive and verify data, compile into monthly batches for quarterly report (1.1, 1.1.1, 3.1, 3.1.1)
Control Site Baseline, Establishment, and Monitoring Methodology in sub-protocol 2	Methodology found in sub-protocol 2
Monthly Project Technical Update Major disturbances observed that month (1.6, specify site) Any planting, person-days of work and socioeconomic restoration partners. Tree nursery data if applicable (1.3)	Compile monthly reports into quarterly report to PPC, share results and analysis with implementing partners
Annual Report Trees planted (1.1), work days created (3.1.1), disturbances (1.6). Socioeconomic impacts (3.1). Trees grown in nurseries (1.3) if applicable.	Aggregated from quarterly reporting
Final Project Report (Y5) Number of trees restored (A, Y5) and cost per tree restored (4.2)	Calculate attainment of target % canopy cover (B) and % change in canopy cover (1.4) per site and compile for program. # of people receiving ecosystem services benefits (3.2), # of hectares under restoration, by ecosystem type and restoration intervention (4.1). Compile data for 1.5, 1.2, 1.2.1. Estimate carbon sequestration (2), Compile data for A, 4.2

The focus will continue to be on sharing both program-wide and project-specific learnings, providing training on best practices, and fostering communities of practice along different thematics, including research on different restoration methods and specialized monitoring topics. This will provide a forum for advancing the overall research agenda of the program, including peer-reviewed publications of program-wide monitoring results and project-specific studies (Annex 4).

Project developers may also work with CI and WRI staff to develop impact evaluation studies alongside monitoring. The impact evaluation approach is described in more detail in Annex 2. Some impact evaluations are desired in all locations (counterfactuals, for example), while others are tailored to a specific project site. Where possible, impact evaluation data is integrated into the existing data collection systems. When this is not possible, the data is collected and analyzed separately. In both cases, the results are shared back with the implementing partners as above.

PPC Program Key Concept Definitions

a. **Forest:** Within the context of the PPC program, a forest is defined as land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10%, or trees able to reach these thresholds in situ, aligned with the FRA 2020 definition. If this definition conflicts with a country's official legal definition of "forest[16]," the local country definition should be proposed for special consideration in that country.

b. **Tree**: Within the context of the PPC program, a tree is defined as a woody perennial plant, typically having a single stem or trunk growing to a considerable height and bearing lateral branches at some distance from the ground (Oxford dictionary). If this definition conflicts with a country's official legal definition of "tree," the local country definition should be proposed for special consideration in that country. Mangroves and palm trees are considered trees, in the context of the project.[17]

c. **Restored Tree:** A tree that meets the definition of tree above that has grown as a result of PPC program activities- either through direct planting or assisted regeneration. Naturally regenerating trees must attain a verifiable age of over 1 year, or an equivalent, regionally specified size threshold, to be counted as 'restored'.

   - Restored trees will be disaggregated by size when counted towards the number of trees restored (Impact Indicator A, see below). Trees of 10 cm DBH and larger are counted in the basic vegetation monitoring plots, and they are also most likely detectable through remote sensing methods. Counts of medium (1-10 cm DBH) and small trees (>1cm DBH) may come from field sampling,[18] but these counts should be kept separate (disaggregated) from the counts of trees >10 cm DBH.

d. **Area under Restoration:** The total land or water surface area (measured in hectares) with active PPC program restoration interventions in planting or monitoring stages, defined using the GIS shapefiles of the restoration activities of the sites with restoration activities.

[16] *For example, in Australia, the average tree height to be considered for carbon sequestration is 2m*

[17] *Please consult with the Global Monitoring Team if you have questions on which plant species count as 'trees'*

[18] *Sub-protocols 3 and 7*

PPC Program Indicator Descriptions

There are two overarching PPC Program Impact Indicators that are derived from the monitoring, one related to the number of trees restored (A) and the other related to the tree cover attained relative to the target tree cover (B) (specific targets to be set by individual projects). These are accompanied by other outcome-specific indicators related to tree density, tree cover, tree species and associated biodiversity, tree survival rates, carbon sequestration, people affected, and restoration practices. The PPC Program indicators are briefly described below, grouped by metric category. All indicators described below are required unless specifically designated as optional.

The full details of each indicator, essential for proper monitoring, can be found in Annex 6- Indicator Reference Sheets. There is a sheet for each indicator that includes the definition, unit of measure, disaggregation, data source and methods for data collection and construction, reporting frequency, baseline timeframe and establishment, verification method, associated sub-protocols, and targets, for the indicator. As needed, sub-protocols are created to further detail the steps needed for data collection. Each sub-protocol is linked to the relevant indicators in Annex 6.

A. Forests: Tree Density

PPC Program Impact Indicator A: # of trees restored (survived and crowded in) after 5 years per area under restoration (this is a centrally calculated data, derived from indicators 1.5 and 1.2, in year 5 of monitoring)

a. **Definition:** The number of trees planted in the restored area that are still living after five years (derived from survivorship (indicator 1.5) monitoring in Y5), plus any additional new trees that established themselves during that time through assisted natural regeneration (derived from natural regeneration (indicator 1.2) monitoring in Y5).

b. **Rationale:** This is the main PPC Program impact indicator to report after 5 years of restoration implementation, that should capture the results of direct and indirect planting methods. Indirect (additional) trees could have grown from the soil seed bank or new seed rain in the area and benefitted from the preparation, management, and maintenance of the site for restoration, amplifying the effect of the plantings. Some interventions may not have any active plantings of trees and focus completely on enabling natural regeneration through improving the growing conditions for trees on the site (specifically measured as indicator 1.2 and included in this summary indicator). We will extrapolate the number of trees that were actively planted into the restored area as a result of the PPC activities (indicator 1.1), which are still surviving after 5 years (indicator 1.5), plus the number of trees that have started to grow in those restored areas during that time (also captured in indicator 1.2). All the trees counted as 'restored' under this indicator will not necessarily be additional and should not be claimed as such without additional investigation. It would be critical to compare the number of trees restored to the number of trees growing (natural regeneration, etc.) in other comparable areas, in order to determine the additionality of the intervention. These 'control' areas should also be identified at the time of the baseline establishment (see Sub-Protocol 2 for guidance on the establishment of control sites).

INDICATOR 1.1: # of trees planted per area under restoration

a. **Definition:** The number of trees planted in the area under restoration

b. **Rationale:** Quantifies how many young trees were actively planted or directly seeded (distinction to be made between the two) into the restored area as a result of the PPC activities. Young trees may be saplings or seedlings, usually prepared in tree nurseries. Young trees may also be responsibly harvested from areas of excessive germination where they could not reach maturity, such as along roadsides or under parent trees, and transplanted into restored areas.

SUB-INDICATOR 1.1.1: # of trees planted, by species, per area under restoration (this is the species disaggregation of indicator 1.1 as long as species-specific data is given)

a. **Definition:** The number of trees, by species (identified by scientific name) planted in the restored area.

b. **Rationale:** This simple figure allows us to calculate the diversity and species richness of the PPC plantings in the restoration area, which are additional to any pre-existing vegetation (the pre-existing vegetation needs to be documented and described during the baseline, please see Annex 6). Lists of the species scientific names must be submitted so that we can get a cumulative program-wide number of species planted, without double counting. How many young trees (saplings, seedlings, usually prepared in tree nurseries but possibly also transplanted) were actively planted. Also, how many were directly seeded (distinction to be made between the two), into the restored area as a result of the PPC activities.

INDICATOR 1.2: # of trees naturally regenerating per area under restoration

a. **Definition:** The number of trees naturally regenerating in the area under restoration

b. **Rationale:** How many trees regenerated in the restored area as a result of the PPC activities. These trees most likely grew from the soil seed bank or new seed rain into the area, or possibly from living roots that had been constantly damaged and prevented from growing (such as by grazing or fire). This can occur in any restoration site, even the actively planted ones, although it is less likely in the agroforestry sites because natural regenerants may be removed as undesirable weeds in the agroforestry system. All of the trees counted as 'naturally regenerating' under this indicator will not necessarily be additional, and should not be claimed as such without additional investigation.

SUB-INDICATOR 1.2.1: # of trees naturally regenerated, by species, per area (at year 5) (this is a centrally extracted data derived from indicator 1.2, as long as species-specific data is given)

a. **Definition:** The number of naturally regenerated trees, disaggregated by species (identified by scientific name) in the restored area after five years. These are new trees that established themselves during that time through assisted natural regeneration (monitored as 1.2), but disaggregated by species.

b. **Rationale:** This figure allows us to calculate the 5-year benchmark for tree diversity and species richness of the PPC restored areas, a snapshot that will allow us to also predict and model forward to what the 'final' species composition of the area might be.

   This is very important for adaptive management of restoration techniques. It's possible that not all of the species that were originally planted (indicator 1.1.1) will survive to Y5, which may indicate that they are not suitable for restoration using the current methods- a very important learning point. We may also observe that some species naturally regenerate at much higher rates than others, which can inform selection of species for enrichment plantings.

(OPTIONAL) INDICATOR 1.3: # of trees grown in nurseries, disaggregated by species

a. **Definition:** The number of trees grown in nurseries, disaggregated by species. Sub-protocol 5 specifies the size and/or age requirement for monitoring nursery counts.

b. **Rationale:** How many young trees (saplings, seedlings,) were prepared in tree nurseries to be planted in PPC projects. Project-specific targets for this will vary greatly depending on the implementation modality. Projects focusing on ANR will have few, or no, trees in nurseries. Applied nucleation will have fewer than direct plantation, and that is expected.

B. Forests: Tree Cover

PPC Program Impact Indicator B: % attainment of target canopy cover for the restored area

a. **Definition:** The percentage of **crown cover** in the restored area at the time of monitoring, compared to the **target crown cover** value established for the specific project.

b. **Rationale:** The natural maximum tree crown cover of any region is defined by bioclimatic factors. The Brandt & Stolle (2020) method led to the creation of the Trees in Mosaic Landscapes (TML) dataset, which maps tree extent in Latin America and Africa. Where the data in Brandt & Stolle (2020) aligns with best-available scientific knowledge of potential tree cover (to be determined on a case-by-case basis), the target canopy cover established in Brandt & Stolle (2020) will be utilized to set the target. In other cases, such as those specified below, the target canopy cover will be determined on a per-project basis considering region and land-use specific constraints.

   For instance, when trees are planted in areas with continued agricultural production, such as in agroforestry systems, the maximum tree cover is further constrained. In these cases, the target canopy cover must be determined by the land managers during the project planning process. Moderate to high targets might be set for shade agroforestry, with lower targets set for grazing and other cropping systems with sun-loving crops[19].

   Tree crown cover increases as trees grow and mature, up to a natural or management-related limit as defined by the target. For example, trees planted at wide spacing into agroforestry plots might have

[19] In 2021 CI (Griscom & Sprenkle-Hyppolite) will produce a global analysis of sustainably increasing Trees in Agriculture as part of the Natural Climate Solutions Roadmap for Climate Smart Agriculture, to further inform agroforestry-related targets

a target of 50% tree cover (management-driven target), whereas a nearby forest undergoing assisted natural regeneration might have a target of 90% (natural-driven target), to match the natural forest cover in the area.

INDICATOR 1.4: % change in tree crown canopy cover in the restored area

a. **Definition:** The percentage of tree crown canopy cover in the area under restoration at the time of monitoring, compared to the baseline value established the year of planting.

b. **Rationale:** Changes in tree crown cover as a result of changed land management practices. Tree crown cover will increase as trees grow and mature, as well as increase in number (density) with new saplings developing visible crowns. This should also be compared to observed cover changes in a counterfactual control site with similar conditions, identified at the time of baseline establishment.

C. Forests: Tree Survival Rate

INDICATOR 1.5: % survival of planted trees

a. **Definition:** The number of trees of each tree species planted in the restored area that are still living during the year of monitoring, divided by the total number planted to give a percentage. This is survivorship, the opposite of mortality.

b. **Rationale:** Tree survival rate is a very important indicator to be measured 6 months to 1 year after planting, depending on local weather patterns, to determine the initial survivorship in the challenging first year after planting. Natural survival rates vary greatly due to the species planted (some are more 'hardy' than others, but the tree species that have higher mortalities might be the most important ones for biodiversity and therefore prioritized in plantings) and the site conditions during the time after planting (good rainfall year vs. drought can cause significant 'year effects'). Survival can be impacted also by competition with other plants and disturbances (see 4.2 below) that can kill trees.

INDICATOR 1.6: # of major disturbances observed per area under restoration (optional indicator, unless disturbance damages >25% of restored trees)

a. **Definition:** Count of occurrences of major disturbances (both natural and anthropogenic) with basic information regarding the disturbance occurrence time period, type, intensity, and extent.

b. **Rationale:** Major disturbances may include fire/flood/hurricanes, uncontrolled grazing/herbivory, pest outbreaks, invasion of sites by non-native grasses or trees, and intentional clearing. Some disturbances are natural, some are human-driven- and all can cause major setbacks to tree restoration efforts, and so they must be reported if and when they occur. Any disturbance causing mortality or significantly impaired growth to more than 25% of the restored trees or restored area must be reported. Details on the disturbance such as the time period, type of disturbance by pre-determined category, average intensity of the disturbance over the area (light, moderate, severe), and extent of disturbance (% of restored area impacted) will be recorded.

D. Carbon Benefits

There is no explicit target set for Carbon. The CO2 potentially sequestered by year 5 of the project will be estimated based on Trends. Earth (see Indicator Table for more details). These estimates of carbon stocks cannot be used to make carbon claims.

INDICATOR 2: Estimated # Tons of CO2 sequestered (by year 5)

a. **Definition:** Estimated change in ecosystem carbon (stocks) per unit area and time stored, also understood as absolute carbon gain before additionality constraints are applied as a consequence of restoration activities.

b. **Rationale:** Reforestation can provide climate benefits through the sequestration of carbon. It is important to quantify these benefits to demonstrate the climate impacts of the intervention.

E. Social/Community Benefits

INDICATOR 3.1: # of socioeconomic restoration partners disaggregated by direct and indirect, gender, age, and ethnicity

a. **Definition:**

- **Direct socioeconomic restoration partners:** Any person who received intentional and direct socio-economic support from PPC Program activities and is aware that they received support. Support may be monetary or non-monetary, and include partnerships created as a direct result of the project that yield economic benefits during the project.
- **Indirect socioeconomic restoration partners:** Family members of people receiving direct socioeconomic benefits, and persons with involvement with local organizations and partnerships that may bring jobs in the future.

b. **Rationale:** Reforestation can provide important socioeconomic benefits beyond job creation, and be a vehicle of development, it is important to quantify these benefits to show the socioeconomic and developmental value of the intervention.

SUB-INDICATOR 3.1.1: # of Person-Days of Work Created

a. **Definition:** The number of hours per year worked by project participants contributing to the PPC project, expressed in 8-hour person-days.[20]

b. **Rationale:** Reforestation can provide important socioeconomic benefits, including job creation. This indicator

[20] *Please consider http://www.fao.org/fileadmin/user_upload/smallholders_dataportrait/docs/Data_portrait_variables_description_new2.pdf for further information*

equates work performed for the PPC project to person-days, which are a standardized number, much easier to interpret than the vague term of "job" which could have any duration from a few hours to a year. This is not meant to be an individual beneficiary count, but rather, the days of work created by the project, which could be distributed over almost any number of participants.

There are multiple kinds of work, from formal (with paid wages/taxes) to informal or voluntary- we will disaggregate as much as possible the different kinds of work. This is also an entry point for monitoring equity of labor in the sense of avoiding child labor, encouraging women's participation in the workforce, and enhancing economic opportunities to local and indigenous peoples.

INDICATOR 3.2: # of ecosystem service restoration partners (centrally extracted data that requires correctly recorded shapefiles of each restored area)

a. **Definition:** This metric counts any person who received ecosystem service benefits from PPC Program's actions. This applies whether or not the person is aware they received the benefits and includes any person who uses natural resources the project/activity maintains or enhances such as water and energy. Ecosystem services may include the following, as described in the Road to Restoration[21]:

    1. *Income (Economic benefits from restoration- this is quantified in the previous indicator, 3.1, so not double-counted here)
    2. *Rights (Secure tenure rights to land)
    3. *Market (Access to markets)
    4. *Finance (Access to financial services)

    Ecosystem services from forests include water, energy, food, and timber, as well as livelihoods, medicines, materials, and culture/spiritual/identity. Furthermore, forests provide climate change adaptation services key to disaster risk reduction such as reducing flooding, wind damage, and landslides during extreme rainfall events.

    This metric is focused on quantifying the number of socioeconomic restoration partners (Sub-Protocol 9). Within the PPC program Sub-Protocol 10 on household surveying, we describe additional household survey questions that can be used to evaluate people's perceptions of the ecosystem services they receive (water, materials, well-being) over the duration of the project. This additional, optional work on Ecosystem Services monitoring may also be paired with biophysical monitoring, and will be done where funding allows.

b. **Rationale:** Reforestation can[22] improve watershed functioning by restoring more natural hydrological flows (increasing infiltration, moisture recycling, reducing runoff and erosion, etc.), moderating local climate (especially temperature), and providing habitat for nesting of pollinators and non-timber forest products to surrounding population, to name only some of the benefits. For example:

    1. A person who lives in or near an area under restoration by the PPC Program, who benefits from improved or secured ecosystem services.
    2. A person who lives near a river in an upland reforested area and uses

[21] Road to Restoration Monitoring Guide available here: https://www.wri.org/publication/restoration-monitoring-guide

[21] There are potential negative effects of reforestation on freshwater systems if certain safeguards are not met, which is to say, if water is diverted for the trees or if non-native trees with high water consumption are used. CI will work on developing value-added water monitoring protocols for the 2022 version.

freshwater originating from that reforested area.

3. People who gain livelihood benefits from non-timber-forest-products (NTFPs) produced by the restored areas

(OPTIONAL) INDICATOR 3.2.1: # people directly benefiting from improved freshwater quality or quantity

a. **Definition:** This metric counts the number of people who are receiving benefits in their freshwater due to PPC Program actions.

b. **Rationale:** Reforestation can improve watershed function and improve water quality or quantity in projects that occur along a waterway or have a watershed restoration design. Improved water quality or quantity can have positive impacts on the local peoples though easier access to usable water for consumption, agriculture, etc.

F. Management

INDICATOR 4.1: # of hectares under restoration, by ecosystem type[23] and restoration intervention type (centrally extracted data that requires correctly recorded shapefiles of each restored area)

a. **Definition:** The total land or water surface area (measured in hectares) with active PPC program restoration interventions in planting or monitoring stages, defined using the GIS shapefiles of the restoration activities.

b. **Rationale:** This indicator captures the hectares of land and coastal areas that are undergoing restoration and that are sequestering carbon over the assessment period. Restoration activities are eligible activities (See Annex 3) that result in an increase in the ecological integrity of an area in a way that is explicitly aligned with the long-term goals of the area's stakeholders. Ecosystems include forest, mangroves, wetlands, as well as certain human-modified landscapes that are striving to recuperate ecological integrity (such as ecologically managed forests, agroforestry areas, etc.).

   Examples of restoration:

   - An active mangrove restoration site where trees have been planted to improve vegetative cover and result in carbon sequestration
   - An area of formerly degraded land that is being actively protected in order for the pre-existing seed layer to germinate and begin naturally restoring vegetative cover.
   - The interplanting of trees and crops in agricultural land in a way that increases the soil water retention, nutrient cycling, and biodiversity of the area and increases crop yield.

INDICATOR 4.2: $ cost per tree grown

a. **Definition:** This indicator includes the cost of implementing partner costs, restoration execution costs, and 5 years of monitoring from 2020-2025, divided by the number of trees restored at project site (as determined by the number at year 5, I.e. PPC Impact Indicator A), and disaggregated by restoration type and geography. The cost is then normalized by country using purchasing power parities (PPP)

b. **Rationale:** Cost-effectiveness is important to any enterprise, especially when trying to achieve scale. Yet, the least expensive route is not always the best, sometimes a threshold investment is required to guarantee success. It is

[23] https://ecoregions.appspot.com/

essential to quantitatively analyze the cost effectiveness of the different methods used in the PPC program to allow for adaptive management and learning in shaping recommendations for subsequent years and initiatives.

G. Biodiversity

(OPTIONAL) INDICATORS 5.1 - 5.4: 5.1 % change in species richness within class, 5.2 Average % change in abundance within class, 5.3 Occupancy Index, 5.4 Community Similarity Index

a. **Definition:** These indicators include metrics to analyze the impacts on associated faunal biodiversity in a holistic manner. They will provide an indication of impacts on species richness, abundance, and relative abundance.

b. **Rationale:** These indicators provide insights into the impacts of restoration on local faunal biodiversity, an important potential co-benefit of restoration. Re-colonization of wildlife species as tree diversity and cover increases is expected, but, the rates of re-colonization are not often quantified. The PPC Program provides an excellent opportunity to observe this process. Wildlife species — such as birds, mammals, amphibians and reptiles— provide key functions to the ecosystems being restored such as seed dispersal, pollination, herbivory control, and soil fertilization among others. While it is too costly and time-consuming to monitor all species, selecting the most cost-effective methods for surveying high priority taxonomic groups can provide core data to understand broader trends in biodiversity. For monitoring how biodiversity responds to restoration, it is also important to assess not only presence-absence of species, but density, abundance or relative abundance, which provides much more detailed information about changes in biological communities. We provide multiple options for biodiversity monitoring from direct observations to automated sensors and eDNA- the most appropriate methods, and indicators, should be determined by each project and context.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H. Data Collection Calendar and Methods

Table 3: Indicators calculated using data collected in the field by project developers

Indicator per Intervention Site
PPC Impact Indicator A: # of trees restored (survived and crowded in at year 5) 1.1 # of trees planted (by species) 1.2 # of trees naturally regenerating (by species) 1.3 # of trees grown in nurseries
PPC Impact Indicator B: % attainment of target canopy cover 1.4 % change in tree crown canopy
1.5 % survival of planted trees 1.6 # of major disturbances observed
3.1. # of people with socioeconomic benefits 3.1.1. # of person-days of work created 3.2. # of Ecosystem service beneficiaries 3.2.1 **# people directly benefiting from improved freshwater quality or quantity**
4.1. # of hectares under restoration, by ecosystem type and restoration intervention **4.2. $ cost per tree grown by restoration intervention type**
5.1 % change in species richness within class 5.2 Average % change in abundance within class 5.3 Occupancy Index 5.4 Community Similarity Index

Table 4: Indicators calculated using remote sensing data

Indicator per Intervention Site
PPC Impact Indicator A: # of trees restored (survived and crowded in at year 5) 1.1 # of trees planted 1.2 # of trees naturally regenerating 1.3 # of trees grown in nurseries
PPC Impact Indicator B: % attainment of target canopy cover **1.4 % change in tree crown canopy**
1.5 % survival of planted trees 1.6 # of major disturbances observed
2. Estimated # Tons of CO_2 sequestered (by year 5)
3.1. # of socioeconomic beneficiaries 3.1.1. # of Person-days of work created **3.2. # of people with improved ecosystem services** 3.2.1 # people directly benefiting from improved freshwater quality or quantity
4.1. # of hectares under restoration, by ecosystem type and restoration intervention 4.2. $ cost per tree grown by restoration intervention type
5.1 % change in species richness within class 5.2 Average % change in abundance within class 5.3 Occupancy Index 5.4 Community Similarity Index

Table 5: Master calendar of data collection for each indicator, including baseline establishment and interval of monitoring. An X indicates mandatory monitoring, while a * indicates optional monitoring. Baselines are always considered mandatory.

Indicator	Type	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
A	Field		Baseline				X			X	
	RS		Baseline							X	
1.1, 1.1.1	Field		Baseline								X
1.2, 1.2.1	Field		Baseline		*	*	X	*	*	X	X
1.3**	Field									X	*
B	RS	Look back period	Baseline							X	
1.4	RS	Look back period	Baseline							X	
1.5	Field		Baseline				X			X	
1.6	Field										X
	RS	Look back period									
2	RS									X	
3.1	Field				X	X		X	X		X
	Field (Survey)		*				*			*	
	GIS		Baseline							X	
3.1.1	Field										X
3.2	Field (Survey)		Baseline*				*			*	
	GIS		Baseline							X	
3.2.1**	Field		Baseline*				*			*	
4.1	Field		X								
4.2	Calculation		X							X	
5**	Field		Baseline*				*			*	

**** indicates an optional indicator or sampling. Rows with a type of 'field' are items contributed by project developers. Rows with types 'RS' or 'GIS' are completed by the global monitoring team.**

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ANNEX 1. PROJECT SELECTION CRITERIA

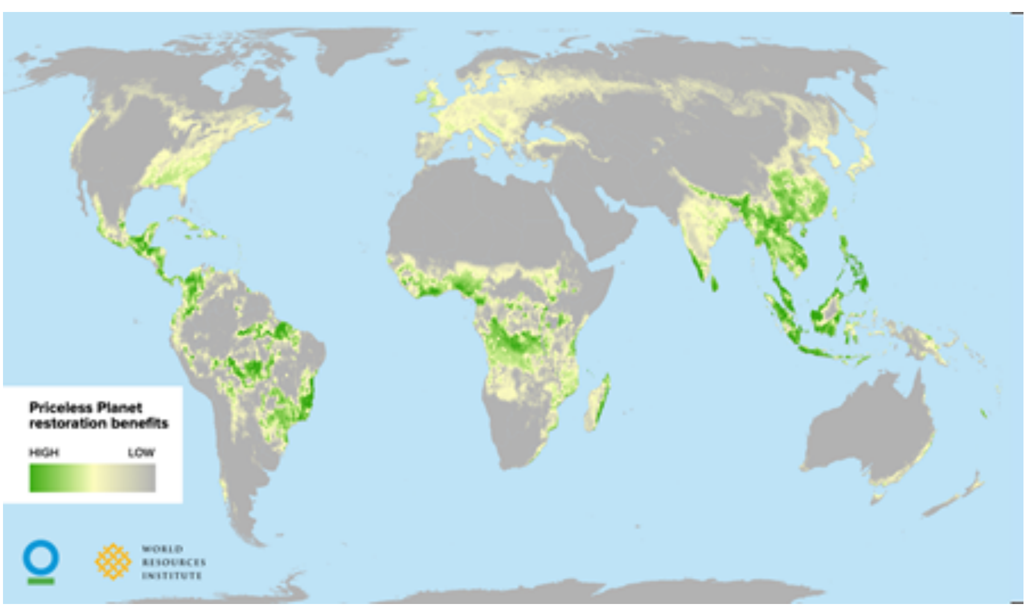
Contributed by Ruth Metzel, CI

HOW ARE PRICELESS PLANET COALITION PROJECTS CHOSEN?

The Priceless Planet Coalition pledges to restore 100 million trees over five years as an initial goal. As partners in the initiative, Conservation International (CI) and World Resources Institute (WRI) are developing a pipeline of high-quality restoration projects, guided by an annual plan that prioritizes projects and geographies with the greatest potential for positive impacts on climate, community, and biodiversity. It is this approach that sets the Priceless Planet Coalition apart, both because of the scale of action, the urgent timeline, and the quality of the restoration work being implemented.

HOW DOES THE PPC PRIORITIZE GEOGRAPHIES?

In the map below, you can see a preliminary map of priority geographies for restoration created in 2020 through a process of combining maps representing biodiversity (total richness, richness at risk and range size rarity of vertebrates)[1], community benefits (ecosystem service provision)[2], and carbon sequestration (carbon accumulation potential)[3]. This map informs the prioritized sites for restoration through the Priceless Planet Coalition and will be adaptively assessed and revised as new information comes online that might inform our approach to restoring the most strategic areas. Already, analyses done by the International Institute for Sustainability (IIS) and CI and by Luther et al in late 2020[4], Co$tingNature and InVEST will inform future siting within the priority areas. For CI staff, an interactive version of this map is available to you on the "Landscape Restoration Sharepoint" on our internal website.



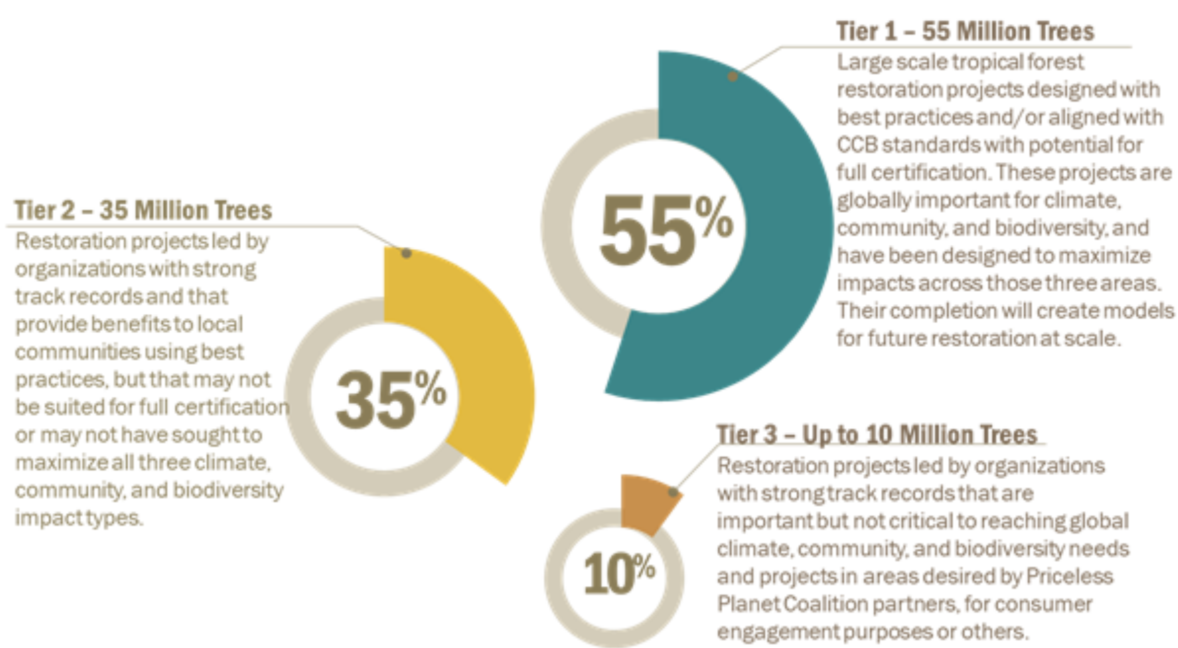
STANDARD PRACTICES ACROSS PROJECTS

PPC Projects should expect to adhere to some basic standard practices to form part of the implementing partners of the coalition. Those are:

a) Deforestation occurred before 2010
b) No invasive species, and no individuals destined for timber harvest
c) Majority native species
d) No afforestation in areas historically not forest
e) Does not create leakage
f) Proper community engagement across planning, implementation and monitoring stages
g) Ecologically and socially appropriate restoration methods (e.g., seeding, assisted natural regeneration, agroforestry, etc.)
h) Robust and standard monitoring and maintenance plans, etc.
i) Adherence to safeguards and optimization of climate, community and biodiversity benefits

TIERING OF PPC PROJECTS

In order to ensure that a high proportion of trees are grown in areas that strive for large scale, strategic geographies (as indicated in the map above) best practices, potential certification and exemplification of the practices listed above, but also to allow the PPC the flexibility to address coalition partner perspectives and engage strategically with the global community, project sites are chosen according to tiers (see graphic below), recognizing that each project working with the PPC contributes a unique value to the global initiative as a whole because of the diverse ways participating projects create impact and scale.



DETAILED PROJECT SITING FACTORS:

The project selection process involves a conversation about many of the details about potential partner projects beyond the mapping and tiering processes, including:

a) Project Goals: Project goals should align with larger PPC goals and recommended standard practices above
b) Narrative: What story does this site convey about the importance of restoration in the global context?

- Key geography for restoration benefits (according to map)
- Tier (highest priority to Tier 1)
- Project area/scale: number of trees and hectares to be restored
- Land tenure type (private, public, indigenous, communal, national protected area): Does the land tenure type give the project developers and the PPC the assurance that restoration will be sustained in the landscape?
- Carbon emissions reductions or sequestration amount
- Combined triple benefits: how does each site fulfill the PPC goals in terms of climate, community and biodiversity
- Timing/Planting Season: This can affect the order in which sites are selected based on logistical factors
- Restoration approach: The PPC seeks to incorporate diverse restoration methods, while prioritizing cost effective, socially and ecologically appropriate and efficient strategies. These can theoretically range from mangrove restoration, agroforestry, plantations, peat restoration, wetland/riparian restoration (if involving trees), enrichment planting and assisted natural regeneration, silvopasture, and seed dispersal. These restoration interventions are detailed in Annex 3.
- Species used: The PPC encourages using a diverse mix of species important for ecological and social goals, including a requirement of majority native species on all projects and does not include planting of invasive or individuals destined for timber harvest. The portfolio allows some non-native species important for agroforestry or other community benefits.
- Baseline: As mentioned elsewhere in this document, it is essential that PPC sites have a look-back period to ensure that land to be restored has not been recently deforested. In line with voluntary market protocols (such as those of the California Air and Resources Board and Climate Action Registry), sites must have less than 10% canopy cover for at least 10 years to be considered for inclusion in the PPC. This check, described in Sub-Protocol 16, can be done on the proposed project area as part of site selection, and should also be repeated on the specific restoration sites as part of the baseline data collection. Including the entire proposed project area and its surrounding areas will provide important information on the risk of reversal of the restoration, and potential leakage of deforestation activities due to the restoration.
- Safeguards in place and community engagement process: PPC project developers will have conducted consultations with the community.

- Capacity for implementation and monitoring: Project developers should be ready to be a part of PPC as the largest global experiment in restoration monitoring, in addition to working to get trees in the ground.
- Amplification potential: Ie, political will, restoration in NDC or other policy documents[1]
- Risk- mitigation strategy: What is the strategy for increasing likelihood of sapling permanence over 10+ years and sustained restoration in the long term?
- Climate risk: What is the relative climate risk of the site?

Although, when considered together, the project selection process and monitoring framework are comprehensive and often daunting, those considering participating in the project selection process for PPC should know that the process of submitting a proposal can be a conversation and that projects are considered for how well they fit holistically across this range of factors, not just based on one selection factor alone. The PPC scoping team is committed to working with implementing partners to discuss some of the ways in which their projects could be incorporated into the larger global initiative.

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ANNEX 2. IMPACT EVALUATION APPROACH

Provided by Carlos Muñoz Brenes, CI

Impact Evaluation for PPC Projects: Realizing restoration potential through a transformational approach to learning, replicating, and scaling

What is the problem?

Natural climate solutions (NCS)—actions to protect, restore and improve the management of natural and human modified ecosystems—are one of the most promising solutions for climate change mitigation, while contributing to our global conservation efforts, overall planetary resilience, and sustainable development goals (Griscom et al., 2017; Griscom et al., 2020). While NCS can potentially deliver about one third of the climate mitigation needed to achieve the Paris goal with at least 11 Gt CO_2e (gigatonnes of carbon dioxide equivalent per year), uncertainty about their effectiveness in delivering desired outcomes and reducing risks is severely impeding the level of investment needed to deliver on the global potential of NCS. Funding additional science-based evidence and learning needed to inform the design of NCS strategies and investment models can unlock and shift the tens of billions in capital required for their adoption at global scale. To realize this potential, we need a fast-track approach to learning, replicating, and scaling NCS interventions and investments based on evidence generated by impact evaluation science—akin to the extraordinary transformation in education, medicine, and human health wrought by the application of science and statistics in the 19th century.

By 2025, through the PPC project CI and WRI will catalyze effective nature restoration solutions and based on impact evaluations evidence deliver on their social and environmental outcomes. The PPC projects present a world first opportunity to generate science-based evidence for learning and informing effective NCS strategies with businesses, donors, multilateral agencies, and governments.

Impact Evaluations (IE) to assess the effectiveness of interventions (i.e., programs, strategies, activities, models) are critical to learn, and put into practice, what works best and in what contexts, and the causal effect on desired outcomes from interventions (Figure 1). Evidence generated from IE is crucial to allow policymakers and project developers to identify and

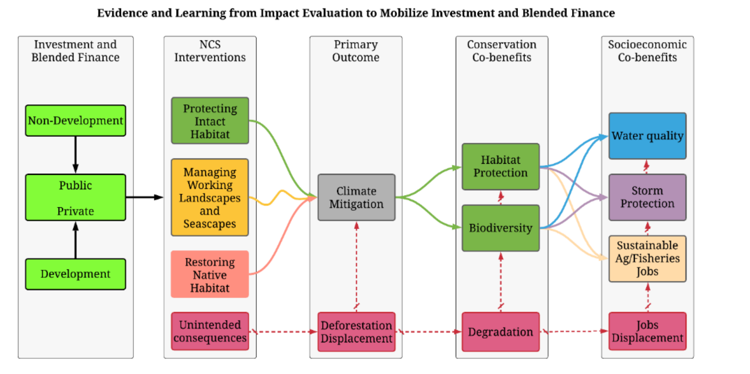

Figure 1. Mechanism and pathways to realize NCS potential

scale cost-effective interventions that deliver on return on investment (ROI).

We propose implementing IE using both retrospective quasi-experimental evaluations and prospective randomized evaluations for strategic NCS projects. Methodological advances across the social and natural sciences and innovations in geospatial and remote sensing make it possible to apply IE methods to NCS at low cost. This is accomplished through sequential steps: defining a theory of change and pathways, identifying the IE method, developing a sampling strategy for treated and counterfactual units, data collection, performing analysis, and reporting findings.

If not designed or implemented properly, a project, policy or program assessment can provide biased results because in most interventions the treatment (e.g., restoration system) is not randomly assigned. In consequence, the results do not capture the treatment effect on the outcome or the analysis overestimate positive effects (Imbens and Wooldridge 2009; Khandker et al. 2011). IE methods control for the non-random allocation of interventions and reduces bias in the estimated impacts. The IE design identifies a counterfactual to estimate the mean difference between the outcome with treatment, and the outcome without it, by a matching procedure. A counterfactual is a comparison of the condition with what would have occurred in the absence of the intervention (Ferraro 2009). IE contributes to providing the scientific evidence to test whether the causal changes are connected to the policy intervention pathways and reveals the ways the program is leading or not to the outcomes (e.g., improved income, increased biodiversity, sustainable yields, climate mitigation).

The opportunity:

CI in collaboration with external partners (J-PAL at MIT, Duke University, University of California at Santa Barbara, University of Wisconsin Madison, Imperial College, TNC, WRI, and others) have been working to advance rigorous impact evaluations of NCS to scale the most effective solutions. We are leading cutting edge science for the global NCS "greatest experiment" (Bronson et al.) to strategically align CI's portfolio and its ROI. From these experiments we will generate evidence and learning to inform policy and scale to cut emissions and help vulnerable communities adapt on a fast track.

Testing the effectiveness of interventions to stabilize the climate by protecting, managing, and restoring nature is critical for directing funding toward strategies that work to meet conservation and human well-being goals. In the past three decades, rigorous impact evaluations (IE) have become increasingly common in international development where they help policymakers identify and scale interventions that alleviate poverty effectively and at low cost. IE methods include both retrospective quasi-experimental evaluations and prospective randomized evaluations and can be designed to measure both what works and why. Methodological advances across the social and natural sciences and innovations in geospatial and remote sensing make it possible to apply these methods to NCS too. Researchers at Conservation International (CI) and the Abdul Latif Jameel Poverty Action Lab (J-PAL) have already applied these methods to quantify the impacts of conservation and development investments in reducing deforestation and fires; protected areas and human well-being; payment for ecosystem services to conserve forests and reduce deforestation; programs to encourage the adoption of rainwater harvesting techniques to improve the resilience of smallholder farmers to climate change.

How it would work:

- **Pilot experiments.** Based on PPC portfolio, we will select an optimal set of specific restoration strategies (i.e., interventions) to evaluate within the flagship and other selected geographies. Specifically, we will:
    - Select representative geographies to account for variability in social and environmental context, restoration strategies, investment designs, and evaluation methods.
    - Screen projects for feasibility and appropriateness of IE method and strategy (e.g., RCT or quasi-experimental design, use of retrospective, prospective, and mixed methods), and identification of outcome to measure (e.g., emission reduction, sequestration, livelihoods, jobs, conservation).
    - Based on the Monitoring Framework, select the sampling strategy, conduct data collection on the relevant indicators in both intervention sites and control sites.
    - Where possible, data collection of impact evaluations is integrated into existing data collection systems and regular monitoring. When impact evaluations are specialized, data is collected and analyzed separately. Results from impact evaluations are shared back with project developers in the same way that monitoring results are shared.
- **Synthesis and Tools.** Fast-track learning from the Pilots of what restoration strategies work, where, and why by (1) synthetizing major findings, actionable evidence, and best practices; (2) developing methodological approaches, research design protocols and visualization tools; and (3) making these products available to the public for learning, dissemination, and practice.
- **Workshopping**. Demonstrate to a broader audience: (1) investors, donors, philanthropists; (2) researchers and scholars; and (3) practitioners the ways to replicate research designs and scale interventions.

What funding is needed to implement impact evaluation?

The cost of an IE for a given PPC geography depends on multiple factors and can be estimated once details on the project design and locality is defined. In general, the cost of an IE can range from 5% to 20% of the total budget allocated for single site embedded in the proposed Monitoring Framework (Lagarde, Kassirer, & Lotenber, 2012).

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ANNEX 3. RESTORATION INTERVENTION TYPES

Provided by Ruth Metzel and Salome Begeladze, CI. Builds off of CI Standard Definitions.

The PPC portfolio permits the following range of tree-based restoration interventions within partner projects. The indicator "# of hectares under restoration, disaggregated by ecosystem and restoration intervention type" requires restoration intervention type definitions found below:

RESTORATION INTERVENTION TYPE DEFINITIONS:

Agroforestry – the intentional mixing and cultivation of woody perennial species (trees, shrubs, bamboos) alongside agricultural crops in a way that improves the agricultural productivity and ecological function of a site. This category includes agroforestry for shade grown crops (cacao, coffee), as well as planting trees at a low density to allow for continued agriculture.

I. Resource: Agroforestry delivers a win-win solution for ecosystem services in sub-Saharan Africa
II. Resource: Identification of Agroforestry Systems and Practices to Model
III. Resource: An Agroforestry guide for field practitioners

Applied Nucleation / Tree Islands – A form of enrichment planting where trees are planted in groups, clusters, or even rows, dispersed throughout an area, to encourage natural regeneration in the matrix between the non-planted areas. [2] .

IV. Resource: Applied nucleation guide for tropical forests.

Assisted Natural Regeneration – the exclusion of threats (i.e. grazing, fire, invasive plants) that had previously prevented the natural regrowth of a forested area from seeds already present in the soil, or from natural seed dispersal from nearby trees. This does not include any active tree planting. Ideally, the specific method(s) of threat control intervention(s) used would be specified so that the relative effectiveness can be evaluated (i.e., whether fencing was installed to control grazing, how often invasive plants were removed, etc.).

V. Resource:
VI. **Farmer Managed Natural Regeneration**, where farmers cultivate the regeneration of trees in their farmland or grazing land, is treated as a sub-category of Assisted Natural Regeneration under this framework
    a. Resource: Farmer Managed Natural Regeneration (FMNR): a technique to effectively combat poverty and hunger through land and vegetation restoration
    b. Resource: Farmer Managed Natural Regeneration (FMNR) Manual

[2] https://www.conservation.org/research/applied-nucleation-report

Enrichment Planting– The strategic reestablishment of key tree species in a forest that is ecologically degraded due to lack of certain species, without which the forest is unable to naturally sustain itself.

VII. Resource: Rehabilitation and Restoration of Degraded Forests

Mangrove Tree Restoration – specific interventions in the hydrological flows and/or vegetative cover to create or enhance the ecological function of a degraded mangrove tree site.

VIII. Resource: A technical guide to mangrove restoration

Peat Restoration – The re-establishment of vegetative cover that will lead to active peat formation. This often involves a mix of planting, seed dispersal, and engineering solutions to pre-disturbance re-establish hydrological dynamics. Threat exclusion is usually a major intervention.

IX. Resource: Global Peatland Restoration demonstrating SUCCESS.

Seed Dispersal/Direct Seeding – The active dispersal of seeds (preferably ecologically diverse, native seed mixes) that will allow for natural regrowth to occur, provided the area is protected from disturbances. This may be done by humans or drones and implies active collection and dispersal, not natural dispersal by local seed dispersers that is part of natural regeneration processes. This is a differentiated category from planting young trees.

X. Resource: Standards For Native Seeds In Ecological Restoration
XI. **Broadcast seeding –** Refers to seeding that places seeds on the soil surface. Typically done by hand or with mechanical spreaders.

Silvopasture – The intentional mixing and cultivation of woody perennial species (trees, shrubs, bamboos) on pasture land where tree cover was absent in a way that improves the agricultural productivity and ecological function of a site for continued use as pasture

XII. Resource: Silvopastoral systems as alternative for sustainable animal production in the current context of tropical livestock production.
XIII. Resource: Silvopasture Manual

Tree Planting – the planting of seedlings over an area with little or no forest canopy to meet specific goals

XIV. Resource: Guidance for successful tree planting initiatives.

Wetland/Riparian Restoration – Specific interventions in the hydrological flows and vegetative cover to improve the ecological function of a degraded wetland or riparian area.

XV. Resource: Wetlands: Wetland Restoration, Enhancement, and Management
XVI. Resource: Riparian Restoration

ANNEX 4. ASSOCIATED RESEARCHERS AND RESEARCH AGENDA

Provided by Starry Sprenkle-Hyppolite for CI and Dow Martin for WRI[3]

The PPC program has ambitious plans for advancing restoration research to contribute to the global body of knowledge on restoration. Research is conducted by the global monitoring team at CI and WRI, associated researchers, local research groups or universities, and project developers. Implementing research within the PPC program by project developers in coordination with CI, WRI, or local organizations is strongly encouraged, as the collaboration between organizations working in global and local contexts can effectively advance restoration research to benefit all stakeholders.

Table 1. Associated Researchers

Affiliation	Last Name	First Name	Specialty	Specific Interest
Center for Sustainable Lands and Waters, CI	Abell	Robin	Freshwater	Freshwater strategy
Moore Center for Science, CI	Ahumada	Jorge	Biodiversity	Ecological monitoring
Oregon State University	Alix-Garcia	Jennifer	Economics	Restoration Impact Evaluation
Center for Natural Climate Solutions, CI	Begeladze	Salome	Restoration	Restoration at a global scale
Moore Center for Science, CI	Bezerra	Maira	Freshwater	Ecohydrology, freshwater ecosystem services
Global Restoration Initiative, WRI	Brandt	John	Computational science, deep learning, GIS	Restoration
Moore Center for Science, CI	Bukowski	Jacob	Forest carbon accounting, spatial analysis	Blue carbon, tropical forests, plantation forestry
Moore Center for Science, CI	Collins	Pamela	Ecosystem services, critical natural capital	ES outcomes of restoration,

[3] *All WRI researchers listed are not confirmed, pending further clarification on each research proposed, budget and timelines.

				conservation, and management activities
IUCN + CI	Cox	Neil	Biodiversity	Biodiversity conservation and monitoring
Global Restoration Initiative and WRI Brasil, WRI	Ferreira	Jefferson	Remote sensing, GIS, landscape restoration	Restoration, NCS in Brasil
Forests, WRI	Harris	Nancy	Carbon, carbon fluxes	Carbon sequestration in agroforestry, forests, and plantations
CI	Harrison	Ian	Freshwater Science and Policy	Freshwater, wetland faunal biodiversity
Center for Natural Climate Solutions, CI	Hillman	Isabel	Monitoring	Restoration monitoring methods
University of California Santa Cruz	Holl	Karen	Restoration Ecology	Testing restoration methods at scale, tree islands
Moore Center for Science, CI	Jagadish	Arundhati	Scaling, Community-based ways of working	Scaling of natural climate solutions, community-based conservation
Moore Center for Science, CI	Larsen	Trond	Biodiversity	Ecosystem science, nature's values
North Carolina State University	Martin	Meredith	Forest Ecology, tropical restoration and reforestation	Ecological silviculture, community-based restoration
Global Restoration Initiative, WRI	Martin	Ornanon g (Dow)	Impact evaluation, MERL, monitoring restoration	Landscape restoration data for project adaptive management
Center for Natural Climate Solutions, CI	Metzel	Ruth	Restoration	Comparative restoration strategies; costs; restoration in productive landscapes
Center for Environmental Policy, Imperial College London, UK	Mills	Morena	Biodiversity Conservation, Scaling	Applied biodiversity conservation research, Impact and scaling of conservation & restoration initiatives
Moore Center for Science, CI	Muñoz Brenes	Carlos	Impact evaluation, Governance	impact evaluation and policy, governance, practice analysis
Smithsonian Institute + CI	Nowakowski	Justin	biodiversity, landscape ecology, impact assessment	spatial analysis, climate adaptation, biodiversity monitoring

Global Restoration Initiative and AFR100, WRI	Okwaro	George	Landscape-scale restoration	Restoration, policy and governance in Kenya
Moore Center for Science, CI	Shaad	Kashif	Freshwater	Hydroinformatics
Amherst College	Sims	Katharine	Economics	Restoration Impact Evaluation
Center for Natural Climate Solutions, CI	Sprenkle-Hyppolite	Starry	Restoration, Landscape, Plant Community Ecology	Landscape-scale restoration ecology
Forests Program, WRI	Stolle	Fred	Remote sensing, GIS	Land and forests data
Duke University	Vincent	Jeffrey	Forest economics	Economics of natural resource management
Moore Center for Science, CI	Vollmer	Derek	Freshwater, biodiversity	Water resource management
Global Restoration Initiative, WRI	Woldemariam	Tesfay	Remote sensing, GIS, landscape restoration	Restoration in Ethiopia, government-led and community-led restoration
Global Restoration Initiative, WRI	Zamora	Rene	Shifting policy incentives	Initiative 20x20, policy change, governance

Table 2. Planned Reports and Publications for the PPC Program (non-exhaustive).[4]

This list is meant to indicate ambition for publication as known in June 2022, it is open to additions. Additions are especially sought with local researchers and project developers, either independently or in concert with the Associated Researchers.

(Draft) Publication Title	Key Content	Lead Authors	Type of Publication	Target Year of Publication
Monitoring the Restoration of 100 M trees	PPC Monitoring Framework (public version)	Same as this document	Report	2022
What will restoring trees do for Ecosystem Services?	Forecast of Potential Ecosystem Services Benefits of Reforestation using Inve$t and Co$ting Nature Models	Pamela Collins, Alex Zvoleff, Starry Sprenkle-Hyppolite	Peer Reviewed	2022

[4] Pending additions from WRI

Halfway there = 50 M trees ?	Mid-Term Report on overall PPC Program Indicators	Isabel Hillman, Salome Begeladze, Starry Sprenkle-Hyppolite, Ruth Metzel	Report	2024
Counting 100 M trees	Investigation of effectiveness of remote sensing + field verification protocols in extrapolation of tree counts, at varying tree sizes, defining minimum size to detect w/remote sensing	Starry Sprenkle-Hyppolite, Tesfay Woldemariam, Dow Martin	Peer Reviewed	2025
WE DID IT! 😊 (working title)	Final Report on achievement of overall PPC Program Indicators + Impact Indicators	Isabel Hillman, Salome Begeladze, Starry Sprenkle-Hyppolite, Ruth Metzel	Report	2026
The best way to restore a trillion trees? Lessons learned from 100 M.	Detailed comparison of effectiveness of different restoration intervention types done in PPC, drivers of variance, exploration of year effects	Starry Sprenkle-Hyppolite, Isabel Hillman, Ruth Metzel, Salome Begeladze	Peer Reviewed	2026
Socioeconomic Impact of PPC Program	Project and/or Country-focused case studies + overall impact for data collected	Carlos Muñoz Brenes, Arundhati Jagadish	Peer Reviewed	2026
Water Impacts of PPC		Maira Berrera, Kashif Shaad, Dereck Vollmer, Ian Harrison, Rob Abell, Starry Sprenkle-Hyppolite	Peer Reviewed	2027
Ecosystem Services Impacts of PPC		Pamela Collins, Alex Zvoleff, Starry Sprenkle-Hyppolite	Peer Reviewed	2027
Biodiversity Impacts of PPC		Justin Nowakowsi, Neil Cox, Jorge Ahumada, Trond Larsen, Derek Vollmer, Starry Sprenkle-Hyppolite	Peer Reviewed	2027

ANNEX 5. DATA PROCESSING RESPONSIBILITIES

All data analyses are conducted by the global monitoring team at CI and WRI. Project developers are responsible for submission of field data into the IMP.

Indicator	Data Analysis	Responsible Institution (for Data Analysis)	Relevant Projects
A	Tree count using CEO	WRI	Mutually agreed upon Tier 1 projects
A	Processing of field vegetation monitoring data	CI	All projects
1.1, 1.1.1	Trees planted analyses	CI	All projects
1.2, 1.2.1	Processing of field vegetation monitoring data	CI	All projects
1.3	Nursery analyses	WRI	Optional
B, 1.4	Canopy cover analyses	WRI	All projects
1.5	Survival analyses	CI	All projects
1.6	Disturbance analyses	WRI	All projects
2	Carbon estimation	CI	All projects
3.1, 3.1.1	Socioeconomic analyses including work days	CI	All projects
3.1	Analysis of household surveys	CI	Optional
3.2	Ecosystem services analyses	CI	All projects
3.2.1	Freshwater analyses	CI	Optional
4.1	Hectares under restoration	WRI	All projects
4.2	Cost per tree analyses	CI	All projects *by restoration strategy for CI projects
5	Biodiversity analyses	CI	Optional
NA	Lookback period analyses	WRI	All projects

ANNEX 6. INDICATOR REFERENCE SHEETS

Compiled by Starry Sprenkle-Hyppolite and updated by Isabel Hillman on June 1, 2022

Contents of Annex 6

PPC Program Impact A: Trees Restored (Required)

Generated by Global Monitoring Team

Indicator Reference Sheet: PPC Program Impact A
Name of Indicator: # of trees restored (survived and crowded in) after 5 years per area under restoration
Name of Result Measured: Program Impact A, Objective 1
DESCRIPTION
Precise Definition(s): The number of trees planted in the restored area that are still living after five years compared to baseline (derived from survivorship (indicator 1.5) monitoring in Y5), plus any additional new trees that established themselves during that time through assisted natural regeneration (derived from natural regeneration (indicator 1.2) monitoring in Y5).
Unit of Measure: tree
Data Type: numerical
Disaggregated by: species
Rationale for Indicator: This is the main PPC Program impact indicator to report after 5 years of restoration implementation, that should capture the results of direct and indirect planting methods. Indirect (additional) trees could have grown from the soil seed bank or new seed rain in the area and benefitted from the preparation and maintenance of the site for restoration, amplifying the effect of the plantings. Some interventions may not have any active plantings of trees and focus completely on enabling natural regeneration through improving the growing conditions for trees on the site (specifically measured as indicator 1.2, and included in this summary indicator). We will extrapolate the number of trees that were actively planted into the restored area as a result of the PPC activities (indicator 1.1), which are still surviving after 5 years (indicator 1.5), plus the number of trees that have started to grow in those restored areas during that time (also captured in indicator 1.2). It is important to compare to the rates of natural regeneration observed in other comparable areas in order to determine the additionality of the intervention. These ‘control’ areas should also be identified at the time of the baseline establishment.
PLAN FOR DATA COLLECTION
Data Source: Primary source is data collected through field vegetation monitoring (Sub-Protocol 4) in all projects. It is accompanied by visual interpretation of satellite imagery using Collect Earth Online to count trees that are visible at baseline and year 5 for Tier 1 projects. Other platforms for counting trees are currently in development, using latest available remotely sensed data. This is an important frontier in research, and we plan to continue to evaluate the potential benefit of switching over to a more accurate platform in the future. The data migration would be handled by the global monitoring team, with the permission of implementors.

Method of Data Collection and Construction: *compilation of the Y5 values for 1.2 and 1.5*
Responsible for Data Collection and Construction: Global monitoring team (remote sensing components), Project developers (field components)
Related Sub-Protocols: Sub-protocols 1, 2, 4

Reporting Frequency: at baseline and once (after 5 years)
Data Collection Calendar:

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
RS		Baseline							X	
Field		Baseline				X			X	

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI (co-led): Starry Sprenkle-Hyppolite
At WRI (co-led): Tesfay Woldemariam

TARGETS AND BASELINE

Baseline Timeframe: within 12 months of planting

Target: 100,000,000 trees, PPC Program- Wide *(will be disaggregated for each partner in their own sheets)*

Rationale for Targets *(optional)*:

Forest: 1.1 Trees Planted (Required)

Reported by Project Developers

Indicator Reference Sheet: Forest: 1.1

Name of Indicator: 1.1: # of trees planted per area under restoration

Name of Result Measured: Objective 1, Outcome 1.1

DESCRIPTION

Precise Definition(s): The number of trees planted in the area under restoration

Unit of Measure: young trees planted, seeds planted

Data Type: numerical

Disaggregated by: type of propagule (young tree or seed- required), species

Rationale for Indicator: Quantifies how many young trees were actively planted or directly seeded (distinction to be made between the two) into the restored area as a result of the PPC activities. Young trees may be saplings or seedlings, usually prepared in tree nurseries. Young trees may also be responsibly harvested from areas of excessive germination where they could not reach maturity, such as along roadsides or under parent trees, and transplanted into restored areas. This simple figure allows us to calculate the diversity and species richness of the PPC plantings in the restoration area, which are additional to any pre-existing vegetation (the pre-existing vegetation needs to be documented and described during the baseline). Lists of the species scientific names must be submitted so that we can get a cumulative program-wide number of species planted, without double counting)

PLAN FOR DATA COLLECTION

Data Source: Site shapefiles and monthly reports including counts of the number of young trees and seeds delivered to the sites and planted in the restored areas.

Method of Data Collection and Construction: partner self-reporting of actual counts, verified by photos (preferably drone shots) and random site verification visitations. Please note that documenting the 'baseline' of trees and saplings already on site at the time of planting is also required (sub-protocol 4)

Responsible for Data Collection and Construction: Project developers
Related Sub-Protocols: Sub-protocols 3, 4

Reporting Frequency: Site establishment reports can be filled in as planting progresses (per site) and will be compiled into monthly and annual reports

Data Collection Calendar:

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
Field		Baseline								X

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory
Individual(s) Responsible at CI (lead): Isabel Hillman **At WRI:** Tesfay Woldemariam
TARGETS AND BASELINE
Baseline Timeframe: document the number of trees and seedlings already present in the area to be restored, prior to project field activities (sub-protocol 4). Comparable control sites encouraged (sub-protocol 2).
Target: No PPC Program- Wide target set. *Each partner will specify their project target number in their project-specific version)*
Rationale for Targets *(optional)***:** Note that the target will not necessarily equal the total number of trees restored, because there will be some mortality, and because not all trees restored will be planted.

Forest: 1.1.1 Tree Species Planted (Required)

Reported by Project Developers

Indicator Reference Sheet Forest: 1.1.1
Name of Indicator: 1.1.1: **# of trees planted, by species, per area under restoration**
Name of Result Measured: Objective 1, Outcome 1.1
DESCRIPTION
Precise Definition(s): The number of trees, by species (identified by scientific name) planted in the restored area.
Unit of Measure: tree
Data Type: numerical
Disaggregated by: tree species
Rationale for Indicator: This simple figure allows us to calculate the diversity and species richness of the PPC plantings in the restoration area, which are additional to any pre-existing vegetation (the pre-existing vegetation needs to be documented and described during the baseline, following sub-protocol 4). Lists of the species scientific names must be submitted so that we can get a cumulative program-wide number of species planted, without double counting. How many young trees (saplings, seedlings, usually prepared in tree nurseries but possibly also transplanted) were actively planted. Also, how many were directly seeded (distinction to be made between the two), into the restored area as a result of the PPC activities.
PLAN FOR DATA COLLECTION
Data Source: Counts of the number of young trees delivered to the sites and planted in the restored area, disaggregated by species scientific name. Lists of the species scientific names must be submitted so that we can get a cumulative program-wide number of species planted, without double counting.
Method of Data Collection and Construction: *see source above for 1.1.* Accompanying geotagged site photos and maps are welcome. Samples will be ground-truthed **Responsible for Data Collection and Construction:** Project developers **Related Sub-Protocols:** Sub-protocols 3, 4
Reporting Frequency: *see frequency above for 1.1.* **Data Collection Calendar:**

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y 2	Y2. 5	Y 3	Y 4	Y 5	Monthly
Field		Baseline								X

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI (lead): Isabel Hillman
At WRI: Tesfay Woldemariam

TARGETS AND BASELINE
Baseline Timeframe: document the number of trees and seedlings already present in the area to be restored, prior to project field activities (sub-protocol 3, 4). Comparable control sites are encouraged (sub-protocol 2). Same as 1.1 above
Target: No PPC Program- Wide target set. *Each partner will specify their project target number in their project-specific version). S*ame as 1.1 above.
Rationale for Targets *(optional)***:** It is very important to set a good target specific to each project, considering expected mortality rates. Even with the best planning and implementation, there will be some tree seedling mortality due to natural causes and disturbances, so, you must plan to plant more trees than you expect to see at the end of the project. However, some restoration methods to be used such as ANR do not require planting saplings.

Forest: 1.2 Trees Naturally Regenerated (Required)

Generated by Global Monitoring Team

Indicator Reference Sheet Forest: 1.2
Name of Indicator: 1.2: # of trees naturally regenerating per area under restoration
Name of Result Measured: Objective 1, Outcome 1.2
DESCRIPTION
Precise Definition(s): The number of trees naturally regenerating in the area under restoration
Unit of Measure: tree
Data Type: numerical
Disaggregated by: species
Rationale for Indicator: How many trees regenerated in the restored area as a result of the PPC activities. These trees most likely grew from the soil seed bank or new seed rain into the area, or possibly from living roots that had been constantly damaged and prevented from growing (such as by grazing or fire). This can occur in any restoration site, even the actively planted ones, although it is less likely in the agroforestry sites because natural regenerants may be removed as undesirable weeds in the agroforestry system.
PLAN FOR DATA COLLECTION
Data Source: Primary data collection and site shapefiles. See sub-protocol 4 which describes site surveys of a *stratified sample* of the restored area to be used to extrapolate values over the entire area.
Method of Data Collection and Construction: See sub-protocol 4 **Responsible for Data Collection and Construction:** Project developers **Related Sub-Protocols:** Sub-protocol 4
Reporting Frequency: annual, if possible, according to project monitoring plan and resources, to facilitate adaptive management. However, it is only required at years 2.5 and 5 as input into Impact Indicator A and Y5 number will take precedent over previous measures. **Data Collection Calendar:**

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
RS		Baseline							X	
Field		Baseline		*	*	X	*	*	X	

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI (lead): Starry Sprenkle-Hyppolite **At WRI:** Tesfay Woldemariam
TARGETS AND BASELINE
Baseline Timeframe: document the number of trees and seedlings already present in the area to be restored, prior to project field activities
Target: No PPC Program- Wide target set. *Each partner will specify their project target number in their project-specific version)*
Rationale for Targets *(optional)*:

Forest: 1.2.1 Tree Species Naturally Regenerated (Required)

Reported by Project Developers

Indicator Reference Sheet Forest: 1.2.1

Name of Indicator:1.2.1: # of trees naturally regenerated, by species, per area (at year 5*)*

Name of Result Measured: Objective 1

DESCRIPTION

Precise Definition(s): The number of naturally regenerated trees, ***disaggregated*** by species (identified by scientific name) in the restored area after five years. These are new trees that established themselves during that time through assisted natural regeneration (monitored as 1.2), but ***disaggregated by species*** *(this is a centrally extracted data derived from indicator 1.2, as long as species-specific data is given).*

Unit of Measure: tree

Data Type: numerical

Disaggregated by: tree species

Rationale for Indicator *(optional)***:** This figure allows us to calculate the 5-year benchmark for tree diversity and species richness of the PPC restored areas, a snapshot that will allow us to also predict and model forward to what the 'final' species composition of the area might be. Natural regeneration control sites should also be specified (see sub-protocol 4).

This is very important for adaptive management of restoration techniques. It's possible that not all of the species that were originally planted (indicator 1.1.1) will survive to Y5, which may indicate that they are not suitable for restoration using the current methods- a very important learning point. We may also observe that some species naturally regenerate at much higher rates than others, which can inform selection of species for enrichment plantings.

PLAN FOR DATA COLLECTION

Data Source: Site shapefiles determine the area. Extracted/compiled from the natural regeneration data (indicator 1.2) collected in year 2.5 and again in year 5 as the 'project endline', disaggregated by species.

Method of Data Collection and Construction: The number of tree species planted in the restored area and still surviving at Y5, plus any new species established during the 5 years of restoration. Compare to regeneration observed at 'control' sites when possible. Tree species identification requires some expertise. Botanists should support on site or remotely with samples brought in. Herbaria could be created/improved upon with additional support. Also provides the opportunity to explore/expand upon smartphone or drone image-based tree species identification technologies. Remote sensing of tree species identification is currently quite limited but could be improved with concerted work/linking to field surveying.

Responsible for Data Collection and Construction: Project developers

Related Sub-Protocols: Sub-protocols 4

Reporting Frequency: Baseline, 2.5 and 5 years after planting.
Data Collection Calendar:

	2010	Y0 (Before planting or time of planting, as appropriate)	6M O	Y1	Y2	Y2.5	Y 3	Y 4	Y 5	Monthly
Field		Baseline		*	*	X	*	*	X	

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI (lead): Starry Sprenkle-Hyppolite
At WRI: Tesfay Woldemariam

TARGETS AND BASELINE

Baseline Timeframe: Establish comparable control site for comparison and document the trees and saplings already on control and intervention site (s) prior to planting (see sub-protocols 2, 3, and 4).

Target: No PPC Program- Wide target set. *Each partner will specify their project target number in their project-specific version)*

Rationale for Targets *(optional)***:** This figure allows us to calculate the 5-year benchmark for tree diversity and species richness of the PPC restored areas, a snapshot that will allow us to also predict and model forward to what the 'final' species composition of the area might be.

This is very important for adaptive management of restoration techniques. It's possible that not all of the species that were originally planted (indicator 1.1.1) will survive to the 5 year point, which may indicate that they are not suitable for restoration using the current methods- a very important learning point. We may also observe that some species naturally regenerate at much higher rates than others, which can inform selection of species for enrichment plantings.

**Forest: 1.3 Nursery Production (Optional)

Reported by Project Developers

Indicator Reference Sheet Forest: 1.3
Name of Indicator: 1.3: # **of trees grown in nurseries, disaggregated by species**
Name of Result Measured: Objective 1, Outcome 1.3
DESCRIPTION
Precise Definition(s): The number of trees grown in nurseries for the PPC Program plantings, disaggregated by species. Trees are counted when they reach a specified size (details to be defined in sub-protocol 5).
Unit of Measure: tree
Data Type: numerical
Disaggregated by: tree species
Rationale for Indicator *(optional)***:** Meant to give an indicative measure of whether projects are on track to meet tree-planting targets, this metric needs to be tracked regularly to show progress. It is meant to capture how many young trees (saplings, seedlings) were prepared in tree nurseries to be planted in PPC projects. Trees should not be double counted in the monthly measurements. Trees raised by service providers under contract may be counted.
PLAN FOR DATA COLLECTION
Data Source: Nursery data reported and photographed
Method of Data Collection and Construction: *preferably integrated into mobile app* **Responsible for Data Collection and Construction:** Project developers **Related Sub-Protocols:** Sub-protocol 5
Reporting Frequency: Monthly during growing season **Data Collection Calendar:**

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
Field										*

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI: Salome Begeladze **At WRI (lead):** Ornanong Dow Martin
TARGETS AND BASELINE
Baseline Timeframe: n/a
Target: No PPC Program- Wide target set. *Each partner will specify their project target number in their project-specific version)*
Rationale for Targets *(optional)***:** Targets for this will vary greatly depending on the implementation modality. Projects focusing on ANR will have few, or no, trees in nurseries. Applied nucleation will have fewer than direct plantation, and that is expected.

PPC Program Impact B: Tree Cover Target Achievement (Required)

Generated by Global Monitoring Team

Indicator Reference Sheet PPC Program Impact B
Name of Indicator: PPC Program Impact Indicator B: % *attainment of target canopy cover for the restored area*
Name of Result Measured: Program Impact B, Objective 1
DESCRIPTION
Precise Definition(s): The percentage of tree ***crown cover*** in the restored area at the time of monitoring, compared to the ***target crown cover*** value established for the specific project. ***Crown cover:*** the portion of land covered by the crown or canopy of trees and is expressed as a percentage. It relates to the size and density of trees in an area.
Unit of Measure: %
Data Type: numerical
Disaggregated by: ecosystem type (extracted from WWF ecoregions map[5] no additional work required by implementors) and restoration intervention(s) used (required information- see types listed in Indicator 4.1)
Rationale for Indicator: The natural maximum tree crown cover of any region is defined by bioclimatic factors. The Brandt & Stolle (2020) method led to the creation of the Trees in Mosaic Landscapes (TML) dataset, which maps tree extent in Latin America and Africa. Where the data in Brandt & Stolle (2020) aligns with best-available scientific knowledge of potential tree cover (to be determined on a case-by-case basis), the target canopy cover established in Brandt & Stolle (2020) will be utilized to set the target. In other cases, such as those specified below, the target canopy cover will be determined on a per-project basis considering region and land-use specific constraints. For instance, when trees are planted in areas with continued agricultural production, such as in agroforestry systems, the maximum tree cover is constrained (see further discussion in 'rationale for targets' section)
PLAN FOR DATA COLLECTION
Data Source: Derived from **Indicator 1.4 (see next indicator box) and Project Targets**
Method of Data Collection and Construction: *remote sensing* **Responsible for Data Collection and Construction:** Global monitoring team (remote sensing components) **Related Sub-Protocols:** Sub-protocol 6

[5] https://ecoregions.appspot.com/

Reporting Frequency: Y5
Data Collection Calendar:

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
RS	Look back	Baseline							X	

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI: Alex Zvoleffi
At WRI (lead): John Brandt or Jessica Ertel

TARGETS AND BASELINE

Baseline Timeframe: For remote sensing look-backs on project sites of tree cover in 2010 to baseline, UMD tree cover loss and deforestation alerts will be used to provide trends and to establish that the land wasn't newly deforested (since 2010). For remote sensing baseline Y0 on tree cover within the project sites, 2020 10 m trees in mosaic landscapes data will be used as the best available data.

Target: At 5 years, 10% minimum cover, in line with the FAO definition of forest. Ultimate target cover in the restored area will vary according to site and restoration method used, striving toward the natural maximum tree density for the site region (see rationale for this indicator).

Rationale for Targets *(optional)***:** Target canopy cover: The natural maximum tree density of any region is defined by bioclimatic factors. To define this, we extract the target natural value for each project location using Brandt & Stolle 2020 global tree restoration potential map. Note that the potential for tree cover restoration, only goes up to 100% in tropical rainforest areas, visible around the edges of the Amazon Rainforest in South America.

If trees are being restored to a natural state, such as in natural regeneration, the 'natural maximum' forest cover becomes the final target canopy cover of reference, even if that level of cover is not expected to be attained in the 5 year monitoring window. Please note that this will almost always be less than 100% tree cover, especially in drier areas.

For instance, when trees are planted in areas with continued agricultural production, such as in agroforestry systems, the maximum tree cover is further constrained. In these cases, the target canopy cover must be determined by the land managers during the project planning process. Moderate to high targets might be set for shade agroforestry, with lower targets set for grazing and other cropping systems with sun-loving crops[16]. Tree crown cover increases as trees grow and mature, up to a natural or management-related limit as defined by the target. For example, trees planted at wide spacing into agroforestry plots might have a target of 50% tree cover (management-driven target), whereas a nearby forest undergoing assisted natural regeneration might have a target of 90% (natural-driven target), to match the natural forest cover in the area.

Forest: 1.4 Tree Cover Change (Required)

Generated by Global Monitoring Team

Indicator Reference Sheet Forest: 1.4
Name of Indicator: 1.4: % ***change in tree crown canopy cover in the area under restoration***
Name of Result Measured: Objective 1
DESCRIPTION
Precise Definition(s): The percentage of ***tree crown canopy cover*** in the area under restoration at the time of monitoring, compared to the baseline value established the year of planting.
Unit of Measure: %
Data Type: numerical
Disaggregated by: ecosystem type (extracted from WWF ecoregions map[6] no additional work required by implementors) and restoration intervention(s) used (required information- see types listed in Indicator 4.1)
Rationale for Indicator: See also rationale for PPC Program Impact Indicator B: % *attainment of target canopy cover for the restored area.* Changes in tree crown cover as a result of changed land management practices. Tree crown cover will increase as trees grow and mature, as well as increase in number (density) with new saplings developing visible crowns. ***This should also be compared to observed cover changes in a counterfactual control sites (when possible) with similar conditions, identified at the time of baseline establishment (sub-protocols 2).***
PLAN FOR DATA COLLECTION
Data Source: Remote Sensing of tree crown cover in restored area and 'control' area for each monitoring period compared to the baseline value established for the year planted utilizing the methodology in Brandt and Stolle (2020).
Method of Data Collection and Construction: *remote sensing* **Responsible for Data Collection and Construction:** Technical team (remote sensing components), Project developers (field components) **Related Sub-Protocols:** Sub-protocol 6
Reporting Frequency: Y5 **Data Collection Calendar:**

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y 2	Y2. 5	Y3	Y 4	Y 5	Monthly

[6] https://ecoregions.appspot.com/

RS	Loo kbac k	Baseline							X	

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI: Alex Zvoleff
At WRI (lead): John Brandt or Jessica Ertel

TARGETS AND BASELINE

Baseline Timeframe: remote sensing for Y0.

Target: No PPC Program- Wide target set. *Each partner will specify their project target number in their project-specific version)*

Rationale for Targets *(optional)*:

Forest: 1.5 Survival (Required)

Generated by Global Monitoring Team

Indicator Reference Sheet Forest: 1.5
Name of Indicator: 1.5: **% survival of planted trees per area under restoration**
Name of Result Measured: Objective 1, Outcome 1.2
DESCRIPTION
Precise Definition(s): The number of trees of each tree species planted in the area under restoration that are still living during the year of monitoring, divided by the total number planted to give a percentage. This is survivorship, the opposite of mortality.
Unit of Measure: %
Data Type: numerical
Disaggregated by: tree species
Rationale for Indicator: Tree survival rate is a very important indicator to consider 6 months or 1 year after planting, to determine whether re-planting efforts are needed (adaptive management). A simplified way to do this is described in the Site-Walkthrough Protocol (Annex 9). There may be early mortality within the first weeks after planting due to poor seedling stock or seedling damage during the transportation and planting process. This can be checked up to one month after planting, and trees planted to replace the failed plantings. In this case, if they are replaced immediately, the originally planted trees that died do not need to count as 'deaths', but nor should the replacement trees be counted as additional trees planted, to avoid inflating the number of trees expected to be present in the restored area). After this window of potential replacement due to human/mechanical error in the first months, further deaths should be counted against survivorship, even within the first year. This indicator is for the 'official' survivorship, determined at Y2.5 and Y5 from the vegetation monitoring (Sub-Protocol 4). Natural survival (the opposite of mortality/death) rates vary greatly due to the species planted and the site conditions during the time after planting (good rainfall year vs. drought can cause significant 'year effects'. Survival can be impacted also by competition with other plants and disturbances (see 4.2 below) that can kill trees.
PLAN FOR DATA COLLECTION
Data Source: Detailed planting records, preferably including site maps of initial plantings, in order to know where trees were planted in the sites. See sub-protocol 4 which describes site surveys of a *stratified sample* of the restored area to be used to extrapolate values over the entire area.

Method of Data Collection and Construction: *Procedures for remote sensing using satellite imagery and site survey sampling are described in sub-protocols 1 and 4.* Depending on project resources available for field monitoring, more intensive sampling, or full site surveying, is allowable, but the details of the methods used must be shared

Responsible for Data Collection and Construction: Global monitoring team (remote sensing components), Project developers (field components)

Related Sub-Protocols: Sub-protocols 1, 4

Reporting Frequency: each establishment year (@6 months optional, end of Y1 required), mid-term (Y2.5) and final (year 5-required)

Data Collection Calendar:

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
RS									X	
Field		Baseline (existing trees)				X			X	

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI (lead): Starry Sprenkle-Hyppolite

At WRI: Tesfay Woldemariam

TARGETS AND BASELINE

Baseline Timeframe: NA- although the existing trees and saplings already on site at time of planting must be documented (sub-protocol 3), so that survivorship can be measured afterwards.

Target: No PPC Program- Wide target set. *Each partner will specify their project target number in their project-specific version)*

Rationale for Targets *(optional)***:** The goal may be to have similar rates of growth, recruitment and survival as regenerating native forests, referencing published studies. Survival targets may vary per species planted, however, an overall target for survivorship for the restored area should be given. Survivorship targets over 80% are considered highly optimistic. Some species are more 'hardy' than others, but the tree species that have higher mortalities might be the most important ones for biodiversity and therefore prioritized in plantings- even with low survival rates.

Forest: 1.6 Disturbances (Required)

Reported by Project Developers

Indicator Reference Sheet Forest: 1.6
Name of Indicator: 1.6: # of major disturbances observed per area under restoration (optional, *unless disturbance damages >25% of restored trees*)
Name of Result Measured: Objective 1, provides explanatory power for poor results in Outcome 1.2, if they occur
DESCRIPTION
Precise Definition(s): Count of occurrences of major disturbances with basic information regarding the disturbance occurrence time period, type, intensity, and extent.
Unit of Measure: count
Data Type: numerical
Disaggregated by: time period, type, intensity, and extent.
Rationale for Indicator: Major disturbances may include fire/flood/hurricanes, uncontrolled grazing/herbivory, pest outbreaks, and intentional clearing. *Invasion of sites by non-native grasses or trees is not noted as a disturbance, but in management practices.* Some disturbances are natural, some are human-driven- and all can cause major setbacks to tree restoration efforts, and so they must be reported if and when they occur. Any disturbance causing mortality or significantly impaired growth to more than 25% of the restored trees or restored area must be reported. Details on the disturbance such as the time period, type of disturbance by pre-determined category, average intensity of the disturbance over the area (light, moderate, severe), and extent of disturbance (% of restored area impacted) will be recorded. Disturbances may need to trigger adaptive management.
PLAN FOR DATA COLLECTION
Data Source: Data collection form (or mobile app module) to report disturbance time period (approximately when the disturbance occurred), type (from proscribed list and definitions), extent (area covered) and intensity.
Method of Data Collection and Construction: *see source above.* Geotagged photos for verification. Intensity ratings: Light- some damage to foliage, but likely to recover this season; Moderate moderate damage to foliage, especially when including damage to apex, that will impact future growth form or stunt future growth; Severe- severe damage to foliage likely causing mortality or requiring a complete re-sprout). If there are multiple disturbances, each should be assigned an intensity and extent. Remote sensing can be used for large scale disturbances such as fires, and aerial imagery could be useful in determining extent and intensity for some types of disturbance **Responsible for Data Collection and Construction:** Global monitoring team (remote sensing components), Project developers (field components)

Related Sub-Protocols: Sub-protocol 7

Reporting Frequency: Monthly (report no disturbances, if there are no qualifying disturbances)

Data Collection Calendar:

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
RS	Look back period									
Field										X

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI: Isabel Hillman
At WRI (lead): Tesfay Woldemariam

TARGETS AND BASELINE

Baseline Timeframe: If possible, note the history and causes of disturbance on the site with the implementing partner, prior to the restoration intervention (potential remote sensing/historical investigations). This should have been described in the application, and site selection. Mitigation of probable disturbances should be considered in the site risk assessment. Establishment of remote sensing baselines/histories will depend on available data.

Target: 0 for "controllable" disturbances such as localized fires, grazing. Targets can't be set for disease or pest outbreaks, hurricanes and large fires.

Rationale for Targets *(optional)***:** Targets are not usually set for negative occurrences- unless as part of adaptive management you are seeking to reduce their frequency- but this requires a baseline establishment (can be done after Y1).

Carbon Benefits: 2 (Required)

Generated by Global Monitoring Team

Indicator Reference Sheet Carbon Benefits: 2
Name of Indicator: 2.1: Estimated # Tons of CO_2 sequestered (by year 5)
Name of Result Measured : Objective 2
DESCRIPTION
Precise Definition(s): Estimate of change in ecosystem carbon (stocks) per unit area and time stored, also understood as absolute carbon gain before additionality constraints are applied as a consequence of restoration activities. Due to resource constraints, the estimate will be limited to aboveground and belowground carbon in trees growing as a result of program interventions. Since additionality is not calculated, the estimate of carbon stocks cannot be used to make carbon claims.
Unit of Measure: tons of CO2
Data Type: numerical
Disaggregated by: Restoration intervention(s) used (required information- see types listed in Annex 3)
Rationale for Indicator: Ecosystem C stocks include main pools to be determined by local ecosystem and intervention activities. Woody biomass C (above and below) is recommended to be estimated at a minimum. Estimates based on changes in land cover and proposed activities i. Above + Belowground Biomass: As trees grow, above and belowground woody biomass stores a significant amount of C. Using a global database of carbon dioxide removal rates from different forest landscape restoration activities (https://doi.org/10.1038/s41586-020-2686-x) projects can estimate the potential sequestration of their activities. Using the restoration module in Trends.Earth, these estimates can be produced by only defining a polygon with the intervention area and the time since restoration activity started. To be conservative in our estimates of carbon, we will us the bottom end of the 95% confidence interval provided by the Cook-Patton dataset and 5 year growth curves Disclaimer: the methods outlined in this protocol provide an estimate of carbon sequestration, but there are many more rigorous calculations completed in the process to attain carbon credits. This calculation cannot replace those, and this calculation does not account for all factors considered in carbon credits, such as leakage and additionality.

PLAN FOR DATA COLLECTION

Data Source:
Above + Belowground Woody Biomass
Tier 1: Restoration site polygons shared by project developers (sub-protocol 14) are uploaded into Trends.Earth for processing.

Other platforms for estimation of carbon potential of restoration areas are currently in development (I.e. restor.eco), using latest available remotely sensed data. This is an important frontier in research, and we plan to continue to evaluate the potential benefit of switching over to a more accurate platform in the future. The data migration would be handled by the global monitoring team, with the permission of implementors.

Method of Data Collection and Construction: see source above. In order to assess the potential carbon sequestered by PPC activities, an estimate of C sequestration over a 5 year period will be conducted. Global datasets can be used to produce high level estimates (see example below from Trends.Earth). Analysis in Trends.Earth will be completed by CI scientists in the Moore Center
Responsible for Data Collection and Construction: Global monitoring team
Related Sub-Protocols: Sub-protocol 8

Reporting Frequency: Year 5
Data Collection Calendar:

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
RS		Baseline							X	

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI (lead): Alex Zvoleff
At WRI: TBD

TARGETS AND BASELINE

Baseline Timeframe: TBD

Target: No PPC Program- Wide target set.

Rationale for Targets *(optional)***:**

Social/Community Benefits: 3.1 Socioeconomic Restoration Partners (Required)

Reported by Project Developers

Indicator Reference Sheet Social/Community Benefits**: 3.1**
Name of Indicator: 3.1 # of socioeconomic restoration partners, disaggregated by direct and indirect, gender, age, and ethnicity, per area under restoration
Name of Result Measured: Objective 3, Outcome 3.1
DESCRIPTION
Precise Definition(s): Direct socioeconomic restoration partners: Any person who received intentional and direct socio-economic support from PPC Program activities and is aware that they received support. Support may be monetary or non-monetary, and include partnerships created as a direct result of the project that yield economic benefits during the project. **Indirect socioeconomic restoration partners**: Family members of direct socioeconomic restoration partners who may have improved education/nutrition/health status etc. as a result of the family member's participation, as well as persons with involvement with local organizations and partnerships that may bring jobs in the future
Unit of Measure: people
Data Type: numerical
Disaggregated by: direct and indirect each disaggregated by socioeconomic benefits type, and then further by gender, ethnicity, and age range
Rationale for Indicator: This may cover a range of socioeconomic benefits including potentially it is a count of the people who meet any of the following criteria: · A person with an increased income (count of individuals with direct job creation) · A person receiving payments (or in-kind benefits) · A member of a community with a newly secured land title, increased protection of traditional livelihoods or customary rights . A member of a cooperative or community who received increased capacity or training · A person (community member, national protected area staff, implementing organization or government employee) who received increased capacity or training. Restoration can be key in helping climate-vulnerable communities adapt to the impacts of climate change and improving livelihoods.
PLAN FOR DATA COLLECTION
Data Source: This indicator is calculated by program staff through the proactive gathering of attendance and other information on people benefitted by their programs, and manually submitted through a data collection form (See below for a preliminary template). More in depth data on socioeconomics can be collected through optional household surveys (sub-protocol 10).
Method of Data Collection and Construction: compilation maintaining disaggregation **Responsible for Data Collection and Construction:** Project developers

Related Sub-Protocols: Sub-protocol 9

Reporting Frequency: Annual
Data Collection Calendar:

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
RS/GIS		Baseline							X	
Field				X	X		X	X	X	X
Household Survey		*				*				*

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI (lead): Arundhati Jagadish
At WRI: Ornanong Dow Martin

TARGETS AND BASELINE

Baseline Timeframe: NA

Target: No PPC Program- Wide target set. *Each partner will specify their project target number in their project-specific version)*

Rationale for Targets *(optional)*:.

*see sample data collection sheet in sub-protocol 9

Social/Community Benefits: 3.1.1 Work Created (Required)

Reported by Project Developers

Indicator Reference Sheet Social/Community Benefits**: 3.1.1**
Name of Indicator: 3.1.1: **# of Person-Days of Work Created per area under restoration**
Name of Result Measured : Objective 3, Outcome 3.1
DESCRIPTION
Precise Definition(s): The number of hours per year worked by project participants contributing to the PPC project, expressed in 8-hour person-days. See also this document by FAO: [17]
Unit of Measure: person-days
Data Type: numerical
Disaggregated by: (if possible): role (type of work/job i.e. planting, maintenance, service…), compensation (paid/volunteer), project design (e.g., private, communal, in collaboration with government entity), sex, age category, and ethnicity (do they identify as indigenous or not, and further by categories used within the national context of each implementing partner potentially around language for example)
Rationale for Indicator: Reforestation can provide important socioeconomic benefits, including job creation. This indicator equates work performed for the PPC project to person-days, which are a standardized number, much easier to interpret than the vague term of "job" which could have any duration from a few hours to a year. There are multiple kinds of work, from paid or voluntary- we will disaggregate as much as possible the different kinds of work. This is also an entry point for monitoring equity of labor in the sense of avoiding child labor, encouraging women's participation in the workforce, and offering economic opportunities to local and indigenous peoples. Restoration can be key in helping climate-vulnerable communities adapt to the impacts of climate change and improving livelihoods.
PLAN FOR DATA COLLECTION
Data Source: data forms filled out by project developers
Method of Data Collection and Construction: see above **Responsible for Data Collection and Construction:** Project developers **Related Sub-Protocols:** Sub-protocol 11
Reporting Frequency: Per site, and monthly **Data Collection Calendar:**

	2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y 2	Y2. 5	Y3	Y 4	Y 5	Monthly

Field										X

**X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI: Arundhati Jagadish
At WRI: Ornanong Dow Martin

TARGETS AND BASELINE

Baseline Timeframe: As this is a new project, the baseline for jobs created due to the project is by definition 0. However, for the comparable, counterfactual control sites identified for the tree cover monitoring, the employment situation will also be quantified by counting total number of individuals with and without work in the comparable community, adjacent to the control site, to establish the actual 'background' control rate of increase or decrease in number of jobs. A similar count must be done in the participating community at the same time.

Target: No PPC Program- Wide target set. *Each partner will specify their project target number in their project-specific version)*

Rationale for Targets *(optional)***:**

* see sample data collection sheet in subprotocol 11

Social/Community Benefits: 3.2 Ecosystem Services (Required)

Generated by Global Monitoring Team

Indicator Reference Sheet : Social/Community Benefits**: 3.2**
Name of Indicator: 3.2 **# of ecosystem service restoration partners per area under restoration** ***(centrally extracted data that requires correctly recorded shapefiles of each restored area,*** **adapted from CI standard metric)**
Name of Result Measured: Objective 3, Outcome 3.2
DESCRIPTION
Precise Definition(s): This metric counts any person who received ecosystem service impacts from PPC Program's actions. This applies whether or not the person is aware they received the impact and includes any person who uses natural resources the project/activity maintains or enhances such as water and energy.
Unit of Measure: people
Data Type: numerical
Disaggregated by: (if possible) type of ecosystem service, gender, ethnicity, and age
Rationale for Indicator: Reforestation improves watershed functioning by restoring hydrological flows (increasing infiltration, reducing runoff and erosion, etc.), moderating local climate (especially temperature), and providing pollination and non-timber forest products to surrounding population, to name only some of the benefits. Restoration can be key in helping climate-vulnerable communities adapt to the impacts of climate change.
PLAN FOR DATA COLLECTION
Data Source: Site Shapefiles.
Method of Data Collection and Construction: Centrally extracted data derived from site shapefiles and population data. There are no detailed data required from implementors for this metric. Implementors may follow additional, optional value-added protocols, such as the one in development for number of people benefitting from water provisioning. More in depth data on ecosystem services can be collected through optional household surveys (sub-protocol 10). **Responsible for Data Collection and Construction:** Global monitoring team **Related Sub-Protocols:** Sub-protocol 13
Reporting Frequency: Year 5 **Data Collection Calendar:**

2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly

RS/GIS	Baseline							X	
House hold Survey	*				*			*	

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI (lead): Isabel Hillman
At WRI: John Brandt

TARGETS AND BASELINE

Baseline Timeframe: Y0

Target: No PPC Program- Wide target set. *Each partner will specify their project target number in their project-specific version)*

Rationale for Targets *(optional)***:**

**Social/Community Benefits: 3.2.1 Freshwater (Optional)
Reported by Project Developers

Indicator Reference Sheet : Social/Community Benefits**: 3.2.1**
Name of Indicator: 3.2.1 **# people directly benefiting from improved freshwater quality or quantity**
Name of Result Measured: Objective 3, Outcome 3.2.1
DESCRIPTION
Precise Definition(s): This metric counts any person who received freshwater impacts from PPC Program's actions.
Unit of Measure: People
Data Type: numerical
Disaggregated by: (if possible) type of ecosystem service, gender, ethnicity, and age
Rationale for Indicator *(optional)***:** Reforestation can improve watershed function and improve water quality or quantity in projects that occur along a waterway or have a watershed restoration design. Improved water quality or quantity can have positive impacts on the local peoples though easier access to usable water for consumption, agriculture, etc.
PLAN FOR DATA COLLECTION
Data Source: Household survey
Method of Data Collection and Construction: Household surveys **Responsible for Data Collection and Construction:** Project developers **Related Sub-Protocols:** Sub-protocol 10
Reporting Frequency: TBD **Data Collection Calendar:**

2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
	*				*			*	

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI: Maira Berreza **At WRI:** TBD
TARGETS AND BASELINE
Baseline Timeframe: Y0
Target: No PPC Program- Wide target set.
Rationale for Targets *(optional)***:**

Management: 4.1 Hectares in Restoration (Required)

Generated by Global Monitoring Team

Indicator Reference Sheet Management: 4.1
Name of Indicator: 4.1: # of hectares under restoration, by ecosystem type[7] and restoration intervention ***(centrally extracted data that requires correctly recorded shapefiles of each restored area-* CI standard metric)**
Name of Result Measured: Objective 4, Outcome 4.1
DESCRIPTION
Precise Definition(s): The total land or water surface area (measured in hectares) with active PPC program restoration interventions in planting or monitoring stages, defined using the GIS shapefiles of the restoration activities.
Unit of Measure: hectares
Data Type: numerical number of hectares extracted from shapefiles of areas under restoration
Disaggregated by: ecosystem type (extracted from WWF ecoregions map- no additional work required by implementors) and restoration intervention(s) used (required information- see types listed in Indicator 4.1)
Rationale for Indicator: This indicator captures the hectares of land and coastal areas that are undergoing restoration and that are sequestering carbon over the assessment period. Restoration activities are eligible activities (See Annex 3) that result in an increase in the ecological integrity of an area in a way that is explicitly aligned with the long-term goals of the area's stakeholders. Ecosystems include forest, mangroves, wetlands, as well as certain human-modified landscapes that are striving to recuperate ecological integrity (such as ecologically managed forests, agroforestry areas, etc.). Examples of restoration: An active mangrove restoration site where trees have been planted to improve vegetative cover and result in carbon sequestration, An area of formerly degraded land that is being actively protected in order for the pre-existing seed layer to germinate and begin naturally restoring vegetative cover, The interplanting of trees and crops in agricultural land in a way that increases the soil water retention, nutrient cycling, and biodiversity of the area and increases crop yield.
PLAN FOR DATA COLLECTION
Data Source: This indicator will be calculated/extracted using the required polygons or shapefiles of area restored at each restoration site, preferably from walking the boundaries of the restored area, but also possibly generated using known mapping of the area(s) – see sub-protocol 14.
Method of Data Collection and Construction: *see source above.* A mobile application will eventually be developed for the mapping. Accompanying geotagged site photos and maps are welcome. Samples will be ground-truthed **Responsible for Data Collection and Construction:** Project developers (provide

[7] https://ecoregions.appspot.com/

shapefiles), Technical team (extracts hectares) **Related Sub-Protocols:** Sub-protocol 14
Reporting Frequency: Defined/reported at site establishment, new sites centrally compiled monthly **Data Collection Calendar:**

	2010	Y0 (Before planting or time of planting, as appropriate)	6M O	Y1	Y2	Y2. 5	Y3	Y 4	Y5	Monthly
Field		X								
RS		X								

X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory
Individual(s) Responsible at CI: Jacob Bukoski **At WRI (lead):** Tesfay Woldemariam
TARGETS AND BASELINE
Baseline Timeframe: NA
Target: 100,000 ha, PPC Program- Wide *(will be disaggregated for each partner in their own sheets)*
Rationale for Targets *(optional)*:

Management: 4.2 Cost per Tree (Required)

Generated by Global Monitoring Team

Indicator Reference Sheet Management:4.2
Name of Indicator: $ cost per tree grown by restoration intervention type
Name of Result Measured: Objective 4, Outcome 4.2
DESCRIPTION
Precise Definition(s): This indicator includes the cost of implementing partner costs, restoration execution costs, and 5 years of monitoring from 2020-2025, divided by the number of trees restored at project site (as determined by the number at year 5, ie. PPC Impact Indicator A). Costs are then normalized by country using purchasing power parities (PPP)
Unit of Measure: USD equivalent, normalized by country
Data Type: numerical
Disaggregated by: (central processing)- Restoration intervention type, geography
Rationale for Indicator: Cost information on different restoration strategies is urgently needed to enhance restoration investment. Financial investors lack the information needed to back forest restoration strategies other than tree planting. Monitoring cost of tree grown by restoration intervention type as a part of this global portfolio can help the global restoration community to identify and refine low-cost, high-impact restoration models. Where monitoring efforts do exist in this space (TEER, etc), they have not measured restoration strategy-specific costs, and so an additional granularity of analysis is needed to encourage alternative restoration strategies to the traditional tree-planting norm. Internal rationale: It is essential to quantitatively analyze the cost effectiveness of the different methods used in the PPC program to understand its cost-effectiveness and allow for adaptive management and learning in shaping recommendations for subsequent years and initiatives. External rationale: This portfolio also presents a unique opportunity to offer information on costs of different restoration strategies in different contexts around the world to the larger restoration community. Note: no specific cost information will be attributed to specific groups or organizations in public information, but rather aggregated to provide general learnings.
PLAN FOR DATA COLLECTION
Data Source: Project budgets and financial reports
Method of Data Collection and Construction: Numerator: PPC site project contract amount, including implementing partner costs, restoration execution costs, and 5 years of monitoring. Denominator: trees restored (survived after 5 years and by restoration strategy, ie. PPC Impact Indicator A)

Responsible for Data Collection and Construction: The data collection for this indicator involves a conversation between project operations staff and project technical leads to create estimates for percentage of line items spent by restoration strategy. This information is then embedded in the format of financial reporting. **Related Sub-Protocols:** NA
Reporting Frequency: Budget at beginning of project, and quarterly in financial reports
Individual(s) Responsible at CI (lead): Ruth Metzel **At WRI:** Ornanong Dow Martin
TARGETS AND BASELINE
Baseline Timeframe: n/a
Target: $2/tree portfolio average
Rationale for Targets *(optional)***:** Donor objective for cost-effective restoration; adaptive management of portfolio to produce efficient results

**Biodiversity Benefits: 5 (Optional)
Reported by Project Developers

Indicator Reference Sheet : Biodiversity Benefits**: 5**
Name of Indicator: 5.1 % change in species richness within class, 5.2 Average % change in abundance within class, 5.3 Occupancy Index, 5.4 Community Similarity Index
Name of Result Measured: Objective 5, Outcome 5.1
DESCRIPTION
Precise Definition(s): These indicators provide insights into species richness, species abundance, relative abundance, and community structure.
Unit of Measure: Fauna
Data Type: numeric
Disaggregated by: Class
Rationale for Indicator: These indicators provide insights into the impacts of restoration on local biodiversity, an important potential co-benefit of restoration.
PLAN FOR DATA COLLECTION
Data Source: Camera traps, acoustic sensors, eDNA, direct observations
Method of Data Collection and Construction: One or multiple of the data collection methods specified in sub-protocol 15 are used to collect data on biodiversity at baseline, Y2.5 and Y5 (to match vegetation monitoring data collection timelines) **Responsible for Data Collection and Construction:** Project developers **Related Sub-Protocols:** 15
Reporting Frequency: TBD **Data Collection Calendar:**

2010	Y0 (Before planting or time of planting, as appropriate)	6MO	Y1	Y2	Y2.5	Y3	Y4	Y5	Monthly
	*				*			*	

**X denotes mandatory monitoring, * denotes optional monitoring. Baselines are always mandatory

Individual(s) Responsible at CI: Jorge Ahumada **At WRI: TBD**
TARGETS AND BASELINE
Baseline Timeframe: Y0
Target: No PPC Program- Wide target set.
Rationale for Targets *(optional)***:**

ANNEX 7. SUB-PROTOCOLS DEVELOPED IN 2020-2022

Sub-Protocol	Indicator	Protocol Subject	Description	Responsible Institution
1	A	Tree Counting using Remote Sensing	Remote sensing baseline establishment and evaluation of # of trees restored (survived and crowded in at Y5). *Applied only to projects agreed upon by CI and WRI (typically Tier 1 only)*	WRI
2	1.1	Control Monitoring, Optional landscape level control sites	Siting and establishment of landscape level control units, siting and establishment of control plots, and monitoring methods for baseline and monitoring	CI
3	1.1	Site establishment	How to complete a site establishment form prior to planting, including documenting planting locations while allowing for species disaggregation	WRI/CI
4	1.2	Vegetation Monitoring	Siting of monitoring plots and field-based vegetation monitoring suitable for baseline establishment and monitoring all restoration methods including natural regeneration, and subsequent calculations of survival rates. It also gives optional guidance for carbon stock assessment	CI
5	1.3	Optional Nursery Tree Counting	Specifying age/stage of counting, documentation of delivery to planting sites	WRI
6	B	Canopy Cover	Remote Baseline Establishment and Evaluation of % attainment of canopy cover, look back period	WRI
7	1.6	Field Disturbance Monitoring	Tracking and reporting of disturbances during the active project period	CI

8	2	Carbon	Estimation method update	CI
9	3.1	Socioeconomi cRestoration Partners	Socioeconomic restoration partner counting and disaggregation, baseline establishment	CI
10		Optional Household Surveys	Defining a sampling group and conducting household surveys for baseline, participating, and control groups	CI
11	3.1.1	Work Quantification	How to report work days	CI
12	3.2	Ecosystem Services	Determining the number of people potentially impacted by ecosystem services changes. Questions in household survey (sub-protocol 10)	CI
13	3.2	Optional Freshwater Monitoring	Criteria for including freshwater monitoring. Methods for analyzing freshwater quality and quantity. Questions in household survey (sub-protocol 10)	CI
14	4.1	Creating Shapefiles	Creating and uploading project and site shapefiles	WRI
15	5	Optional Faunal Biodiversity	Methodological options and sampling designs for monitoring faunal biodiversity	CI
16	NA	Look back period	Analysis of restoration sites for disturbance including deforestation to 2010	WRI

All protocols pertain to required components of monitoring in all projects, unless specifically designated as optional

ANNEX 8. GLOSSARY

Additionality - Evaluates the degree to which an intervention causes a benefit above and beyond what would have happened in a no-intervention (business as usual) baseline scenario.

Agroforestry – the intentional mixing and cultivation of woody perennial species (trees, shrubs, bamboos) alongside agricultural crops in a way that improves the agricultural productivity and ecological function of a site.

Applied Nucleation / Tree Islands – A form of enrichment planting where trees are planted in groups, clusters, or even rows, dispersed throughout an area, to encourage natural regeneration in the matrix between the non-planted areas. Guide[8] available.

Assisted Natural Regeneration – the exclusion of threats (i.e. grazing, fire, invasive plants) that had previously prevented the natural regrowth of a forested area from seeds already present in the soil, or from natural seed dispersal from nearby trees. This does not include any active tree planting. Ideally, the specific method(s) of threat control intervention(s) used would be specified so that the relative effectiveness can be evaluated (i.e., whether fencing was installed to control grazing, how often invasive plants were removed, etc.).

Controllable Disturbance- Disturbances to the restoration site that project developers can influence (Ex: grazing, localized fires)

Crowded in - Refers to natural regeneration and/or growth from planted seeds

Enrichment Planting– In restoration, the strategic reestablishment of key tree species in a forest that is ecologically degraded due to lack of certain species (differs from forestry definition).

Global Monitoring team - refers to staff at Conservation International or the World Resources Institute who are responsible for completing remote sensing analyses or processing field data for the PPC program

Introduced Species - A plant introduced with human help (intentionally or accidentally) to a new place or new type of habitat where it was not previously found

Invasive Species - A plant that is both non-native and able to establish on many sites, grow quickly, and spread to the point of disrupting plant communities or ecosystems.

Land under restoration (direct) - Land within the boundaries of the restoration site, shared in shapefiles, where restoration activities are taking place

Land under restoration (indirect) - Land that benefits from restoration activities, but is not within the restoration site boundaries

[8] https://www.conservation.org/research/applied-nucleation-report

Leakage (socioeconomic) - Occurs when interventions displace emissions to other locations, times, or forms. For example, leakage occurs in forest carbon offset credit programs when a reduction in timber harvesting at a project site causes timber harvesting to increase somewhere else to meet demand

Mangrove Tree Restoration – specific interventions in the hydrological flows and/or vegetative cover to create or enhance the ecological function of a degraded mangrove tree site.

Native Species - A plant that is a part of the balance of nature that has developed over hundreds or thousands of years in a particular region or ecosystem

Naturalized Species - A non-native plant that does not need human help to reproduce and maintain itself over time in an area where it is not native, and so has established a more or less permanent presence in the ecosystem

Neutral Species - A plant that is non-native but does not cause harm to the local ecosystem

Plantations – the planting of seedlings over an area with little or not forest canopy to meet specific goals

Peat Restoration – The re-establishment of vegetative cover that will lead to active peat formation. This often involves a mix of planting, seed dispersal, and engineering solutions to pre-disturbance reestablish hydrological dynamics. Threat exclusion is usually a major intervention.

Project Developer – The person(s) or organization(s) who are implementing a restoration project

Seed Dispersal/Direct Seeding – The active dispersal of seeds (preferably ecologically diverse, native seed mixes) that will allow for natural regrowth to occur, provided the area is protected from disturbances. This may be done by humans or drones- implies active collection and dispersal, not natural dispersal by local seed dispersers that is part of natural regeneration processes. This is a differentiated category from planting young trees.

Silvopasture – The intentional mixing and cultivation of woody perennial species (trees, shrubs, bamboos) on pasture land where tree cover was absent in a way that improves the agricultural productivity and ecological function of a site for continued use as pasture

Site - A site must be a contiguous plot of land, that is subdivided into sections based on intervention type (required). The site can also be subdivided by other strata (optional, see protocol 5 on vegetation monitoring for details on strata). The subdivision(s) should be specified in the attribute table. If the restoration project contains disparate plots of land, then there are automatically more than 1 site

Survived – Planted saplings that live through the monitoring period

Wetland/Riparian Restoration – Specific interventions in the hydrological flows and vegetative cover to improve the ecological function of a degraded wetland or riparian area.

ANNEX 9. SITE WALKTHROUGH GUIDANCE

Provided by Isabel Hillman and Starry Sprenkle-Hyppolite, CI.

Timeframe: 6 months after restoration activities begin

Methodology

This walk through of the sites should cover at least 25% of the restoration site, with more effort where planting activities occurred (for example, if applied nucleation was used, then the walk through should focus on nucleation locations), and should include checking for:

1) **Disturbances** (significant disturbances should be reported in the monthly reporting). Note any disturbances observed, even if they are minor, and include descriptions of actions needed to address disturbances, if applicable.

2) The presence of **invasive species**, including documentation of any actions needed to manage invasives, and details on how the presence of invasives is/could affect planted trees. Baseline levels of invasive species are documented in the Baseline and Site Establishment form, and the level of invasives at the walkthrough should be compared to baseline. Higher presence to invasive species than at baseline should trigger management activities.

3) The success of previous **maintenance** and documentation of additional maintenance actions needed.

4) **Survival of planted trees and evidence of natural regeneration**. Details about evidence of seedling health (or die-off), and presence (or lack of) natural regeneration, including information on which species are healthy, dying, regenerating etc., with estimates of survival and natural regeneration rates, if possible. If direct seeding methods were used, this is a chance to estimate the success rate (number of trees growing vs. number of seeds planted). Descriptions of further actions needed to compensate for die-offs, etc.

Documentation of this walk through, with consideration of each item above including actions that will be taken as part of adaptive management, should be shared as part of the technical narrative and photos showing the details mentioned in the items above should be submitted in the technical narrative of monthly reporting in the integrated monitoring platform. At least 1 photo per applicable item above, with a description as part of the technical narrative is recommended.

SUB-PROTOCOLS

For PPC Program Use

SUB-PROTOCOL 1: REMOTE SENSING OF TREES

Subprotocol 1: Remote Sensing of Trees
Remote baseline establishment and evaluation of # of trees restored

Provides guidance for indicator A: # of trees restored (survived and crowded-in at year 5)

Created by Tesfay Woldemariam at WRI

Guidance for Users

A brief guide on how to collect tree count data using satellite imagery for the global monitoring team. The subprotocol also highlights formulas for calculating derivative analyses using tree count such as survival and number of trees restored per project area. This subprotocol is used for setting baseline (defined as at the planting date) and measuring progress from baseline at year 5 (end of project cycle).

This methodology is applied to a subset of PPC projects. The specific projects are selected each year, but in general this methodology should be applied at least to Tier 1 projects, including all flagships.

The results generated from this analysis, which is limited to trees that are large enough to be visible in the imagery, will be compared with the field vegetation monitoring data (subprotocol 4) which provide more detailed information from a smaller area. The field data includes counts of trees in multiple size classes including trees that are 1<10 cm DBH, which may not be detectable with the remote sensing approach. Whereas the field vegetation monitoring is only done on one sample area per hectare, the remote sensing of trees is done taking far more samples distributed across the entire area under restoration information from both methodologies will be useful in informing the final # of trees restored for the program.

Importance

This subprotocol generates data on the number of trees of a certain size visible with remote sensing at the date of planting (baseline and year 5), developed from best and most timely available satellite data at plot level granularity; it is the basis for tracking progress towards the target number of trees to be grown in the site. This data is also important input for survival estimation. The size of trees that can be seen is highly dependent on the spatial resolution of imagery being used for data collection. MAXAR[9] imagery which has up to 30cm spatial resolution is being used when available for tree counting. This theoretically implies that objects bigger than

[9] Maxar Blog

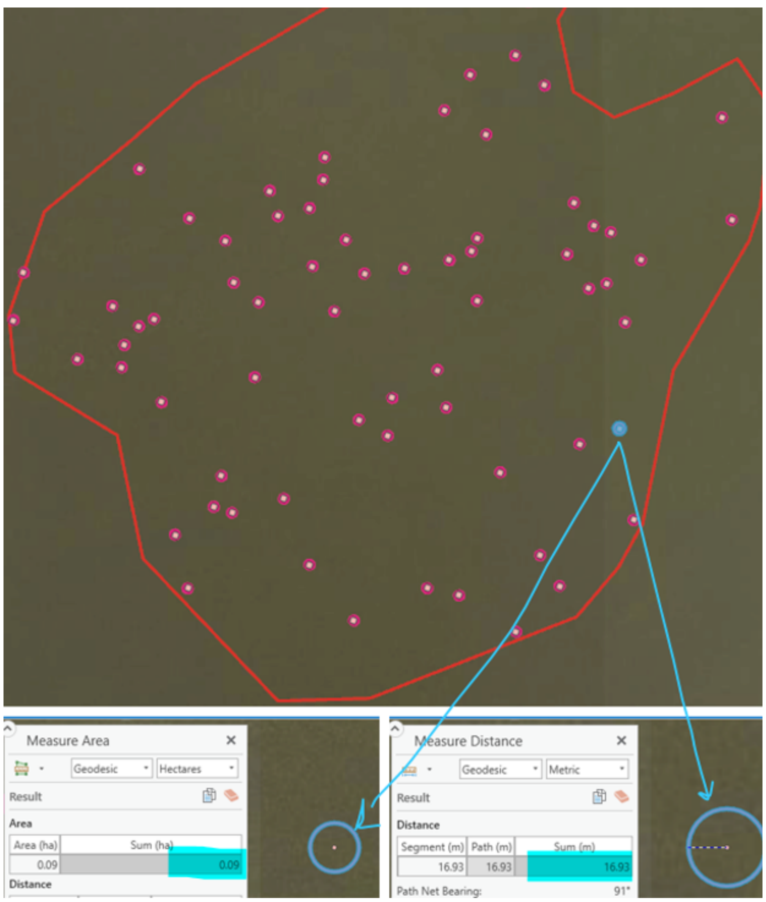
30cm*30cm can be detected. However, for the baseline we are focusing on bigger/mature trees and hence, not counting all young regeneration. The young regeneration and planted seedlings will be collected in the field vegetation monitoring.

Methodology

Setting the baseline is the most important measurement for projects because progress cannot be measured if we do not know the conditions at the baseline. There are two starting points for restoration: (i) an area that is bare or without trees and (ii) an area with residual trees. Establishing the baseline in bare area is simple, but a more common scenario is that at baseline an area of interest will have residual trees. In those situations, we must determine how many trees existed at the time of site establishment prior to restoration activities.

Sampling

Sample size and design



Sampling is conducted only for projects within PPC projects. Primarily the flagship (tier 1) projects and Brazil projects with Silvopastoral interventions. We adapted the Winrock sample size

Figure 2 Sampling design details for a site calculator[10] to determine the minimum sample size required for statistical soundness. Real examples from test data were used to generate the calculator's required input parameters like standard deviation and project site area. A simple random sampling design of 0.09ha circular plots were selected. Sample plots were created in ArcGIS using ArcGIS's "Create Random Points" tool to create the plot centers followed by buffering 16.93m around the points to generate the circular plots (Fig. 1). The minimum distance to plot centroids was set to 60m. The small plot with narrow spacing option minimizes the possibility of missing samples in small project sites, while keeping cost of data collection affordable by using smaller plots to optimize the time required to collect data per plot.

A randomly generated **PLOTID** field is added to the attribute table as unique ID to each plot. The file needs to be reprojected into WGS 1984 coordinate system, EPSG 4326. These are required formats for importing the plots into the CEO platform as a shapefile (.SHP). Export the final formatted shapefile and zip it with the name.**shp**, name.**shx**, name.**dbf** and name.**prj**. "name"

[10] A/R Methodological Tool: Calculation of the number of sample plots for measurements within A/R CDM project activities (Version 02.1.0)

stands for the file name preceding the file extension specification. All these four files need to be zipped together for the shapefile to be useable. Plots are now ready for import. The entire process can be streamlined using ArcGIS ModelBuilder tools. Edge plots are less prevalent simple random sampling and remains unclipped to project boundary. However, they will be tagged for identification in the analysis.

Integration with CEO Platform

Collect Earth Online[11] (CEO) is a cloud platform where project administrators can design sampling and survey questions, add members where they can participate in data collection for projects they are added into as members. The data collection manual[12] is tuned towards operators who would be collecting data. For acquaintance with CEO, please, refer to the support materials in the included links.

1. To start the process, open Collect Earth Online (CEO) and navigate to the institution page.
2. Click on create institution (your project page) if there is none already or create project within the existing institution if there is already an existing institution. Once on the project creation page of CEO platform, the 3rd and 4th steps are project creation steps (Fig. 2) are as part of sampling design on the CEO platform part.
3. Select the "import SHP file" (Fig.2) option from the dropdown choices click on "Upload Plot File" button.
4. Navigate to the folder where the earlier created zipped shapefile was saved and select the zipped file.

Figure 3 CEO plot design example using the import option of the SHP file created in ArcGIS

If the import is successful, the file name will appear next to "upload plot file" button. If import fails, go back to the shapefile, and make sure the formatting is correct.

[11] https://collect.earth/downloads/CEO_Manual_InstitutionProject_EN_20210331.pdf
[12] https://collect.earth/downloads/CEO_Manual_DataCollector_EN_20210331.pdf

5. Click Next, at the bottom right of the window.

The 4th step (Fig. 2) in CEO survey designing is about setting the sample points inside those plots created in the previous step. There are two arrangement options: regular/gridded or random arrangements of sample points. For the number of sample points, we have three options: no points, single center point, or multiple for chosen arrangement. Those settings are applied to all plots of the project/survey automatically.

The importance of having multiple points inside a plot is to accommodate spatial variability (heterogeneity) within a plot. This is relevant for bigger plots when dealing with mappable indicators like tree cover, landcover.

In our case we are using a single center point per plot (Fig.3). This is enough for the tree count indicator as we are dealing with a non-spatial (not mappable) indictor, the tree count, and very small plots. In the case of tree count indicator, our concern is about how many trees exist inside a plot regardless of where in the plot. Hence, having multiple points does not add value.

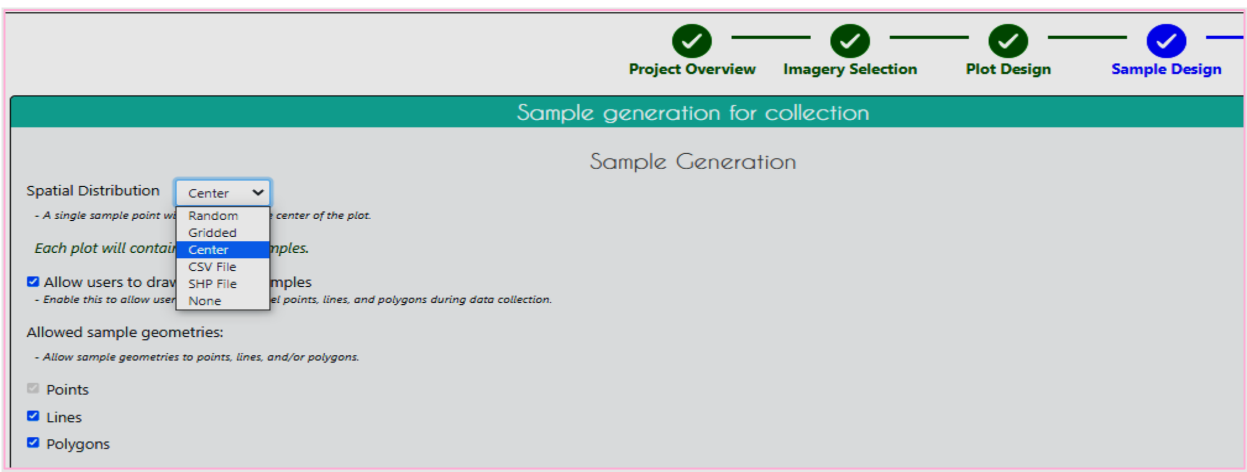


Figure 4 Sample Point Creation

The next step is creating the survey cards/questions, which are customizable based on the objective of the study and the indicators to be assessed. In our case the only indicator of interest is tree count. Thus, we have 3 cards, one for the number of trees (numeric) and the other two for general comments about the plot (text) (Fig. 4). The imagery date is automatically registered for MAXAR imagery.

The CEO system prints a summary of the survey once the survey creation is complete (Fig. 5).

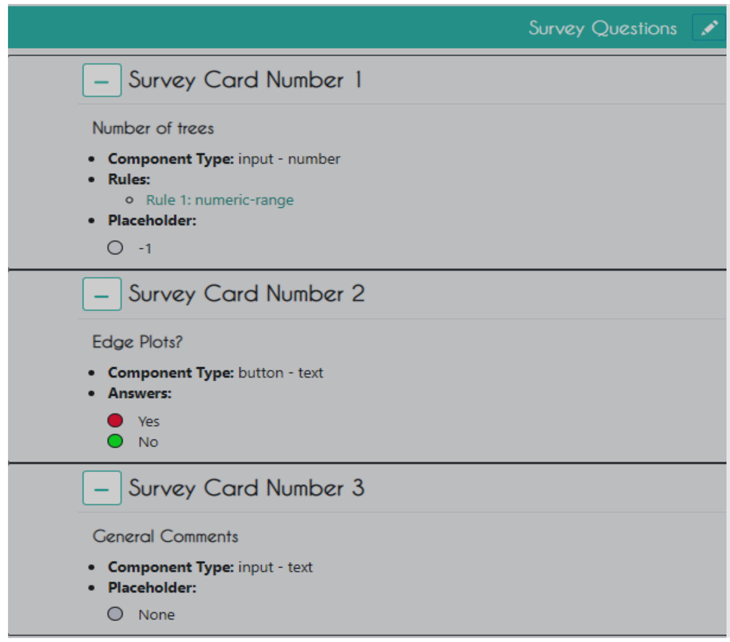


Figure 5 Figure 4 CEO Survey Cards

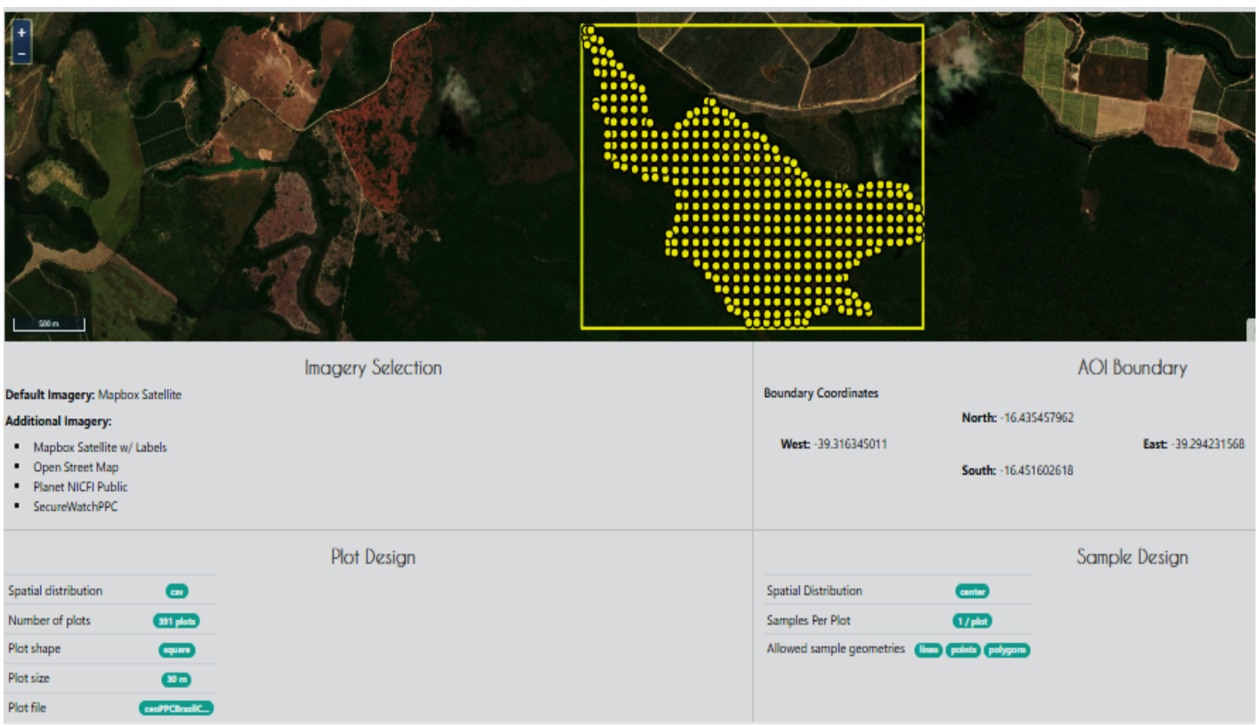


Figure 6 CEO Sampling Summary

Data Collection

The survey created will be stored on the cloud in CEO platform. Data collection team members are added into the project by project owner/administrator using their registered emails to access the survey. A consulting firm with previous experience in CEO is contracted to conduct the data collection with oversight from WRI. Three to five experts are conducting the data collection. Plots are randomly assigned to the data collectors to minimize systematic bias associated to operators' subjectivity. The best available MAXAR satellite imagery closest to, but preceding the site establishment date, are used. All trees inside a plot are counted. Visual image interpretation clues like the crown size, texture and shape, shadows, are used to differentiate bigger trees from young regeneration. Operator's intuition and site observation by zooming and out to compare the feel and look of mature trees in the surrounding areas are key to judge it is a tree or not as tree.

We are not counting all young visible regeneration here even when it can be seen on imagery for the following logical reasons and challenges it entails to count them remotely:

1) The intention of baseline tree count being to separates trees pre-existed the interventions that would thrive anyway without intervention, we want to focus on grown trees that will survival regardless of the intervention activities.
2) When we attempt younger regeneration to be monitored remotely, we will run into trouble of differentiating trees from shrubs. At a younger age crown differentiation is minimal and hence, more difficult to know if it is a tree or not.
3) Young trees may still require some nurturing/care to grow to maturity (e.g., weeding, thinning, etc., to promote growth). Hence, it would not be wise to conclude interventions would no impact on their survival and maturity.
4) By focusing on well differentiated crowns of mature trees, visually comparing how mature trees appear in the surrounding areas, we are better conforming with tree definition in the monitoring framework as DBH and height are not being considered with remote method.

When canopy is closed and it becomes impossible to count individual trees, we will corroborate these gaps using either of the following approaches:

1) Use crown segmentation and infer tree count for those challenging plots from the new Trees on Mosaic Landscape (TML) map.
2) Using the FAO Collect Earth reference of 30 trees or more/0.5ha plots as closed forest, use the filtered average number of trees of the densely crowded-in plots. E.g., Filter all plots with more than 10 trees per 0.09ha plot. Get the average number of trees per plot for those filtered plots and adapt that number for closed canopy plots in that project location.

The statistics from this sampling will be used as an input to discount the pre-existing trees that may still be present in year 5. This is to help disaggregate how many trees pre-existed the intervention and not a result of the interventions (M0).

Other Data Required

At year 5 (project end year), which is within 12 months of the project end date, the total number of trees (T5) will be counted again returning to the same CEO plots used in baseline year. T5 will be the sum of surviving preexisting trees (M5), surviving planted seedlings that are now trees (P5), and surviving naturally regenerated/crowded-in grown trees in year 5 (R5). At the baseline (year 0) the number of seedlings planted (P0) and the number of naturally regenerated saplings (R0), and ideally pre-existing trees (M0) for validation of CEO data, are expected to be collected and reported by project developers in the field using the field vegetation monitoring subprotocol 4, in addition to the CEO data on pre-existing trees. CEO cannot collect data remotely on the very young trees because they will be indistinguishable from shrubs. Together with CEO data on pre-existing trees (M0), and field reported data on young regeneration, survivorship and target attainment analysis can be conducted.

Figure 6 below shows the different potential scenarios expected depending on project site characteristics. The data on pre-existing trees from baseline year will be used with other field report data to calculate year 5 total count and as part of survivorship calculation.

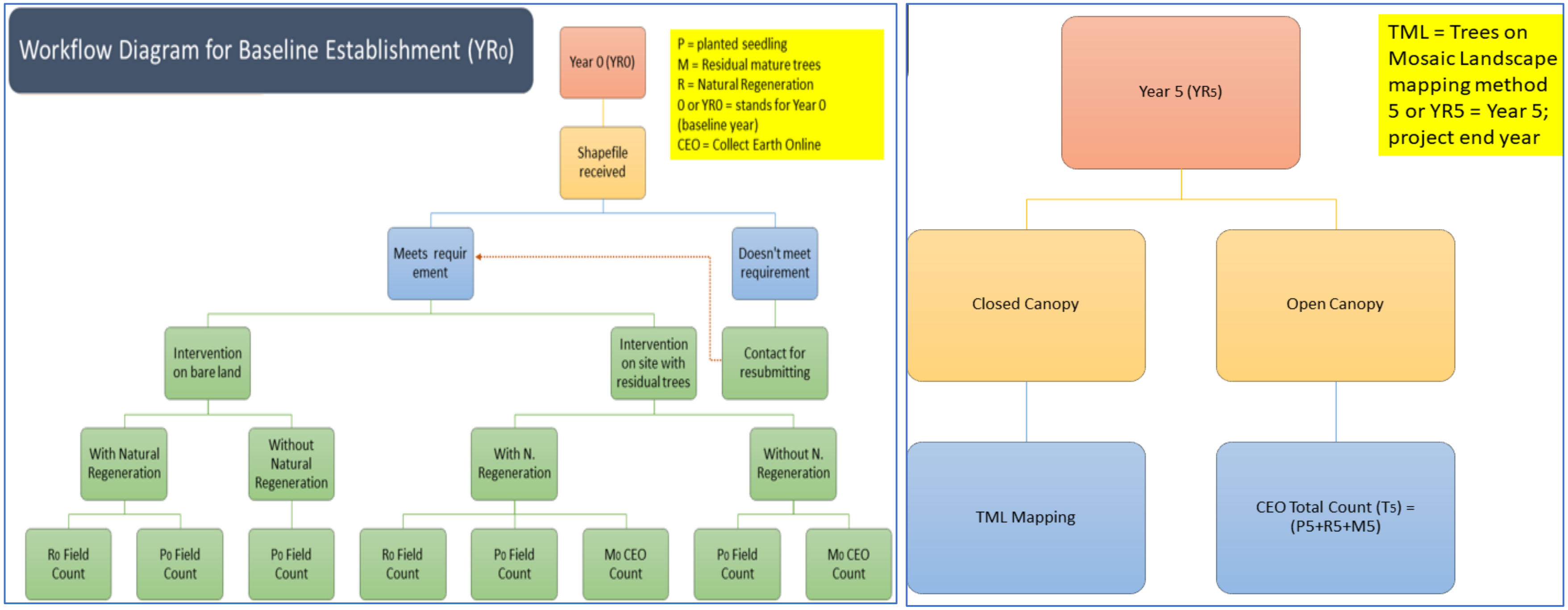


Figure 7 A schematic Diagram for Potential Scenarios Expected in Tree Count Data Collection and Analysis at the Baseline (left) and Year 5 (right)

The CEO Data

The completed plots turn from yellow to blue (Fig. 7, left). Project managers and members can follow the progress on the fly. It is also possible to download the survey in progress and review if necessary. The CEO surveys create two datasets, namely plot data and sample data (Fig 7, right). The download options for the completed data are CSV tables.

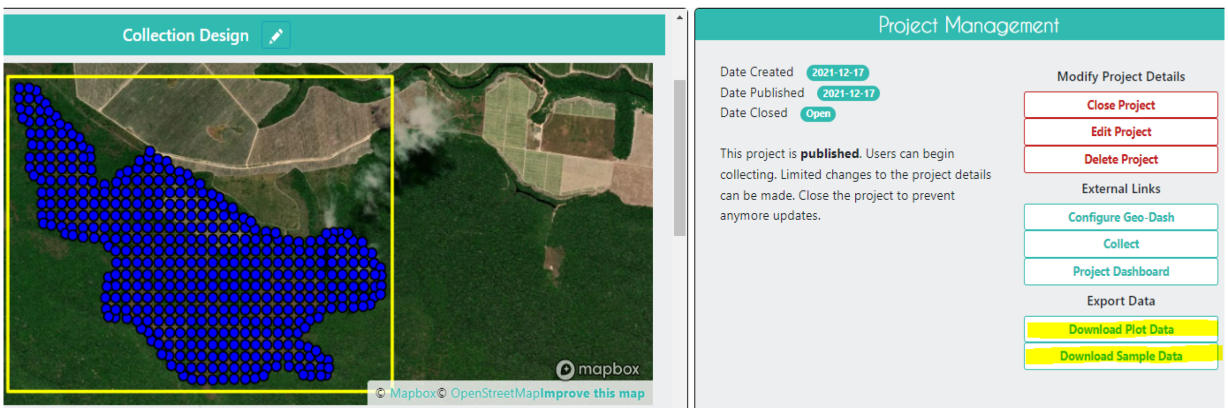


Figure 8 Completed CEO survey ready for download

When multiple sample points are set, the plot and sample datasets provide slightly different information. The two datasets have PLOT ID as a common key and can be cross referenced. This topic becomes more relevant when mappable indicators like landcover and tree cover in big, heterogeneous plots is the scenario. For our case, i.e., for tree count indicator in small plots with single sample point, this topic is not of significance. Tree count is not a spatial indicator. I.e., we will count all the trees inside a plot and enter the total, but we are not attempting to specify where within a plot the tree is located. So, multiple sample points do not have an added value for this indicator ana hence, we have one central plot point for each of the 0.09ha plots.

Quality Assessment

Quality assurance and quality control processes conducted include: Intensive training and piloting of photo interpretation ahead of the data collection was part of the quality assurance approach.

As part of quality control and evaluation, a cross-check method was applied. This method consists of reviewing and refilling a random selection of survey plots by different photo interpretation. In total, quality control has been done for about 5% of the total number of plots.

The analysis has consisted of comparation of the results of the re-inventoried plots with the original results, providing an estimation of the uncertainty of the photo interpretation results. The random selection of the plots has been done using a Python script based on the library *random*.

The random selection of plots was controlled using python script as follows:

```
plots=[x for x in range(1,449)]
[5]  ✓ 0.2s
```

```
import random
print(sorted(random.sample(plots,12)))
[6]  ✓ 0.2s
... [14, 17, 60, 180, 211, 226, 238, 307, 351, 352, 378, 426]
```

The re-analyzed plots are: 14, 17, 60, 180, 211, 226, 238, 307, 351, 352, 378 and 426 whose results are in table 1.

Table 1 Comparison between control points and survey. Source: Veilca

Plot Id	Number of trees	Survey (Cross-validation)	Difference
14	75	75	0
17	30	29	-1
60	90	94	4
180	43	40	-3
211	14	16	2
226	60	61	1
238	30	35	5
307	73	76	3
351	43	40	-3
352	0	0	0
378	66	62	-4
426	65	70	5

- 16.67 % of the control plots there is a perfect match with the tree count.
- 16.67 % of the control plots differ +/- 1
- 8.33 % of the control plots differ +/- 2
- 25.00 % of the control plots differ +/- 3.
- 16.67 % of the control plots differ +/- 4.
- 16.67 % of the control plots differ +/- 5.

The full *report on quality assessment is* available here:

Analysis of CEO Data

Basic descriptive statistics were calculated using pivot table summaries. The total tree count per sampled area, average number of trees per plot, standard deviation, etc., can be generated using pivot table analysis (table 2).

Table 2 Basic statistics of tree count baseline results

Statistics	Project Area (ha)	Population Size (# of Plots that can fit in project area)	Sample Size (# of plots)	Sampled Area (ha) (#of Plots *Plot Area)	Total Number of Trees (Per sampled Area)	Plot Size (ha)	Alpha	Sample Mean (m)	Sample StDev	Std Error of Mean	Coefficient of Variation (CV)	Total # of Trees/Project Area	Confidence Interval (CI)
With Edge Plots	165	402	370	152	13,227	0.41	0.05	36	16.44715	0.85505	0.46008	14,387	36 ±1.676 (±4.69%)

source: Summary Table used for Reporting.xlsx

Extrapolation of sample Statistics to Population parameters (project Area)

Using the sample statistics, we will be able to infer estimates for population parameters like Population Mean and Total number of trees over the entire project area[13]

[13] https://www.scribbr.com/statistics/inferential-statistics/

SUB-PROTOCOL 2: CONTROL SITES

Includes details for siting and establishment of landscape level control units, siting and establishment of control plots within sites, and monitoring methods for baseline and monitoring.

Provides field data for Indicator 1.1: # of trees planted per area under restoration

Created by Starry Sprenkle-Hyppolite, Isabel Hillman and Elise Harrigan at CI

Data collected by project developers and submitted to IMP. Analyses completed by the global monitoring team. Control plots are a required minimum in all projects, but inclusion of landscape level control units is optional.

Guidance for Users

This sub-protocol is intended for use by *project developers* to guide identification and selection of control units (plot or landscape-level).

Disclaimer*: It is extremely challenging to achieve a generic set of monitoring requirements that can be spread across all of the possible PPC Program sites. The following is meant as guidance for the minimum set of requirements for the PPC Program. If you would like to add more rigorous monitoring in addition to what is laid out here, you are encouraged to do so by contacting the global monitoring team.*

Timeline*: Control units and plots should be established directly prior to restoration activities. Monitoring is required to establish the baseline and in Y2.5 and Y5. Monitoring in other years varies based on how many optional monitoring activities are undertaken and which indicators are scheduled for monitoring in a given year.*

Importance of Control

Whereas the driving purpose of the PPC program is restoring tree cover, in order to understand how much of the observed tree restoration is actually due to the activities of the project, we need to have control units. Control units areas designated for no intervention (i.e. restoration). By comparing control units to restored areas, we can determine the additionality of the restoration intervention(s) used in the restoration activity, because the control units mirror the restored sites in terms of degradation intensity and the duration since both sites were last intact and represent a 'business as usual' continuation of those conditions (Marchand et al., 2021). Basically, control units are used to demonstrate the change(s) that would normally take place over the same period of time, but in absence of the restoration intervention (i.e. planting or assisted natural regeneration of trees). Since multiple different restoration interventions are used in the PPC Program, it is critical to clearly define what the restoration intervention(s) are that are being applied, and, the type(s) of intervention may also impact the selection of the control unit.

For the PPC program, control units are established for the key impact indicator of 'number of trees restored.' Control units will allow us to answer the following key question for all projects across this initiative:

> How many additional trees would be present, without our restoration interventions?

With a good 'control' unit, we can also answer other questions about restoration's impacts on biodiversity, biomass/carbon accumulation, ecosystem services, microclimate, socioeconomic benefits. We can compare the restoration intervention treatments between sites or plots, among other units of analysis.

Essentially, control units allow us to avoid attributing all of the observed changes in the restored areas directly to the restoration intervention. They allow us to isolate the additionality of the restoration interventions.

Compliance with the PPC Monitoring Framework will provide the minimum level of data needed to support a very minimal Impact Evaluation under the quasi-experimental approach, with the main goal of determining the number of trees restored as discussed above.[14]

II. Theoretical Foundations: Types of Control

1. Types and Qualities of Control Units

Key Definitions:

A *plot-level contro*l is an area (designated plot) within the restoration area where the restoration method ('treatment') is not applied. We assume that any biophysical changes observed within the control plot, for instance erosion or natural regeneration, would have taken place without the restoration.

A *landscape-level control unit* is a unit of land that is separate from the restoration site, but similar enough to the restoration site (see criteria in Table 1, Annex 1) to be comparable, where the restoration method ('treatment') is not applied. We assume that the changes observed in the control, are the same changes that would have occurred in the restored area, if there was no restoration.

In an ideal situation, both plot-level and landscape-level controls would be included in the restoration design. Implementing both types of controls makes for a more robust experimental design, but may not be feasible due to cost, or land availability/access, therefore, choosing a control type should be dependent on the resources available.

One key aspect of selecting control units is that these need to be as similar as possible to the units under restoration, i.e. comparing "apples to apples" and avoid comparing "apples to oranges." In a within-plot, or plot-level control, this is almost guaranteed, because the control plot is contained within the restoration site.

Selecting a landscape-level control is challenging. Variables that could be considered to assess similarity between control and interventions units include similar elevation, have similar slope, have similar precipitation levels, are located at similar distances to major towns, etc. (See Table 1

[14] In some restoration sites, teams will conduct more detailed analysis under a much more detailed experimental approach. If you are interested in collaborating at the level, please write to email X

in Annex 1). Control units and treated sites need not be directly adjacent to each other. For example, a control that complies with the comparability principle could be located kilometers apart from a treated (restored) unit and that would be acceptable, if that is where a similar site can be accessed. The most important thing is to maximize similarity/comparability between the control units and restored sites.

1.a. Plot-level control (minimum standard): setting aside a part of the potential restored area as a 'control plot' is a typical experimental approach, and it helps to guarantee that many of the environmental factors/site conditions are identical (Table 1). This approach is often used for plantation style restoration methods where a part of the plot might be left with 'no planting.'

However, control plots within restored sites may still benefit from and be impacted by the restoration interventions. Specifically, they will probably be less likely to be subject to certain disturbances (grazing, fire), due to the protections established in the restored areas. In this way they are only a partial control and should be analyzed as such. This is where having a similar, but separate, entire unit designated as landscape-level control, could allow for an improved counterfactual control.

1.b. Landscape-level control (preferred) 'units' should be as comparable as possible to the restored sites. The landscape-level control is outside the boundaries of the restored area, but still in close proximity. It is important to note that landscape-level control units can be on land that was never intended for the restoration intervention. Therefore, they do not diminish the amount of land available for restoration. There are several factors to consider when establishing a control unit (Table 1).

If landscape-level control units are feasible in your situation, please refer to Sub-protocol 2, Annex 1, which will guide you in choosing landscape-level control units. Please note that control plots within landscape-level control units are still needed, and will be established using the same method described below.

Methodology 1: Control Plot Selection and Demarcation

1. Size of Control Plots:

Control plots, either inside restored areas or within landscape-level control areas, are the same size as regular monitoring plots (30m x 30m) and should be mapped, marked, and monitored in the same manner as the restoration monitoring plots (Sub-protocol 4). If a site is between ½ and 1 hectares in size, then the control plot can be 10m x 10m instead of 30m x 30m. If a site is less than ½ a hectare in size, no control plot is required.

2. Number of controls per number of restoration sites:

(Minimum) Ideally there should be at least one control plot per restoration site. However, if there is significant variation in the restoration site, then multiple control plots may be needed to encompass that variation. Types of variation include topography (steeply sloped vs. flat), land cover and ecotype, land use history, and disturbances. If a site is less than ½ a hectare in size, then no control plot is required.

(Complex Situation Guidance) Different situations may require modifications to the number of needed controls. For instance, in situations where more than one treatment is being implemented in the same space, then it is ideal to also have a "0/no" treatment plot and two individual treatment plots (1 for each type of treatment). For instance, if tree planting is being done with monthly grass cutting, the would be one control with no tree planting or grass cutting (0/no treatment control), one control with only tree planting and no grass cutting (1st treatment control) and one control with no tree planting and only grass cutting (2nd treatment control). This is what is considered a "full factorial" design, and more guidance can be found here.

If in doubt about the proper number of control plots, please contact the global monitoring team. WRI/CI welcomes conversations around proper control unit design and is available to help determine the right specifications for any given site.

3. Location of plots: The location of control plots should be randomized[15] within the restoration site, in order to better ensure that they represent the conditions in the site. Tools such as the Create Random Points Tool in ArcGIS can be used to identify locations of the plots, but the use of GIS is not required. Simple field methods can be used with random number generation determining the number of steps from the edges of the site where the corner of the control plot should be placed.

- **Submission of Site Plan including Control Plots:** The mapping of the planned restoration intervention should include the proposed location of the control plot(s) and a description of the rationale for their location, if not completely randomized. This applies for both plot-level and landscape-level control units.
- *If in doubt about the proper location of control plots, please contact the global monitoring team We welcome conversations around proper control unit design and is available to help determine the right specifications for any given site.*

1. Sampling within Control Plots

a. **Dimensions of Control Plots:** The control plots will be the same size as the regular vegetation monitoring plots, 30 m x 30 m (s). If there are more than one control plot per restored site, at least one of the control plots must have smaller nested plots for monitoring of smaller vegetation (details below, and see Figure 1). If there is only one control plot per site, it will be a nested plot.

[15] Some restoration methodologies may make it unrealistic to randomize the locations of the control plots (I.e. applied nucleation). Please contact X email if seeking an exception to the randomization requirement

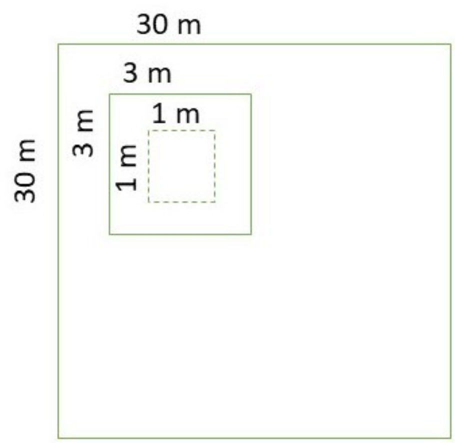


Figure 1: Nested Monitoring Plot arrangements of 30m x 30m (900 m^2), 3m x 3m (9m^2), and optional 1m x 1m (1m^2) plots

b. **Control plot marking:** Control plots are permanent, and should therefore be mapped and marked to facilitate ease of monitoring the same plot through the project cycle (up to Y5). The corner points should be recorded in the data collection form (integrated monitoring platform) along with the device margin of error. Each corner must be georeferenced with landmarks in the ground (wood staking, iron pipes or PvE tubing) at 1.2 m in height (PACTO, 2013).

c. **Measurements in Control Plots:** In each monitoring sampling plot, counts of the trees/saplings per tree species must be recorded by size class, following the same protocol as in the vegetation monitoring (Sub Protocol 4, summarized in next paragraphs). Three (3) photos should also be taken from one corner of the plot, one each with the edge of the plot in the centerline, looking at the opposite corner, and one looking across the diagonal. The corner from which the photos are taken should be the corner that provides the best overview of the plot (accounting for slope, existing vegetation, etc) and should be noted (NW, NE, SW, SE as noted in the GPS coordinates). For example, if the photos are being taken from the northwest corner in the plot diagram below, one photo would have line NW to NE (one side), one with line NW to SW (other side), and one with line from NW to SE (the diagonal).

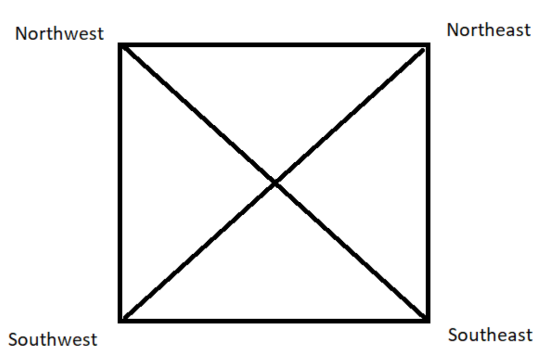


Figure 4. Sightlines for photos taken as part of control plot monitoring

In each control plot, the trees and species must be recorded. Tree diameter (DBH) and height can also be recorded, but this is optional. In the 30 m x 30 m plots all large trees and their species are recorded. DBH (>10cm) and height are optionally recorded. In the nested 3 m x 3m (9 m^2) all medium sized trees (diameters 1 – 9.9 cm DBH) and species are recorded. DBH and height are optionally recorded. Sampling in the smallest nested plots is optional. In the smallest nested plot, 1m x 1m (1 m^2) all tree sapling or trees (<1 cm DBH) will be counted and identified to species or species type as much as is possible (no height or DBH measurements for this small category, adapted from Celentano et al., 2020)

Measuring protocols:

1. (Optional) Diameter at Breast Height (DBH): Use a forestry-grade DBH measuring tape at diameter at breast height (1.3 m) around the stem or trunk of the tree. Record in metric units.
    a. If stems have bifuricated below 1.3m, DBH should be taken from all stems above 1.3m (PACTO, 2013)
2. (Optional) Height: Use a clinometer, or for Saplings or regenerants too small for the use of a clinometer, use a measuring stick.

1. **Data Recording:** Data should be recorded following the template of Form 1 in Sub-protocol 2, Annex 2, which will be done using the integrated monitoring platform data collection app.

IV. Expected costs of control plots and technical assistance available

Control plots are not expected to create significant costs because they have no interventions. For landscape-level control units, the units only need to be accessed for the monitoring. This access should be negotiated with the lowest possible cost (if any) and may also be a consideration in the control site selection. Estimation of the time required for monitoring is an area of work in development, and details will be updated as that work proceeds.

V. Data Analysis

The data is analyzed in the control plots in the same way as it is in the vegetation monitoring plots (please see Sub-Protocol 4).

The control plot represents the state that we would expect the restored area to be in, in the absence of the restoration intervention- a 'coutnterfactual.' It is different than a baseline measurement, because the control area may change over time just as the restored areas change over time. There might especially be some natural regeneration in the control plot.

Comparing the changes in the restored areas to their controls for any of the vegetation indicators (trees restored, tree cover) gives an estimation of the amount of observed change that is additional- that would not have happened without the restoration intervention. Fine-scale differences in microclimate and soil properties can also be quantified by additional measurements in control and 'restored' areas.

VI. References

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Sub-protocol 2, Annex 1: Landscape-level control units

Going beyond control 'plots' that primarily show changes in vegetation, landscape-level 'control' units allow quantification of restoration's impacts on biodiversity, ecosystem services, socioeconomic benefits, and more accurate quantification of changes in biomass/carbon accumulation (following the additional/optional sub-protocols).

Size of Control Units

Following the logic of "apples to apples" we still seek to compare similar units for the restoration treatment and control. Hence, ideally the restoration sites and control units would be of similar size. In practice, for small restoration sites (< 5 ha), landscape-level control units can be the same size as the restored site they are controlling for. However, if the restored area is very large, it may not be feasible for the control unit to be the same size. In this case, the control unit can be smaller. Generally, the control unit should not be more than 50% smaller than the area restored, but not smaller than 0.5 ha or larger than 25 ha.

Number of Control Units per Number of Restoration Sites

If a project has multiple areas restored in the same year, it is not necessary to have a landscape-level control for each area restored. We should strive to have at least 1 control site per group of 5 very similar restored sites.

If all of the restored sites have similar characteristics in terms of size, and the environmental and socioeconomic factors listed in Table 1, then you would only need one control site per 5 similar sites. However, if the sites vary significantly in terms of the factors listed in Table 1, then, each group of sites with similar characteristics should have a control site.

> *For example: If the sites vary by size, and you have 3 sites that are >5 ha and 3 sites that are <1 ha, you should have 1 control unit > 5 ha and 1 control unit <1 ha. If the sites vary by previous land use, and you have 15 sites in abandoned pastures and 5 sites in agricultural land, you should have 3 control units in abandoned pastures and 1 in agricultural land. Also, if you have sites that are in different geographical regions, for example separated by more than 10 km, you should have a control unit in each region. These are only a few examples, please adapt the logic to your situation.*

Factors to consider in control selection

When establishing control units at the landscape scale, it is important to prioritize ecological and socioeconomic factors that will help determine the needed properties of, and therefore the location of, the control. Table 1 below details several factors to consider when choosing the control unit. Proper selection of the control will lead to a more accurate experimental design.

Table 1. Prioritization of ecological and socioeconomic factors to indicate a suitable control unit.

Factor	Reason

• Land Cover and Ecotype	Consistency in the type of vegetation (especially forest cover), topography, biotic and abiotic conditions
• Land Tenure and Ownership	Ownership or type of property should be considered to reduce necessary number of agreements. This includes protected areas and private verse public land.
• Land use history	Previous land use, especially those causing degradation, could have impacts on the future viability or success of the restoration activities (Crouzeilles et al., 2017). Degradation intensity in the control matches that in the treatment location (Marchand et al., 2021b) in practice. For example, if a restoration site has cattle excluded with fencing, the control unit should have cattle grazing. It is not enough to simply not have fencing.
• Distance to restored site	Proximity will keep environmental variables similar (slope, elevation, ecotype etc.)
• Disturbances	Natural or human disturbances such as fire, hurricane etc.
• Distance to community/housing (settlements)	Control units inside protected areas may not have households impacted which would produce a bias impact evaluation (Ferraro, 2009)
• Household survey opportunities	Household surveys are needed for socioeconomic analyses, so control unit locations should allow for surveying that meets the criteria specified in sub-protocol 18

How To Select a Control Unit:

<u>Step 1: Determine the scale of your restoration project and the appropriate number, type, and size of control units.</u>

Do you have budget and land access to create both a landscape-level control unit and plot-level control?

If yes, then proceed with steps 2-4 for siting landscape level controls.

If no, please focus on following the plot-level control described in the main sub-protocol 3 text.

<u>Step 2: Identify the types of data necessary to create your control.</u>

Use the prioritized factors in Table 1 to find the appropriate data layers to establish your control locations.

Table 2: Factors for siting landscape control sites

Suggestions of data sources for factors	
Factor	**Data source**

Land cover/ecotype	See Restoration Siting Guide Data Library*
Land tenure	See Restoration Siting Guide Data Library*
Land use history	See Restoration Siting Guide Data Library*
Distance to restored site	Use shapefiles for restored sites and calculate distance to proposed control locations
Disturbances	See Restoration Siting Guide Data Library*
Distance to community/housing	Refer to the households identified in the socioeconomic subprotocol to calculate the distance to proposed control locations. (Subprotocol 10)
Household survey opportunities	Refer to the socioeconomic subprotocol (10)

**The Restoration Siting Guide can be provided upon request by emailing the Global Monitoring Team*

<u>Step 3: Define geographic range of the search for the control site</u>

How far from the restored sites could you select your control? This determines the area of the mapping exercise.

<u>Step 4: Prioritization and Weighting of Layers</u>

A 'weighted overlay' in which different data layers are assigned different weights (for example, if variable a (I.e. land cover/ecotype) is x (I.e 2) times more important than variable y (I.e. land tenure), then variable a has a weight of 2), and then these are mapped and overlaid. More details on this process can be found in the Restoration Siting Guide, which can be provided upon request by emailing the global monitoring team.

<u>Step 5: Create a map of the potential, optimal control units</u>

Use the data layers to create a map of the potential, optimal control units in the landscape.

<u>Step 6: Feasibility and selection of control sites</u>

Considering all of the potential optimal control units, investigate the feasibility of being able to access each one. Will there be added costs to access the units? Can any be accessed through a no-cost agreement? Please document the reasoning behind the final decision with regards to the control units.

<u>Step 7: Submission of Site Plans including Locations of Landscape level controls relative to restored areas and locations of control plots within the landscape level controls</u>

The mapping of the planned restoration intervention should include the proposed location of the landscape-level control sites and control plot(s), and a description of the rationale for their location.

Landscape Control Unit Monitoring

Within the control unit, the same monitoring protocols are followed as in the restored sites. For instance, the same baseline site information should be entered into the information system, especially including the site GIS shapefile, which will enable remote sensing analysis of tree cover and other site properties. Moreover, in terms of field work, a 'control' vegetation monitoring plot must be established following the similar procedures as described in the main text of this sub-protocol.

Expected Costs:

Control units are expected to be slightly more expensive than control plots due to the potential additional cost of accessing land that may not be under the same ownership as the restored sites. Estimation of costs by activity is an area of work in development, and details will be updated as that work proceeds

Sub-protocol 2, Annex 2: Data collection sheet

Table detailing the information collected during vegetation monitoring. Items highlighted in grey are optional. Data is collected using KoboToolbox, which can be accessed on the IMP.

Data Collected	Options	Data Type	Notes
General Information			
Date		Date	
Organization Name		Select one from list	
Site ID		Select one from list	
Sampling Timeframe	Y0 (baseline), Y2.5, Y5, Other	Select one from list	
Site Type	Control, Restoration	Select one from list	
Start time of data collection		Time	
End time of data collection		Time	
Plot Information			
Plot ID		Text	
Plot Type	Control, restoration	Select one from list	All restoration should be looking for natural regen
Strata		Text	NA if only 1 stratum, if multiple in restored area then match answer with strata identified in site establishment form
Coordinate System Used		Text	
Northeast corner of plot (30x30)		GPS coordinate	
Device margin of error (NE corner)			Automatically included in KoboToolbox

Northwest corner of plot (30x30)		GPS coordinate	
Device margin of error (NW corner)			Automatically included in KoboToolbox
Southeast corner of plot (30x30)		GPS coordinate	
Device margin of error (SE corner)			Automatically included in KoboToolbox
Southwest corner of plot (30x30)		GPS coordinate	
Device margin of error (SW corner)			Automatically included in KoboToolbox
Trees in 30m X 30m Plot All trees > 10cm DBH by species and type should be recorded. ** Note that DBH and height measurements are not required, only a count by size class, disaggregated by species and type*			
Count of trees (>10 cm DBH)	Disaggregated by species and type (naturally regenerating, planted by your project, already present prior to project, don't know)	Integer + species + select one from list (type)	If using this sheet for data collection, repeat this line for each species and type. Ex: species A, count of 2, and naturally regenerating Species A, count of 3, planted by your project
Notes		Text	
3 geotagged photos of AB, AC, and AD sightlines (in vegetation monitoring protocol)- specify corner		Picture upload + text (corner chosen)	Photos should be taken from the corner that provides the best overview of the plot (accounting for slope, existing trees, etc)
Trees in 3m X 3m Plots In the nested 3m x 3m sub-plots all trees with a diameter between 1 – 9.9 cm DBH are recorded ** Note that DBH and height measurements are not required, only a count by size class, disaggregated by species and type*			
Number of resamplings needed for 3m x 3m sub-plot	0, 1, 2	Select one from list	A resampling (relocation of the sub-plot within the 30m x 30m plot) occurs if there are no trees 1 - 9.9 cm DBH in the sub-plot
Count of trees (1-9.9 cm DBH)	Disaggregated by species and type (naturally regenerating,	Integer + species +	If using this sheet for data collection, repeat this line for each species and type.

	planted by your project, already present prior to project, don't know)	select one from list (type)	Ex: species A, count of 2, and naturally regenerating Species A, count of 3, planted by your project
Notes		Text	
Centroid		GPS coordinate	
Description of location within 30m x 30m plot		Text	
(Optional) Additional Photos			
Saplings in 1m X 1m Plots In the smallest nested plot, 1m x 1m (1 m2) all saplings (regenerants) (<1 cm DBH) will be recorded. At this size, it is important to distinguish between trees and shrubs			
(Optional) Count of saplings (<1cm DBH)	Disaggregate by species and types (naturally regenerating, planted, don't know)	Integer + species + select one from list (type)	
(Optional) Centroid		GPS coordinate	
(Optional) Description of location within 3m x 3m plot		Text	
Additional Information			
(Optional) File Upload		File upload	

Special Circumstance: Restoration Site is between ½ HA and 1 HA In this scenario, a 10m x 10m monitoring plot with a 3m x 3m sub-plot is sampled.
All data collection is the same as above. The only difference is the size of the monitoring plot

SUB-PROTOCOL 3: SITE ESTABLISHMENT FORM

Details on how to complete a site establishment form prior to planting, including documenting planting locations while allowing for species disaggregation.

Provides field data for indicator 1.1: # of trees planted, by species, per area of restoration

Created by Isabel Hillman at CI and Tesfay Woldemariam at WRI

Data collected by project developers and submitted to IMP.

Guidance for Users

This sub-protocol provides step-by-step guidance for *project developers* on how to create site boundaries and submit site level details on plantings and plantings like planting pattern, species composition and intervention types, restoration methods to the integrated monitoring platform accurately and consistently in ways that will allow CI and WRI to report progress to the Priceless Planet Coalition.

Disclaimer: It is extremely challenging to achieve a generic set of monitoring requirements that can be spread across all of the possible PPC Program sites. The following is meant as guidance for the minimum set of requirements for the PPC Program. If you would like to add more rigorous monitoring in addition to what is laid out here, you are encouraged to do so by contacting the CI or WRI global monitoring team.

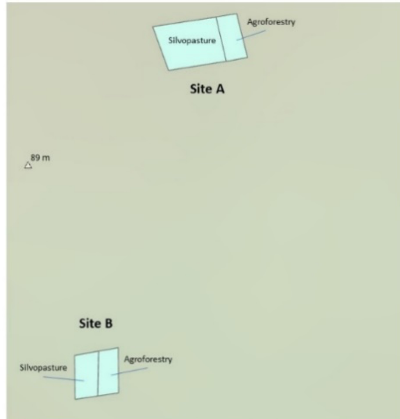
Importance

Accurate site boundaries and related details of activities, evidence and other information submitted in a timely matter provides CI and WRI partners with regular flow of updates needed to report to PPC. Further, reporting data, evidence, and independently derived data can all be used by project developers for adaptive management and/or serve as insights to the field team's decision-making.

What is a site?

A site must be a contiguous plot of land, that is subdivided into sections based on intervention type (required). The site can also be subdivided by other strata (optional, see protocol 5 on vegetation monitoring for details on strata). The subdivision(s) should be specified in the attribute table. If the restoration project contains disparate plots of land, then there are automatically more than 1 site (Figure 1). The only case where multiple sites (non-contiguous areas of land) can be combined into one is if they are owned by the same landowner, have the same landscape characteristics (slope, soil condition, etc) and are less than 100m apart. The sub-protocol is used for the Baseline & Site Establishment Report, which is completed every time there is a new site.

Figure 1: Digital boundary of multiple sites with multiple intervention types



A site boundary includes the area of active restoration, which can be thought of as the area within which we will count trees towards the PPC target. The entire area within the boundary will be included in vegetation monitoring (sub-protocol 5) and for remote sensing analyses (canopy cover, hectares in restoration, carbon, etc). If there are different management activities across the site, they should be denoted as strata (sub-protocol 3). For example, if you plant trees in one part of the site, but do erosion control uphill from where trees are planted and plan to count trees that grow from natural regeneration in the erosion control areas, then the whole area is counted as the site, but includes strata (planted and erosion control).

Methodology

All information will be submitted using the Baseline and Site Establishment Report in the integrated monitoring platform when site selection is finalized and as restoration activities begin. This should be before planting begins.

The boundary creation method for site is similar to that of the method used for project boundary creation as described in sub-protocol 14. Please, refer sub-protocol 14 for step-by-step guidance.

In addition to submission of site boundaries, the Baseline and Establishment Report includes:

Category	Data	Input Format	Notes
Basic Information	Name	Text	
	Email	Email	
	Organization name	Select one from list. *List: evolving*	
Baseline Information	Site Name	Text	
	Site Description	Text	Conditions of site currently
	Expected end date	Date	
	Restoration Method	Select multiple from list. *List: mangrove tree restoration, assisted natural regeneration,*	

		agroforestry, plantations, peatland restoration, wetland/riparian restoration, enrichment planting, applied nucleation/ tree islands, silvopasture, seed dispersal	
	Description of Site History	Text	Including land use history, disturbance history, ownership history if relevant, etc
	# of existing, mature trees on site	Integer	Gives a baseline count of trees that were already present when restoration started- may be few to many, depending on the site conditions
	Land tenure type	Select one from list. *List: public, private, indigenous, communal, national protected area, other*	
	Soil condition (level of degradation)	Select one from list. *List: severely degraded, poor, fair, good, no degradation*	
	Presence of invasives	Species + Select one from list for each species. *List: dominant species, common, uncommon*	List invasive plant species observed, if any, and their prevalence on the site. Details on how these will be managed should be included in the technical report
	Stratification for heterogeneity	Integer + text description	Name and describe each strata. For example, if the site contains multiple vegetation types or restoration interventions. More information in sub-protocol 5 on vegetation monitoring. Example: 1: areas with secondary growth, 2: areas without secondary growth (a diagram/drawing of the strata is strongly recommended to include in the photos section)

Targets (for year 5)	Target survival rate of planted trees	Percentage	Based on program objectives and site conditions- may be lower at some site and higher at others, compared to 'average' overall for project
	Target survival rate of direct seeding (if applicable)	Percentage	Same as above
	Expected # of trees per hectare for natural regeneration	Integer	Optional for sites where assisted natural regeneration is not a restoration strategy
	# of hectares the natural regeneration estimate applies to	Decimal	Area of site in which natural regeneration will be allowed (it might be suppressed in agroforestry areas, for example, or in areas where only planted trees will be allowed to grow)
	Target crown cover	Percentage	From project objectives
Establishment	Establishment Date	Date	
	# of trees planted by species	Species + integer	
	Kg of seeds planted, if applicable	Decimal	
	Weight and # of seeds weighed	Decimal + integer	Weight of a subset of seeds needed. Minimum 1g, but 10g to 1kg preferred, or no more than 500 seeds, whichever is less
	Planting pattern	Text	Description of planting pattern I.e. grid spacing, clumping, etc (a diagram/drawing displaying planting details is strongly recommended to include in the photos section)
	Photos/Videos	File upload	
	Photo/Video safety concerns	Text	

SUB-PROTOCOL 4: VEGETATION MONITORING

Includes siting of monitoring plots and field-based vegetation monitoring suitable for baseline establishment and monitoring all restoration methods including natural regeneration, and subsequent calculations of survival rates. Also gives optional guidance for carbon stock assessment.

Provides field data for impact indicator A: # of trees restored (survived and crowded in) after 5 years, indicator 1.2: # of trees naturally regenerating per area under restoration, and indicator 1.5: % survival of planted trees after 5 years.

The results generated from this analysis will be compared with the remote sensing of trees data (subprotocol 1) which only works on trees of a size visible by remote sensing. Whereas this field vegetation monitoring is only done on one sample area per hectare, the remote sensing of trees is done taking far more samples distributed across the entire area under restoration. Information from both methodologies will be useful in informing the final # of trees restored for the Program.

Created by Starry Sprenkle-Hyppolite, Danielle Celentano, Leon Theron, Isabel Hillman, Ludmila Pugliese, and Elise Harrigan at CI, with references to monitoring protocols listed in Reference section.

Data collected by project developers and submitted to IMP. Analyses completed by the global monitoring team. Required in all projects.

Disclaimer: It is extremely challenging to achieve a generic set of monitoring requirements that can be spread across all of the possible PPC Program sites. The following is meant as guidance for the minimum set of requirements for the PPC Program. If you would like to add more rigorous monitoring in addition to what is laid out here, you are encouraged to do so by contacting the global monitoring team.

Guidance for Users

This subprotocol was developed to provide clarity on placing monitoring plots within restoration sites and field-based vegetation monitoring (including monitoring of natural regeneration) for *project developers*. Natural regeneration monitoring is not required for projects that exclusively consist of tree planting. However, we recommend that even tree planting projects monitor natural regeneration that is additional to their planted seedlings, in order to measure the total number of trees restored in their project, even if this method was not mentioned explicitly among their chosen methods in project targets.

This protocol also describes the data processing completed on the resulting data by the global monitoring team.

The data collected in the monitoring plots, following this procedure, will be used to extrapolate the data for the entire restored area, based on the fraction of the site that was directly measured in the monitoring plots. Because of this, it is extremely important that the monitoring plots capture representative, average areas of the restored area (potentially with a need for stratification, if there are major differences). It is also essential that there are an adequate number of monitoring plots. Guidance for this is given in the following sections.

This protocol includes both the minimal required monitoring to satisfy the PPC Program requirements, as well as additional optional guidelines for more intensive monitoring for projects seeking to estimate the carbon sequestered. Please note that the additional vegetation monitoring suggested here, by itself, will not be enough to allow for carbon crediting, and, carbon crediting is not possible in all of the areas that the PPC works. There are many more steps to this process, including submitting more detailed Project Design Documents, baseline analyses, and analysis of additionality and leakage. Full guidelines for this are still in development (expected by end of 2022).

Field-based monitoring of vegetation is designed to inform and connect to remotely sensed monitoring, covered in subprotocol 1.

Timing & Frequency of monitoring:

Monitoring of restored areas should consist of a baseline (to document existing trees prior or at the time of planting), Year 2.5 and Year 5, but if time and resources allow, it could be monitored every year. This monitoring doesn't replace site management that may need to occur more frequently.

Importance of Vegetation Monitoring

Monitoring of vegetation allows us to calculate overall diversity and species richness of planted and regenerating trees (regenerants) in restoration sites. This monitoring will help to inform potential adaptive management, especially in situations where the planted tree species have low survival rates and learning about more appropriate species is needed. Any learnings should be carried over into species selection for future enrichment plantings.

METHODOLOGY

We assume that the site, or 'restored area,' is already defined by a GIS shapefile and the basic site information has been submitted in the establishment report.

The following procedures must be followed to ensure proper data collection.

> **Definition of Restored Areas by Restoration Methodology**: In general, an area defined as a 'restored area' will have a single restoration method (or a designated combination of methods) applied ***consistently*** across the ***entire site***. If this is not the case, and different restoration methods are used in different parts of a restored area, separate polygons within a shapefile are created for the areas with the different methods (or combination of methods). The easiest example to illustrate this is if the site is divided in half, with one method on one side and another on the other, as in an experimental design to test different methods (See Figure 1). Each of these areas would need to be treated separately

for monitoring: the monitoring protocol described below would apply to each of those sub-divided restored areas, separately.

Stratification: If the restored area has significant diversity of topography, vegetation, land use history, disturbance etc., that may significantly impact the restoration success, the implementors should stratify the monitoring plots to represent and capture these differences (Figure 1). For example, if half of the site has a very strong slope and half is flat, plots should be randomized within the sloping half and the flat half. This may be especially important if there are multiple vegetation types (i.e. bare ground vs. grass vs. secondary growth) in the area. Implementors need to define the different zones and ensure that monitoring plots are placed in those zones. This stratification, or zoning, should be noted in the monitoring plot information. This is especially important if the developer is planning to make carbon estimations for the restored area.

Stratification in context of carbon standard compliance: Grouping similar vegetation types together based on biomass, species composition, soil type and structure helps to reduce the overall variance and reduces uncertainty. Satellite imagery is most often used in the first iteration of stratification and it can then be further refined combined with topographic maps and initial field sampling.

The planned restoration area can be first classified using the most recently available and highest resolution satellite imagery available and the area can be classified based on canopy cover, although canopy cover classification can be difficult for sparse, degraded forests. Adjustments can be made following a trial field survey.

It must be noted though that stratification is not essential for carbon verification, but it does bring down uncertainty and prevents confidence deductions. Verifiers will not scrutinize the actual stratification in great detail unless a specific project has reason to distinguish carefully between land cover classes. Verifiers will focus on the uncertainty (variation) levels of each stratum.

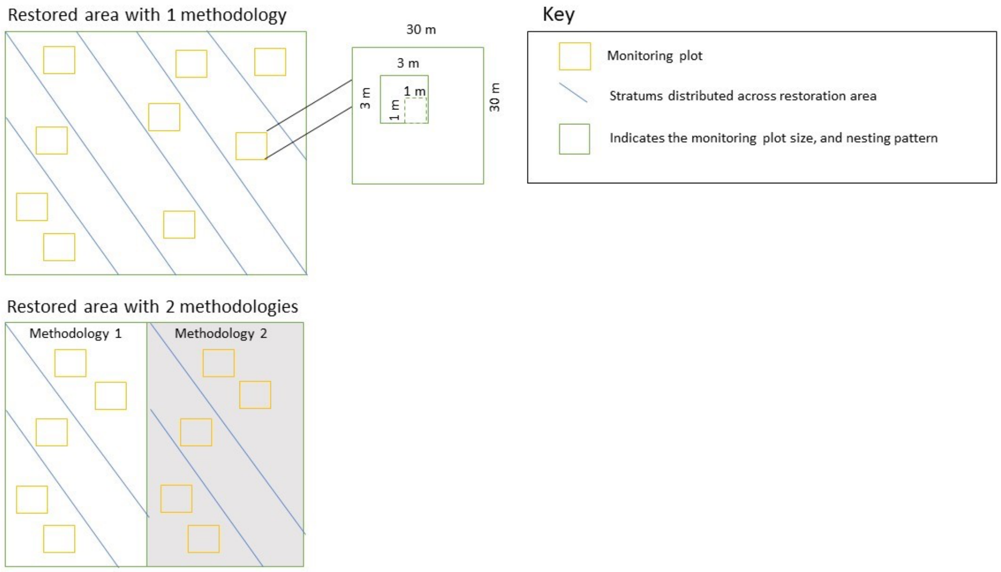


Figure 1. Restored areas using 1 (above) or 2 restoration methodologies

Determining the number of monitoring plots according to the size of the restored area in hectares for restored areas (sites)

In order to ensure adequate sampling for data extrapolation, it is extremely important that there are an adequate number of monitoring plots. The number of monitoring plots required is based on the size of the restored area, and varies whether or not the developer is pursuing field-based carbon estimation (optional). We propose a simple area-based method for determining the number of monitoring plots, which also sets the required minimum, in Table 1. Implementors who would like to use a more technical method for determining the correct sampling ratio, for example utilizing their own knowledge of expected variance to conduct a power analysis, are welcome to do so. If a more technical method is utilized, the global monitoring team must review and approve it. The number of monitoring plots cannot be less than the required minimum (Table 1) unless the method is approved and the number of plots agreed with the global monitoring team.

Table 1: The minimum number of monitoring plots based on the size of the restored area (in hectares).

Restored Area (ha) = A	**Number of Plots (minimum PPC standard)**
A ≤ 50	1 per hectare
A > 50 ≤ 100	1 per ha for 1st 50, 1 per 2ha for 2nd 50
A > 100	1 per ha for 1st 50, 1 per 2ha for 2nd 50, 1 per 5ha for all over 100

Determining the number of plots per stratum for carbon projects.

For carbon verification, the density of sampling is determined by the level of uncertainty[1] desired. If the uncertainty exceeds 10%, confidence deductions will have to be applied to carbon values: the baseline must be adjusted upwards and the project carbon stock downwards (see ar-am-tool-14-v4.2.pdf (unfccc.int)).

The following Clean Development Method (CDM) A/R Tool describes how to calculate the number of plots per stratum: CDM AR (unfccc.int)

Winrock has a spreadsheet tool that can be used to calculate the number of plots per stratum Winrock_Sample_Plot_Calculator_Spreadsheet_Tool and it can also be used to get cost estimates of sampling.

In order to ensure adequate sampling for data extrapolation, it is extremely important that there are an adequate number of monitoring plots. The number of monitoring plots required is based on the size of the restored area, and varies whether or not the developer is pursuing field-based carbon estimation (optional). We propose a simple area-based method for determining the number of monitoring plots, which also sets the required minimum, in Table 1. Implementors who would like to use a more technical method for determining the correct sampling ratio, for example utilizing their own knowledge of expected variance to conduct a power analysis, are welcome to do so. If a more technical method is utilized, the methodology should be reviewed and approved by the global monitoring team must review and approve it. The number of monitoring plots cannot be less than the required minimum (Table 1) unless the method is approved and the number of plots agreed with the global monitoring team., as long as the frequency of monitoring (plots/ha) does not fall below the minimum requirement in Table 1.

Determining the location of monitoring plots within the restored area

Location and orientation:

Each corner of the monitoring plot should be recorded using a GPS device.

Distribution of plots:

The sampling plots should be evenly distributed across the site, (I.e. they cannot be clumped in one or two ends/edges of the site). You could imagine a one-square hectare grid spreads across the site, and one plot should be placed in each square hectare (for example, for sites up to 50 ha in size).
The location of the monitoring plots should be random, within the square-hectare grid. All plots should be oriented so their edges run along north-south and east-west axes.

To determine where plots should be placed the center points of the plots, referred to as "plot centroids," can be generated in ArcGIS using the Fishnet tool at 30-meter spacing, and telling the program to randomly choose the locations of the centroids. Alternatively, you can use a random number generator like a stopwatch to determine the number of steps or meters away from the edges of the site a plot should be placed.

Some corrections may be needed to the randomized placement. For example, the distribution of plots should also account for any strata present across the site. For example, if your site has no vegetation on 30% of its area, and some secondary growth on 70%, those are two different vegetative strata. You might need to break the rule of random placement for some of the plots to ensure that the right fraction are in each stratum.

Your monitoring plots should have the same distribution within the strata- 30% of your vegetation monitoring plots should fall in the no vegetation area, or stratum, while the other 70% fall within the secondary growth area, or stratum. If you have multiple strata in a small restored area, and the number of vegetative strata exceeds the number of hectares being restored, you will need to exceed the 1/ha minimum monitoring requirement, to ensure some monitoring coverage in each strata (i.e. 2 plots would be needed in a 1 ha plot w/2 vegetative strata).

Finally, plots should also not be placed within 5 meters of the restoration site's boundary, to avoid edge effects.

Monitoring Plot Description:

All monitoring plots are 30 m x 30 m, where all large tree species (> 10 cm Diameter at Breast Height – DBH) are recorded. Within each stratum, for each hectare of restored area, the 30m x 30m plot will contain 1 or 2 smaller nested plots, one that is 3 m x 3m (9 m^2) and, inside of that one, one optional plot that is 1m x 1m (1 m^2), for the monitoring of smaller trees, as described in the section below (illustrated in Figure 2). The location of the sub-plots consisting of the 3m x 3m and 1m x 1m plot are randomized within the permanent 30m x 30m plot the first time, but thereafter should remain permanent.

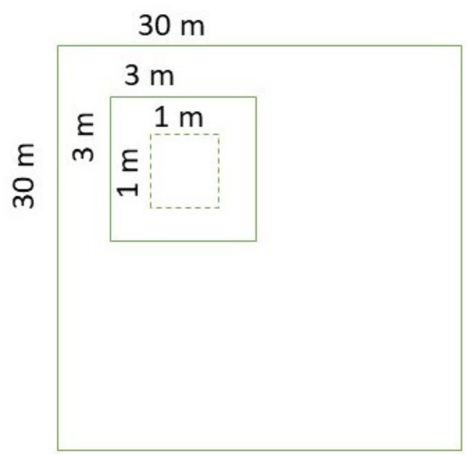
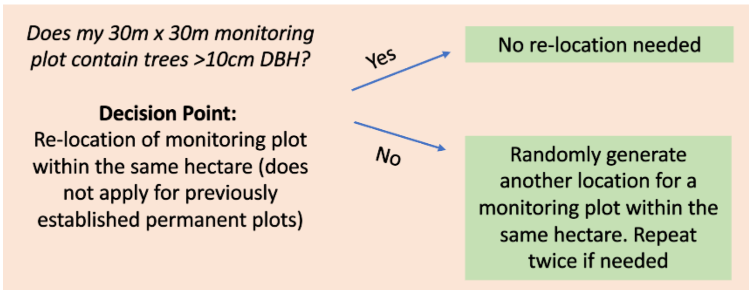


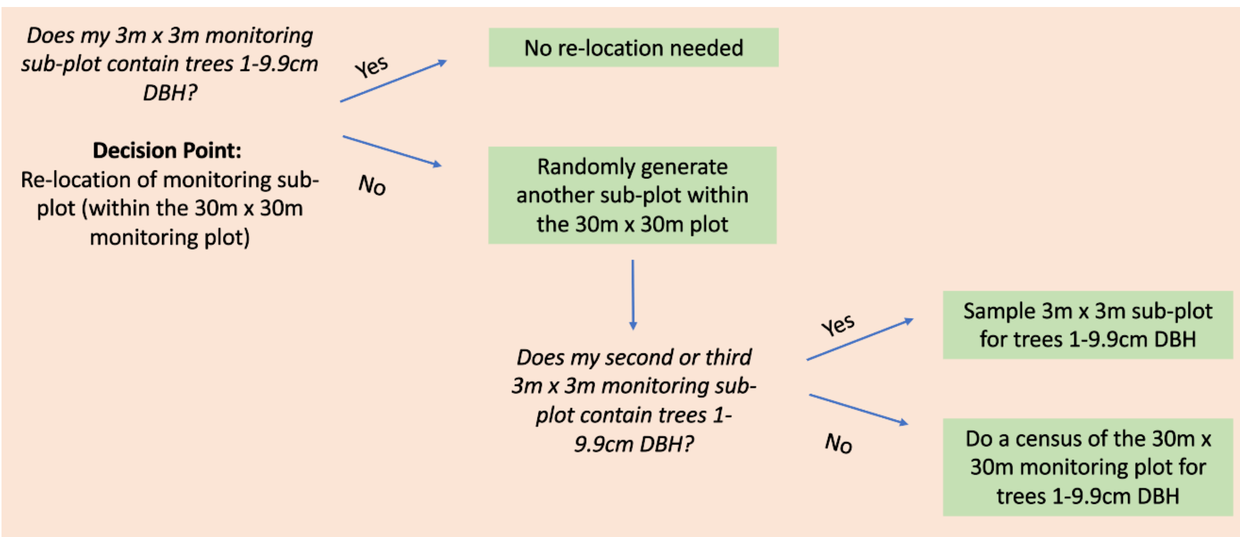
Figure 2: Nested Monitoring Plot arrangements of large 30m x 30m (900 m^2), medium 3m x 3m (9m^2), and optional small 1m x 1m (1m^2). **Modifications for Empty Plots:**

If there are no trees > 10 cm DBH found in the initial 30 x 30 m plot, then that plot should be counted as 'empty' and a new plot selected in a new random location within the same 1 ha sampling area. This may be done twice. If 2 additional empty plots are found, then, the 3rd plot should be monitored, even if it is empty. The fact that there were 2 empty plots registered prior to the placement of the plot should be noted, as it will be factored into the extrapolation of the data.

If this 3rd plot is also devoid of any trees > 10 cm DBH, this can be noted in the data sheet. The nested 3 x 3 plot should then be checked for trees 1-9.9cm. If there are none, then, the nested plot should also be counted as empty and a new plot selected in a new random location within the 30x30 m plot. Again, this may be done twice. If 2 additional empty plots are found, then, a full census count of the 1-9.9 cm size class should be done in the entire 30x30 m plot.

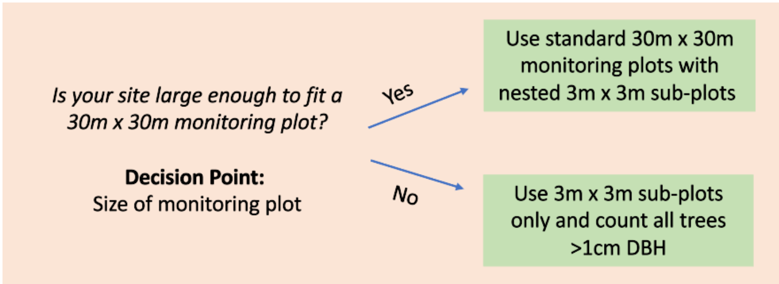
If, on the contrary, there are trees > 10 cm DBH found in the initial 30 x 30 m plot, but then, there are no trees 1-9.9 cm within the 30x30 m plot, the same procedure as above applied: the nested plot should also be counted as empty and a new plot selected in a new random location within the 30x30 m plot. Again, if 2 additional empty plots are found, then, a full census count of the 1-9.9 cm size class should be done in the entire 30x30 m plot.





Modification for Sites Smaller than 30m Wide

If an entire restoration site is smaller than 30m wide, and therefore a 30m x 30m vegetation monitoring plot will not fit on the site, then this constraint should be denoted in the data sheet, and a 3m x 3m sub-plot should still be used. In this scenario, all trees >1cm DBH within the 3m x 3m plot should be recorded in the data sheet. The number of 3m x 3m plots should match the number of plots outlined in Table 1.



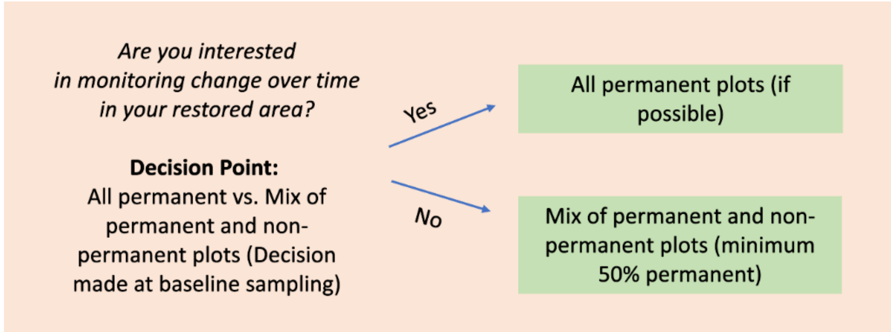
Permanent & Non-Permanent Plots

Permanent monitoring plots, where the same exact location is monitored every time data is collected, are recommended if the focus is scientific research or when the funding comes from banks or official agencies (PACTO, 2013) or if the project will seek accreditation with one of the carbon standards. A combination of permanent plots and non-permanent plots (where the location is randomized each time) is also acceptable – **but a minimum of 50% permanent plots should be maintained** (PACTO, 2013).

The locations of the large (30x30m) monitoring plots will be randomly selected within the project area for baseline data collection. Subsequently, if some non-permanent plots are desired, then half of the large plots should still remain as permanent plots, and the other 1/2 will be re-randomized at each data collection (Y2.5 and Y5 or more frequently if more monitoring is done). If there is only one plot, or an uneven number of plots, then the plot should be permanent.

Each permanent plot must be georeferenced with landmarks in the ground (wood staking, iron pipes, rebar, or PvE tubing) at 1.2 m in height (PACTO, 2013) and GPS corner points and centroids recorded along with device margin of error. The GPS corner points and centroids of non-permanent plots will also be recorded at the time of monitoring, but they do not need to be marked with landmarks. Each plot should also be denoted as permanent or non-permanent in data collection to avoid accidental re-randomization of permanent plots. If the plot is nested and permanent, the corners of the nested (3m x 3m and 1m x 1m) plots should also be georeferenced with landmarks, but only the centroid is recorded using the GPS. All nested plots (3m x 3m and 1m x 1m) should also have descriptions of their locations within the larger (30m x 30m) plot. In areas with a lot of human activity where there is a risk that visible markers might be taken, plots can be monumented (permanently demarcated) by driving a metal stake into the ground which can be found again with a metal detector.

The number of trees that have been planted into each 30x30 **permanent** monitoring plot as part of the restoration intervention (regardless of their DBH, and disaggregated by species) should be recorded in the baseline information. The locations of the planted trees in permanent monitoring plots should be documented with extra care (possibly with a drawing of their locations within the plot, or at least noting their spacing and planting pattern), to enable follow-up vegetation monitoring and survival rate calculations.



Data collection and tools:

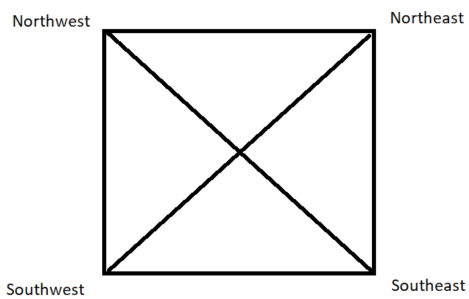


Photo: Three (3) geotagged photos should also be taken from one corner of the 30x30 m plot, one each with the edge of the plot in the centerline, looking at the opposite corner, and one looking across the diagonal. The corner from which the photos are taken should be the corner that provides the best overview of the plot (accounting for slope, existing vegetation, etc) and should be noted (NW, NE, SW, SE- as noted in the GPS coordinates). For example, if the photos are being taken from the NW corner in the plot diagram below, one photo would be from the NW corner to the NE corner (one side), one from the NW corner to SW corner (other side), and one from the NW corner to the SE corner (the diagonal).

In each monitoring sampling plot, ***counts of the trees/saplings per tree species*** must be recorded for different size classes following the instructions below. The tree diameter (DBH) and height can also be recorded, but is optional, if the developer wants to make field-based carbon estimations.

In the 30 m x 30 m plots all large trees (> 10cm DBH) per tree species are counted. DBH and height can be optionally recorded for each individual tree. In the nested 3 m x 3m (9 m^2) all medium sized trees/saplings (diameters 1 – 9.9 cm DBH) per tree species are recorded. DBH and height can also be recorded for each individual tree, but are optional.

The smallest nested plot is completely optional. The 1x1 plot gives an indication of the emerging, very young trees on the site, and may be useful for projecting future tree density, but, individuals of the smallest size class (<1 cm DBH) will not be included in the tree count or carbon estimations. In the smallest nested plot, 1m x 1m (1 m^2) all tree saplings (<1 cm DBH) will be counted and identified to species or species type as much as is possible (no height or DBH measurements for this small category, adapted from Celentano et al., 2020) Data should be recorded following the template of Form 1 in Sub-protocol 4, Annex 1, which will be done using the integrated monitoring platform data collection app.

When this protocol is followed in the baseline period, the presence of existing trees in the restoration sites (inside the monitoring plots) is important to note. These trees will not be counted as trees restored by the project, because they were already present. The number of trees in the sampling plot will be extrapolated across the total restored area. Hence, if there are parts of the plot with more trees already present in the baseline period, it is important to follow a good stratification procedure based on the vegetation type (I.e., with trees vs. without trees), to generate an accurate extrapolation across the restored area.

Measuring protocols:

- (Optional) Diameter at Breast Height (DBH): Use a forestry-grade DBH measuring tape at diameter at breast height (1.3 m) around the stem or trunk of the tree. Record in metric units.
    - If stems have bifurcated below 1.3m, DBH should be taken from all stems above 1.3m (PACTO, 2013)
- (Optional) Height: Use a clinometer, or for Saplings or regenerants too small for the use of a clinometer, use measuring stick. Note that for carbon accreditation, height is sometimes an optional recording, it depends on the allometric model used.
- Species must also be recorded for carbon accreditation, again to apply the correct species specific allometric models (there are many generic ones to).

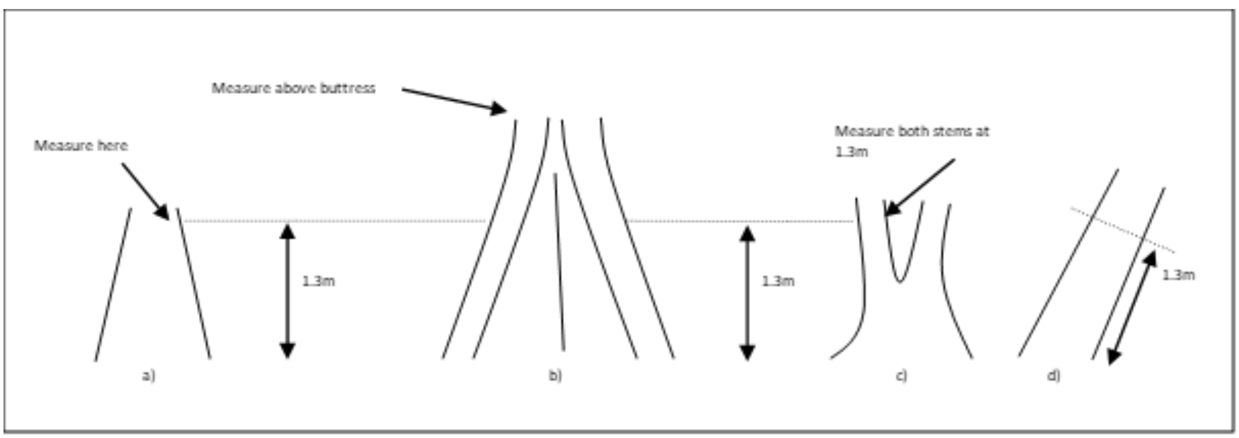


Figure 5. Measuring position for various different trunks, **a**) single, straight trunk, **b**) trunk with buttresses, measured above buttresses and **c**) trunk that forks before 1.3m and **d**) a leaning tree.

How to Distinguish a Naturally Regenerating Tree from a Planted/Seeded Tree

In plots where direct planting and natural regeneration both occur, it may be challenging to distinguish the planted trees from the naturally regenerating trees. The developer may have chosen to tag the planted trees or mark their positions, for example with a stake, but such markings may become lost, damaged, or even stolen during the full duration of the monitoring.

The historical knowledge of the planting patterns used (I.e. if it was a grid, what was the spacing of the grid, and/or what was the orientation (N/S/E/W) and spacing of the rows) will be essential to help in this task of distinguishing between a planted/seeded tree and a naturally regenerating tree.

In general, a tree is probably a regenerant (i.e., not planted) when any of the three following conditions apply:

1) it is located outside a known planting row or grid position

2) it is an obviously different size (either bigger or smaller suggesting more than one year's difference in age) than the observed range of sizes of the planted/seeded trees or

3) it is not included in the species list of planted/seeded trees (PACTO, 2013)

While it can be difficult to distinguish between planted and naturally regenerated trees, a localized mechanism to judge which trees are planted and which are naturally regenerating helps to count the total number of trees restored (Impact Indicator A). If a different method for distinguishing trees is used in your plots, it should be shared for discussion with the global monitoring team.

Determining When a Tree is 'Regenerated'

Naturally regenerating saplings must attain a verifiable age of over 1 year, or an equivalent, regionally specified size threshold, to be counted as 'restored' in reporting to the PPC. An absolute minimum threshold size should be 1 cm DBH, I.e., trees that would meet the requirement for monitoring in the "medium" 3 x 3 m nested plot. The individual counts of smaller regenerating trees from the 1x1m nested plots are indicative of the seed bank and biodiversity, but trees in that size class will not be counted as "restored" or "regenerated" in Y5. We note that the field monitoring procedure will likely allow for better detection of the "medium" size class of saplings, which may not be detectable by remote sensing.

Reporting:

Data sheets are provided in this sub-protocol's annex for your use to collect, record and track over the project's duration. Data should be reported for each monitoring plot.

Data Processing (to be done by the global monitoring team from the plot monitoring data submitted):

In order to extrapolate Impact Indicator A: # of trees restored (survived and crowded in) after 5 years, Indicator 1.2: # of trees naturally regenerating per area under restoration and Indicator 1.5: % survival of planted trees, the data from the Y5 monitoring will be compared to the baseline data.

To get A: # of trees restored (survived and crowded in) after 5 years & Indicator 1.2: # of trees naturally regenerating per area under restoration – both potentially disaggregated by species and by origin (pre-existing, planted, naturally regenerated) requires multiple steps for each disaggregated group:

1. Calculating sampling ratios per stratum:

The area monitored in each stratum (including the number of 'empty' plots if applicable) will be divided by the total area of the restored area in that stratum, to get the sampling ratio for the stratum. If no strata were defined, then, the total area monitored can be divided by the total restored area to get the sampling ratio. See table 1 for minimum sampling ratio.

2. Extrapolations within each monitoring plot:

If the regular nested protocol was followed, the number of medium trees with DBH > 1 cm observed in the 3x3 (9 m2) plot will be extrapolated to the 30m2 plot by multiplying by (30/9). This number will be added to the total number of large trees with DBH > 10 cm that were directly observed in the 30 m2 plot, to get the total extrapolation of trees for the monitoring plot.

If there were 1-2 'empty' plots, but then a successful 3x3 plot, then the multiplication factor will decrease (30/18 for 1 empty plot, 30/27 for 2). If there were 3 empty plots, resulting in a census of the 30x30 plot, then the censused number can be used directly as the number of trees in the monitoring plot.

Because we will be later subtracting the number of trees counted in the baseline, all trees except the trees that are known to have been planted should be included in these calculations (i.e., including trees that were potentially already on site at the baseline).

3. Extrapolations to restored area:

The extrapolations of total trees for each monitoring plot will be summed within each stratum and multiplied by 1/sampling ratio, to extrapolate the total trees for the stratum. If no strata were defined, then, the extrapolations of total trees for each monitoring plot can be summed and multiplied by 1/sampling ratio.

1. Finally, the extrapolation of total trees present during the baseline monitoring should be subtracted from the total extrapolation of naturally regenerated trees present in the monitoring period (not including trees planted), to get the number of trees naturally regenerated (indicator 1.2).

Calculating Survival Rate:

Survival rate at Y5 will be calculated using this simple equation:

Within Plot Survival Rate = (# of living planted trees in 30 x 30 m plot at Y5** / # of planted trees in 30 x 30 m plot at Y_0) * 100

***may be done either with a full census of the 30 x 30 m plot for planted trees at Y5 or by extrapolating the number of living planted trees from the number found in the 3x3 m plot, proportionately*

Survival rates within each monitoring plot will be averaged to produce the overall survival rate for the site.

Additional data that can be generated per site with this data:

(if recorded): Average size (DBH and/or height) of trees, disaggregated by species

Calculating carbon content:

There are many ways to calculate ex-ante carbon stocks. In forestry projects Mean Annual Increment data and Biomass Expansion Factors are typically used, sourcing the data from local growth charts or simply using IPCC defaults. For natural regeneration projects data on regrowth can be sourced from suitable literature.

For post ex calculations, the first step is to select an appropriate allometric equation. Globallometree is a global source of equations http://www.globallometree.org/

It is important to make sure that allometric equations used are conservative if they are not site specific and peer reviewed. Generic non-specific equations often work well in certain forest types. Make sure that whichever equation is chosen that it is applied within it's limits, e.g. if a specific equation was developed for DBH between 5 and 55cm it cannot be ablied to trees with a DBH over 55 or below 5 cm.

The following CDM methodology can be used to calculate carbon stocks ar-am-tool-14-v4.2.pdf (unfccc.int).

Please note that even if all of the above procedures are followed, this procedure alone will not make a project eligible to issue carbon credits. There are other important steps related to project design and verification, following authorized carbon standards, that are required to do so.

Resources:

Celentano, D., Rousseau, G. X., Paixão, L. S., Lourenço, F., Cardozo, E. G., Rodrigues, T. O., E Silva, H. R., Medina, J., de Sousa, T. M. C., Rocha, A. E., & de Oliveira Reis, F. (2020). Carbon sequestration and nutrient cycling in agroforestry systems on degraded soils of Eastern Amazon, Brazil. Agroforestry Systems, 94(5), 1781–1792. https://doi.org/10.1007/s10457-020-00496-4

Chazdon, R. L., & Guariguata, M. R. (2016). Natural regeneration as a tool for large-scale forest restoration in the tropics: prospects and challenges. Biotropica, 48(6), 716–730. https://doi.org/10.1111/btp.12381

Chazdon, R. L. (2013). Making Tropical Succession and Landscape Reforestation Successful. Journal of Sustainable Forestry, 32(7), 649–658. https://doi.org/10.1080/10549811.2013.817340

FAO. 2019. Restoring forest landscapes through assisted natural regeneration (ANR) – A practical manual. Bangkok. 52 pp. Licence: CC BY-NC-SA 3.0 IGO.

PACTO. (2013). PACTO Pela Restauração da Mata Atlântica. Atlantic Forest Restoration Pact. https://www.pactomataatlantica.org.br

Sub-protocol 4, Annex 1. Data Collection Form Description
Table detailing the information collected during vegetation monitoring. Items highlighted in grey are optional. Data is collected using KoboToolbox, which can be accessed on the IMP.

Data Collected	Options	Data Type	Notes
General Information			
Date		Date	
Organization Name		Select one from list	
Site ID		Select one from list	
Sampling Timeframe	Y0 (baseline), Y2.5, Y5, Other	Select one from list	
Site Type	Control, Restoration	Select one from list	
Start time of data collection		Time	
End time of data collection		Time	
Plot Information			
Plot ID		Text	
Plot Type	Control, restoration	Select one from list	All restoration should be looking for natural regen
Plot permanence	Permanent, Randomized	Select one from list	
Strata		Text	NA if only 1 stratum, if multiple in restored area then match answer with strata identified in site establishment form
Number of resamplings needed for 30m x 30m monitoring plot	0, 1, 2	Select one from list	A resampling (relocation of the plot within the same hectare) occurs if there are no trees >10cm DBH in the plot. Does not apply to permanent plots except at baseline
Description of tree planting pattern within monitoring plot (if planting has already occurred)		Text	Grid spacing, clumping, etc
Coordinate System Used		Text	

Northeast corner of plot (30x30)		GPS coordinate	
Device margin of error (NE corner)			Automatically included in KoboToolbox
Northwest corner of plot (30x30)		GPS coordinate	
Device margin of error (NW corner)			Automatically included in KoboToolbox
Southeast corner of plot (30x30)		GPS coordinate	
Device margin of error (SE corner)			Automatically included in KoboToolbox
Southwest corner of plot (30x30)		GPS coordinate	
Device margin of error (SW corner)			Automatically included in KoboToolbox
Trees in 30m X 30m Plot All trees > 10cm DBH by species and type should be recorded. Separately, any PLANTED trees that have not yet reached 10cm DBH should also be recorded. ** Note that DBH and height measurements are not required, only a count by size class, disaggregated by species and type*			
Count of trees (>10 cm DBH)	Disaggregated by species and type (naturally regenerating, planted by your project, already present prior to project, don't know)	Integer + species + select one from list (type)	If using this sheet for data collection, repeat this line for each species and type. Ex: species A, count of 2, and naturally regenerating Species A, count of 3, planted by your project
Count of PLANTED trees (only trees that are smaller than 10cm DBH)	Disaggregated by species	Integer + species	If using this sheet for data collection, repeat the line for each species. Ex: species A, count of 2
Notes		Text	
3 geotagged photos of AB, AC, and AD sightlines (in vegetation monitoring protocol)- specify corner		Picture upload + text (corner chosen)	Photos should be taken from the corner that provides the best overview of the plot (accounting for slope, existing trees, etc)
Trees in 3m X 3m Plots In the nested 3m x 3m sub-plots all trees with a diameter between 1 – 9.9 cm DBH are recorded			

** Note that DBH and height measurements are not required, only a count by size class, disaggregated by species and type*			
Number of resamplings needed for 3m x 3m sub-plot	0, 1, 2	Select one from list	A resampling (relocation of the sub-plot within the 30m x 30m plot) occurs if there are no trees 1 - 9.9 cm DBH in the sub-plot
Count of trees (1-9.9 cm DBH)	Disaggregated by species and type (naturally regenerating, planted by your project, already present prior to project, don't know)	Integer + species + select one from list (type)	If using this sheet for data collection, repeat this line for each species and type. Ex: species A, count of 2, and naturally regenerating Species A, count of 3, planted by your project
Notes		Text	
Centroid		GPS coordinate	
Description of location within 30m x 30m plot		Text	
(Optional) Additional Photos			
Saplings in 1m X 1m Plots In the smallest nested plot, 1m x 1m (1 m2) all saplings (regenerants) (<1 cm DBH) will be recorded. At this size, it is important to distinguish between trees and shrubs			
(Optional) Count of saplings (<1cm DBH)	Disaggregate by species and types (naturally regenerating, planted, don't know)	Integer + species + select one from list (type)	
(Optional) Centroid		GPS coordinate	
(Optional) Description of location within 3m x 3m plot		Text	
Additional Information			
(Optional) File Upload		File upload	

Special Circumstance: Restoration Site is too small to fit 30m x 30m plot In this scenario, a 3m x 3m sub-plot is sampled. A count of trees >1cm DBH is conducted

Count of trees (>1cm DBH)	Disaggregated by species and type (naturally regenerating, planted by your project, already present prior to project, don't know)	Integer + species + select one from list (type)	If using this sheet for data collection, repeat this line for each species and type. Ex: species A, count of 2, and naturally regenerating Species A, count of 3, planted by your project
Notes		Text	
Centroid		GPS Coordinate	
Description of location within 30m x 30m plot		Text	
(Optional) Additional Photos			

Special Circumstance: Sub-plot is resampled 3 times, and still contains no trees from 1-9.9 cm DBH In this scenario, a census of the 30m x 30m plot is done for trees from 1-9.9 cm DBH in addition to trees >10cm DBH. Separately, any PLANTED trees within the plot that aren't >1cm DBH should also be recorded			
Count of trees (1-9.9 cm DBH)	Disaggregated by species and type (naturally regenerating, planted by your project, already present prior to project, don't know)	Integer + species + select one from list (type)	
Notes		Text	
(Optional) Additional Photos			

SUB-PROTOCOL 5: NURSERIES (OPTIONAL)

Nursery tree counts specifying age/stage of counting

Provides guidance for indicator 1.3: # of trees grown in nurseries

Created by Ornanong (Dow) Martin at WRI

Data collected by project developers and submitted to IMP. Analyses completed by the global monitoring team. Optional in all projects.

Guidance for Users

This sub-protocol, designed for project developers, describes how to provide a final seedling/young tree count with evidence to be submitted to the Monthly Forms. This protocol is used prior to the tree planting date for each site, and it can be used throughout the project lifetime.

Disclaimer: It is extremely challenging to achieve a generic set of monitoring requirements that can be spread across all of the possible PPC Program sites. The following is meant as guidance for the minimum set of requirements for the PPC Program. If you would like to add more rigorous monitoring in addition to what is laid out here, you are encouraged to do so by contacting the CI or WRI global monitoring team.

Importance

Nursery tree count is an intermediary progress indicator for the number of trees planted/grown indicator. In the early stages of project implementation, when seedings or saplings have not been planted, projects can still report progress of their seedlings, showing partners and investors that their tree planted/grown target are in progress.

Methodology

Seed cultivation and plant development can take from a few days to over a year, depending on the stage they will be planted either as seedlings or saplings. For restoration interventions that require germination in nurseries, each project will be required to report the number of viable seedlings by species for each site – Viable seedling means that from seeds filled in sockets, at least 1 seedling was formed with 2-3 adult leaves, in the Monthly Forms. Seedings are counted as soon as they reach the viable stage, disaggregated by species, and each seedling is only counted once. The information can be requested from the nursery or compiled in-house by the project developer and is submitted in the Monthly Forms in the integrated monitoring platform.

(Optional) In addition, projects may consider providing evidence of nursery production progress at key moments following the example below: at target setting stage and at assessment of capacity to deliver stage. All documentation should be shared in the Monthly Reporting Form in the integrated monitoring platform as part of the technical narrative. This information can be uploaded only once, or as needed, while the number of viable seedlings is reported every month that nurseries are active.

(Optional) Example

Once the site or sites in a project have been determined, each project can upload:

1) at target setting stage

- Site planting plans that includes the estimated number of seedlings or young trees will be planted,
- A schedule working backwards from the date of planting on site, delivery date, viable seedling care and maintenance period, successful germination, filling sockets with seeds, and acquiring seeds.

2) at assessment of capacity to deliver target seedling to site stage

1. A sentence explaining any risks to not delivering the target number of seedlings such as low seed availability, high-price of soil, limited space, etc.
2. A sentence describing adjustments to seedling production towards site target based on capacity to deliver, inputs, and progress on execution

References

ICRAF, 2021. “The Resources for Tree and Tree Planting Platform.” https://tree.worldagroforestry.org/.

SUB-PROTOCOL 6: CANOPY COVER

<u>Remote baseline establishment and evaluation of % attainment of target canopy cover, look back period.</u>
Provides guidance for Indicator B: % attainment of target canopy cover in restored area
Created by John Brandt and Justine Spore at WRI
Analyses completed by the global monitoring team. Required in all projects.

Guidance for Users
The sub-protocol describes how tree canopy cover at year 0 and year 5 will be calculated for all sites in a project by the *global monitoring team*. Year 0 is 12 months within the Baseline and Site Establishment date, and year 5 is five years from the baseline and site establishment date or the end of the project.

Importance
The Trees in Mosaic Landscapes (TML) dataset (Figure 1) and analyses establish Year 0 tree cover, Year 5 tree cover, as well as the change in tree canopy cover for all sites in a project. This is an impact indicator that shows the growth of trees over the lifetime of the project. The result can be used for adaptive management. For example, if a project used the same methods in two sites, but have different changes in tree cover percent across the project lifetime ~~%~~, this insight can be used to understand the contributing factors of project success and/or failure (e.g. soil type, aspect, slope, project size, planting month).

Methodology
Data Source
WRI developed a new deep learning methodology to create ~~a~~ globally consistent tree cover data at the 10-meter scale. The methodology addressed many of the barriers to deep learning in large-scale remote sensing identified in Ma et al. (2019) by incorporating recent approaches to improving generalized and per-pixel accuracies of convolutional neural networks. A full description of the methodology can be found in Brandt and Stolle (2020). WRI modified the methodology to -improve detection of small and scattered trees:

- Training the model on 18,1002-hectare photo-interpreted plots
- Applying terrain flattening to Sentinel-1 data
- Improving cloud shadow detection
- Altering the neural architecture to improve generalizability through improved hyperparameter tuning and model architecture searches
- Adjusting the input remote sensing indices based on hyperparameter tuning

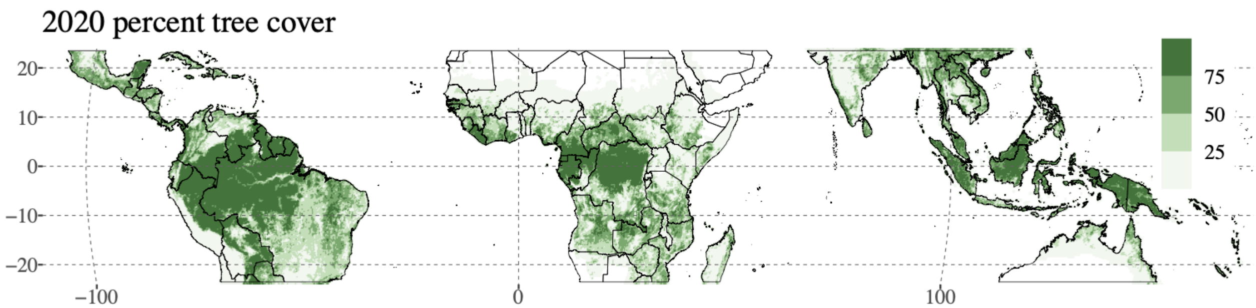


Figure 1. Tree cover in the tropics. Pixel values are average resampled from 10 meters to 10 km.

The 2020 TML map in the tropics enables accurate monitoring of trees in urban areas, agricultural lands, and in open canopy and dry forest ecosystems. TML maps tree extent with high accuracy across the tropics, achieving an average of 97% user's and producer's accuracy (Figure 2).

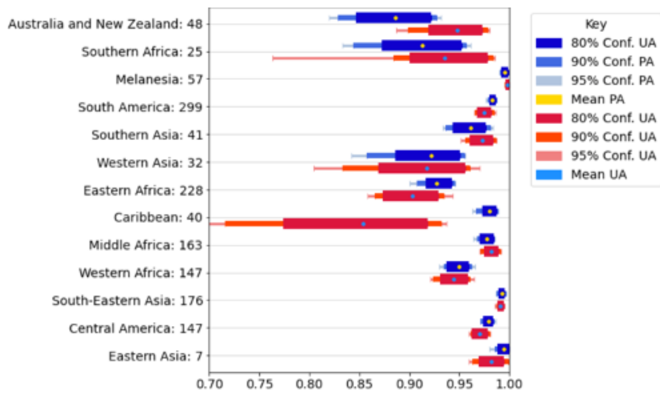


Figure 2. User's accuracy (UA) and producer's accuracy (PA) for 1,418 test plots, totaling 278,000 10x10m pixels, disaggregated by subregion. Error bars represent the 80, 90, and 95 percent confidence intervals derived from 10,000 bootstrap iterations.

Year 0 Data Analysis

TML data will be used to analyze tree cover within all site polygons in a project to calculate the baseline tree cover percent at the year of site establishment (Figure 3). The analysis will be shared with project managers to estimate/adjust the target canopy cover at Year 5.
We will use the published accuracy metrics to calculate confidence intervals for the tree cover area assessments for areas where the predicted uncertainty is under 10%. These metrics will be broken down by global region and land use type. Otherwise, we will conduct short photointerpretation exercises to establish confidence intervals for the tree cover distribution in the project areas. In addition, we will account for error in imagery co-registration, which affects tree cover measurements at the edges of project polygons.

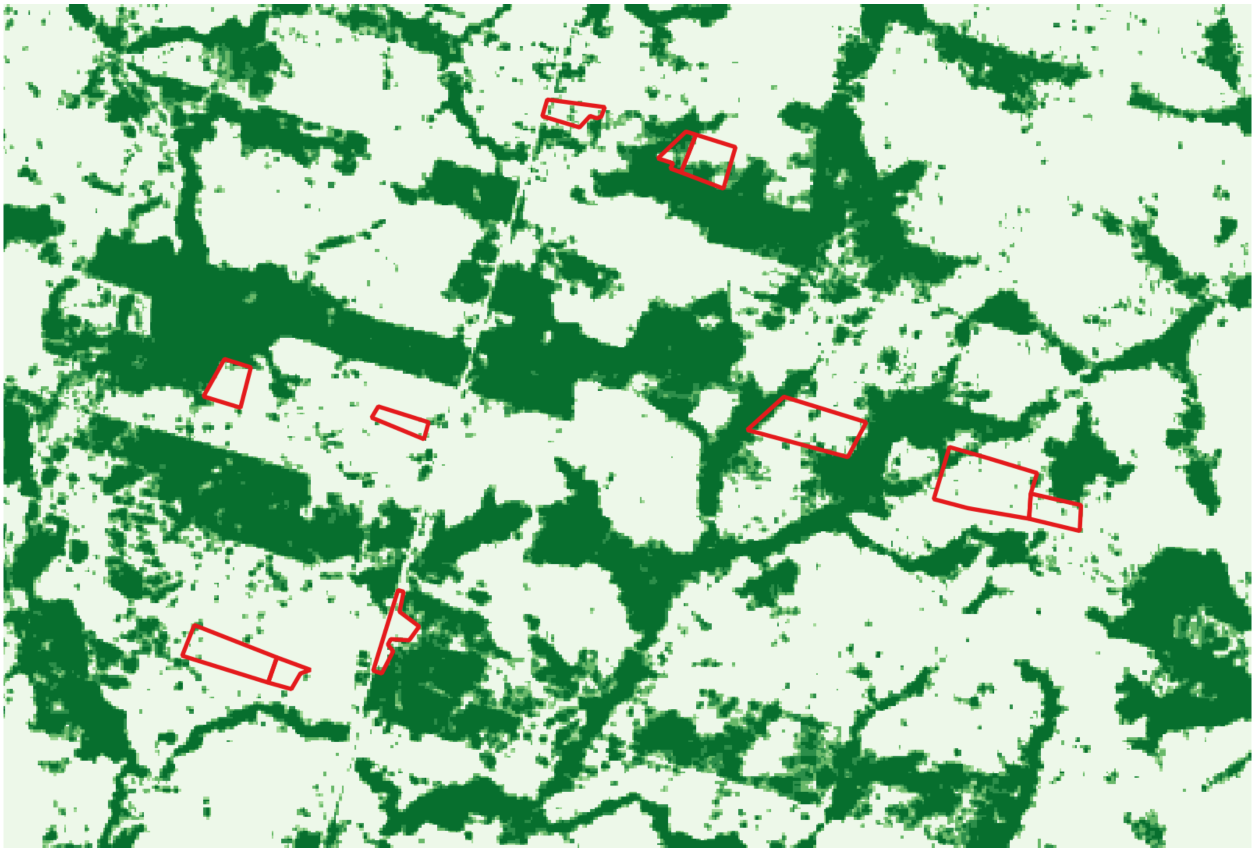


Figure 3. Example baseline tree cover data for project polygons.

Year 5 Data Analysis

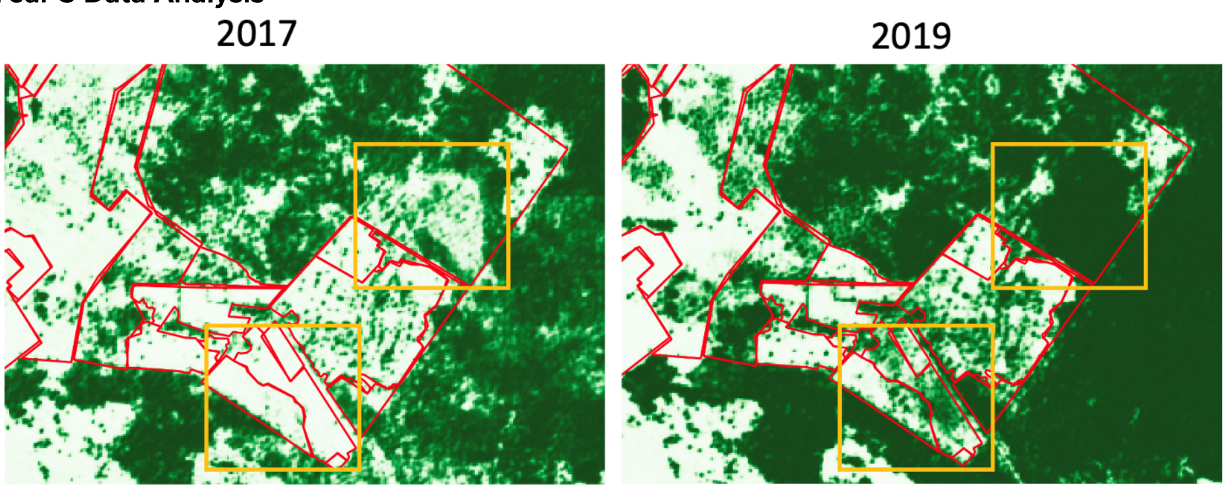


Figure 4. shows an illustrative example of how the TML dataset presents change in tree cover visually in a mixed agroforestry and reforestation area in Mexico in red. The yellow squares highlight the increase tree cover change.

The TML data will be used to calculate change in percent tree cover on all sites of the project areas five years from the respective baseline year. Year 0 and Year 5 for projects will be different and based on project reported site establishment dates.

The difference in tree cover percent from Year 0 (e.g. site establishment and/or project set-up of all sites of the project area) will be calculated with an established change detection methodology and will be adjusted based on the calculated confidence intervals for each project polygon (Indicator 1.4).

Indicator 1.4: Remote Baseline Establishment and Evaluation of tree crown canopy / area Analysis

The change in tree cover from Year 0 to Year 5 will be calculated by applying change detection methods from Wu et al. (2017) to the corresponding years of TML data for each site polygon. This change detection method uses Bayesian soft fusion to adjust the simple difference in tree cover based on an unsupervised change detection algorithm (iterative slow features analysis) on the satellite imagery. This minimizes the impact of seasonality, camera angle, and other random effects on the calculated tree cover change. The intrinsic and extrinsic errors for each year of TML data will be compounded and applied to ensure that the tree cover change data is statistically significant.

References

Brandt, J., Stolle., F. A global method to identify trees outside of closed-canopy forests with medium resolution satellite imagery. *International Journal of Remote Sensing* **42,** 1713-1732 (2020).

Brandt, J.,Ertel., J., Spore, J., Stolle, F., 2022. The extent of trees in the tropics. Working Paper.
Ma, L., Liu, Y., Zang, X., Ye, Y., Yin, G., Johnson, B. Deep learning in remote sensing applications: A meta-analysis and review. *ISPRS Journal of Photogrammetry and Remote Sensing* **152**, 66-177 (2019).

Wu, C., Du, B., Cui, X., Zhang, L. A post-classification change detection method based on iterative slow feature analysis and Bayesian soft fusion. *Remote Sensing of Environment* **199**, 241-255 (2017).

Explore data on Resource Watch and Global Forest Watch, and the code and methodology on GitHub.

SUBPROTOCOL 7: DISTURBANCES

Includes details on how data on disturbances is collected during the project

Provides field data for indicator 1.6: # of major disturbances observed

Created by Isabel Hillman at CI

Guidance for Users

This protocol is used by *project developers* to submit disturbance data each month in the integrated monitoring platform (IMP)

Importance of disturbance data collection:

In cases where disturbances cause damage to restoration efforts, the collection of disturbance data allows us to understand how those disturbances impacted restoration work. It also allows us to build a better understanding of the challenges faced by restoration projects.

Methodology - Completed by project developers

Project developers share information about disturbances that occur on their sites during the project period in the monthly updates. For each disturbance, the extent, type, and severity of the disturbance are indicated, and an accompanying narrative describing the disturbance is submitted, including any damage to plantings. Disturbances can be ecological, such as pest invasion, climatic such as fires or floods, or human-caused, such as illegal grazing or vandalism. Any disturbance causing mortality or significantly impaired growth to more than 25% of the restored trees or restored area must be reported.

SUBPROTOCOL 8: CARBON ESTIMATION

This protocol describes the process followed by the global monitoring team for estimating carbon sequestered by the PPC Program
Provides guidance for indicator 2: # Tons of CO_2 sequestered by year 5
Created by Isabel Hillman, Starry Sprenkle-Hyppolite, and Anand Roopsind at CI

Guidance for Users
This protocol outlines the process used by the *global monitoring team* to estimate carbon sequestered in PPC project sites over the project lifespan.

Importance of carbon estimation:
Positive impacts on climate mitigation are a key goal of the PPC program, and this estimation of carbon allows us to apply a global, standard method across all PPC projects. The estimate outlined in this protocol is different from the carbon capture targets based on the number of trees to be restored that are made when projects are selected. That per-tree target is included in periodic reports to satisfy donor requests but will be replaced by the results of this estimation in final reporting, as details about the project aren't known when that target is made (I.e exact locations of sites, hectares, etc). The estimation method outlined here relies on global remote sensing data so that comparable calculations can be made for all sites, and to minimize the burden placed on project developers.

The methods outlined in this protocol provide an estimate of carbon sequestration, but there are many more rigorous calculations completed in the process to attain carbon credits. This calculation cannot replace those, and this calculation does not account for all factors considered in carbon credits, such as leakage and additionality. If a project is interested in pursuing carbon credits, more information can be found in sub-protocol 4 on vegetation monitoring.

Methodology
This protocol outlines a method for estimating change in carbon stocks in living biomass using remote sensing to detect aboveground and belowground biomass. It does not account for dead organic matter, carbon stocks in soils or non-CO_2 greenhouse gas emissions, which are beyond the scope of available remote sensing technologies.

Projecting Carbon over 5 Years
To project the amount of carbon sequestered by the project over 5 years, an ex ante analysis using the Cook-Patton 2020 dataset on carbon accumulation in natural forest regeneration (per hectare) is run using Trends.Earth and the restoration area shapefiles provided by project developers.

The Cook-Patton dataset gives an average annual linear growth rate (Mg C/ha/yr) that would be expected over thirty years. For the PPC program we project the annual rate for the 5 years period of the program, although if the restored trees continue to grow and sequester carbon, and the rates would be most accurate over a full 20-30 year period.

This ex-ante projection produces results in megagrams of carbon per hectare per year (Mg/C/Ha/Yr), summed over 5 years. To convert to US tons of carbon, the result is multiplied by 1.1.

Equation:

Mean carbon sequestration rate (Mg C/ha/yr) per site * Area (ha) * 5 years = Total C accumulation per site for 5 years

There is an inherent level of uncertainty to the Cook-Patton (202 dataset, which has a standard deviation of 13% across all geographies and is concentrated in far northern regions. The uncertainty is further increased in our proposed application of the dataset by the fact that the Cook-Patton (2020) carbon accumulation rates were built with carbon data from areas of ***natural forest regrowth***, where trees grow in uncontrolled competition with other trees, shrubs, and grasses.

The actual carbon accumulation growth rates of other restoration strategies such as active tree planting, agroforestry, and even assisted natural regeneration will probably be different. There is no global dataset available for these other methods, but, both WRI and CI are part of a broad collaboration to develop those and will consider their additional application to this process ASAP (expected mid-2023).

The uncertainty in the carbon estimations is a product of the inherent level of uncertainty associated with the model itself, the fact that we are applying the rate to only the first 5 years of growth and the compounded uncertainty from applying it to different types of tree restoration. The compounded uncertainty will need to be further analyzed and reported with the final results.

Finally, the Cook-Patton (2020) carbon accumulation rates only account for aboveground live biomass. Other carbon pools such as belowground biomass and soil organic carbon are not included in this dataset. They tend to be more variable, and are also not available in global datasets.

At the time of writing this protocol (2022), the authors judge the Cook-Patton dataset to be the best available dataset for estimating carbon for tree restoration activities because it takes into account local climatic factors in a more advanced way than others before it. Moreover, the estimations will tend to be conservative because they only include aboveground biomass and the restoration methods used in the program are likely to result in faster carbon sequestration than natrual regeneration (trees are further apart and might benefit from weeding and fertilization, etc.). The PPC global monitoring team will periodically reassess if this dataset remains the best available, and will update this methodology to include better datasets if needed.

Resources:
Penman, J., Gytarski, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., et al. (2003). *Good Practice Guidance for Land Use, Land-Use Change and Forestry.* Intergovernmental Panel on Climate Change, National Greenhouse Gas Inventories Programme (IPCC-NGGIP) [2003]

Cook-Patton, S.C., Leavitt, S.M., Gibbs, D. *et al.* Mapping carbon accumulation potential from global natural forest regrowth. *Nature* **585,** 545–550 (2020). https://doi.org/10.1038/s41586-020-2686-x

SUB-PROTOCOL 9: SOCIOECONOMIC RESTORATION PARTNERS

Socioeconomic restoration partners counting and disaggregation, baseline establishment

Provides field data for indicator 3.1: # of socioeconomic restoration partners, disaggregated by direct and indirect, gender, age, and ethnicity, per area under restoration

Created by Arundhati Jagadish, Isabel Hillman and Starry Sprenkle-Hyppolite at CI

Data collected by project developers and submitted to IMP. Analyses completed by the global monitoring team. Required in all projects.

Guidance for Users

This sub-protocol provides information for *project developers* about how to collect data to report on the number of socioeconomic restoration partners from restoration activities annually.

Disclaimer: It is extremely challenging to achieve a generic set of monitoring requirements that can be spread across all of the possible PPC Program sites. The following is meant as guidance for the minimum set of requirements for the PPC Program. If you would like to add more rigorous monitoring in addition to what is laid out here, you are encouraged to do so by contacting the global monitoring team.

Importance of Socioeconomic Data Collection

Collection of this data allows us to track the direct and indirect socioeconomic impacts of restoration on local peoples. It also allows us to track equity of labor in the sense of avoiding child labor, encouraging women's participation in the workforce, and enhancing economic opportunities to local and indigenous peoples.

METHODOLOGY

Table 1. Important Definitions

This monitoring method was developed using Conservation International's institutional monitoring method.

Term	Definition
Direct socioeconomic restoration partners	Any person who received intentional and direct socio-economic support from PPC Program activities and is aware that they received support. Support may be monetary or non-monetary, and includes partnerships created as a direct result of the project that yields economic benefits during the project.
Indirect socioeconomic restoration partners	Family members of direct partners, and persons with involvement with local organizations and partnerships that may bring jobs in the future.

An example of the data collection form for socioeconomic restoration partners from the restoration intervention is found in Table 3. Each impact category is ideally tracked, but some projects may elect not to track all impact categories. If your project is influenced by the impact category, then it should be tracked. For t categories that are not tracked, 'not monitored' or 'N/A' should be entered into the data collection form, not '0'. The most appropriate method for tracking each category should be determined by the project developer.

For the income category, workers whose work is counted in the work day monitoring (sub-protocol 11) may be counted here as well.

The 'Total' field can include double counting, and is simply the sum of all people listed in each row.

The field for 'Total without Double Counting' should reflect the total number of people impacted without double counting. For example, if 50 people have increased capacity and 50 people receive income, but 25 of those people overlap, then the total is 75.

Table 2. Benefit categories

Term	Definition	Example
Income	An individual who receives money on a regular basis for work due to the restoration project	A worker is paid
In-kind benefits	An individual who receives a non-cash benefit with monetary value due to the restoration project	A community member receives a cellphone so they are able to report if anyone enters the restoration site
Conservation agreement payments	An individual who receives money from a conservation program for a certain action due to the restoration project	A farmer receives payments for utilizing no-till practices
Increased market access	An individual who is more easily able to enter a market due to the restoration project	A fisherman is more easily able to go to market when a new road is constructed
Increased capacity	An individual who increased their abilities, skills, or resources due to the restoration project (but not as part of training, which should be counted as training)	A farmer controls weeds on her farm using techniques learned by doing restoration work for the project
Training	An individual who attends trainings to increase capacity due to the restoration project	A business owner is better able to manage finances after attending a class
Newly secured land title	An individual who purchased or received new land through legal channels due to the restoration project	A person in the community is able to purchase a plot of land

Increased market access	An individual who is more easily able to enter a market due to the restoration project	A fisherman is more easily able to go to market when a new road is constructed
Increased protection of traditional livelihoods or customary rights	An individual who's way of life becomes more stable	A local regulation is passed giving indigenous people more control over their land
Increased productivity	An individual who is able to produce more goods or services due to the restoration project	A farmer produces more crops
Other (specify)		

The number in the categories gender, age, and ethnicity in each row should match across all 3 categories. For example, if there are 3 female restoration partners in the income row, then the age category could have 2 for the 24-64 option and 1 for the unknown option, if it adds to 3. An example can also be seen in Table 3 below.

Reporting on the number of socioeconomic restoration partners is completed annually in the integrated monitoring platform.

Table 3. Data collection form

Benefit Category	TYPE	GENDER				AGE				ETHNICITY			
		Female	Male	Nonbinary	Decline to specify	15-24	24-64	65+	Unknown	Indigenous (please specify)	Other (please specify)	Unknown	Decline to specify
Income	Direct	3					2		1	3			
	Indirect	0											
In-kind benefits	Direct	0											
	Indirect		1			1						1	
Conservation Agreement Payments	Direct	NA											
	Indirect	NA											
Increased market access	Direct	0											
	Indirect		1					1				1	
Increased capacity	Direct	4				2	2			4			
	Indirect	3					3				2	1	
Training	Direct	NA											

	Indirect	NA											
Newly secured land title	Direct				2			2					2
	Indirect	0											
Increased protection of traditional livelihoods or customer rights	Direct	NA											
	Indirect	NA											
Increased productivity	Direct		1						1			1	
	Indirect	0											
Other (specify)	Direct	NA											
	Indirect	NA											
Total Restoration Partners (Allowing double counting of benefits)		15											
Total Unique Restoration Partners (without double counting)		12											

Analyses

Analysis of this data is completed by the global monitoring team. Analyses are conducted at the project level and each disaggregation within the data collection table is utilized. For example, data is analyzed by benefit category to understand in what ways people are impacted by the project. The data is also analyzed by gender, age, and ethnicity to understand if benefits are equitable across these criteria.

SUB-PROTOCOL 10: SOCIOECONOMIC MONITORING, OPTIONAL HOUSEHOLD SURVEYS

Includes details on defining a sampling group and conducting household surveys

Created by Carlos Munoz Brenes, Arundhati Jagadish, Pamela Collins, Isabel Hillman, Elise Harrigan and Starry Sprenkle-Hyppolite at CI

Data collected by project developers or consultants. Analyses completed by the global monitoring team. Optional in all projects.

Before conducting household surveys, ethics and safeguards procedures must be followed. Please contact the global monitoring team to learn about these processes.

Guidance for Users

The socioeconomic subprotocol provides guidance for *project developers* on baseline establishment and data collection for optional household surveys. It also provides guidance to the *global monitoring team* about how field data will be complemented by Remote Sensing and GIS-based analyses, and how data collected in the field will be processed by the global monitoring team. The aim of this document is to provide instructions for data collection on socioeconomic variables and methods for each restoration project.

The subprotocol will support the development of the baseline and additional data collection which will provide a disaggregated count of people involved in the project across several dimensions of gender, age, and ethnicity. The data collected on selected indicators (e.g., age, gender, employment) prior to or in Year 0 of the project will be used to see the distribution of the selected indicators for a baseline amongst the surveyed and monitored households and participating communities.

The household survey method is not part of the standard monitoring within the PPC monitoring framework, but is encouraged if capacity and funding allow for additional socioeconomic monitoring.

Disclaimer: It is extremely challenging to achieve a generic set of monitoring requirements that can be spread across all of the possible PPC Program sites. The following is meant as guidance for the minimum set of requirements for the PPC Program. If you would like to add more rigorous monitoring in addition to what is laid out here, you are encouraged to do so by contacting the global monitoring team.

Importance of socioeconomic data collection:

Socioeconomic data collection helps project developers to assess whether and how restoration has impacted local people given biophysical changes in each landscape. Taking this additional step in socioeconomic monitoring will provide data for impact evaluation which is essential to identify how restoration projects can become more durable and scale

Methodology (Field Component) - Completed by Project Developers

The data collection process is aimed at helping project developers to establish a baseline and data collection plan across all potential communities.

Safeguards: The methodologies described below include interaction with local peoples and communities. Therefore, it is especially important to keep safeguards in mind during the data collection process, and ensure compliance with all standards and institutional protocols for the protection of human subjects.

It is important to note that participation in the household survey is voluntary. The project developers should gain informed consent prior to interview. Informed consent is the voluntary agreement of a respondent to participate in a survey, after information has been provided about that survey (Dillman et al. 2009).

When:

- During Year 0 to establish the baseline
- At Year 2.5 to sequence and measure trends and changes in the indicators from the baseline.
- At the end of the project period (Year 5) to measure the status of the indicators at the end of the project compared to previous measurement periods (e.g., Y0, Y2.5).

How: There are two options for data collection that we have specified below based on field capacity. In-person household data collection and phone interviews with respondents. While the in-person household survey is more comprehensive, it will require visits by local staff to households that have been chosen for surveys. Phone interviews can be done remotely and responses noted, while this method is less time and effort consuming for the field staff, the response rate may be lower. Given the varied contexts, the field staff can choose either of the means. Prior experience with data collection methods can also be a contributing factor in determining the suitable method. Other considerations include pandemic and social distancing concerns, biases introduced by un/familiarity with data collectors, anonymity. For both methods, there are standardized surveys that have been developed.

- (**Preferred**) Survey are administered using a surveying application (to be specified). Project developers will visit selected households to administer the survey in-person. The field developer/ enumerator will record the responses and complete the survey. I(**Minimum**) Surveys are administered using a survey application (to be specified) for data collection. Project developers conduct interviews via telephone, and fill in the survey into the surveying application on behalf of the respondent. In this scenario, project developers must have access to telephone numbers of local households.
- If neither of the above options appears feasible due to accessibility constraints, alternatives can be considered, please discuss by contacting the global monitoring team.

Who:

Table 1: Key definitions

Term	Definition
Community	A group of people living in the same place
Participating community	Group or community of active participants and the communities they belong to
Active participant	An individual who is directly involved in the restoration project during planning, implementing, or monitoring through employment, volunteering, decision making, etc.

1) To determine who should be sampled, the participating community must first be defined (Table 1). The participating community can include one or multiple neighborhoods or communities (or other smaller units) containing at least 5% of active participants of the project. It is important to note that the representation of one or more individuals (representing their entire household) qualifies the broader community which they are a part of to be included in the sampling.

2) Once the participating community has been identified, all households within it must also be identified. This can be done by compiling or obtaining a list of households in the community through secondary sources such as census, local administrative offices (eg - municipal offices, provincial offices). Project developers must define unique identification numbers or codes for (1) the community (2) sub-unit (if applicable), (3) household, and (4) individual participant (if applicable). A minimum sample size of 25 – 30 households is appropriate for a participating community that ranges in size from 100 to 500 families (Angelsen, Larsen, Lund, Smith-Hall, & Wunder, 2011, p. 55). Another way to consider the sampling size is to sample 6 –25% of the households in the participating community.

3) Once a sample size is determined, a random sample needs to be generated (Glew et al., 2012). Please note, the random sample will likely include some households with active participants, and this is acceptable.

To *generate a random sample*:

a) Give each household in the participating community (i.e., the complete list of all households), a unique number.

b) Write the number for each household on a separate small piece of paper. All pieces of paper should be the same size and color.

c) Fold each piece of paper so that the number written upon it cannot be seen.

d) Place all of the pieces of paper in a hat or similar container.

e) Mix the pieces of paper well, so that the last pieces of paper are not all at the top and the first pieces are not all at the bottom.

f) Remove the numbered pieces of paper from the hat one-by-one, recording the number written on each on to the sampling form for that settlement. It does not matter who removes the pieces of paper from the hat, as long as they do so without looking into the hat.

g) Continue drawing numbers from the hat, until you have reached the required sample for that settlement.

h) Keep the numbered pieces of paper which have not been selected in a safe place. They will be needed if a household has to be replaced.

i) Record the names and identification numbers of households to be interviewed on the settlement sampling form.

In community units where a household list is unavailable, the total number of households can be used to determine the sample respondents. The households will be selected based on a randomization process such as walk throughs where every third HH is selected for survey or every alternating house on one side of the street, etc. The method of randomization will depend on the layout of the community unit. The process of household selection will be done till desired sample size is reached.

Control Units: These can include any non-participating communities or non-participating households in a community (it is acceptable to have as controls non-participating households from a participating community). The main distinction of controls from intervention households is that no person within a control household is associated with the restoration intervention in any way.

If there are landscape level control sites as part of your project (see sub-protocol 2), then the households selected to interview as control units will likely be located in the closest population center to the control site, as long as they are not associated with the interventions in any way, as stated above. The details of defining control units when landscape level control sites are present can be discussed with the global monitoring team.

Details on Surveying

Selection and training of Surveyors: As applicable, surveyors should be familiar with local people and customs, and should be chosen to maximize the a) comfort of the people being interviewed and b) the quality of the survey responses. Previous interview experience is preferable. Surveyors should be trained on how to conduct surveys in households, including understanding the rationale for the surveys, the survey method, identifying household heads and requesting interviews, informed consent and confidentiality, and types of questions and responses. More information can be found in Glew et al., 2012 (referenced below). Best practices: Detailed information on best practices for conducting household surveys can be found in Glew et al., 2012 (referenced below). If additional guidance is needed, please contact the global monitoring team for more information. Some general best practices are here:

- Explain the purpose of the monitoring to local officials as needed
- Seek the informed consent of households randomly selected for interview
- Conduct household interviews at a time convenient to the household head or their representative
- Check household surveys for completeness at the end of each day.

In this survey, we do not pay households for their participation. In some cases, it may be appropriate to provideparticipating households with a small token of appreciation for their time. For example, in some instances, the field team provides betel nut, pens or tea as a token to participating households.

Sampling Effort: Each survey contains 30 to 60 questions and is anticipated to take between 40 to 90 minutes to complete per household. The wide range in both the number of questions and time effort is due to (i) the need to capture high quality and critical information related to restoration, (ii) the characteristics of the respondent and (iii) application of questions to local context and environmental conditions. Multiplying the time per survey and the number of households provides an estimate of total time needed with the exclusion of travel, availability of the interviewee and other local conditions or contingencies. Typically interviews involve two interviewers: 1 for asking questions and 1 for taking notes and filling in the survey. This should be accounted for in sampling effort estimations as well.

Costs

It is estimated that 100 household surveys would cost approximately $20,000 to deliver and analyze. However, 100 surveys aren't needed for every project, and costs will vary by location and context. When budgeting for household surveys, local knowledge on costs should be taken into consideration.

Central Analysis

The following data will be collected by the project developers via household surveys using the provided survey template (Table 2). **All variables tracked will be disaggregated by gender, ethnicity, and level of education (to be collected by project developers)**

Project developers are responsible for the field data collection using the survey. Post processing of the data and GIS analyses will be completed by CI or WRI. This includes items such as currency conversions, conversions from numbers to percentages, etc.

Table 2: Variables included in field sampling

Variable of Interest/ Impact	Description of variable	Indicator (including units)
Income	Money received on a regular basis for work or through investments.	Local currency converted to USD equivalent. Aggregated at annual level.
Education	Receiving systemized instruction through a school or university	% of children enrolled in school AND Number of years of schooling of the head of the participant household.
Infrastructure	Presence of infrastructure that is relevant for restoration activities	Presence of roads, water for irrigation, river docking facilities, hospitals/clinics, schools, community centers

Capacity building/ Training	The action of teaching a person a particular skill or type of behavior	# of training programs, learning exchanges, workshops, training manuals, restoration education
Livelihood security	A means of supporting one's existence, especially financially or vocationally linked to land and complementary activities not associated with restoration	Quantity and diversity of options to support livelihoods (farming, forestry, agriculture, commerce)
Status of customary rights	Property access, withdrawal, alienation, exclusion, management	Presence and classification of: Grant of land rights and native title; Protection of sites and sacred sites; Hunting and fishing rights
Jobs	Tracks the number of jobs created	# people employed by the project, unemployment rate in the village/ community.
Food security	Would be used to assess direct benefits from improved tree cover (cultivated foods, medicines, fruits) and indirect benefits (water, energy, etc.)	Number of meals/day that members of a household take
Presence of other projects	Other projects for conservation, restoration, development, or infrastructure are active in the area Include start/end date	# of projects (conservation, restoration, development, infrastructure)
Social conflicts over resources	Competition over material goods, economic benefits, property or power OR parties believe their needs cannot be met OR parties perceive that their values, needs or interests are under threat	# reported conflicts
Place attachment	The emotional bond between person and place	# of years of residence
Ecosystem Services Variables		
Water provisioning and flood risk management	The quality, quantity, and distribution of water in time and space and its alignment with meeting municipal and agricultural needs while not harming property or lives.	Quality, quantity and distribution of water supply and relative risk of flooding (and change over time)
Forest (or wild-harvest) products	The availability of wild-harvested products such as foods, fibers, medicines, fuel, and building materials from forests, grasslands, or other terrestrial (or aquatic) ecosystems.	Quantity of materials being used (and change over time)

Agriculture	Presence/absence and abundance of pollinator species, and how/if these change over time.	Categories and counts (and change over time)
Cultural identity	Sense of place, mental well-being, community, belonging, religion, traditions.	Strength of items listed in description

Methodology (GIS component) - Completed by the Global Monitoring Team

For monitoring over time and conducting impact evaluations of restoration activities, the data collected in the household surveys (described above) will be complemented with GIS data using global/regional/national/jurisdictional level variables (based on availability) and other datasets for many of these variables, recognizing that local data availability may vary by project and locality.

When:

1. During Year 0 to establish the baseline
2. At the end of the project period (Year 5) to measure the status of the indicators at the end of the project compared to previous measurement periods (e.g., Y0).

How: The variables listed in Table 3 will be extracted using GIS with the listed data sources and site shapefiles provided by project developers. In cases where the temporal resolution of the dataset does not match the Y0 and Y5 of the project, data of the closest year available will be used. Some variables are not expected to change (Ex: slope and elevation), so the analysis is only performed at Y0.

Table 3: Variables included in GIS analyses

Variable of Interest/ Impact	Description of variable	Indicator (including units)	Data source
Human Footprint	Impacts of human activities in comparison to wilderness areas	Relative human impact	NASA Human Footprint Dataset
Elevation	Height above sea level	Elevation at site centroid (m)	Site shapefile (Sub-protocol 14)
Slope	Change in elevation over unit distance	Average site slope in degrees	Highest resolution DEM dataset available
Temperature	Intensity of heat present	Average annual temperature (C) at site	To be determined
Precipitation	Atmospheric vapor falling to the ground	Average annual precipitation (cm) at site	To be determined
Size of site	Site area	Site size in hectares	Site shapefiles (Sub-protocol 14)

Distance to infrastructure	Distance from site to important infrastructure.	Distance (km) of site centroid to: -Roads -Rivers -Major town (specify size) -Nearest border of closest protected area	Site shapefiles (Sub-protocol 14) Local infrastructure layers, as available

METHODOLOGY: Data Processing and Analyses – Completed by the Global Monitoring Team

Project developers are responsible for the field collection of the data using the survey. Post processing of the data and GIS analyses will be completed by the global monitoring team. This includes items such as currency conversions, conversions from numbers to percentages, etc.

The global monitoring team will use these data to conduct the analysis and generate science-based findings for better decision making.

Resources:

Alden Wily, Liz. 2011. The tragedy of public lands: The fate of the commons under global commercial pressure. Rome: International Land Coalition. Available at: http://www.landcoalition.org/en/resources/ tragedy-public-lands-fate-commons-under-global-commercial-pressure.

Angelsen, A., Larsen, H. O., Lund, J. F., Smith-Hall, C., & Wunder, S. (2011). Measuring livelihoods and environmental dependence: Methods for research and fieldwork. Bogor, Indonesia: Center for International Forestry Research (CIFOR).

Ceccon, E., Barrera-Cataño, J. I., Aronson, J., & Martínez-Garza, C. (2015). The socioecological complexity of ecological restoration in Mexico. *Restoration Ecology*, *23*(4), 331–336. https://doi.org/10.1111/rec.12228

Donatti, C.I., Martinez-Rodriguez, M.R., Fedele, G., Harvey, C.A., Andrade, A. Scorgie, S. &Rose, C. (2021). Guidelines for designing, implementing, and monitoring nature-based solutions for adaptation. Conservation International. 2nd Edition. http://doi.org/10.5281/zenodo.4555407

Glew, L., Mascia, M. ., & Pakiding, F. (2012). Solving the Mystery of Marine Protected Area Performance: Monitoring social impacts: Field Manual. Wwf, (September), 357.

Rights and Resources Initiative. 2015. Who Owns the World's Land? A global baseline of formally recognized indigenous and community land rights. Washington, DC: RRI.

Sub-Protocol 10, Annex 1: Household Survey

SUBPROTOCOL 11: WORK QUANTIFICATION

Includes details for how to report work days

Provides field data for indicator 3.1.1: # of person days of work created per area under restoration

Created by Isabel Hillman at CI

Data collected by project developers and submitted to IMP each month. Analyses completed by the global monitoring team. Required in all projects.

Guidance for Users

This sub-protocol provides information for *project developers* about how to collect data on the number of workdays created each month.

Disclaimer: It is extremely challenging to achieve a generic set of monitoring requirements that can be spread across all of the possible PPC Program sites. The following is meant as guidance for the minimum set of requirements for the PPC Program. If you would like to add more rigorous monitoring in addition to what is laid out here, you are encouraged to do so by contacting the global monitoring team.

Importance of Workday Data Collection

Collection of these data allows us to track the direct economic impacts of restoration on local peoples. It also allows us to track equity of labor in the sense of avoiding child labor, encouraging women's participation in the workforce, and enhancing economic opportunities to local and indigenous peoples.

METHODOLOGY

A person day of work is defined as 8 hours of work completed, or the legal amount of time in the workday for the country of the activity. If this is not 8 hours, it must be noted, and the legal workday length disclosed. Once an alternative definition is agreed upon between project developers and the global monitoring team, work days will be reported using the agreed upon standard (not 8-hour days). The work does not have to be consecutive hours. Hours completed over different days can be summed into person days of work. Counting includes project developers staff and associated volunteers. The work is disaggregated by role (project management, monitoring, site establishment, etc.) and type (paid or volunteer). Then, participants are further disaggregated by gender, age, and ethnicity within each of the types of work (Table 1). This information is collected separately for each restoration project or site, as applicable, while also allowing for disaggregation by site. Specifications on ethnicity should be treated as optional and only be recorded if that information is not sensitive. The 'decline to specify' column can be used in this case.

Work that is directly contributing to this project is counted. For example, the hours that someone works planting seedlings in the ground.

The number in the categories gender, age, and ethnicity in each row should match across all 3 categories. For example, if there are 3 female paid person days in the project management row, then the age category could have 2 for the 24-64 option and 1 for the unknown option, if it adds to 3. For rows where no applicable work has been completed that month, the rows can be left blank. An example can also be seen in Table 1 below.

Reporting on work days is completed each month as part of monthly reporting in the integrated monitoring platform. It is completed at a project level for the project management, seed collection, nursery establishment and other categories (Table 1). It is completed by site for the site establishment, planting, monitoring, and maintenance categories (Table 2). In instances where there are multiple sites, then the table is filled out for each unique site.

Table 1. Data collection sheet for collecting person days of work each month at a *project* level.

ROLE	TYPE	GENDER				AGE				ETHNICITY			
		Female	Male	Nonbinary / Other	Decline to specify	15-24	24-64	65+	Unknown	Indigenous (please specify)	Other (please specify)	Unknown	Decline to specify
Project management	Paid Person-Days	3					2		1	1		2	
	Volunteer Person-Days												
Nursery Operations including Seed Collection	Paid Person-Days												
	Volunteer Person-Days			1					1		1		
Other	Paid Person-Days												
	Volunteer Person-Days												
Total		6											

Table 2. Data collection sheet for collecting person days of work each month at a *site* level.

ROLE	TYPE	GENDER				AGE				ETHNICITY			
		Female	Male	Nonbinary / Other	Decline to specify	15-24	24-64	65+	Unknown	Indigenous (please specify)	Other (please specify)	Unknown	Decline to specify
Site establishment	Paid Person-Days												
	Volunteer Person-Days												
Planting	Paid Person-Days												
	Volunteer Person-Days												
Monitoring	Paid Person-Days												
	Volunteer Person-Days												
Maintenance	Paid Person-Days												
	Volunteer Person-Days												
Other	Paid Person-Days												
	Volunteer Person-Days												
Total													

Analyses

Analysis of this data is completed by the global monitoring team. Analyses are conducted at the project and site level, and each disaggregation within the data collection table is utilized. For example, data is analyzed by role to understand in which parts of a restoration project take the most work. The data is also analyzed by gender, age, and ethnicity to understand if work days created are equitable across these criteria.

Resources

Angelsen, A., Larsen, H. O., Lund, J. F., Smith-Hall, C., & Wunder, S. (2011). *Measuring livelihoods and environmental dependence: Methods for research and fieldwork*. Bogor, Indonesia: Center for International Forestry Research (CIFOR).

FAO, 2017. Small Family Farms Data Portrait. Available at: https://www.fao.org/fileadmin/user_upload/smallholders_dataportrait/docs/Data_portrait_variables_description_new2.pdf.

SUBPROTOCOL 12: ECOSYSTEM SERVICES

Includes details on how the ecosystem services portion of the household survey (sub-protocol 10) is applied, and a standard GIS analysis is conducted

Provides field data for indicator 3.2: # of ecosystem services restoration partners

Created by Pamela Collins, Starry Sprenkle-Hyppolite and Isabel Hillman at CI

Guidance for Users

This protocol is used by *project developers* who have elected to use the optional household survey outlined in subprotocol 10, and for the CI *technical team* that is conducting the GIS based analysis.

Importance of ecosystem services data collection:

By collecting ground-based observations of changes in ecosystem services provision over time, as seen by local observers familiar with the ecosystems in question, we are able to track potential ecosystem function responses to forest restoration in ways that are not necessarily detectable by, and thus are complementary to, remote sensing observations.

Methodology (GIS/analysis component) - Completed by the Global Monitoring Team

A simple estimation of potential ecosystem services restoration partners is applied using GIS and site shapefiles. A 10 km buffer is created around each site. The buffer is used to extract a population estimate from a global gridded population count (WorldPop) dataset. This analysis is run at baseline (Year 0) and endline (Year 5).

Please note that detailed remotely sensed analyses of specific ecosystem services are time consuming and beyond the scope of this monitoring framework. If you're interested in conducting more in depth analyses using GIS or remote sensing methods, please contact the CI/WRI technical team.

Methodology (optional field component) - Completed by project developers

Household Survey

Ecosystem services questions were integrated into the socioeconomic household survey outlined in sub-protocol 10. The ecosystem services variables that were integrated in the survey can be seen in Table 1 below, and the specific questions are shown in Table 2 below.

Please reference sub-protocol 10 for the procedure for conducting household surveys.

Table 1. Ecosystem services variables integrated into the socioeconomic household survey

Ecosystem Services Variables		
Variable of Interest/ Impact	**Description of Variable**	**Indicator (including units)**
Water provisioning and flood risk management	The quality, quantity, and distribution of water in time and space and its alignment with meeting municipal and agricultural needs while not harming property or lives.	Quality, quantity and distribution of water supply and relative risk of flooding (and change over time)
Forest (or wild-harvest) products	The availability of wild-harvested products such as foods, fibers, medicines, fuel, and building materials from forests, grasslands, or other terrestrial (or aquatic) ecosystems.	Quantity of materials being used (and change over time)
Agriculture	Presence/absence and abundance of pollinator species, and how/if these change over time.	Categories and counts (and change over time)
Cultural identity	Sense of place, mental well-being, community, belonging, religion, traditions.	Strength of items listed in description

Table 2. Questions in household survey relating to ecosystem services

Question Number	Question	Related Ecosystem Service
11	What materials resources do you get from your forest areas?	Forest (or wild-harvest) products
12	Do you go to the forests for reasons other than listed above?	Cultural identity
13	Do you notice runoff in your land when it rains?	Water provisioning and flood risk management
14	In the last 12 months have you noticed any landslides uphill or downhill from your land?	Water provisioning and flood risk management
15	Have you noticed any wildlife including pollinators (insects, birds, bats) on your land?	Agriculture
34-41	*Refer to sub-protocol 13 on freshwater for water and flood related questions	Water provisioning and flood risk management

*Please refer to Annex 1 in subprotocol 10 to see fully detailed questions

For project developers interested in pursuing additional field based ecosystem services monitoring, please contact the CI/WRI technical team.

Data Analysis – Completed by the Global Monitoring Team

Scoring and analysis of the ecosystem services questions in the household survey will follow the same methodology outlined in subprotocol 10.

Resources:

Clerici, N., Armenteras, D., Kareiva, P. *et al.* Deforestation in Colombian protected areas increased during post-conflict periods. *Sci Rep* **10,** 4971 (2020). https://doi.org/10.1038/s41598-020-61861-y

Devenish, K., Desbureaux, S., Willcock, S. *et al.* On track to achieve no net loss of forest at Madagascar's biggest mine. *Nat Sustain* (2022). https://doi.org/10.1038/s41893-022-00850-7

SUBPROTOCOL 13: FRESHWATER (OPTIONAL)

Includes details on how the freshwater portion of the household survey (sub-protocol 10) is applied, and used

Provides guidance for indicator: 3.2.1 # people directly benefiting from improved freshwater quality or quantity

Created by Maira Bezerra, Derek Vollmer, Robin Abell, Ian Harrison, Kashif Shaad, Starry Sprenkle-Hyppolite and Isabel Hillman at CI

Guidance for Users

The freshwater subprotocol provides guidance for *project developers* on baseline establishment and data collection for optional household surveys. It also provides guidance to the *global monitoring team* about how field data can be complemented, and how data collected in the field can be processed by the global monitoring team. Therefore, this protocol is divided into 2 sections: household survey and detailed freshwater monitoring.

Both are not part of the standard monitoring within the PPC monitoring framework, nonetheless, it is encouraged if capacity and funding allow for additional freshwater monitoring. In general, the household survey can and should be applied whenever possible, regardless of the characteristics of the site interventions, at least to establish a basic baseline on count of people involved in the project across different dimensions of freshwater. Knowledge on the baseline can then determine if subsequent surveys should be applied in the context of freshwater. More specific freshwater monitoring, on the other hand, should only be used when appropriate, according to the following questions:

1. **Are water benefits relevant for the sites/region where restoration actions will take place?**
2. **Are restoration actions taking place in a dispersed fashion, or clustered?** *(For reference, a restoration cluster can be interpreted as concentrated reforestation actions that, for example, can help an entire first to second-order watershed be fully covered with forest (when counted together with forest canopy already present).)*
3. **Is the scale of each restoration cluster of sites large?** *(Large = at least 70% of the watershed area receiving the specific restoration cluster will be covered with forest when both restored and intact forests are accounted for.)*

To qualify for detailed freshwater monitoring, the answers to the above questions should look like this: 1. Yes; 2. Clustered; and 3. Yes.

After passing the qualifying criteria for detailed water monitoring, the Watershed and Environment Monitoring protocol is a good resource to determine what/where/when to monitor freshwater impacts. More information is provided on topic 2 below.

Disclaimer: It is extremely challenging to achieve a generic set of monitoring requirements that can be spread across all of the possible PPC Program sites. The following is meant as guidance for the recommended approach within PPC. If you would like to add more rigorous monitoring in addition to what is laid out here, you are encouraged to do so by contacting the CI or WRI global monitoring team. The household survey is meant as general guidance and may require customization to your context. Household survey data can only reveal *the possibility of a link between on-site restoration and perceived changes in water benefits*. More specific and detailed methods will be needed to be able to understand the full implication of forest restoration on freshwater benefits/beneficiaries.

Importance of freshwater data collection

With the growing appreciation of forests as a potential sink for carbon, restoration projects have become a central pillar of the strategy to limit global warming and freshwater benefits have commonly be considered co-benefits from restoration interventions. However, long-term, empirical evidence on the water benefits from reforestation efforts is lacking at the scale required to significantly demonstrate the benefits to local communities. Therefore, there is a fundamental need for field programs to monitor restoration projects that claim restoration of freshwater benefits. It is only by establishing monitoring schemes—when appropriate—that it will be possible to quantify the actual impact of restoration interventions on freshwater benefits.

1. Household Survey for Freshwater

Collection of the household survey data can allow one to track the potential indirect impacts from restoration on local freshwater benefits/beneficiaries. More specifically, the PPC household survey freshwater module targets clean water access and supply reliability, water treatment needs, and damage from flooding.

1.1 Methodology (field component) - Completed by project developers

Please refer to sub-protocol 10 for instructions on using the household survey.

1.2 Methodology (analysis component) - Completed by Global Monitoring Team

Data generated by the household survey can potentially inform the directionality of the indirect effects of restoration on benefits associated with freshwater, namely: water supply reliability, water treatment needs, and damage from flooding. Questions on water source(s) provide helpful context.

The application of the household survey on Year 0 provides the baseline on count of people involved in the project across different dimensions of freshwater. Subsequent applications, on Year 2.5 and Year 5, will generate data to be compared with that from Year 0 to provide a sense on whether the restoration interventions might have affected water provisioning (quantity, reliability, and quality) and flood risk management.

For each survey application (Year 0, Year 2.5, and Year 5), analysis of data involves calculating percentages of household for each question. For example, for questions 35a and 36a, the final information will be the percentage of the population using improved drinking-water sources. This information can then be disaggregated depending on the research interest, for instance, per micro-watershed, and per administrative division. Comparisons to establish possible changes overtime is made in terms of percent change.

The table depicts what kind of information can be obtained by asking questions on freshwater in the survey related to specific water benefits as well as the context at which the implementation of forest restoration could contribute to.

Question	**Information**	**Context at which forest restoration could contribute to, if the project scale is large enough**
Q34: Are there natural sources of water on the property?	Provide a sense of the extent of water bodies that could be impacted by restoration actions	Over time responses for this question should remain the same
Q35a: What is your household's main source of drinking water in the wet season? Q36a: What is your household's main source of water in the dry season?	Provide a sense of whether water sources originate from protected or unprotected sources	Over time responses for this question may show that water sources change from unprotected to protected
Q35b: Is it (the water source) reliable during the wet season? Q36b: Is it (the water source) reliable during the dry season?	Provide sense of water reliability during wet and dry seasons	Over time responses for this question may show that water reliability increases
Q37: How much did your household pay for water charges last year? Q38: Did your household treat water in any way to make it safe to drink during the last month?-Q39: How do you usually treat your water?	Provide sense on water treatment needs	Over time responses for this question may show that water treatment needs decreases
Q40: How often in a year does someone from your household experience gastrointestinal issues?	Provide sense on potential presence of water related diseases	Over time responses for this question may show that water related diseases decreases
Q41: Is your house located in a floodplain?	Provide sense on damage associated with flooding	Over time responses for this question may show that damage associated with flooding at those houses outside floodplains decreases

Note: For all water benefits listed above, despite those changes may be detected over time through survey applications, such changes may or may not be correlated with restoration actions. Determining the links between changes and restoration efforts will require more detailed investigation.

1.4 Estimated Costs

Please refer to sub-protocol 10 for details on the costs associated with conducting household surveys.

1. Detailed freshwater monitoring

After assessing the need for detailed freshwater monitoring based on the criteria listed above, the *project developers* should identify which benefit they should focus their efforts on. The decision tree of protocol provided below is suggested for this. Note that the link to the protocol takes the user to an interactive version of the protocol.

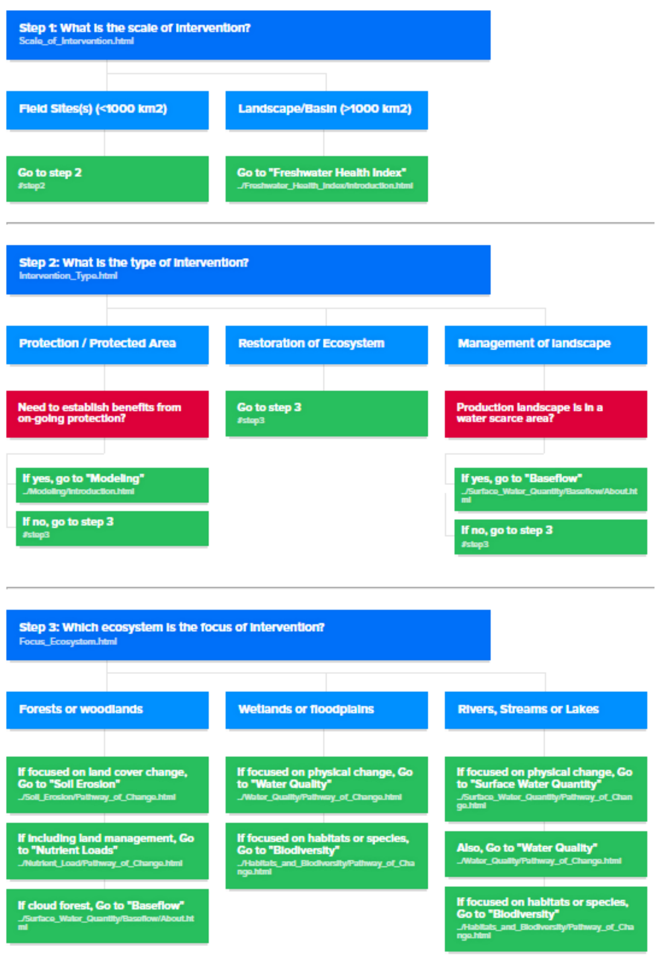


Figure 1. Decision tree of the Watershed and Environment Monitoring protocol to identify focus benefit based on the scale of intervention

With benefit(s) identified to focus water monitoring efforts, the *project developers* need to develop an understanding of how change occurs for that benefit and then, identify which parameters could be measured in the time frame of the project. For example, a terrestrial tree restoration project would most likely end up in the left column of step 3 under forests or woodlands, where either "Soil Erosion," "Nutrient Loads," or "Baseflow" would be the focus benefit, depending on the specific intervention. The Watershed and Environment Monitoring protocol provides more detailed monitoring information once a user clicks on a particular benefit in the decision tree of the interactive protocol.

After the specific parameter(s) of a particular benefit have been identified, the protocol informs on the method options, the level of effort required and how to budget for this effort, so that the user determines which may be viable for monitoring that specific parameter.

Resources:

National Institute of Statistics. 2014. Cambodia Socio-Economic Survey 2014.

Water & Ecosystems: Monitoring & Evaluation guidance for interventions. Conservation International.

SUB-PROTOCOL 14: CREATING PROJECT/SITE BOUNDARY SHAPEFILES

Provides guidance for indicator 4.1: Area under restoration by intervention and ecosystem types. Used as input for tracking progress against targets (tree count, tree cover, hectares restored, etc.)

Created by Tesfay Woldemariam, WRI

Guidance for Users

This sub-protocol provides a step-by-step guide for *project developers* on how to create a project and site polygon for all sites in your project. This protocol is used prior to submitting the Project Establishment and Site Establishment report from each new site.

Importance

The site polygons and their related information are critical to the assessment of impact indicator A, impact indicator B, and indicators 1.5, 2, and 3.2. It is the basis for generating accurate tree count, tree cover and data for other indictors within each site area over the lifetime of the project. For example, shapefiles are required as input to create Collect Earth Online surveys that are used to collect tree count data and are required to accurately estimate the hectares under restoration by intervention and ecoregions.

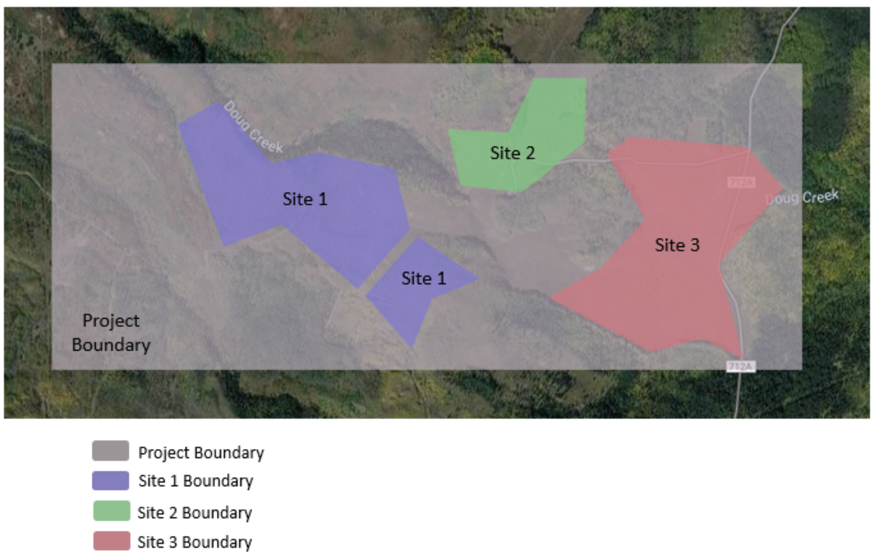
Definitions

Project	A project can consist of a single site or of multiple non-contiguous sites. In the latter case, each site may have different interventions (e.g., tree planting, agroforestry) or the same interventions in separate locations of the same locality (village for instance).
Site	An individual site is the most important unit for reporting, demarcated as precisely as possible to cover the exact areas where intervention activities are happening. A site must be a contiguous area of land. It may contain several different interventions (stratified by intervention types) or single intervention type.
Boundary	A boundary is the outline of the site or project.
Polygon	A polygon is used in Geographic Information Systems (GIS) to describe the data that represents the boundary of a site. It is NOT a point or a line and must be a shape that demarcates an enclosed area.
Shapefile	A shapefile refers to a commonly used terminology to represent vector data as opposed to raster data in Geographic Information Systems (GIS). Here shapefile is specifically referring to the polygon (s) which are the boundary outlines of your site(s).

Methodology

Project Setup Form

The shapefiles submitted in this form on the integrated monitoring platform are at the project level. Ideally, project developers will submit a single shapefile with multiple polygons where the polygon boundaries are the site boundaries (if there's more than 1 site). If there is only 1 site, then the shapefile can contain only 1 polygon. It is also acceptable to provide a shapefile that shows the general project area. If a general project area is submitted, it should encompass the locations of all sites of active interventions as closely as possible and can be disaggregated into multiple polygons if sites are not all in the same region.



Site Establishment Form

The site establishment form must be completed for each site in the integrated monitoring platform and will contain a shapefile or KML of the exact site boundaries. A site must be a contiguous plot of land that is subdivided into sections based on intervention type (required). The site can also be subdivided by other strata (optional, see protocol 5 on vegetation monitoring for details on strata). The subdivision(s) should be specified in the attribute table. If the restoration project contains disparate plots of land, then there are automatically more than one site (Figure 1). The only case where multiple sites (non-contiguous areas of land) can be combined into one is if they are owned by the same landowner, have the same landscape characteristics (slope, soil condition, etc) and are less than 100m apart.

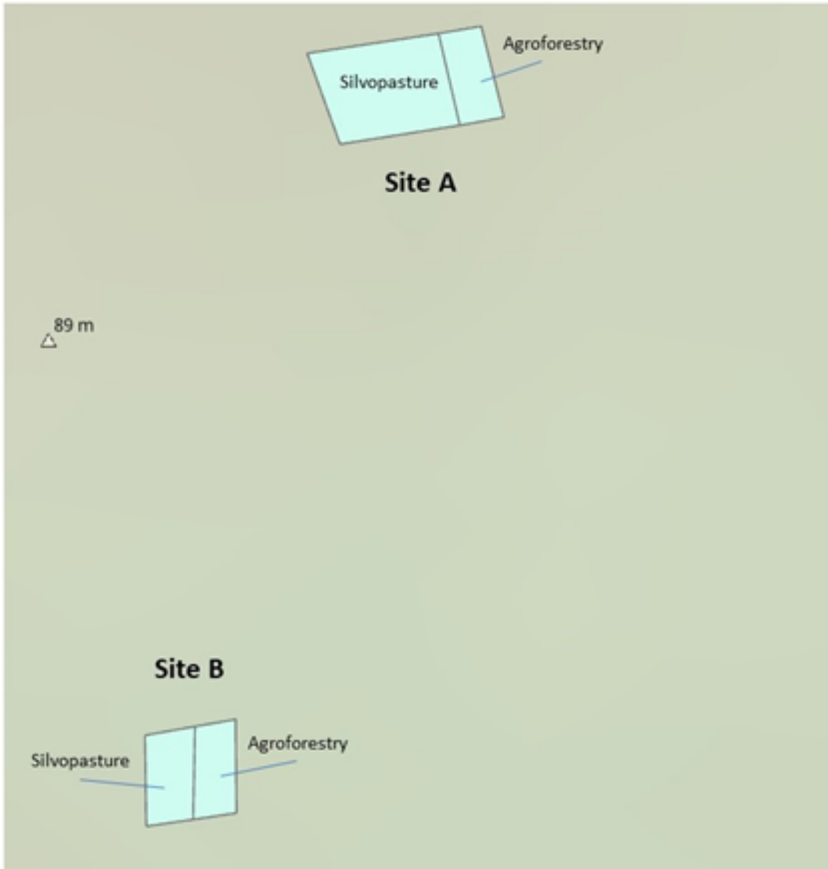


Figure 1 A project with Multiple Sites and multiple interventions per site

A site boundary includes the area of active restoration, which can be thought of as the area that we will count trees towards the PPC target within. The entire area within the boundary will be included in vegetation monitoring (sub-protocol 4) and for remote sensing analyses (canopy cover, hectares in restoration, carbon, etc). If there are different management activities across the site, they should be denoted as strata (sub-protocol 3). For example, if you plant trees in one part of the site, but do erosion control uphill from where trees are planted and plan to count trees that grow from natural regeneration in the erosion control areas, then the whole area is counted as the site, but includes strata (planted and erosion control).

Each site shapefile must contain a Site ID, site name, and restoration intervention(s) in the attribute table (Table 1). Additional attributes are welcome, but not required. Boundaries are submitted as a standard GIS file type, such as KML/KMZ (Google Earth) or Shapefile (SHP). Shapefiles must also have a defined projection and datum information. The global projection WGS84 is preferred. In addition to a boundary GIS file, edit the attribute table of the GIS file to add these relevant fields in Table 1, Fig. 1.

The attribute table must contain a country, organization name, site name and the intervention type. It is strongly preferred that the column names and intervention types are in English and exactly match the names shown below. The intervention types should be taken from the list in Annex 3 (also shown in the site establishment form on the IMP). A translation of each attribute header and intervention type is provided in tables 2 and 3 below, with English highlighted in orange. Submission of table 1 as excel with these field headings and field value completed per site is satisfactory if editing the shapefile attribute table itself poses a challenge.

Table 1. Attribute table minimum fields required to include in the project shapefile

Country	Organization Name	Name of Site	Intervention Type
Brazil	CI Brazil	Site 1	Silvopasture
Brazil	CI Brazil	Site 1	Agroforestry
Brazil	CI Brazil	Site 2	Direct Seeding

Table 2. Translations of attribute table headers

Country	País	Pays	País
Organization Name	Nombre de la organización	Nom de l'organisation	Nome da organização
Site Name	Nombre del centro	Nom du site	Nome do site
Intervention Type	Tipo de intervención	Type d'intervention	Tipo de intervenção

Table 3. Translations of intervention types

Intervention Type	**Tipo de Intervencion de Restauracion**	**Type d'intervention de Restauration**	**Tipos de Intervenção de Restauração**
Agroforestry	Agroforestería	Agroforesterie	Agroflorestal
Applied Nucleation	Nucleación aplicada	Nucléation appliquée	Nucleação Aplicada
Assisted Natural Regeneration	Regeneración natural asistida	Régénération naturelle assistée	Regeneração Natural Assistada
Enrichment Planting	Plantación de enriquecimiento	Plantation d'enrichissement	Plantio de Enriquecimento
Mangrove Restoration	Restauración de manglares	Resauration de la mangrove	Restauração de árvores de manguezal
Peat Restoration	Restauracion de la turba	Restauration de la tourbe	Restauração de turfa
Direct Seeding	Siembra directa de semillas	Dispersion de graines	Dispersão de Semente
Silvopasture	Silvopastoreo	Sylvopastoralisme	Silvopastura
Tree planting	Plantación de árboles	Plantation de arbres	Plantio de árvores
Wetland restoration	Restauración de humedales	Restauration des zones humides	Restauração de Pantanal

How-to Guide to create project boundary GIS files

Accurate tree-based progress assessment and verification are only possible if site boundaries can be drawn as precisely as possible to represent the intervention area.

To create a polygon of your project site(s), there are many free mobile and desktop tools. We provided a guide for "GPS Fields Area Measure" Phone App available in the Google Play store. However, you may use other tools you are more comfortable with.

1. Here is a written tutorial
2. Here is a video

This video created by Kevin Dalferth explains how to and why to create polygons.

How to Submit Boundaries

KML/KMZ Files

When the project developer is using Google Earth to generate Site boundaries, they should include PolygonID in the Title field and the Intervention Type listed in the Text box below, please refer to Figure A. Google Earth, unlike ArcGIS, does not allow for flexibility in adjusting attribute tables but this information stored in the Title and Text box will provide WRI and CI the information necessary to differentiate areas restoration activities.

In the case when your project has one polygon with different intervention types the project developer would need to generate as many polygons necessary to complete the multi-intervention polygon, refer to Figure B. In this situation it is recommended to take note of the required attribute fields, listed above for WRI and CI to properly organize and differentiate each polygon, refer to table 2.

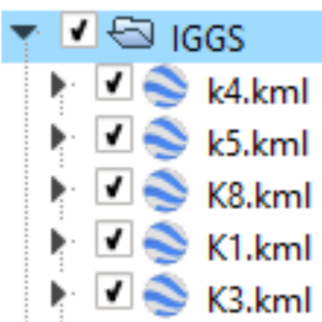
Figure B

Table 2

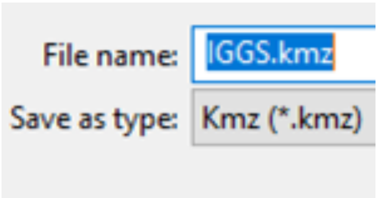
PolygonID	Name of Site	Name of Project	Country	Intervention Types
PolygonID01	Brazil_1	CERT	Brazil	Reforestation
PolygonID02	Brazil_2	CERT	Brazil	Agroforestry
PolygonID03	Brazil_3	CERT	Brazil	Silvopasture

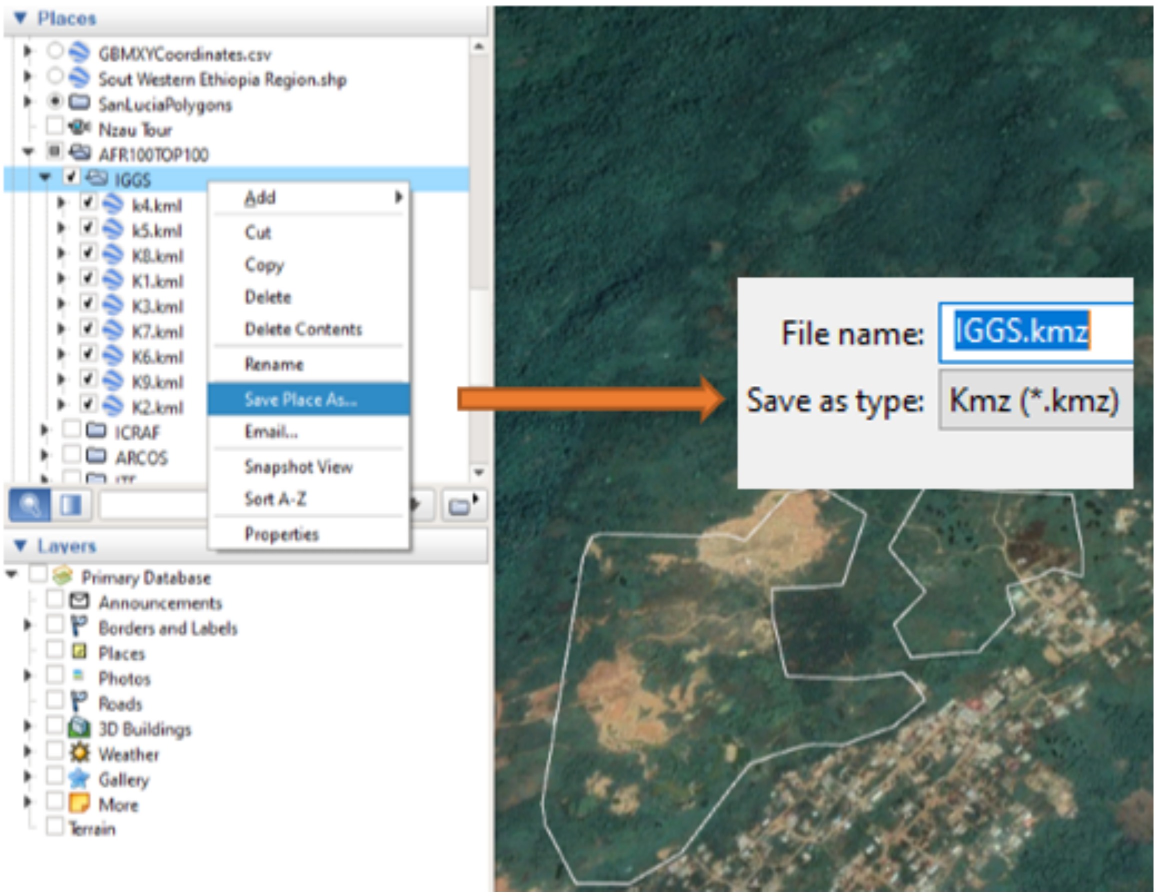
Submitting multiple sites as a single file: You can submit multiple sites as single file to save time.

For KML, create a folder and move the individual site KMLs inside that folder by drag and drop on Google Earth (see example below).



Once you have all sites moved under that folder, select the folder name, right click on it, and choose “Save Places As” option ; name it and click OK (see below).





This will automatically save your multiple site KMLs as KMZ, which is a single file containing multiple KMLs. Using Windows File Explorer, go to the folder location where you saved your KML/KMZs, and upload/submit the files.

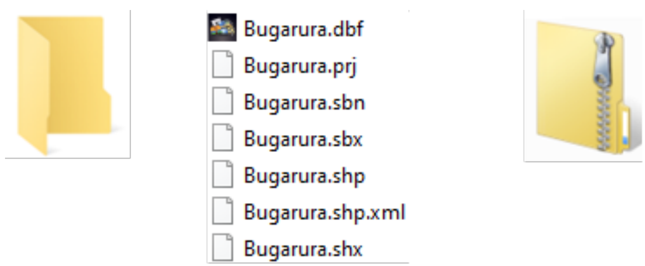
Shapefiles (SHP)

Shapefiles are vector-based data formats that store geospatial information associated with the project developer defined polygon boundary.

Shapefiles automatically generate multiple companion files that MUST be located in the same folder. Note not all files may not be visible on GIS software. Use windows file explorer to view them.

In the example below, the project developer defines their project folder and saves the shapefile into that directory. Once saved, the folder is populated with a series of formats, the project developer is required to submit at least the *bugarura*.**dbf**, *bugarura*.**shp**, *bugarura*.**shx**, and *bugarura*.**prj** files zipped together (*Name*.**zip**). "***bugarura***" here refers to the site name the user defined. There may be more files in the folder (see below) but at the minimum .**dbf, .shp, .shx** and **.prj** files are required for the shapefile to be opened on GIS software.

Project Folder ---> Bungarua ----> Bungarua.zip



Note: if the shapefile you are accessing to zip is open in GIS software, you may see more files and also a lock status on some of them because it is being accessed by another application. It is advisable to close the GIS project or remove the file from the GIS software before you zip the folder.

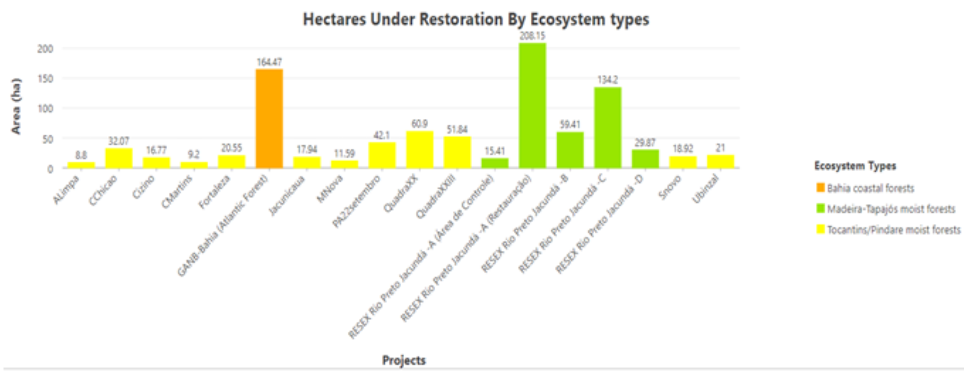
1. Review and Quality Control of Submitted Project Shapefiles

The WRI and CI team reviews the submitted KML or Shapefile to make sure the files can be opened in GIS software or in Google Earth (KML). We will then ensure that the area reported in the application of the proposals is equivalent to the area of the submitted project shapefile. Additionally, we will ensure that the attribute table (when included) fields and coordinate system information are correctly reported.

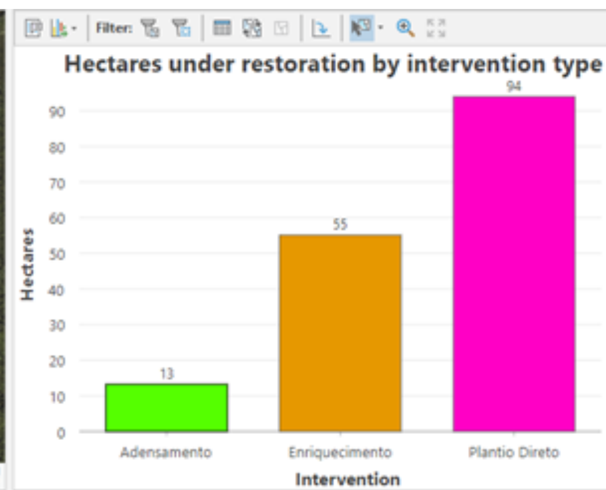
Analysis Approach and Result Examples

For hectares under restoration by ecosystem type, we are using an existing global WWF Ecoregions map[1]. We use simple ArcGIS overlay operations like spatial join to extract the hectares by respective overlapping area of the project sites and ecosystem layer.

Here is an example of what the results would look like.



To enable calculation of hectares under restoration by intervention type, boundaries by intervention (strata) are also required besides site boundaries. Similar overlay operations are used whenever the required intervention level boundaries are available. Here is an example from a PPC project. If no stratification, only mention of the existing interventions would be possible, no charts or map display as shown below.



SUBPROTOCOL 15: FAUNAL BIODIVERSITY MONITORING (OPTIONAL)

Guidelines for biodiversity monitoring in areas undergoing restoration

Provides guidance for indicators:
5.1 % change in species richness within class
5.2 Average % change in abundance within class
5.3 Occupancy Index
5.4 Community similarity Index

Created by Jorge Ahumada, Justin Nowakowski, Trond Larsen, Neil Cox, Isabel Hillman, and Starry Sprenkle-Hyppolite at Conservation International

Guidance for Project Developers

This protocol describes four different possible methods for *project developers* to use for biodiversity monitoring. These methods are 1) acoustic sensors 2) camera traps 3) direct observations and 4) eDNA. Each is described in detail below, and can be used to calculate species richness, diversity, abundance, occupancy and community similarity.

Disclaimer: It is extremely challenging to achieve a generic set of monitoring requirements that can be spread across all of the possible PPC Program sites. The following is meant as guidance for the recommendations for the PPC Program. If you would like to add more rigorous monitoring in addition to what is laid out here, you are encouraged to do so by contacting the CI or WRI global monitoring team.

Rationale

In addition to sequestering carbon and improving vegetation and soil health, restoration can provide additional benefits that enhance the effectiveness of ecosystems as a nature-based solution for climate change. One such benefit is the passive re-colonization of wildlife species as tree diversity and cover increases. Wildlife species — such as birds, mammals, amphibians and reptiles— provide key functions to the ecosystems being restored such as seed dispersal, pollination, herbivory control, and soil fertilization among others. These functions enhance the capacity of forests to sequester carbon, promote colonization of native trees, and improve soil health as restoration activities proceed. For example, without wildlife species that disperse seeds, the carbon storage capacity of tropical forests could decrease by up to 12% (Osuri et al. 2016), or by as much as 26–37% in Amazonian forests (Peres et al. 2016). These intricate relationships between vegetation, wildlife and soil organisms create a positive feedback loop that accelerates the rate of carbon sequestration increasing the effectiveness of restored areas to combat climate change.

However, we currently do not have any systems in place to monitor the rate at which wildlife species return to restoration areas. Such systems are critical to demonstrate the additional biodiversity co-benefit that restoration creates. While it is too costly and time-consuming to monitor all species, selecting the most cost-effective methods for surveying high priority taxonomic groups can provide core data to understand broader trends in biodiversity. We also propose the adoption of standardized as well as automated (camera traps and acoustic monitoring) methods, since this makes data more comparable among different researchers (avoiding individual bias), study sites and over time (Larsen 2016). For monitoring how biodiversity responds to restoration, it is also important to assess not only presence-absence of species, but density, abundance or relative abundance, which provides much more detailed information about changes in biological communities. Here we present some basic guidelines on monitoring wildlife (how, what and when) and suggest some indicators that can measure these biodiversity co-benefits directly.

Methodology

The most appropriate method for monitoring biodiversity depends on the context of your project. Some factors that can help you determine which method is most applicable to your situation are shown below. It is important to consider all the factors that will influence which method is the most suitable for your context when making a decision between methods. For example, some methods have higher costs for equipment but lower costs for time in the field. The global monitoring team can provide more insight as needed.

Table 1. Outlines various factors to consider in selecting which monitoring method to utilize. Adapted from Zwerts et al. 2021.

Method	**Fauna**	**Substrate**	**Site Size**	**Relative Cost of Equipment**	**Relative Cost of Field Staff Time**	***Overall Cost Effectiveness**
Camera Traps	Large and medium sized ground-dwelling birds and mammals))	NA	Most suitable for large sites	High	Low	Medium/High (with current data post-processing solutions)
Acoustic Devices	Birds, amphibians, primates and other arboreal mammals	NA	Most suitable for large sites	High	Low	Medium/High
Direct Observations	Birds, arboreal mammals, amphibians, and reptiles	NA	Suitable for sites of all sizes, especially small sites	Low	High	Medium
eDNA	Varies	Soil, water, sediment	Suitable for sites of all sizes	High	Low	Medium

*Cost effectiveness accounts for costs of equipment, staff time (training, work in field, data processing), and the quality of the data received

Timeline

For all methods described below, we suggest a sampling timeline of Y0 (baseline), Y2.5 (midline), and Y5 (endline) at a minimum. This timeline matches the vegetation monitoring timeline described in sub-protocol 4, so your team will be in the field for that monitoring already and adding this in at the same time maximizes efficiency. If it is possible, annual biodiversity monitoring is recommended. Considerations for seasonality should be taken into account as described below.

a. Camera Traps and Sound Recorders

Basic monitoring design

Passive sensors: The most cost-effective way to monitor the presence (and absence) of a large variety of wildlife species in an area, is to distribute passive sensors throughout this area. These passive sensors, such as trail cameras (or more commonly known as camera traps) and sound recorders, are small autonomous devices that sense the presence of wildlife species and record an image, video or sound of such species making the data verifiable (and therefore of high quality). Camera traps have a differential heat and motion sensor that triggers the camera as an animal walks by it. Sound recorders also have sensors that detect sound, and can be programmed to record sound at times when most species are vocal (dawn/dusk for birds and mammals, midnight and early morning for amphibians). Both sensor types are commercially available (price range between $10 -$500) and are used frequently in tropical forest settings.

How many sampling locations and at what density: Each sensor acts as a species "observer", so it is important to adequately replicate the number of sensors distributed across the area under restoration to account for variation in habitat, soil, or other factors. Table 2 below outlines the appropriate number of sensors for sites of different sizes.

Table 2. Number of sensors (camera traps or sound recorders) needed for sites of various sizes

Site Size	1-5 ha Site	5-25 ha Site	25-100 ha Site	100-1000 ha Site
Number of Sensors Needed	1-5 sensors	6-10 sensors	11-15 sensors	20 sensors

When and for how long should sensors be deployed: This depends on the specific questions and objectives of the project, but in the context of restoration activities, it is recommended that sensors are deployed at baseline, year 2.5 (midline), and year 5 (endline) at a minimum (aligns with vegetation monitoring timeline, sub-protocol 4), but annually or biennially are recommended. Sensors are placed during a consistent climatic season (usually a dry season or 'less rainy time' in tropical forests). Some species are seasonal breeders (e.g., amphibians), so sampling in the breeding season (usually a rainy season) might be needed if these are species of interest. Each sensor should be left out in the field for a minimum of 30 days. Additional sampling days accrue diminishing returns in terms of number of species captured unless sampling very rare species.

Field effort: Sensors can be deployed easily by 2-3 field crews each with two people. After a sampling design and locations of sensors have been agreed upon, each crew can deploy between 4-5 sensors per day depending on the structure of the habitat, terrain, weather and trail availability. For example, two field crews deploying 4 sensors a day can deploy 60 sensors in 7.5 days. Picking up sensors after sampling is completed usually takes less time (in the case above between 5-6 days).

Additional Data: The GPS location of each device, date of deployment, and duration in the field must be recorded along with any technical details such as the length of active data collection. For example, the amount of time between images for camera traps or the time of day that the sensor is set to record.

Post data collection activities: After data has been collected, images and sound data should be organized and processed.

Camera Traps: Images can be processed directly on Wildlife Insights (wildlifeinsights.org), CI's global platform to process, manage, analyze, and store camera trap data.

Sound Recorders: Sound data will be processed by partners

With these tools, data processing should take about 10-12 days depending on the number of recordings and or images. With 2-3 data processing teams working in parallel, this time can be cut down substantially.

b. Direct Observations on Site

Direct observations by researchers in the field can be especially effective for assessing the presence and abundance of a variety of species, many of which may not be detected by the other methods described here (e.g., automated sensors, eDNA), and therefore provide an important complementary approach. However, since many researchers use varying methods that complicate comparisons across sites and over time, we recommend following the methods published by CI (Larsen 2016), which includes guidance for a wide variety of plants and animals, including terrestrial and freshwater (https://www.conservation.org/docs/default-source/publication-pdfs/ci_biodiversity_handbook_lowres.pdf). These methods are specifically designed for surveys that are rapid and relatively cheap (typically 4-5 days per survey site), yet provide a large amount of relevant data.

The taxa included in this guide were selected because they are widely recognized as cost-effective indicators that can help to understand broader trends in biodiversity. It is not necessary to survey all of these taxonomic groups, but rather to focus on taxa that are of particular relevance to the project (e.g., they are especially sensitive to changes expected in the focal landscape, or they include species of particular conservation importance in the study area), and to include as many taxa as project resources allow. Below, we highlight just two taxonomic groups as good example candidates for study, but please refer to the complete guide for more information on these and others.

Direct observations of birds: Birds have often been shown to be the most cost-effective of all terrestrial taxa for biodiversity surveys. They are a well-studied group and it is not difficult to find experts in all parts of the world. Point count surveys are a common and effective method for surveying and monitoring bird assemblages. We recommend conducting 15 or 20-min, 50-m radius point count surveys between dawn to mid-morning. Many bird species are difficult to observe during warmest times of the day or when raining. Therefore, stopping times for conducting point counts will depend on bird activity, which varies with both weather and habitat. It is also important to consider the seasonal timing of surveys. For example, migrant species may be absent during certain months, while resident species may be easier to detect during the breeding season. To conduct point counts, observers stand at fixed point and count all birds heard and seen within 50 m of each point. Observers should record the date, time of day, location of the point count, number of individuals, and species identity. Other ancillary information may be collected, such as sex and age class of birds, weather, and habitat conditions. To ensure point counts are spatially independent, point count stations should be spaced at least 200-250 m apart; this is the maximum distance at which many forest bird species can be acoustically detected.

Direct observations of amphibians and reptiles: Amphibians and reptiles are a useful group to study because many species tend to be highly threatened and are especially sensitive to changes in habitat and microclimate. For direct observation of amphibians and reptiles, transect surveys are the most commonly used method. Transects should be standardized in both length and duration. We recommend 50 x 4 m transects each surveyed for 25 min. Transect surveys should be conducted at night because most amphibians and many reptile species are nocturnal. Many nocturnal species are difficult to observe during the day while diurnal and crepuscular species are often observable at night. Therefore, nighttime surveys typically yield observations of greater numbers of individuals and species than daytime surveys. Season also affects the activity of amphibians and reptiles and may be considered when determining the timing of surveys; for example, many amphibians are most active during the early rainy season in wet tropical regions. Along each transect, one or two observers slowly walk and visually scan the ground and understory vegetation using bright headlamps. As with point counts for birds, observers should record the date, time of day, location of transect, number of individuals, and species identity, along with any other ancillary information of interest.

Design of direct observation surveys: Well-designed and standardized survey protocols can generate robust datasets that can be analyzed with a wide array of modeling approaches, including those that account for imperfect detection. To allow for analysis of data in a multispecies occupancy (or abundance) modeling framework, as with camera trapping data, we recommend use of a ‘robust design’ when possible. A ‘robust design’ is a standardized survey design that includes replicated temporal or spatial sub-samples within a defined spatial unit, and these sub-samples are collected over a short period to assume the populations are closed to immigration and emigration (Mackenzie & Royle, 2005; Pollock, 1982). For example, within a given restoration area, multiple fixed point count stations and/or transects can be established across the area, either in a regularly spaced grid or randomly located, while maintaining minimum spacing. To generate temporal sub-samples, each station or transect would be repeatedly sampled at least three times within a short period of time (e.g., within one week or one season). Alternatively, if only a single visit is feasible, spatial sub-samples can be collected instead by defining spatial units within each restoration area (e.g., 1 or 5-ha plots, depending on minimum spacing requirements). Within these plots, at least three point count stations and/or transects can be surveyed to generate spatial sub-samples that allow for modeling of imperfect detection.

The design described above is considered best practice, but in cases where there is limited time or budget, less rigorous approaches can be discussed. Please contact the global restoration team to do so.

c. eDNA

eDNA, or environmental DNA, is the DNA of any organism found within an ecosystem. Samples for eDNA can be taken in restoration project areas and analyzed for the quantification of levels of DNA of various taxonomic groups such as freshwater invertebrates, fish, amphibians, reptiles, mammals, bacteria, etc. (separate analyses for each group).

Substrates: eDNA samples can be collected in a variety of substrates including freshwater (streams and rivers), soils, sediments, and saltwater. While the most appropriate substrate to sample varies based on the characteristics of the project (size, site location design, etc), freshwater samples are typically the most effective and frequently used, although soil samples may be particularly useful for monitoring biodiversity changes associated with restoration.

Basic Monitoring Design: The sampling design of each project will be unique depending upon budget available, objectives of the data collection, and range of analyses required. Sampling costs depend on how many primers are used in the analysis. For most projects, a single primer that identifies all vertebrate species is appropriate, but in some cases it may be advantageous to include invertebrates or primers that are more specific to particular groups of vertebrates, such as fishes, which provide slightly more detail than the general vertebrate primer. Some examples of sampling designs for other projects can be found in Tables 3 and 4 below. Details for sampling in various settings can be found in the Nature Metrics protocols.

Aquatic Protocol - NatureMetrics

Barcoding Protocol - NatureMetrics

Soils and Sediments Protocol - NatureMetrics

Inverts Protocol - NatureMetrics

Table 3. Examples of number of samples needed and associated costs for various purposes, site sizes and habitats. Cost is highly dependent on number of analyses conducted- costs per sample are lower if a single analysis is conducted (i.e. vertebrates only).

Size	Habitat	Purpose	Number samples	Analysis	Cost not inc. VAT
Localized river crossing	River	EIA top up	15	Vertebrates(+2 groups)	USD 5k (USD 9k)
4,000 Ha	Mangroves	Restoration & protection	45	Fish (+2 groups)	USD 16k (USD 28k)
Small mine	Aquatic	Baselining	20 + 20 (technical replicates)	Vertebrates + Fish	~USD 20 - 25k
50 km river length	River	EIA Hydropower	50 x 2seasons	Vertebrates + Fish	USD 49k
Different sized patches of woodland	Terrestrial Soils	Road Infrastructure	80	Bacteria, Fungi, Metazoa	USD 40k
200,000ha	Mixed Forest/Savannah	EIA Baseline	160	Vertebrates	USD 58k
Larger mine	Aquatic Soil	Baselining	50 aquatic 80 soil	Verts, Fish, Inverts	~USD 132k

Table 4. Examples of the number of samples needed and associated costs for various purposes and site sizes in marine habitats. Cost is highly dependent on number of analyses conducted- costs per sample are lower if a single analysis is conducted (i.e. vertebrates only).

Size	Habitat	Purpose	Number samples	Analysis	Cost not inc. VAT
800Ha	Giant kelp	Carbon &BNG	30	Vertebrates (+2 groups)	10k USD (17,500 USD)
1,000Ha	Seagrass	Carbon market	30	Vertebrates (+2 groups)	10k USD (17,500 USD)
4,000Ha	Mangroves	Restoration & protection	45	Fish (+2 groups)	15k USD (26k USD)
10,000Ha	Mangroves	Protection & livelihoods	50	Decapods (+2 groups)	17,500 USD (30k USD)
350,000Ha	Mangroves	Restoration	200	Vertebrates (+2 groups)	70k USD (120k USD)
1,200,000Ha	Sediment	Impact of trawling exclusion	300	Fish (+2 groups)	103k USD (178k USD)

Costs: The cost per sample at the NGO rate:

- £200 (approx. $240) per sampling kit, providing training, sampling strategy design, analysis of one taxonomic group and the report
- £275 (approx. $330) per sampling kit, providing training, sampling strategy design, analysis of two taxonomic groups and the report
- £350 (approx. $420) per sampling kit, providing training, sampling strategy design, analysis of three taxonomic groups and the report

Indicators

There are several indicators that can measure biodiversity trends in restored areas. We propose three types: species richness estimators, occupancy/relative abundance estimators, and community similarity (species composition) estimators. The first two indicators for species richness and abundance are disaggregated by class, but can also be disaggregated by IUCN red list category or functional group (pollinators for example).

Species richness:

% change in species richness within class

The number of observed species (observed species richness) is a simple measure of how many species are present in the area being monitored. However, observed richness can be misleading if some species are easier to detect than others, if the sampling effort varies over time and space, or if different habitats are at different stages of regeneration. Thus, species richness is often estimated using species rarefaction curves and models. Rarefaction curves produce a model of how the number of species varies with sampling effort or abundance, allowing different areas (or different times between the same area) to be compared side by side (Hsieh et al. 2016). Rarefaction curves can also weigh observations of each species by its detection probability, correcting for species that are less likely to be detected. The figure below shows an example from a camera trapping project in Amazonia, comparing two SRCs, one inside a protected area and one outside it. For the same level of effort the number of species is 1.5 times higher inside the protected than outside of it.

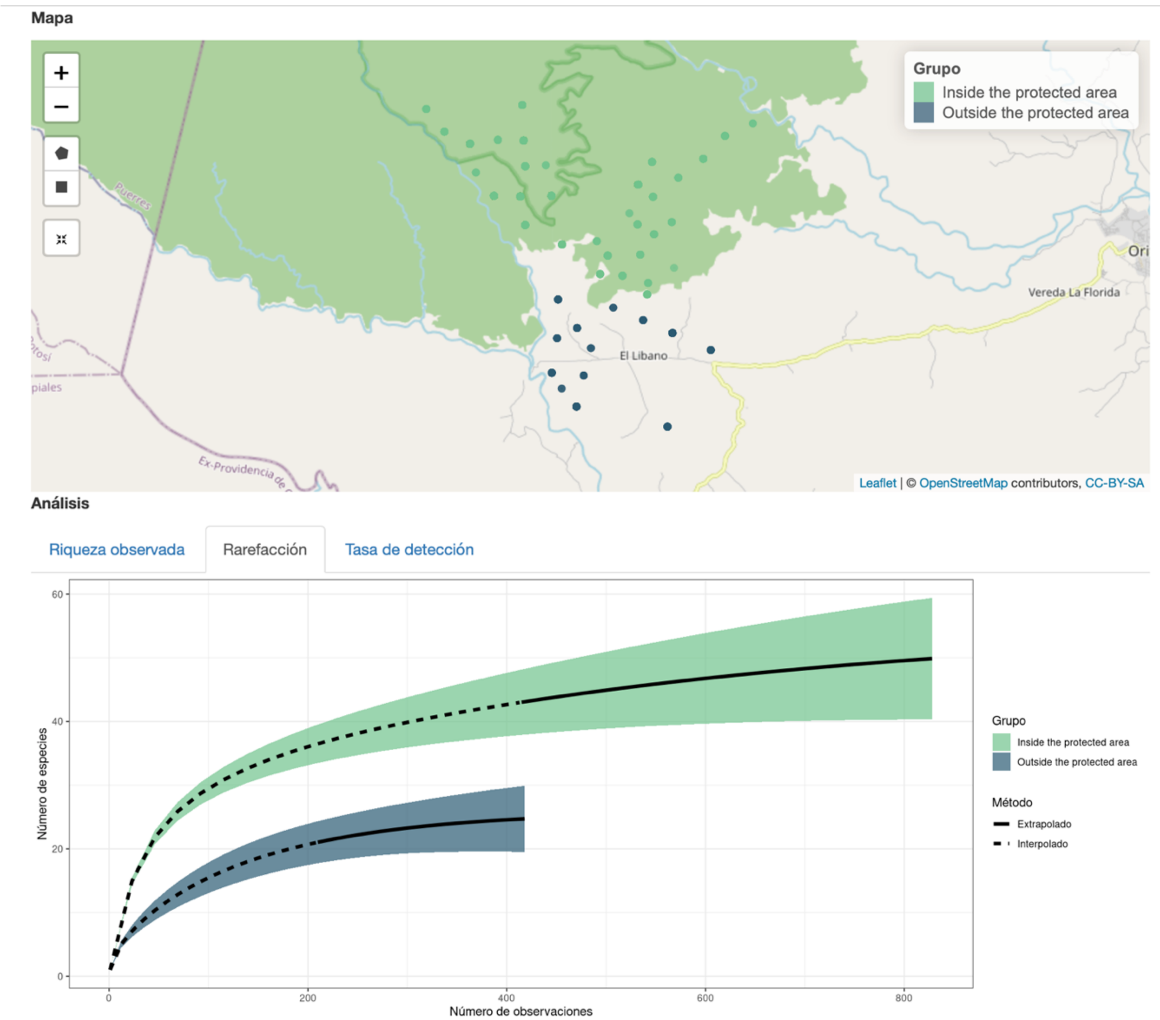


Figure 1. Graph comparing two species rarefaction curves from a camera trapping project in Orito Sancturay (Colombia).

Abundance:

Average % change in abundance within class

Rather than just estimating the number of species, a good biodiversity indicator will also consider changes in the density, relative abundance, or other measure of how common each species is in the community. This is important, because biodiversity can decrease if the relative abundance of some or all species decline, even if species richness is constant. Therefore, indicators that combine measures of relative abundance, density, and/or occupancy are more sensitive to various community measures that affect biodiversity, such as species evenness, dominance, species richness and relative abundance (Buckland et. al 2005). All of the methods proposed here will provide some information on abundance, with the most detailed data provided by direct observations of birds and camera trapping.

Occupancy:

Occupancy Index such as the Wildlife Picture Index (WPI)

Occupancy indices rely on the estimation of occupancy (or relative abundance) for each species at each monitoring survey area. Occupancy is defined as the proportion of sensor locations within the survey where the species was detected corrected by detection probability[16]. Occupancy can be estimated for each species in the community and then averaged over each year relative to the baseline occupancy in the first year (O'Brien et al. 2010). This creates an index that always starts at 1 and decreases below 1 when occupancy, richness, or species evenness changes. The figure below shows the Wildlife Picture Index (WPI) along the Volcan Barva transect in Costa Rica between 2007 and 2016 from an annual camera trap survey (TEAM network). The index shows that biodiversity decreased in this highly fragmented landscape by about 60% over 9 years.

[16] When a species is not observed at a location it could be due to two reasons: 1) the species is present at that location, but it is was not detected (for example the bird did not sing while recording), or 2) the species is not truly there (absent). The type of sensor data collected by camera traps and acoustic recorders allows to correct statistically for this observation problem, which if ignored can result in bias in the estimated occupancy.

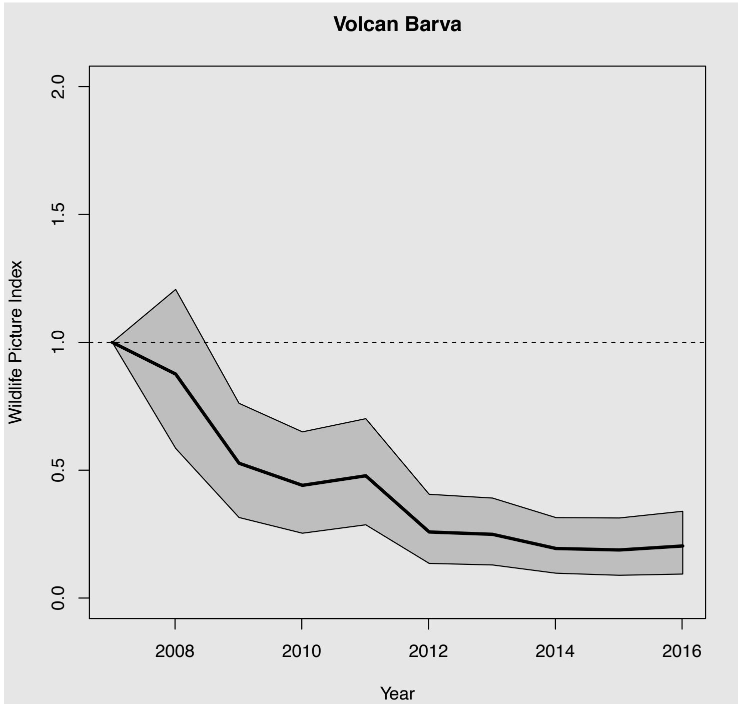


Figure 2. Changes in the Wildlife Picture Index in Volcan Barva transect, one of the TEAM network sites in Costa Rica.

The WPI can also be calculated from relative abundance data rather than occupancy. Relative abundance indexes estimate the abundance of a species at a camera trap or recorder by dividing the number of independent observations of that species by a measure of effort (usually 100 sampling days). However, this measure of relative abundance does not correct for detection probability as occupancy estimation does, so results must be interpreted carefully when comparing different monitoring surveys or comparing data over time. Alternatively, multispecies abundances (counts) can be analyzed using community N-mixture models that correct for detection probabilities (Kery and Royle 2016).

Community Similarity:

Community similarity index

Community similarity and dissimilarity indices measure the structural similarities/differences of communities between pairs of sites, or at the same site between two different points in time. They are especially useful for monitoring the biodiversity impacts of restoration, since they can provide a measurement of how species composition changes over time. For example, as forest regenerates, disturbance-tolerant species are slowly replaced by forest specialist species, and it is possible that species richness and abundance don't change at all even when there is complete turnover of the community. Since these forest specialists tend to be more extinction-prone than the generalists they replace, low similarity (or high dissimilarity) values generally indicate higher conservation value. We recommend indices that measure changes in species abundance as well as composition, such as Morisita-Horn. There is free software available that makes these analyses relatively easy, such as EstimateS.

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SUBPROTOCOL 16: LOOKBACK ANALYSIS

Includes details on lookback periods ensuring projects are completed in areas where deforestation occurred before 2010. Lookback analysis will cover the historical disturbances going back to 2010 depending on data availability on disturbance indicators. This is separate from the field monitoring of disturbances which will focus on the active project period (year 0 to 5 years), described in subprotocol 7.

Provides guidance for indicator 1.6: # of major disturbances observed

Created by Tesfay Woldemariam at WRI

Guidance for Users

The analyses described in this protocol are completed by the *global monitoring team* to verify that deforestation occurred in the project area prior to 2010, using remote sensing. Remote disturbance monitoring can be re-visited in year 5 to assess the 5-year period of active project duration which can complement the regular field collected data on disturbances. The field data collection component is completed by *project developers* to share information about disturbances detected on the ground during the project period.

Importance

Major disturbances may include fire/flood/hurricanes, uncontrolled grazing/herbivory, pest outbreaks, and intentional clearing. *Invasion of sites by non-native grasses or trees is not noted as a disturbance, but in management practices.* Some disturbances are natural, some are human-driven- and all can cause major setbacks to tree restoration efforts, and so they must be reported if and when they occur. Disturbances may need to trigger adaptive management.

Methodology

Project sites are uploaded on the Global Forest Watch (GFW) platform using an API script. Data layers relevant to disturbances are selected from the GFW platform. After running the script, an Excel file will be generated with an annually aggregated summary result of indicators for the data layers used (see below). Each row in those tables represents the site with columns of indicator values.

Data Source and General Data Selection Criteria

- **Relevance and feasibility:** Should be relevant to disturbance indicator and feasible to assess remotely
- **Coverage**: Global
- **Spatial Resolution**: 30m or higher resolution data layers. For coarser resolution, verify with Google history imagery.

- **Time scale**: 2010-2021.
- **Frequency**: Annual- aggregated by year if we have finer resolution (daily or monthly data)

The primary source for lookback analysis data is from Global Forest Watch (GFW) data layers.

The following data layers were selected for lookback analysis based on the above criteria. Please, refer to the referenced links under the footnote links for details on the data characteristics.

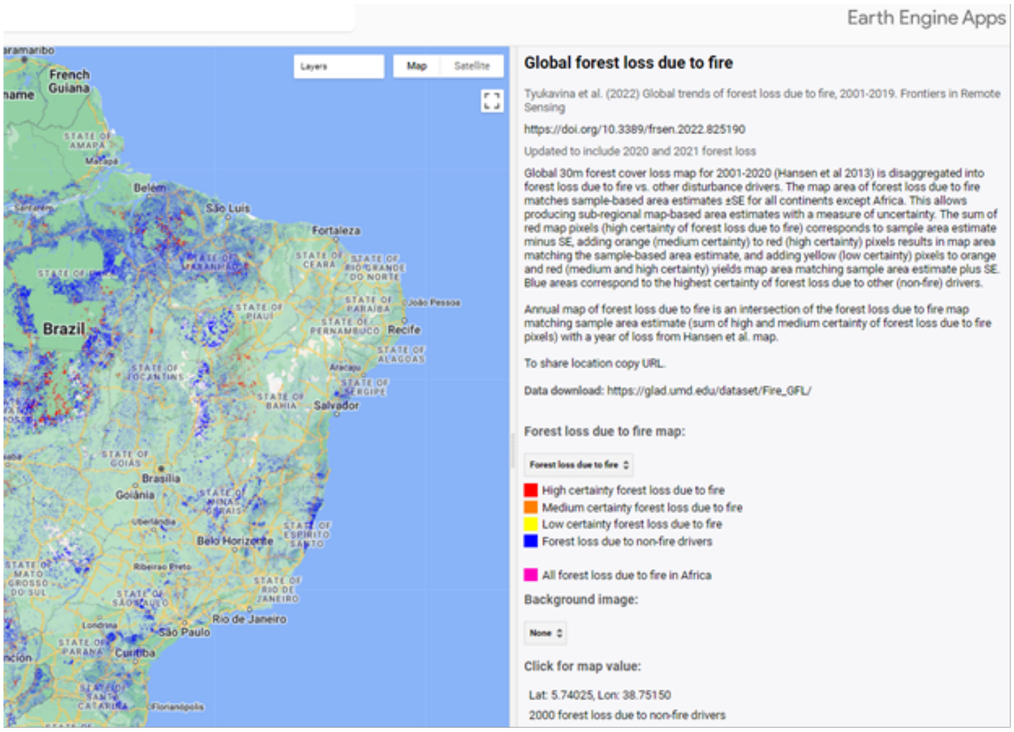
- **UMD tree cover loss (**Global, 30m, annual, 2001-2020**)**

  Shows year-by-year tree cover loss, defined as stand level replacement of vegetation greater than 5 meters, within the selected area.

  Note that "tree cover loss" is not the same as "deforestation" – tree cover loss includes change in both natural and planted forest and does not need to be human caused. The data from 2011 onward were produced with an updated methodology that may capture additional loss.[1]

- **Tree cover loss due to fires (**Global, 30m, annual, 2001-2020**)**

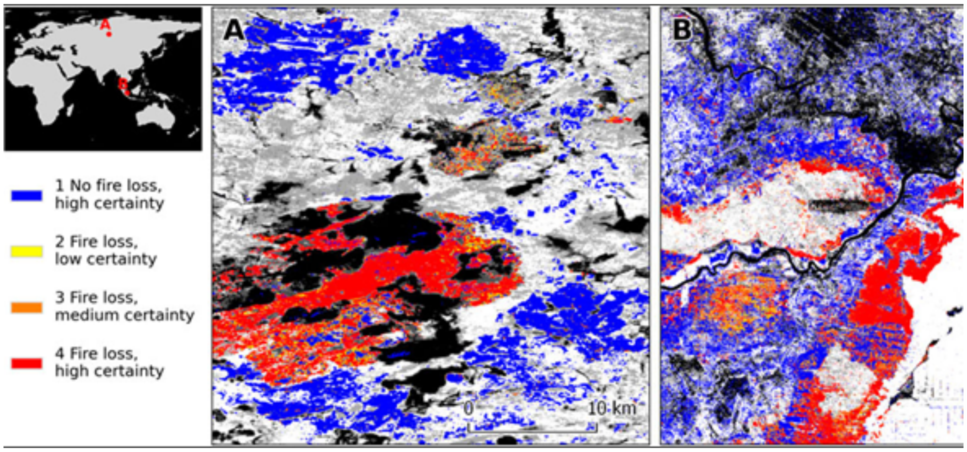
  Identifies areas of ***tree cover loss due to fires compared to all other drivers of tree cover loss.*** *This data is produced by the Global Land Analysis & Discovery (GLAD) lab at the University of Maryland and measures areas of tree cover loss due to fires compared to all other drivers across all global land (except Antarctica and other Arctic islands) at approximately 30 × 30-meter resolution. The data were generated using global Landsat-based annual change detection metrics for 2001-2020 as input data to a set of regionally calibrated classification tree ensemble models. The result of the mapping process can be viewed as a set of binary maps (tree cover loss due to fire vs. tree cover loss due to all other drivers)*[2].



Source: *https://glad.earthengine.app/view/global-forest-loss-due-to-fire#lon=-64.88890488795008;lat=-25.14263539814906;zoom=4*;

*Global 30m forest cover loss map (Hansen et al 2013) for 2001-2019 (updated to include 2020) is disaggregated into **forest loss due to fire** vs. **other disturbance drivers**. The map matches the sample-based area estimates of forest loss due to fire ± SE for all continents except Africa. This allows producing sub-regional map-based area estimates with a measure of uncertainty.*

***code 4** (high certainty of forest loss due to fire) corresponds to sample area estimate **minus SE**, adding **code 3** (medium certainty) to code 4 (high certainty) pixels results in map area matching the sample-based area estimate, and adding **code 2** (low certainty) pixels to codes 3 and 4 (medium and high certainty) yields map area matching sample area estimate **plus SE**. **Code 5** corresponds to all forest loss due to fire in Africa; **code 1** corresponds to forest **loss due to other (non-fire) drivers**.*



See the corresponding labels for the codes here.

Source: *https://www.frontiersin.org/files/Articles/825190/frsen-03-825190-HTML/image_m/frsen-03-825190-g004.jpg*

Analysis

Python API script was created to pull in the shapefiles of project boundary files into the GFW platform and run the analysis to generate tabular data for the identified indicators above.

The analysis generates an annually aggregated table of simple CSV file where project sites are printed out as rows. Occasional map views of significantly impacted sites can be also generated to highlight. The unit of measure is area (ha) calculated using the pixel count pixels of the impacted area and pixel size.

Table 3. Lookback analysis of site disturbances

Site	Total Tree Cover Loss (ha)	Loss due to fires (ha)	Loss due to other drivers (ha)
RESEX Rio Preto JacundÃ¡ - Poligono A (Ãrea de Controle)	**12.83**		
RESEX Rio Preto JacundÃ¡ - Poligono A (RestauraÃ§Ã£o)	**174.72**		
RESEX Rio Preto JacundÃ¡ - Poligono B	**48.22**		
RESEX Rio Preto JacundÃ¡ - Poligono C	**36.75**		
RESEX Rio Preto JacundÃ¡ - Poligono D	**2.13**		

Resources:

[1] Global Forest Watch. “Tree cover loss in [country/province name]”. Accessed on 24/05/2022 from www.globalforestwatch.org.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PRICELESS PLANET COALITION

CONSERVATION INTERNATIONAL

Draft Public Report
September 2022