MONITORING & EVALUATION
ECOLOGICAL TESTS

ecosystem restoration
camps
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WHAT IS THE DIFFERENCE BETWEEN 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, 24 and 36 months later, with the results compared to those collected during the baseline. The final assessment takes place at the end of the time-frame, with the results compared to the midline and the baseline to show progress achieved throughout the monitoring exercise.

Evaluation is the analysis of the data collected during the monitoring period. Once all of the data has been received, it is time to compare the results from the beginning of the period to the midline, to the final. You should see a difference in the results and be able to generate some conclusions from them about how the camp is developing. You then write the results and the analysis and subsequent conclusions into a report and send it to the Foundation.

OUR HOLISTIC FRAMEWORK

We have created this framework with input from various members of our team, campers and experts/key-thinkers in the field of ecosystem restoration. Inspired in Kumar’s book\(^1\), 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 the degraded nature of the ecosystems around them.

This document presents the ‘**Soil**’ or ecological dimension of our framework, focussing on the community of living organisms in conjunction with their so-called nonliving environment. Such biotic and abiotic components interact as ecosystems through nutrient cycles, energy flows and other feedback loops\(^2\).

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2 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
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.

**Summary**

As shown in the summary table below, the first column describes the outcomes that we want the camp's activities to produce. The second describes the indicators which are signs that the outcomes area being met. The third, ‘means of verification,’ refers to the methods or tests used to measure the outcomes.

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*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 feedbacks that are life-affirming and increase the resilience of our global ecosystem. More on feedback loops/tipping points: [https://www.landecology.org/content/are-your-feedbacks-positive-or-negative](https://www.landecology.org/content/are-your-feedbacks-positive-or-negative); [https://www.pnas.org/content/pnas/105/6/1786.full.pdf]*
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<td>NA</td>
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*Table 1 Summary of outcomes/indicators included in the Framework. Highlighted in yellow are some other ecological tests that will become available soon.*
BEFORE YOU BEGIN

Collecting data at your camp is a vital way of learning about what is happening within your landscape. We know that each camp is unique and at different stages of development, but these are some things you need to consider before you start monitoring.

First, you need to become familiar with your ecosystems(s) and the kind of issues you wish to address. This will help you find out what you want to implement in terms of ecosystem restoration, which can be expressed as a design or sitemap of your camp. Alongside with the goals of your Ecosystem Restoration Camp projects, the ‘design’ is used to define what areas or interventions/techniques you will be monitoring over time. Having selected the areas you’re interested in studying, you can dive into the different sampling sites (i.e exact locations on your land where you will be collecting the data from or ‘sampling design’). Finally, collecting data helps you understand whether what you are doing in these areas is working or not.

For example, you have an area of your land that has high levels of erosion. As you may have expected, your baseline study shows low levels of topsoil/organic matter/vegetation in comparison with other areas. You need to decide what it is that you are planning to do to restore this area and promote healthy soil and vegetation there. This could then become one of the sites you monitor closely. Once you have collected the data from this site, you can analyse whether the practices you have implemented to resolve the ecological problems here have been working.

In short, our advice is not to start monitoring until you understand what is going on at your camp and define what you’re going to implement - or have implemented already - in terms of restoration on your land, and where. These conditions make the exercise of monitoring useful, efficient and possible to continue over time.

In case you have started restoration work before you began with monitoring & evaluation, select a few neighbouring/similar sites that resemble how you first encountered the land you are working with, to collect baseline data. Consider aerial images to inform the selection of control sites.
WHY DO WE NEED TO MONITOR & EVALUATE?

Monitoring & 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 at ecosystem restoration camps. 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 policy-makers, partners, land owners 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 camp. Despite offering a common framework, successful monitoring will depend on our capacity to (1) monitor those indicators that are sensitive to changes in ecosystems and (2) interpret changes in the indicator values. We can do this when we understand how our restoration activities and other 'disturbances' (such as fires) affect the ecosystems we are working with. Creating a conceptual model\(^3\) as a basis for the research question(s) and the hypotheses you would like to test, may help you reach that understanding. For example, if your question is "how to increase water retention?", one hypothesis derived from such a model could be "mulch application increases water retention". Then, you could choose the method(s) to validate your hypothesis, say the water holding capacity test. Based on the results of your experiments, you start to understand what practices restore water systems.

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\(^3\)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 ecological restoration, they illustrate assumed and/or hypothesized impacts of management and other factors on the state of ecosystems. Bestelmayer et al (2017) provides more information and practical applications of “state-and-transition” conceptual models, which could help you make sense of monitoring & evaluation at your camp.
Learning & Adaptive management

Above all, the purpose of this guidance is to support continuous improvement of on-the-ground work through adaptive management. It demonstrates what restoration activities are undertaken worldwide, and how effective these activities are, i.e how they are changing ecosystems. Although most cases will be highly complex and require context-specific solutions, lessons can be learned from other places with similar traits and/or pressures. In turn, these can help find and develop best practices at the camp-level.

WHAT DO WE MEASURE?

Common indicators

As mentioned above, it is our ambition to demonstrate the impact of the global ecosystem restoration camps movement. However, this is easier said than done as we acknowledge the great diversity of camps, the different ecosystems and restoration outcomes they work with. Using a set of common metrics makes for better aggregation and comparison of data across camps. Therefore, the ERC foundation proposes monitoring a core set of ecological indicators:

- Success rate after 1 year planting (perennial crops, shrubs and/or trees)
- Before & after pictures
- Biodiversity (flora and fauna)
- Soil organic matter content
- Soil compaction
- Water infiltration
- Carbon sequestered in biomass (*measured by our partners Crowther Lab*)

Camp-specific indicators

Of course, we do not expect all camps to just monitor the same parameters everywhere. Each camp is unique and our advice is to consider a set of site-specific outcomes and indicators, which may include - but need not be restricted to⁴ - the ones included in this framework.

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⁴ For example, measuring the concentrations of certain elements in the soil may be a good exercise for a camp that is restoring a contaminated site.
We recommend identifying your particular constraints to inform how you select the indicators for monitoring ecosystem restoration. Acknowledging the long-term goals typical of restoration efforts, it is wise to consider the time, effort, expertise and technology required to monitor different ecosystem restoration indicators. For example, camps that are financially constrained will need to prioritize affordable/cost-effective monitoring systems. Other considerations or questions arise in relation to the ecological attributes themselves: what data is available or easy to collect? Are these ecological indicators comprehensive in representing the desired restoration outcomes?

**SAMPLING DESIGN - WHERE DO WE START?**

As we identify the different habitats and interventions that (will) shape the sites we are restoring, an important question is *how do we study the impacts of our work?* Ecologists recognise the difficulty of surveying entire zones, populations or habitats. Therefore, well considered sampling designs are key to learning about ecology and its context to ecosystem restoration.

Good sampling is key because (1) we want our samples to be representative of the areas we want to study and; (2) we want to understand, compare and aggregate findings across multiple ecosystem restoration camps.

Sampling units refers to the 'camp's zones' that will be monitored over time. Sampling sites are the exact locations we collect data from, selected to represent each of these zones.

*Define camp zones (or sampling units)*

It is crucial to establish on what basis different zones are distinguished. There are many factors that will define the zones on your camp. These will be site specific, but they may include;

1. Restoration activities or types of land-use
2. Landscape traits like soil type (see Indicator 1), altitude, moisture levels, etc.

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5 You could do so by ranking the ecological indicators herein proposed based on different assessment criteria. Excellent guidance on how to do this is offered in Chapter 3 of *The road to restoration: a guide to identifying priorities and indicators for monitoring forest and landscape restoration* (Buckingham et al., 2019).

6 The Intergovernmental Panel on Climate Change (IPCC) defines six broad land-use categories: forest land, cropland, grassland, wetland, settlement and other land. You can define more locally relevant or specific forms of land-use such as camping land, agroforestry land, etc.
3. Control areas, i.e., neighbouring plots where conventional practices in place.

In line with the vision and goals of your restoration project, current/future interventions are outlined in your camp design. A set of questions was developed to help camp managers and campers understand soil formation processes and study the landscape they are attempting to restore (in Appendix 1). Other zones may function as control areas against which progress of restoration work is studied through comparative temporal/spatial analyses.

Finally, we come up with different ‘homogenous units’ from which we can sample, based on management practices or landscape traits such as the type of soil, altitude and so on. Say you have an area that you are reforesting, you can differentiate between areas with different forest types, or different ages. These can then be overlayed on a camp’s polygon file or aerial images. All of this helps deliver more accurate and useful findings to the growing community of ecological restorationists.

Sample design

Figure 1: Stratified Random Sampling chart whereby
Yellow = camp area
Green = camp’s zones/sampling units/strata
Blue = sampling sites/samples

Ecological research is fundamentally concerned with comparisons. Stratification helps us compare different strata or ‘subpopulations of a statistical population’. We are interested in comparing one zone to another zone, or a group of zones to a different group of zones.

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7 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 GIS specialist from ERC advisory board, Michiel Damen at michiel.damen@icloud.com, who has access to specialist software to help you analyse the aerial images of your sites.

8 We propose “Stratified Random Sampling” to account for different landscape traits as well as different types of management or restoration techniques. In case the former do not apply to your camp, you could consider a different sample design method. You can find a good overview of different sample design methods here: www.landscapetoolbox.org/monitoring-design/sample-design/
Assuming that different camp’s zones differ in surface area, we get the most out of stratification by knowing the specific sizes (e.g. m² or km²) of each zone. This allows us to determine the relative size/proportion of each strata/sampling unit, which in turn helps with proportionate allocation of samples/sampling sites. See below a simple example of how this works in practice:

All other things being equal, assume you are interested in studying a camp in which 20% of the land is (a) grazed, 15% (b) ungrazed and 5% (c) afforested. Proportionate allocation or probability sampling means that, if you take an amount of samples/sampling sites for the afforested zone \( N(c) = Y \), then \( N(a) = 4 \times Y \) and \( N(b) = 3 \times Y \).

**TIME-FRAME**

As we understand what restoration measures are needed and where, monitoring helps us to see changes in the state of the ecosystems we are working with. Increasing biodiversity, accumulated organic matter, soil fertility and crop yields are typical signs of ecological function. However, we know that the recovery of degraded ecosystems extends over the long term. So we may ask, when- and how often should we collect data?

Figure 2: Monitoring & Evaluation timeline
First of all, we recommend conducting a baseline study before the restoration activities are implemented. If your camp has already started its restoration activities, then the best thing to do is to select a piece of land that is still being managed in the same way as your camp plot/restoration site was being managed before your restoration work began. Take data from that plot to use as your baseline data. It is up to you how regularly you conduct these tests and collect data, but we recommend that it happens once a year to every two years, for at least one full monitoring cycle of 5 years - after which key learnings/outcomes can be synthesized - and celebrated! - in a 5-year report.

Most ecological data should be collected in Spring, when seeds and animals come out of winter dormancy or hibernation and begin their reproductive and nesting activities. Evidently, this does not apply when data is collected ‘continuously’ - we can choose when and what time-period we want to assess for indicators such as carbon sequestration, land cover change and temperature differentials. In rainy season-driven, non-temperate ecosystems with a less obvious spring, we suggest monitoring during or at the end of the rainy season.

Regardless of your location, it is crucial to do these tests at the same time every year, to avoid introducing noise from annual cycles. So, timing is a determining factor in measuring restoration outcomes and important to obtain standardised data for comparison between ecosystem-restoration initiatives worldwide.

Evidently, some indicators have high variation and others vary slowly. The amount of time needed to observe change or depends on the natural conditions of an ecosystem (e.g. seasonal and weather patterns) and the type of ecological parameters being monitored. Generally, feedback relationships are visible sooner in warm/moist tropical ecosystems than in more temperate or even boreal regions. More details on specific periods of time between sampling moments is included in the description of the ecological indicators and associated methods.

For the sake of harmonisation, we recommend monitoring all camp-relevant ecological indicators (at least) every year, for 5 years to assess how the work of restoration initiatives relates to established goals and flourishing ecosystems. If this is not done earlier, after the first 5 years camps are able to reevaluate their vision and associated practices. Depending on the findings and indicators used, monitoring efforts could be extended for another 5 years.
DOCUMENTATION AND COMMUNICATION OF RESULTS

Beyond data collection at Ecosystem Restoration Camps, successful Monitoring & Evaluation depends on well documented data and findings. If done carefully, such exercise is both a useful tool to substantiate/improve on-the-ground work and a means of sharing effective restoration techniques with the world.

There are a few common elements that help storing data systematically, even when different people collect data in different moments and/or formats (i.e. using the online datasheet, on paper or via mobile applications in the future).

As described above, a few sampling sites will be selected to study the impact of restoration activities at camps. We know from complex ecological systems that the data may be explained by human interventions (e.g. soil amendments, different forms of land-use, etc), unplanned/spontaneous and abiotic factors (e.g. severe flooding, altitude) or - and most likely - a combination of both through so-called ‘interaction-effects’.

Gradually, our ambition is to contribute to a holistic understanding of complex ecosystems and understand what is or could be our place within them. To become acquainted with the ecology of place and figure out how to serve ecosystems in the long-term, we need to document our data in a systematic way. For example, it is important to describe exactly where and when the measurements take place, especially if we assume different people will be collecting data year on year.

1. Record geo-coordinates and environmental factors

In your datasheet, record the exact geo coordinates of your sampling sites. You can do this by labelling pins at these locations and saving them in different lists for each of the indicators. Besides, keep track of any environmental factors or unusual events that call your attention relating to temperature, light, salinity, proximity to pollutants and so on. Depending on the objectives of your study, we recommend defining the environmental factors you would like to keep track of (such as weather and temperature) as this might help explain unexpected variation in the data.

2. Upload the data into camp’s database

If you are not directly logging your data into a common datasheet (online), take the time to do so after collecting data using a physical record sheet. Preferably, do this
as soon as possible while your observations and any unexpected encounters are ‘fresh’.

3. Evaluate & communicate results

Once all of the data has been collected, it is time to evaluate the results. Looking at the data, assessing trends and drawing insights is what we call ‘evaluation’. Evaluations often take the form of reports, which we can share with donors to prove the efficacy of our work.

Our recommendation is that you write a baseline report, after you have collected the initial ecological data, summarising your findings and how they are going to inform how you restore your land. In subsequent years, you can compare and analyse collected data against baseline values and/or control sites. We propose that each camp produces a report together with data collectors at the end of each monitoring cycle. We have developed a template to help with this task.

Before and after photos

One of the quickest and easiest ways to demonstrate the impact that your camp is having is by taking before and after photos of the areas that you are restoring. The best before and after images are taken with drones. If you do not have access to a drone, use the ‘Fixed Point Photography Method’, where you take photographs of the site from the same point(s) over time.

The Method

1. Mark out specific points on your camp-zone(s) with markers. (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.
4. Store these photographs in a Google drive folder and send them to ashleigh@ecosystemrestorationcamps.org
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

The 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

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

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9 Adapted from the The Permaculture Research Soil Test Handbook
The 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 \( \frac{1}{4}, \frac{1}{2}, \frac{3}{4} \) and \( \frac{4}{4} \) of the jar's capacity)

2. Select 1 representative sampling spot that best reflects each zone you want to study (including 'control areas')

3. Remove a vertical slice of soil approx. 30 cm deep from each sampling spot

4. Remove any large rocks or organic matter, then break up all the lumps

5. Fill half of the jar(s) with soil

6. 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

7. Fill the jar(s) to the \( \frac{3}{4} \) mark with water and shake vigorously for 3 minutes until soil is suspended in water

8. 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**

9. 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)

10. 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)

11. 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)

12. Using a ruler/tape measure, use the distances on the jar to calculate relative proportions of sand, silt and clay in soil sample(s)

13. Using the soil texture triangle below, determine the type(s) of soil you are working with

14. Record your results
Figure 1 Triangle to classify soil by texture
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 (I): Drop and Shatter

The 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.

The 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 and again, adding organic matter.

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

The Method
1. Select 1 representative sampling spot that best reflects each zone you want to study (including ‘control areas’)
2. First remove the 0-5 cm topsoil containing the dense root systems, without disturbing the soil underneath
3. Remove a 20x20x20cm cube of topsoil with the spade
4. 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. Do not drop any piece of soil more than three times
5. Part each clod by hand along any exposed fracture planes or fissures.
6. Transfer soil onto large plastic bag

Adapted from http://adlib.everysite.co.uk/adlib/defra/content.aspx?id=000HK277ZX.0HDED9M9K7GFQ02
7. 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.

- 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

Note: the slaking test is not very effective in soils with a high content of clay.

The 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.

Materials Needed

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

The Method

1. Select 1 representative sampling spot that best reflects each zone you want to study (including 'control areas')
2. Fill the jar(s) with water
3. ‘Hang’ a piece of the mesh inside-/at the top of each jar (to prevent that soils sinks to the bottom directly)
4. 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)
5. Place different soil fragments in different meshes/jars
6. Observe soil fragment for 10 minutes
7. 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)

References

- http://soilquality.org/indicators/slaking.html
INDICATOR 3: TOPSOIL

Means of Verification: Depth of Topsoil

The Why
Natural regeneration and assisted ecological succession depend on growing healthy soils. 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.

Results
By subtracting previous* topsoil measurement from your own measurements, you are able to assess whether certain interventions are helping to grow (if 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. All of this should help camp manager(s) adapt management.

*from baseline or last year’s study

Materials Needed
- Shovel
- Tape measure

The Method
1. Select at least 3 points representing each of your land's zones
2. Mark these points with markers of some kind, both physically and on your (digital) site map so that you are able to come back to them again for taking subsequent measurements
3. Label these sites with numbers, letters or names so that they are distinguishable from one another
4. Dig holes 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)
5. If you cannot easily reach this depth, make a note in datasheet
6. Measure thickness of topsoil layer (cm) in each of the holes, from the surface until the edge with subsoil
7. Calculate the average topsoil depth for each zone
8. Record these values (in cm) in the excel datasheet 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
9. Repeat the process every year (digging holes roughly one-meter away from the marks, to avoid digging where soil was moved in previous measurements)
Additional References
If you wish to know what is going on in your soil in greater depth, we recommend looking into your soil profile as described elsewhere:

-  https://www.nrcresearchpub.com/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054308
-  https://doityourselfforestryblog.wordpress.com/2016/05/27/what-are-the-different-soil-horizons/
**INDICATOR 4: TEA BAG DECOMPOSITION RATE**

**Means of Verification: ‘Tea-Composition’**

**The 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 camps located in the Northern Hemisphere or in November/December for camps 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. By comparing results across zones or even camps, management of ecosystem restoration interventions can be adapted accordingly. In the future, such data could be included in a vaster database, aligned with global research on soil ‘teacomposition’.

**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
- 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

**The 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 using sticks/metal poles/coloured stones so you can find them easily
3. Record altitude and GPS coordinates of these areas and if possible, the soil type
4. 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

12 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
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.

5. Weigh the tea bags before burial (preferably on 4 decimal places) and record the weight
6. Place tea bags in zip-lock bag or (tupperware) box until burial
7. Note the starting date of incubation/tea burial
8. Using string and nails, mark 4 lines in each sampling area (each 40-cm long, with 10 cm between lines)
9. Gently dig 4 slots (approx. every 10 cm, at least 5cm deep) along each line, creating a pocket for the tea bags
10. 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
11. Plan the retrieval dates or sampling points in your calendar (3, 12, 24 and 36 months after burial)

Retrieval of tea bags...

12. 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) from each plot (one 'incubation' line per sampling point
13. This leads to 4 bags of Green and Rooibos tea retrieved per sampling point and zone
14. 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
15. Place every tea bag in zip lock bag/box, checking the label (if missing, reconstruct based on previous/following bag number in the line)
16. Dry tea bags at 70deg for 48 hours
17. Determine weight of empty tea bag and note the weight
18. Record results in datasheet
19. Repeat procedure after 12, 24 and 36 months.
Figure 3: Sampling design of TeaComposition method used in GLORIA study
INDICATOR 5: SOIL SEDIMENT LEVELS

Means of Verification: Soil Accumulation Test
This is the indicator that shows that there has been an accumulation of soil, rather than a loss, thanks to the use of regenerative practices.

The means of verifying this is called the Soil Accumulation Test, with the instructions below:

The 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 can actually be accumulated rather than lost.

The 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

The Method
1. Select 3 spots that best reflect each zone you are working on, preferably along contour lines if the camps use them, inside swales/sediment traps
2. Select a minimum of 2 control spots within fields/locations that are being managed conventionally
3. Push your pole halfway into the ground (so if the poll is 1 metre, push it into the ground 50cm deep), so that it’s in there securely and won’t move around on its own
4. Spray paint the level at which the pole goes into the ground
5. Return to the poles one year later and mark the current soil level
6. Record the coordinates of each spot where threaded rods have been installed
INDICATOR 6: SOIL COMPACTION

This is the indicator that shows that there is a decrease in the compaction of the soil at your site.

Means of Verification
We suggest 2 different means of verifying this. 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).

The Why
Soil compaction greatly 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 caused by the removal of vegetation from the land and is a major cause of desertification.

(a) Penetrometer Test

Materials Needed
- A penetrometer
- Small flags or coloured stones or something to mark the fixed data collection points

The Method
1. Select one point for each zone
2. Label these points with numbers, letters or names both physically (marking) and on your site map so that you are able to come back to them again for taking subsequent measurements
3. Take the penetrometer and measure the PSI count of your sites and document the count alongside the name of the site in a spreadsheet
4. Pick a control site (a site that is closeby and has the same climate, soil type etc, but is not subject to the same forces of compaction, i.e. ploughing, etc). Repeat the process of selecting points and labeling them.
5. Use the penetrometer to measure the PSI count of these sites and record them in the same spreadsheet under the header of ‘control site’
6. Repeat the process again once a year, at the same time of year, in the same locations
The Results
You will end up with a set of PRI numbers between 0 - 400 PSI. The higher the PSI number, the higher the level of compaction you have. You should be aiming for a PSI level of around 200, depending on your soil type and moisture levels. The higher the clay content in your soil, the higher the PSI will be. The lower the moisture levels, the higher the PSI will be, so these factors should be taken into consideration when analysing your results.

(b) Bulk Density Test (and water content)

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

The Method
1. Select 1 point per zone - if these have been defined last year, walk 2 steps away from the former
2. Label these points with numbers, letters or names both physically (marking), on your site map and datasheet so that you are able to come back to them again subsequently
3. Remove top/bottom of tin so you are left with a metal tube
4. Push the tin firmly into the soil (with a piece of wood/hammer) until it is at least $\frac{3}{4}$ in
5. Measure the diameter of the ring and then half it to obtain the radius
6. 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 to get the depth the tin has gone into the soil
7. Record the values from steps 6 and 7 on your datasheet
8. Dig around- and remove ring with trowel underneath it, preventing loss of soil
9. Place entire sample in bag and label
10. Repeat this for each zone you wish to study
11. Record the weight of your wet soil sample(s) (subtract the bag or container that goes on top of the scale)
12. 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 its weight does not change after a drying cycle, then it is dry.)
13. Measure the weight of your dry soil sample and record this on your datasheet.
14. Calculate the bulk density using the formulas in your datasheet (see below; you could also work out the water content and porosity of your soil!)

*Formulas for final calculations (estimated automatically in last 3 columns of datasheet):

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

Soil bulk density (g/cm³) = \( \frac{\text{oven dry weight of soil (g)}}{\text{volume of soil (cm³)}} \left( \frac{\text{soil bulk density}}{2.65} \right) \)

Soil porosity (%) = 1 - \( \frac{\text{oven dry weight of soil (g)}}{\text{volume of soil (cm³)}} \)

**The Results**
Following this protocol in a systematic fashion gives an indication of how loose or compact your soil is (as well as information about the soil's porosity and water content). High bulk density means that there is little porosity and thus high compaction.
INDICATOR 7: WATER PERCOLATION AND RETENTION

Means of Verification
This is the indicator that shows that there is more water being held in the soil than there was before the camp began work. The **(a) Water Holding Capacity Test** 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.

**The 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, measuring the infiltration of your soil tells something about the ‘sponge behaviour’ of your soil as well as other ecological functions of water storage and conservation.

The results of (one or both) of these tests could guide future soil management practices so as to promote water infiltration and reduce water loss from runoff and/or evaporation.

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

**Materials needed**
- 1 watering can and water (a hose and spray nozzle can also be used)
- 3 or 4 trash bags, small tarps, or pieces of thin sheet plastic
- 1 sensitive scale (0.01 g)
- 1 spade
- 1 clean bucket
- 1 kitchen sieve or screen material with ~2 mm holes
- Mortar and pestle or other way to grind/break up soil
- 1 Kitchen oven or toaster oven set to 105°C
- A glass, metal, or ceramic dish/container to hold soil in oven (withstand 105°C)

**The Method**
1. Select and mark out at least three sample sites in the zone(s) that you are restoring
2. Free a 1x1 m area of soil from vegetation and soak it slowly and for several hours with water until saturated (ideally after a substantial rainfall event with clear forecast for the next three days)
3. Avoid pooling and runoff
4. Cover with plastic sheet, pin it down and wait for 48-72 hours, the sheet will prevent evaporation
5. Remove the plastic sheet, take sharp spade and cut a soil sample (15cm deep, 5cm thick and the width of the spade), make sure that the slice represents the entire top 15cm of the soil, repeat this for all sample sites
6. Mix samples together and omit any roots or stones
7. Take about 3 to 6 cups of the mixed sample and put it on a pan or another high-temperature container
8. Zero the scale, weigh the soil and record its weight
9. Bake the soil in an oven at 105°C for 24 hours until the water has evaporated, let it cool
10. Grind the sample with a mortar and sieve it through a 2 mm mesh, sift out all remaining stones and roots
11. Weigh the now dry soil sample and record weight
12. Weigh the empty clean pan and record weight
13. Calculate the water holding capacity (WHC) of the soil sample using the equation WHC = (PSw - PSd) / (PSd – P – RR)
   1. PSw = weight of pan and wet soil together
   2. PSd = weight of pan and dry soil together
   3. P = weight of pan
   4. RR = weight of rocks and roots
14. Units for WHC are reported as kg H₂O / kg soil and can be converted to a percent (multiplying WHC by 100)
15. When repeating the test make sure to use the same procedure in order to get meaningful results

(b) Infiltration test

Materials Needed
- Hand sledge and wooden block
- Empty food tin or bottomless cake pan
- Marker
- Plastic wrap
- 500 mL bottle
- Water
- Stopwatch or timer

The Method
1. Remove top/bottom of tin or so you are left with a metal tube
2. Randomly select one sample site per zone
3. Label these points with numbers, letters or names (e.g. infl) both physically (e.g. using marking sticks) and on your site map so that you are able to come back to them again for taking subsequent measurements
4. Free a 1x1 m area of soil from vegetation and soak it slowly and for several hours with water until saturated (ideally after a substantial rainfall event with clear forecast for the next three days)
5. Clear sampling area/trim vegetation
6. Drive the metal tube in the soil it is half-way in
7. If soil is wet or near field capacity, go to step 8; If soil is dry, pour 500 mL water inside the ring & wait until the surface is exposed
8. Start the timer as you pour 500 mL water as gently as possible into the tin
9. 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.
10. Record time counts for each of the sample sites/management areas in datasheet

**The 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 test throughout the restoration process shows if restoration efforts are successful.

**INDICATOR 8: PH**

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

**The 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 even trees.

**The 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 ponder on what you would like to grow, or how you would like to feed your soil.

**Materials Needed**
- Bag or box to mix soil
- pH paper & chart
- cup
- water
The Method
1. Mix soil from at least 3 points representing each of the zones that exist on your land
2. Fill your cup \( \frac{2}{3} \) full with soil
3. Add water to the cup so that the soil is covered
4. Stir well for 1 minute
5. Completely immerse pH strip in soil solution for 3 seconds
6. Remove strip and rinse quickly with water (from the same source as was used in the solution)
7. Hold pH paper up to the light and compare colour to color table below
8. Identify and record pH value in datasheet
9. Repeat the procedure for the other zones
INDICATOR 9: BIOLOGICAL ACTIVITY IN SOIL

Means of Verification: Earthworms Test
The earthworm test is not suitable for all ecosystems. Please get in touch if you would like to help us develop alternative tests for such cases.

This is the indicator that reflects the biologic activity as an essential component of building soil, cycling nutrients and much more.

The Why
Establishing the number of earthworms present in your soil 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).

The Results
The total number of earthworms present in your sample sites gives a rough indication of ecological functions such as nutrient cycling, soil structure and fertility.

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)

The Method
1. Randomly select one sample site per management area
2. Label these points with numbers, letters or names both physically (e.g. using marking sticks) and on your site map so that you are able to come back to them again for taking subsequent measurements
3. Measure 30x30 cm square plot (NOTE: avoid sampling where earthworm populations might be affected i.e. mulch or compost piles).
4. Dig down 30 cm with a hand trowel/shovel, minimizing damage to the earthworms...
5. Count number of earthworms (against pale-colored background to help locate them)
6. Add mustard solution to the hole and wait for deep-burrowing earthworms to appear (usually within 5 mins).
7. Count the number of deep-burrowing earthworms and add to amount of 3 to obtain total # earthworms
8. Record yearly counts for each of the zones/sample sites in datasheet
9. Rinse earthworms in water and return them to the soil.
INDICATOR 10: SOIL FAUNA

Means of Verification: DIY Tullgren Funnel

The 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.

Materials Needed
- Zip-loc 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)

The 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 half way 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 organism and classify them according to their size (see below)
8. Return the insects to their habitat
9. Repeat this procedure for each soil samples

Adapted from https://www.isqaper-is.eu/soil-quality/visual-soil-assessment/225-soil-fauna
The 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).
**INDICATOR 11: FAUNA DIVERSITY**

Ecosystem restoration is a recipe for better habitats. Measuring changes in biodiversity helps to increase support for this work at a time when many populations of wildlife are in swift decline. In addition to the nature diary (see appendix 2), we propose two ways of monitoring fauna diversity:

**a) Wildlife Quadrat Survey**

**The Why**

To effectively survey changes in biodiversity in your camp we need to gather data in a planned way. This will help us to investigate how biodiversity responds to habitat change over time. This quadrat survey will allow you to do that in a fun and engaging way.

A quadrat is simply an approximately square plot or area that is marked out on a piece of land to identify it as an area to survey wildlife within. The first step is to identify at least one quadrat on your camp that you wish to survey. How many quadrats you wish to survey will depend on how much effort and how many people you have to do the surveys. If you only have up to a few people, and a few hours to spare, we recommend 3 quadrats. If you have a bigger team of 5-6 people or more, and over 3 hours time to spare, we recommend 5-8 quadrats.

The quadrat should ideally be a minimum of 10m by 10m but there are no maximum sizes. The quadrat size depends on what habitat features you might want to include in it. For example; if you want to include a section of stream or pond, you may want to make your quadrat larger (20 x 20 m). If you have trees and want to include those in the quadrat, then perhaps larger still (50 x 50 m).
The Method

(NOTE: This will be different with an app or web-based form)

1. Mark the 4 corners of the quadrat with poles or stakes in the ground to allow easy identification of the quadrat for other surveyors. Remember, the quadrat will remain in the same location for as many years as you wish to survey it.

2. Before starting your survey record the following data on your data sheet (or app): Date; Camp Name; Quadrat ID; Survey Number; Current Weather and if possible Temperature; Number of people participating in the survey; Start Time

3. Define your trajectory and start/end points of the survey (for example you may want to always use the corner on the south east and finish on the north west)

4. Walk through the quadrat from the start to the end point

5. When you encounter a species of interest, record its identity as best you can\(^\text{14}\). If you know the common name or scientific name, record that.

6. Sometimes you might not be able to fully identify a species so in these cases do as best as you can – for example, you might be able to tell that a bird you are looking at is a crow but not know which species of crow it is. Record how many individuals you see in the form of a tally. e.g.

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<th>Survey</th>
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<th>Time</th>
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<th>Beetle</th>
<th>Mouse</th>
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<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

7. When you encounter the next interesting species record on the next row of the data sheet.

\(^{14}\) 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 camp. 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.
8. Keep a tally or count of the number of individuals you see of each species you encounter. Each species encountered should only appear once on a line with the total number of individuals, rather than a separate line for each individual encountered.

9. When you reach the end of your survey record the finish time.

b) Nocturnal Insects

The Why
Many species will play important roles in the ecosystem such as pollinators or species that help with pest/plague control. As a simple proxy for biodiversity, nocturnal insects are a useful group to assess because you don't have to actively look for them. Instead, you can just wait for them as nocturnal insects are attracted to light.

The higher the quality of the ecosystem restoration, the more nocturnal insects you can expect to see. That is likely to be true for the number of species present (diversity) and also the number of individuals of those species (abundance).

The Results
The photographs of the complete surface will be used to calculate how much ‘white’ area remains after 2 hours. Over time you can expect the amount of ‘white’ surface to decrease as habitat quality improves.

Materials Needed
- Headtorch (to get to- and from site)
- Light source
- A light colored vertical surface (2x1.5m) to shine the light on
- Washing line/rope/string & pegs to hang your sheet
- Camera or mobile (cell) phone with camera function

The Method
1. Select one sample site per zone you wish to survey, far from other artificial lights and, if possible, within the quadrat used for the quadrat survey
2. (Make sure that the different sample sites are a minimum of two football fields apart to avoid attracting insects from the other areas. If your site is not bigger than two football fields, one test is ok.
3. Mark the location(s) both physically and on your (digital) site map so that you are able to take subsequent measurements
4. Select an evening that is dry & without wind
5. Find or set up a vertical surface of at least 2x1.5m in the areas you wish to survey (If using a sheet you can do this by attaching the rope to two trees or poles and hanging the sheet over the rope. Alternatively, hang your sheet over a branch or fence.)

6. One hour after sunset time (you can check this on your weather app), switch on the light so it is illuminating the whole surface area for 2 hours (depending on your situation, and the equipment you are using, you might need to adjust the position of the light source to maximise the amount of surface that is lit up)

7. Record date/time of survey

8. At the end of 2 hours take a photograph of the whole surface.

9. Look in more detail at the insects on your surface and take photographs of interesting species you see. You might be surprised by how many species turn up. Why not see how many you can identify using resources such as iNaturalist (see the note below about identification).

10. Send those photos to the ERC team for analysis

11. Repeat the test in other areas as necessary. If you are doing this test at multiple locations it is okay to do this on different nights
INDICATOR 12: FLORA BIODIVERSITY

Means of Verification: Square Method

The Why
Tracking changes in plant biodiversity 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 Results
Healthy, indigenous plant communities are signs of biodiversity, overall ecosystem health and resilience. Repeating the test throughout the restoration process indicates whether we are successfully promoting the species desired in the ecosystem (depending on the goals of the project, we may be aiming at nitrogen fixing plants or native species).

Materials Needed
- A one 1m² 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 hoola hoop, so long as you know its area and it is always 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)

The Method
1. Explore plant encyclopedias/local botany resources to help with flora surveying
2. Randomly select* different points within different zones (avoiding crop production areas where weeding by humans takes place if you can); if possible, do this within the quadrat used for the quadrat survey
3. Label these points with numbers, letters or names both physically (e.g. using marking sticks) and on your site map so that you are able to come back to them again for taking subsequent measurements
4. Place the quadrat on each of the points
5. Count the number of different plant species you can see inside the quadrat
6. Record the values in the datasheet (Optional)
7. Take a picture of the quadrat
8. If possible, identify/record the species names found in each quadrat
9. 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
NOTE: If you would like to know more about the occurrence of certain species at your sites, look into the tab *(Additional) Plant frequency*. The method is similar: the more quadrat samples you dive into, the more you learn about patterns of plant communities.

**INDICATOR 13: TEMPERATURE DIFFERENTIALS**

Means of Verification: Temperature Measurements

**The Why**
Temperature is a crucial ecological factor, 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 °C in temperate ecosystems and at 50 °C in the tropics, while metabolic activity is low under 0 °C and above 40 °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 at different zones within your camp.

One method to do this is described below, but it can be as simple as manually logging surface temperature measurements in each season (just 2 - dry and wet - seasons in the tropics) in each of these zones. What matters is to do so in a consistent manner - taking and recording measurements of the same sites over time for subsequent interpretation.

**The 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. CAMP max surface temperature < BARE FIELD max surface temperature in hot days; CAMP min temperatures > BARE FIELD min surface temperature in cold events), you know you are helping with the process of homeostasis in/around your ecosystem, that it is more resilient to sudden climatic events & weather shocks. So it also stimulates proactive management in the face of potential disturbances (such as droughts or spread of fires).

**Materials Needed**
- Data loggers
The Method

1. Identify sample spots for the zones you wish to study (e.g. neighbouring control site, forest, (silvo)pasture, crop production, etc.)
2. Install data logger(s)
3. Record min/max temperatures, date, geo coordinates/labels, zone and height
4. Repeat the process in all the zones you wish to study
INDICATOR 14: EVAPOTRANSPIRATION RATES

Means of Verification: DIY Atmometer

The 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

The Making of a DIY Atmometer
1. Drill a 15mm hole in center of the bottle cap
2. Glue 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 moisten the cloth on the top also
11. Replace the cap on the bottle and you're done

Adapted from https://xperimentia.com/2012/09/01/a-homemade-atmometer/
The Method
1. Record the date, time and coordinates of each measurement
2. Mark the starting level of water by placing a rubber band around the 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 in your camp, repeat the process in different points and 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

The Results
High evapotranspiration rates usually mean that water may be a limiting resource for plant growth. Such insights can inform your camp’s irrigation programs 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

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 Color test”

The 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\textsuperscript{16} and associated (primary or crop) productivity, soil trafficability* 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).

\*defined as a soil’s capability to support agricultural traffic without degrading soils and ecosystems

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

Materials Needed

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

The Method

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 ziploc 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 ziplock bag to transfer to the lab (0.7 litres of soil should be sufficient).

\textsuperscript{16}SOM contains nearly all soil N and typically the majority of CEC
The 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 calibrate or validate SOC estimates based on satellite imagery and mathematical relationships.

Additional References and maps with predicted SOC values:
- [https://www.soilgrids.org/](https://www.soilgrids.org/)
- [https://www.isric.org/explore/soil-geographic-databases](https://www.isric.org/explore/soil-geographic-databases)
- (restor)
Means of Verification (2): Soil Colour Test

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

The 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 color 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

The Results

- 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

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”
INDICATOR 16: (REMOTE SENSING) LAND COVER CHANGE

Means of Verification: High Resolution Satellite Imagery + Groundtruth (CROWTHER LAB)

The Why
Effective ecological 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.

The Method
Land cover change is being tracked by different platforms, often based on the same datasets. 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.

Thus, successful monitoring of land cover change also depends on validating such 'computed' datasets with ground information at/around the camps, as well as the consistent use of such datasets (i.e. without shifting between different remote sensing datasets). Nevertheless, there are many datasets that show land cover (and land use) changes through time. By uploading your 'camp's polygon', you are able to understand what preceded your interventions as well as what the trends are in the landscape surrounding you.

Additional References & (free) options to monitor land cover change:
- Global Forest Watch is a versatile tool that allows uploading of (kmz or kml camp) polygons. Besides providing near real-time data on how forests are changing worldwide, its maps include datasets/layers of land cover, land use, climate and biodiversity too. (www.globalforestwatch.org/map/)
**INDICATOR 17: ‘CAMP PRODUCTIVITY’**

This indicator is relevant for camps where (regenerative) agricultural practices are in place. The definition of camp productivity is usually - but not necessarily - associated with the economic benefits a camp is deriving from ecosystems.

**Means of Verification: Camp Yields**

**The Why**
As a measure of the above-ground biomass, monitoring your 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.

**The 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. The meaning of your results depends on your camp’s objectives. The results of this test are particularly informative when analysed alongside with other ecological attributes.

**Materials Needed**
- Scale
- Notebook (to record mass of each harvest)
- Sitemap

**The Method**
1. Determine what ‘products’ you want to monitor over time and classify them accordingly (e.g. as ‘annuals’, ‘perennials’, ‘animal products’, ‘timber’, etc.) (Although we hope to see diverse (agro)ecosystems, you might only be able to-/interested in monitoring one or two crops, 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 the date and weight of each harvest of the respective products in your ‘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
7. Repeat the process as often as you want to monitor changes in your yields
<table>
<thead>
<tr>
<th>Products</th>
<th>Product type</th>
<th>Surface area (ha)</th>
<th>Total harvest (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crop 1</td>
<td>annuals</td>
<td>...</td>
<td>(after 1 year)</td>
</tr>
<tr>
<td>Crop 2</td>
<td>annuals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>etc</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSION

We hope that this guide provides you with the information and tools that you need to collect data according to the Ecosystem Restoration Camps framework. It is our ambition to be able to collect data from all of our camps so that we can show the world how effective they are at sequestering carbon, increasing biodiversity, increasing water holding in the soil, building community, strengthening livelihoods and increasing skills and knowledge.
APPENDIX 1: EXAMPLES OF 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 camp?** (Consider sun-orientation and wind exposure)
APPENDIX 2 NATURE DIARY

To begin studying nature and biodiversity across ERC camps we need to gather information and data on a regular basis to find out what is active in your individual camp.

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 time in camp.

The data that contributes to the diary can consist of a combination of observations of animals that are encountered at the camp 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 camp. 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 different ways, choose something that works for your situation. You could print out the form below and take it into the field, you could use the google survey form provided and fill that out from your mobile phone, or you could use a voice recording app on your mobile phone and record your encounter that way. Having a blackboard or whiteboard in the communal area of the camp where people can add their recent sightings is a great way to share what people have been seeing with the camp 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 camp.

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:

<table>
<thead>
<tr>
<th>Camp Name</th>
<th>The name of the camp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>The date of the observation</td>
</tr>
<tr>
<td>Time</td>
<td>The time of the observation</td>
</tr>
<tr>
<td>Observer Name</td>
<td>The observers name</td>
</tr>
<tr>
<td>Species Name</td>
<td>The common or local name of the species observed (if known)</td>
</tr>
<tr>
<td>Scientific Name (if known)</td>
<td>The scientific name of the species (if known)</td>
</tr>
<tr>
<td>Location on camp</td>
<td>Where on the camp 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.</td>
</tr>
<tr>
<td>Description of encounter</td>
<td>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.</td>
</tr>
<tr>
<td>Behaviour</td>
<td>Describe what the animal was doing when you saw it, e.g. feeding, climbing, mating, sleeping, flying etc.</td>
</tr>
<tr>
<td>Nearby vegetation</td>
<td>Describe the nearby vegetation, what crops are being grown in the area of the observation?</td>
</tr>
<tr>
<td>Weather and temperature</td>
<td>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.</td>
</tr>
<tr>
<td>Number of Individuals</td>
<td>How many individuals of the species did you see in this encounter?</td>
</tr>
<tr>
<td>Certainty (certain, likely, unsure)</td>
<td>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.</td>
</tr>
</tbody>
</table>
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, lifestage)
Were there any other things you noticed that might be of interest? Could you tell the sex or the lifestage 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 & ABBREVIATIONS

- **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 camp actin as control against which progress on restoration activities is measured; albeit less reliable, ‘[control sites]’ may also function as a references/points of departure
- **Datasheet**: refers to the place where you can log the data you are collecting at your camp.
- **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).
- **ERC**: the Ecosystem Restoration Camps foundation
- **Ecosystem restoration camps**: are locations for people around the world to participate in ecosystem restoration; living laboratories where effective ecosystem restoration techniques are developed and spread through education.
- **Evaluation**: the analysis of data collected during the monitoring period in relation to the established goals/outcomes
- **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).
M&E: Monitoring & Evaluation

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 at the camps, and enhance

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

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

Sample site: herein broadly defined as the area that will be assessed/sampled; sample site(s) should be representative of the different zones.

Standardisation: in our context, is the process of implementing/developing standards based on wide (scientific) consensus. Standardized methodologies help ensure compatibility, repeatability and quality of measurements.

Zone(s): refer to the different areas/locations of your camp as defined in the design of the site. The criteria used to designate each zone will vary per camp—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.
REFERENCES