TECHNICAL GUIDE

Orbify's Afforestation, Reforestation and Revegetation (ARR) Templates

Table of Contents

Glossary

ARR (Afforestation, Reforestation, and Revegetation): Activities that establish or enhance forest cover.

Baseline: A reference scenario representing what would have occurred without a carbon project, used to measure project impact.

Donor Pool Area: A geographically similar region used for comparison and control purposes in baseline assessments.

Control Points: Selected sampling points within the donor pool area that are matched to project points based on similar characteristics.

Dynamic Baseline: A baseline approach where reference conditions are continuously updated based on real-world remote sensing data, rather than being fixed at project inception.

EVI (Enhanced Vegetation Index): A vegetation index optimized to reduce atmospheric and soil background noise, improving measurement of plant health.

Leakage: The displacement of deforestation or other emissions-generating activities from the project area to other locations.

NDVI (Normalized Difference Vegetation Index): A commonly used index to measure vegetation greenness and plant health.

Performance Benchmark: A statistical measure used in additionality assessments to compare project performance with control points and determine credit issuance.

Project Points: Sampling points within the project area used for monitoring and assessment.

Project area: The area where project activities are carried out. This must be an area where there is no forest. Only the area where project activities take place must be included in the project area.

Stocking Index (SI): A remote sensing-derived metric that correlates with terrestrial aboveground biomass (AGB) and is used to track vegetation growth. See here.

Additionality: The requirement that carbon credits represent emissions reductions that would not have occurred without the project.

VM0047: Verra's methodology for ARR projects, which employs dynamic baselines and performance benchmarks to improve additionality assessments.

An Introduction to VM0047 and the Performance Benchmarking Methodology

Orbify's ARR template is based on Verra's *VM0047 Afforestation, Reforestation, and Revegetation* methodology, developed to quantify carbon removals from activities that increase the density of trees and woody vegetation. VM0047 is widely considered to be a high-quality methodology, and it serves as the foundation of our template. Our components build on VM0047 to ensure our project assessments indicate any areas where quality and additionality are not guaranteed.

Verra is the organisation that oversees the Verified Carbon Standard (VCS) Program, the world's most widely used greenhouse gas (GHG) crediting program. Methodologies are the documents and guidelines project developers use to design projects, and there are specific methodologies for various types of projects, including plastics reductions and methane reductions. Many of these methodologies originated from specific project needs, and until recently, several methodologies existed for ARR projects, each with slightly different requirements and tools (similarly for REDD+ projects). Verra has recently made an effort to consolidate several similar methodologies for ARR and REDD+ projects, resulting in VM0047 (ARR) and VM0048 (REDD+). Not only have the methodologies been consolidated, but the approach employed by these methodologies to calculate additionality has also changed considerably. These changes are widely regarded as a significant improvement over previous methodologies, and are likely to result in higher quality projects and credits on the voluntary carbon market. For this reason, we have employed this methodology as the basis of our assessment.

Verra's New VM0047 Methodology as compared to the older approaches. (*BeZero*, 2024)

Factor	AR-ACS0003 and AR-AMS0007	VM0047
Baselines	Both methodologies employ alternative scenario analysis, which identifies the most likely scenario in the absence of the project, and uses that to set the baseline.	Offers two approaches: **Area-based**: Employs traditional plot-based sampling methods in matched control plots outside of the project area, in combination with remote sensing data, to establish a project's baselines. **Census-based**: Primarily designed for projects where the activity does not result in a change in land use, such as agroforestry, and where a complete census of plantings is practical.
Additionality	Both AR-ACS0003 and AR-AMS0007 demonstrate additionality through barrier, investment, and common practice analysis, or an approved standardized baseline appropriate to the project.	Additionality testing depends on the baseline setting approach. However, both approaches require regulatory surplus tests, plus an investment analysis when there are revenues/financial incentives other than carbon credits. **Area-based:** Must exceed the carbon storage that is evidenced from the same dynamic performance benchmark that is used in the baseline setting. **Census-based**: Must occur in lands with less than 10% forest cover and subject to continuous cropping, in settlement(s), or on lands categorized as 'other lands'. Projects must also apply a common practice assessment which considers anything over 15% to be common practice.
Leakage	Leakage for both methodologies is estimated using the CDM tool AR-TOOL15. The tool estimates the increase in emissions based on changes in carbon stocks in the affected carbon pools in the land receiving displaced activities. It considers increases in GHG emissions associated with secondary effects to be insignificant and therefore they are not accounted for. This tool does not stipulate time spans from and for which leakage assessment must be derived or applied.	Requires projects to apply the newly published leakage module VMD0054. This provides a standardized approach to accounting for leakage associated with displacing pre-project agricultural activities caused by the baseline agent or other actors. It incorporates a set historical period of three years or one crop rotation, whichever is greater, and quantifies leakage for five years following project establishment.
Carbon pools	In AR-ACM0003 and AR-AMS0007, accounting for deadwood, litter and soil organic carbon pools is optional, whilst non-woody biomass is not included.	In the area-based approach litter and aboveground and belowground non-woody biomass must be included if the project activity significantly reduces these carbon pools. Soil organic carbon must be included where soil disturbance from the project activity occurs more than once during the crediting period, and/or when it involves soil inversion to a depth exceeding 25 cm.

Dynamic Baselines

The project baseline, often referred to as the 'business-as-usual scenario', represents the expected carbon stock trajectory in the absence of the project activities. All carbon projects issue credits based on the difference between this baseline and the observed changes in biomass. However, because the baseline is a hypothetical scenario, determining an accurate baseline is one of the most difficult (and contentious) aspects of carbon accounting.

Historically, different methodologies have used static baselines, which assume a fixed rate of land-use change or carbon accumulation based on historical trends. However, these approaches can be prone to overestimation or manipulation.

In contrast to these methods, VM0047 employs dynamic baselining, in which the baseline is established using remote sensing data from comparable areas outside the project boundary. This ensures a more objective and transparent reference scenario for evaluating project performance.

> *VM0047 Methodology: "The baseline scenario is represented by the business-as-usual growth of carbon stocks, as observed on representative remotely sensed control points located outside of any registered AFOLU project area. The baseline scenario is represented by business-as-usual changes in above-ground biomass in control points. This approach creates the most plausible baseline scenario because remote sensing provides continual and quantifiable observations of changes in aboveground biomass allowing for the real-time comparison of project and baseline."*

Dynamic baselines are said to be 'ex-post' (meaning 'after the event'), because the baseline is created as the project develops. Dynamic baselines are constructed by comparing the condition of a number of sampled points surrounding the project area to the condition of sampled points within the project area. These surrounding points are selected based on a similarity to a number of different characteristics to the project area. This is widely accepted to be a high-quality methodology, and has been employed by ratings agencies and researchers looking to assess the true impact and additionality of projects (including REDD+ projects). Dynamic baselining is thought to be a big improvement on previous Verra ARR methodologies since dynamic baselines are likely to be less prone to manipulation and (in theory) should be easy to replicate. However, there are some disadvantages. For example, it is not easy to construct a dynamic baseline before the project has started, or to forecast the baseline, which makes it hard for developers to plan ahead.

Dynamic baselines as applied in the Verra methodology is used to generate a performance benchmark. The performance benchmark can be thought of as a discount factor, which is applied to the calculated removals, to reflect the additionality of the project.

The following describes the process of generating a performance benchmark, using a dynamic baseline methodology. Since dynamic baseline methodologies are ex-post, it is only possible to generate a performance benchmark for projects which have already been established. For the estimation of performance benchmarks for new projects, see the discussion here, but it is recommended that the following is understood first.

How dynamic baselines are created

The following outlines the creation of a baseline in accordance with VM0047. For further guidance, consult **APPENDIX 1: Performance Method in VM0047 methodology**.

The methodology can be simplified as the following steps:

1. Take samples from the project area (project points)
2. Create a 'donor pool region', an area similar to the project area which can be sampled, to create 'donor points'.
3. Take many samples from the donor pool region ('donor points'), and match the sampled project points (see below). Project and donor pool samples are matched based on the historical stocking index (see section below), and 5 unique donor pool samples are selected for each project point. These unique donor pool samples are known as control points
4. Generate statistics for the matching of the project and control points for review.
5. Plot averaged stocking index for project points alongside weighted averages of control points.
6. Generate and compare lines of best fit for project points and control points. If deemed statistically significant from each other, use the slopes of the lines to generate a performance benchmark. The performance benchmark represents a discount factor which can be applied to the net removals calculations, which represents the additionality of the project.

Stocking Index

The Stocking Index (SI) is a remote sensing metric used to approximate aboveground biomass (AGB). It serves as a proxy for carbon stock estimates, allowing for the comparison of project and control sites in the performance benchmark assessment.

The choice of an appropriate Stocking Index is crucial, as different indices may yield different results. No single metric is universally suitable across all landscapes. Some commonly used indices include:

- NDVI (Normalized Difference Vegetation Index): Measures vegetation greenness and is widely used in remote sensing.
- EVI (Enhanced Vegetation Index): Similar to NDVI but incorporates additional corrections for atmospheric conditions and soil background effects.
- Radar-based indices (e.g., RNDVI, RVI): Useful in areas with persistent cloud cover where optical indices may be unreliable.

Calculating a performance benchmark requires ten years of historical data. Since long-term datasets with global coverage are required, most stocking indices used in VM0047 are derived from Landsat imagery, ensuring consistent historical analysis. While proprietary AGB or canopy height models may be considered a better option, their use within VM0047 remains uncertain due to concerns about replicability, transparency, and accuracy. Independent validation studies have shown that AGB models often have high error rates when applied across diverse ecological zones and should be used with caution.

How we generate a Performance Benchmark:

Step 1: Sample the project area

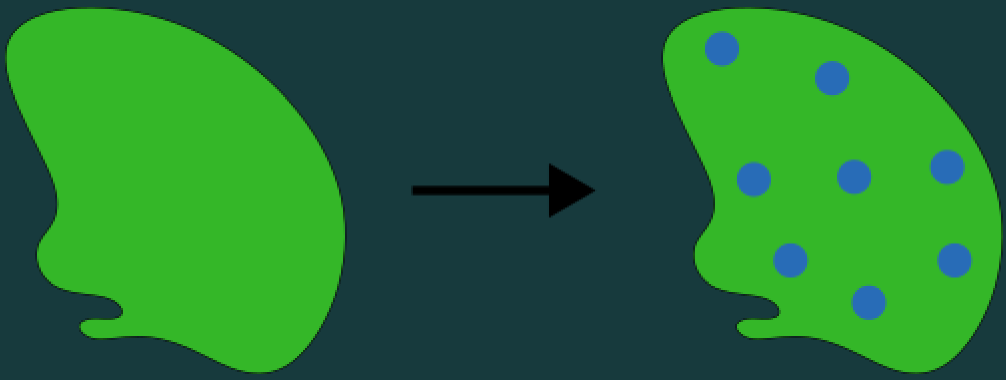


Figure 1: The project area is sampled to generate project points. A minimum of 30 project points are generated

VM0047: "Select a representative sample of n = 30 or more project points, via random or systematic, stratified, or un-stratified sampling"

Step 2: Delineate the donor pool area

Figure 2: A donor pool area is created, representing a geographical area very similar to that of the project area.

Data sources required to delineate the donor pool area found in VM0047 (Table A1):

> VM0047: "Required factors and source data to delineate donor pool area, evaluated for time t = 0. Time variant geospatial layers used must be current as of t = 0, ±5 years."

Table A1 (part1)

Factor	Procedure and data source (GIS layer)
Jurisdictional boundary	Where the project area is within a subnational jurisdiction either registered under Jurisdictional and Nested REDD+ (JNR) or delineated by the national or subnational government for reporting REDD+ (e.g., delineated as a discrete Forest Reference Emission Level), the relevant jurisdictional boundary is the subnational jurisdiction (no lower than the second administrative level from the national level). Otherwise, the jurisdictional boundary used is the national boundary. Source: the GIS layer for the jurisdictional boundary must be from a published or official national government source.
Ecoregion	The donor pool area must exclude any areas not within the same ecoregion (biome level) as the project.

Table A1 (part2)

Factor	Procedure and data source (GIS layer)
Policy environment	The donor pool area must exclude any areas of the jurisdictional boundary (defined above) with presence/absence of any operating subnational government-funded program providing incentives for tree planting that differs from the project area. Operating government-funded program providing incentives for tree planting A currently (as of the relevant evaluation date) funded and implemented national or sub-national government policy/program providing monetary incentives for tree planting (e.g., USDA Conservation Reserve Program)
Outside any registered AFOLU project	Optionally, and as available, the donor pool area may exclude boundaries of any AFOLU projects registered under a carbon offset program. Source: kml files from project registries (e.g., Verra registry)
Land tenure	All land tenure classifications present in the project area must be represented in the donor pool. Exclude any areas with different land tenure classification than the project area. Land tenure classification should be sourced from published or official government sources. At a minimum, land tenure classification must distinguish between public and private lands. More precise classifications (e.g., indigenous reserves, concessions, private industrial lands) may be used where available. Source: published or official government source
Distance from project plot	Exclude areas beyond a 100 km radius of the centroid of the project plot.

The donor pool represents an area which is broadly similar to the project area. From this area, we can take samples which will be compared to the project points based on the historical stocking index, and matched samples will become the control points.

Note:It may be necessary to adjust the donor region in order to better reflect the project activities. For example, a project taking place within protected areas would not exclude protected areas from the donor pool region.

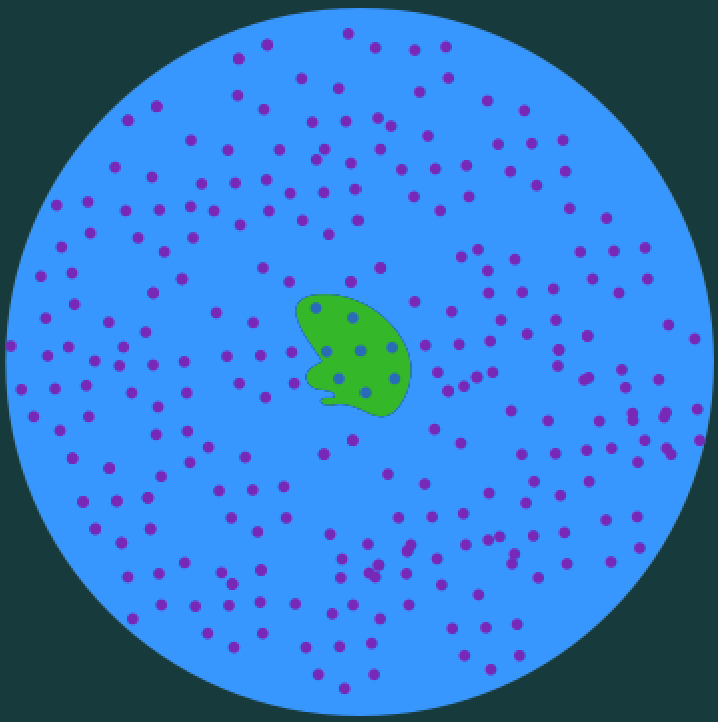


Figure 3: The donor pool is sampled 5000 times to create donor points. These points will be filtered and only those which are similar to the project points will be retained.

Step 3: Generate control points

In order to create the control points, we first sample the donor pool area 5000 times. From this we match 5 donor pool points (k =5) to each project point (30), resulting in 150 control points.

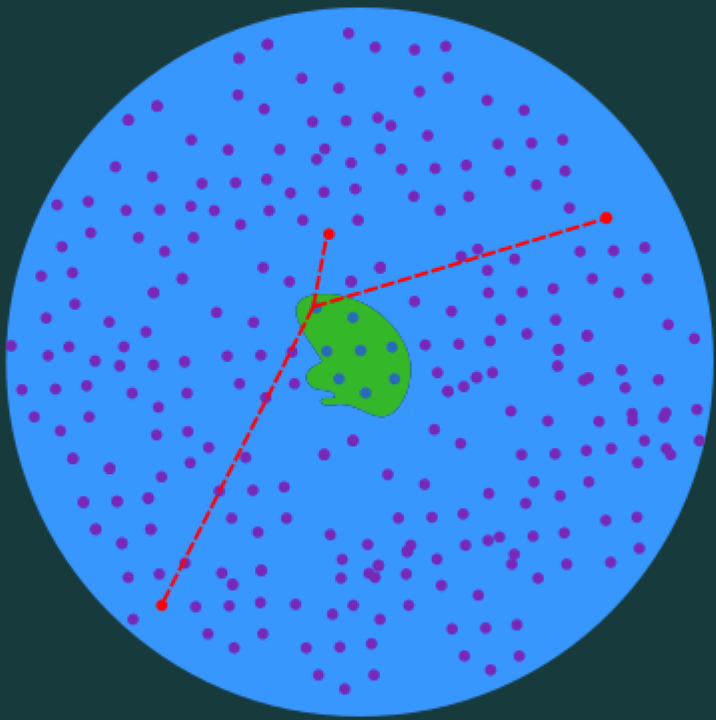


Figure 4: The donor points matched to each of the project points by the historic EVI values. Here the project points are matched to three donor points (k=3), but our analysis uses k=5.

Control points are small plots within the donor pool that are similar to the project points. They are matched as follows:

1. Quantify historic and initial conditions of stocking index via a time series analysis for a representative of control and project points.
2. Run a regression for the stocking index (SI) of each control and project area as a function of time including at a minimum three time points between -10 and -8 years and between -8 and -1 years, and t = 0 (project start).
3. For each control plot, calculate a multivariate distance metric, MD (e.g., Euclidean distance, Mahalanobis distance), across the vector of covariates (i.e., the minimum three time points referenced above), relative to the project area.
4. To match control points with project points, apply a k-nearest neighbor optimal matching approach without replacement (i.e., control points may not be matched to multiple project sample plots). The number of control points matched to each project area, k, is selected by the project proponent. k must be kept constant for each match (e.g., if k=5 for project area A, k must remain 5 for the project lifetime). Select the k control points with the lowest multivariate distance metric values and derive relative weights proportion.

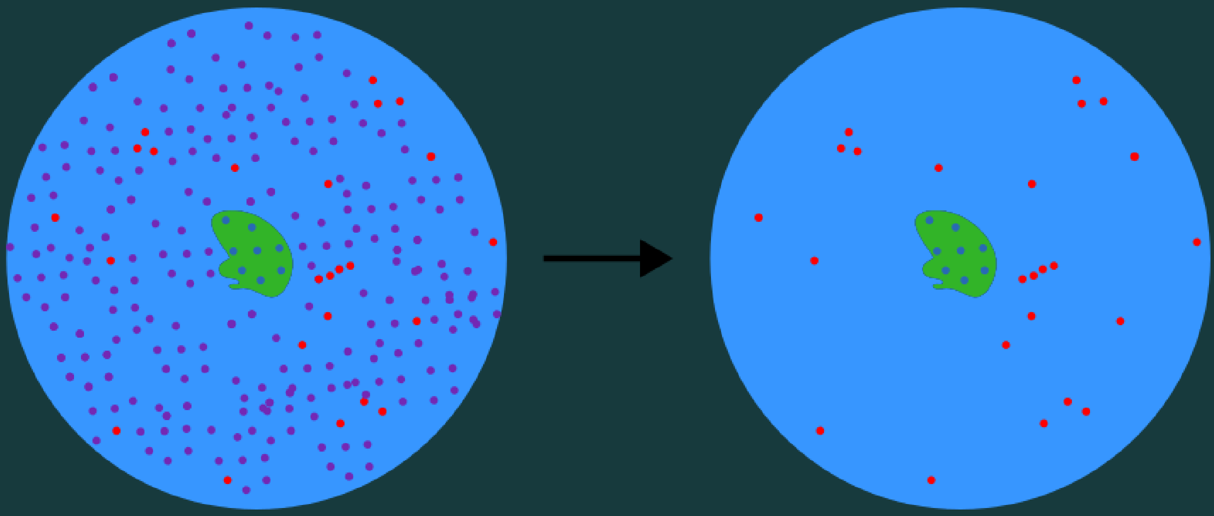


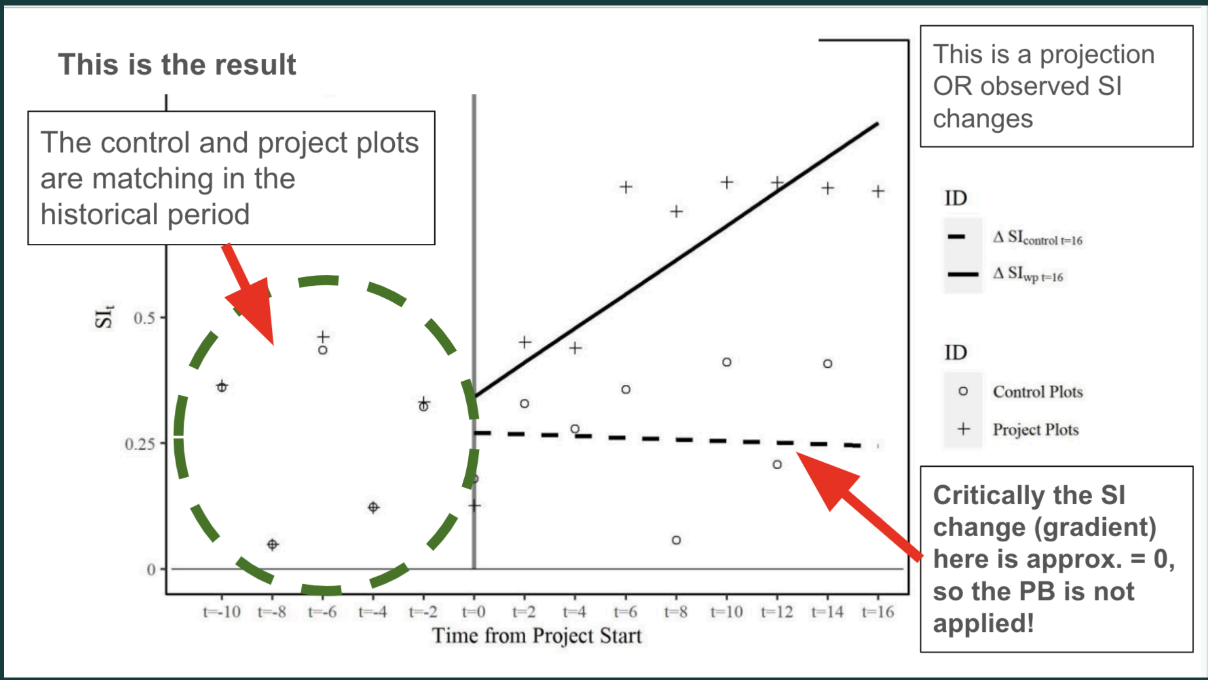
Figure 5: The control points are selected based on their similarity to the project points and the rest of the donor points are removed from the analysis.

> *VM0047: "The approach to select control points outlined below constitutes a matching approach widely used in impact evaluation in the environmental field (Ferraro & Hanauer, 2014). Matching approaches are not expected to produce exact matches for individual land parcels, but rather to produce robust estimates of impact for sample "populations" of matched pairs (controls and treatments)."*

Step 4: Performance Benchmark analysis

Next, compare the average value of the stocking index for all of the project points to the weighted averages of the control points, and plot them in a chart.

This graph shows the final result of the Performance Method of the VM0047 methodology. Project points are matched to control (or reference plots) in the surrounding area. In the historic period (10 years before the project start date) the project and control points have very similar characteristics. After the project start date, the characteristics diverge. The extent of the difference between the project and control points after the project start date defines the additionality of the project.



In this example the control points and project points both show an increase in the stocking index (EVI). This means that there is a discount to the number of credits a project will generate (a non-zero stocking index). In order for the performance benchmark to be non-zero, the project line will need to exceed the control plot line, and the difference has to be statistically significant.

The performance benchmark is generated using the gradient of the control points vs the project points.

NOTE: If the gradients do appear to be different but the result is not statistically significant, the performance benchmark will be set to 1.

How to interpret the Performance Benchmark result:

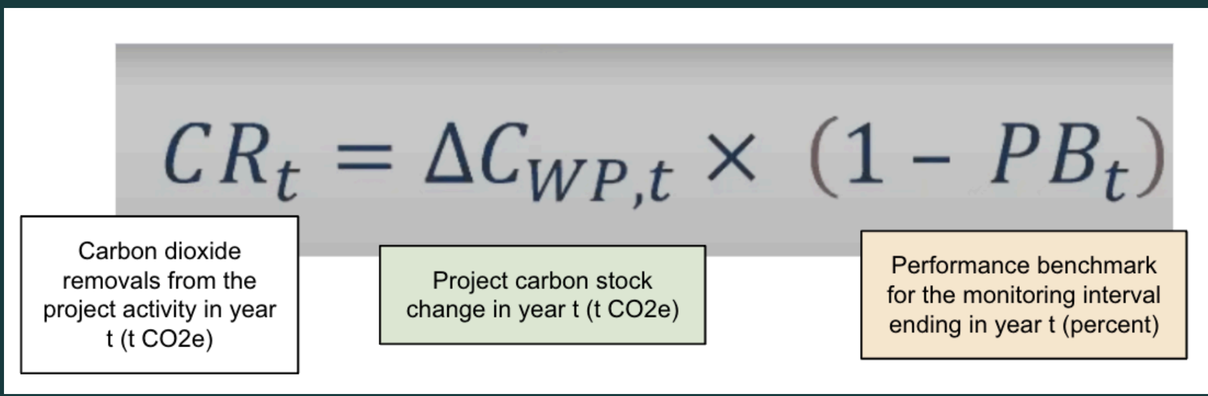
- Very Low, 0: The project is additional, and the project activities are significantly different from surrounding activities. There is unlikely to be high rates of afforestation in the region.
- Low, 0 - 0.3: The project is additional, and the project activities are significantly different from surrounding activities.
- Medium, 0.3 - 0.5: The project is additional, but the performance benchmark is likely to be significant and additionality may be called into question.
- High, 0.5 - 0.8: The project may not be additional, but it is likely afforestation/reforestation activities are occurring in the surrounding area.
- PB = 1. The project is not additional. There are high rates of reforestation/afforestation within the buffer pool, and project activities are unlikely to be considered additional.

Note: It may be useful to consider the performance benchmark as a percentage, representing the percentage of credits which are not additional.

How the Performance Benchmark is applied to carbon removals

Although the stocking index is used as a proxy for AGB, it is not used to derive carbon removals. Instead, it is used to derive a performance benchmark, which can then be applied to the calculations of net removals:

> *VM0047: "Assessing plots using remote sensing, does not involve direct estimation and reporting of carbon stocks. Remote sensing is used only to estimate relative stock change between control and project points. Accounting of emission reductions and removals is treated in Section 8 and is dependent on direct field measurement."*



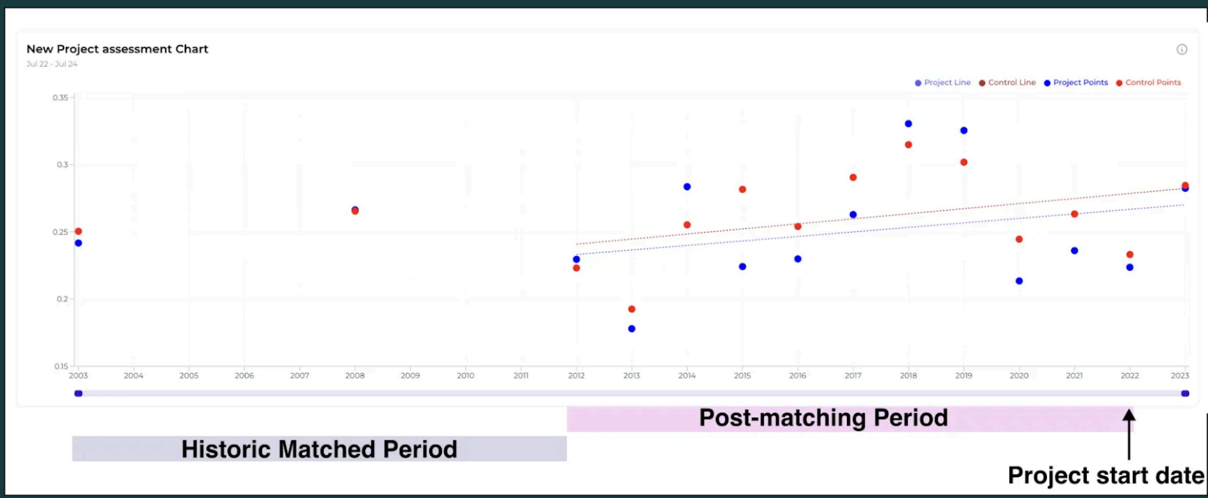
The performance benchmark acts as a discount factor, which is used to reduce the number of credits that can be issued from a project, if the additionality of the project is not considered to be total.

How to calculate a Performance Benchmark for new projects

> *VM0047: "To demonstrate additionality at validation projects must apply an ex-ante calculation to demonstrate an expected difference between modelled performance of the project and the forecasted performance benchmark. Area-based projects must reassess additionality using the Z test in Appendix 1, Equation (A5), at every verification."*

The VM0047 methodology recommends that the performance benchmark is estimated for new projects using the ex-ante projections of carbon removals, and the control plot slope between t-10 and t0 (historical period of 10 years) (See section 8.6 Ex-Ante Estimation). It is not possible to automate the ex-ante projections of carbon removals since this is dependent on the planned project activities. However, the approach proposed in the methodology appears flawed, applying the methodology as described would almost certainly result in a PB of zero, regardless of the true additionality of the project, since matched control points are expected to have a SI similar to the unforested project points. This is potentially problematic for new projects, generating unrealistic zero baselines. For this reason, Orbify has decided to implement the following to apply a more conservative performance benchmark based on a historic assessment of the stocking indices.

Our approach to generating ex-ante performance benchmark estimates:



We simulate the ex-ante performance benchmark using the slope of the control plot line for the time period t-10 to t-0. We use the time period t-20 to t-10 to match the project and control points. This allows the project and control plot points to diverge. The slope of the control plot line allows us to estimate the performance benchmark.

Orbify's Afforestation, Reforestation, and Revegetation Template

Discover how the Orbify Platform's monitoring and assessment template supports existing Afforestation, Reforestation, and Revegetation (ARR) projects.

1. Introduction

Orbify's ARR templates are designed to provide users with automated reports for areas which are undergoing afforestation and reforestation. The template follows many of the steps outlined in VCS (Verra's) VM0047, which is considered a high-integrity methodology, and is likely to be the most commonly used methodology for ARR projects in the future. Our template also provides tools which go beyond VM0047s requirements in order that users are able to identify any potential hazards at the project design stage and indicators which will allow users to demonstrate high-quality.

Please note that it is not currently possible to *fully* automate the Performance Benchmarking analysis of VM0047 to obtain a compliance result, especially for new projects, as some tailoring of the results (and user input) may be required. Please reach out to Orbify if results need to be Verra Compliant.

New projects vs Existing projects

Orbify provides two templates with very similar structures. The distinction is made because the requirements for new projects differ in many key ways to projects where trees have become established, and *critically* trees planted in existing projects can be observed with remote sensing data and an ex-ante performance benchmark can be generated as described in the VM0047 methodology.

In the guide below, some sections are split for new projects and existing projects.

New Projects: The template for Existing ARR Projects is specifically designed for carbon projects that have been active for less than five years or about to begin. New projects may have vegetation which is too sparse to be detected using remote sensing, and generating a performance benchmark may result in misleading results.

Existing projects: The template for Existing ARR Projects is specifically designed for carbon projects that have been active for more than five years and generates a performance benchmark as described in the introduction section.

Project boundaries

User Requirements:

Submitted plot boundaries should only contain areas which will be subject to ARR project activities. Areas containing existing forest cover will be detrimental to the determination of the performance benchmark and should be excluded before running the template.

> *VM0047 pg. 9: "For the area-based quantification approach, the spatial extent of the project boundary encompasses all lands subject to implementation of the ARR project activity."*

Template Walkthrough

This guide gives a tab-by-tab overview of the Orbify ARR templates. We aim to provide as much relevant information and guidance as possible within the template, and much of the information provided in the template is repeated here.

Hints:

🚀**The rocket emoji** brings attention to the key use case of the component.

📖 **The open book emoji** provided guidance based on Verra's methodology. Often this will provide direct quotes or guidance.

⚠️ **The warning emoji** brings attention to any additional important considerations which may affect the interpretation of the results. Often this will bring attention to limitations of certain components.

Component Specific Information:

More detailed information regarding the datasets and the approach taken to generate data in each component can be found using the information button 'ⓘ' which is found in the upper right hand corner of each box, or in the legend of the map layers.

1. Project Overview

The first section of the template is designed to give an overview of the project. It includes:

Project Description: This automatically generated textbox contains a description of the project, describing the projects location, ecoregion, project area.

1. Project Description

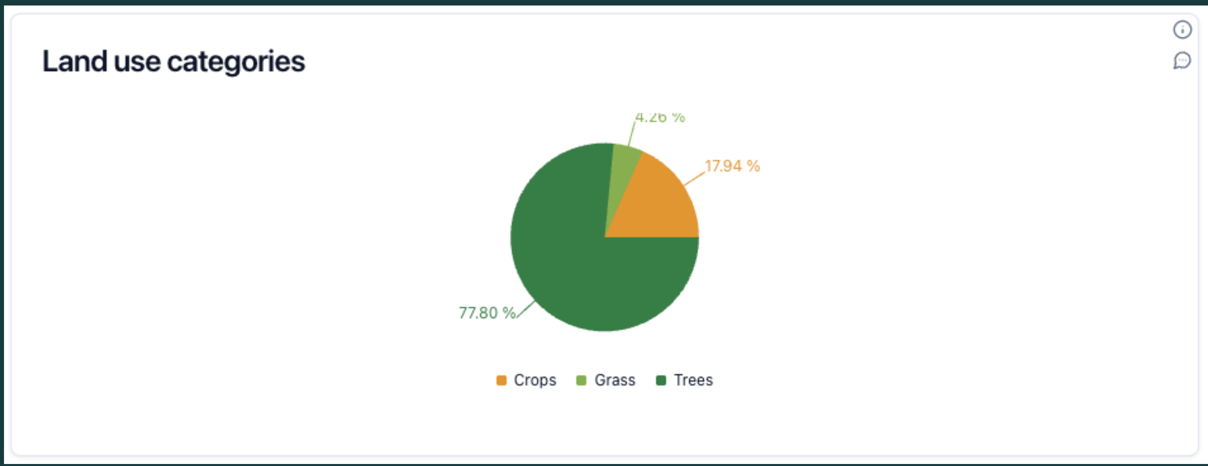
This **2.88 hectare** project is located in the **Pomorskie** administrative unit of **Poland**, within the **Baltic mixed forests** ecoregion, which is part of the **Temperate Broadleaf & Mixed Forests** biome.

Project area: We calculate the total project area using a digital elevation model (DEM). This method accounts for terrain slopes to provide an accurate representation of the plot area. Consideration of high slopes is critical as this template and VM0047 make use of remote sensing data.

2.88 ha	2.91
Area	Including elevation

Map box: Land use categories

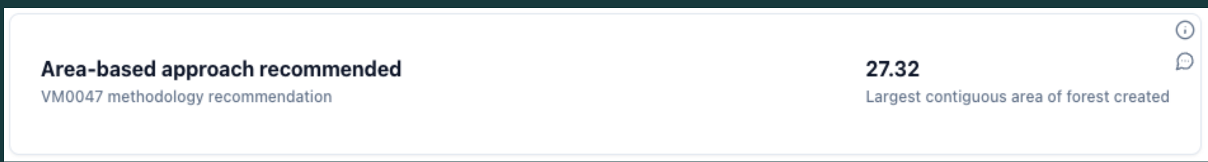
We generate the land use classification using Dynamic World dataset, which gives the current land use cover at 10 m spatial resolution. The land use cover is also presented as a pie chart representing the area covered by each land use class.



⚠️ Dynamic World makes use of Sentinel 2 data, which is affected by cloud cover.

⚠️ It is not always possible to detect young trees and young projects may not register land cover as 'Trees' until the canopy has closed.

Stat-box: Area vs Census based methodology recommendation.



Two approaches are defined within VM0047, these are:

1. **Area-based approach**
    - Appropriate when project activities produce continuous tree and/or shrub cover exceeding one hectare
    - Employs a dynamic performance benchmark to demonstrate additionality and determine the crediting baseline
2. **Census-based approach**
    - Appropriate when a project activity does not produce continuous tree/shrub cover on any contiguous area exceeding one hectare.
    - May not result in a change in land use (agroforestry for example)
    - A complete census of plantings is practical.

Users with the **Area-based approach recommendation** are required to generate a performance benchmark, as outlined in the **Baseline tab.**

Users with the **Census-based approach** may find the **Common Practice** tab more relevant for evaluating additionality, as the **performance benchmark method is not required** for determining a crediting baseline.

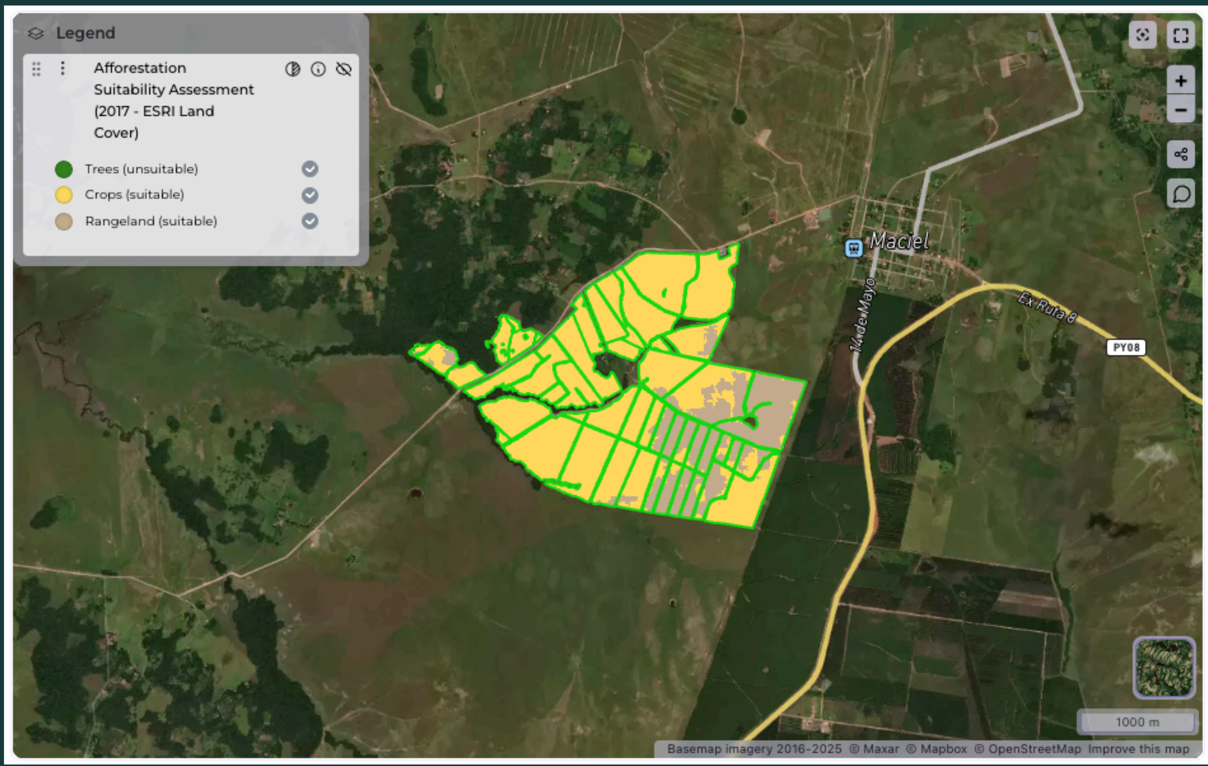
2. Project Eligibility

The Project Eligibility section allows users to assess whether the project meets the requirements of both **VCM VM0047 ARR methodology v1 and VCS Standard v4.7**.

The site assessment tab determines if the project area is suitable for afforestation, or if there are conditions which might indicate that the project is not suitable under VM0047. It will also indicate if the project has previously been forested, which may suggest that the forest is part of a plantation, potentially reducing the additionality of the project.

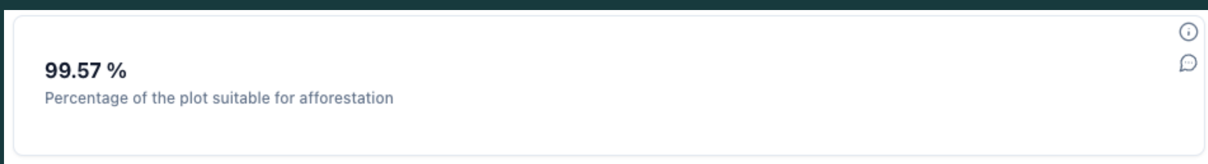
Under VM0047, the following conditions apply:

> "
>
> *Project activities MUST NOT involve mechanical removal offsite or burning of significant stocks of preexisting dead wood (e.g., for site preparation). Where project site preparation includes chipping, mastication or machine piling, all material must remain onsite within the project boundary.*
>
> - *Project activities MUST NOT take place in tidal wetlands (e.g., mangroves, salt marshes)*
> - *Project activities MUST NOT occur on organic soils or in wetlands and result in a manipulation of the water table. Planting species that do not naturally occur in organic soils or wetlands is considered a manipulation of the water table. Where projects take place on organic soils or wetlands and manipulate the water table, they must be developed using a multiple project activity design applying this methodology and a Wetland Restoration and Conservation methodology (e.g., VM0036 Methodology for Rewetting Drained Temperate Peatlands). In such cases, the project activities must comply with all applicable conditions of the selected Wetland Restoration and Conservation methodology and this methodology.*
>
> "



Map box: Suitability based on ESRI Land Cover Classes: The map box shows the different land cover classes for the project area and indicates if they are suitable for afforestation under VM0047. The layer indicates the land cover class each year between 2017 and 2023 at 10m spatial resolution. The maps are derived from a composite of LULC predictions for 9 land use classes, derived from ESA Sentinel-2 imagery. Accuracy is assessed to exceed 75%. (Karra, Kontgis, et al., 2021, #) The land use classes water, trees, flooded vegetation, built area, snow/ice are deemed unsuitable for afforestation, whilst crops, bare ground and rangeland are deemed suitable. This dataset was deemed the highest quality land use map appropriate for assessing suitability for ARR projects.

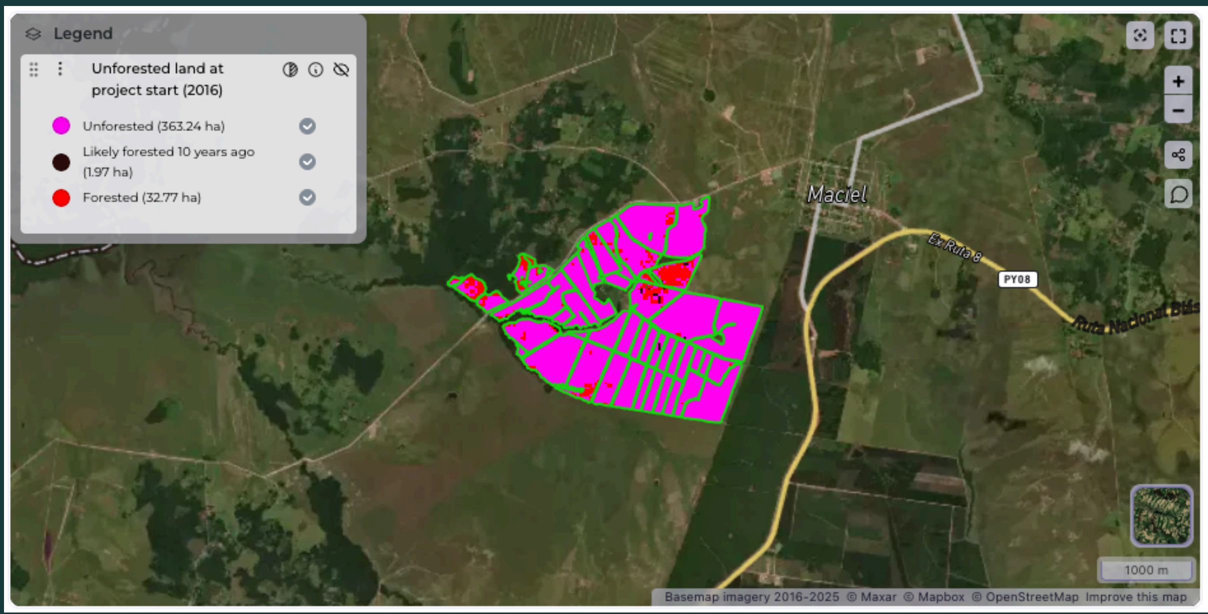
Suitability stat box: The stat box indicates if the site is suitable for afforestation or not, and what percentage of the project area is suitable for afforestation.

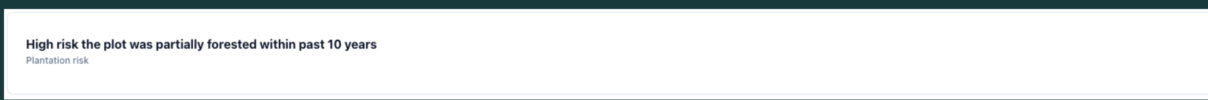


Historic Assessment

Under the VCS Standard v4.7, it is required that a project area must have remained unforested for the previous 10 years in order to be considered eligible for ARR credits.

Credits issued from areas which were previously forested may be considered as part of a plantation scheme where harvesting trees and regrowing them is considered to be *business-as-usual*. For this reason, we provide a map layer showing any areas which are currently forested, or have been previously forested within 10 years, and provide a warning indicating if there is a risk a project may be considered non-additional due to the presence of historic forest cover.





3. Site Assessment

The **Site Assessment** tab provides key environmental and soil-related information to support the planning and implementation of afforestation or reforestation projects. Understanding site conditions is critical to selecting suitable species, determining planting strategies, and anticipating potential challenges.

Three map layers are available:

- **Soil Texture Class**
  This layer displays soil texture classifications based on the USDA system at a 0 cm depth (surface soil). Soil texture influences water retention, nutrient availability, and

root penetration, all of which are vital for tree growth.

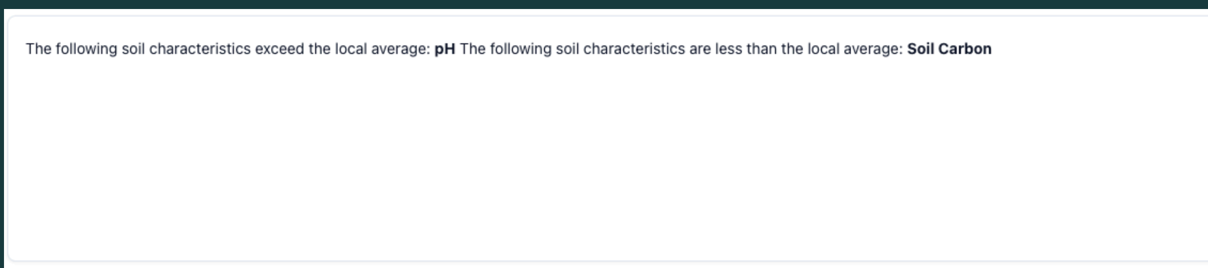
- **Soil Organic Carbon (SOC)**
  Derived from the SoilGrids database, this layer estimates the amount of organic carbon stored in the soil's fine earth fraction (in decigrams per kilogram, dg/kg). SOC is a key indicator of soil health, fertility, and its capacity to support vegetation.

- **Terrain (Elevation)**
  Based on the SRTM (Shuttle Radar Topography Mission) digital elevation model, this layer provides topographic data at ~30 m resolution. Terrain affects drainage, erosion risk, and microclimate, making it important for site design and logistics.

Why this is useful:
These layers support informed decision-making for project design, species selection, and operational planning by providing insights into soil suitability, carbon storage potential, and physical accessibility of the site.

⚠️ Site assessment components are derived from model data, and are available at lower special scales. This means that data may not reflect changes in soil properties resulting in local management practices or site preparation.

Soil Characteristics Table:


The following soil characteristics exceed the local average: **pH** The following soil characteristics are less than the local average: **Soil Carbon**

The text box lists soil characteristics which are significantly different from local averages. Some characteristics may result in better conditions for planting or forest growth, or may suggest additional management practices that have to be introduced to mitigate the effect of these soil conditions.

The soil conditions considered are:
- Cation exchange capacity “CEC”
- Clay content
- Sand content

- Silt content
- Nitrogen content (topsoil)
- pH
- Soil Carbon (0-30 cm)

Note: These conditions do not take into account local management practices or small scale fluctuations in soil conditions.

Climate and Soil Moisture Assessment

This section provides key climate and soil moisture indicators to help evaluate environmental conditions relevant for afforestation or reforestation planning.

Indicators Included:

- **Annual Precipitation**
  Represents long-term water availability, which is crucial for tree establishment and growth. A bar chart is generated to visualize precipitation trends over the past 35 years within the selected project area. This aids in identifying climatic patterns and potential risks related to water scarcity or excess.

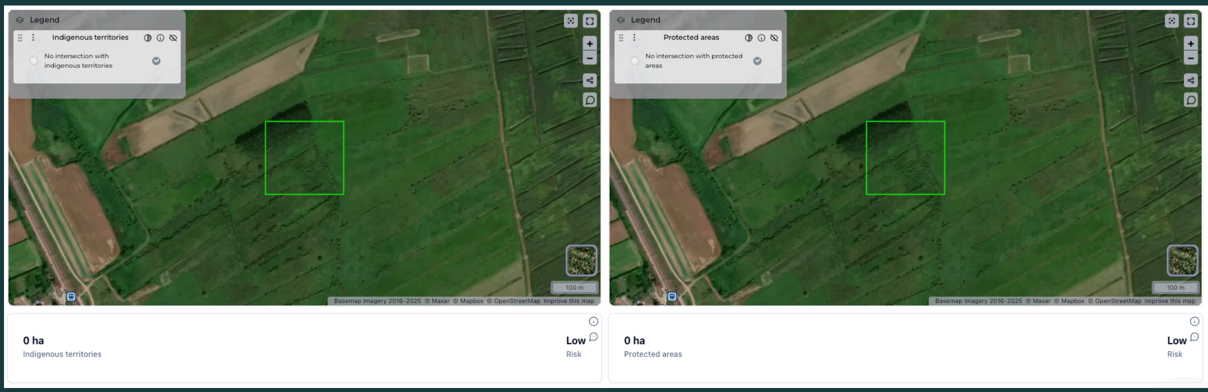
- **Soil Moisture**
  Indicates the soil's capacity to retain water, directly influencing seedling survival, establishment, and resilience to drought. Monthly average values are derived from NASA's SMAP (Soil Moisture Active Passive) satellite mission.

- **Surface Temperature**
  Informs on local thermal conditions that affect evapotranspiration, plant metabolic activity, and general ecosystem suitability. Data is sourced from the Global Forecast System (GFS), offering insight into weather-driven risks and trends.

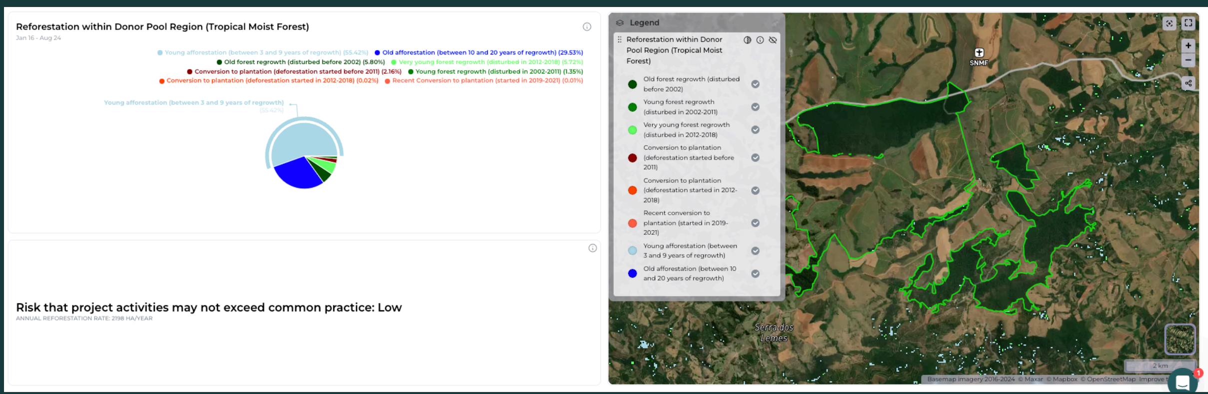
Understanding these environmental variables supports better species selection, optimal planting windows, and climate adaptation strategies.

4. Indigenous and Protected Areas

This tab provides two map layers, showing protected areas or indigenous territories within or near the project area. It makes use of multiple datasets to provide this analysis, but full coverage cannot be guaranteed. If the project area is present within the protected areas or indigenous territories, there may be additional steps needed to ensure the project is compliant with VM0047 or that proper land tenure and rights have been obtained.



5. Common Practice



Demonstrating that project activities exceed common practice is only required when using the census-based approach. However, it is useful for the user to understand what is common practice in the area even when using the area-based approach. This analysis can be considered as complementary to the baseline section, where a performance benchmark is calculated, reflecting the common practice in the area. It is important to consider that the project activities may differ from the common practice activities, and this should be considered in an assessment of the result.

The common practice components use the donor region (defined here) to represent the area where similar incentives might occur for reforestation/afforestation. The tool uses the

Tropical Moist Forest dataset to determine areas which have been reforested between 2002-2021 and this is shown in the map layer. The user may want to inspect these layers to be informed about the type of reforestation/afforestation occurring in the region (C. Vancutsem, F. Achard, J.-F. Pekel, G. Vieilledent, S. Carboni, D. Simonetti, J. Gallego, L.E.O.C. Aragão, R. Nasi., 2021).

In the common practice stat box, the extent of the afforestation/reforestation is assessed in order to determine if the project is likely to be additional or not based on afforestation rates. This is carried out by first generating afforestation rates for tropical jurisdictions by analysing changes in tropical forest cover between 2010 and 2021. We identify areas that were either deforested or classified as 'other' land in 2010 and then check for regrowth in these areas by 2021. The values for categorising the annual reforestation rates were created using the 50th, 75th, and 90th percentiles reforestation rates. These thresholds were calibrated based on analysis of the afforestation rate distributions in tropical areas and validated against regions with known high afforestation rates and performance benchmarks.

The thresholds are applied as follows, relating to jurisdictional afforestation rates:

- Low (below the 50th percentile)
- Medium (50th to 75th percentile)
- High (75th to 90th percentile)
- Very High (above the 90th percentile)

Double Counting Risk

In this section of the common practice tab, the map box identifies registered carbon projects within a buffer zone of the project area, and the projects identified are listed in the table. This allows the user to:

- Mitigate risks of overlapping boundaries and avoid double-counting
- Provides insights into the quality of nearby carbon projects

6. Dynamic Baseline

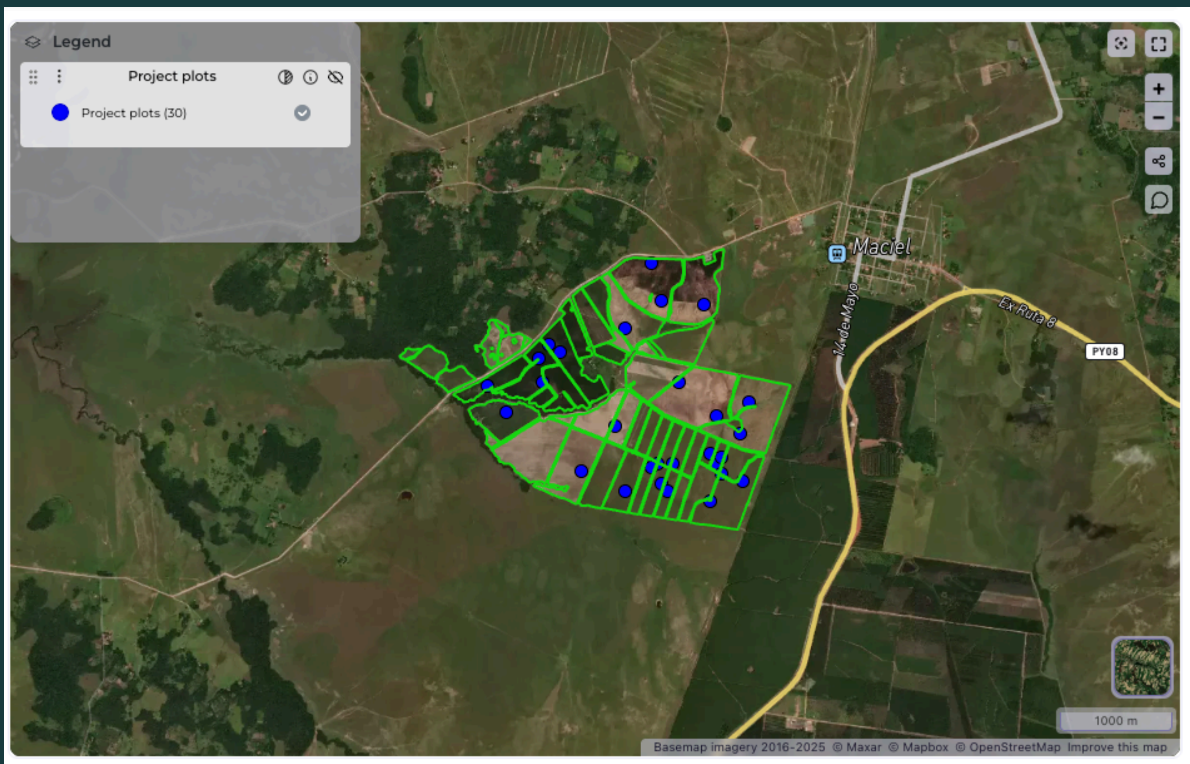
In order to demonstrate 'Additionality', the following must be demonstrated for a ARR project using the 'area-based' approach:

"
Projects using the area-based approach must apply the following steps to demonstrate additionality:
Step 1: Regulatory surplus
Step 2: Performance benchmark
Step 3: Investment barrier *
*Project must apply Step 3 only when there are revenues or financial incentives other than from the sales of carbon credits.
"

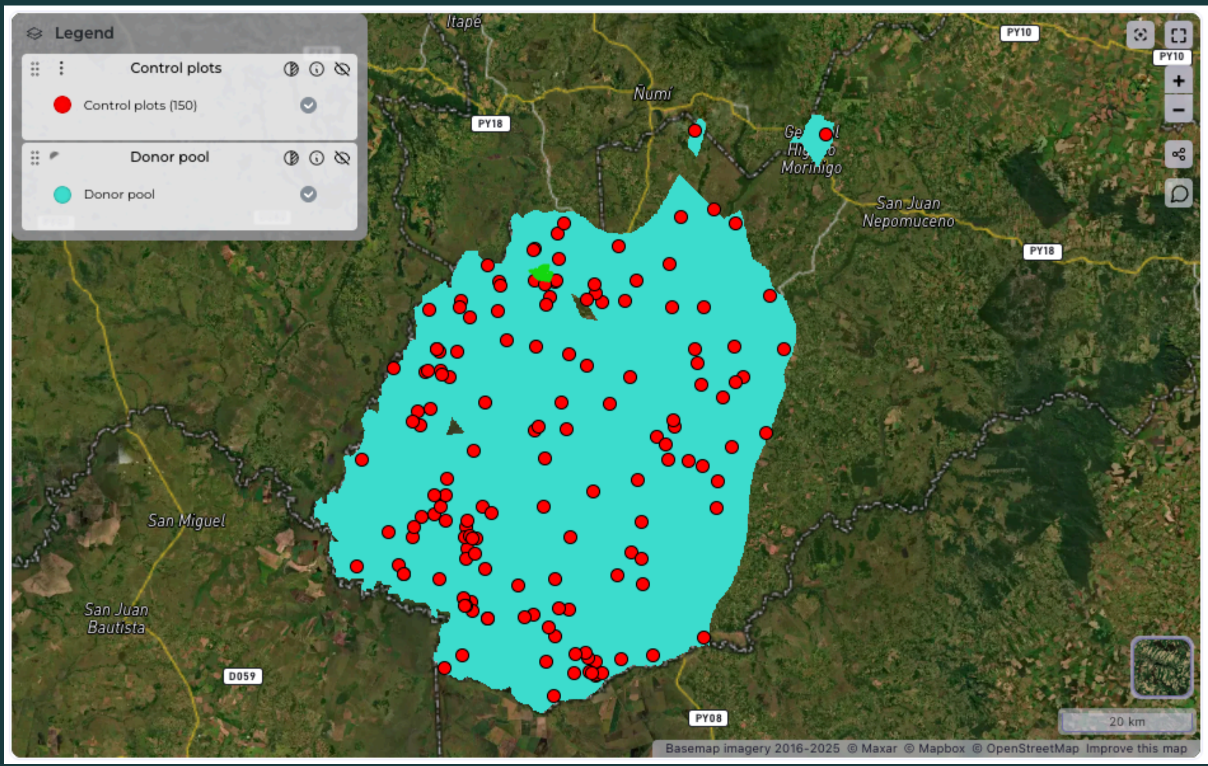
In the baseline tab, a user can show how a performance benchmark (Step 2) has been generated for a specific project based on the Performance Benchmark assessment of VM0047 (Section 7 and Appendix A).

A discussion of the methodology is found above.

Generation of Project Plots



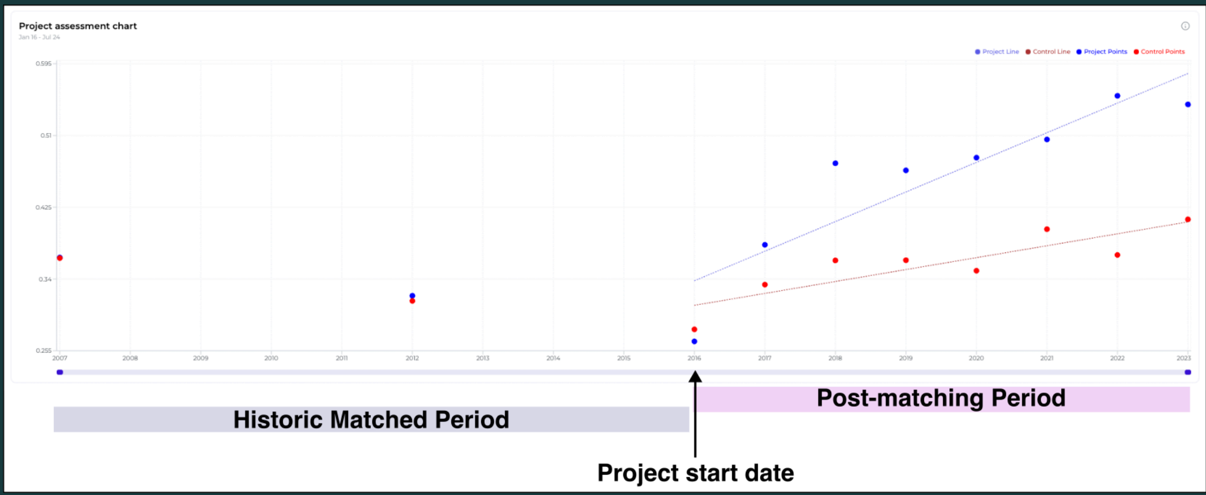
Generation of Donor Pool and Control Plots



Project Assessment Chart

Existing projects: The 'Ex-post Project Assessment Chart' will show the matched project and control points in the historical period (t-10 to t0), and the project stocking indices from t0 (start date) to the current date. Lines of best fit will be applied to the data, which will be used to generate the performance benchmark.

New projects: The 'Ex-ante Project Assessment Chart' will show the matched project and control points for the period t-20 to t-10. It will also show the stocking indices of the project and control points following the matching period. The control point line is then used to estimate the ex-ante performance benchmark.

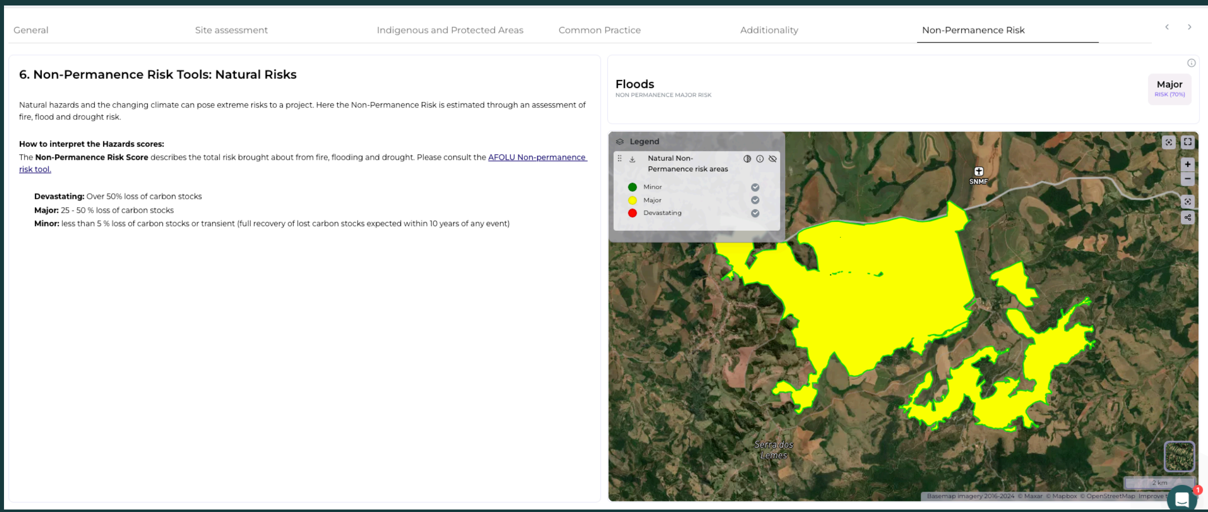


The benchmark provides insights into additionality, with values ranging from highly additional (0) to not additional (1). Lower benchmarks indicate significant differences between project activities and the surrounding region, while higher benchmarks suggest less distinction or alignment with local vegetation changes. A value of 1 indicates no additionality, showing no notable difference between project activities and local trends.

This assessment is vital for determining the project's effectiveness and the distinctiveness of its activities. Projects with non-zero performance benchmarks may require further evaluation to ensure their activities are genuinely additional and impactful.

- Very Low, 0: The project is highly additional, meaning project activities significantly differ from surrounding activities.
- Low, 0 - 0.3: The project is additional, with activities notably distinct from the surrounding region.
- Medium, 0.3 - 0.5: The project is additional, but the performance benchmark suggests the difference might be less significant.
- High, 0.5 - 0.8: The project may not be additional, with surrounding afforestation/reforestation activities possibly influencing the results.
- PB = 1: The project is not additional, indicating no significant difference between project activities and local vegetation changes.

6. Non-Permanence Risk



Non permanence describes the risk a project will fail and carbon will be re-released due to natural hazards like floods, fires, and droughts. These risk assessment components try to identify if there are any major sources of risk which might threaten the project's ability to store sequestered carbon.

This insight provides users with a comprehensive understanding of which natural event has historically influenced the plot, allowing for informed decision-making to enhance project resilience against natural hazards in the future.

Types of Natural Hazards:

- Floods: can damage carbon-storing ecosystems.
- Fires: can quickly release carbon back to the atmosphere.
- Droughts: can reduce carbon sequestration capacity.

Risk categorisation:

- Minor: the sum risk from all fire, floods, droughts risk analysis is low.
- Major: at least one component from the risk assessment has a medium risk.
- Devastating: an area is only considered at devastating risk if it faces severe threats from at least two out of the three hazards.

Risk area percentage:

The *percentage* of the project area at risk of experiencing a *category* level of impact from the identified *hazard*.

For example, "70% of the project area is at Major risk of losing carbon stocks due to floods."

References

BeZero. (2024). Assessment of Verra's new VM0047 ARR methodology. https://bezerocarbon.com/insights/assessment-of-verra-s-new-vm0047-arr-methodology

C. Vancutsem, F. Achard, J.-F. Pekel, G. Vieilledent, S. Carboni, D. Simonetti, J. Gallego, L.E.O.C. Aragão, R. Nasi. (2021). Long-term (1990-2019) monitoring of forest cover changes in the humid tropics. *Science Advances*.

Patchama. (2024). An initial evaluation of carbon proxies for dynamic reforestation baselines. https://pachama.com/blog/dynamic-reforestation-baselines/

Verra. (2022). *VCS Program Methodologies*. https://verra.org/methodologies-main/