# SOIL FRAMEWORK

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ecosystem
restoration
communities

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## WHAT IS NEW IN THIS VERSION?

We have updated the ERC Soil Framework to make it more user-friendly, robust, and effective in supporting land-based restoration projects through improved methodologies and practical guidance. Specifically, this version includes:

### Enhanced clarity and accuracy

Streamlined content for greater conciseness and corrected several typographical errors to improve readability and user experience.

### Expanded and more context-specific methodologies

Additional methods for measuring soil biological activity and assessing biodiversity, providing a more comprehensive toolkit for ecosystem restoration efforts around the world.

### New complementary field manual

Added a practical field manual to guide data collection activities, offering concise step-by-step instructions to support effective and efficient fieldwork.

## WHAT IS MONITORING AND EVALUATION?

Monitoring is the continuous collection of data within a fixed time period. For example, a standard time frame for monitoring is one year, with baseline data collected at the beginning of the year, before any of the project's activities have been implemented. Then a 'midline' monitoring exercise is done, where data is collected 12 and 36 months later. Finally, the '5-year' data is collected at the end of the monitoring cycle.

Evaluation is the analysis of the data collected over time. Once all of the data has been received, it is time to compare baseline data with midline and ultimately final (e.g. 5-year) data from each monitoring cycle. This process helps you to assess how ecosystems and people are changing for the better.

## WHY DO WE NEED TO MONITOR AND EVALUATE?

Monitoring and Evaluation (M&E) requires time and energy that otherwise might be allocated to help restoration activities on the ground. So, it is pertinent to ask why it is a wise and necessary investment of our resources. Out of many, three good reasons why M&E is worth investing stand out:

### Evidence of impact & transparency

This framework was designed to show ecological and social transformation taking place within and around ecosystem restoration projects. Once we have evidence of the impact of our work, we can share proven cases and stories with the world which will increase our legitimacy and credibility and increase our support base and income. Reporting on the progress of ecosystem restoration is key to engage policymakers, partners, landowners and donors.

### Validate your hypotheses

One of the aims of this guidance is to help you dive into your own guesses and the ecology of your specific site. Monitoring thus helps us to research specific hypotheses or conceptual models[1], and to understand how our restoration activities affect the ecosystems we are working with.

### Learning & Adaptive management

Good data supports the continuous improvement of on-the-ground work through adaptive management. Although most cases will be highly complex and require context-specific solutions, good practices can be learned from (and shared with) other places with similar traits and/or pressures.

## OUR HOLISTIC FRAMEWORK

We have created this framework with input from various members of our team, ERC partners, volunteers and key thinkers in the field of ecosystem restoration. Inspired in Satish Kumar's book[2], we designed a holistic framework based on three core components of ecosystem restoration: **Soil**, covering the ecological transformation happening on the ground; **Soul**, reflecting changes in people's attitudes and behaviour; **Society,** relating to the positive impact on human societies and economies linked to restoration initiatives

This document presents the '**Soil'** or ecological dimension of our framework, focusing on the community of living organisms in conjunction with their environment. Such biotic and abiotic components interact as ecosystems through nutrient cycles, energy flows and other feedback loops[3]. Tracking changes at the level of various ecological attributes helps to understand how these interact with one another, which is essential to promote life-enhancing relationships and become effective at ecosystem restoration.

[1]You can find more information about 'conceptual models' in the glossary of key concepts

[2] Kumar, S. (2013). *Soil, soul, society: a new trinity for our time*. Lewes: Leaping Hare Press.

[3] For more information, please consult 'feedback loops' in glossary

## SUMMARY

| Outcomes | Indicators | Methods | When |
|---|---|---|---|
| Improved soil texture | Soil texture | Soil Jar Test | n/a |
| Improved soil structure/consistency | Soil structure score<br><br>Aggregate stability score | Drop & Shatter<br><br>Soil Slaking Test | n/a |
| Increase in topsoil | Depth of topsoil | Soil Profile | Spring |
| Increased soil decomposition rate | Weight of buried teabags | Tea Composition Test | n/a |
| Decreased levels of soil erosion | Soil sediment levels | Soil Accumulation Test | Spring |
| Decreased levels of soil compaction | PSI levels<br><br>Bulk density | Penetrometer Test<br><br>Bulk Density Test | Spring |
| Increased water availability | %WHC<br><br>Time for water to infiltrate | Water Holding Capacity Test<br><br>Water Infiltration Test | Spring |
| Improved soil pH | Soil pH | pH test | n/a |
| Improved biological activity in soil | Microbial fungi/bacteria<br><br>Soil biological activity | MicroBiometer<br><br>Earthworms/termites | Spring |
| Increase soil biodiversity | Soil fauna | DIY Tullgren Funnel | Spring |
| Increased biodiversity | Flora & Fauna diversity | Quadrat Survey<br><br>Plant Quadrat<br><br>Moth Trapping | Spring |
| Reduced temperature differentials | Temperature differentials | Data Loggers | n/a |
| Reduced evapotranspiration | Evapotranspiration rates | DIY Atmometers | Spring |
| Increased organic matter content | % Soil organic matter content | Loss on Ignition Lab test<br><br>Soil colour | Spring |
| Increased carbon in biomass | Carbon storage in biomass | NDVI/Satellite imagery | n/a |
| Improved ecosystem productivity | Ecosystem services | n/a | n/a |

*Table 1: Summary of impact outcomes, indicators, methodologies and respective timings as outlined in this Framework*

## BEFORE YOU BEGIN

Understanding and monitoring your ecosystem is crucial for effective restoration. Prior to data collection, familiarize yourself with the ecosystem and identify the issues your project aims to address, such as ecosystem pressures and degradation factors. Collecting baseline data, including a survey of undisturbed 'reference sites', is essential for setting restoration goals and informing the design process.

Develop a Restoration Design or Plan tailored to your site, detailing which areas and techniques will be monitored. Establish specific sampling plots (representing whole sites) to track the progress of your interventions and their effectiveness.

For instance, in areas showing low vegetation and soil erosion, baseline comparisons to healthier neighbouring areas can guide targeted restoration strategies. By repeatedly monitoring chosen plots over time, you'll assess if practices like soil amendments or holistic grazing are contributing to your restoration objectives.

Regardless of the project stage, historical data or control site comparisons are valuable. Always document your restoration approaches and plot them on a sitemap to enhance the significance of your monitoring efforts.

## STAGES OF RESTORATION

While "**Planning",** grow a comprehensive understanding of the ecosystem's condition and the social factors influencing the project area. It's essential to conduct a Baseline Inventory documenting the biotic and abiotic elements, causes of degradation, and potential for natural recovery (Gann et al. ,2019). This inventory shapes the project's vision, goals, and the Restoration Design or Plan, which outlines the interventions and monitoring actions to be undertaken.

*Figure 1: Adaptive Restoration Journey*

In the "**Doing**" phase, implement the planned restoration activities, with monitoring to track progress and capture any unexpected developments, ensuring that actions align with the goals.

To **"Review"** and reflect your work, an analyse the gathered data and assess the project's impact. Use insights for adaptive management to refine techniques and share successful practices with the restoration community, enhancing the collective knowledge and approach to ecosystem restoration.

# RESTORATION INDICATORS

Monitor the essential key impact indicators that reflect the core objectives of your restoration efforts. Tailor additional indicators to the specific goals of your project, considering available resources, to build a sustainable and long-term Monitoring & Evaluation (M&E) plan. Start with a manageable number of indicators and expand as needed.

### Key Impact Indicators

These indicators are central to showcasing the global impact of the ERC movement, capturing the progress and effectiveness of restoration initiatives across diverse ecosystems. Key indicators facilitate the aggregation and comparison of data globally, collective impact figures and knowledge sharing:

- Success rate after 1 year planting (perennial crops, shrubs and/or trees)
- Before & after pictures
- Area under restoration (hectares)
- Tree survival rate (% from logging tree counts, or using tree mapper)
- Biodiversity (flora AND/OR fauna, supported by anecdotal evidence)
- Soil organic matter & carbon content
- Soil compaction OR water infiltration

### Context-Specific Impact indicators

Each ecosystem's complexity calls for context-specific monitoring approaches. Select indicators that align with your project's unique goals and are feasible within your M&E constraints, including available time, effort, expertise, and technology. Focus on affordable and relevant metrics, especially when resources are limited.

Consider the availability and relevance of data: are the chosen indicators representative of desired restoration outcomes? An effective monitoring system captures progress toward outcomes[4].

# SAMPLING DESIGN

Ecologists and anyone working with statistics have long recognized the difficulty of surveying whole populations and ecosystems. Well-considered sampling designs are key to assessing changes in the elements and relationships that characterize the overall condition of an ecosystem. We want our samples to be representative of the areas we will be monitoring,

[4] For instance, measuring the concentration of certain elements in the soil may be crucial for a project aiming to remediate a contaminated site. Guidance on how to adapt indicators based on ecosystems is detailed in Chapter 3 of *The Road to Restoration* by Buckingham et al (2019).

analyse (compare and aggregate) data across multiple ecosystem restoration sites. Below we explain how to define monitoring plots and sampling points.

In our context, a Zone refers to a specific area that you hope to restore and monitor over time. Sampling points or plots are the exact locations we collect data from, selected to represent each of these zones. Sampling plots/points should therefore remain accessible throughout the process of ecosystem restoration.

## The process

If you are doing a baseline study, pick at least 10 sampling points across the site you hope to restore (upon which infrastructure will not be built). If you are already "doing" restoration, find below a list of important considerations for the definition of zones.

Generally, more sampling points means more significant results, but it also means more effort i.e. time and resources) are required. We advise starting with few zones (and sampling points) first, and gradually expanding to the whole project area.
If there are 10 zones, select the 5 most important ones, and define at least 2 sampling points in each. In subsequent years you can do the same for the other zones or increase the number of sampling points per monitoring area.

## Defining monitoring zones

Some factors should be considered when establishing what specific areas you will be monitoring. These will be site specific, but our recommendation is to define zones based on the following:

1) Different restoration approaches/treatments' (including control sites)
2) Reference sites (e.g. within largely undisturbed/conserved areas)
3) (Different landscape traits (e.g. soil type, altitude, moisture levels) to incorporate landscape effects in the definition of zones for monitoring)

## Defining sampling points (or just samples)

Sampling points should be representative of the zones and accessible over time. Generally, our advice is to focus on as many sampling points (per zone) as you can realistically keep track of (see also "Summary" section). In other words, the number of sampling points selected depends on the capacity for monitoring. When defining sampling points, mark these physically (using sticks and labels) and digitally by recording their geocoordinates and depicting them in the digital polygons/map of the project site.

## TIMING AND FREQUENCY

The recovery from a degraded condition to a restored condition is a long-term process. So we may ask, when - and how often - should we collect data?

Adopting consistent **timing** is key to ensure harmonization, enabling aggregation and comparison of data over time and across sites.

We advise to collect ecological data in Spring when seeds and animals come out of winter dormancy and begin their reproductive and nesting activities. In rainy season-driven, non-temperate ecosystems with a less obvious spring, we suggest monitoring during or at the end of rainy seasons.

- DC period 1 (N. Hemisphere & S. tropical region): April/May
- DC period 2 (S. Hemisphere & N. tropical region): October/November

Baseline data represents a 'starting point' or background against which change can be measured in time. If ecosystem restoration activities are already being implemented, then baseline data can be collected from a site resembling how the restoration area was being managed before the restoration work began. In other words, we advise collecting data from "baseline sites" to represent pre-restoration conditions (see also 3) in 'Sampling Design').

In terms of **data collection frequency,** it is up to you how regularly you conduct these tests, but we recommend that it happens at least 3 times (e.g. y0, y1 and y5) within the first restoration cycle of 5 years. The appropriate frequency also depends on (a) the specific indicators (some ecological attributes have a faster rate of change, while others vary slowly) and (b) the natural conditions of an ecosystem (e.g. seasonal and weather patterns). (Generally, change occurs faster in warm/moist tropical ecosystems than in more temperate or boreal regions).

We recommend restoration projects use M&E data and reports from the first 5 years, to reassess/update their vision, evaluate project goals, and adapt management accordingly. Depending on the degree of recovery achieved and the resources secured for M&E, we advise extending monitoring efforts over the longer term (e.g. collecting data every 3 or 5 years, for 15 years).

### Sequence of monitoring activities

Planning the sequence of monitoring activities (prior to collecting data on the ground) contributes to more efficient allocation of monitoring resources. This is helpful as some methods involve similar steps (e.g. digging for the "Soil structure & aggregate stability" tests, and for the "Earthworms test"). Below is a sequence (proposed by former ERC volunteers) for conducting the tests at the different sampling points:

*Drop & Shatter - Jar - Topsoil - Earthworm - Slaking - Soil Organic Matter – pH...*

## DOCUMENTATION & COMMUNICATION OF RESULTS

Accurate and detailed documentation is crucial for understanding and communicating the impacts of restoration activities, while promoting interoperability with other systems. To ensure your data is comprehensive/useful:

1. *Capture geo-coordinates and specifics*

Document geo-coordinates and environmental details at each sampling site using the ERC template record sheet, ERC data collection app, or digital tools. Note all significant observations in the field to capture real-time conditions and anomalies.

2. *Entry and transfer of data*

Transfer data from any physical records to the digital format as swiftly as possible. This ensures your findings are recorded in the shared open database while they're still fresh, securing data quality and continuity of monitoring efforts.

3. *Evaluate and reporting*

After data collection, evaluate to discern trends and inform your plans/strategy. Write a baseline report detailing initial conditions and restoration targets. Subsequently, compare fresh data with this baseline to assess the effectiveness of the restoration actions. Through collaboration, produce and share detailed reports with the broader restoration community and stakeholders at each cycle's end.

## SETTING THE CONTEXT FOR RESTORATION

This section highlights key elements to map out the eco-social context of restoration projects. Our advice is to document these as part of a baseline inventory and/or restoration plan, which can be shared with relevant stakeholders and through the project's communication channels.

### Before and after photos

One of the easiest and most appealing ways to demonstrate changes in ecosystems is to take before and after photos of the areas undergoing restoration. The best before and after images are taken with drones. If you do not have access to a drone[5], use the 'Fixed Point Photography Method' described below, where you take photographs of the site from the same point(s) over time.

Method:

1. Mark out specific points on your zone(s) with labelled sticks or flags. (If possible, mark as well the height at which you will take a photo with your smartphone camera)
2. From those points, take a photo of the zone(s) OR if you have a drone, use the marker as a reference as you take aerial photo(s)
3. Keep the markers in place and take again a photo from the same location(s) and angle one year later.

[5] *You can reach out to hello@erc.earth for affordable drone imagery of your site(s).*

4. Store these photographs in ERC's database (and digital cloud/drive folder) and send them to hello@erc.earth

### Extent of restoration

Given that gains from ecosystem restoration are highest at large scale, the extent of restoration is an important element of ecosystem restoration. (Note that ERC welcomes and supports projects of any size).

#### Method

1. Draw polygon(s) of the area undergoing restoration (within your own restoration site or beyond-the-fence where you contribute to the restoration of other sites), and the potential restoration area (that is, area where you know restoration might happen even if no formal plans or property agreements exist; for example, think of neighbouring public or private lands you think may be allocated to restoration in a collaborative effort to establish wildlife corridors, replicate what you are doing at your site, or perhaps where you may be doing restoration consultancy work).
2. Some platforms (e.g. Restor, MyMaps) may auto-generate the extent or area (m2 or ha) you are interested in analysing.
3. Record the extent of the area undergoing restoration and the potential restoration area (m2 or ha) and the date.

### Habitat connectivity

In ecosystem restoration, natural recovery processes play an important role and should be facilitated. Often, recovery processes and ecosystem resilience depend on habitat connectivity (e.g. for seed dispersal, providing shelter for fauna, etc.).

#### Method

1. Identify and describe the particular type(s) of habitat you wish to see recovering in/around your restoration site(s) (this may include complex agroforestry systems based on principles of ecological succession and whereby future human intervention is minimized; it should not include agricultural areas, human settlements, where human intervention is high.)
2. Using regional maps and/or satellite imagery, measure distance between patches of the particular habitat within the project area and/or between the project and broader landscape or aquatic environment
3. Calculate and record the average distance between habitat patches

## Land cover change

Effective ecosystem restoration goes hand in hand with an understanding of pressures on ecosystem function and associated biodiversity. As detrimental changes in land cover contribute to terrestrial ecosystem degradation and biodiversity loss, tracking land cover is of crucial importance. It helps you understand what preceded your interventions as well as what the trends are in the landscape surrounding you.

### Method

Land cover detection is a complex process that involves sensing reflectance of different wavelengths of the electromagnetic spectrum with satellite-mounted sensors, which in turn need 'trained' algorithms and ground data for calibration. Today, open-source satellite imagery (e.g. from satellites like Sentinel II) makes it easy to do a quick assessment of land cover change. Some platforms may autogenerate the land cover classes of the area you wish to monitor. Typically, free satellite imagery has a spatial resolution ranging between 10m-60m (pixels equal to or larger than 100m2). Depending on this resolution, you may be able to identify the specific pre-degradation or pre- pre-restoration land cover classes of the area(s) you are interested in. Through satellite imagery from different points in time, you can see changes in the extent of these land cover classes. Considering the polygons of your restoration site(s), record changes in land cover classes (% increase/decrease) yearly on your record sheet.

**Free digital tools and platforms** to help monitoring land cover change:

- https://restor.eco/
- https://openlandmap.org/
- http://earthmonitor.org/
- www.globalforestwatch.org/map/
- http://maps.elie.ucl.ac.be/CCI/viewer/index.php
- http://earthenginepartners.appspot.com/science-2013-global-forest
- https://www.oneearth.org/navigator/

# SOIL HEALTH

## Indicator 1: Soil texture

As with most physical attributes of soils, soil texture is more of an informative indicator rather than something we want to change. Of course, this too can be monitored over time if we aim to effect change in terms of soil texture, but we need to be aware of the (slow) expected rate of change.

### Means of Verification: Soil Jar Test[6]

#### Why

The soil jar test establishes the proportion of clay, silt and sand of your soils, which is key to understanding the retention of water and nutrients in your soils. For example, clay-rich soils tend to hold water and nutrients well, but are also more susceptible to compaction and waterlogging under wet conditions, or 'baking' in dry conditions. Sandy soils usually have a more stable structure and usually do not retain water and nutrients very well.

#### Results

Sandy soils contain large particles or grains and allow for easy root development/penetration, but they do not hold water/nutrients for long.

Silty soils contain medium sized particles and hold water, nutrients and roots well. However, silty soils are easily washed away through surface runoff and/or could become compacted.

Clay soils have very small particles – platelets - with a high surface area-mass ratio, which means that clay soils can hold water and nutrients very well, perhaps too well sometimes... Too well, because they may form 'hard pans' when dry and/or become heavily compacted when wet, which makes for difficult penetration by roots and even garden tools.

Often described as the 'best garden soils', loamy soils are made up of a mix of 30-50% sand, 30-50% silt and 20-30% clay, with 5 to 10% organic matter.[7]

#### Materials needed

- Glass jar
- Timer
- Water
- Ruler/tape measure
- Fine-tip marker

#### Method

1. Mark your glass jar(s) at the halfway point of the total volume, and then split it each half further in two (you should end up 4 marks at ¼, ½, ¾ and 4/4 of the jar's capacity)

[6] Adapted from the *The Permaculture Research Soil Test Handbook*

[7] As described in "Teaming with Microbes: The Organic Gardener's Guide to the Soil Food Web" by Lowenfels & Lewis (2010)

2. Remove a vertical slice of soil approx. 30 cm deep from each sampling spot
3. Remove any large rocks or organic matter, then break up all the lumps
4. Fill half of the jar(s) with soil
5. Using your fingers, press the soil down as much as possible to reduce the pore space and the level of soil on the side of the jar with a pen
6. Fill the jar(s) to the ¾ mark with water and shake vigorously for 3 minutes until soil is suspended in water
7. Set down the jar(s) on a level surface where it/they can be left undisturbed for at least a day and **start the timer**
8. After 1 minute mark on the side of the jar the level of settled particles at the bottom – this is the volume of sand in the sample(s)
9. After 2 hours mark on the side of the jar the level of settled particles – this is the volume of silt in the sample(s)
10. After the water has cleared (this may take longer than 24 hours) mark on the side of the jar the level of particles – this is the volume of clay in the sample(s)
11. Using a ruler/tape measure, use the distances on the jar to calculate relative proportions of sand, silt and clay in soil sample(s)
12. Using the soil texture triangle below, determine the type(s) of soil you are working with

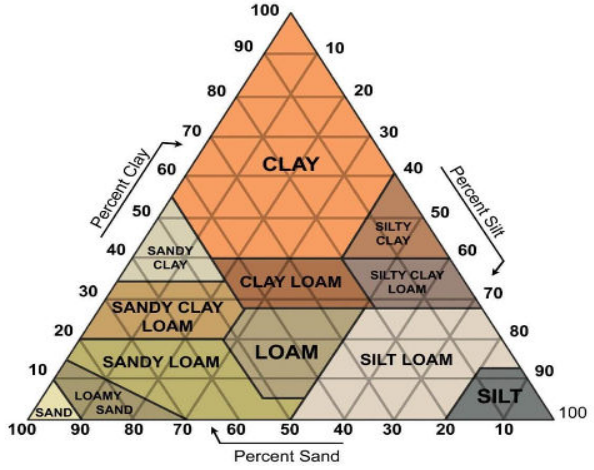



*Figure 2: Triangle to classify soil by texture*

13. Record your results

## Indicator 2: Soil structure and aggregate stability

As a physical indicator, soil structure and aggregate stability tend to be correlated with the ability of a soil to provide water and air for roots and soil biota.

### Means of Verification (1): Drop and Shatter[8]

#### Why

Soil structure regulates soil aeration and gaseous exchange rates, movement and storage of water, soil temperature, root penetration and development, nutrient cycling and resistance to structural degradation and erosion. It is a vital factor for seed germination and emergence, biomass productivity and quality.

#### Results

Good structure means that plant roots can explore a larger volume of soil, nutrients and water. On the contrary, bad structure increases the likelihood of waterlogging, surface runoff/erosion and drainage issues, thereby limiting the amount of nutrients and water available for plant growth and other (micro)life-forms.

Usually, you can improve soil structure by incorporating organic matter in your soils. If you are dealing with a 'shallow pan', planting root crops like potatoes may help. For deeper compaction issues, you could consider not doing anything or tilling once to loosen up the soil and subsequently adopting soil conservation practices, adding organic matter, etc.

#### Materials needed

- Firm container (can be a bucket/plastic box)
- Garden spade
- Large transparent plastic bag

#### Method

1. At each sampling point, first remove the 0-5 cm topsoil containing the dense root systems, without disturbing the soil underneath
2. Remove a 20x20x20cm cube of topsoil with the spade
3. Drop the soil sample a maximum of three times from a height of one metre (waist height) onto the firm base of your container.
    - If large clods break away after the first or second drop, drop them individually again once or twice.
    - If a clod shatters into small units after the first or second drop, it does not need dropping again.
4. Part each clod by hand along any exposed fracture planes or fissures.
5. Transfer soil onto large plastic bag or wheelbarrow

[8] *Adapted from http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HDED9M9K7GFQ02*

6. Move the coarsest parts to one end and the finest to the other end to obtain a measure of the aggregate-size distribution. Compare your distribution of aggregates with the three photographs below.

2 = GOOD 1 = MODERATE 0 = POOR

*- Good condition (2): Good distribution of finer aggregates with no significant clodding.*
*- Moderate condition (1): Soil contains significant proportions of both coarse firm clods and friable, fine aggregates.*
*- Poor condition (0): Soil dominated by extremely coarse, very firm clods with very few finer aggregate*

Means of Verification (2): Soil Slaking Test[9]
*Note: the slaking test is not very effective in soils with a high content of clay.*

Why
Slaking is a simple test that says something about the stability of soil aggregates, resistance to erosion and/or susceptibility to waterlogging issues. Slaking happens when large, air-dry soil aggregates (>3-5 mm) break down into smaller micro aggro aggregates (< 0,25mm) when suddenly immersed in water)

Results
Generally, soils with high SOM do not readily slake (fall apart) when wetted. In other words, the more organic matter – a component that holds the particles together in soils - the slower the soil breaks up. You should aim for a score of 1 for each of your zones.

[9] *Adapted from https://www.isqaper-is.eu/soil-quality/visual-soil-assessment/73-soil-slaking-test-soil-stability ; http://soilquality.org/indicators/slaking.html*

### Materials needed

- Sheet of 1cm mesh
- Glass bottles/jars (one for each zone you will be surveying)
- Water

### Method

1. Fill the jar(s) with water
2. 'Hang' a piece of the mesh inside-/at the top of each jar (to prevent the soil sinking to the bottom directly)
3. Take an air-dry soil aggregate (4-6 cm diameter) from each zone (if you have conducted the visual inspection test, select three pea-sized lumps of soil from each soil slice/zone)
4. Place different soil fragments in different meshes/jars
5. Observe soil fragment for 10 minutes
6. Give a score for each zone:

*1 = Complete slaking/poor condition (aggregate breaks down completely into sand grains)*
*2 = Partial slaking/moderate condition (aggregate breaks but some remain intact on top)*
*3 = No slaking/good condition (no change, water is clean)*

## Indicator 3: Topsoil

### Means of Verification: Depth of Topsoil

### Why

Sustaining multiple plant and animal species in complex trophic cascades, fertile soils form the basis of biodiverse and resilient ecosystems. Measuring the thickness of the litter- and topsoil (or organic matter) layers tells you whether your soil is being nurtured or negatively affected by certain interventions[10].

### Results

By subtracting previous* topsoil measurement from your own measurements, you are able to assess whether certain interventions are helping to grow (if the value is positive) or lose topsoil (if negative). Evidently, the magnitude of the value says something about the rate at which topsoil is growing or disappearing.

*from baseline or last year's study

[10] *If you'd like to analyze your soil in more detail, check out the resources below: http://www.fao.org/tempref/FI/CDrom/FAO_Training/FAO_Training/General/x6706e/x6706e02.htm; http://www.sciencepartners.info/smsp/module03/FieldProtocolSoils.pdf; https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054308; https://doityourselfforestryblog.wordpress.com/2016/05/27/what-are-the-different-soil-horizons/*

### Materials needed

- Shovel
- Tape measure

### Method

1. At each sampling point, dig a hole at least 50cm deep if possible (or until soil changes colour, from darker tones where roots thrive to lighter subsoil with little/no root mass)
2. If you cannot easily reach this depth, make a note in datasheet
3. Measure thickness of topsoil layer (cm) in each of the holes, from the surface until the edge with subsoil
4. Calculate the average topsoil depth for each zone
5. Record these values (in cm) in the record sheet and which of the bands it falls into: very shallow (VS) = <15 cm; shallow (S) = 15-30cm; moderately deep (MD) = 30-50cm; deep (D) = > 50cm)
6. Repeat the process every year (avoid digging where soil was moved before)

## Indicator 4: Teabag decomposition rate

**Means of Verification: 'TeaComposition'**[11]

*Note: contact hello@erc.earth if you would like to request teabags for this test*

### Why

Assessing how 'litter' decomposes in soils is a common method used to analyse the soil function such as decomposition of organic matter and nutrient cycling. The 'TeaComposition test' is a simple, cheap and standardized method that uses commercially available (green and rooibos) tea bags as pre-made "litterbags". Ideally, this test is done at the start of June at sites located in the Northern Hemisphere, or in November/December for sites in the Southern Hemisphere. The remaining weight of teabags is measured in 4 different moments - 3 months after burial, and then 1, 2 and 3 years after burial.

### Results

With this method, we are able to calculate the % of tea that is decomposed in each zone. The decomposition rate says something about the biology and nutrient cycling of your soil. Besides carbon inputs from vegetation, decomposition rates are critical to forecast whether soils will lose or gain carbon in a changing climate. If collected systematically, your data can contribute to the global database and research on soil 'tea composition'.

### Materials needed

- 8 Sticks/metal poles per zone
- 16x Lipton Green tea bags (EAN no.: 8 722700 188438) per zone
- 16x Lipton Rooibos tea bags (EAN no.: 8 722700 188438) per zone

[11] *Source: www.teacomposition.org/wp-content/uploads/2019/05/TeaComposition-protocol_GLORIA_final.pdf ; For more background information on the TeaComposition Initiative visit: www.teacomposition.org*

- Water-proof pen to label tea bags
- Zip lock bags, Tupperware or any other water-proof recipient(s) with lid
- Weighing scales
- Little spade
- Tape measure

Method

1. Select two representative sampling areas of at least 1m2, with gentle slope (avoiding very steep/flat sites along slope) within each zone
2. Physically mark these areas (e.g. w/ metal rods) so you can find them easily
3. Label tea bags with a unique identifier code that represents the number of the tea bags (1-16), the type of tea, the zones you are studying and the sampling area you are studying (i.e. 1 or 2); for example: 2GRCOM1 = second green tea bag buried in 'area treated with compost' in sampling area 1.
4. Record weight of all tea bags before burial (preferably on 4 decimal places), as well as one empty tea bag
5. Place tea bags in Ziplock bag or (Tupperware) box until burial
6. Note the starting date of incubation/tea burial
7. Using string and long nails, mark 4 lines in each sampling area (each 40-cm long, with 10 cm between lines)
8. Gently dig 4 slots (approx. every 10 cm, at least 5cm deep) along each line, creating a pocket for the tea bags
9. In each line, bury 2 green + 2 rooibos tea bags roughly 5cm deep or in mineral soil layer making sure the identifier codes on the tags are visible on the surface
10. Plan the retrieval dates or sampling points in your calendar (3, 12, 24 and 36 months after burial)

Retrieval of tea bags:

11. Collect 2 bags of Green tea and 2 bags of Rooibos tea (avoiding pulling the rope and lift the soil to retrieve tea bags instead)
12. This leads to one incubation line/4 bags of Green & Rooibos tea retrieved
13. Clean tea bags from roots, soil etc (careful not to damage the bag/lose any tea!) and note if bag was damaged or found at surface
14. Place every tea bag in zip lock bag/box, checking the label (if missing, reconstruct based on previous/following bag number in the line)
15. Dry tea bags at 70° C for 48 hours, then record the weight of dry tea bags
16. Record the results & repeat procedure after 12, 24 and 36 months.

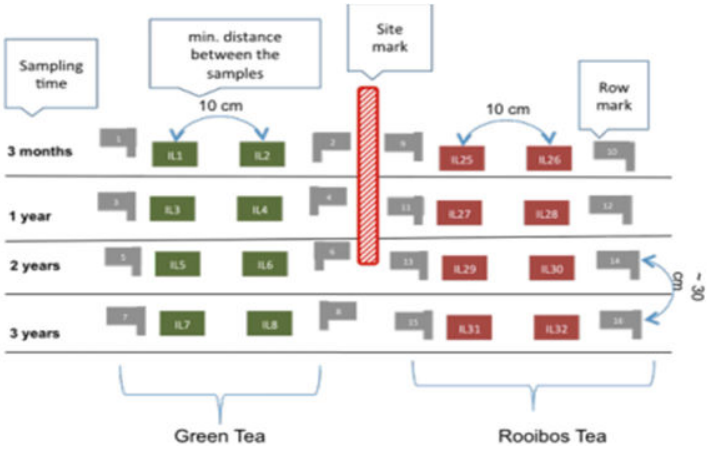


Figure 3: Sampling design of TeaComposition

## Indicator 5: Soil sediment levels

Means of Verification: Soil Accumulation Test

### Why

Modern industrial land use is a major cause of soil erosion. When the soil is de-vegetated, the fertile topsoil becomes loose and can easily be blown away by the wind or washed away by the rain. By reversing this trend, soil is built and not lost.

### Results

Taking the average height difference amongst your zone-specific spots and multiplying that by the area size of your plot, gives you an estimated value for the amount of soil that was accumulated (or lost) at your land (expressed as a unit of volume). You can then estimate such values for all the areas you want to survey and record the yearly average of soil accumulation in each zone.

### Materials needed

- 1 metre threaded rods (picked up from your local hardware store)
- (Spray) paint

### Method

1. At each sampling point, push your pole halfway into the ground (so if the poll is 1 meter, push it into the ground 50cm deep), so that it's in there securely and won't move around on its own; record the geocoordinates
2. Spray/paint the level at which the pole goes into the ground
3. Return to the poles one year later and mark the current soil level

## Indicator 6: Soil compaction

### Why

Soil compaction restricts the ability of plants to grow as their roots struggle to penetrate into the ground, and water and oxygen struggles to reach them. Measuring the compaction of your soil will allow you to ascertain whether what you plant will be able to survive, or whether more decompaction needs to be done. Soil compaction is typically associated with the removal of vegetation from the land and the use of (heavy) machinery on land.

Means of Verification: We suggest 2 alternative methods to measure soil compaction. The easiest one is the so-called **(a) Penetrometer test**, but if you do not have a penetrometer run the alternative **(b) Bulk density test** (for which you will need a microwave oven).

### (a) Penetrometer Test

**Materials needed:** penetrometer

### Method

1. At each sampling point, push down the penetrometer until it reads above 300 psi
2. Record the depth (at >300 psi) as the "top level" of your compaction layer
3. Decrease the pressure but continue pressing down into the penetrometer until psi values below 300 psi are found
4. Record the second depth/level (at <300psi) (i.e. bottom of "compaction layer)
5. Repeat this several times within each zone/monitoring unit

### Results

For each zone you are studying, if the penetrometer resistance

- never exceeds 300 psi, there is no significant compaction constraining root systems
- exceeds 300 psi but never falls below 300 psi, this indicates a deep compaction layer, which will likely be problematic for root systems and may require subsoiling activities

| % sampling points whereby >300 psi in top 40 cm | compaction rating | subsoil recommended |
|---|---|---|
| <30 | Little to none | No |
| 30–50 | Slight | No |
| 50–75 | Moderate | Yes |
| >75 | Severe | Yes |

(b) Bulk Density Test (and soil moisture content)

Materials needed

- Garden trowel
- Flat bladed knife
- Sealable bag & marker
- Scale (0.01g precise)
- Sturdy tube/ring (or soil corer)
- Ruler or tape measure
- A hammer/mallet and wood block to drive in the ring
- Microwave oven

Method

1. Push the tube firmly into the soil (with a piece of wood/hammer) until it is ⅔ in
2. Measure the diameter of the ring and then half it to obtain the radius
3. To determine the exact depth that the tin has gone into the soil, measure the height from the top of the tin to the soil surface four times evenly spaced and record the average, subtract this from the total height of the tin
4. Record the values from steps 5 and 6 on the app/datasheet
5. Dig around- and remove ring with trowel underneath it, preventing loss of soil
6. Place entire sample in bag and label
7. Repeat this for each zone you wish to study
8. Record the weight of your wet soil sample(s) (subtract the bag or container that goes on top of the scale)
9. To dry, place the soil sample(s) in a microwave and for 2 or more 4-min cycles at full power. Open the microwave door for 1 min between cycles to allow venting. (To determine if the soil is dry, weigh the sample and record its weight after each 4-minute cycle. When the weight no longer changes, it is dry.)
10. Measure & record the weight of your dry soil sample
11. Obtain the bulk density using the app or datasheet (using the formulas below); you could also work out the water content and porosity of your soil!

Soil water content (g/g) = $\frac{weight\ of\ moist\ soil - weight\ of\ oven\ dry\ soil}{weight\ of\ oven\ dry\ soil}$

Soil bulk density (g/cm3) = $\frac{oven\ dry\ weight\ of\ soil\ (g)}{volume\ of\ soil\ (cm3)}$

Soil porosity (%) = $1 - (\frac{soil\ bulk\ density}{2{,}65})$

**Results:** Following this protocol in a systematic fashion gives an indication of how loose or compact your soil is. Higher bulk density means that there is little porosity and thus high compaction.

## Indicator 7: Water percolation and retention

### Why

Healthy soils hold and infiltrate water, unhealthy soils don't. Soil moisture is the basis for photosynthesis and ecosystem functioning. WHC typically increases with organic matter and carbon content. Measure WHC before, during and after the restoration process to track changes.

If you cannot do the WHC test, the infiltration test indicates how easily water penetrates through the soil. The results can guide future soil management practices to promote water infiltration, reduce water loss and/or evaporation.

Means of Verification: This is the indicator that shows that there is more water being held in the soil than there was before restoration began. The **(a) Water Holding Capacity Tes**t is good if you have an oven that could be on for 24hrs and sensitive scale, but if you are looking for an easier/quicker means to assess the hydrology of your soil, do the **(b) Water infiltration** test.

### (a) Water Holding Capacity (WHC) Test

### Materials needed

- Coffee Filter
- Rubber Band
- Open can/cylinder (both ends removed)
- 50 grams oven dried soil samples (labelled accordingly - including zone, date)
- Kitchen/microwave oven that reaches 105° C

### Method:

1. Take a composite soil sample from each zone and label accordingly
2. Using the oven: Bake the soil in an oven at 105° C for 24 hours until the water has evaporated, let it cool
   Using the microwave: Place the soil sample(s) in a microwave for 2 or more 4-min cycles at full power. Open the microwave door for 1 min between cycles to allow venting. (To determine if the soil is dry, recording weight of the sample after each 4-minute cycle; it is dry if weight no longer changes
3. Place the filter paper on the end of the can with a rubber band.
4. Slightly moisten the filter paper on the end of the can and weigh; (record weight R)
5. Place the (105° C) oven-dried soil in the can and reweigh it. (again, record this weight, S)
6. Set the can (filter paper down) in water, so that the lower half is immersed
7. Leave it for 14-16 hours (or overnight).
8. After this time, remove from the water and transfer to a rack where it can drain for approximately 30 minutes.
9. Wipe surface of can dry, blot once (5 sec) and weigh (record "WS")

10. Calculate the water holding capacity (WHC) of the soil sample using the equation **WHC = 100 x (WS-S)/S**, whereby

    - WHC: Water holding capacity (mass of water retained by 100g of dried soil (mL))
    - S: Dry soil weight (g)
    - WS: Soil + water added (g)

### (b) Soil Water Infiltration test

*Note: if no water is available near your sampling sites, do this test after a rainy day*

#### Materials needed

- Hand sledge and wood block
- sturdy tube (e.g. from steel or pvc)
- Marker
- Plastic wrap
- 500 mL bottle
- Water
- Stopwatch or timer

#### Method

1. Free a 1x1 m area of soil from vegetation (if the soil isn't wet already, soak it slowly until saturated)
2. Drive the tube in the soil it is half-way in
3. Start the timer as you pour 500 mL water as gently as possible into the tin
4. Stop time when water is infiltrated (when surface is just glistening rather than submerged). If soil is uneven, count time until half of the surface is exposed and just shining.
5. Record time counts for each of the sample sites/management areas in datasheet

#### Results (WHC and infiltration test)

A small water holding capacity or long water infiltration could indicate the presence of a 'hardpan'/high soil compaction and/or a small percentage of soil organic matter. (In general, clay-rich and shallow soils drain more slowly than sandy, deep soils). This could also lead to increased risks of surface runoff with heavy rainfall events. We therefore gain a better understanding of the soil health as well as insight on which strategies to prioritise. Repeating the tests throughout the restoration process shows if restoration efforts are successful.

## Indicator 8: pH

Means of Verification: pH Colour Test (or probe)

This indicator can be tested by pH testing paper (litmus paper), which is cheap and easily available online, at pharmacies, high school chemistry etc.

### Why

Establishing the acidity/alkalinity of your soil leads to useful insights about your soil's needs and potential of growing healthy plants, vegetables or trees.

### Results

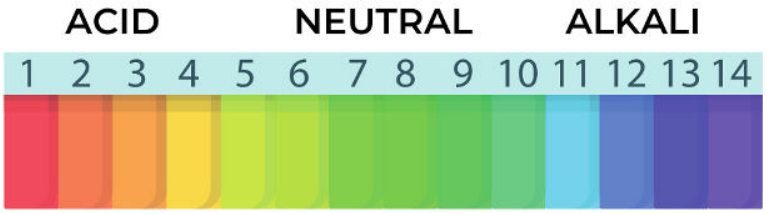
Most plants need a pH between 6 and 7/5 to grow well, but some actually prefer more acidic or alkaline soils. This should help you decide on what species to grow or what soil amendments you can use to feed your soil and influence its pH.

### Materials needed

- Bag or box to mix soil
- pH paper & chart
- Cup
- Water

### Method (colour strip)

1. Mix soil from at least 3 different spots in each zone/area of interest
2. Fill the cup with 2/3 soil and 1/3 water (such that the soil is covered)
3. Stir well for 1 minute
4. Completely immerse pH strip in soil solution for 3 seconds
5. Remove strip & rinse quickly (with same water as used for the solution)
6. Hold pH paper up to the light and compare colour to colour table below
7. Identify and record pH value in datasheet



## Indicator 9: Biological activity in soil

This is the indicator that reflects the biologic activity as an essential component of building soil, cycling nutrients and much more. For this indicator, we suggest focussing on earthworms for temperate ecosystems and termites for tropical ecosystems, respectively. If you are interested to understand the microbiological activity in your soil, we advise purchasing a microBiometer kit.

### Why

Monitoring soil biological activity with earthworms and termites is crucial because these organisms enhance soil structure, nutrient cycling, and fertility. Their presence indicates healthy, resilient soils that support plant growth and biodiversity. Assessing the activity of these biological proxies helps ensure restoration efforts are successfully rebuilding vital soil functions.

If you are in a temperate region, the **(a) earthworm count** is a proxy indicator for soil biological activity. These important creatures help with breakdown of organic residue and create channels that improve infiltration and aggregation (due to earthworm burrowing). If you are in a tropical region, then it is the **(b) termites** who doing decomposing and burrowing organic matter, serving as a useful indicator for soil biological activity. If you are in the subtropical region, you can choose the tests based on the most abundant organisms in your sites (or try out both if you don't know what you'll find!)

### Means of Verification (a) Earthworms (Temperate/subtropical region)

#### Materials needed

- 2 L tap water
- Hand trowel or shovel
- Large jar/container for worm collection & cleaning
- Mustard solution (2 tablespoons mustard powder in 2 liters of water)

#### Method

1. Measure 30x30 cm square plot (NOTE: avoid sampling where earthworm populations might be affected i.e. mulch or compost piles).
2. Dig down 30 cm with a hand trowel/shovel, minimizing damage to the earthworms...
3. Count number of earthworms (against pale-coloured background to help locate them)
4. Add mustard solution to the hole and wait for deep-burrowing earthworms to appear (usually within 5 mins).
5. Count the number of deep-burrowing earthworms and add to amount of 3 to obtain total # earthworms
6. Record yearly counts for each of the zones/sample sites in datasheet
7. Rinse earthworms in water and return them to the soil.

Means of verification (b) Termite Activity (Tropical/subtropical region)

Materials Needed

- Termite identification guide (simplified for volunteers)
- Camera or smartphone for photographing termite activity
- Protective gloves (optional)
- Data recording sheet or app

Method

1. Measure 30x30 cm square plot (NOTE: avoid sampling where termite populations might be affected i.e. mulch or compost piles).
2. Inspect each sampling point for signs of termite activity, such as termite mounds, mud tubes, foraging trails, or discarded wings.
3. Use a termite identification guide to distinguish termites from other insects
4. Record the number of active termite nests or structures within each 30x30 cm plot
5. Take photographs of significant termite activity for verification and further analysis.
6. Note the size, height, and condition of termite mounds, as well as the presence of foraging trails or other behaviours indicative of active colonies.
7. Enter all observations, including counts and mound characteristics, into your datasheet or app.

Results (Earthworms and termites)

A higher number of earthworms or active termite structures indicates robust ecological functions such as organic matter decomposition, soil aeration, and nutrient cycling, contributing to overall soil health and fertility.

## Indicator 10: Soil fauna

*Note: building a DIY Tullgren funnel may be time-consuming (and fun)*

Means of Verification: DIY Tullgren funnel[12]

Why

Soil ecosystems are home to different animals, mostly 'permanent residents' but also some 'temporary occupants'. Soil animals are engineers, active participants in the genesis of their own habitat. The species composition, diversity, quantity and function of soil animals shifts with different soil types. However, the main groups represented are roughly the same. Hopefully, this test will help you to study soil biodiversity and population density in an easy, inexpensive, fun and engaging way.

[12] *Adapted from https://www.isqaper-is.eu/soil-quality/visual-soil-assessment/225-soil-fauna*

Materials needed

- Zip lock backs for soil samples
- 1 funnel
- Sheet of 1-cm mesh (could be the same one as used for the soil slaking test)
- 1 jam jar/collecting vessel with slippery sides
- Moist tissue (to place at the bottom of the jar)
- Desk light (incandescent, one that produces heat)

Method

1. Label one bag for each zone you are going to study
2. Collect 1kg soil sample(s) (between 0-20cm depth) from the area(s) you wish to study and place in the respective bag(s)
3. Then, inside, place the mesh halfway through the funnel and place a moist tissue at the bottom of your jar/insect collecting vessel
4. Place the funnel with mesh above your jar/insect collecting vessel
5. Take a handful of your soil sample and place inside the funnel
6. Position the light so that it shines on the soil within the funnel

   *Over a period of 16-22 hours, insects, mites and other invertebrates present in the soil gradually work their way down away from the light and heat, falling into your vessel. Maximum extraction of soil microfauna can be recorded after a duration of 16 to 22 hours of continuous heating at temperature ranges between 35.1° C to 35.2° C (Bano and Roy, 2016).*

7. Record the number of organisms and classify them according to their size (see below)
8. Return the insects to their habitat
9. Repeat this procedure for each soil samples

Results

i. Microfauna: organisms whose body size is between 20-200 µm. Just one group, protozoa, is found wholly within this category; among the others, small mites, nematodes, rotifers, tardigrades and copepod crustaceans all fall within the upper limit.
ii. Mesofauna: organisms whose body size is between 200 µm-2 mm. Microarthropods such as mites and springtails, are the main representatives of this group, which also includes nematodes, rotifers, tardigrades, small araneidae, pseudoscorpions, opiliones, enchytraeids, insect larvae, small isopods and myriapods.
iii. Macrofauna: organisms whose size is between 2-20 mm. This category includes certain earthworms, gastropods, isopods, myriapods, some araneidae and the majority of insects.
iv. Megafauna: organisms whose size exceeds 20 mm. The members of this category include large size invertebrates (earthworms, snails, myriapods) and vertebrates (insectivores, small rodents, reptiles and amphibians).

# BIODIVERSITY

## Indicator 11: Biodiversity quadrats

### a) Flora & Fauna Survey

Why

Ecosystem restoration is a recipe for better habitats. Measuring changes in biodiversity within specific areas assesses ecological health, biodiversity trends, and gauges the impact of human activities. In addition, biodiversity monitoring supports conservation planning and scientific research, and engages communities in nature stewardship. All this is crucial at a time when many populations of wildlife are in swift decline. Wherever you are, please engage in observations with minimal disturbance to wildlife, preserving natural behaviours and conditions.

| Sampling Strategy | Description | Presence/Absence Data | Examples |
|---|---|---|---|
| Opportunistic | Observations made based on convenience or chance without a predetermined plan. Often relies on encountering species during regular activities or in easily accessible areas. | Primarily documents presence, with absence data being less reliable due to the unsystematic nature of the sampling. | Spotting a rare bird during a hike; noting wild flowers along a trail. |
| Systematic | Involves a structured approach with predefined intervals or plots to ensure comprehensive coverage of the study area. Designed to reduce bias and improve data reliability. | Enables accurate assessment of both presence and absence, offering detailed insights into species distribution and abundance. | Quadrat Sampling: Dividing a study area into smaller, equal-sized plots and surveying each systematically |

Materials needed

- Smartphones with the iNaturalist, Observation.org, Merlin Bird ID, and/or eBird[13] apps installed
- Marking sticks (with flags)
- Measuring tape or rope for marking quadrats
- GPS device or smartphone with GPS capability
- Notepad and pen for additional notes
- Magnifying glass or portable microscope (optional for close observations)
- Binoculars (for bird observations)

Method

1. **Duration per quadrat:** A commonly used duration for quadrat surveys is approximately 15-30 minutes per person per quadrat, based on peer-reviewed literature suggesting this range provides a balance between thoroughness and practicality for diverse taxa (source: "Methods in Ecology and Evolution," British Ecological Society).

2. Quadrat setup and team Coordination (if applicable):
   2.1. Outline the 10x10 meter quadrat in the selected study area, using sticks (with flags), measuring tape or rope to visually define the area.
   2.2. Capture the GPS coordinates of the corner's quadrat.
   2.3. If applicable, divide tasks among team members to cover broader taxa efficiently (e.g. one focuses on flora and fauna using iNaturalist/Observation.org, and another focuses on birds with Merlin Bird ID/eBird).

3. Survey procedure:
   3.1. Note the start and end time of the survey to adhere to the recommended duration, ensuring consistent effort across quadrats.
   3.2. Within the quadrat, survey for plants, insects, and other life-forms. Ensure the entire area is covered.
   3.3. Document observations using designated apps, ensuring accurate tagging for each entry.
   3.4. Adhere to ethical observation practices, prioritise safety, and ensure minimal environmental impact.

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[13] *iNaturalist: Offers free image recognition software to assist in species identification from photographs; users can contribute to and create project collections, facilitating data organization and collaborative research; the platform also allows for community verification of observations, enhancing data reliability.*

*Observation.org provides similar image recognition software for species identification and supports the creation of groups and challenges to engage users in specific monitoring goals or thematic surveys. It's particularly useful for documenting a wide range of biodiversity data, including plants, animals, and fungi.*

*Merlin Bird ID and eBird focus on bird identification through photos, sounds, or answering simple questions about what the user observed. It leverages the vast database of bird species and vocalizations to provide accurate ID assistance. Merlin Bird ID is designed for ease of use, making it accessible for both beginners and experienced birders.*

### b) Vegetation Survey

#### Why

Tracking changes in plant diversity over time could tell you whether your interventions (or the absence of them) are attracting species and increasing the overall resilience and complexity of these ecosystems. You'll be hoping to see a greater diversity of plants within your site than you found in your baseline survey. The assessment of species richness and (native and invasive) species abundance indicates whether we are successfully promoting the "target species" desired in the ecosystem. Although the Flora & Fauna Survey also gives an indication of what species are present (or absent) in your study areas, this survey is advised if you want to track changes in species richness and abundance in greater detail.

#### Materials needed

- A one $1m^2$ frame/quadrat (this can be made of wood, or nails connected with string, any other material that you think would be suitable to use; this could also be a hula hoop, as long as you know its area and always use the same instrument!)
- A camera/smartphone
- A plant identification guide for your region
- Marking sticks (could be small, coloured stones, small flags etc)
- (Tape measure if doing the square method along a transect)

#### Method

1. Explore plant encyclopaedias/local botany resources to help with flora surveying
2. Place the $1m^2$ within the different zones (avoiding crop production areas where weeding or even ploughing is likely to happen); if applicable, do this within the quadrat used for the Flora & Fauna Survey
3. Mark the corners of each quadrat physically (e.g. using marking sticks)
4. Take a picture of each quadrat
5. Identify the names of species you find in each quadrat and attribute unique labels to those you cannot identify (use therefore local plant ID guides or phone app such as observation.org, plantnet, or iNaturalist); if possible, classify each species as "native", "introduced" and/or "unknown/other")
6. Count the number of distinct plant species you can see inside the quadrat (this is the "**species richness** per $m^2$")
7. In each quadrat, make a visual estimate of the % quadrat area covered by the 3-5 most dominant species, the remaining area vegetated for "other species", and the % naked soil (this is how you assess "**species abundance")**
8. Record the values in the datasheet
9. *(Optional)* If you would like to study the relationship between other ecological variables (e.g. moisture), survey your flora quadrat along transects with a (moisture or elevation) gradient

## Indicator 12: Moth trapping

*Note: building a DIY Robinson trap may be time-consuming (and fun)*

### Why

Moths are invaluable as ecological indicators. Their diversity and abundance are reflective of the broader health and biodiversity of ecosystems. As pollinators and significant components of the food web, moths support various ecological functions. Their presence, absence, or population changes can indicate shifts in environmental conditions, making them a proxy for assessing ecosystem health and the impact of conservation measures.

### Results

Data collected from the moth monitoring will contribute to understanding the ecological dynamics within the surveyed area, offering insights into the health of the ecosystem and the effectiveness of restoration or conservation efforts.

### Materials

- UV light LED strip
- White plastic funnel
- Clear Plexiglas sheets
- Plastic bucket with a lid
- Wooden board and a stick or small pipe for mounting the LED strip
- Zip ties
- Recycled egg boxes
- Portable power bank (≥10,000 mAh)
- Camera or smartphone
- Insect identification guide or app (e.g. iNaturalist)

### Method

1. DIY Robinson trap assembly:[14]
   1.1. Attach the UV LED strip around the stick/pipe using zip ties
   1.2. Cut the Plexiglas sheets to fit as vanes around the bucket's circumference and secure them above the lid level with zip ties.
   1.3. Place the funnel inside the bucket lid opening, ensuring it leads into the bucket.
   1.4. Set the LED strip's power source to the power bank and mount the entire assembly on a wooden board for stability.
2. Site selection and setup:
   2.1. Choose a location away from artificial lights and preferably within varied habitats for a representative sample. Mark the site using GPS for consistent placement in follow-up studies.

[14] *https://butterfly-monitoring.net/sites/default/files/Pdf/moth%20monitorin/Self-made%20your%20LEDmoth%20Trap.pdf*

2.2. Place the trap on an elevated platform to avoid ground predators and set it to operate from dusk till dawn.

3. Data collection:
   3.1. After the night of operation, photograph the trapped moths for species identification. Use an app like iNaturalist for preliminary IDs and record the species and number of individuals.
   3.2. Gently release the moths back into their habitat.
   3.3. Compile the photographs and data into a report, including observations on moth diversity and abundance.
   3.4. Submit the report to the ERC database, adhering to the required format for data integration and analysis.

# (MICRO)CLIMATE

## Indicator 13: Temperature differentials

Means of Verification: Temperature Measurements

### Why

Temperature is a crucial factor in ecological transformation, regulating physiological and metabolic processes of plant and animal species (e.g. transpiration, photosynthesis, germination, respiration). We know living beings thrive in so-called optimum temperature ranges - not too cold, not too warm. Generally, photosynthesis stops at 40 $^{o}$C in temperate ecosystems and at 50 $^{o}$C in the tropics, while metabolic activity is low under 0 $^{o}$C and above 40 $^{o}$C. On the other hand, changing temperatures influence other systems like the water cycle, precipitation patterns and/or overall (micro)climate. Therefore, it is important to keep track of how temperature is changing throughout ecosystem restoration.

One method to do this is described below, but it can be as simple as manually logging surface temperature measurements in each season (dry and wet seasons in the tropics), in each zone. What matters is to collect data on temperature in a consistent fashion by recording measurements of the same sites over time for subsequent interpretation.

### Results

Monitoring how temperature changes across different sites and heights, helps you gain an understanding of energy flows. If you are able to reduce temperature differentials with your interventions (e.g. restoration site's max surface temperature < control site's max surface temperature in hot days; restoration site's min temperatures > control site's min surface temperature in cold events), you know you are probably helping with the process of homeostasis in/around your ecosystem. In other words, you are promoting an ecosystem that is more resilient to sudden climatic events & weather shocks.

**Materials needed:** Data loggers or thermometers

### Method

1. Identify locations to install data loggers in the zone(s) you wish to study (preferably including at least one control site)
2. Install data logger(s)
3. Ensure continuous recording of min/max temperatures, as well as the recording date/time, geo coordinates, zone, and height

## Indicator 14: Evapotranspiration rates

*Note: building a DIY Atmometer may be time-consuming (and fun)*

Means of Verification: DIY Atmometer[15]

### Why

Evapotranspiration is the water lost through plant transpiration and soil and plant evaporation, a key process of the hydrological cycle that deserves proper attention especially in arid and semi-arid areas. There are many ways of measuring evapotranspiration rates, including the well-established soil water balance method, using micro-meteorological methods/atmometers, and even computer models or remote-sensing techniques (Feddes & Lenselink, 1994). Measuring evapotranspiration helps to study microclimates and can inform efficient irrigation strategies. For this indicator, we propose creating a homemade atmometer given that professional atmometers are quite expensive.

### Materials needed

- 1 liter bottle with cap
- 1 Unwanted CD/DVD
- Absorbent fabric (e.g. old underwear or jeans)
- 3 paper clips
- Glue
- Rubber band
- Ruler or tape measure

### Making a DIY Atmometer

1. Drill a 15mm hole in center of the bottle cap
2. Glue the disk to the top of the cap aligning the center hole of the CD/DVD over the hole in the cap
3. Cut a circular piece of cloth to just cover the disk
4. Cut three narrow (~15mm) strips of cloth about 6.5cm to 7.5cm longer than the height of the bottle
5. When the glue is dry screw the cap with the attached disk onto the bottle
6. Feed the three cloth strips through the hole in the bottle cap until they just reach the bottom of the bottle
7. Lay the exposed portions of the strips out flat on the disk and trim them to the edge of the disk
8. Arrange the cloth strips so that they are evenly distributed on the disk
9. Place the cloth circle on the disk and fasten it and the strips in place using the paper clips
10. Carefully unscrew the cap from the bottle and fill the bottle with water until the water is near the top of the straight side of the bottle. It is a good idea to also moisten the cloth on the top
11. Replace the cap on the bottle and you're done

[15] Adapted from https://xperimentia.com/2012/09/01/a-homemade-atmometer/

### Method

1. Record the date, time and coordinates of each measurement
2. Mark the starting level of water by place rubber band around bottle at that level
3. Adjust the rubber band if you refill the bottle or start new measurements
4. Take a reading at each zone – including an uncultivated/undisturbed 'reference area' - you wish to study by measuring the distance from the rubber band to the new water level
5. To compare evapotranspiration rates between different forms of land-use, repeat the process across different zones
6. To assess how your interventions are affecting evapotranspiration rate over time, repeat the test every year or every other year on the same date/time and georeferenced locations

### Results

High evapotranspiration rates usually mean that water may be a limiting resource for plant growth. Such insights can inform irrigation requirements and prompt the adoption of certain water conservation practices (e.g. increasing the amount of mulch/soil cover).

## Indicator 15: Soil Organic- Matter (SOM) & Carbon (SOC) content[16]

This is the indicator that shows how the organic matter- and carbon content of your soil changes over time, with particular forms of land-use and/or restoration interventions. The most accurate way of measuring this is with the "Loss on Ignition" (LOI) lab test. However, if you do not have access to a lab, you could get a general indication of how SOM/SOC is changing by using the "Soil Colour test".

### Why

If we want to know why Soil Organic Matter (SOM) is important, we must know what SOM means. SOM is the basis for fertile soils, healthy terrestrial ecosystems and climate: a complex component of the soil made up of microbial, plant and animal tissues in different stages of decomposition (Stockmann et al, 2013). It is also the largest terrestrial pool of organic carbon (SOC) (Liang et al, 20200), storing almost three times more carbon than the aboveground biomass, double that in the atmosphere and even more than the atmosphere and vegetation combined (Eswaran et al, 1993). Thus, increasing soil organic matter in the soil is also increasing organic carbon, which is why ecosystem restoration helps to mitigate our changing climate. In turn, showing that carbon is being sequestered into the soil is a powerful sign to the world that this is a solution worth investing in.

Beyond carbon, organic matter is a crucial storehouse for nutrients and a major contributor to aggregate formation and stability, playing a central role in ecosystem functioning for all soil types (sandy, clay, loamy and all the ones in between). SOM influences fertility[17] and

[16] Soil Organic Matter/Carbon content is also a good "SOIL HEALTH" indicator

[17] SOM contains nearly all soil N and typically the majority of CEC

associated (primary or crop) productivity, soil trafficability[18] and hydrology (infiltration/runoff rates and flood regimes) (He et al, 2012; Hatten & Liles, 2019), as well as maintaining pH and perhaps most importantly, keeping decomposing organisms well-fed… That is, promoting a steady nutrient cycle. So, increasing SOM levels influences other soil-related outcomes such as decreasing bulk density, increased water holding capacity, infiltration and root proliferation (Hillel & Hatfield, 2005).

Means of Verification (1): Loss on Ignition (LOI) Lab Test

Materials needed

- 1 spade/auger
- 1 clean bucket
- 1 clean zip lock bag to hold the sample

Method

*NOTE: if you have lab-specific protocols, neglect the method/procedures below*

Soil sampling procedures

1. Determine and prepare locations of subsamples you will take: At least five to ten locations should be chosen that represent the zone you want to study, for example from the top, middle, and bottom of a slope; or scattered locations in a field, pasture, or garden bed. Avoid sampling in irregular and border areas.
2. At each of the selected zones, take two soil subsamples 5m apart, and mix the subsamples together into one sample in a zip lock bag.
3. Remove any residue or plant material above the soil surface.
4. Use the spade to dig a small hole in the center of the prepared area, about 8 inches deep. From the side of the hole take a vertical, rectangular slice of soil, aim for 6 inches deep and 2 inches thick. Remove any extra soil so that you have a more or less uniform "slice of soil" that is 6 inches deep, 2 inches thick and the width of the spade. Try to ensure that the slice represents the top 6 inches with equal representation across the depth of the sample. Place the slice of soil into the clean bucket.
5. Repeat the sampling procedure at each location that you chose for this area and combine the soil in the bucket. Break up the soil and thoroughly mix the subsamples in the bucket.
6. Once the soil is sufficiently mixed, take an amount needed by the lab for analysis (specify that you want to measure Soil Organic Matter (SOM) using the Loss on Ignition (LOI) test, and transfer into the clean zip lock bag to transfer to the lab (0.7 liters of soil should be sufficient).

Lab testing procedures

1. Baking of soil samples: 24 hours at 105° C
2. Weigh the crucible.

[18] defined as a soil's capability to support agricultural traffic without degrading soils and ecosystems

3. Weigh approximately 15 to 20 g of each baked sample and place it in the crucible. Ensure proper labelling
4. Place the crucible in the oven after weighing.
5. Burn at ~ 550° C for 3 hours.
6. Once cooled to ~ 150° C, place the crucible in the desiccator, cool for 30 minutes and then weigh.

### Calculations

SOM (%) = [[(dry mass 105° C) - (dry mass 550° C)] / (dry mass 105° C)] * 100

### Results

Once you have received your results back from the lab, you will be given a percentage of soil organic matter/carbon found in the sample that you sent off. Healthy soils have around 6% organic carbon content. Degraded soils have 1-2%. To work out how much organic carbon you have in your soil, multiply the number by 0.58. The answer gives you the amount of organic carbon in your soil (Ponce-Hernandez et al, 2004). Additionally, data from the lab can be used to calibrate or validate SOC estimates based on satellite imagery and mathematical relationships.

## Means of Verification (2): Soil Colour Test[19]

### Materials needed

- 1 spade/auger
- Zip lock bags to carry soil samples

### Method

1. Take a moist soil sample from an uncultivated/undisturbed area, place it in a bag and label it as 'reference sample'
2. Take a moist soil sample from the area you want to study, place it in a bag and label it with '(code of the zone) sample' (also include a number, in case you are doing multiple surveys within the same zone)
3. Using the three photographs below, compare the relative change in soil colour between a handful of soil from the 'reference sample' and another handful of soil from the zone you are monitoring
4. Record the scores in your datasheet
5. Repeat the process at all zones you wish to monitor

[19] *Adapted from http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HDEDH0VQJKFQ1P; If you would like to obtain more (accurate) information from soil colors, our advice is to get hold of "Munsell's soil color chart"*

Results

2 = GOOD 1 = MODERATE 0 = POOR

- *Good condition (2):* Dark coloured topsoil that is not too dissimilar to that from reference.
- *Moderate condition (1):* The colour of the topsoil is somewhat paler than reference
- *Poor condition (0):* Soil colour has become significantly paler compared with reference

Additional references

http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/soilhealth_prac_soil_colour_pdf/$FILE/PracNote_Colour.pdf

## Indicator 16: Above ground carbon capture

This is the indicator that shows how much carbon is being stored in the living biomass of restoration sites. We are not (yet) able to recommend a specific 'citizen science-friendly' method that can be used in different types of ecosystems, to quantify above ground carbon. However, there are a number of organisations that can help individual projects quantify and verify their carbon stocks (see this webpage for more information on carbon credit certification).

Alternatively, there is a long list of experiments and case studies focusing on measuring above ground carbon capture on the field. For example, it is possible to calculate carbon stored per year (ton/ha/year), by using so-called allometric equations. These ecosystem/site-specific equations require data that is often obtained by surveying quadrats (e.g. 10x10 m, or the same one used for indicator 11), retrieving a list of the specific species present at in those quadrats, the number of individuals of each species (i.e., number of trees or shrubs from the same species present in each quadrat), values for Diameter at Breast Height (i.e., diameter of a tree at approximately 130cm altitude, in cm), Wood Density (g/cm3) and Height (cm). Through statistical analysis, this data can then be used to estimate biomass values (ton/ha) of larger restoration sites. Alternatively, above ground biomass (ton/ha) can be estimated using

vegetation indices derived from satellite imagery, such as Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI), and Net Primary Productivity values. Again, this total biomass can subsequently be used to calculate carbon stock above the ground. Situmorang et al (2016) presents one out of many case-studies following such approaches to calculate above ground carbon stocks (both on the field and remotely through satellite imagery).

Given the scientific expertise and challenges involved with the above-described approach, our advice is to work with estimates of above-ground carbon stocks from models based on state-of-the-art remote sensing techniques, (which integrate indices such as NDVI while continuously improving resolution and accuracy), and associated machine learning. For example, the ERC movement is partnering up with Restor, a platform that is hoping to be able to monitor different types of ecosystems and even species present at sites undergoing restoration through remote sensing and integrating such variables in (evermore robust) models to predict how much carbon is accumulating in living biomass. If you are interested in helping to advance this field, your project's restoration sites could function as experimental plots! (Reach out to us at hello@erc.earth for more information).

# ECOSYSTEM PRODUCTIVITY

## Indicator 17: Ecosystem services

*This indicator is relevant for restoration projects where (regenerative) production of goods/services take place. The definition of productivity is usually - but not necessarily - associated with the economic benefits deriving from ecosystem restoration.*

Means of Verification (1): Quantification of Ecosystem Services

### The Why

Monitoring yields helps you to track changes in the productivity of your land. In agriculture, crop yield or 'agricultural output' is a measure of both the yield of a crop per unit (cultivated) area and seed generation of the plant itself (e.g. if three grains are harvested for each grain seeded, the resulting yield is 1:3). A 1:3 yield is considered by agronomists as the minimum required to sustain human life. One out of 3 seeds should be set aside for the next planting season, the other 2 either consumed by the grower(s), or split – one for humans, one for livestock. Besides agricultural production, you may be interested in monitoring timber production, or income generated through tourism activities.

### Results

Decreasing crop yields might be a sign that you are depleting your soils, while effective soil restoration practices are likely to improve your yields. To a great extent, the meaning of your results depends on your restoration objectives and production models. The results of this test are particularly informative when analysed alongside with other ecological attributes.

| Product | Product type | Occupied surface area (ha) | Total Harvest (kg/year) or Volume (m3/year) | Yield (kg/ha/year or m3/ha/year or $/year) | Average share of final price (%) |
|---|---|---|---|---|---|
| | | (where applicable) | (where applicable) | | (where applicable) |

Method (to quantify food production as 'provisioning service')

1. Determine what 'products' you want to monitor over time and classify them accordingly (e.g. as 'annual crops', 'perennials crops/herbs', 'animal products', 'timber', etc.)
   *(Although we hope to see diverse (agro)ecosystems, you might only be able to/interested in monitoring one or two products, which play a key role as a 'provisioning' ecosystem service.)*
2. Determine the surface area that is used to produce each of these 'products' in hectares
3. Log date and weight of each harvest of the respective products in 'harvest notebook'
4. Sum the weight values to obtain the total harvest at the end of each year for annual crops or at the end of your growing-harvesting cycles (e.g. timber)
5. Calculate the crop yield in kg/ha
6. Upload the data into your record sheet

# CONCLUDING REMARKS

We hope that this guide provides you with the information and tools that you need to collect data while engaging local community and other relevant stakeholders. It is our ambition show the world how grassroots restoration helps to increase biodiversity, improve water cycles, capture carbon, build community, develop restoration-based livelihoods and increase skills and knowledge.

Considering the goals of monitoring within ecosystem restoration projects, it is important to acknowledge key considerations and limitations of this framework:

### Evidence of impact & transparency

While this framework helps monitor the impact of restoration efforts (and report progress to donors), ecosystem restoration is complex and causes of change usually cannot be isolated. In other words, it is practically impossible to prove the extent to which impact has been caused by an individual agency/organization (e.g. ERC initiatives themselves, partners, (in)direct donors, etc).

### Validate hypotheses

Collecting (reliable) data helps restoration practitioners validate their hypotheses and associated restoration practices, while contributing to global research on societal challenges. Yet the quality of the data depends on how rigorously the methodologies are implemented, especially if a given project relies on different staff, volunteers or data collectors over time.

### Learning & adaptive management

Robust M&E datasets can inform restoration planning, design and/or adaptive management practices at project-level. To spread such lessons with the ERC network and future restoration initiatives, it is important to share about unexpected outcomes as well as success stories.

# APPENDIX 1: LANDSCAPE TRAITS AS CRITERIA FOR SAMPLING DESIGN

We formulated a set of questions that could help you navigate through the different layers of your landscape, as outlined below.

- *Where does the soil come from?* (What is the lithology & parent material of soil)
- *How is the soil formed?* (Could be through physical- (e.g. disintegration due to temperature differences and so on), chemical- (chemical reactions) and biological (related to life) weathering processes
- *What has the soil been used for?* (What was the traditional land-use?)
- *What type of landforms are there?* (E.g. low hills, river valleys, etc)
- *What is the water gradient like?* (Look into the hydrology of the site, some areas have more or less water than others)
- *What is the orientation of different areas within your restoration sites?* (Consider sun-orientation and wind exposure)

# APPENDIX 2: STRATIFIED RANDOM SAMPLING DESIGN

You are experimenting with multiple approaches to forest restoration on a 4000m$^2$ land parcel that was used for intensive agriculture in the past. Before expanding your work to the rest of the project area, you hope to learn what works best in your context; therefore, you are planning to:

a) apply TOPSOIL amendments and plant trees ('moderately' assisted recovery[20])
Area (Zon-Top) = 2000m$^2$

b) create HABITAT features to attract seed dispersers ('lightly assisted recovery')
Area (Zon-Hab) = 1500m$^2$

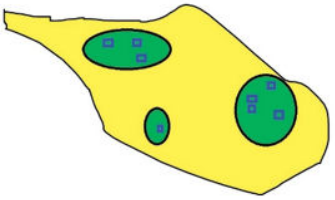
c) control, i.e. "do nothing" other than monitoring ('natural recovery')
Area (Zon-Con) = 500m$^2$

d) collect data for M&E indicators from REFERENCE site (e.g. native forest)
Area (Zon-Ref) = 500m$^2$

Within each of these areas, you could differentiate between different types of soils (e.g. clay-rich, sandy), forest types (deciduous, evergreen) and/or different age stands. These can then be overlayed on a polygon file or aerial images[21]. All of this helps deliver more accurate and useful findings to the growing community of ecological restorationists.

Now, let's assume areas a, b and c are the units we will be monitoring over time (and d was used to obtain target values during the baseline inventory). We know the size of (a) is 4x larger than (c), and (b) = 3x larger (c). Probability sampling means that, if you take 5 samples for (c), you should take 5 x 4 = 20 samples for (a), and 5 x 3 = 15 samples for (b).

Stratified Random Sampling chart whereby
Yellow = total project area
Green = project's zones/sampling units/strata
Blue = sampling sites/samples



[20] Chazdon et al, 2021

[21] Recent aerial images tell something about different forms of present land-use and restoration activities in place. Old aerial images could provide reference scenarios/baseline data and help locate control sites for monitoring. If pertinent, get in touch with a GIS specialist from the ERC advisory board, Michiel Damen/michieldamen@icloud.com, who can help you analyze the aerial images of your sites.

# APPENDIX 3: PLANNING & DESIGN PRACTICES

At the *Planning & Design stage* of an ecosystem restoration project and as part of your **restoration plan,** we recommend including the following elements[22]:

1) **Eco-social context**[23], including
    a) diagrams/maps of project in relation to surrounding landscape or aquatic environment; (potential) connectivity between habitats and restoration site;
    b) stakeholder analysis, engagement strategies; and
    c) site tenure security (ensuring site does not regress to a degraded state)
2) **Baseline inventory**[24], documenting
    a) biotic (e.g. surveying persisting native, ruderal, non-native, threatened and invasive species) and abiotic elements (e.g. conditions of streams or soils, using photographs and other means);
    b) the causes[25], intensity and extent of degradation, as well as barriers to natural recovery[26]; and
    c) the potential for natural recovery after removal of causes of degradation, including what (a)biotic elements are missing and need to be reinstated
3) **Vision, goals** and/or associated (native) **reference ecosystem**(s)
4) **Restoration design** in space and time, including a description of
    a) Restoration approaches/activities and logistics involved (to achieve (3))
    b) M&E system (including logistics/resources involved, adaptive management strategies, and, if relevant, conceptual models, research questions, testifiable hypotheses, etc.)

[22] Adapted from the *Standards of Practice for Planning and Implementing Ecological Restoration Projects* (Gann et al, 2019)

[23] It is important to recognize (and remain sensitive to) the dynamic behavior of ever-changing, complex eco-social systems wherein ecosystem restoration efforts take place

[24] For further guidance, consult Section 3 (1.4) and Principle 5 from the Standards (Gann et al, 2019)

[25] For a standard Threats Taxonomy, consult the Open Standards Threat Classification

[26] e.g. human pressures, unsuitable substrates, lack of resources, absence of (or altered) niches, niches, herbivory, competition, lack of propagules

# APPENDIX 4: NATURE DIARY

To begin studying nature and biodiversity across the global ERC movement we need to gather information and data on a regular basis to find out what is active in your individual restoration initiative.

One of the easiest ways to start doing this is with a Nature Diary. This is an ongoing record of encounters with nature that you observe during your restoration experience.

The data that contributes to the diary can consist of a combination of observations of animals that are encountered as well as animal signs. Animal signs can include calls, tracks, trails, scats, feathers and the shed skin of reptiles.

The information recorded should include as much detail as you can give. However, even the smallest details can help build a picture of what is happening in your restoration sites. Often it is not possible to record all of the suggested fields in the form below, or you might not remember everything about your encounter. Fill out as much of the form for each encounter you have.

### Notes on Data Collection

Notes can be taken in many ways, choose something that works for your situation. You could print out the form below and take it into the field or you could use a voice recording app on your mobile phone and record your encounter that way. Having a blackboard or whiteboard in a communal area where people can add their recent sightings is a great way to share what people have been seeing with the local community and encourages volunteer engagement.

### Notes on Identification

With so many species of birds, insects, and mammals, it can be a bit overwhelming to begin identifying the species that you encounter. Remember, we are interested in all species that are seen at your ERC initiative.

Online communities like iNaturalist, BugGuide.net, Project Noah, and What's That Bug, have photos of a multitude of species already identified and allow users to submit their own photos for identification by a community of experts.  Phone apps such as Merlin, Picture This, Google Lens can all be extremely useful for identification purposes.

A template for recording your encounters is outlined below:

| | |
|---|---|
| ERC Name | The name of the ERC initiative |
| Date | The date of the observation |
| Time | The time of the observation |
| Observer Name | The observers name |
| Species Name | The common or local name of the species observed (if known) |
| Scientific Name (if known) | The scientific name of the species (if known) |
| Location on ERC | Where on the ERC site was the observation made, are there identifiable landmarks, for example: “near the…. compost bins, a well-known tree, a particular building, a field with a name, a pond or river. |
| Description of encounter | Describe in as much detail as you can what you saw. This can include what the animal was situated on when you saw it (e.g. leaf, stem, tree trunk, in leaf litter, on bare ground or in water). If it was on a plant and you know the name of the plant, record that too. |
| Behaviour | Describe what the animal was doing when you saw it, e.g. feeding, climbing, mating, sleeping, flying etc. |
| Nearby vegetation | Describe the nearby vegetation, what crops are being grown in the area of the observation? |
| Weather and temperature | What was the weather at the time of the observation (e.g. sunny, cloudy, light rain, heavy rain etc). If you are able to take it (mobile phone), record the temperature. |
| Number of Individuals | |

| | |
|---|---|
| | How many individuals of the species did you see in this encounter? |
| Certainty (certain, likely, unsure) | How sure are you that you correctly identified the species? If you are unsure of the identification, or can't identify the species, give as much detail about what the animal looked like in the notes section. Remember to include what kind of animal it was (e.g. bird, mammal, lizard etc), what colours you saw, an estimation of size. |
| Method of observation | How did you make the observation? Did you physically see it, use binoculars, was it a footprint, a call, a scat, a feather? |
| Notes (e.g. sex, life stage) | Were there any other things you noticed that might be of interest? Could you tell the sex or the life stage of the animal e.g. baby or adult? Any information about the appearance of the animal if you couldn't identify it (see the Certainty field above). |
| GPS location | If you have a GPS machine then please record the GPS location here. |

## GLOSSARY OF KEY CONCEPTS

- **Adaptive management:** 'an intentional approach to making decisions and adjustments in response to new information and changes in context' (USAID 2018)

- **Baseline**: the documented starting point of your restoration project, acting as control against which progress or impact is measured; albeit less reliable, **'control sites'** may also function as baseline references/points of departure

- **ERC initiative:** refers to a (semi)permanent restoration project involving public participation.

- **Conceptual models:** as with any model, conceptual models help us to simplify complex (eco)systems. They are not statistical or predictive and do not attempt to explain all possible processes and relationships. Good conceptual models contain just the relevant information. In the context of ecosystem restoration, they illustrate assumed and/or hypothesized impacts of management and other factors on the state of ecosystems. For example, if your question is "how to increase water retention?", one hypothesis included in your conceptual model could be "mulch application increases water retention". You would then choose indicators/method(s) to help you verify your hypothesis (e.g. water holding capacity test). Based on the results of your experiments, you start to understand what practices restore water systems. For more information and practical applications of conceptual models, we recommend consulting the work of Bestelmayer et al (2017)

- **Datasheet**: refers to the place where you can log the data you are collecting.

- **Ecosystem:** a geographic area where a community or group of living organisms (e.g. plants, animals) interact between themselves and their physical/chemical environment (e.g. landscapes and weather) to form a microcosmos of life.

- **Ecological Restoration**: is 'a practical management strategy that restores ecological processes to maintain ecosystem composition, structure and function.' (Apfelbaum & Chapman 1997).

- **Ecosystem Restoration:** 'The process of halting and reversing degradation, resulting in improved ecosystem services and recovered biodiversity. Ecosystem restoration encompasses a wide continuum of practices, depending on local conditions and societal choice' (UN, 2019)

- **Ecosystem Restoration Communities (ERCs):** are locations for people around the world to participate in ecosystem restoration; living laboratories where effective ecosystem restoration techniques are developed and spread through hands-on experiences and education.

- **Evaluation:** the analysis of data collected during the monitoring period in relation to the established goals/outcomes

- **Feedback loops** are key in systems thinking and help us to understand complexities. A negative feedback loop is 'stabilizing', one that tends to balance or slow down a process, whereas a positive feedback is 'reinforcing', encouraging the system to continue in one direction. Negative feedback loops include predator-prey interactions (as prey populations go up (+), the predator population eats well and grows, until there are too many predators and the prey population decreases (-)). Positive feedback loops are often described as 'vicious or virtuous cycles' as two processes reinforce each other, such as when water availability supports plant growth (+) and more plants (through greater water infiltration and decreasing evapotranspiration rates) increase water available to support plant growth. Positive feedback could also have 2 'minuses' such as when deforestation leads to decrease in biomass, more naked soils and nutrient runoff and smaller amounts of biomass that can grow on such soils.

- Multiple feedbacks may interact at once. That is what is implied in the idea that human disturbances may push the Earth system past critical thresholds or 'tipping points' into qualitatively different states (e.g. irreversible climate change) such that a certain moment in time, a tiny perturbation can have long-term or even irreversible consequences for a system, i.e. "when little things can make a big difference". Through ecosystem restoration, we believe we can promote positive feedback that is life-affirming and increase the resilience of our global ecosystem.

- **Indicators**: are clues or signs that tell us whether the outcomes are being met.

- **Land use or land management:** refers to the human arrangements, activities and inputs producing, changing or maintaining certain land-cover types (UNCCD 2016).

- **Means of verification:** are the different tests used to measure the outcomes

- **Monitoring:** is the systematic process of collecting data within a given time frame

- **Outcomes:** are the goals we hope to reach and enhance through restoration

- **Remote Sensing:** Is the collection of Earth observation data from satellites, aircraft or other remote sources

- **Reference ecosystem/sites:** represent the (approximate) condition of the ecosystem where restoration is targeted, had degradation been less significant or not occurred at all (Gann et al, 2019)

- **Restoration:** '(...) a process that aims to regain ecological functionality and enhance human well-being across degraded landscapes' (Buckingham et al, 2019).'

- **Sample site or sampling location:** herein broadly defined as the specific sites where the collection of ecological data takes place over time; should be representative of a given zone.

- **Standardisation***:* in our context, is the process of implementing/developing standards based on wide (scientific) consensus. Standardized methodologies contribute to inter-operability of data and help to ensure the repeatability and quality of measurements.

- **Zone(s)**: refer to the different areas/locations within the overall project site, as defined in the design of the site. The criteria used to designate each zone will vary per restoration project - could be based on the different forms of management (e.g. grazing, mulch), ecosystem types (e.g. forests, wetlands), altitudes, distance from communal area, etc.

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