Year 2 Template

Based on Café Apui

Draft

TerraBio Reporting Template To Café Apuí-Draft

Background

In compliance with the roles and responsibilities agreed upon through the Memorandum of Understanding signed between the International Center for Tropical Agriculture – CIAT on behalf of the Alliance of Bioversity International and CIAT, and Amazônia Agroflorestal Comercialização de Produtos Agroflorestais Ltda (hereafter referred to as "Amazônia Agroflorestal"), we submit the following TerraBio results report according to clause 2.2.4.

Following the second collaborative application of TerraBio in Amazônia Agroflorestal's coffee initiative called Café Apuí, which took place on October 17 - 19, and lead by Amazonia Agroflorestal between November 2 - 8th, this report summarizes the data finding corresponding to the environmental monitoring and evaluation indicator requirements by the Amazon Biodiversity Fund (ABF). TerraBio indicators are aligned and respond to ABF Key Performance Indicators (Annex 1).

TerraBio is a methodological framework that provides monitoring, evaluation, and reporting for environmental impact assessment. It supports businesses that commercialize forest and sustainable agriculture products and invest in sustainable business models. The methodology was developed by the Alliance of Bioversity International and CIAT, in partnership with USAID, Spatial Informatics Group (SIG) and the SERVIR-Amazônia program, under the Catalyzing and Learning through Private Sector Engagement (CAL-PSE) program.

Previously the TerraBio team had shared a report containing the biodiversity results only. This was due to missing information on the total number of farms formerly engaged in the Cafe Apui initiatives supported by ABF. Here we provide an updated version of the 2022 report including the geospatial results. Was w to missing geospatial information being gathered by Amazônia Agroflorestal at the time of completion of this report, the present only describes the biodiversity baseline results. This information was required for Given that TerraBio to provide an integrated understanding of the biodiversity and geospatial impacts of shaded coffee in Apui. is a monitoring and evaluation assessment approach that integrates geospatial and biodiversity monitoring data, the results described will be subjected to revision once the TerraBio team has access to the complete set of data inputs required for analysis and inter

pretation. Please understand this The present document described the baseline information from which to compare to whcih to ras a first draft to provide insights on the performance and impacts of agroforestry systems onin biodiversity conservation through the expansionexpasion of activities by Amazonia Agroforestal.

Summary of Results

Table x. Area (in hectares) and percent of total area for each MSPA classification.

TerraBio Indicators	Result	Short Interpretation
Land Cover/Land Use Indicators		
1. Carbon Sequestration Emission Reductions	**287 tons carbon converted to plant biomass (1053.4 tons CO2 equivalent) from 2017 - 2021 within the farm boundary.**	**Between 2017 and 2021, approximately 287 tons of carbon were sequestered as plant biomass within the farm boundary.**
2. Regenerated/Reforested Area (ha) Within Intervention Sites	**1 ha**	**An estimated 1 ha of vegetation was gained within the Syntropic intervention site from 2017 to 2021. This estimation roughly corresponds to the assigned planted area in 2022 (1.1 ha).**
3. Conserved Forest Area (ha) within Farm Boundaries	**30.8 ha**	**Within the farm boundary, a total of 30.8 ha of forest classified area is being conserved. This includes the Forest Reference area and the Restoration site.**
4. Change in Patch Connectivity Function	**Forest Core: 1,204 ha Edge: 570 ha Branch: 35 ha Bridge: 211 ha Loop: 59 ha Island: 103 ha Perforation: 158 ha Core-opening: 8 ha Border-opening: 74 ha Background: 1507 ha**	**At baseline, the Syntropic system is not yet contributing to forest connectivity since it is at its early stages. As the system matures, part of the intervention may resemble a tree cover habitat, and may be detected as island or branch forest patch areas increasing the connectivity of the landscape.**
Biodiversity Indicators		
Effective Species Richness	SAF: 37 (n=5) Fallow: 68 (n=4) Pasture: 22 (n=3) Forest Reference: 84 (n=4)	Compared to pasture areas, coffee agroforestry systems (SAF) had a larger number of arthropod species, yet these were lower than those found in fallow plots and forest reference areas.
Paired-site Species Composition Comparison	Most similar: Pasture and SAF, Pasture and Fallow. Least similar: SAF and Forest, Forest and Fallow. Midway similarity: Pasture and Forest, SAF and Fallow.	The potential impact of Café Apuí's SAF system in conserving forest arthropod species is currently low. It is assumed that the species found in pastures are common throughout the landscape and found in other land cover/use systems.
Species Assemblage Across Sites	Forest sites were the most distinct from the other land use types. Pastures were the most similar to the other land use types.	The composition of species in Café Apuí's SAF system were most similar to the counterfactual pasture sites.This may be due to the fact that these two sites had the lowest number of species and that these species are common in the landscape.

TerraBio Application Results

Land Cover/Land Use Indicators

1. Carbon Sequestration - Emission Reductions

TerraBio estimates carbon sequestration through biomass accumulation rates based on land cover and forest age. TerraBio used satellite imagery to monitor vegetation gains and losses (biomass change) overtime. At Horta da Terra, carbon sequestration was estimated by measuring the change in vegetation, specifically plant biomass. Plant biomass was measured before and after 2021, when the implementation of the Syntropic system and restoration activities took place. Hence, for the carbon emission reduction indicator, 2017-2021 results are considered as the 5 year baseline value to compare with moving forward. The contributions to carbon emission reductions were estimated annually in metric tons (t) at the farm level and for the intervention sites (Table 2). A five year period between 2017 and 2021 was used to provide historical land cover/land use context.

At the farm level, Horta da Terra demonstrated a positive upward carbon sequestration trend across the five year time period (Fig. 6). In 2017 the full extent of the Horta da Terra farm was storing approximately 2,181 t of carbon as plant biomass. By 2021, the total amount of plant biomass increased to 2468 t of carbon, a difference of 287 t carbon. The annual average amount of carbon captured at Horta da Terra was around 71.8 t carbon reductions/year, and most of the biomass gain took place at the Restoration site (compared to the other highlighted areas). In the Syntropic system, there was a slight decline in vegetation from 2017 to 2020, and a slow gain from 2020 to 2021 associated with the implementation of the Syntropic system

Table 2. Historical (2017- 2021) and annual (2021) carbon emission reductions (and CO2 equivalent) at the farm and site level at Cafe Apui.

Land Cover/Land	Use 2017 Carbon (C) Totals	2021 Carbon (C) Totals	CO2 eq. eductions from 2017 - 2021	Units
Farm Level				tC (CO2 eq.)
Intervention: Agroforestry Systems (SAF)				tC (CO2 eq.)
Secondary Succession/Fallow Area				tC (CO2 eq.)
Forest Reference				tC (CO2 eq.)

Counterfactual Pasture				tC (CO2 eq.)

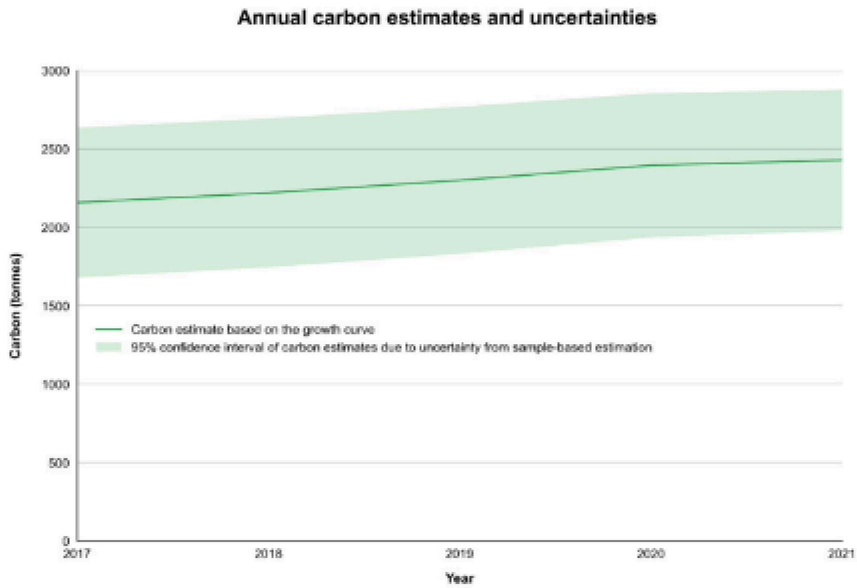

Fig 6. Metric tons of carbon stored as plant biomass in each land use system at the Horta de Terra farm between 2017 to 2021.

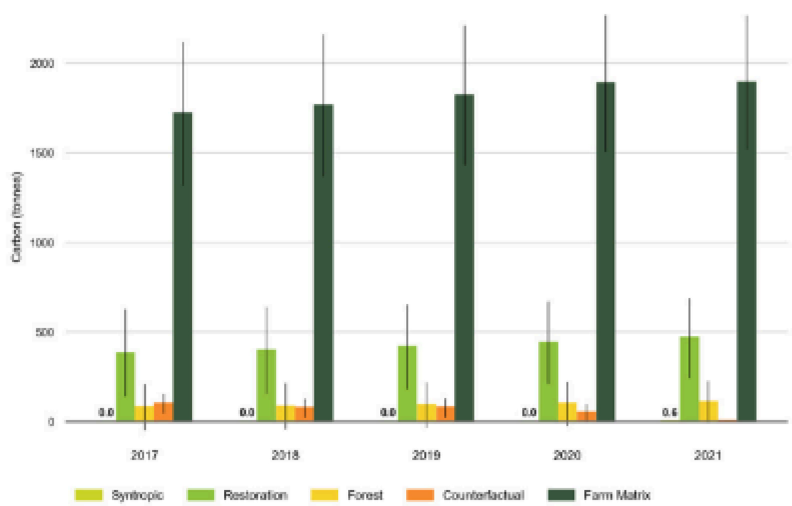

Fig 7. Estimates of carbon stored as plant biomass within Horta de Terra farm boundary between 2017 and 2021.

2. Regenerated/Reforested Area (ha) Within Intervention Sites

The implementation of sustainable activities in ABF funded projects are monitored by measuring areas showing improved biophysical conditions through increases in vegetation cover over time. TerraBio uses satellite images and remote sensing to compare gains in vegetation before and after implementation, and moving forward. At Horta da Terra, differences in vegetation were monitored at the syntropic system and the restoration area for a 5-year period between 2017 to 2021. This time period was chosen to serve as a historical baseline to compare with for the following years of TerraBio implementation. Areas of improved biophysical conditions are calculated as the number of hectares detected as vegetation cover gain within the intervention site(s).

At Horta da Terra, the results for improved biophysical condition indicate that 1.0 ha of vegetation was gained within the syntropic intervention site from 2017 to 2021 (Fig. 8). This estimation roughly corresponds to the assigned planted area (1.1 ha). An additional 1.8 ha of vegetation gain were detected within the open area where Horta plans to expand the syntropic system, and along the entrance to the property and surround the management facility. The metric of gain in vegetation cover represents improved biophysical condition, and is occuring in areas not managed for production. That shows a change in land cover from bare soil to grass/shrubs. As per the restoration area, no changes in land cover vegetation were mapped. However, through image interpretation of time series images at a selection of samples, we observed gains in vegetation density during the monitored period. This indicates that the restoration area had biophysical improvements over the monitoring period. A total of 18.7 ± 4.0 ha experienced vegetation gain within the farm boundary from 2017 to 2021 based on the image interpretation of time series images.

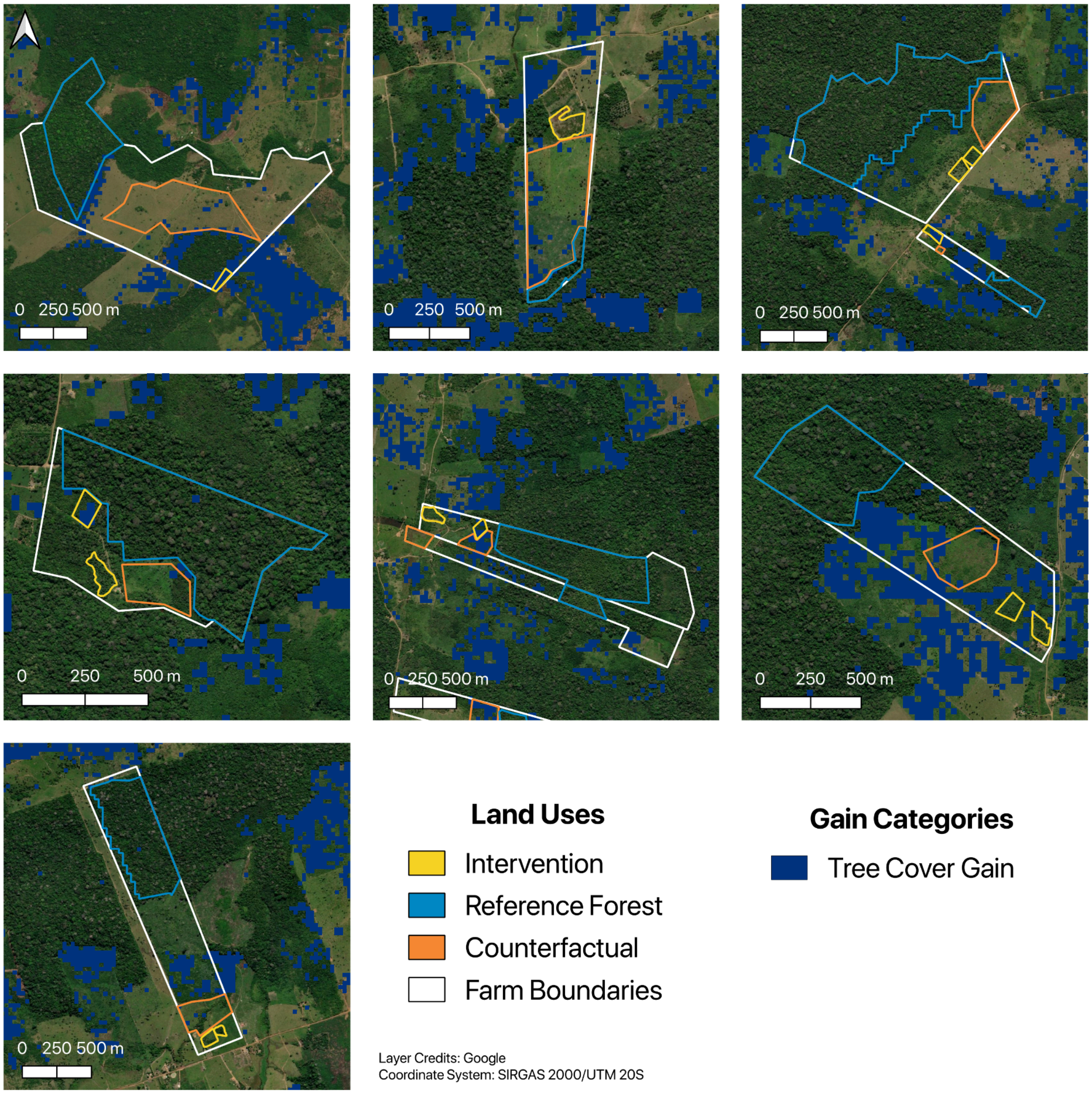

Fig. 9. Vegetation gain at the restoration site. Within the Horta da Terra restoration area (green boundary), it is possible to see bigger tree crows in the 2022 image compared to the 2017 image. However, since the canopy cover was already established in 2017, without clear land cover changes from the satellite perspective (e.g., bare soil to forest), the model did not detect vegetation gains within the restoration area. The red dashed line shows the location of the first two image frames within the Horta da Terra boundary.

3. Conserved Forest Area (ha) Within Farm Boundaries

TerraBio's landscape conservation indicator monitors forest land cover areas by estimating and subtracting forest disturbance. By forest disturbance TerraBio distinguishes between deforestation and degradation. Landscape conservation results at Horta da Terra indicate that 30.8 ± 2.7 hectares were conserved from 2017 to 2021 (74.5% - 88.8% of the farm area). Included in this area is the Forest Reference area and the Reforestation site, and represents the forest cover baseline values to monitor moving forward by TerraBio. Deforestation detected within the Horta da Terra property for this period was relatively small (0.2 ± 0.2 ha) and corresponds to a recent (2021) clearing event for the expansion of the Syntropic system, as well as forest loss that occurred at the south boundary of the farm. This may have been a spill over consequence of deforestation activities carried out by the neighbor in their property (Fig. 10). Degradation was also detected (1.3 ± 1.2 ha), and similarly, at the edge of recent clearings (Fig. 11). Overall forest cover disturbance from 2017 to 2021 was about 1.5 ± 1.3 ha (Fig. 12).

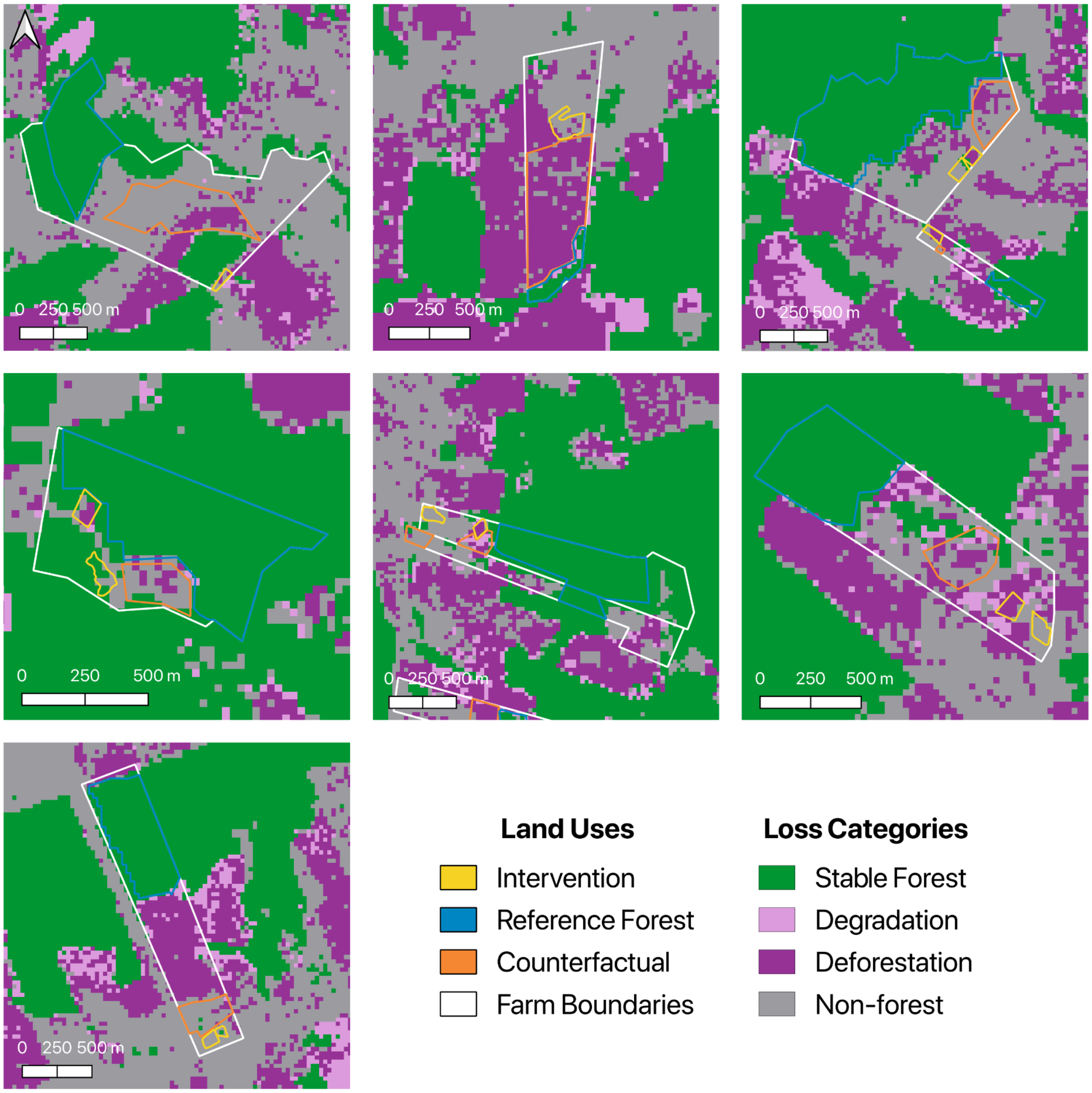

Fig. 10. Conserved forest areas at Horta da Terra based on land cover change from 2017 - 2021.

4. Change in Patch Connectivity Function

Habitat protection is measured in Café Apui by monitoring changes in spatial pattern following the implementation of ABF funded sustainable activities. The Morphological Spatial Pattern Analysis (MSPA) is used to monitor how the areas of interest (e.g. intervention sites) are improving landscape connectivity over time and in relation to their surrounding environment.

According the MSPA results displayed in figure 10, within the Café Apui farm boundaries, a total of 2,027.85 ha can be considered forest core (green), 61.14 ha are forest patches that branch out from the core (orange), 46.12 ha are forest islands (brown), 41.83 ha are forest bridges that connect other forest patches (red), 25.21 ha are forest loop that connect to the same forest patch, 110.80 ha are perforated areas inside forest patches, and 247.17 ha are considered forest edge areas to the foreground forest class. When considering non-forested areas, the sum of background, core opening, and border opening areas total 1,433.03 ha. Comprising 1327.36 ha, 26.05 ha, and 79.63 ha, respectively.

Currently, as baseline for the year 2022, the Syntropic intervention site (1.1 ha) is classified as background. The restoration intervention area along with the stable forest areas are for the most part considered core forest areas, with small perforations and core openings. Outside of the Horta da Terra farm, the entire Counterfactual area (1.8 ha) is classified as background.

Figure 10. MSPA results within the Café Apui boundaries. As input for MSPA, a forest/non- forest image was generated from a supervised classification. MSPA results are described in the legend above. In the MSPA analysis, the edge class is considered 1 pixel (i.e. 10 meters from the forest edge to the forest core).

The habitat protection results for Horta da Terra provide insights about the current potential for Horta's property to serve as habitat for wildlife. Of the total area (37.7 ha), 81% can be considered protected habitat, which complies with the Forest Code for Amazon-biome based properties. Yet, the implementation of the Syntropic intervention is currently not contributing to the percentage of habitat protected areas. Given the early stage of the system, the system resembles a conventional agricultural system rather than a forest. As the system matures, part of the intervention may resemble a tree cover habitat, and may be detected as island or branch forest patch areas increasing the connectivity of the landscape.

Class	Area (ha)	Percent of Total (%)
Background	1327.36	33.24
Core	2027.85	50.78
Branch	61.14	1.53
Perforation	110.80	2.77
Edge	247.17	6.19
Bridge	41.83	1.05
Loop	25.21	0.63
Island	46.12	1.16
Core Opening	26.05	0.65
Border Opening	79.63	1.99
Total	3927.4	100

Biodiversity Indicators

Effective Species Richness

Biodiversity monitoring was carried out using environmental DNA, which helps detect the number of species (effective species richness) present at a given site. As TerraBio's first application in Café Apuí, effective species richness measures will be used as baseline values to compare annually moving forward. According to the analysis, shaded coffee systems (SAF) had an average of 37 species for SAF (n = 5). Secondary succession/fallow areas had an average of 68 species (n = 4; Fig. 6). The conventional pasture sites had the lowest average effective species richness at 22 species (n = 3), while reference forest sites had the highest average at 84 species (n = 4).

The SAF sites assessed included recent and older implemented shaded coffee production systems (dates to be confirmed by Amazônia Agroflorestal). Regardless of the date of implementation, the design and composition of the agroforestry systems was characterized by having a mostly open canopy, and a limited number of shade and intercropping species. The ground at the SAF plots was however, covered with leaf litter protecting the plant's root system and maintaining soil moisture. In general, SAF sites had on average more species than the counterfactual pasture sites. These initial results may suggest that even in the early stages of the SAF systems, there is an increased number of Arthropod species present. However, in general the effective species richness of SAF systems remain significantly below the forest reference and fallow sites.

Secondary succession/fallow areas were characterized by having a greater number and density of plant species compared to the SAF systems. In some of the fallow areas assessed, the canopy was completely closed resembling a patchy forest area, while in others tall grasses and vines covered the majority of the site. These biophysical characteristics likely explain the increased number of effective species richness compared to the agroforestry system. Fallow periods are often used to allow previous agricultural areas to regenerate and restore lost soil properties and nutrients depleted during the production years. The TerraBio results in Café Apuí highlight the conservation value of fallow areas in providing habitat to a larger community of arthropods compared to agricultural areas.

The results for Cafe Apui in 2022 follow the expected pattern, with pasture at the lower end of species richness, followed by the early SAF systems, secondary succession/fallow areas, and forest reference areas. The present results provide the baseline to monitor changes in species presence and thus, use of these habitats in the future. As the forest overstory develops in SAF systems, we expect the effective species richness values in the shaded coffee system to increase and more closely resemble those in the secondary succession/fallow sites and forest areas.

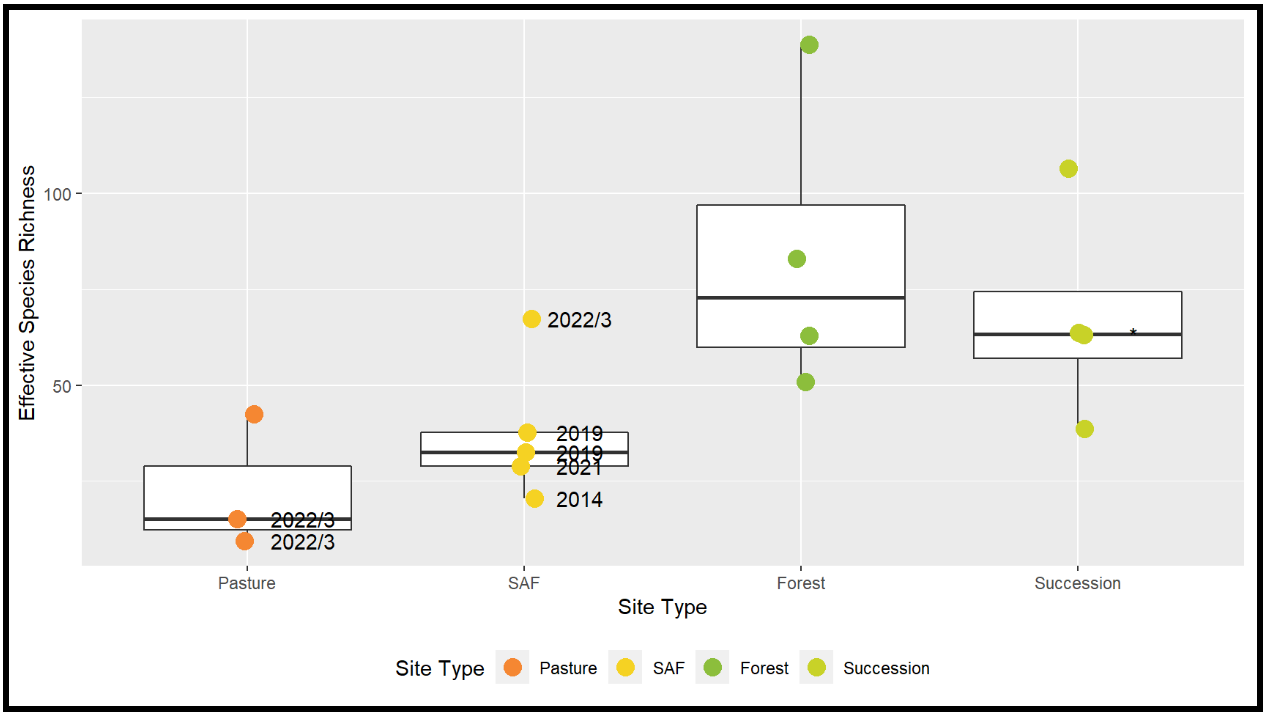

Figure 6. Effective species richness for each land use site type sampled at Cafe Apui. At each farm field, 1.5 liters of soil was collected in one bag and three replicates were taken from this bag. Each dot represents the pooled number of species detected across all three replicates for each farm field sampled. The years are based on information from Café Apuí, on which we are still waiting for confirmation.

Box X. Measuring Species Presence using Environmental DNA (eDNA) and Effective Species Richness

Effective species richness is a "true diversity" measure that represents the number of equally abundant (i.e. common) species for a site. Effective species richness allows for accurate comparisons between different sites and land uses.

The effective species richness values for Café Apuí should be interpreted as the number of equally-abundant arthropod groups (technically called Amplicon Sequence Variants (ASVs) which approximate species or sub-species) observed in each sample. They can be compared directly, where a sample with 60 effective species has twice the diversity as a sample with 30 effective species.

Paired-site Comparison of Species Composition

The goal of comparing the species composition between different land use types is to see how many species (or ASVs, in the case of eDNA) the sites have in common. Species composition is the specific group of arthropod species detected at each site. How many species are shared or different between pairs of sites provides insights into how ecologically similar these communities are. From a theoretical perspective, the more similar the habitat, including tree species and stand age, the more similar the community of arthropods detected should be. Ideally, the community of arthropods detected in an intervention area, such as the SAF system, should resemble the community of species detected in the forest environment. When these intervention systems are close to forest systems, we have strong evidence of the positive impact of sustainable productive systems on ecological communities, including through improved habitat availability.

At Cafe Apuí, a larger number of species shared between the SAF and the forest reference area, would indicate that more arthropods found in forest habitat are using the shaded coffee system plot areas as habitat to eat, rest, and mate. The Aitchison Distance plot (Fig. 7) is used to visualize how close or far apart the arthropod communities belonging to different sites are from one another. Lower distance values show that site pairs have more species in common, while higher values show that they have fewer species in common. In the chart below, land use pairs with similar species compositions would look yellowish, and land use pairs with different species compositions would look dark green.

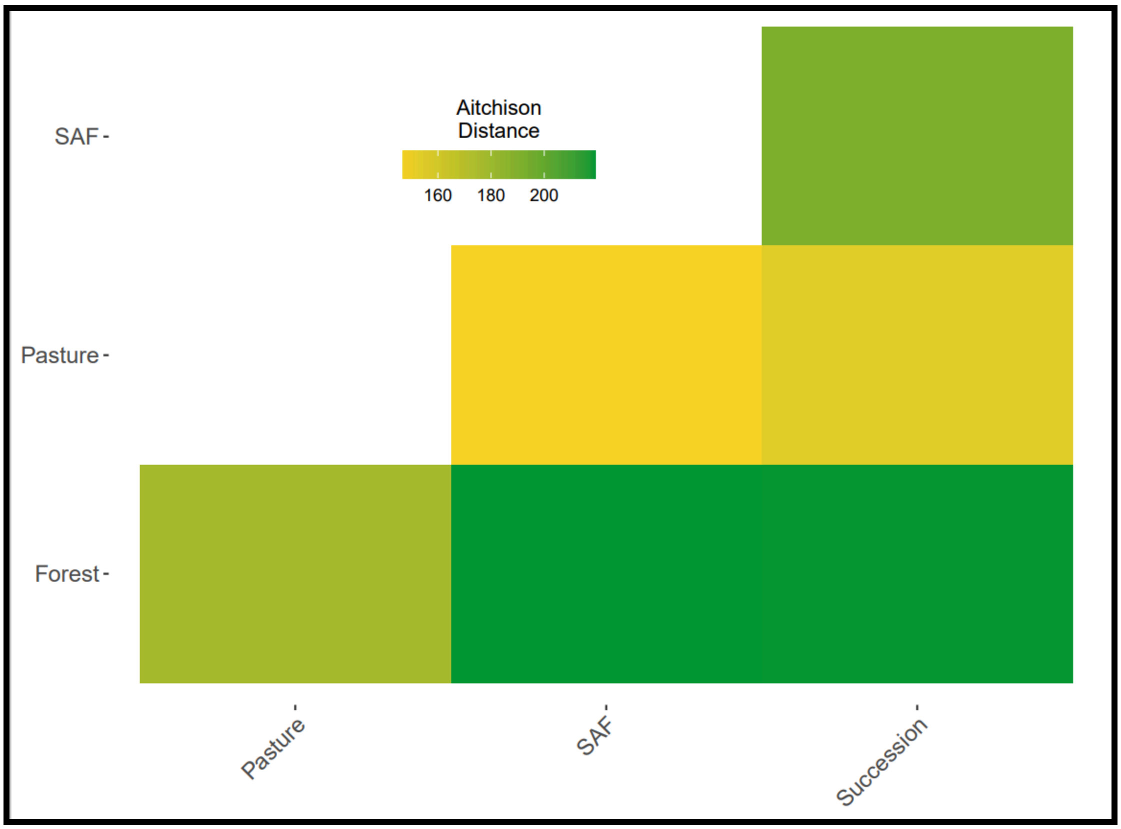

Figure 7. Aitchison distance between paired pooled land use types. Pairs with lower Aitchison distance values have arthropod communities that are more similar to one another (yellowish cells), while pairs with higher Aitchison distance values have arthropod communities that are less similar to one another (greener cells). Note that the pasture (n = 3) had fewer samples than the other groups (forest and secondary succession n = 4; SAF n = 5), however species accumulation curves indicated that this land use type was more fully sampled than Succession and SAF sites.

At Café Apuí, the pasture and SAF sites were closest to one another (lowest distance) in terms of species similarity. This was followed by the pasture and secondary succession/fallow comparison. The pasture and forest pair, along with the SAF and secondary succession/fallow pair, were in the middle. Furthest from one another (highest distance) were the forest and secondary succession/fallow pair, and the forest and SAF pair comparison. These results indicate that the species currently hosted by the SAF system may not be forest-dwelling species, thus reducing the potential biodiversity conservation impact desired by the project. However, as the Café Apuí SAF systems are established and mature, over time it is expected to see an increase in species composition similarity with secondary succession/fallow sites and the forest areas (Fig. 8). This will depend of course on multiple landscape-scale factors, including how quickly planted trees grow and provide habitat for arthropods, how quickly vertical vegetation structure develops, and how easily forest species can move from nearby forests to colonize SAF and secondary succession sites.

Figure 8: A member of the field team stands in front of a secondary succession/fallow site. The site is beginning to develop vertical vegetation stratification, with a growth of a defined canopy and under-canopy vegetation layers.

The paired comparison of the pasture sites with the other three land use types showed the most species similarities (lowest distance). This may be because the fewer species found in pastures are regionally common and generalist species also found throughout the landscape and in the other land use types. However, TerraBio does not make distinctions regarding the habitat preference of the community of species detected at a particular site. This type of information is species-specific and often lacking for arthropods in the Amazon. The TerraBio tool assumes that a species presence in a given location reflects its habitat preference, and is the reason for conducting paired-site comparison using forest areas as reference sites.

Box X: **Because Composition Matters: Pair-site Species Comparisons, AKA Beta Diversity**

Beta diversity is a measure of the turnover in species assemblages between pairs of different sites or land uses. In other words, it estimates the number of species that are different between the two sites. The larger the difference, the larger the Beta diversity value.

Aitchison distance is a measure of Beta diversity. It measures how similar or dissimilar two species communities are. For example, if two communities share most of the same species, then the two communities will be very similar (low Aitchison Distance value). If two communities have almost no species in common, they will be very dissimilar and have a high Aitchison Distance value.

Description of Species Assemblages

Visualizing the assemblage of species across sites helps understand how the different communities relate to one another. The species assemblage graphic can be interpreted simply. Sites with more similar species compositions will appear closer to one another than sites with less similar species compositions. We use ellipses for each land use site type to encapsulate the area of the plot included in a 95% confidence interval around the "average" community for that land use. When this ellipse is small, the species detected in each individual sample are similar (low within land use variability). However, when the ellipse is large, it means that the community in each individual sample was less similar (high within site variability). To increase the accuracy of these results, a larger number of samples is recommended to improve the detection of the arthropod species and thus community representative of that land use. The visualization of the communities in space complements the information provided by the paired-site comparison analysis.

At Café Apuí, the visual representation of the sites supports the results from the paired comparison. The counterfactual pasture sites, which are clustered in the middle of the species assemblage graphic (Fig. 9), are relatively close to the other three land cover/land uses. Coupled with the low effective species richness results, it is likely that the species found in pastures are common species occurring in the landscape. The forest reference sites are the most different, both from one another and from the other land cover/land use types. This can be observed by the position of the forest sites (green circles) in the lower quadrants and the large ellipse size representing the confidence interval. One of the secondary succession/fallow sites is found within the forest ellipse (upper left quadrant), suggesting that the arthropod community in this particular secondary succession/fallow site is more similar to those found in the forest reference areas. If secondary succession/fallow areas are not converted into other uses, over time it would be expected for these sites to become secondary forest areas and host a community of species characteristic of these habitats.

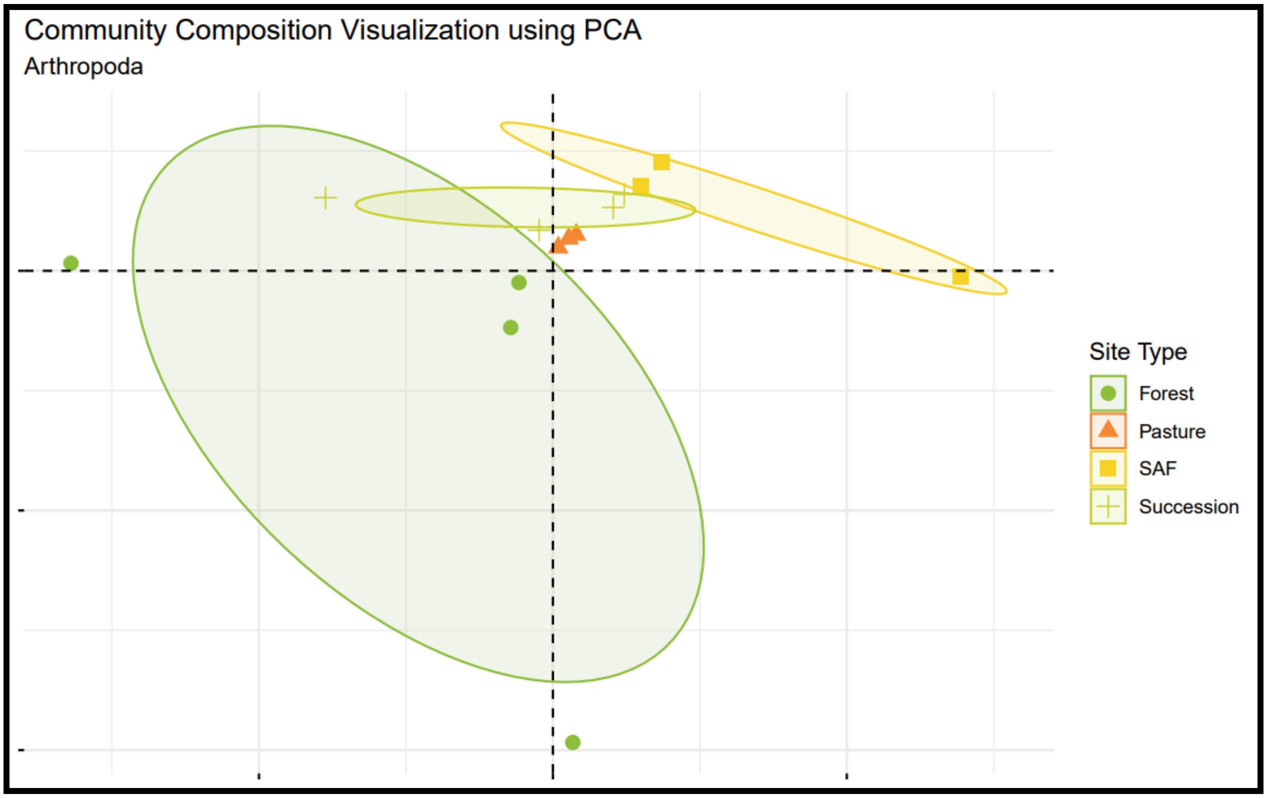

Figure 9. Visual representation of the arthropod community compositions at the four different land cover/use types. Each point represents one sample, consisting of three pooled replicates. Points that are closer together in the graphic have more similar community compositions than points that are further apart. The ellipses help visualize the part of the graphic occupied by samples from each land cover/ use type. The size of the ellipse represents how similar the replicates within a site type are.

Box X: **Visualizing Information using Principal Component Analysis**

Principal Component Analysis (PCA) is an ordination technique used to visualize information based on the level of relative similarity of samples or groups of samples. PCA translates datasets into an abstract two dimensional plot. Each axis represents an abstracted gradient along which the communities differ. TerraBio uses PCA to display the information contained in a distance matrix.

However, some caution should be used when interpreting this plot, as the axes are not as "strong" in describing the arthropod community as we might like.