Regeneration Credit: Sintropia Method

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Abstract

The Regeneration Credit is a (P2P) funding system designed to incentivize the regeneration of ecosystems. To measure the amount and diversity of trees and plants, the protocol relies on an on-chain RegenerationIndex and on off-chain evaluation methods. This document describes the Sintropia Method, the first methodology registered within the protocol, designed to assist inspectors in performing field data collection via a mobile application.

1 How to evaluate regeneration?

Measurement of the level of regeneration of an ecosystem is a great challenge. Many variables and indicators can be used. It is so complex that it is a science without an end, we can always improve to get better results. But there is a fact: All methods for measuring carbon, biodiversity, water, soil, or other regeneration indicators did not get the final result right. Therefore, when a project estimates the amount of carbon stored, it is only an estimation based on a methodology and not the true result of the amount of carbon present. The reason is that life is too complex for us to perfect measure it, at least yet. The core indicators, *Trees Count* and *Species Diversity*, are simple, universally understandable proxies for ecosystem health. While they do not capture the full complexity of an ecosystem, they provide a robust and verifiable signal that the process of natural succession is being actively supported.

It is not that we should not seek the greatest possible precision in the result, but what is important is not the final result, but the direction in which life is heading. Is it going on the direction of becoming a forest or the native ecosystem of the area? If the answer is yes, the goal is being achieved.

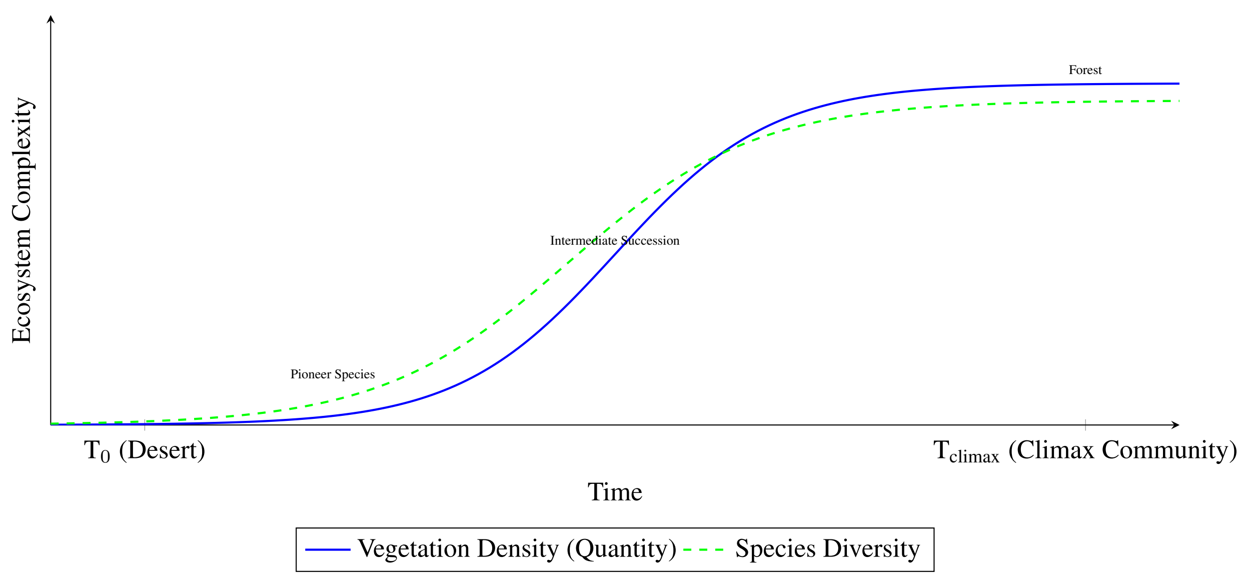

Figure 1: Conceptual graph of natural succession. Over time, an area transitions from barren land (low density and diversity) towards a climax community or forest (high density and diversity).

2 The Regeneration Index Scoring Mechanism

To standardize the evaluation, the protocol employs a smart contract, the *RegenerationIndexRules.sol*, which converts raw data from inspections into a single, quantifiable score. This contract serves as an immutable, on-chain rulebook that defines the official scoring criteria. The index is built upon two core, verifiable indicators: the quantity of trees and the level of biodiversity.

`Trees` This indicator measures the total quantity of trees, palm trees, and other significant plants (defined as being over 1 m in height and 3 cm in diameter) within the designated regeneration area. It serves as a direct proxy for biomass accumulation and the physical structure of the recovering ecosystem.

`Biodiversity` This indicator measures the number of distinct species among the qualifying plants described above. It acts as a proxy for the ecological richness and resilience of the area, rewarding diversity over monoculture plantations.

For each of the two categories, the raw number reported by the Inspector is mapped to one of seven "Regeneration Index Levels." Each level has a name and a corresponding point value. The specific thresholds required to achieve each level are defined in the contract and presented in Table 1 and Table 2.

Table 1: Scoring Thresholds for the **Trees** Category

Required Tree Count	Assigned Level	Points Awarded
$\geq 50\,000$	`REGENERATIVE 6`	32
$25\,000 \leq \text{count} < 50\,000$	`REGENERATIVE 5`	16
$12\,500 \leq \text{count} < 25\,000$	`REGENERATIVE 4`	8
$6250 \leq \text{count} < 12\,500$	`REGENERATIVE 3`	4
$3125 \leq \text{count} < 6250$	`REGENERATIVE 2`	2
$20 \leq \text{count} < 3125$	`REGENERATIVE 1`	1
< 20	`NEUTRO`	0

Table 2: Scoring Thresholds for the **Biodiversity** Category

Required Species Count	Assigned Level	Points Awarded
≥ 160	`REGENERATIVE 6`	32
$80 \leq \text{count} < 160$	`REGENERATIVE 5`	16
$40 \leq \text{count} < 80$	`REGENERATIVE 4`	8
$20 \leq \text{count} < 40$	`REGENERATIVE 3`	4
$10 \leq \text{count} < 20$	`REGENERATIVE 2`	2
$5 \leq \text{count} < 10$	`REGENERATIVE 1`	1
< 5	`NEUTRO`	0

The final `RegenerationScore` for a given inspection is calculated as the sum of the points awarded for each of the two categories.

$$RegenerationScore = \text{Points}_{\text{Trees}} + \text{Points}_{\text{Biodiversity}}$$

This resulting score serves as a key input for the protocol's reward distribution mechanisms, creating a direct link between verifiable ecological outcomes and the economic incentives for the Regenerator. As a result of the index, to increase rewards, a Regenerator should provide services guiding the area into the direction of becoming an extreme dense biodiverse forest.

2.1 Off-chain Evaluation Methods

To bridge the gap between complex real-world analysis and the simplified on-chain indicators, the protocol allows for the integration of off-chain evaluation methods. These are tools and methodologies, proposed and registered on-chain by *Researchers*, designed to assist *Inspectors* in their data collection work.

3 The Sintropia Method

The Sintropia Method is the first off-chain evaluation method registered in the protocol. It is implemented as a mobile application (the ”Sintropia App”) designed to guide inspectors through a standardized process for data collection. The application is available as an APK via a public GitHub repository and on major mobile application stores.

3.1 Methodology Overview

The method standardizes the collection of the two core indicators: `Trees` and `Biodiversity`. A ”qualifying plant” is defined by a standard cut-off threshold:

- Minimum height: 1 m
- Minimum diameter at 1m height: 3 cm

For all data collection, the inspector registers findings using the application. For each entry (species or individual plant), the application captures a photographic record and the corresponding geospatial coordinates (geolocation) at the time of registration.

The registration of **Biodiversity** is consistent across both collection modes: for each distinct species identified in the area that meets the cut-off criteria, the inspector must capture one photo and its location.

3.2 Data Collection Modes

The Sintropia App offers two distinct modes for quantifying the `Trees` indicator, providing flexibility for different area sizes and densities.

Manual Method In this mode, the inspector is required to traverse the entire designated area and manually register *every individual plant* that meets the cut-off criteria. Each registration involves capturing a photo and geolocation. This method is highly accurate but labor-intensive, making it most suitable for smaller or sparsely vegetated areas.

Sampling Method For larger areas, a statistical sampling method is provided. The inspector defines a circular sample plot by specifying its radius, r. The inspector may repeat this process for k number of sample plots, choosing new random locations for each. Within each plot, the inspector registers every individual plant (n_i) meeting the cut-off criteria. The application then computes the average count from all samples and extrapolates this average to estimate the total population for the entire area.

3.3 Statistical Extrapolation (Sampling Mode)

The extrapolation algorithm is based on calculating the *average density* of qualifying plants across multiple sample plots and applying this density to the total area of the regeneration project.

Let:

- A_{total} be the total area of the regeneration project (in m^2).
- r be the radius of the circular sample plot (in m).
- k be the total number of sample plots measured by the inspector.
- n_i be the number of individual plants counted within the i-th sample plot (for $i = 1, \ldots, k$).

First, the area of a single sample plot (A_{sample}) is calculated (assuming a constant radius r for all k plots):

$$A_{\text{sample}} = \pi \cdot r^2$$

Next, the *average number of plants* per sample plot ($\bar{n}$) is computed from the k samples taken:

$$\bar{n} = \frac{1}{k} \sum_{i=1}^{k} n_i = \frac{n_1 + n_2 + \cdots + n_k}{k}$$

Using this average count, the *average plant density* ($\bar{\rho}$) is determined:

$$\bar{\rho} = \frac{\bar{n}}{A_{\text{sample}}} = \frac{\bar{n}}{\pi \cdot r^2}$$

Finally, the estimated total number of trees (N_{total}) for the entire project area is extrapolated by multiplying this average density by the total area:

$$N_{\text{total}} = \bar{\rho} \cdot A_{\text{total}} = \left(\frac{\bar{n}}{\pi \cdot r^2}\right) \cdot A_{\text{total}}$$

Example: In a project area (A_{total}) of $100\,000\,\mathrm{m}^2$ (10 hectares), an inspector uses a $5\,\mathrm{m}$ radius ($r = 5$) and takes $k = 3$ samples.

- Sample 1 (n_1): 40 trees
- Sample 2 (n_2): 45 trees
- Sample 3 (n_3): 38 trees

The calculation would be:

1. $A_{\text{sample}} = \pi \cdot (5)^2 \approx 78.54\,\mathrm{m}^2$
2. $\bar{n} = (40 + 45 + 38)/3 = 123/3 = 41$ trees (average)
3. $\bar{\rho} = 41/78.54 \approx 0.522$ trees$/\mathrm{m}^2$
4. $N_{\text{total}} = 0.522 \cdot 100000 \approx 52\,200$ trees

3.4 Reporting and Verification

Beyond the quantitative data, the method mandates the collection of verification imagery.

- **Proof of Presence:** The inspector must obligatorily capture a photograph that includes the Regenerator (or their representative) at the inspection site.
- **Area Photos:** The inspector can supplement the report with additional photographs of the area, captured either with the mobile device or from other sources, such as drones.

Upon completion, the application generates two distinct reports:

1. **Inspection Report:** A document containing the final calculated results for the `Trees` count and the `Biodiversity` count.
2. **Photo Report:** A compilation of all photographic evidence collected, including species identification, individual plant records (in Manual mode), and verification photos.

These reports provide the necessary off-chain evidence for the inspector to download and subsequently call the `realizeInspection` function on the protocol's smart contracts.

4 Current Limitations and Proposed Improvements

The Sintropia Method and its reference application represent a foundational first step (MVP). Significant improvements are both possible and necessary.

- **Image Quality:** A primary limitation is the quality of the stored images. Due to technical constraints on the maximum size of the generated reports, images are currently downscaled, resulting in low resolution. Future development should focus on strategies (e.g., improved compression, decentralized storage links, or alternative report structures) to accommodate high-resolution imagery for better verification.
- **Collection System Enhancements:** The data collection workflow itself can be optimized. This includes improving the user interface (UI/UX) for inspectors, refining the random sampling process, and enhancing the precision of geospatial data capture.

5 Development and Collaboration

The project is open-source, and contributions from the community are encouraged.

5.1 Project Repository

The source code and APK releases for the Sintropia App are hosted on GitHub:

- **Repository:** `https://github.com/Sintrop/Sintropia-method`

5.2 Key Contributions

The initial front-end development of the Sintropia App was contributed by Emanoel A. Freires. The development work was done with 14 PRs can be reviewed via the following pull requests:

- **Pull Request 1:** `https://github.com/Sintrop/Sintropia-method/pull/1`
- **Pull Request 3:** `https://github.com/Sintrop/Sintropia-method/pull/3`
- **Pull Request 4:** `https://github.com/Sintrop/Sintropia-method/pull/4`
- **Pull Request 14:** `https://github.com/Sintrop/Sintropia-method/pull/14`
- **Pull Request 15:** `https://github.com/Sintrop/Sintropia-method/pull/15`
- **Pull Request 16:** `https://github.com/Sintrop/Sintropia-method/pull/16`
- **Pull Request 17:** `https://github.com/Sintrop/Sintropia-method/pull/17`
- **Pull Request 18:** `https://github.com/Sintrop/Sintropia-method/pull/18`
- **Pull Request 20:** `https://github.com/Sintrop/Sintropia-method/pull/20`
- **Pull Request 22:** `https://github.com/Sintrop/Sintropia-method/pull/22`
- **Pull Request 24:** `https://github.com/Sintrop/Sintropia-method/pull/24`
- **Pull Request 25:** `https://github.com/Sintrop/Sintropia-method/pull/25`
- **Pull Request 27:** `https://github.com/Sintrop/Sintropia-method/pull/27`
- **Pull Request 28:** `https://github.com/Sintrop/Sintropia-method/pull/28`

6 Future Work and Invitation

The Sintropia Method is a starting point for a broader ecosystem of on-the-ground evaluation tools. We invite researchers, developers, ecologists, and data scientists to collaborate on two primary fronts:

1. **Iterating on the Sintropia Method:** Enhancing the statistical robustness of the sampling methodology, improving the application's features, and refining the data verification process.
2. **Developing New Methodologies:** Proposing and developing entirely new off-chain methods that can be registered with the protocol.

The long-term vision is to integrate complementary technologies to increase the accuracy, scalability, and cost-effectiveness of ecosystem measurement. Future possibilities include:

- **Drone and Lidar Surveys:** Utilizing aerial photogrammetry and Lidar to automate tree counting and biomass estimation.
- **Satellite and Remote Sensing:** Employing multispectral satellite imagery and machine learning models to assess regeneration indicators over vast areas.

7 Conclusion

The Sintropia Method, as the inaugural off-chain evaluation tool for the Regeneration Credit protocol, establishes a foundational framework for verifiable ecosystem regeneration. By providing a clear, mobile-app-driven process for quantifying tree count and species diversity, it bridges the gap between on-the-ground ecological dynamics and on-chain incentivization. While the current implementation marks a significant first step, the pathway for continuous improvement is broad, inviting a collaborative community of researchers and developers to refine its accuracy, enhance its technological integration, and explore advanced methodologies.