ASES ON-CHAIN PROTOCOL

METHODOLOGY FOR THE ISSUANCE OF VERIFIED SOIL CREDITS

IV. Methodologies V2.2

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INTRODUCTION

Soil health is an essential component of our planet's ecological system, and its deterioration can have serious consequences for the ecosystems and human health. Intensive agriculture and poor land management practices have led to widespread soil degradation associated with increasing topsoil erosion, nutrient depletion, pollution, compaction, and loss of organic matter.

Soil restoration activities have been widely recognized as a crucial tool to improve soil health, which in turn can lead to a range of environmental and societal benefits. To acknowledge, support, and incentivize such efforts, the aOCP offers a methodology to issue soil credits based on the assessment of erosion reduction and soil health improvements resulting from restoration activities.

We have implemented a comprehensive soil credit system that recognizes and rewards efforts in both erosion reduction and soil health improvement. Our system issues two distinct types of soil credits, each targeting specific aspects of sustainable land management. The first type focuses on erosion reduction, acknowledging the implementation of measures and practices that effectively mitigate soil loss. By calculating the erosion reduction in the project area, we quantify the soil credits earned for preventing soil erosion and preserving valuable topsoil. The second type of soil credit rewards improvement in soil health, emphasizing practices that enhance soil health, fertility, and resilience. Physical, chemical and biological indicators are evaluated to determine the credits earned for enhancing overall soil health. By incentivizing both erosion reduction and soil health improvement, we encourage a holistic approach to land stewardship, promoting sustainable soil management practices and ecosystems conservation and restoration.

The objective of this methodology is to provide a standardized framework for measuring the effectiveness of soil restoration efforts and their alignment with the definition of Sustainable Soil Management (SSM) included in the Voluntary Guidelines for Sustainable Soil Management (VGSSM; (FAO, 2017)).

The VGSSM define Sustainable Soil Management as:

“Soil management is sustainable if the supporting, provisioning, regulating, and cultural services provided by soil are maintained or enhanced without significantly impairing either the soil functions that enable those services or biodiversity. The balance between the supporting and provisioning services for plant production and the regulating services the soil provides for water quality and availability and for atmospheric greenhouse gas composition is a particular concern”.

Consequently, SSM supports a number of Sustainable Development Goals (SDGs):

• Sustainable productivity (SDG 2: ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, and that progressively improve land and soil health).

• Soil water availability (SDG 6: freshwater withdrawal as a proportion of available freshwater resources).

• Soil pollution (SDG 11: Make cities and human settlements inclusive, safe, resilient, and sustainable) • Sustainable use of agricultural inputs (SDG 12: achieve the management of chemicals and all wastes, and significantly reduce their release to air, water and soil).

• Soil carbon capture (SDG 13: Take urgent action to combat climate change and its impacts).

• Soil degradation (SDG 15: Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).

Observing the VGSSM principles, the UN SDGs, and the EU Soil Manifesto targets, the elements to be taken into account for the SSM assessment under the aOCP are:

a) Supporting and provisioning services for plant growth for food, livestock, fibre and forestry.
b) Supporting services for above and below ground biodiversity.
c) Regulating services for water quality and quantity.
d) Reduction of land desertification, soil erosion and sealing.
e) Reduction of pollution and restoration enhancement and
f) Regulating services to increase carbon sequestration and limit the emission of greenhouse gases.

It is worth noting that soil health possesses inherent and dynamic characteristics. The former is determined by fundamental soil-forming factors such as climate, parent material, time, topography and vegetation, which are reflected in land capability classifications. The latter reflects the current or past land uses and management decisions, describing the soil's condition or status. This methodology focuses on the assessment of the dynamic properties of soils. Section 2 focuses on the methodology for soil health assessment and crediting, while Section 3 covers the methodology for soil erosion reduction assessment and crediting.

I. Definitions

The following definitions also apply to this technique in addition to those in the most recent edition of the Program Definitions:

- **Erosion:** Process in which the top layer of soil, which provides plants with most of the nutrients and water they need, is lost. When this fertile layer is displaced, the productivity of the land decreases
- **Soil quality index (SQI):** quantitative measurement tool used to assess the overall health and productivity of soil. It integrates physical, chemical and biological indicators to provide an index score that represents the soil's capacity to support plant growth, nutrient cycling, water infiltration, and resistance to degradation.
- **Soil texture:** refers to the relative proportions of different-sized mineral particles present in the soil, including sand, silt, and clay. It is a fundamental property of soil that influences its ability to hold and transport water, retain nutrients, and support plant growth.
- **Soil works:** deliberate construction or implementation of structures and techniques to mitigate erosion and protect the soil. These measures can include the creation of terraces, contour plowing, and planting vegetation on slopes.

II. Methodological considerations

II.1 Application of methodology

To be eligible for registration in the aOCP, Project activities shall meet the following characteristics:

a) The type of Projects that may use this Methodology for the estimation of carbon health and erosion assessment are shown in Table 1.

b) The Project complies with the eligibility requirements, rules, standards and methodologies of the aOCP Program;

TABLE 1. APPLICATION OF METHODOLOGY BY PROJECT TYPE

Type of project	Methodology					
	Soil health and erosion	Biochar	Carbon in vegetation	Carbon in soil	Biodiversity	Water
Regenerative agriculture	✓					
Forest management	✓					
Silvopastoral management	✓					
Urban forest	✓					
Water restoration	✓					
Biochar	✓					
Soil restoration	✓					
Water saving in agriculture	✓					

II.2 ELIGIBLE ACTIVITIES

The Ases On-Chain Protocol is a voluntary program of the Nature Market applicable on a global scale for the certification of biodiversity conservation and restoration projects. Activities eligible for certification can be applied by individuals, non-governmental organizations (NGOs), government organizations, private companies, and/or communities.

This section outlines the activities eligible for inclusion in soil health and erosion assessment projects under the aOCP framework. Eligible activities encompass a range of interventions designed to enhance soil quality and prevent erosion. These activities are critical in mitigating land degradation, soil loss, and supporting ecosystem services.

Type of project	ID	Eligible Activities	Eligible Habitats							
			B	SE	S	M	Q	D	AT	VI
Reforestation/ Afforestation	AD-1	Reforestation with native trees and shrubs.	✓	✓	✓	✓	✓	✓	✓	✓
	AD-5	Afforestation in previously non-forested areas.	✓	✓	✓	✓	✓	✓	✓	✓
	AD-2	Promotion of natural regeneration	✓	✓	✓	✓	✓	✓	✓	✓
Green Infrastructure	GI-1	Vegetation cover planting	✓	✓	✓	✓	✓	✓	✓	✓
	GI-2	Establishing vegetative buffers along waterways (Riparian Buffer Strips)	✓	✓	✓	✓			✓	
	GI-3	Creating grass-planted channels for water Flow (Grass Waterways)		✓	✓	✓	✓		✓	✓
	GI-4	Stabilizing and restoring gullies with vegetation and check dams (Gully reclamation)	✓	✓	✓	✓	✓	✓	✓	✓
Sustainable Agriculture/ Management Practices	MS-6	Implementing contour plowing and planting			✓	✓	✓	✓	✓	✓
	MS-7	Constructing terraces on steep slopes	✓	✓	✓	✓	✓	✓	✓	✓
	MS-8	Applying organic or inorganic mulch	✓	✓	✓	✓	✓	✓	✓	✓
	MS-9	Adding compost, manure, or biochar to enhance soil fertility and structure.	✓	✓	✓	✓	✓	✓	✓	✓
	MS-10	Installing fences around sensitive areas to prevent grazing and allow vegetation recovery.	✓	✓	✓	✓	✓	✓	✓	✓
Agro-forestry and Silvopasture	AS-1	Integrating trees and shrubs into farming systems.			✓	✓	✓	✓	✓	✓
Sustainable Management	MS-1	Sustainable forestry	✓	✓	✓	✓	✓	✓	✓	✓
	MS-3	Regenerative agriculture	✓	✓	✓	✓	✓	✓	✓	
	MS-4	Sustainable grassland management					✓		✓	✓

Habitat classification according to the Red List scheme, version 3.1

B: Forest; SE: Jungle; S: Savannah; M: Thicket; Q: Grasslands; D: Desert; AT: Artificial – terrestrial; VI: Introduced vegetation.

III. METHODOLOGICAL CONSIDERATIONS

III.1. PROJECT BOUNDARIES

III.1.1. PHYSICAL

The physical delineation and/or geographic area of the project activity shall include adjoining polygons that allow for comparison of project impacts and consideration of natural variation beyond the Project area (figure 1). These polygons are:

- Parcel with land ownership. Includes the land where the Project will be implemented. Land tenure corresponds to the area registered in the PSF.
- Microbasin where the Project is located. This polygon will be assessed to acknowledge the Project's impact at microbasin scale.
- Microbasin excluding the Parcel with land ownership. This polygon will serve as control group to assess natural environmental variations outside the Project area. impact at microbasin scale.

III.1.2. SCOPE

Verified Soil Credits under the aOCP can be issued from two types of benefits:

- Soil health improvement
- Erosion reduction.

This aOCP methodology details the assessment of both. Project activities aiming to obtain verified soil credits must specify in the project documentation (PSF, monitoring and verification reports) which scope(s) the project will be assessed for.

IV. BASELINE SCENARIO

The baseline scenario represents the expected outcome if the Project activities were not implemented. This baseline scenario should consider factors such as existing land use practices, regulatory requirements, and environmental conditions.

Soil erosion will be assessed for 4 scenarios, the first two form part of the baseline scenario:

1. Before degradation (optional). If the Project area experienced land use change before the start of the project. This scenario is representative of the original cover and serves to define the restoration target.

2. After degradation. Representative of the Area degraded and before Project implementation, experiencing high rates of erosion. This scenario represents the starting point from which Project activities' benefits will be measured.

3. After project implementation. Representative of the Project area once restoration activities took place. This scenario serves to acknowledge the initial impact of Project implementation.

4. Restored scenario. Is the expected outcome of the project once the Project reaches maturity. There are two ways to establish it.

a) Asynchronic: the Project area will be compared with itself before degradation (if scenario 1 is available).

b) Synchronic: an area with the best ecological conditions, at the moment of Scenario 2 assessment, will be selected within the microbasin (at a comparable land use). This will be done in areas within the microbasin with similar conditions at the beginning of the project and which do not undergo anthropogenic land use/land cover change. This will allow the comparison of the natural evolution of soil erosion in the absence of restoration activities.

In order to smooth and account for differences due to natural variation (plant phenology, rainfall, cloudiness, temperature, soil moisture, etc), Soil erosion will be assesses quarterly at the end of each season, a yearly average will be used for the estimation of Project's impact.

IV.1. ADDITIONALITY

Additionality of nature-based solution projects consist in the determination of the genuine environmental benefits resulting from the project's implementation. This assessment ensures that the project's impacts are accurately measured, providing a solid basis for evaluating its effectiveness and supporting Verified Nature Positive Credits issuance.

Additionality can be evidenced by combining the applying the following approach:

- The first step is to establish the baseline scenario.
- By comparing the expected outcomes of the counterfactual scenario with the actual project outcomes, the additional environmental benefits brought about by the nature-based solution project can be determined.
- Additionality assessment can include both quantitative and qualitative indicators. Quantitative indicators may involve measuring changes in groundwater recharge rates, land cover, or other relevant environmental parameters. Qualitative indicators can include social and economic considerations, such as community engagement, job creation, or

ecosystem services provided. These indicators help capture the multifaceted impacts of the project and determine if the achieved benefits go beyond what would have occurred naturally or through other interventions.

- Engage with stakeholders and experts to gather their perspectives and insights regarding the additionality of the project. This may involve conducting consultations, expert reviews, or third-party evaluations. Stakeholder input and expert opinions provide valuable perspectives on the project's uniqueness, its contributions to environmental goals, and the extent to which the project goes beyond business-as-usual practices.

IV.2. QUANTIFICATION

The *aOCP Methodology for soil health and erosion assessment* encompasses two components, which can be implemented together or individually. The first one is the assessment of soil health through physical, chemical and biological indicators integrated into a soil quality Index (SQI). Verified Soil Credits (VSC) are issued from improvements in the SQI. The second component is the soil erosion assessment, which uses the Revised Universal Soil Loss Equation (RUSLE) to quantify erosion and determine VSC emission as a function of the mass of soil prevented from being lost/eroded as a result of Project activities.

IV.3. SOIL HEALTH ASSESSMENT

This methodology was based on two main references for soil health assessment tools: the Soil Management Assessment Framework (SMAF; Andrews et al., 2004) and Cornell's Comprehensive Assessment of Soil Health (CASH; Moebius-Clune et al., 2016). These methods stand out for offering a comprehensive assessment of soil health by including biological, chemical and physical indicators and their applicability in different ecosystems (Karlen et al., 2008).

The SMAF (Andrews et al., 2004)has been utilized worldwide as a tool for evaluating and measuring changes to soil health/health (SQ) resulting from land use and agricultural practices. This tool evolved from studies applying principles of systems engineering (Karlen et al., 1994a, 1994b) and ecology (Andrews & Carroll, 2001) to interpret soil physical, chemical and biological data collected in various soil management studies (Karlen et al., 2008).

Long-term trends in soil health within the same management unit are best examined through repeated assessments over time. The initial measurements establish a baseline for the soil's condition, and subsequent measurements show trends in response to soil management decisions. Periodic measurements, typically **every 3 to 5 years**, reveal whether soil management practices are leading to improvements, declines, or stability in the indicators. In addition, the use of remote sensing techniques allows continuous monitoring and the collection of valuable data on the state of different soil properties in a time- and cost-efficient manner.

The method follows a three-step process, including (i) selection of a minimum data set of relevant soil health indicators, (ii) interpretation of measured indicator values using scoring functions, and (iii) integration of indicator scores into an overall soil health index.

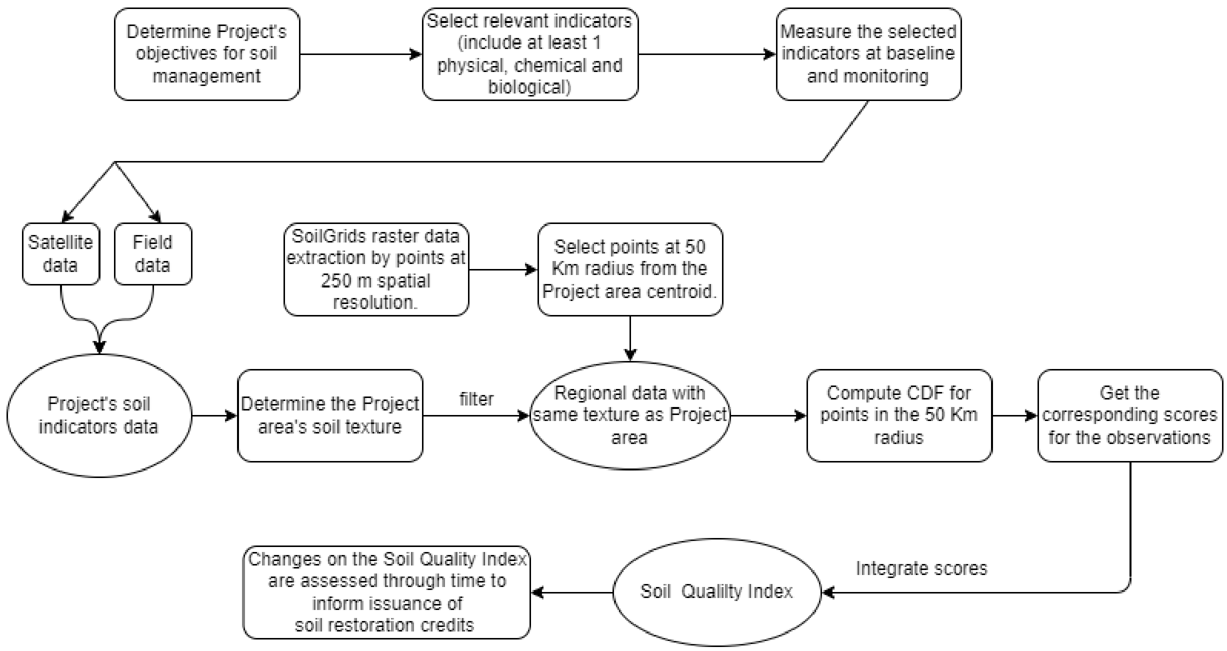


FIGURE 1. OVERVIEW OF THE SOIL HEALTH ASSESSMENT PROTOCOL

SOIL HEALTH INDICATORS SELECTION

It is important to tailor the selection of indicators for soil health assessment to reflect the specific ecological and management characteristics of the system being studied. For example, in agricultural ecosystems, indicators such as soil organic matter content, soil pH, and nutrient availability are often used to assess soil health. These indicators are important because they can affect crop productivity and the sustainability of farming practices. In forest ecosystems, indicators such as soil microbial activity, carbon sequestration, and nutrient cycling may be more relevant because forests play a critical role in regulating climate, water, and nutrient cycles. Similarly, in agroforestry systems, which combine elements of both agriculture and forestry, indicators such as soil structure, water infiltration, and nutrient cycling are particularly important as they can help optimize the balance between crop production and environmental sustainability. In mangrove ecosystems, indicators such as sediment accumulation, salinity, and nutrient cycling may be relevant, as these areas are particularly susceptible to soil erosion and degradation.

The data set should include physical, chemical and biological indicators that influence soil functions important for meeting the management or restoration goal(s). Table 1 shows eighteen potential indicators, which were selected based on the literature and data availability. Some of them, marked with **, can be monitored remotely. A detailed description of the indicators is provided in Appendix 1, including guidance on their selection according to the type of ecosystem and management practices of the aOCP Project activities under study. As recommended by Andrews et al. (2004) and FAO-ITPS (2020), at least one indicator of each type (physical, chemical and biological) shall be included in the assessment.

TABLE 2. SOIL HEALTH INDICATORS CONSIDERED IN THIS AOCP METHODOLOGY

Physical	Chemical	Biological
Bulk density	Electric conductivity	Soil Organic Matter **
Soil texture	Cation Exchange Capacity	Soil respiration rate
Aggregate stability	$CaCO_3$	Microbial diversity
Infiltration rate	P	Organic Carbon % **
Erosion rate	N	
Available water capacity	K	
Soil Moisture Index **	pH	
Soil erodibility**	Ox_Al	
	Ox_Fe Soil redness index **	

INTERPRETATION OF MEASURED INDICATOR VALUES USING SCORING FUNCTIONS

Soil health indicators are individually scored using Standard Scoring Functions and integrated into an overall soil health index (SQI) focusing on chemical, physical and biological aspects. The *scoring curve algorithms* transform indicator values expressed in different units into unitless scores ranging from 0 to 100, allowing individual indicators to be combined into an overall index to assess the effects of land use and management on soil functions. The soil sector scores (i.e. chemical, physical and biological) identify the main soil constraints and can therefore be used to set priorities for specific management actions.

Scoring curves take one-of-three forms (Figure 2): more is better (eg. Soil organic C), less is better (eg. Bulk density) and a local optimum (eg. pH). A more is better scoring curve represents a situation where as the value of the soil indicator increases, soil functions affected by the indicator also increase. Eventually a threshold is reached where further increases have no significant effect on the soil function. A less is better scoring curve represents a situation where as the value of the soil indicator decreases, soil functions affected by the indicator increase. As an indicator in this type of curve increases, there is as threshold value that must be exceeded before the soil function declines. A local optimum scoring curve represents the situation where optimum soil function occurs at a given indicator value and the function declines as the value of the indicator increases or decreases from that optimum value.

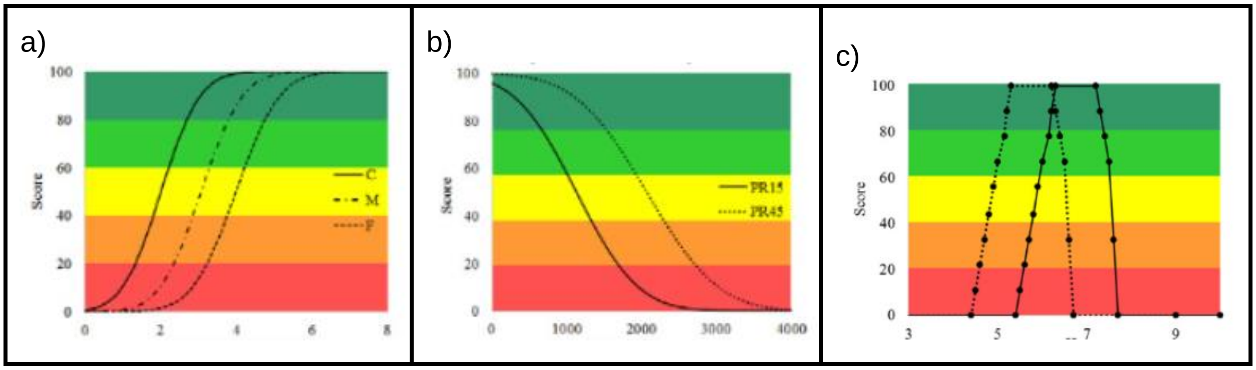


FIGURE 2. TYPES OF CURVES FOR INDICATOR SCORING. A: MORE IS BETTER (EX. ORGANIC MATTER %), B: LESS IS BETTER (EX. PENETRATION RESISTANCE) AND, C: OPTIMUM AREA (EX. PH).

This aOCP methodology follows the CASH approach (Moebius-Clune et al., 2016; pp. 32-36) for determining scoring curves for each indicator. This is done by estimating the cumulative normal distribution (CND) function using the mean and standard deviations of regional samples. The CND function is essentially the scoring function, as it provides the score on a scale ranging from 0-100.

The scoring functions establish a framework that delineates the range of variation for each of the assessed indicators, within a 50 Km radius of the Project area centroid. These samples are obtained from the SoilGrids.org website raster layers. In other words, the score for a particular indicator represents the percentage of samples in the calibration set with values lower than or equal to that of the sample being scored.

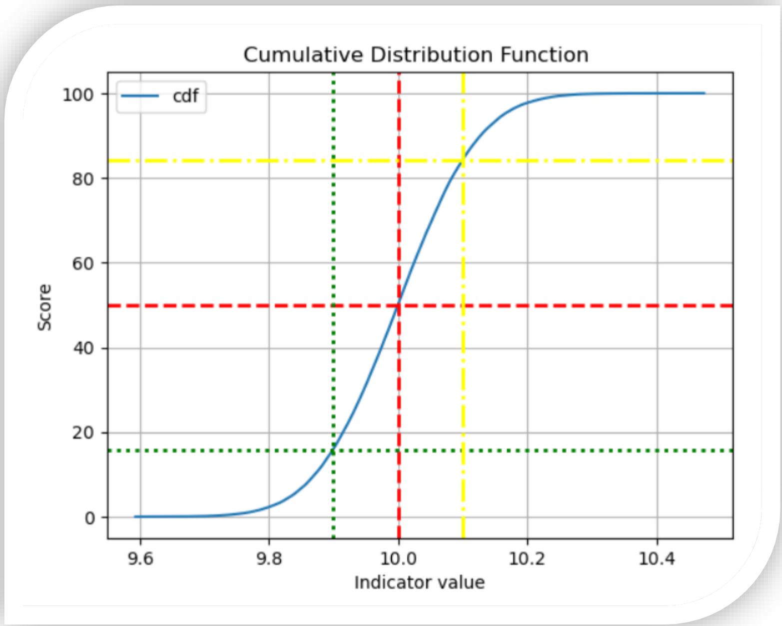


FIGURE 3. CUMULATIVE NORMAL DISTRIBUTION FOR SCORING AN HYPOTHETICAL INDICATOR. FOR INSTANCE, IN THIS CDF, FOR A MEASURED VALUE OF 9.9, THE SCORE IS 15.9 (GREEN LINE); FOR A MEASURED VALUE OF 10 -IN THIS CASE, THE MEAN-, THE SCORE IS 50.0 (RED LINE) AND FOR A MEASURED VALUE OF 10.1, THE SCORE IS 84.1 (YELLOW LINE).

Topsoil textural class refers to the simplified textural classes for 0–30cm used in the Harmonized World Soil Database (version 1.1, 2009). Three simplified textural classes were used for the selection of observation points:

a) Coarse textured: sands, loamy sands and sandy loams with less than 18 percent clay and more than 65 percent sand.
b) Medium textured: sandy loams, loams, sandy clay loams, silt loams, silt, silty clay loams and clay loams with less than 35 % clay and less than 65 % sand; the sand fraction may be as high as 82 percent if a minimum of 18 percent of clay is present.
c) Fine textured: clays, silty clays, sandy clays, clay loams and silty clay loams with more than 35 percent clay.

Steps for calculation of scoring curves using Python:

1. Load points within the 50 Km radius in which SoilGrids values have been extracted.
2. Locate the point(s) of the Project area.
3. Determine the soil texture.
4. Select from the SoilGrids points those with the same soil texture.
5. Compute Cumulative Normal Distribution function.
6. Obtain the CND y-value for the assessed indicator. This is the score for that individual indicator. Score for indicators with Low-is-better curve, is computed as 100-CND. Score for indicators with optimum-type curve, is computed with the normal distribution function.

INTEGRATION OF INDICATOR SCORES INTO AN OVERALL SOIL HEALTH INDEX

Besides obtaining individual indicator scores, a combined SQI serves to integrate all of the indicator scores into a single, additive index value. The overall score is a non-weighted average of the sum of individual indicator scores. This step is accomplished by computing the unweighted average of the individual scores, (Eq. [1]):

$$SQI = \left(\frac{\sum_{i=1}^{n} S_{\mathrm{i}}}{\mathrm{n}}\right) \quad [1]$$

Where *S* represents the scored indicator value and *n* is the number of indicators assessed.

Categorical scores are calculated similarly. Regional scoring functions can similarly be developed based on the regional soil health statistics.

DETERMINATION OF SOIL HEALTH CREDITS

The amount of Soil health credits that will be issued depends on the increase in Soil health Index and the size of the project area.

1. Establish the scoring function for the selected indicators, considering the location and its characteristics.
2. Score the baseline or initial values of the selected indicators.
3. Monitor the selected indicators, score them, calculate the overall SQI.

4. The Soil health Index ranges from 0 to 100. One (1) soil health credit will be issued for each **unit** increase in the SQI, for every 100 m^2. For instance, a project in an area of 400 m^2, where SQI was 65 at baseline and 68 at monitoring, will be issued 12 soil health credits (3 units increase in 4 times 100m^2).

IV.4. Soil erosion reduction assessment

Soil erosion assessment

We can quantitatively analyze erosion rates and make informed comparisons to determine the effectiveness of erosion control measures implemented by aOCP Project activities, by utilizing the Revised Universal Soil Loss Equation (RUSLE) equation (Renard et al., 1996). The RUSLE equation is a widely accepted method used to estimate soil erosion rates by taking into account multiple factors that contribute to erosion, such as rainfall erosivity (R), soil erodibility (K), slope length and steepness (LS), cover management (C), and support practices (P). Certain project activities, such as soil works and reforestation, contribute to erosion reduction. This is reflected in the P- and C- factors, respectively. This assessment will provide valuable insights into the impact of erosion control measures and help determine the magnitude of soil loss prevented. The estimate of soil erosion is calculated based on the following equation (Eq. 2) (Lee, 2004). An explanation of each parameter is provided below.

$$A = R \times K \times C \times LS \times P \qquad [2]$$

Where:

A: annual average soil loss per hectare (t ha^{-1} yr^{-1}),

R: rainfall erosivity factor (MJ mm $ha^{-1}h^{-1}$ yr^{-1}),

K: soil erodibility factor (t ha h $ha^{-1}MJ^{-1}mm^{-1}$),

C: cover-management factor (Unitless),

LS: slope length and slope steepness factor (Unitless),

P: Conservation Practices factor (Unitless).

Rainfall erosivity (R) factor

The erosivity of rainfall is represented by the R-factor. The erosivity of an individual rainfall is computed as the product of the rainfall's total energy, which is closely related to the amount of water and the rainfall's maximum 30-minute intensity (Cooper, 2011; Lee, 2004). Several authors (Torri et al. 2006; Loureiro & Coutinho, 2001; Naipal et al., 2015; Sholagberu et al., 2016) have derived rainfall erosivity equations for different Köppen–Geiger climate classifications which may be transferable to areas of similar climate that do not have the long-term detailed rainfall data required. An example of such equations is shown in Table 2 below.

TABLE 2. EQUATIONS FOR CALCULATING THE R-FACTOR IN DIFFERENT COUNTRIES/REGIONS (BENAVIDEZ ET AL., 2018).

Location	Equation
Indonesia (Bols, 1978) Malaysia (Teh, 2011)	$R = \frac{2.5P^2}{100(0.073P + 0.73)}$
Honduras (Mikhailova et al, 1997)	$R = -3172 + 7.562P$
Italy (Torri et al., 2006)	$R = -944 + 3.08P$
Conterminous U.S. (Renard, Fremund, 1994)	$R = 0.04830P^{1.51}$
S.E. Australia (Yu, Rosewell, 1996)	$R = 0.0438P^{1.61}$

SOIL ERODIBILITY (K) FACTOR

The Soil erodibility factor represents the susceptibility of soil to erosion by runoff. Soil properties such as texture, structure, permeability, and organic matter content influence the capability of soil to resist detachment and subsequent transport of eroded particles. An algebraic approximation of the nomograph that includes five soil parameters (texture, organic matter, coarse fragments, structure, and permeability) is used by ESDAC in the computation of RUSLE a European level (Panagos et al., 2014):

$$K = \frac{(2.1\times10^{-4}M^{1.14}(12-OM)+3.25(s-2)+2.5(\mathrm{p}-3))}{100} \times 0.317 \quad [3]$$

where

K: soil erodibility factor,

M: textural factor from the first 15 cm of soil surface, calculated using Equation [4],

$$M = (100 - \mathrm{Mc}) \cdot (\mathrm{Msilt} + \mathrm{Mvfs}) \quad [4]$$

Where

M*c:* % of clay (<0.002 mm),

Msilt: % of silt (0.002 - 0.05 mm),

Mvfs: % of very fine sand (0.05 - 0.1 mm).

For regions with limited data the K-factor can be computed with these formulae. However, K-factor maps have been developed for most European countries which can be accessed from the European Soil Data Centre (ESDAC) website.

OM: percentage (%) of organic matter content,

s: soil structure class (s = 1: very fine granular (1–2 mm), s = 2: fine granular (2–5 mm), s = 3, medium or coarse granular (5–10 mm), s = 4: blocky, platy or massive (> 10 mm)),

p: soil permeability class (p = 1: very rapid, …, p = 6: very slow; table 3).

TABLE 3. SOIL PERMEABILITY CLASSES AND SATURATED HYDRAULIC CONDUCTIVITY RANGES ESTIMATED FROM MAJOR SOIL TEXTURAL CLASSES (PANAGOS ET AL., 2014).

Permeability class (p)	Texture	Saturated hydraulic conductivity (mm h^{-1})
1 (fast and very fast)	Sand	> 61.0
2 (moderate fast)	Loamy sand, sandy loam	20.3–61.0
3 (moderate)	Loam, silty loam	5.1–20.3
4 (moderate low)	Sandy clay loam, clay loam	2.0–5.1
5 (slow)	Silty clay loam, sand clay	1.0–2.0
6 (very slow)	Silty clay, clay	< 1.0

SLOPE LENGTH AND STEEPNESS (LS) FACTOR

The effect of topography in erosion processes is represented in RUSLE as the slope length and steepness (LS) factor. The LS factor can be calculated with the equation from Moore & Wilson (1992);

$$LS = (\frac{As}{22.13})^m \, (\frac{\sin(\theta)}{0.0896})^n \qquad [5]$$

Where;

As: unit contributing area (m),

θ: slope in radians

m (0.4–0.56) and n (1.2–1.3) are exponents. Default values of m = 0.4 and n = 1.3 may be used.

CONSERVATION PRACTICES (P) FACTOR

P-factor describes the supporting practices such as terraces, strip cropping, contouring among others which help manage erosion. The P- factor values range from 0 to 1 where a P- factor of 1 indicates no conservation practices in place.

P-factor values based on various support practices have been proposed by a number of authors and can be used as a reference (Benavidez et al., 2018; David, 1988; Panagos et al., 2015).

APPROXIMATE CONSERVATION PRACTICE OR MANAGEMENT FACTORS

a) Terracing, contouring and strip cropping (David, P., 1988; Table 9).

Land slope (%)	Terracing		Contouring	Contour strip cropping
	Bench	Broad-based		
1-2	0.10	0.12	0.60	0.30
3-8	0.10	0.10	0.50	0.15
9-12	0.10	0.12	0.60	0.30
13-16	0.10	0.14	0.70	0.35
17-20	0.12	0.16	0.80	0.40
21-25	0.12	0.18	0.90	0.45
>25	0.14	0.20	0.95	0.50

b) Mulching and cover management (David, P., 1988; Table 9).

Surface cover	Percent cover	Percentage cover of mulch or vegetation at ground surface					
		0	20	40	60	80	100
None	0	1.0	0.53	0.33	0.20	0.10	0.02
Tall weeds or short bush, 0.5 cm effective height	25	1.0	0.56	0.36	0.23	0.11	0.03
	75	1.0	0.71	0.53	0.40	0.22	0.06
Bush or brushes 2 m effective height	25	1.0	0.55	0.35	0.22	0.11	0.03
	75	1.0	0.61	0.43	0.27	0.14	0.04
Trees. 4 m effective height	25	1.0	0.55	0.33	0.21	0.10	0.03
	75	1.0	0.56	0.36	0.23	0.11	0.03

c) Tillage and residue management (David, P., 1988; Table 9).

Tillage practice	P Value
Conventional tillage	1.0
Zoned tillage	0.25
Mulch tillage	0.26
Minimum tillage	0.52

d) Other erosion control measures based on water runoff reduction

Type of structure	P Value	Source
Gabion dams	0.47	Ez-zahouani et al., (2024)

COVER MANAGEMENT (C) FACTOR

The effect of vegetation cover in management of erosion is represented by the C-factor. The C_{rA} and C_{VK} are two extensively used remote sensing methods to calculate the C-factor from the Normalized Difference Vegetation Index (NDVI) (Almagro et al., 2019; Durigon et al., 2014). The NDVI is a widely used indicator of green vegetation vigor by the calculation of the spectral reflectance difference between red and near-infrared bands of the satellite image. The application of C_{rA} approach is most suitable for tropical climates and C_{VK} adapted to European climates. C-factor values range from 0 to 1 where 1 represents no vegetation cover and vice-versa. The C_{rA} and C_{VK} are calculated with the equations [6] and [7], respectively.

$$CrA = 0.1(\frac{-NDVI+1}{2}) \qquad [6]$$

$$Cvk = \exp(-\alpha\frac{NDVI}{(\beta - NDVI}) \qquad [7]$$

Where,

C_{rA} and C_{VK} are estimated C-factors,

α and β are constants 2 and 1 respectively (van der Knijff et al., 1999).

It is essential to note that, whereas the R-, K- and LS- factors may remain constant overtime for an area, the C- and P- factors may change depending on the development of vegetation as well as the management practices implemented to manage erosion. Hence periodic monitoring of these factors in erosion assessment is key.

NB: For areas within Europe, developed RUSLE parameters maps exist and can be obtained from the European Joint Research Center Data Base for RUSLE, from the following links.

LS Factor Data: https://esdac.jrc.ec.europa.eu/themes/slope-length-and-steepness-factor-ls-factor

R Factor Data: https://esdac.jrc.ec.europa.eu/themes/rainfall-erosivity-europe

K Factor Data: https://esdac.jrc.ec.europa.eu/themes/soil-erodibility-europe

C Factor Data: https://esdac.jrc.ec.europa.eu/themes/cover-management-factor

P Factor Data: https://esdac.jrc.ec.europa.eu/themes/support-practices-factor

DETERMINATION OF SOIL LOSS REDUCTION CREDITS

Given that results of RUSLE equation are in tons ha^{-1} $year^{-1}$, the calculation of soil loss reduction credits is straightforward: 1 soil credit represents 1 ton of soil that has been prevented from eroding. The calculation of the impact of Project activities on soil erosion prevention is calculated as follows:

1. Calculate percent change in soil erosion from the baseline scenario to the monitoring period, both inside and outside the Project area, according to equation [8].

$$Ac = \frac{(Ab - Am)}{Ab} \quad [8]$$

Where,

Ac: proportion of change in soil erosion rate,

Ab: erosion rate at baseline* (t ha^{-1} yr^{-1}),

Am: erosion rate at monitoring period* (t ha^{-1} yr^{-1}).

2. Use the percent change from the area out of the Project area to estimate the amount of soil that would be lost in the Project area if Project activities were not implemented.

$$Awp = Amp \times (1 + Aco) \quad [9]$$

Where,

Awp: hypothetical erosion rate in the project area if Project activities were not implemented (t ha^{-1} yr^{-1}),

Amp: calculated erosion rate in the Project area for the monitoring period (t ha^{-1} yr^{-1}),

Aco: calculated proportion of change in soil erosion rate (eq.8) outside the Project area for the monitoring period.

3. Subtract this amount of soil loss minus the estimated soil loss in the Project area for the Project scenario (eq. 9).

$$Ar = Awp - Amp \quad [10]$$

Where,

Ar: reduction in soil erosion rate due to Project activities.

4. Multiply by the surface of the Project area in hectares. This is the mass of soil (tons) that has been prevented from eroding as a result of Project implementation.

$$Slp = Ar \times Pa \quad [11]$$

Where,

Slp: Mass of soil that was prevented from eroding due to Project implementation (tons y^{-1}).

Pa: Project surface area (ha).

*In order to account for seasonal variations in erosion due to changes in vegetation cover. Erosion rate shall be assessed quarterly, and a yearly average shall be used in the calculations.

IV.4. MONITORING

DATA AND PARAMETERS USED IN BOTH VALIDATION AND MONITORING

Parameter	*Si*
Data unit	Unitless
Description	*Soil health indicators score*
Equations	1
Source of data	Calculated for each monitoring period from laboratory test results or remote sensing indexes
Calculation method or default value applied	Scoring function, following a Cumulative distribution (for more-is-better or less-is better curve types) or Normal distribution function (for optimum area curve type).
Frequency of monitoring/recording	Each 3 to 5 years, or different if the monitoring plan establishes so.
QA/QC procedures to be applied	Technical verification by repetition of the calculation. Laboratory tests must be performed by a certified laboratory.
Purpose of data	Input for the calculation of Soil Health Index
Comments	

Parameter	R-factor
Data unit	MJ mm $ha^{-1} h^{-1} yr^{-1}$
Description	Rainfall erosivity factor

Equations	Eq. 2 and Table 2
Source of data	For areas within Europe, it can be retrieved from the ESDCA website[1] . For areas out of Europe, it can be Calculated based on mean annual precipitation (P) for the last 30 years. P is calculated on Google Earth Engine from the “CHIRPS Daily: Climate Hazards Group InfraRed Precipitation With Station Data (Version 2.0 Final)” dataset (Funk et al., 2015).
Calculation method or default value applied	Equations in table 2.
Frequency of monitoring/recording	Calculated at project registration, the same value will be used along the Project life.
QA/QC procedures to be applied	Technical verification by repetition of the calculation.
Purpose of data	Input for the calculation of soil erosion
Comments	

Parameter	K-factor
Data unit	t ha h $ha^{-1}MJ^{-1}mm^{-1}$
Description	Soil erodibility factor
Equations	Eq. 2, 3 and 4
Source of data	For areas within Europe, it can be retrieved from the ESDCA website[2] . For areas out of Europe, it can be Calculated based on soil texture and organic matter %.
Calculation method or default value applied	Eq. 3 and 4
Frequency of monitoring/recording	Calculated at project registration, the same value will be used along the Project life.

[1] https://esdac.jrc.ec.europa.eu/search/node/rusle

[2] https://esdac.jrc.ec.europa.eu/search/node/rusle

QA/QC procedures to be applied	Technical verification by repetition of the calculation.
Purpose of data	Input for the calculation of soil erosion
Comments	

Parameter	LS-factor
Data unit	Unitless
Description	Slope length and steepness factor
Equations	Eq. 2 and 5
Source of data	For areas within Europe, it can be retrieved from the ESDCA website[3] . For areas out of Europe, it can be calculated based on the DEM.
Calculation method or default value applied	Eq. 5
Frequency of monitoring/recording	Calculated at project registration, the same value will be used along the Project life.
QA/QC procedures to be applied	Technical verification by repetition of the calculation.
Purpose of data	Input for the calculation of soil erosion
Comments	

Parameter	P-factor
Data unit	Unitless
Description	Conservation Practices factor
Equations	Eq. 2

[3] https://esdac.jrc.ec.europa.eu/search/node/rusle

Source of data	Literature reporting on P-factors for specific types of practices and ecosystems.
Calculation method or default value applied	Retrieved from literature
Frequency of monitoring/recording	Calculated before project implementation, and updated every time there are changes in conservation practices along the life of the project.
QA/QC procedures to be applied	Technical verification by review of the bibliographic sources.
Purpose of data	Input for the calculation of soil erosion
Comments	

Parameter	C-factor
Data unit	Unitless
Description	Cover Management Factor
Equations	Eq. 2, 6 and 7
Source of data	Calculated based on NDVI.
Calculation method or default value applied	Equations 6 or 7, depending on the region.
Frequency of monitoring/recording	Calculated before project implementation, quarterly for each monitoring period, at the end of the season.
QA/QC procedures to be applied	Technical verification by repetition of the calculation.
Purpose of data	Input for the calculation of soil erosion
Comments	

Parameter	A* (Amp: calculated in the Project area for the monitoring period)
Data unit	%

Description	Soil erosion rate
Equations	Eq. 2, 8, 9 and 10
Source of data	Calculated based on assessed erosion.
Calculation method or default value applied	Equation 2
Frequency of monitoring/recording	Calculated before project implementation, quarterly for each monitoring period, at the end of the season and yearly as the average of the last 4 quarterly assessments.
QA/QC procedures to be applied	Technical verification by repetition of the calculation.
Purpose of data	Input for the calculation of soil erosion credits
Comments	

Parameter	Ac* (Aco: out of Project area)
Data unit	Unitless
Description	Proportion of change in soil erosion rate
Equations	Eq. 8 and 9
Source of data	Calculated based on assessed erosion.
Calculation method or default value applied	Equation 8
Frequency of monitoring/recording	Calculated yearly.
QA/QC procedures to be applied	Technical verification by repetition of the calculation.
Purpose of data	Input for the calculation of soil erosion credits
Comments	

Parameter	Awp
Data unit	t ha^{-1} yr^{-1}
Description	Hypothetical erosion rate in the project area if Project activities were not implemented
Equations	Eq. 9 and 10
Source of data	Calculated based on assessed erosion.
Calculation method or default value applied	Equation 9
Frequency of monitoring/recording	Calculated yearly.
QA/QC procedures to be applied	Technical verification by repetition of the calculation.
Purpose of data	Input for the calculation of soil erosion credits
Comments	

Parameter	Awp
Data unit	t ha^{-1} yr^{-1}
Description	Hypothetical erosion rate in the project area if Project activities were not implemented
Equations	Eq. 9 and 10
Source of data	Calculated based on assessed erosion.
Calculation method or default value applied	Equation 10
Frequency of monitoring/recording	Calculated yearly.

QA/QC procedures to be applied	Technical verification by repetition of the calculation.
Purpose of data	Input for the calculation of soil erosion credits
Comments	

Parameter	Ar
Data unit	t ha^{-1} yr^{-1}
Description	reduction in soil erosion rate due to Project activities.
Equations	Eq. 10 and 11
Source of data	Calculated based on assessed erosion.
Calculation method or default value applied	Equation 10
Frequency of monitoring/recording	Calculated yearly.
QA/QC procedures to be applied	Technical verification by repetition of the calculation.
Purpose of data	Input for the calculation of soil erosion credits
Comments	

Parameter	Slp
Data unit	t yr^{-1}
Description	Mass of soil that was prevented from eroding due to Project implementation
Equations	Eq. 11
Source of data	Calculated based on assessed erosion.

Calculation method or default value applied	Equation 11
Frequency of monitoring/recording	Calculated yearly.
QA/QC procedures to be applied	Technical verification by repetition of the calculation.
Purpose of data	Input for the calculation of soil erosion credits
Comments	

DESCRIPTION OF THE MONITORING PLAN

Sample design

Soil Health Assessment

For laboratory testing, semi-stratified sampling technique is used to select sampling locations within the study area. The sampling locations will be permanent along the Project life. While there is no ideal number of sample size for any given area as it depends mainly on heterogeneity of the study area with respect to soil physico-chemical characteristics, topography and purpose of study, however as a rule of thumb, a minimum of 20 samples per hectare is recommended.

It is important to note the higher the number of soil samples, the higher accuracy in results obtained.

Soil erosion assessment

The remote sensing approach implies the assessment of the whole Project area and the comparison with the microbasin where it is located, given that GIS are used to analyze the satellite images and other layers in raster format. Therefore, no sampling is needed as the areas (Project and control) are assessed completely.

Monitoring plan

Soil Health Assessment

Changes in the indicators included in the Soil Health Index can be monitored every 3 to 5 years or less if there are reasons to expect changes to become evident on yearly assessments.

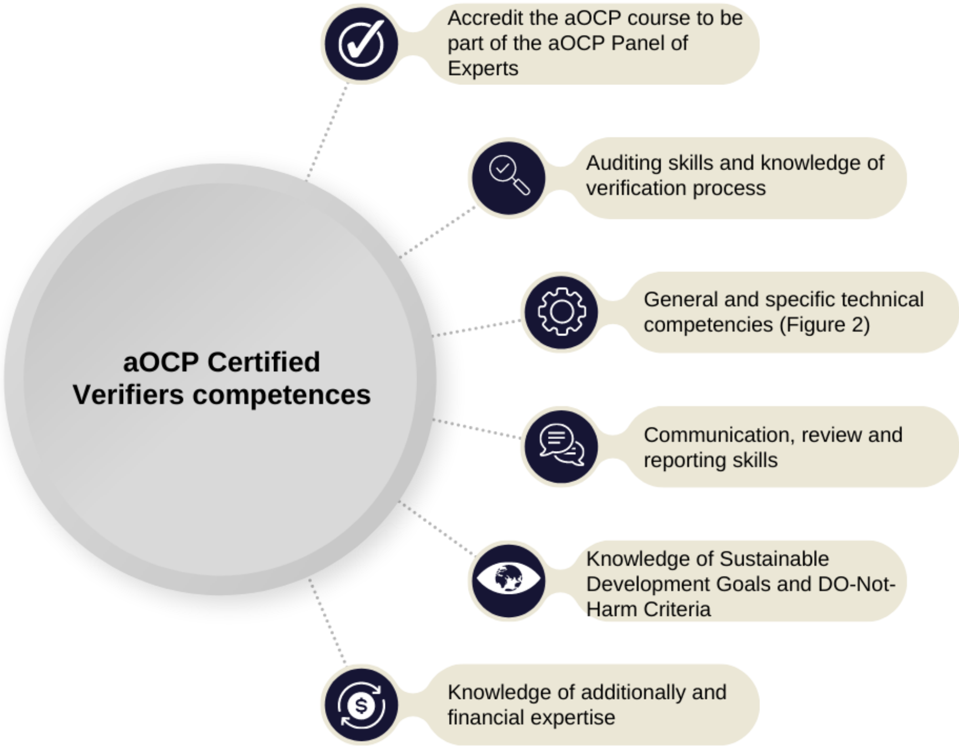
Soil erosion assessment

The impact of Project activities in soil erosion reduction will be assessed quarterly, in order to take into consideration variations in vegetation cover (and consequently in erosion rate) due to phenology. A 2-week window will be used at the end of each season to select the least cloudy Sentinel-2 image. This image will be used to calculate the C-factor. RUSLE will be calculated quarterly and a yearly average will be computed.

By quantifying the soil erosion rates before and after implementing our project, we can estimate the amount of soil that was avoided from eroding. The utilization of the RUSLE equation, coupled with the understanding that soil works, and reforestation positively impact erosion-related factors, allows us to accurately evaluate the success of Project activities in preserving soil integrity and promoting sustainable land management practices.

V. AOCP SCOPE APPLICABLE TO VALIDATORS AND VERIFIERS

The aOCP-approved validators and verifiers that will assess the potential and/or achieved impacts of the proposed or registered Project activity shall comply with the generic competencies established in numeral VII.3.3. of the Procedure for the Approval of Validators and Verifiers aOCP (as shown in Figure 3), and with the valid accreditation of an aOCP course on water restoration assessment.


aOCP Certified Verifiers competences
Accredit the aOCP course to be part of the aOCP Panel of Experts
Auditing skills and knowledge of verification process
General and specific technical competencies (Figure 2)
Communication, review and reporting skills
Knowledge of Sustainable Development Goals and DO-Not-Harm Criteria
Knowledge of additionally and financial expertise

References

Almagro, A., Thomé, T. C., Colman, C. B., Pereira, R. B., Marcato Junior, J., Rodrigues, D. B. B., & Oliveira, P. T. S. (2019). Improving cover and management factor (C-factor) estimation using remote sensing approaches for tropical regions. *International Soil and Water Conservation Research*, *7*(4), 325–334. https://doi.org/10.1016/j.iswcr.2019.08.005

Andrews, S. S., & Carroll, C. R. (2001). Designing a Soil Quality Assessment Tool for Sustainable Agroecosystem Management. *Ecological Applications*, *11*(6), 1573. https://doi.org/10.2307/3061079

Andrews, S. S., Karlen, D. L., & Cambardella, C. A. (2004). The Soil Management Assessment Framework. *Soil Science Society of America Journal*, *68*(6), 1945–1962. https://doi.org/10.2136/SSSAJ2004.1945

Benavidez, R., Jackson, B., Maxwell, D., & Norton, K. (2018). A review of the (Revised) Universal Soil Loss Equation ((R)USLE): With a view to increasing its global applicability and improving soil loss estimates. *Hydrology and Earth System Sciences*, *22*(11), 6059–6086. https://doi.org/10.5194/HESS-22-6059-2018

Cooper, K. (2011). *Evaluation of the relationship between the RUSLE R-Factor and Mean Annual Precipitation*.

David, W. P. (1988). Soil and Water Conservation Planning: Policy Issues and Recommendations. *Philippine Institute for Development Studies*, *15*, 47–84.

Durigon, V. L., Carvalho, D. F., Antunes, M. A. H., Oliveira, P. T. S., & Fernandes, M. M. (2014). NDVI time series for monitoring RUSLE cover management factor in a tropical watershed. *International Journal of Remote Sensing*, *35*(2), 441–453.

FAO. (2017). *Voluntary Guidelines for Sustainable Soil Management*. Food and Agriculture Organization of the United Nations.

FAO-ITPS. (2020). *Protocol for the assessment of Sustainable Soil Management*. FAO. https://www.fao.org/fileadmin/user_upload//GSP/SSM/SSM_Protocol_EN_006.pdf

Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., Husak, G., Rowland, J., Harrison, L., Hoell, A., & Michaelsen, J. (2015). The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. *Scientific Data 2015 2:1*, *2*(1), 1–21. https://doi.org/10.1038/sdata.2015.66

Karlen, D. L., Andrews, S. S., Wienhold, B. J., & Zobeck, T. M. (2008). Soil Quality Assessment: Past, Present and Future. *Electronic Journal of Integrative Biosciences*, *6*(1), 3–14.

Karlen, D. L., Wollenhaupt, N. C., Erbach, D. C., Berry, E. C., Swan, J. B., Eash, N. S., & Jordahl, J. L. (1994a). Crop residue effects on soil quality following 10-years of no-till corn. *Soil and Tillage Research*, *31*(2–3), 149–167. https://doi.org/10.1016/0167-1987(94)90077-9

Karlen, D. L., Wollenhaupt, N. C., Erbach, D. C., Berry, E. C., Swan, J. B., Eash, N. S., & Jordahl, J. L. (1994b). Long-term tillage effects on soil quality. *Soil and Tillage Research*, *32*(4), 313–327. https://doi.org/10.1016/0167-1987(94)00427-G

Lee, S. (2004). Soil erosion assessment and its verification using the Universal Soil Loss Equation and Geographic Information System: A case study at Boun, Korea. *Environmental Geology*, *45*(4), 457–465. https://doi.org/10.1007/s00254-003-0897-8

Loureiro, N. de S., & Coutinho, M. de A. (2001). A new procedure to estimate the RUSLE EI30 index, based on monthly rainfall data and applied to the Algarve region, Portugal. *Journal of Hydrology* , *250*(1–4), 12–18.

Moebius-Clune, B. N., A.J. Ristow, H. M. van E., & Abawi, G. S. (2016). *Comprehensive Assessment of Soil Health – The Cornell Framework* (3.2). Cornell University. https://soilhealth.cals.cornell.edu/manual/

Moore, I. D., & Wilson, J. P. (1992). Length-slope factors for the Revised Universal Soil Loss Equation: Simplified method of estimation. *Journal of Soil and Water Conservation September* , *47*(5), 423–428.

Naipal, V., Reick, C., Pongratz, J., & Oost, V. K. (2015). Improving the global applicability of the RUSLE model – adjustment of the topographical and rainfall erosivity factors. *Geoscientific Model Development*, *8*(9), 2893–2913.

Panagos, P., Borrelli, P., Meusburger, K., van der Zanden, E. H., Poesen, J., & Alewell, C. (2015). Modelling the effect of support practices (P-factor) on the reduction of soil erosion by water at European scale. *Environmental Science and Policy*, *51*, 23–34. https://doi.org/10.1016/j.envsci.2015.03.012

Panagos, P., Meusburger, K., Ballabio, C., Borrelli, P., & Alewell, C. (2014). Soil erodibility in Europe: A high-resolution dataset based on LUCAS. *Science of The Total Environment*, *479–480*(1), 189–200. https://doi.org/10.1016/J.SCITOTENV.2014.02.010

Renard, K. G., Forster, G. R., Weesies, G. A., McCool, D. K., & Yoder, D. C. (1996). Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). In *Agriculture Handbook* (703rd ed.).

Sholagberu, A. T., Mustafa, M. R. U., Yusof, K. W., & Ahmad, M. H. (2016). EVALUATION OF RAINFALL-RUNOFF EROSIVITY FACTOR FOR CAMERON HIGHLAND, PAHANG, MALAYSIA. *Journal of Ecological Engineering*, *17*(3).

van der Knijff, J. M., Jones R.J.A, & Montanarella, L. (1999). *Soil Erosion Risk Assessment in Italy*. European Soil Bureau, European Commission.

DOCUMENT HISTORY		
Version	**Date**	**Comments**
V2.0	25/06/2023	Second version released for review by the aOCP Steering Committee under the aOCP Version 1.
V2.2	15/07/2024	Third version released for review by the aOCP Steering Committee under the aOCP Version 2.0.