
Food and Agriculture
Organization of the
United Nations
The Global Soil Health Index
Methodology
Luis Rodriguez Lado
18th Meeting of the
International Network
of Soil Information
Institutions (INSII)
15-16-17 January 2025
INSII
GLOBAL SOIL
PARTNERSHIP

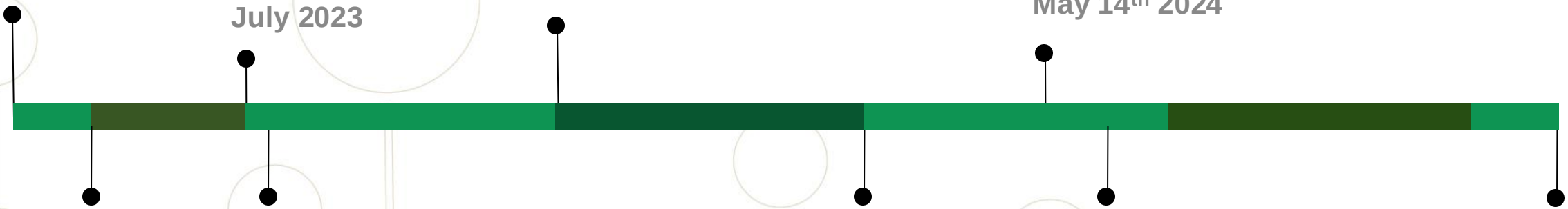
Timeline

ISAF 1st Meeting
Introduction - Zero Draft
April 2023

ISAF 3rd Meeting
Second Draft
July 2023

9th INSII
Presentation
Nov 2023

ISAF 5rd Meeting
Fourth Draft
May 14th 2024



May 2023
ISAF 2nd Meeting
First Draft

July 11th 2023
11th GSP PA
Presentation and request PA to delegate INSII

March 2024
ISAF 4th Meeting
Third Draft

June 2024
12th GSP PA
Final Draft Presented

Jan 2025
10th INSII
WE ARE HERE

Conceptual Approach for GSHI - May 2023 - 1st Draft

$$SHI = (SI_1 \, x \, W_1) + (SI_2 \, x \, W_2) + \ldots + (SI_n \, x \, W_n)$$

Soil Health Index

Score for the Indicator 1

Score for the Indicator 2

Weight

Weight

where:

- ***SHI: SI1, SI2, …, SIn:*** Scores for each of the n soil indicators, classified into poor, fair, good, or excellent categories based on predetermined ranges or cutoff values. Scores are assigned values of 1 to 4, with 4 being the highest score for an excellent category, and 1 being the lowest score for a poor category.

W1, W2, …, Wn: Weights assigned to each soil indicator in the SHI equation, expressed as percentages of the overall SHI. The weights can be adjusted based on the specific needs and objectives of a given study or management practice

Conceptual Approach for GSHI - May 2023 - 1st Draft

Candidate Indicators for GSHI

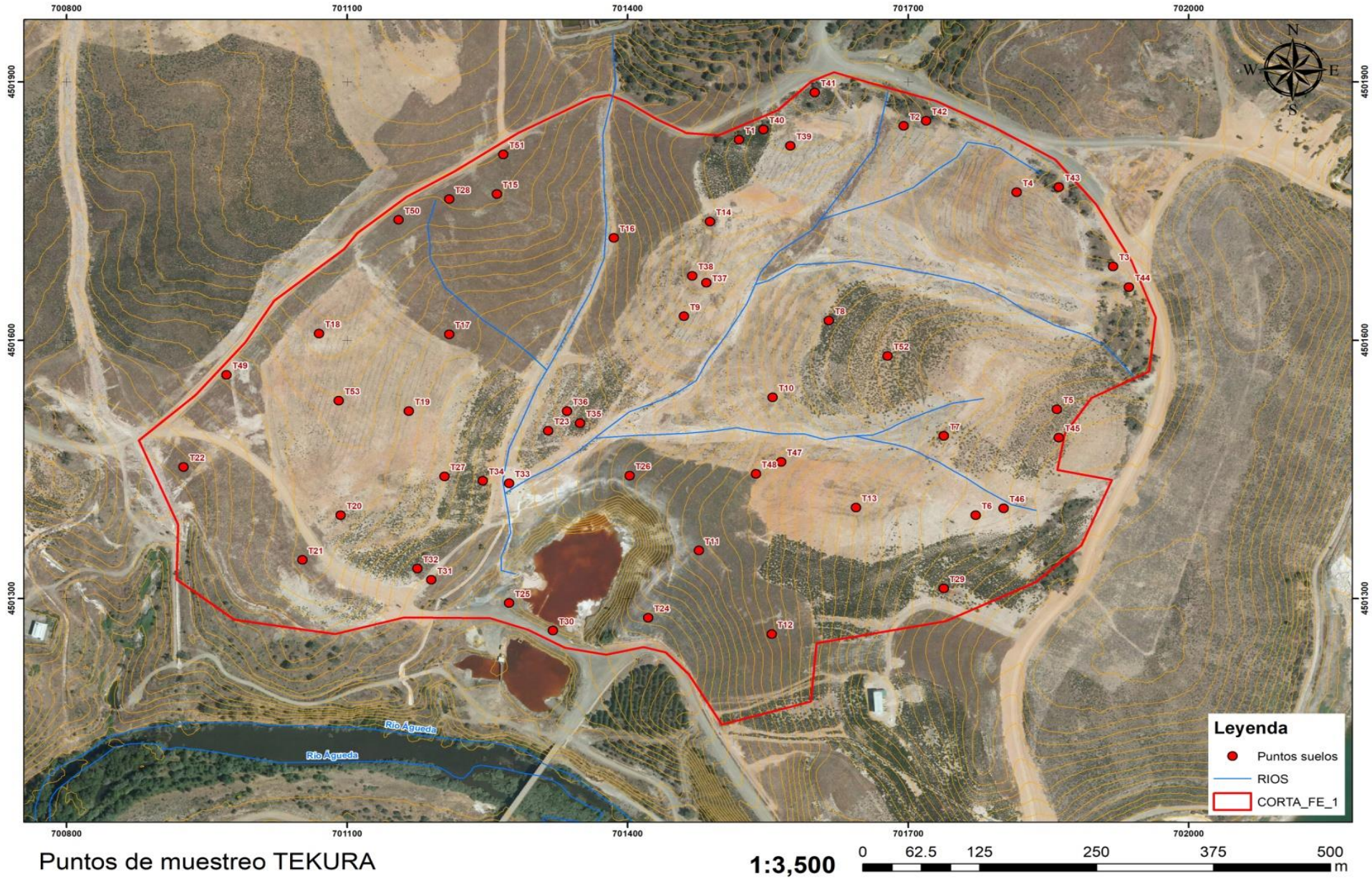
Indicator (SI)	Readiness*	Poor	Fair	Good	Excellent	SHI Weight (%)
Predicted SOC Stocks (tonnes/ha)	GSOCmap	<10	10-30	30-80	>80	20%
Predicted SOCseq Potential (tonnes/ha/yr)	GSOCseq	<0.2	0.2-0.5	0.5-1.0	>1.0	10%
Measured or Predicted Electrical Conductivity (EC) (dS/m)	GSASmap	>4	2-4	1-2	<1	5%
Predicted Annual Soil Erosion (water) (tonnes/ha/yr)	ESDAC	>5	2-5	1-2	<1	10%
Available K Concentration (kg/ha)	GSNmap	<50	50-100	100-200	>200	10%
Available P Concentration (kg/ha)	GSNmap	<5	5-10	10-20	>20	10%
Available N Concentration (kg/ha)	GSNmap	<50	50-100	100-200	>200	10%
Bulk Density (g/cm^3)	GSNmap	>1.6	1.4-1.6	1.2-1.4	<1.2	5%
Soil Microbial Biomass Carbon (MBC) (mg C/kg)	TBD	<50	50-200	200-500	>500	15%
Soil pH	GSASmap	1 (pH < 5.0) or 2 (pH > 8.5)	2 (pH 5.0-5.5 or pH 7.5-8.5) or 3 (pH 5.5-6.5 or pH 6.5-7.5)	3 (pH 6.0-6.5 or pH 7.0-7.5)	4 (pH 6.5-7.0)	5%

GLOBAL SOIL PARTNERSHIP

Soil Health Concept

- **Definition by ITPS**: Soil health is the soil's ability to sustain productivity, diversity, and ecosystem services.
- **Soil Health Index Concept**: A conceptual value adjusted for different ecosystem services and management systems.
- **Thresholds for soil properties** will be assigned considering the ecosystem services that soils provide. The scores for indicators will be assigned for each ecosystem service that soils provide and **these scores will be regionalized based on agro-ecological zones**
- **Benefits**: Provides a comprehensive assessment of soil health in context.

SOIL SAMPLING (TEKURA PROJECT)



Puntos de muestreo TEKURA

1:3,500

0 62.5 125 250 375 500 m

Reactive wetland with an initial spread of hyperreductive and eutrophic basal Technosols


October 2019
Reducing-andic-eutrophic Technosols improve the equilibrium dissolution of the underlying soil and runoff waters.
Hyperacid calderas with jarosite
Leachates from Technosols begins to improve the stormwater pond. From jarosite to ferrihydrite.

Reactive wetland

June 2019. Neutral to alkaline waters. Normal biodiversity in natural waters.


2018


2020

Five weeks after the start of the rain: vegetative growth begins, surface waters become neutral, and the caldera becomes acidic and oxidizing. Biodiversity.

The stormwater pond exhibits Schwermannite stability rather than Jarosite.


End of March 2020
Stormwater pond: From jarosite and alunite to gibbsite, kaolinite, and goethite. From extremophiles to acidic lagoon biodiversity
Caldera. Jarosite-schwermanite equilibrium


April 2020
Kaolinite
Pyrofilite
Kaolinite,
gibbsite
Schwermanite


May 2020


May 2020


May 2020

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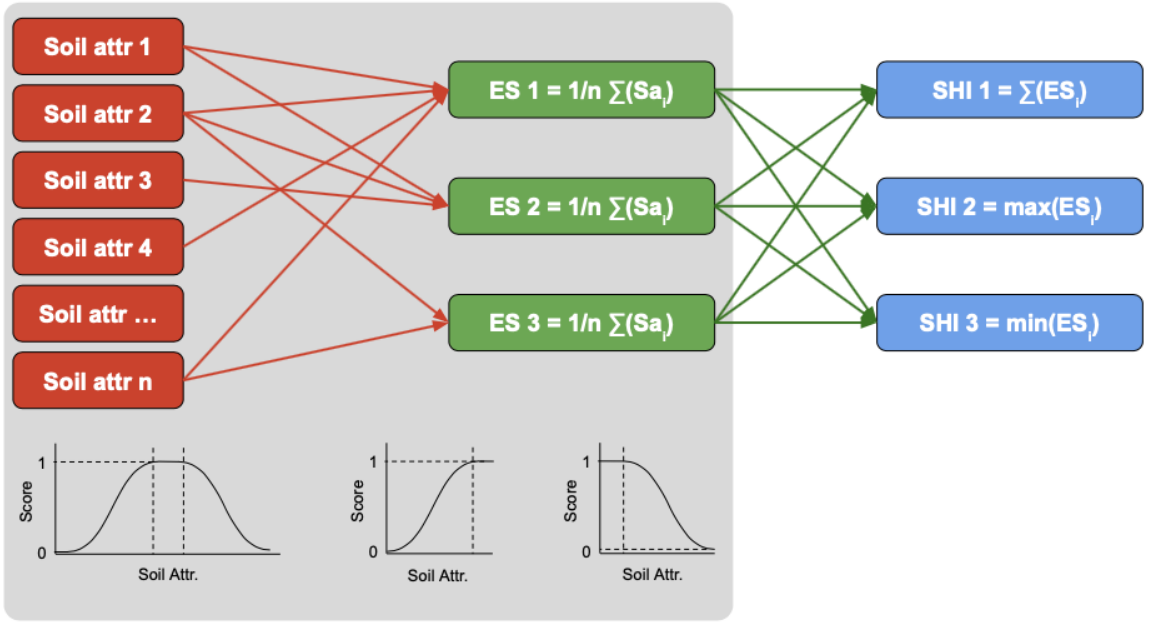
- **Benefits**: Provides a comprehensive assessment of soil health in context.

Conceptual Approach for GSH - July 2023 - 2nd Draft

- **Assessment Tool**: Uses a set of Soil Ecosystem Services for evaluating soil health.
- **Soil Functions**: Determined by physical, chemical, and biological soil indicators by Agro-Ecological Zones.
- **Scoring System**: GSHI based on scores of Soil Functions.



$$SHI = \sum_{i=1}^{n} \left(\frac{1}{m} \sum_{j=1}^{m} SI_j \right)_i$$

Where,

- SHI: Soil Health Index,
- SI_j: Soil indicator for the ecosystem service i, (SI_j ranges from 0 to 1 using a fuzzy logic membership function, and the SHI ranges from 0 to n.)
- m : number of soil indicators for each ecosystem service,
- n : number of ecosystem services.

Soil Health Indicators and related Soil Properties

Soil Ecosystem Service	Relevant Soil Characteristics
Carbon Sequestration (1)	- Soil Organic Carbon stock (t/ha 30 cm) GSOCmap v1.6 and https://soilgrids.org/
Nutrient Cycling (6)	- Soil Organic Carbon stock (t/ha 30 cm) GSOCmap v1.6 and https://soilgrids.org/ - Cation Exchange Capacity (CEC) GSASmap and https://soilgrids.org/ - Base Saturation http://globalchange.bnu.edu.cn/research/soilw *10km - pH https://soilgrids.org/ - Total Nitrogen https://soilgrids.org/ - Total Phosphorus https://world-olsen.agr.nz/ 1km - Total Potassium http://globalchange.bnu.edu.cn/research/soilw *10km
Water Regulation & Storage (4)	- Soil Organic Carbon stock (t/ha 30 cm) GSOCmap v1.6 and https://soilgrids.org/ - Volumetric Water Content http://globalchange.bnu.edu.cn/research/soilw - Soil Texture (Sand, Silt, Clay content) https://soilgrids.org/ - Bulk Density https://soilgrids.org/ - Electrical Conductivity http://globalchange.bnu.edu.cn/research/soilw *10km
Supporting Biodiversity (5)	- Organic Carbon Content https://soilgrids.org/ - pH https://soilgrids.org/ - Soil Texture https://soilgrids.org/ - Bulk Density https://soilgrids.org/ - Electrical Conductivity http://globalchange.bnu.edu.cn/research/soilw *10km

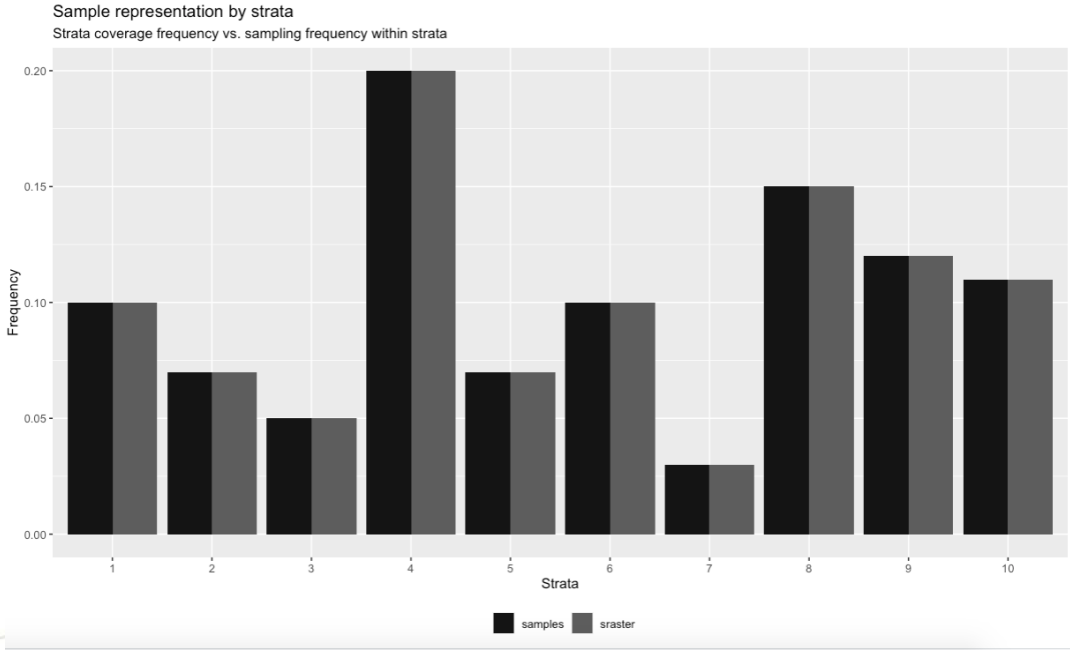
Soil Health Indicators and related Soil Properties

Soil Ecosystem Service	Relevant Soil Characteristics
Erosion Control (3 +2)	- Soil Texture https://soilgrids.org/ - Bulk Density https://soilgrids.org/ - Organic Carbon Content https://soilgrids.org/ **- Vegetation cover, slope**
Filtration and Buffering (4)	- Cation Exchange Capacity https://soilgrids.org/ - pH https://soilgrids.org/ - Soil Texture https://soilgrids.org/ - Organic Carbon Content https://soilgrids.org/
Climate Regulation (2 + 1)	- Organic Carbon Content https://soilgrids.org/ - Soil Albedo (related to texture and moisture content) **- Vegetation cover**
Cultural & Recreational (2)	- General Soil Fertility (influences vegetation and landscape diversity) - Soil Texture https://soilgrids.org/

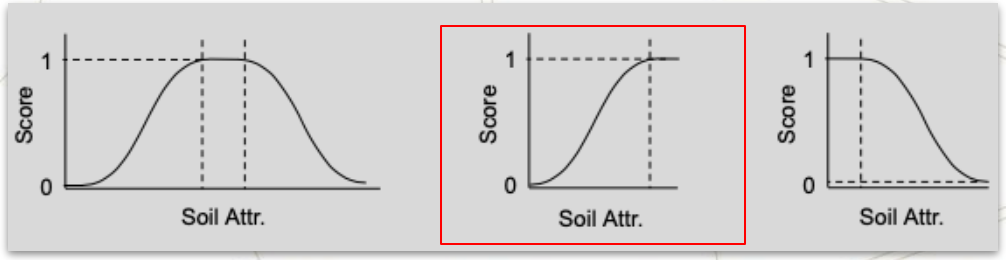
Implementation Procedure

Soil Ecosystem Service - Carbon Sequestration

- **Score calculation**:
  - Stratified random sampling on AEZ strata (20,000 samples/AEZ)
  - Extract SOC values on points
  - Determine the expected shape of the distribution function
  - Calculate ECDF and fit a function (nls)
  - Predict pixel scores upon the ECDF probability



Samples distribution by AEZ



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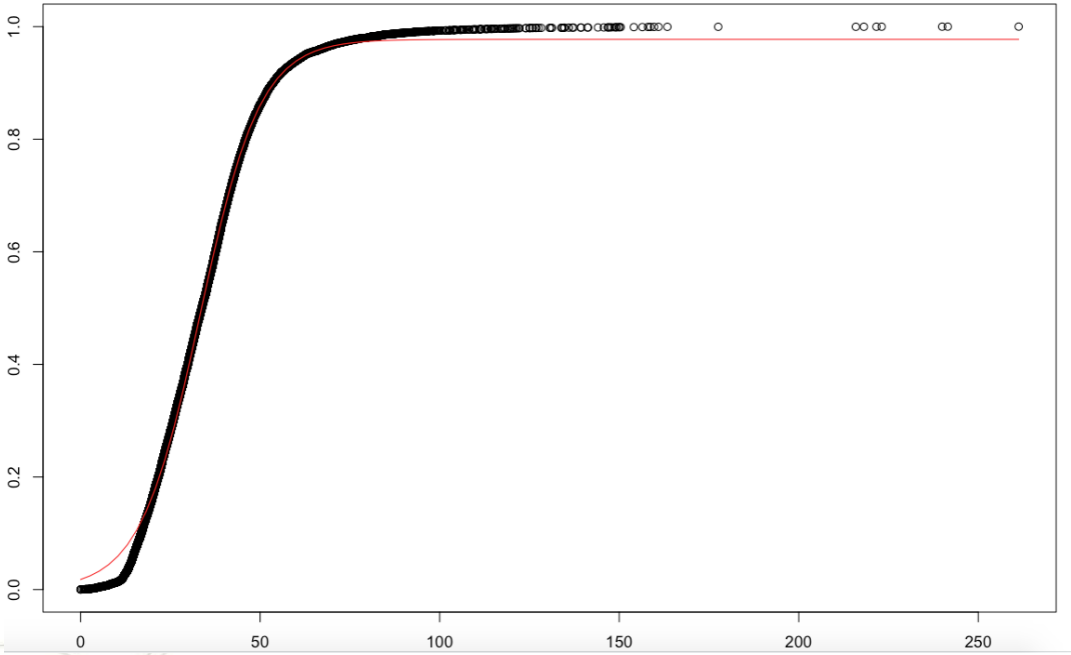
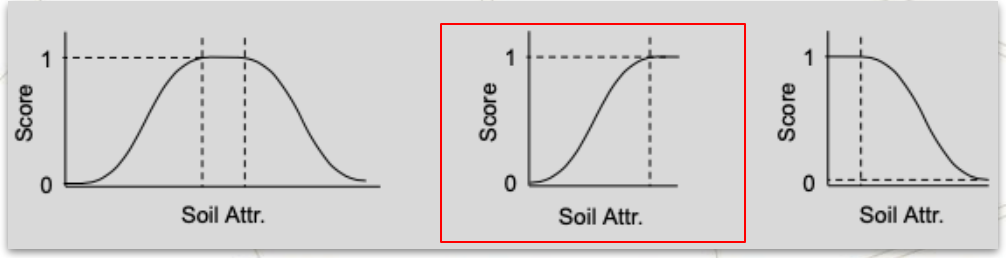
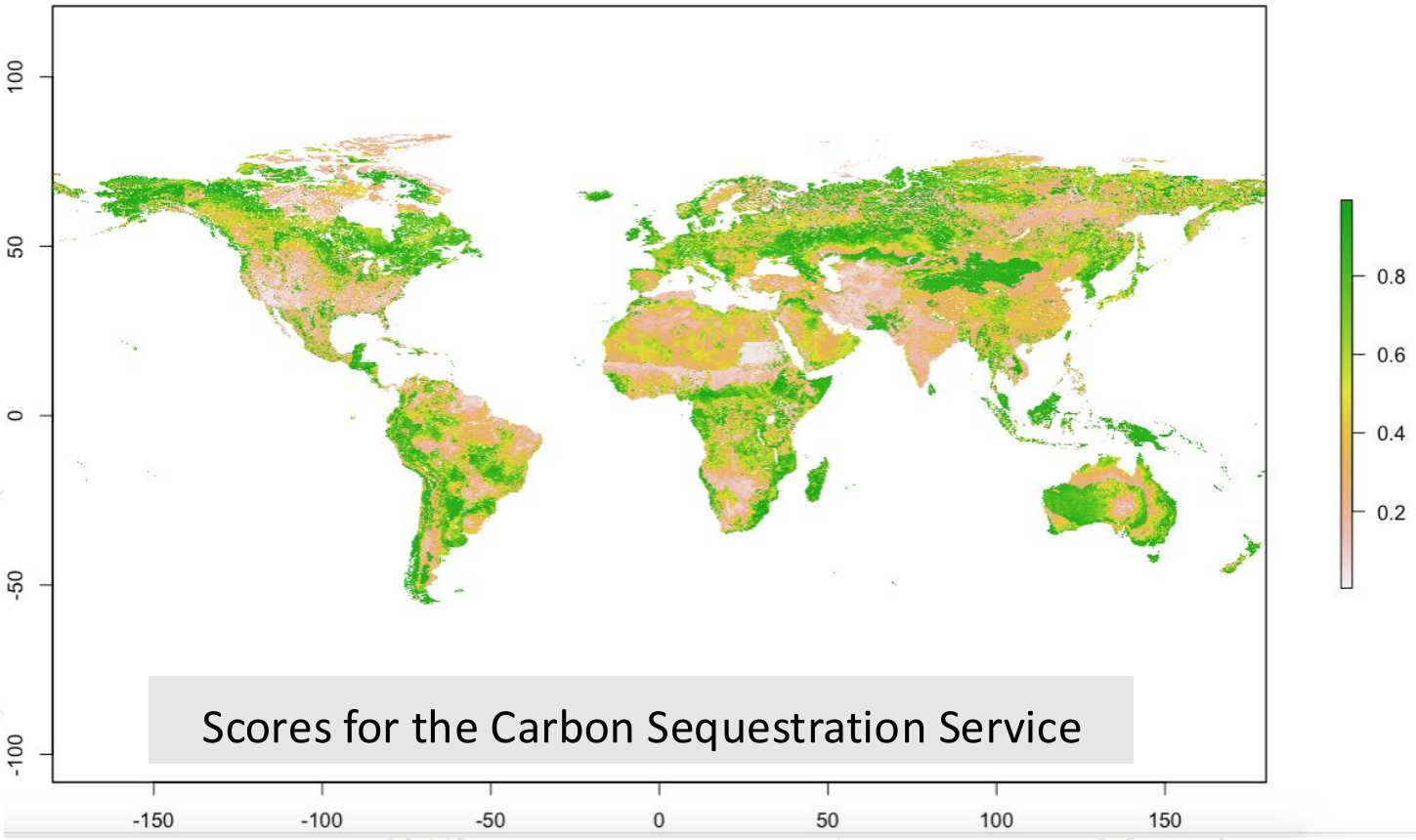


ECDF for SOC in Tropical Savannah and fitted function



Implementation Procedure

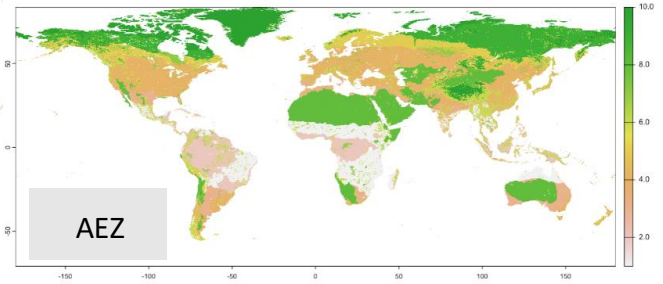
Soil Ecosystem Service - Carbon Sequestration



Scores for the Carbon Sequestration Service

Results:

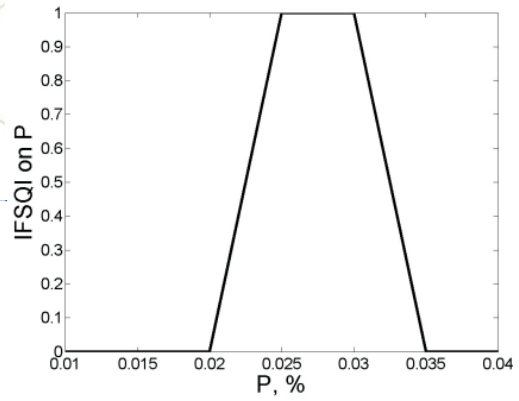
- Scores from 0-1 representing the quantile position between minimum and maximum of SOC in the AEZ .
- The scores are weighted by AEZ
- Values near to 1 indicates that existing SOC values are close to the maximum SOC registered in the AEZ, thus with relative higher carbon sequestration capacity.

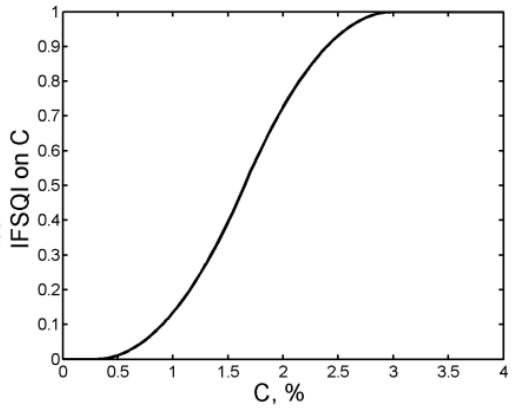


AEZ

Soil attribute intervals within which values of are more suitable for crop production (Kaiumov, 1977)

Soil	pH	SOM (%)	P_2O_5 (mg/kg)	K_2O (mg/kg)
Loam	6.5-7	1.8-2.2	250-280	200-260
Loamy sand	6-6.5	2.0-2.4	200-250	180-200
Sandy	5.5-6	2.2-2.6	180-200	140-160
Turf	5-5.5	-	500-600	600-800

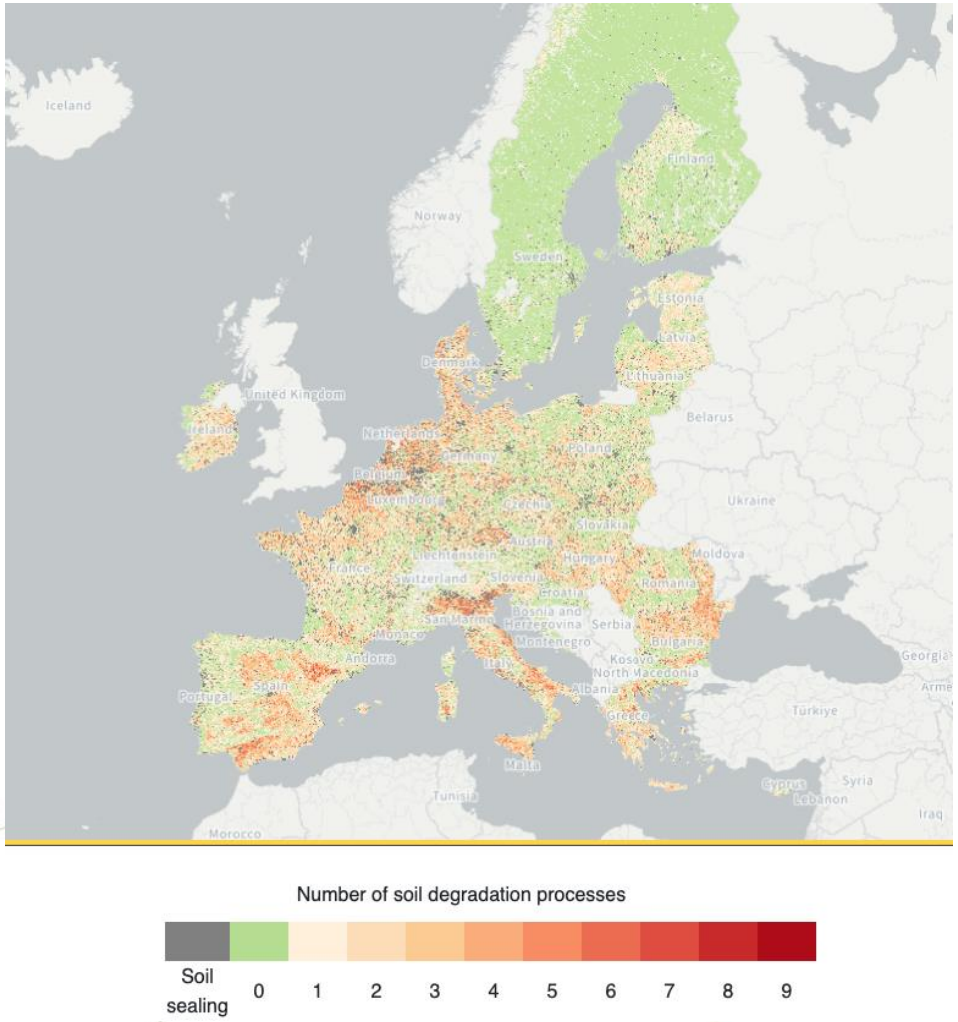




Conceptual Approach for GSHI - March 2024 - 3rd Draft

Last Approach to GSHI. It is calculated as the sum of Degradation Processes occurring at each location.

This approach is **in alignment** with the reported outcomes from the **Status of the World's Soil Resources Report** and the EU Soil Observatory Soil Dashboard.



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GLOBAL SOIL PARTNERSHIP

Indicators and Methodological Approach

Concept Note for the Global Soil Health Index

Soil threats from the Report of the World Soil Resources

1) SOC decline
2) Salinization and sodification
3) Erosion
4) Soil Sealing
5) Nutrient imbalance
6) Biodiversity loss
7) Compaction
8) Acidification
9) Contamination
10) Waterlogging

Soil Threats and Indicators

Domain	Indicator	Metric	Unit	Tier 1 Data	Spatial Res.	Essential/Supplementary1 (E/S)
SOC decline	**Soil Organic Carbon Stock**	**Variation on SOC Stocks**	**Mg/ha**	**GSOCmap**	**1 km x 1 km**	**E**
SOC decline	Soil Organic Carbon Sequestration Potential	Predicted SOCseq Potential	Mg/ha/yr	GSOCseq	1 km x 1 km	S
SOC decline	Soil Organic Carbon Content	Soil Organic Carbon content	% or g/kg	SOILGRIDS	1 km x 1 km	S
Salinization/ sodification	**Electrical Conductivity**	**Measured or estimated EC**	**dS/m at 25ºC**	**GSASmap**	**1 km x 1 km**	**E**
Salinization/ Sodification	Exchangeable Sodium percentage or Sodium Adsorption Ratio	Estimated/Measured ESP or SAR	% or mmol(+)^1/2	GSASmap	1 km x 1 km	S

Soil Threats and Indicators

Domain	Indicator	Metric	Unit	Tier 1 Data	Spatial Res.	Essential/Supplementary
Erosion	**Water Erosion Rate**	**Predicted Annual Soil Loss by Water**	**tonnes/ha/y > TH**	**JRC/ESDAC -Glosem 1.3 -Global Soil Erodibility -EPM**	**100 m x 100 m (crops) 1 km x 1 km 800 m x 800 m**	**E**
Erosion	Water Erosion Rate	Area under severe risk of erosion	ha	Borrelli et al. 2017	250 m x 250 m	S
Erosion	Tillage Erosion Rate	Predicted Annual Soil Loss by Tillage	tonnes/ha/y > TH	N/A		S
Erosion	Wind Erosion Rate	Susceptibility to Wind Erosion	tonnes/ha/y > TH	N/A		S
Sealing	**Soil Sealing**	**Sealed area**	**ha or % of sealed area/pixel**	**N/A**		**E**
Nutrient imbalance	**Soil Nutrient Budget**	**Predicted/Calculated Nutrient Budgets for NPK**	**kg/ha/yr**	**GSNBudget**	**250 m x 250 m**	**E**
Nutrient imbalance	Available Nutrient Contents	Nutrient Concentrations (NPK)	kg/ha >th	GSNmap	250 m x 250 m	S

Soil Threats and Indicators

Domain	Indicator	Metric	Unit	Tier 1 Data	Spatial Res.	(E/S)
Biodiversity loss	**Microbial Activity**	**Soil microbial biomass carbon (MBC)**	**mg C/kg**	**N/A**		**E**
Biodiversity loss	Soil Respiration	CO_2 production	(g C/m^2/day or year?)	Ni, Huang; Li, Wang (2020). Global annual soil respiration from 2000 to 2014		S
Compaction	**Soil Compaction, texture**	**Bulk Density**	**g/cm^3**	**GSNmap**	**250 m x 250 m**	**E**
Acidification	Soil Reaction	Soil pH	N/A	GSNmap	250 m x 250 m	E
Contamination	**Heavy Metal Concentrations**	**Predicted/Measured Heavy Metal Concentrations**	**Ppm > TH**	**N/A**		**E**
Contamination	Contaminated Sites	Number, type of site, type of main pollutant	Integer (#)	N/A		S
Waterlogging	**Soil Drainage**	**Soil Drainage classes**	**NA**	**N/A**		**E**

Concept Note for the Global Soil Health Index

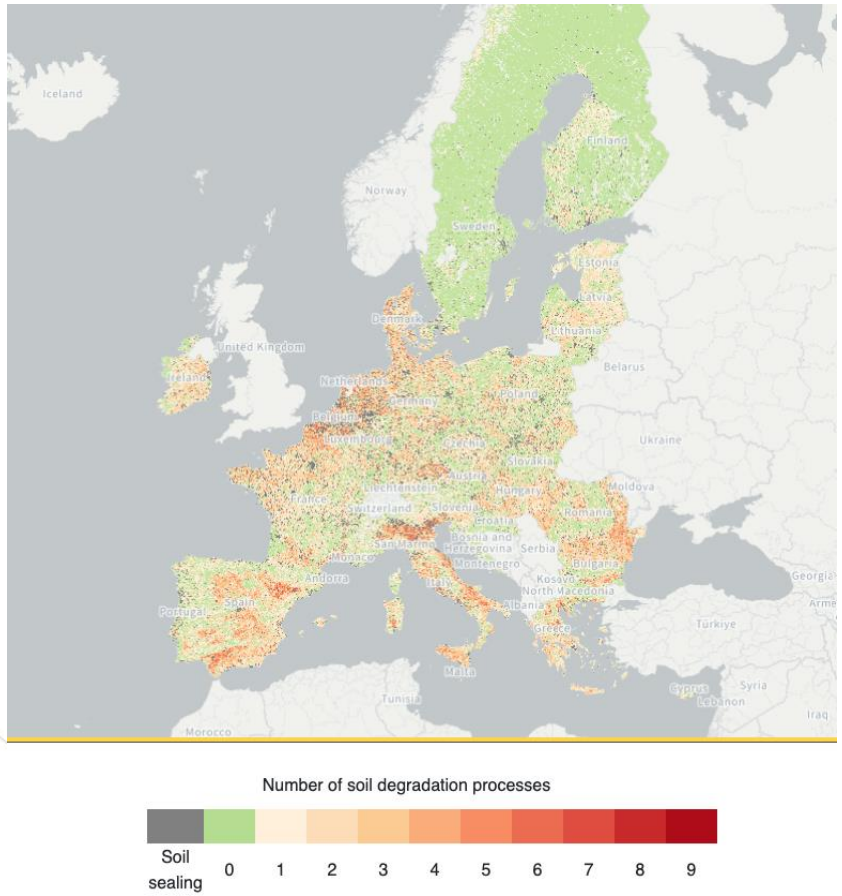
Data Sources : Tier Approach

- **Tier 1:** Use global default datasets as a starting point for GSHI mapping, validated by national experts.
- **Tier 2:** Incorporate country-specific spatial datasets where available, replacing global datasets to improve accuracy.

Concept Note for the Global Soil Health Index

Visualization

- Spatial representation of the GSHI using a **traffic light color-coding system** (green for healthy soils, red for degraded soils) and display specific threats for each location.



Concept Note for the Global Soil Health Index

Reporting Mechanism

- Countries report aggregated assessments as 1 km × 1 km raster maps including metadata (data sources, methods, limitations).
- Establish an official approval process involving national contributors, the ISAF Working Group and INSII to ensure data accuracy and reliability.
- Timespan TBD (aligned with the WSR Report?)

Concept Note for the Global Soil Health Index

Quality Assurance/Quality Control

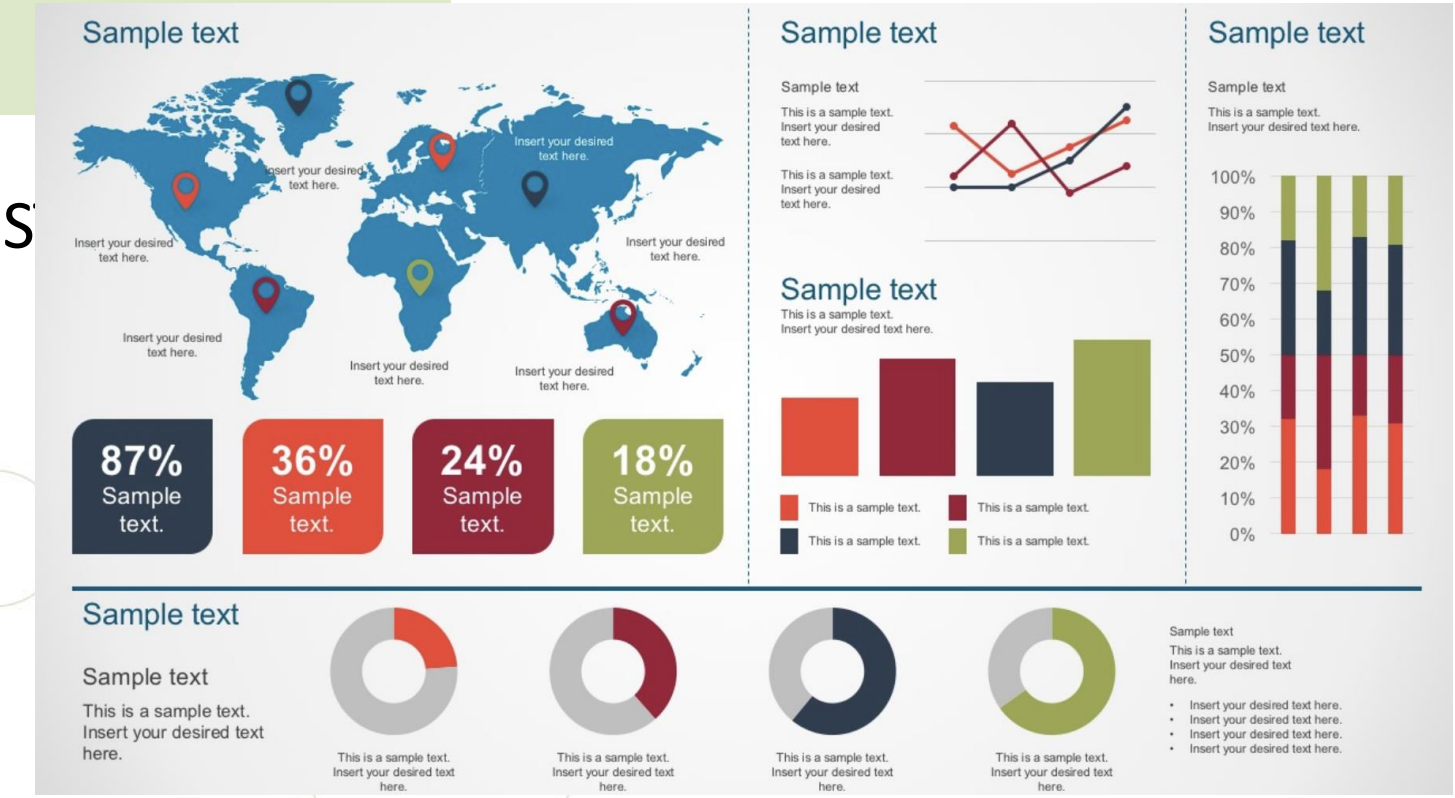
- Implement guidelines for data validation, comparability, and uncertainty assessment.
- Conduct plausibility checks to ensure reported data aligns with expected scientific trends.
- Document and report uncertainties, specifying their sources and impact.

Concept Note for the Global Soil Health Index

GHSI Dashboard

GSHI Dashboard on the SoilS

platform.



Request for INSII

- Evaluate the GSHI methodology and prepare it for endorsement at the next GSP Plenary Assembly.
- Provide expert support to establish thresholds for soil indicators within each soil threat, including potential zonification, particularly for pollution-related threats.
- Encourage countries to contribute national datasets to complement and enhance global datasets.
- Promote partnerships with research institutions to address critical data gaps, particularly in areas such as biodiversity loss, microbial activity, and baseline concentrations for heavy metals.
- Assist in data quality assessment of national contributions to ensure consistency, reliability, and accuracy.
- Facilitate capacity building to support the implementation of the GSHI methodology and the mapping of soil threats.

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