METHODOLOGICAL DOCUMENT

Sustainable Management and Conservation of Water Resources

BWS0001

Methodology for Quantifying Net Water Gains from Increased Infiltration in Watersheds

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1 Introduction

Integrated water resource management is essential to the sustainability of life on the planet. Although 71% of the Earth's surface is covered by water, only 2.5% is freshwater, and most of it is either frozen or stored in underground aquifers. Less than 1% of freshwater is available in surface bodies such as rivers, lakes, and reservoirs, which are critical sources for both human use and ecosystem functioning.

The availability of this vital resource is under increasing pressure from multiple factors, including deforestation, soil erosion, pollution, and inefficient water use in productive activities. These pressures are especially severe in arid and semi-arid regions and have led to growing water stress in many watersheds.

Protecting, restoring, and sustainably managing watersheds is essential for preserving water supply and regulation, maintaining ecological balance, and promoting climate resilience and water security for communities. These actions align with international commitments such as the Sustainable Development Goals (SDGs), particularly SDG 6 on clean water and sanitation.

In this context, this methodology sets out the technical framework for quantifying net water gains from increased infiltration, resulting from conservation and sustainable water management activities. The methodology enables the certification of Verified Water Credits (VWC) under the BioCarbon Water Standard, expressed in cubic meters per year (m^3/year) of additional infiltration attributable to the project. These credits may be used as financial instruments to channel investments into watershed restoration, water security, and climate adaptation.

2 Objectives

This methodology provides the technical guidelines and specific requirements for quantifying net water gains from increased infiltration resulting from sustainable water management and conservation activities, in alignment with the BioCarbon Water Standard.

Specifically, this methodology establishes:

(a) the requirements for identifying the project area, delineating the watershed, and conducting the initial hydrological characterization;

(b) the eligibility criteria for activities and the applicability conditions based on ecosystem status and land use;

(c) the procedures to establish the infiltration baseline, including the collection of data through satellite sources, hydrological modeling, and field measurements;

(d) the standard equation for estimating net water gains, expressed in cubic meters per year (m^3/year), associated with improved infiltration;

(e) he parameters and techniques for stratification and monitoring of intervention areas;

(f) the requirements for calculating certifiable units as Verified Water Credits (VWC), as defined by the BioCarbon Water Standard.

3 Terms and definitions

Agricultural Expansion Deforestation

Conversion of forests and other natural areas into cropland or pasture, contributing to habitat loss, biodiversity decline, and climate change.

Baseline

Initial condition of the water resource and soil, used as a reference to assess project impacts.

Biochar

Carbon-rich material obtained through biomass pyrolysis, applied as a soil amendment to improve its water retention capacity.

Crop Residue Burning

Practice of burning post-harvest crop residues, which may release pollutants, contribute to GHG emissions, and degrade soil quality (FAO, 2006).

Cover Crops

Plants grown primarily to protect and improve soil quality between crop cycles, helping prevent erosion, enhance structure, and increase organic matter (FAO, 2013).

Erosion Control

Set of practices and techniques aimed at preventing and reducing soil loss caused by water and wind, helping preserve soil quality and reduce sedimentation in water bodies.

Evapotranspiration

Combined loss of water through evaporation from soil and transpiration from plants (Allen et al., 1998).

Excessive Use of Agrochemicals

Disproportionate or uncontrolled application of fertilizers and pesticides, causing water contamination, soil degradation, and risks to biodiversity and human health (LIFE MedWetRivers, n.d.).

Flow Rate

Volume of water flowing through a cross-section of a water body over a given time, expressed in m^3/s.

Hydrological Modeling

Simulation of the behavior of water within a watershed, including processes such as precipitation, runoff, and infiltration.

Hugelkultur

A gardening technique using raised beds made of dead wood and organic materials, designed to improve water retention and soil fertility.

Infiltration

Process by which water penetrates the soil from the surface, contributing to aquifer recharge and subsurface water storage (EPA, 2000).

Infiltration Capacity

Maximum rate at which soil can absorb water, typically expressed in mm/day.

Infiltration Trenches

Channels constructed on slopes to capture runoff and enhance water infiltration into the soil (Pizarro et al., 2004).

Integrated Water Resources Management

Coordinated and sustainable management of all dimensions of the water cycle—physical, ecological, social, and economic—through stakeholder participation and interdisciplinary approaches (GWP, 2000).

Monoculture

Agricultural practice of cultivating a single crop species over large areas for prolonged periods, often leading to reduced biodiversity and soil degradation (FAO, 2006).

Mulching

Agricultural technique of covering soil with organic or inorganic materials to retain moisture, reduce erosion, and improve fertility (Elevitch & Wilkinson, n.d.).

Natural Land Cover

Landscape areas dominated by native or semi-natural ecosystems that retain their structure, composition, and ecological functions, and have not been significantly altered by human activity.

Net Water Gains

Additional volume of infiltrated water (m^3/year) attributable to the implemented project activities, relative to the baseline.

Nutrient Control

Management and regulation of nutrient levels (such as nitrogen and phosphorus) in water bodies to prevent eutrophication and protect aquatic ecosystems.

Overexploitation of Water Resources

Intensive and unsustainable use of water, particularly in agriculture, leading to reduced availability and biodiversity impacts.

Precipitation

Any form of water—rain, snow, hail, or drizzle—that falls from the atmosphere to the Earth's surface (NOAA, 2017).

Project Area

Geographic area within the watershed where water conservation and sustainable management activities are implemented.

Removal of Hedges and Field Borders

Clearing of vegetation that marks field boundaries, often resulting in biodiversity loss and habitat degradation.

Runoff

Surface water flow generated when precipitation exceeds the infiltration capacity of the soil (Dunne & Black, 1990).

Sediment Control

Strategies designed to prevent soil erosion and reduce sediment loads in water bodies, helping maintain water quality and ecosystem health.

Soil Organic Matter

Component of soil composed of decomposed plant and animal residues, crucial for improving structure and water retention.

Stratification

Classification of project areas into homogeneous units (strata) for the purpose of infiltration analysis, monitoring, and quantification.

Surface Water

Water present on the Earth's surface, such as in rivers, lakes, streams, lagoons, and reservoirs.

Terrace Design

Construction of flat or stepped surfaces on sloped terrain to reduce erosion and facilitate cultivation.

Verified Water Credits (VWC)

Certified units representing the additional volume of water infiltrated into the soil as a result of project activities, expressed in m^3/year.

Water Footprint

Indicator that quantifies the total volume of freshwater used in the production of goods and services, including direct and indirect consumption throughout the supply chain (Hoekstra & Chapagain, 2008).

Water Governance

Processes, structures, and mechanisms through which decisions and policies related to water are made and implemented, involving various stakeholders to ensure equitable and sustainable management (GWP, 2018).

Water Supply

Total amount of water available in a region from both surface and groundwater sources (FAO, 2011).

Water Regulation

Natural or artificial processes that control the flow and distribution of water within a hydrological system (The Nature Conservancy, n.d.).

Water Resource

Available water from rivers, lakes, aquifers, and precipitation, used for human needs and ecological functions (Ministry of Environment, Colombia, n.d.).

Water Security

Condition in which sustainable, safe, and adequate water access is ensured for human, environmental, and economic needs (The Nature Conservancy, n.d.).

Water Storage

Accumulation of water in natural or artificial reservoirs, including dams, aquifers, lakes, and wetlands.

4 Eligible activities

The eligible activities are divided into two categories: sustainable water management activities and water conservation activities.

4.1 Sustainable water management activities

Sustainable water management activities are aimed at actions that improve the efficiency, use, and conservation of water resources within productive systems, where positive interventions are being implemented to enhance water availability and regulation.

4.1.1 Soil improvement techniques

Infiltration and organic matter enhancement techniques promote water infiltration, prevent soil degradation, and reduce surface runoff. These include the implementation of agricultural and soil conservation practices such as:

(a) Contour farming, which involves arranging crops and agricultural practices along the natural contour lines of the terrain to reduce water velocity, prevent erosion, and facilitate infiltration;

(b) Infiltration trenches, shallow channels designed to capture and retain rainwater, allowing gradual infiltration into the soil and contributing to aquifer recharge;

(c) Terracing, the construction of stepped surfaces on slopes to reduce erosion, improve water retention, and optimize land use on inclined terrain;

(d) Half-moon catchments, crescent-shaped structures built in arid and semi-arid soils to capture runoff and improve moisture availability in the root zone of crops;

(e) Addition of organic matter, through the incorporation of plant residues, manure, and compost to improve soil structure, increase water-holding capacity, and stimulate microbiological activity, thereby enhancing nutrient availability;

(f) Organic fertilization, using natural inputs such as compost, vermicompost, and biofertilizers to improve soil fertility without disrupting ecological balance;

(g) Soil conditioning to enhance infiltration, including techniques that improve the soil's water absorption capacity—such as contour farming, infiltration trenches, terracing, half-moon catchments, addition of organic matter, and organic fertilization, among others. These practices help reduce runoff and enhance aquifer recharge.

4.2 Water conservation activities

Water conservation activities involve interventions aimed at the protection, restoration, and functional maintenance of strategic water-related ecosystems and vegetative cover. These actions seek to ensure the availability and quality of water resources, reduce soil erosion, and preserve associated biodiversity.

Eligible activities under this category shall contribute directly to hydrological regulation and the restoration of key ecosystem services within the project areas.

The following are the eligible practices defined under this methodology.

4.2.1 Conservation and Restoration of Water-Related Ecosystems

The conservation and restoration of water-related ecosystems are directly linked to water conservation, climate change mitigation, and the sustainability of agricultural and livestock activities. Combining ecological restoration with sustainable agricultural practices and resource protection helps ensure the continuity of ecosystem services and enhances the resilience of landscapes and vegetative cover in the face of current environmental challenges.

Rehabilitation of Wetlands and Degraded Watersheds

Wetlands and watersheds play a crucial role in regulating the water cycle, retaining sediments, and conserving biodiversity. Restoration activities may include:

(a) reforestation and revegetation with native species to stabilize soil and enhance infiltration;

(b) restoration of the hydrological regime in wetlands, including the rehabilitation or reestablishment of the water storage capacity of wetland ecosystems, so they can act as reservoirs;

(c) implementation of artificial wetlands to improve water availability.

Conservation of Vegetative Buffers along Water Bodies

Vegetative buffers along riverbanks and stream margins play a key role in filtering pollutants, reducing erosion, and regulating water temperature. Conservation and establishment activities may include:

(a) protecting and restoring natural vegetation in these areas;

(b) implementing live fences and vegetative barriers in agricultural areas near water sources.

Soil Management to Prevent Erosion and Improve Infiltration

Soil can be protected against erosion through practices that enhance its stability and water retention capacity. These practices include:

(a) Revegetation with native species and natural vegetative cover;

(b) Management of vegetative cover in agricultural areas to reduce surface runoff;

(c) Establishment of tree barriers or agroforestry systems, especially in areas with water scarcity, to improve microclimatic conditions and conserve soil moisture.

4.2.2 Conservation and Restoration of Vegetative Cover

Water conservation activities are closely linked to nature-based solutions (NbS), which enhance landscape and habitat features, increase functional connectivity, or fulfill both roles simultaneously within the ecosystem—while also contributing to biodiversity conservation.

Afforestation and Revegetation

Afforestation refers to the planting of trees in areas where forests did not previously exist. Revegetation is the process of restoring or reintroducing vegetation in areas that have been degraded, altered, or destroyed due to natural factors or human activities, such as deforestation, mining, construction, or wildfires. The primary objectives are to restore ecological balance, improve soil quality, prevent erosion, and enhance biodiversity. These activities may include:

(a) creating new forest ecosystems on degraded lands;

(b) converting pastures and grasslands into natural vegetative cover;

(c) sowing seeds and planting native trees and shrubs;

(d) controlling invasive species and implementing techniques to improve soil and water conditions.

Reforestation and Landscape Management Tools

Reforestation is the process of repopulating areas that have lost their forest cover due to natural causes (such as wildfires, pests, or climatic events) or human activities (such as deforestation, urbanization, agriculture, or livestock grazing). **Landscape Management Tools (LMTs)** are elements within the landscape that create or enhance habitat, increase **functional connectivity**, or fulfill both purposes simultaneously, contributing to **biodiversity conservation**. These activities may include:

(a) forest plantations using native species to restore forest cover and its ecological functions;

(b) landscape management tools (LMTs) that enhance ecological connectivity and ecosystem services;

(c) establishment of forest systems (pure or mixed) to stabilize soils and reduce the impact of erosive phenomena.

Rehabilitation of Forest Cover in Productive Areas

These activities aim to restore and recover tree cover in productive areas, promoting ecological recovery without compromising their use for agriculture, livestock, or forestry. Instead of reverting these areas to their original state, strategies are implemented that integrate vegetation with productive activities, optimizing both environmental conservation and economic performance. These activities include:

(a) silvopastoral systems, which optimize agricultural and livestock production while conserving soil and water resources;

(b) assisted natural regeneration, which promotes landscape diversification and improves soil quality and water retention;

(c) crops under sustainable production models, which enhance ecosystem structure and function within agricultural landscapes;

(d) agroforestry systems that integrate trees and crops to optimize land use.

5 Applicability Conditions

The applicability conditions for project areas and for sustainable water management and conservation activities are outlined below. These conditions complement the provisions established in the BioCarbon Water Standard and shall be fully met by projects applying this methodology.

(a) Project areas shall not be classified as forest, in accordance with the definition established in the BioCarbon Water Standard;

(b) Implemented activities shall not result in the transformation of natural ecosystems, either directly or indirectly;

(c) Interventions shall be conducted exclusively in areas with verifiable evidence of natural land cover transformation that occurred at least ten (10) years prior to the start of the project;

(d) Species used in conservation or restoration activities shall not be exotic or invasive, and shall be adapted to local ecological conditions; the use of introduced or naturalized species is only allowed within agroforestry arrays, with a participation of maximum 10% (ten percent), and adequately justified based on socially and culturally accepted uses (provision of wood for domestic uses, firewood, fruits, fibers and others) in the intervention area.

(e) Sustainable water management and conservation activities shall not cause soil degradation or loss of organic matter and shall instead promote its recovery and functionality;

(f) These activities shall prioritize the restoration, rehabilitation, and recovery of gallery forests and other ecosystems that are strategically connected to the watershed's hydrological network;

(g) Activities shall not compromise water quality through the use of fertilizers, herbicides, fungicides, or other substances with toxic effects on aquatic or terrestrial ecosystems;

(h) Soil improvement practices implemented by the project shall be agroecological in nature, and may include infiltration trenches, mulching, hugelkultur, cover cropping, application of compost and biochar, terracing, and keyline systems, among others;

(i) Activities shall be carried out exclusively in watershed units that exhibit hydrological conditions compatible with this methodology, including:

i. high runoff;

ii. a curve number (CN) equal to or greater than 60; and

iii. evidence of water stress.

Additionally, sustainable water management and conservation activities shall be environmentally responsible and shall not cause adverse impacts on biodiversity or lead to the contamination of natural resources within the eligible area. In this regard, practices that compromise ecological integrity or water quality are not compatible with this methodology, including but not limited to:

(a) extensive monoculture practices;

(b) excessive use of pesticides and chemical fertilizers;

(c) deforestation for agricultural expansion;

(d) overexploitation of water sources;

(e) burning of agricultural residues;

(f) introduction of exotic and/or invasive species;

(g) hunting of wildlife

Failure to comply with this provision disqualifies the area and associated activities for certification under this methodology.

6 Watershed Water Balance

To identify the hydrological variables that may be positively affected by a project focused on the conservation and sustainable use of water resources, it is necessary to quantify the water balance within the project areas. This analysis makes it possible to estimate the volume of infiltrated water, expressed in cubic meters per year (m^3/year), which serves as the basis for determining the net water gains attributable to the implementation of the project

In this context, the water balance plays a central role in evaluating the positive impact of the activities implemented in the project areas. Interventions focused on the conservation and sustainable management of water resources directly influence three key components of the balance:

(a) reduction of surface runoff,

(b) increase in the soil's infiltration capacity, and

(c) enhancement of net water storage in the soil profile and aquifers.

These improvements are fundamental to technically support the net water gains derived from the project.

The water balance allows for the assessment of water dynamics within a watershed and serves as the technical foundation for estimating net water gains from infiltration. The general water balance equation is as follows:

$$P = Q + ET + I \pm \Delta S$$

Donde:

P	Precipitation (mm)
Q	Runoff (mm)
ET	Evapotranspiration (mm)
I	Infiltration (mm)
ΔS	Change in storage (mm)

This equation represents the relationship between inputs (precipitation) and the outputs or destinations of water within the watershed. In the context of this methodology, special emphasis is placed on the infiltration component (I), as it forms the basis for quantifying the net water gains generated by project activities.

7 Baseline Assessment

The baseline refers to the initial condition of the project areas and the watershed in which the water conservation and sustainable management activities are implemented. This reference scenario allows for the evaluation of project-attributable changes and serves as the starting point for quantifying net water gains.

7.1 Information for Baseline Assessment

The baseline assessment for hydrological modeling requires the collection of cartographic, meteorological, and soil-related data to characterize the hydrological state of the watershed at the beginning of the project. Below is a list of the necessary inputs for the analysis and hydrological modeling of the watershed.

7.1.1 Meteorological station catalog

A catalog of daily data from meteorological stations shall be compiled, including stations located within the watershed's area of influence as well as those in adjacent watersheds whose data are relevant for the analysis. This information is essential for generating isohyets, estimating long-term average precipitation, and analyzing historical precipitation patterns over a period of at least twenty (20) years prior to the start of the project.

If there are not enough meteorological stations within the watershed, satellite-based precipitation data available through platforms such as Google Earth Engine may be used. Some of the most commonly used datasets include:

(a) Precipitation Data

GPM IMERG (Global Precipitation Measurement) (NASA, n.d.): Provides global precipitation estimates in multiple versions (Early, Late, and Final Run). It is ideal for recent analyses and offers high spatial and temporal resolution.

TRMM 3B42 (NASA, n.d.): Delivers daily precipitation data for tropical and subtropical regions. Although the TRMM mission operated from 1997 to 2015, its dataset remains valuable for historical studies in these areas.

CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) (NASA, n.d.): Combines satellite-based data with meteorological station observations, improving accuracy in regions with limited station coverage.

PERSIANN-CDR (NASA, n.d.): Uses artificial intelligence techniques to estimate daily global precipitation, offering a continuous and multiyear record.

Additional sources may include national meteorological networks and multiyear precipitation series from local weather stations.

Directly collected precipitation data in the Project area, using simple, local instrumentation in the watershed, through community participation and social appropriation of information strategies can also be used.

(b) Temperature Data

MODIS Terra Land Surface Temperature and Emissivity Daily (MOD11A1) (NASA, n.d.): Provides daily global land surface temperature data from the Terra satellite, with a resolution suitable for multiyear analyses.

MODIS Aqua Land Surface Temperature and Emissivity Daily (MYD11A1) (NASA, n.d.): Similar to the Terra product, this dataset offers daily global land surface temperature data from the Aqua satellite, enabling complementary analysis and result validation.

Additional sources may include national meteorological networks and temperature time series from local weather stations.

Directly collected temperature data in the Project area, using simple, local instrumentation in the watershed, through community participation and social appropriation of information strategies can also be used.

(c) Evapotranspiration Data

MODIS Global Evapotranspiration Product (MOD16A2) (NASA, n.d.): Provides global evapotranspiration estimates. Although delivered as an 8-day composite, it is one of the primary datasets available on Google Earth Engine for multiyear evapotranspiration analysis.

Additional sources may include national meteorological networks and historical evapotranspiration series from local weather stations.

7.1.2 Digital Elevation Model (DEM)

To obtain geomorphological and elevation data for the watershed, a Digital Elevation Model (DEM) with a spatial resolution between 5 meters and 30 meters should be used.

ALOS PALSAR DEM, which offer resolutions of 12.5 meters and 30 meters,

ASTER GDEM (NASA, s.f.): with approximately 30-meter global resolution,

ALOS World 3D (AW3D30) (Japan Aerospace Exploration Agency, s.f.): It offers spatial resolutions of 12.5 and 30 meters,

Copernicus DEM (Comisión Europea, s.f.): Free version available at 30 meters; commercial versions offer resolutions up to 10 meters,

TanDEM-X (Deutsches Zentrum für Luft- und Raumfahrt, s.f.): Provides resolutions close to 12 meters in some areas.

Elevation information or DTMs provided by official geographical research institutions or, alternatively, other available sources, appropriately justified.

If precise identification of terrain slopes is not available, it is recommended to use high-resolution data obtained through LiDAR technology or drone-based photogrammetric surveys. These inputs are especially useful for project activities that require greater sensitivity, topographic detail, and accuracy in elevation characterization.

7.1.3 Soil Mapping

Soil data shall be obtained for the watershed, including mainly soil types, texture, drainage capacity, and other relevant properties. This information should be available at a scale of 1:100,000 or finer and will be used to characterize the hydrological response of the soil in the project areas and to support hydrological modeling of the watershed.

SoilGrids (ISRIC) (Hengl et al., 2017): A global platform that provides maps of soil properties (e.g., texture, pH, organic carbon) at 250 m resolution, based on modeling and machine learning.

European Soil Data Centre (ESDAC) (European Commission, n.d.): Although focused on Europe, this center offers raster-based data and maps of soil characteristics (including classification, texture, and other attributes) derived from multiple sources, with resolutions suitable for scales finer than 1:100,000.

GlobalSoilMap (Batjes et al., 2016): An initiative that uses geospatial modeling and remote sensing data (including satellite imagery) to generate high-resolution maps of soil properties.

USDA NRCS SSURGO Soil Data (United States Department of Agriculture, n.d.): This database provides detailed information on soil types in the United States, including classification, texture, drainage capacity, and other attributes.

OpenLandMap Soil Property Datasets (Hengl et al., 2018): This global dataset offers raster maps of various soil properties (e.g., texture, organic matter content, pH, sand, clay, and silt fractions), which can be used to analyze the physical and chemical characteristics of soils.

NASA SMAP (Soil Moisture Active Passive) (NASA & USDA, n.d.): Although primarily focused on soil moisture, SMAP provides data that can be useful for understanding the hydrological behavior of soils globally and for complementing watershed-scale water dynamics studies.

Information on soil quality directly collected in the Project area, or information provided by national information systems, can also be used, provided that the scale is **1:100.000 or higher**.

7.1.4 Land Cover

The analysis of land cover change and transformation shall be based on multitemporal data collection, preferably using the CORINE Land Cover methodology at a scale of 1:25,000 or finer. Alternatively, reliable satellite-based services that provide information on land cover changes may be used, as well as official national sources with historical land cover series from different years.

CORINE Land Cover – Copernicus Land Monitoring Service (European Commission, n.d.): Provides up-to-date land cover data for Europe based on the CORINE methodology, with resolutions suitable for detailed analysis.

CORINE Land Cover – European Environment Agency (EEA) (European Environment Agency, n.d.): The EEA offers various CORINE Land Cover products (e.g., CLC 2018, CLC 2012), enabling the download of raster data for detailed land cover change analysis.

EU Open Data Portal – CORINE Land Cover Datasets (European Union Open Data Portal, n.d.): The EU Open Data Portal provides access to CORINE

Land Cover datasets in various raster and vector formats, facilitating the analysis of land cover transformations.

7.2 Baseline Analysis

Using the collected baseline data, the analysis shall integrate the following components to characterize the hydrological condition of the watershed:

(a) the distribution and transformation of land cover;

(b) the degradation of the curve number (CN) based on land use and cover, and soil type, for a period of at least **10 years**, or compatible with the period used for other baseline variables;

(c) the historical behavior of meteorological variables such as precipitation, temperature, and evapotranspiration; the variation analysis of precipitation in the area must be performed for the longest possible period, to isolate the potential effects of non-periodic climate phenomena (such as ENSO) on data, allowing for a precise quantification of credits.

(d) the identification of areas with a tendency toward water stress;

(e) the analysis of watershed morphometric parameters; and

(f) the historical modeling of runoff up to the project start date.

This analysis forms the basis for establishing the hydrological baseline of the watershed and for defining the reference scenarios used to quantify net water gains.

7.2.1 Morphometric Parameters of the Watershed

The hydrographic and geomorphological analysis of the watershed shall consider both its internal configuration and water dynamics, in order to better understand and model the hydrological behavior of the system with greater precision.

In addition to the basic morphometric parameters, the following complementary elements should also be incorporated into the hydrological modelling of the watershed:

(a) **Identification and Ordering of the Drainage Network**: Determining the drainage network and assigning stream order (e.g., using the Strahler method) helps identify the hierarchy of watercourses. This is essential for establishing connectivity between rivers and tributaries and for estimating each sub-watershed's contribution to total flow.

(b) **Shape and Form Factor**: The shape of the watershed (elongated, circular, or irregular) influences the speed and volume of runoff. The form factor quantifies this characteristic and helps predict the watershed's response to rainfall events, allowing for the estimation of the time of concentration.

(c) **Area, Perimeter, Length, and Width**: The area defines the catchment surface extent, while the perimeter, length, and width relate to storage capacity and exposure to erosive processes. These parameters are fundamental for hydraulic design and water balance assessments.

(d) **Minimum, Maximum, and Mean Elevation**: Knowing the watershed's minimum and maximum elevation helps determine its altitudinal gradient, which is key to calculating average slope. Mean elevation provides insights into the climate regime and precipitation distribution.

(e) **Watershed Slope and Slope Index**: The average slope directly affects water flow velocity and erosive energy. The slope index allows for a quantitative assessment of erosion potential and sediment transport capacity within the watershed.

(f) **Main Channel and Drainage Network Length**: The length of the main channel and the total length of the drainage network provide information on water dispersion and convergence. These metrics are essential for estimating travel times and simulating hydrological responses to storm events.

(g) **Compactness Index (Gravelius Index)**: This index compares the watershed's shape to that of a perfect circle. Values close to 1 indicate more compact basins with shorter times of concentration and faster hydrological responses, while higher values suggest a more diffuse response.

(h) **Drainage Density**: Calculated as the ratio between the total length of the drainage network and the watershed area. A high drainage density indicates greater capacity to collect runoff, which may reflect higher flood potential and quicker response to rainfall events.

Each of these parameters provides not only quantitative information, but also key elements for establishing functional relationships and correlations within the context of hydrological modeling. The integration of these data allows for:

(a) calibrating flow and concentration time simulation models;

(b) identifying critical areas for erosion, sedimentation, or water accumulation;

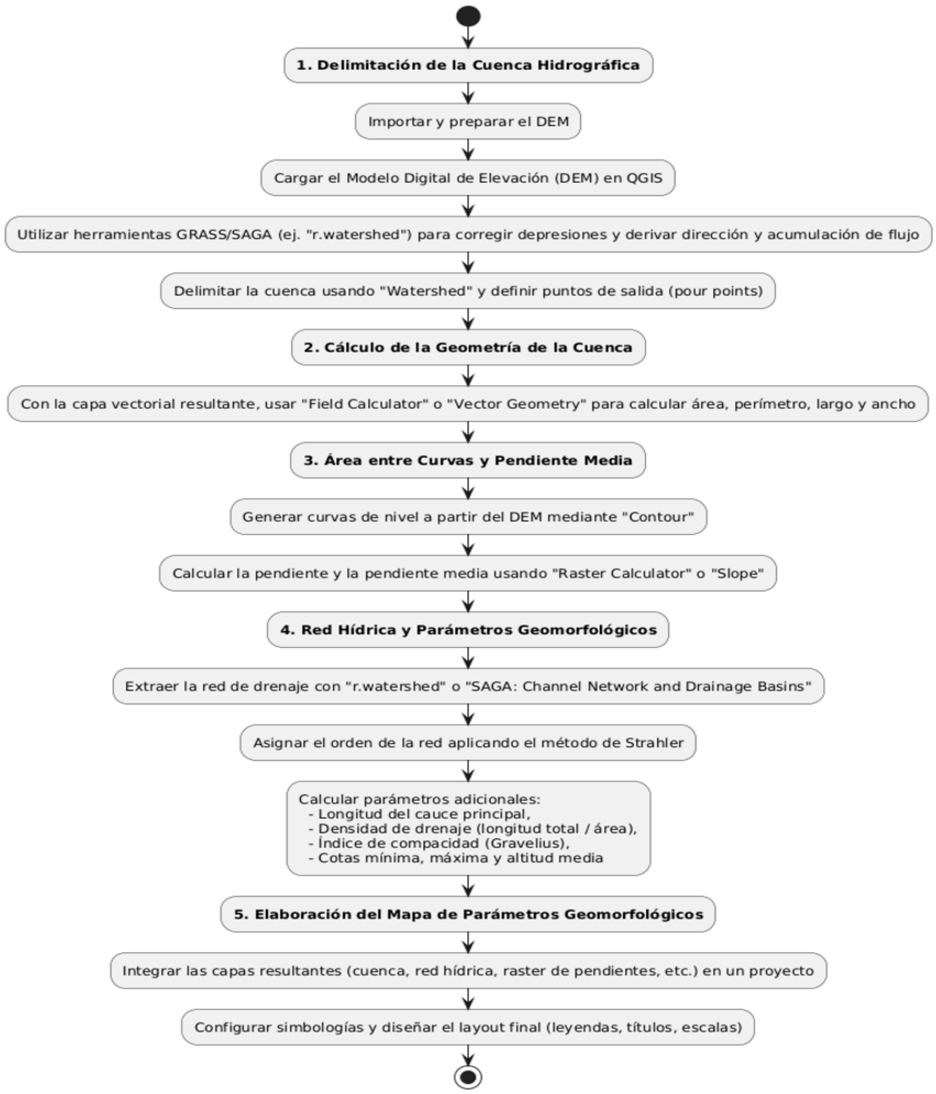
(c) appropriately sizing hydraulic infrastructure and water conservation interventions;

(d) and planning intervention strategies based on watershed morphology and hydrodynamics.

The procedures for calculating the geomorphological parameters are presented in the following Figures.

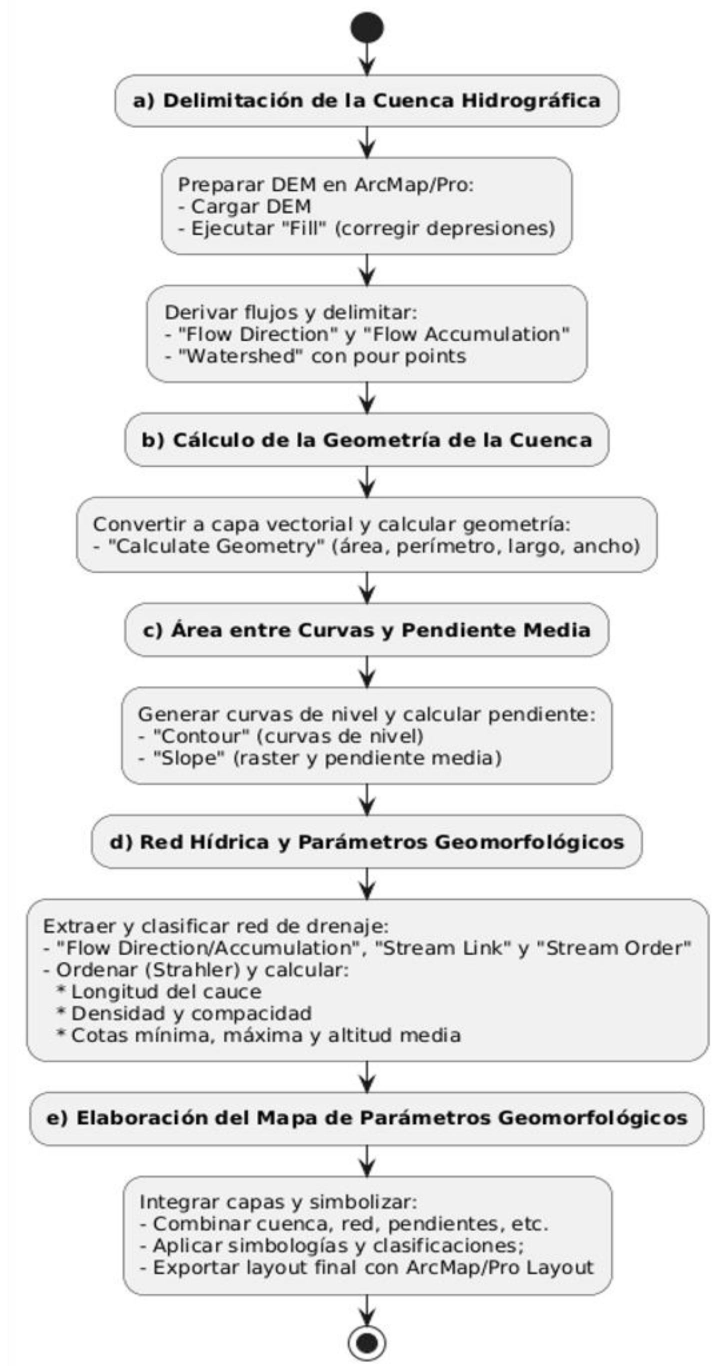
QGIS Procedures

Figure 1. Procedure in QGIS for calculating geomorphological parameters


1. Delimitación de la Cuenca Hidrográfica
Importar y preparar el DEM
Cargar el Modelo Digital de Elevación (DEM) en QGIS
Utilizar herramientas GRASS/SAGA (ej. "r.watershed") para corregir depresiones y derivar dirección y acumulación de flujo
Delimitar la cuenca usando "Watershed" y definir puntos de salida (pour points)
2. Cálculo de la Geometría de la Cuenca
Con la capa vectorial resultante, usar "Field Calculator" o "Vector Geometry" para calcular área, perímetro, largo y ancho
3. Área entre Curvas y Pendiente Media
Generar curvas de nivel a partir del DEM mediante "Contour"
Calcular la pendiente y la pendiente media usando "Raster Calculator" o "Slope"
4. Red Hídrica y Parámetros Geomorfológicos
Extraer la red de drenaje con "r.watershed" o "SAGA: Channel Network and Drainage Basins"
Asignar el orden de la red aplicando el método de Strahler
Calcular parámetros adicionales:
- Longitud del cauce principal,
- Densidad de drenaje (longitud total / área),
- Índice de compacidad (Gravelius),
- Cotas mínima, máxima y altitud media
5. Elaboración del Mapa de Parámetros Geomorfológicos
Integrar las capas resultantes (cuenca, red hídrica, raster de pendientes, etc.) en un proyecto
Configurar simbologías y diseñar el layout final (leyendas, títulos, escalas)

ArcGIS Procedures

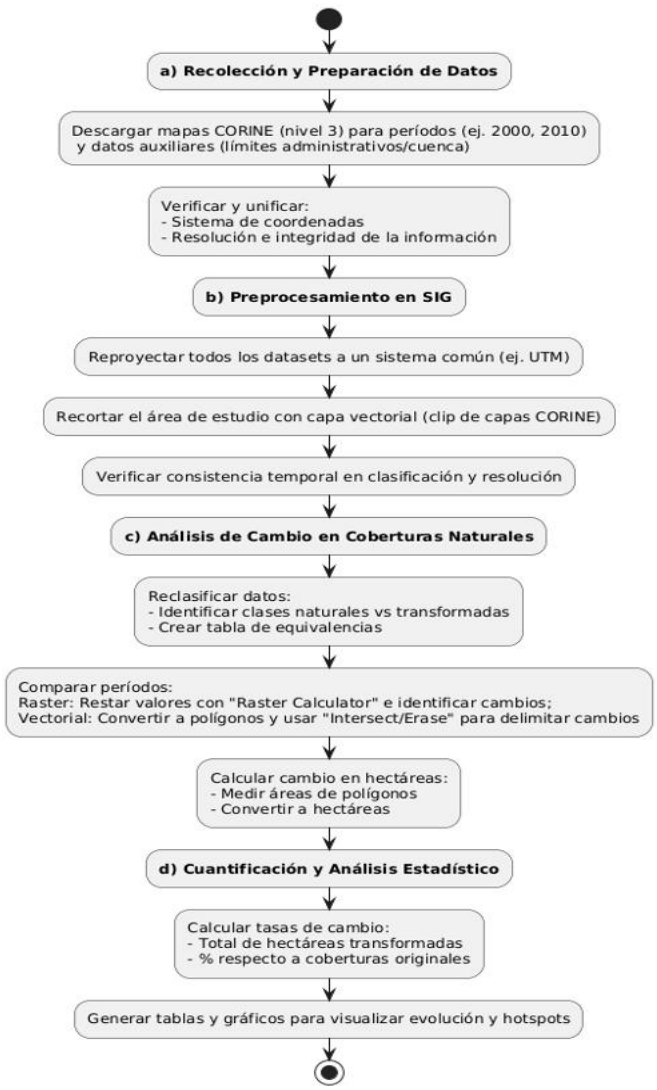
Figure 2. Procedure in ArcGIS for calculating geomorphological parameters



7.2.2 Degradation of Natural Land Cover

The quantification of natural land cover degradation shall be carried out through spatial analysis processes using Geographic Information Systems (GIS) in order to determine the rate of land cover loss within the project area. This analysis shall cover a minimum period of ten (10) years prior to the start of the project and is intended to verify that no recent deforestation or land transformation processes have occurred that would compromise the area's eligibility.

Figure 3. Procedure for Natural Land Cover Transformation Analysis



7.2.3 Analysis of Curve Number (CN) Increase

The analysis and quantification of the runoff curve number (CN) in the watershed allow the identification of areas with more susceptibility to superficial runoff and is key to the determination of the hydrological baseline. The analysis shall be conducted using geospatial processes in Geographic Information Systems (GIS), involving the spatial clipping of the watershed and intersecting the land use and soil type layers, allowing for the assignment of a CN value to each spatial unit.

(a) land use type,

(b) hydrologic soil group (A, B, C, or D), and

(c) hydrologic condition (good, fair, or poor).

To carry out the described procedure, Tables 1 and 2 shall be used together in order to accurately calculate the runoff curve number (CN) for the various land cover types present in the watershed.

> **Table 1** provides CN values based on land use type, hydrologic soil group (A, B, C, or D), and the type of treatment applied.
>
> **Table 2** complements this information by outlining the criteria that define hydrologic condition (good, fair, or poor) for different types of land cover such as crops, pastures, shrublands, and forests.

The combined use of both tables enables the assignment of representative CN values to each spatial unit within the GIS analysis, which is essential for modeling surface runoff in the watershed.

Table 1. Runoff Curve Number Rating Table

Land Cover Type	***Treatment and Management***	***Number of runoff curves by hydrological soil type***				
		Drainage condition	A	B	C	D
Fallow	Bare soil	- - -	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90

Land Cover Type	***Treatment and Management***	***Number of runoff curves by hydrological soil type***				
		Drainage condition	A	B	C	D
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR+ CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C+ CR	Poor	69	78	83	87
		Good	64	74	81	85
	Contouring and Tapping (C & T)	Poor	66	74	80	82
		Good	62	71	78	81
	C & T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Transient small grain crops	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR+ CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C+ CR	Poor	62	73	81	84
		Good	60	72	80	83
	C Y T	Poor	61	72	79	82
		Good	59	70	78	81
	C & T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Direct seeding or broadcasting	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C Y T	Poor	63	73	80	83
		Good	51	67	76	80
	NA	Poor	68	79	86	89
		Regular	49	69	79	84

Land Cover Type	***Treatment and Management***	***Number of runoff curves by hydrological soil type***				
		Drainage condition	A	B	C	D
Pasture, range or rangeland/continuous forage for grazing		Good	39	61	74	80
Continuous meadow pasture/protected from grazing and generally for hay.	NA	Good	30	58	71	78
Shrubs / forest / grass	NA	Poor	48	67	77	83
		Regular	35	56	70	77
		Good	30	48	65	73
Forest - grass combination (orchard or logging)	NA	Poor	57	73	82	86
		Regular	43	65	76	82
		Good	32	58	72	79
Forest	NA	Poor	45	66	77	83
		Regular	36	60	73	79
		Good	30	55	70	77
Farm: buildings, roads, driveways and rural land	NA	NA	59	74	82	86
Gravel roads	NA	NA	72	82	87	89
Hard roads	NA	NA	76	85	89	91

Source: USDA (United States Department of Agriculture, s.f.)

Table 2. Types of Hydrologic Conditions by Land Cover Type

Hydrologic Condition		
Hydrologic condition for different land cover types	The hydrologic condition is based on a combination of factors that affect infiltration and runoff, including: (a) the density and canopy of vegetated areas, (b) the amount of vegetative cover maintained throughout the year, (c) the presence of grasses or legumes planted nearby, (d) the percentage of surface residue cover, and (e) the degree of surface compaction.	
Fallow / Row Crops / Small Grain Crops / Broadcast Seeding	Poor:	The factors hinder infiltration and tend to increase runoff.
	Good:	The factors support average to above-average infiltration and tend to reduce runoff.

Hydrologic Condition		
Pasture, Meadow, or Grassland (Continuous Forage for Grazing) / Protected Continuous Meadow (typically used for hay)	Poor:	Less than 50% vegetative cover or heavily grazed with no mulch.
	Regular:	50% to 75% ground cover with light grazing.
	Good:	> 75% ground cover with light or occasional grazing.
Shrubs / Forest /Grass	Poor:	Less than 50% ground cover.
	Regular:	50% to 75% ground cover.
	Bueno:	> 75% ground cover.
Forest–Grass Combination (Orchard or Managed Forest) / Forests	Poor:	Forest litter, small trees, and undergrowth are destroyed by intensive grazing or frequent burning.
	Regular:	Forests are cleared but not burned, and some forest litter covers the ground.
	Good:	Forests are protected from grazing, and forest litter and undergrowth adequately cover the ground.

Source: USDA (United States Department of Agriculture, s.f.)

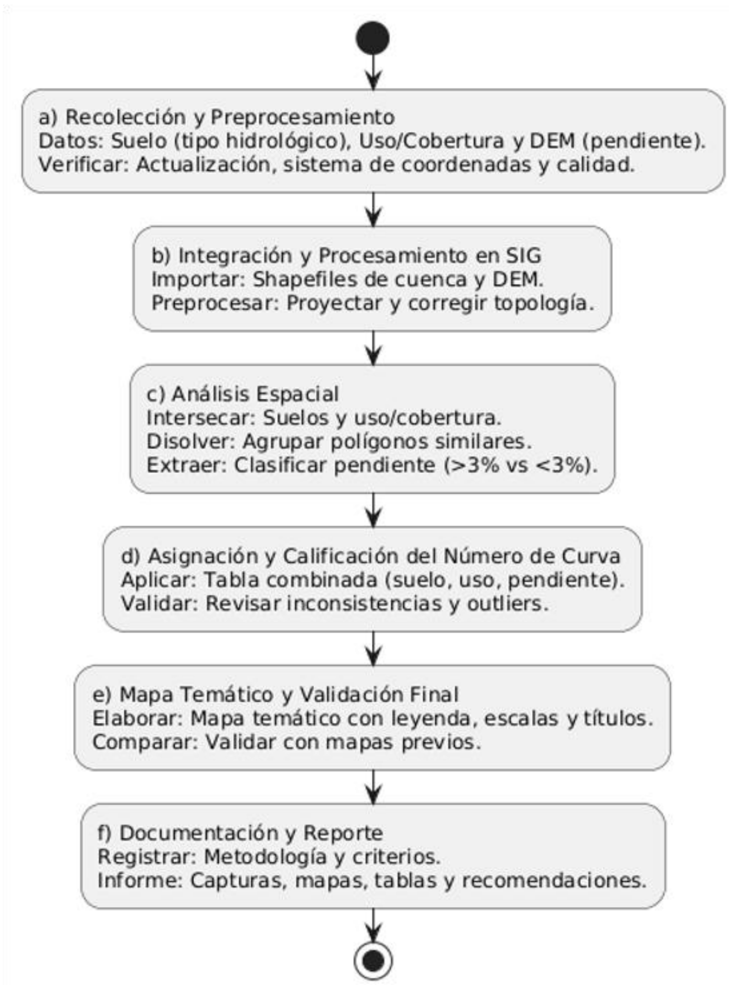
Finally, for the year right before the initiative´s start date, a runoff curve number (CN) distribution map shall be generated for the various land cover types present in the watershed. This map enables visualization of the spatial variability of CN values (ranging from 0 to 100) and helps to identify areas with higher susceptibility to surface runoff (Figure 4). These areas offer high potential for implementing sustainable water management and conservation activities aimed at increasing infiltration and reducing water loss due to runoff, as indicated in Section 7.3.

7.2.4 Water Stress Analysis of the Watershed

The water stress analysis of the watershed shall be conducted by comparing the total annual precipitation with the evapotranspiration from, at least, the year immediately preceding the start of the project; however, the analysis should be performed for the longest possible period, to avoid biases introduced as effects of climate variability and non-periodic climate phenomena (such as ENSO). This analysis requires the use of geospatial tools capable of overlaying interpolated raster layers with distributed precipitation and evapotranspiration data across the entire watershed. The results make it possible to identify areas with critical water deficits, which should be prioritized for the implementation of activities aimed at improving water regulation.

This analysis allows for the determination of whether the watershed is experiencing conditions of scarcity or water stress due to insufficient precipitation in certain areas. These zones, characterized by arid or low-rainfall regimes and limited water storage, present a high potential for positive impact through the implementation of sustainable water management and conservation activities aimed at improving the regulation and availability of water resources.

Figure 4. Procedure for Calculating the Runoff Curve Number (CN)



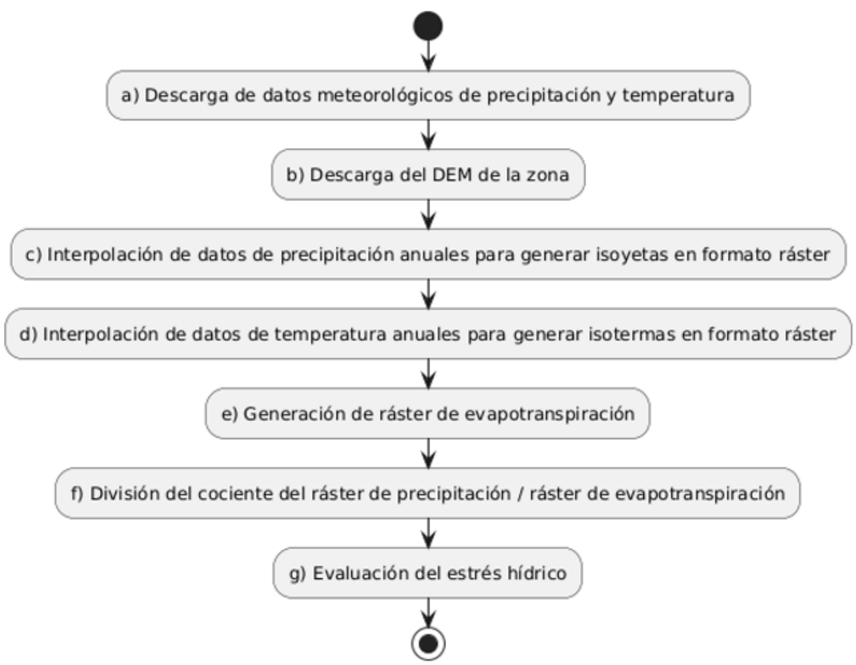
The following section describes the information to be collected and the procedure to be followed for the assessment of water stress in the watershed.

Procedure for Assessing Watershed Water Stress

To identify areas within the watershed where precipitation does not generate surpluses and is entirely returned to the atmosphere through evapotranspiration, a spatial water stress analysis shall be conducted. This analysis enables the identification of zones with insufficient water availability, which should be prioritized for vegetative cover restoration aimed at enhancing soil moisture retention and biomass increase.

The water stress analysis shall be performed using a geospatial procedure in Geographic Information Systems (GIS), following the methodological flow illustrated in Figure 5. This procedure allows for the identification and classification of watershed areas based on the balance between precipitation and evapotranspiration.

Figure 5. Procedure for Water Stress Assessment



1) Download of Meteorological Data: Precipitation, Temperature, and DEM

The first step in the procedure is to download and process precipitation and temperature data corresponding to the year immediately preceding the start of the project, or to the selected period of analysis. It is essential to ensure the temporal continuity of the data, avoiding gaps that could affect the analysis. To achieve this, multiple measurement points should be used, located both within the watershed and in surrounding areas. Data may come from available meteorological stations or, if not accessible, from reliable satellite sources, with randomly distributed spatial points selected to ensure representative coverage of the territory.

Subsequently, the Digital Elevation Model (DEM) of the watershed shall be downloaded. This will be used to calculate terrain slopes and support the spatial analysis of water stress. Additionally, a properly georeferenced watershed boundary polygon shall be available to precisely define the analysis area for use in GIS-based procedures.

2) Interpolation of Isohyets and Isotherms

To generate isohyets (lines of equal precipitation) and isotherms (lines of equal temperature) within the watershed, the following procedure shall be followed (see Figure 6).

3) Generation of the Evapotranspiration Raster

To estimate the annual potential evapotranspiration in the watershed, an evapotranspiration raster shall be generated using the empirical method of Holdrich (Holdrich, 1995). This procedure requires:

(a) having an isotherm raster (annual mean temperature in °C), and

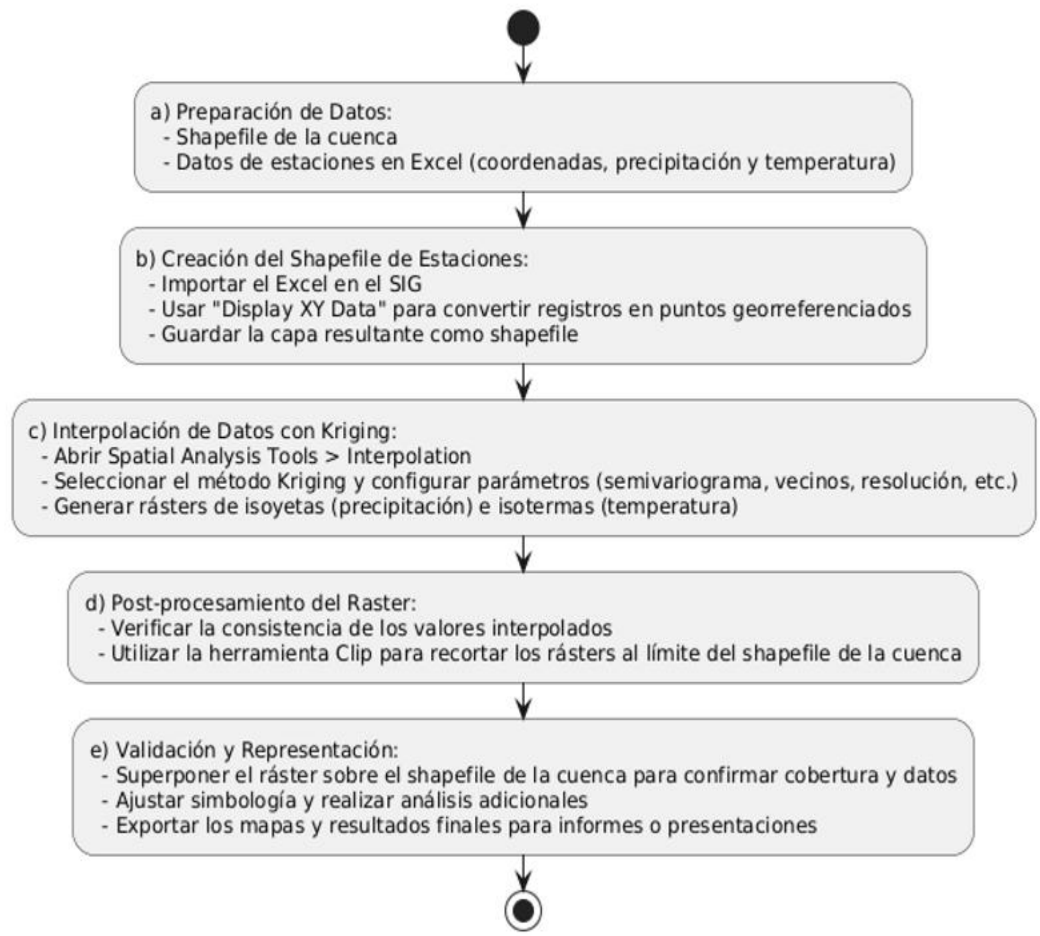
(b) applying the following expression using a raster calculator within the GIS environment:

$$\text{Evapotranspiration} = \text{temperature in °C} * 58.93$$

This experimental equation was developed for a specific area of the world; so, it is possible for projects to use other local equations that better match the conditions and characteristics of area where the intervened watershed is located. The application of such equations must be adequately referenced and justified.

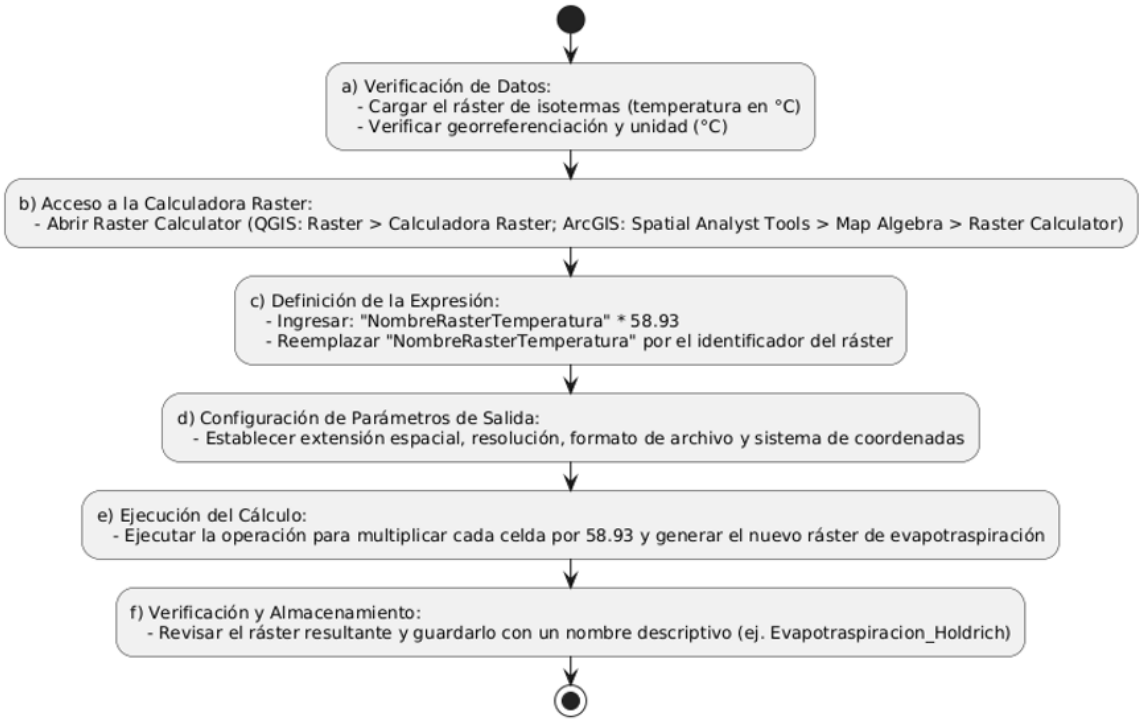
This calculation produces a spatial layer representing the distribution of evapotranspiration across the entire watershed and serves as a critical input for both the water balance analysis and the water stress assessment.

Figure 6. Procedure for Generating Isohyets and Isotherms



The following procedure describes how to generate the annual evapotranspiration raster for the year preceding the start of the project, using temperature data and the previously described Holdrich method (see Figure 7). This raster will provide a spatial representation of atmospheric water demand across the watershed and serves as an essential input for the water stress analysis.

Figure 7. Procedure for Generating the Evapotranspiration Raster



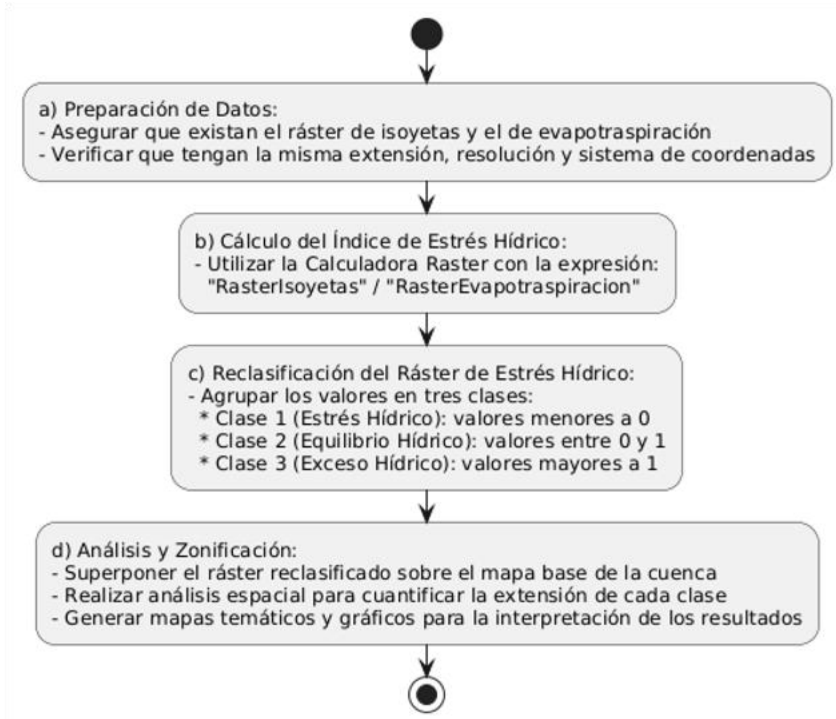
4) Assessment of Watershed Water Stress

The assessment of water stress provides key information on the level of water scarcity in different zones of the watershed. It identifies areas where all precipitated water is lost to evapotranspiration, leading to arid or desert-like conditions; areas in hydrological balance, where precipitation is comparable to evapotranspiration and allows for some level of infiltration; and water surplus areas, where precipitation exceeds evaporative demand.

This spatial classification is essential for informed decision-making in selecting project areas, prioritizing those with the greatest potential for improvement through sustainable water management and conservation activities.

The water stress assessment is conducted using the procedure described in Figure 8 below.

Figure 8. Procedure for Water Stress Assessment



7.3 Prioritization of intervention areas

The areas in the watershed where infiltration will be increased - through the implementation of restoration, rehabilitation, recovery of forests and other ecosystems; agri-ecological soils improvement, including infiltration trenches, mulching, *hugelkultur*, cover cropping, application of compost and biochar, terracing, and keyline systems, etc. – must be prioritized according to the baseline analysis and the following criteria:

- There is evidence of water stress, according to the procedure described in section 7.2.4;
- There is strong evidence of the deterioration (increase) of the Curve Number (CN), related to an inter-temporal increase of the superficial runoff;
- There are changes in land cover in the period of analysis, indicating the loss or degradation of natural ecosystems;

The combination of these criteria will allow to select the places in the watershed where project interventions will have a stronger impact on increased infiltration and water storage in soil and aquifers.

Not all these three criteria must be simultaneously satisfied, but at least one or two of them should.

7.4 Hydrological Modeling of the Watershed

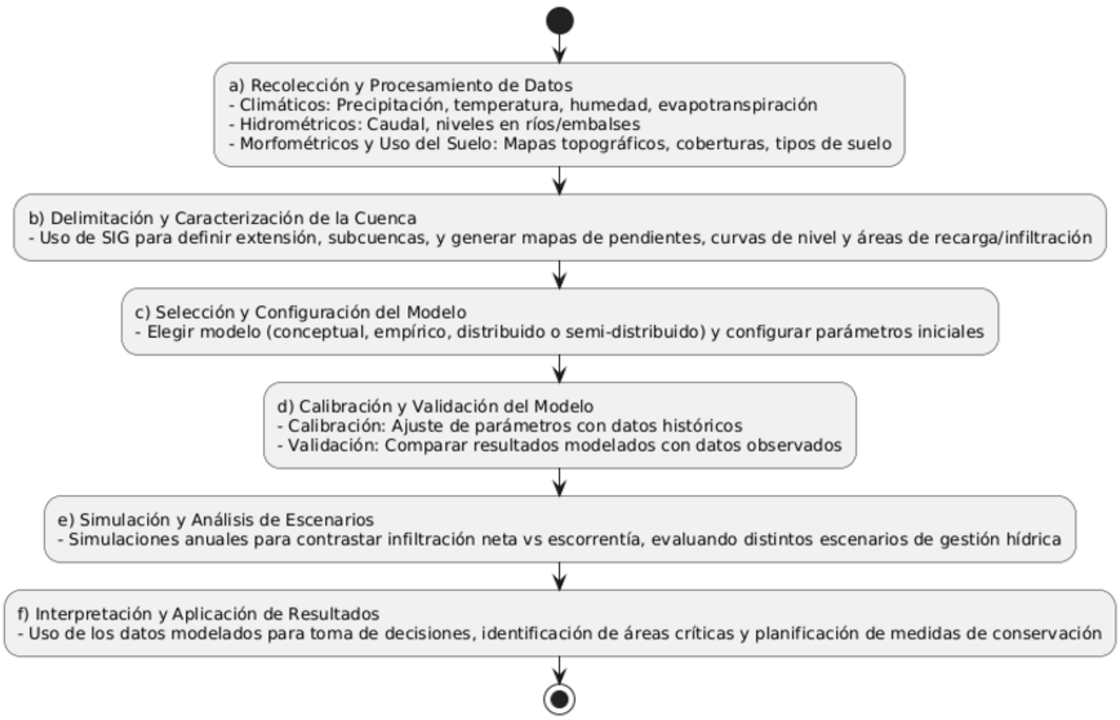
Hydrological modeling of the watershed shall be carried out using Geographic Information Systems (GIS), integrating both baseline information and available hydrometric data to calibrate the model. Inputs shall include historical records of precipitation, temperature, evapotranspiration, and the morphometric parameters of the watershed, in order to accurately feed the model and realistically simulate the hydrological dynamics of the system.

The objective of the hydrological modeling is to estimate the flow contributions generated by the watershed during the year preceding the start of the project and to conduct an annual simulation that allows for a comparison between surface runoff and net water gains from infiltration. This integrated approach enables the analysis of interactions among key hydrological processes, improves the understanding of the relationship between infiltration and runoff, and provides a robust foundation for decision-making in sustainable water resource management.

7.4.1 General Procedure for Hydrological Modeling

The steps to be followed for the hydrological modeling of the watershed are shown in Figure 9.

Figure 9. Procedure for Hydrological Modeling



7.4.2 Distributed and Semi-Distributed Models

For modelling, a distributed or semi-distributed type of model must be selected, depending on the conditions of the watershed and its instrumentation. Below, the characteristics of each of these types of models are presented.

Distributed Models Based on Geographic Information Systems (GIS)

Distributed hydrological models allow for the integration and analysis of spatial data (such as topography, land use, vegetation cover, and morphometric parameters) to subdivide the watershed into smaller units (such as sub-watersheds or pixels) and simulate hydrological processes in a spatially explicit manner.

This approach enhances the representation of the physical heterogeneity of the territory and enables a more accurate analysis of hydrological behavior across different areas of the watershed.

The following GIS-based systems and tools are commonly used for implementing distributed hydrological models in the context of watershed analysis.

(a) ArcGIS Pro (ESRI) (Environmental Systems Research Institute, s.f.)

- Tools: Spatial Analyst, Hydrology Toolbox, Interpolation Tools.
- Supports hydrological models such as SWAT (Soil and Water Assessment Tool).

(b) QGIS (Open Source) (QGIS Development Team, s.f.)

- Add-ons / Plugins: SAGA GIS, GRASS GIS, Processing Toolbox.
- Useful Plugins: QSWAT, Interpolation y Raster Calculator.

Semi-Distributed Models

Semi-distributed hydrological models represent the heterogeneity of the watershed by grouping the territory into homogeneous units with similar characteristics. This approach enables more detailed simulations than simple empirical models, without requiring the full computational complexity of a completely distributed model. It is well suited for medium-sized watersheds and for projects that require a balance between precision and operational efficiency.

Below are some of the tools commonly used to implement semi-distributed hydrological models for watershed analysis and simulation:

(a) **SWAT (Soil and Water Assessment Tool) (**Texas A&M University, s.f.**):** Widely used to simulate hydrological and water quality processes at the watershed scale, accounting for processes such as erosion, infiltration, and runoff generation.

(b) **HEC-HMS (Hydrologic Modeling System) (**U.S. Army Corps of Engineers, s.f.**):** Used to simulate the complete hydrological cycle of the watershed, allowing the modeling of precipitation events and their runoff responses.

(c) **MODFLOW (U.S. Geological Service):** Internationally recognized model to simulate and predict groundwater conditions as well as the interactions between superficial and groundwater.

7.5 Stratification of Areas Within the Project Boundaries

Proper stratification ensures that infiltration measurements, sampling, and net water gain calculations are representative, comparable, and technically robust across the entire project area.

The stratification of land cover where sustainable water management and conservation activities are implemented shall be based on the classification of the different land cover types present in the project area, such as degraded bare lands, fallows, prairies and grasslands, permanent row crops, deforested forest areas, shrublands, and secondary vegetation, among others.

This stratification allows infiltration to be analyzed separately by stratum, acknowledging that hydrological behavior varies significantly depending on the physical and functional characteristics of each land cover type.

Stratification is based on initial differences in infiltration rates observed between cover types at the start of the project. Its purpose is to enable representative and stratified measurement both in the baseline assessment and in subsequent annual monitoring, thereby capturing changes in infiltration attributable to the implemented activities.

In this context, to ensure a differentiated and technically sound assessment of infiltration according to land cover type, the following considerations shall be considered:

(a) Stratification basis

The initial differences in infiltration rates among land cover types at the start of the project.

(b) Land cover types commonly identified as strata (for example):

i. Degraded bare lands

ii. Fallows

iii. Prairies and grasslands

iv. Permanent row crops

v. Deforested forest areas

vi. Shrublands

vii. Secondary vegetation

viii. Other relevant land cover categories present in the project area

(c) Application in the baseline and annual monitoring:

Strata shall be used to guide both the **infiltration baseline assessment** and the **annual follow-up measurements**, ensuring that changes in infiltration are **captured consistently** and can be directly attributed to project activities within each land cover type.

The defined strata are used to:

(a) measure infiltration rates during the baseline assessment, and

(b) capture the changes generated year by year as a result of project activities.

The number of strata depends on land cover types present in the watershed and the project´s intervention areas. So, a range of 3-4, and no more than 7, strata, corresponding to those landcover categories, is recommended.

7.6 Infiltration Baseline Assessment

To establish the infiltration baseline in the project areas where sustainable water management and conservation activities will be implemented, it is essential to conduct direct field measurements using manual or automatic infiltrometers. These measurements shall be performed by strata defined at the start of the project and will provide a reliable reference point for evaluating, over time, the net water gains attributable to the interventions.

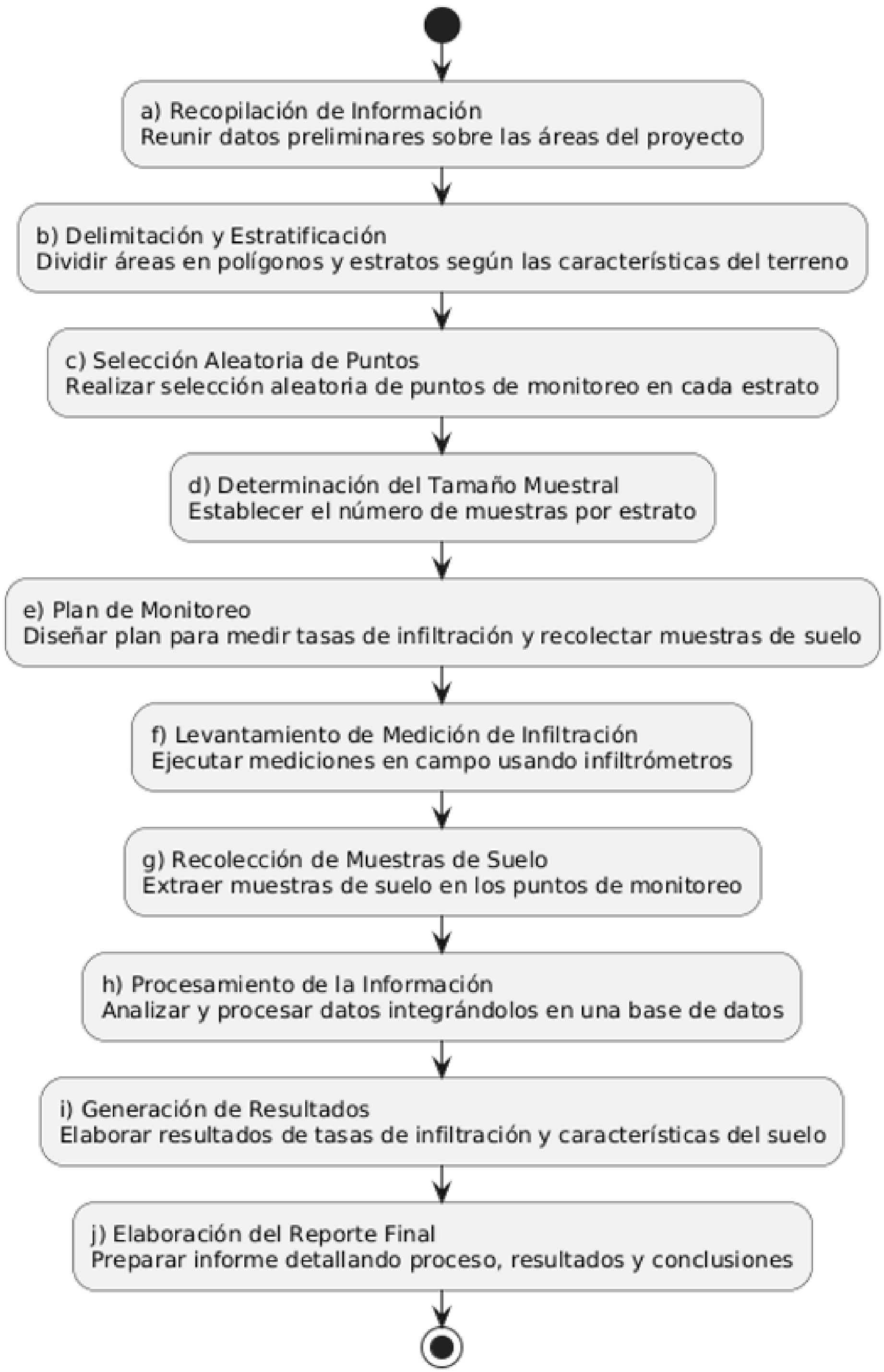
The baseline quantification shall be carried out through stratified random sampling, ensuring the spatial representativeness of the selected points within the project areas. Each measurement point shall be georeferenced, and its location documented, thus facilitating follow-up and comparison during subsequent monitoring periods.

The infiltration baseline must be estimated in both dry and rainy seasons, depending on the temporal distribution of precipitation (unimodal, bimodal); the infiltration baseline will be the average of those two measurements.

All collected data —including infiltration rates and relevant soil properties— shall be integrated into a shapefile, containing the geographic location and attribute information for each point. This spatial database will be essential for technical project management and for performance evaluation analyses.

The detailed steps for the baseline assessment are presented in Figure 10.

Figure 10. Procedure for Infiltration Baseline Assessment



8 Net Water Gains from Increased Infiltration

The net gains in water regulation associated with increased infiltration across the different strata of the project area (e.g., bare soils, croplands, pastures, forests, among others) shall be calculated in cubic meters per year (m³/year). These gains represent the additional volume of water that infiltrates as a direct result of the sustainable water management and conservation activities implemented by the project.

The expression for calculating net water gains (NWG) per stratum is presented below.

$$GN_{\frac{m^3}{Año}} = \frac{(1-\theta) * A * \sum_{d=1}^{D}[\min(I_{act}, P_d) - \min(I_{base}, P_d)]}{1000}$$

Table 3. Description of Variables in the Net Water Gain Equation

Symbol	Description	Unit	Source / Calculation method
θ	**Fraction (0 -1) of the precipated water that results in the initial saturation of soil**, before the aquifer recharge actually starts.	dimensionless	Calibrate with piezometers, water balance models or analog soil literature. In absence of better information, a default 0,15 – 0,20 value can be used.
A	Area of the stratum	m²	GIS / official mapping of the project.
1000	Conversion Factor **mm → m** (1 mm = 0.001 m).	---	Converts the infiltrated film into volume.
D	Number of rainy days during the monitoring period	days	Observed daily series (local network or satellite: GPM, CHIRPS).
Pd	Daily Precipitation.	mm/day	Observed daily series.
I_{act}	Actual infiltration rate	mm/day	Average of infiltration meters, corrected for initial humidity.

Symbol	Description	Unit	Source / Calculation method
I_{base}	Baseline Infiltration Capacity (Previous Year)	mm/day	Average of infiltration meters, corrected for initial humidity.

8.1 Calculation of Net Water Gains

The process of quantifying net water gains from infiltration begins with the collection of baseline information and data required to carry out the calculations established by this methodology. This information includes:

(a) the delimitation of the stratum or project area (A),

(b) the fraction of precipitation that saturates the soil, before deep infiltration and runoff start (θ),

(c) the infiltration rates before and after the intervention, and

(d) the daily precipitation records (P ≥ 1 mm/day) during the monitoring year.

These inputs allow for the accurate estimation of the difference in infiltration between the project scenario and the baseline scenario, and for the calculation of the additional volume of infiltrated water attributable to the implemented activities. All data used shall be representative, traceable, and georeferenced, in accordance with the guidelines of this methodology.

Once the baseline data have been collected, daily infiltration shall be calculated for each rainy day (precipitation ≥ 1 mm/day), distinguishing between the with-project and baseline scenarios.

The daily calculation is performed using the infiltration formula by stratum, considering:

(a) the post-intervention infiltration rate (in mm/day),

(b) the baseline infiltration rate (in mm/day), and

(c) the observed daily precipitation

The difference between both infiltration rates is evaluated on a daily basis, with the maximum infiltration value limited to the actual recorded precipitation for each day. This ensures that the infiltrated volume is not overestimated, thereby maintaining the technical integrity of the calculation.

For each rainy day, apply the following equation:

$$\Delta \text{ Daily Infiltration} = [\min(I_{act}, P_d) - \min(I_{base}, P_d)]$$

Where:

Δ Daily Infiltration	Net daily infiltration gain (mm)
I_{act}	Actual infiltration (mm)
I_{base}	Baseline Infiltration (mm)
P_d	Daily precipitation

This equation, that considers the use of automatic infiltrometers, allows for the calculation, on each rainy day, of the difference in the water layer infiltrated under the intervention scenario versus the baseline scenario. To ensure consistency in the calculation and avoid overestimations, the daily precipitation is set as the upper limit.

In other words, if the soil's infiltration capacity exceeds the volume of rainfall recorded on a given day, it is assumed that the effective infiltration cannot be greater than the precipitation, and the rainfall value is used as the maximum amount that can infiltrate on that day.

Next, the sum of daily infiltration differences obtained throughout the monitoring period shall be calculated. This total represents the cumulative additional volume of infiltrated water on all rainy days of the year, comparing the intervention scenario against the baseline.

The result constitutes the total annual additional infiltration depth per stratum, expressed in millimeters (mm).

$$\sum_{d=1}^{D}[\min(I_{act}, P_d) - \min(I_{base}, P_d)]$$

Once the total additional infiltration depth (in mm) has been obtained for each stratum, it shall be converted into volume (in cubic meters per year, m³/year). To do this, multiply the infiltration depth by the area of the stratum (in m²) and divide by 1,000 to convert millimeters to meters:

$$\frac{A * \sum_{d=1}^{D}[\min(I_{act}, P_d) - \min(I_{base}, P_d)]}{1000}$$

This result represents the additional volume of water infiltrated per stratum in one year.

In case manual infiltrometers are used to measure the infiltration, it will be necessary to adjust the former equations to reflect the frequency of measurement with manual instruments, and to use the measured values as average for the related periods.

Finally, a correction shall be applied using the deep infiltration fraction (θ), which represents the proportion of infiltrated water that effectively contributes to aquifer recharge (excluding rapid or superficial flows that do not support water regulation).

By multiplying the infiltrated volume by the value of θ, only the portion of additional water considered effective for the generation of Verified Water Credits (VWC).

$$\frac{\theta * A * \sum_{d=1}^{D}[\min(I_{act}, P_d) - \min(I_{base}, P_d)]}{1000}$$

This value represents the final volume of additional infiltrated water attributable to the project within the corresponding stratum.

This procedure shall be repeated for each stratum defined in the project areas, applying the same calculations for infiltration depth, volume, and correction using the deep infiltration fraction (θ). The corrected volumes from all strata shall then be summed to obtain the total volume of additional infiltrated water (m^3/year) generated by the project during the corresponding verification period.

This total volume serves as the technical basis for the quantification and certification of Verified Water Credits (VWC) from infiltration.

$$\mathrm{NG}_{\frac{\mathrm{m}^3}{\mathrm{Year}}}\ \mathrm{totales} = \mathrm{NG}_{\frac{\mathrm{m}^3}{\mathrm{Year}}}\ \mathrm{stratum}\ 1 + \mathrm{NG}_{\frac{\mathrm{m}^3}{\mathrm{Year}}}\ \mathrm{stratum}\ 2 + \mathrm{NG}_{\frac{\mathrm{m}^3}{Year}}\ \mathrm{stratum}\ \mathrm{n}$$

The total net water gains represent the annual additional volume of infiltrated water (m^3/year) attributable to the sustainable water management and conservation activities implemented in the project areas. This value constitutes the primary quantifiable outcome under this methodology.

In addition to this hydrological benefit, the implemented activities also generate significant environmental co-benefits, such as the enhancement of biodiversity, the functional recovery of ecosystems, and the increased storage of carbon, both in aboveground biomass and in soil carbon reserves.

9 Quantification of Water Credits from Increased Infiltration

The variables used for the quantification of Verified Water Credits (VWC) shall be expressed in cubic meters per year (m^3/year). These units reflect the additional volume of infiltrated water attributable to the sustainable water management and conservation activities implemented in the project areas and serve as the basis for credit certification in accordance with this methodology.

To quantify Verified Water Credits (VWC) from infiltration, generated through the implementation of sustainable water management and conservation activities, the equations established in this methodology shall be applied. These formulas allow for the estimation of the additional volume of infiltrated water per year (m^3/year) attributable to the project and shall be used during each verification period to ensure traceability and consistency of the calculation.

$$\text{Verified Water Credits } (VWC) = \text{Water Net Gains } (NG)\ (m^3/Year)$$

The sum of the net water gains from infiltration, expressed in cubic meters per year (m^3/year) and obtained across all strata within the project areas, constitutes the technical basis for determining the Verified Water Credits (VWC) generated. The relationship between the additional infiltrated volume and the number of VWC issued is directly proportional, provided that the calculations and measurements used comply with the requirements set forth in this methodology, including representativeness, traceability, and data consistency.

10 Monitoring of the project activities

The monitoring of sustainable water management and conservation activities is necessary to verify:

(a) the effective implementation of the project's planned interventions,

(b) progress in the restoration of natural vegetation cover, and

(c) improvement in soil infiltration capacity.

In addition, monitoring allows for the evaluation of compliance with projections and for the annual estimation of net water gains from additionality and the reduction in water use within the targeted landholdings, serving as the basis for the quantification of Verified Water Credits (VWC).

10.1 Monitoring Method.

The implementation of the monitoring plan shall be structured based on the stratification of land cover types present at the start of the project. This implies that:

(a) each type of cover to be restored or improved shall constitute a specific monitoring stratum;

(b) field measurements shall be conducted within each stratum to ensure representativeness and comparability across monitoring periods.

The monitoring plan shall include, at a minimum, the following elements for each stratum:

(a) Infiltration rates (before and after intervention);

(b) Soil data, including texture, bulk density, and soil organic matter;

(c) Biodiversity indicators, particularly in strategic ecosystems;

(d) Monitoring of vegetation cover recovery;

(e) Estimates of increased plant biomass as a complementary indicator of ecosystem functionality.

10.2 Components of the Monitoring Plan.

The monitoring plan includes two complementary components:

10.2.1 Field monitoring

Includes the execution of direct infiltration measurements, soil characterization (texture, density, moisture), and, when applicable, socioeconomic aspects related to water resource management in the project areas.

10.2.2 Satelite Monitoring

Involves the analysis of biophysical variables at spatial scale using satellite platforms and GIS tools, including precipitation, temperature, evapotranspiration, biomass changes, and land cover transformation.

The monitoring plan shall be implemented annually, with at least one campaign conducted during the rainy season and another during the dry season, in accordance with the precipitation patterns of the project area. This approach allows for the capture of seasonal variations and improves the representativeness of the data used for the quantification and verification of results.

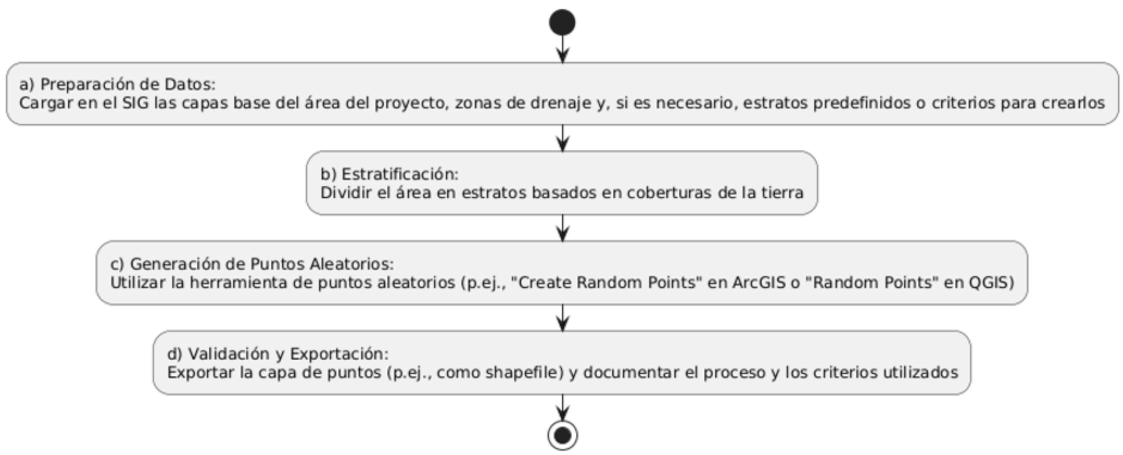
10.3 Monitoring Points.

Monitoring points shall be selected through stratified random sampling, using random point generation tools within Geographic Information Systems (GIS).

The distribution of points shall take place within each defined stratum, ensuring that they are located in representative drainage zones within the project areas. This guarantees the spatial validity of the measurements and enables comparability across monitoring campaigns.

The procedure for generating and distributing random points is presented in Figure 11.

Figure 11. Procedure for Generating Random Monitoring Points



10.4 Sample size.

The sample size should be determined in such a way as to ensure statistical representativeness within each defined stratum. For this purpose, a sufficient number of sampling units per stratum should be selected, considering a confidence level of 95 % and a margin of error of less than 5 %.

Sample size determination can be done using recognized statistical methods, such as Cochran's formula for simple samples or Neyman's allocation for stratified samples. These formulas allow the monitoring effort to be optimally distributed, adjusting to the internal variability of each stratum and to the total project area..

Sample size per stratum (Cochran equation) (Cochran, 1977):

$$Tm = \frac{Z^2 * p * (1 - p)}{e^2}$$

Where:

Z	critical value of the normal distribution (for 95% confidence, Z=1.96).
P	estimated proportion of the characteristic of interest (if not known, use p=0.5p = 0.5p=0.5 to maximize variability)
e	maximum allowable sampling error (in this case, 0.05 for 5%).

In the case of projects with multiple strata, the total sample size n can be distributed among the different strata using Neyman's proportional allocation, which allows sampling to be optimized according to the relative size of each stratum.

The formula for proportional allocation is:

$$Zh = n * \frac{N_h}{N}$$

Donde:

T_h	Sample size assigned to stratum h
N_h	Population size of stratum h
N	Total Population Size (sum of all strata)
n	Sample size

If it is desired to improve sampling precision by considering the internal variability of each stratum, Neyman's optimal allocation (Neyman, 1934) can be applied. This method distributes the total sample size proportionally to the product of the size and the standard deviation of each stratum, prioritizing those with greater variability.

The formula is as follows:

$$n_h = n * \frac{N_h * S_h}{\sum_{h=1}^{L} N_h * S_h}$$

Donde:

n_h	sample size assigned to stratum h

N_h	population size of stratum h
S_h	standard deviation of stratum h
n	Total sample size

This approach makes it possible to optimize the sampling effort, improving statistical precision according to the heterogeneity observed between strata.

10.5 Distribution of monitoring points in project areas.

The spatial distribution of monitoring points should be randomized within each stratum, using random point generation tools available in geographic information systems (GIS).

The points should be organized in independent shapefile layers, where the limits and attributes of each stratum corresponding to the activities of sustainable management and conservation of water resources are clearly identified. This organization facilitates spatial analysis, traceability of measurements and follow-up during the different monitoring periods.

10.6 Monitoring Frequency.

Infiltration monitoring should be conducted at least annually, preferably incorporating multiple campaigns throughout the year to improve the representativeness of the data. It is advisable to take measurements during both the rainy and dry seasons in order to capture seasonal variability in infiltration rates.

Monitoring planning should consider the predominant precipitation regime in the project area (either monomodal or bimodal), to ensure that measurements adequately reflect the hydrological conditions of the territory.

10.7 Measurement with infiltrometers.

Ideally, high precision infiltration meters should be used to measure the infiltration rate (mm/day) at random and georeferenced points within each stratum. The data obtained should be recorded and managed through geographic information systems (GIS), ensuring traceability, spatial organization and availability for subsequent technical analysis.

However, if manual infiltrometers are used, due to conditions of access, safety, economic feasibility, or other considerations, it will be necessary to adequately justify this decision and to adjust the equations to quantify net water gains from increased infiltration (section 8) to account the frequency of measurement with manual instruments, and to use the measured values as average for the related periods.

Table 4. Infiltrometer types for baseline and infiltration monitoring

Infiltration Device Type	**Main Characteristics**	**Diameter (cm)**	**Primary Use**
Double Ring Infiltrometer (Van Walt, n.d.)	Measures water infiltration rate in soil; ideal for field studies.	30	Infiltration studies in agricultural soils
Mini Disk Infiltrometer (TecFresh, n.d.)	Easy setup and compact size; ideal for field measurements.	4.5	Hydrology studies and rapid field measurements
Automatic Infiltrometer (Plant-e, n.d.)	Automated device for real-time measurement of infiltration and soil temperature	N.A.	Real-time infiltration rate monitoring.

10.8 Verification and quality control of the data

A quality control procedure shall be applied to the data obtained in the different monitoring activities, including infiltration, precipitation, temperature, texture and soil density, both in field and satellite measurements, in order to identify and exclude outliers that may generate biases in the quantification.

Any data that exceeds one (1) standard deviation with respect to the mean of the data within each stratum should be eliminated, unless there is documented technical justification. Additionally, it shall be verified that the total error of the monitoring is kept below 10%, in order to ensure the reliability of the results used in the estimation of net water gains.

11 Assumptions and limitations of the methodology

This methodology is based on a series of technical and operational assumptions that allow for the standardized application of quantification procedures. Among them, it is assumed that:

(a) that the climatic and edaphic data used are representative of the project area;

(b) that the relationship between infiltration and deep recharge can be estimated from point data and extrapolated by stratum.;

(c) and that the modeled hydrological processes show moderate temporal variability, allowing interannual comparisons.

Likewise, the approach may present limitations in contexts with scarce local information or high spatial heterogeneity not adequately captured by the available inputs, or difficult access due to physical, social or financial conditions. In such cases, the use of regional assumptions, multi-year averages or secondary data should be duly documented and justified.

When the project is implemented in areas outside the edaphoclimatic conditions common to the methodology, or when alternative data or proxies are used, a partial recalibration of the model or a complementary sensitivity assessment is recommended.

12 Project document management

12.1 Management of project databases

The implementation of all the procedures established in this methodology shall be supported by an integrated database, which allows managing, storing and updating the technical information generated during the project cycle.

The use of Geographic Information Systems (GIS) is essential for the organization and analysis of spatial data. It is recommended to structure the database on robust platforms, such as the GDB model of ArcGIS (Environmental Systems Research Institute), which allows the efficient integration of multiple thematic layers, attributes and metadata.

Alternatively, open-source solutions can be used, such as QGIS, which allows the use of compatible databases such as QPK and integration with other external sources to improve visualization, traceability and spatial analysis.

Proper document management ensures that all project information is organized, available and verifiable, facilitating technical analysis, informed decision making and compliance with monitoring and verification requirements.

13 Verification and quality assurance

The results generated through this methodology will be subject to independent auditing processes, in accordance with the requirements of the BioCarbon Water Standard. In particular, the following conditions shall be met to ensure the traceability and validity of the Verified Water Credits (VWCs):

(a) All information used in the calculations shall be documented, geo-referenced and available for review;

(b) Data collection, analysis and modeling procedures shall be consistent with this methodology, including the use of the formats, equations and variables indicated;

(c) Field measurements and satellite data used shall be traceable to their sources, with sufficient technical support to demonstrate their representativeness;

(d) Consistency between baseline data, project scenarios and quantified results shall be subject to review by the certification body.

Failure to comply with these conditions may affect the approval of the project and, thus, the issuance of the credits requested. The project holder is responsible for maintaining an updated and verifiable information system as part of its monitoring and document management plan.

14 References

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration: Guidelines for computing crop water requirements (FAO Irrigation and Drainage Paper No. 56). FAO. https://www.fao.org/3/X0490E/x0490e00.pdf

Banco Mundial. (2014). Water storage: Analysis and design. https://openknowledge.worldbank.org/bitstream/handle/10986/21042/Water-Storage-Analysis-and-Design.pdf

BioCarbon Cert. (2025). BWS0001. Metodología para cuantificar las ganancias netas de agua por manejo de la infiltración en cuencas hidrográficas. Versión Consulta Pública.

Climate Hazards Group. (s. f.). CHIRPS Daily [Conjunto de datos]. https://developers.google.com/earthengine/datasets/catalog/UCSB_CHG_CHIRPS_DAILY

Cochran, W. G. (1977). Sampling techniques (3rd ed.). John Wiley & Sons.

Convención Marco de las Naciones Unidas sobre el Cambio Climático. (s. f.). Recursos hídricos. https://unfccc.int/sites/default/files/ch6_water_resources-handbook.pdf

Convención de las Naciones Unidas de Lucha contra la Desertificación. (s. f.). Recursos hídricos. https://www.unccd.int/sites/default/files/2018-06/GLO%20Spanish_Ch8.pdf

Deutsches Zentrum für Luft- und Raumfahrt. (s. f.). TanDEM-X [Conjunto de datos]. https://tandemx-science.dlr.de

Dunne, T., & Black, A. (1990). Soil erosion and runoff. FAO. https://www.fao.org/3/t0688e/T0688E00.pdf

Environmental Protection Agency. (2000). Soil infiltration rate testing. https://www.epa.gov/sites/production/files/2015-08/documents/infiltration_rate_testing.pdf

Elevitch, C. R., & Wilkinson, K. M. (s. f.). Sheet mulching: Greater plant and soil health for less work. Permanent Agriculture Resources. https://www.ctahr.hawaii.edu/oc/freepubs/pdf/Sheet_Mulching.pdf

FAO. (2006). La larga sombra del ganado: Cuestiones y opciones ambientales. https://www.fao.org/3/a0701s/a0701s.pdf

FAO. (2011). The state of the world's water. https://www.fao.org/3/a-i2917e.pdf

FAO. (2013). Conservación y rehabilitación de suelos en América Latina y el Caribe. https://www.fao.org/3/i3340s/i3340s.pdf

FAO. (2019). El estado de la biodiversidad para la alimentación y la agricultura en el mundo. https://openknowledge.fao.org/server/api/core/bitstreams/79dee2e1-bbf2-4fee-8159-5ef8e50e91b9/content

Fundación Biodiversidad. (s. f.). Guía de restauración ecológica. https://ieeb.fundacionbiodiversidad.es/sites/default/files/guia_de_restauracion_ecologica_baja_0.pdf

Global Water Partnership. (2000). Integrated water resources management (Background Paper No. 4). https://www.gwp.org/globalassets/global/toolbox/publications/background-papers/2000_11_integrated_water_resources_management.pdf

Global Water Partnership. (2018). Gobernanza del agua: Estrategias y desafíos para la gestión sostenible. https://www.gwp.org/es/docs/gobernanza_del_agua.pdf

Hoekstra, A. Y., & Chapagain, A. K. (2008). Globalization of water: Sharing the planet's freshwater resources. IWA Publishing. https://waterfootprint.org/media/downloads/RefThesis.pdf

Holdrich, J. (1995). Métodos empíricos para la estimación de la evapotranspiración en condiciones semiáridas [Informe técnico]. Instituto Nacional de Recursos Hídricos.

Holzer, S. (2011). Desert or paradise: Restoring endangered landscapes using water management, including lake and pond construction. Permanent Publications.

Instituto Nacional de Hidrología. (2010). Conceptos básicos de hidrología y medición del caudal. https://www.hidrologia.gob.mx/docs/hidrologia_basica.pdf

Japan Aerospace Exploration Agency. (s. f.). ALOS World 3D – 30 m (AW3D30). https://www.eorc.jaxa.jp/ALOS/en/aw3d30/

National Oceanic and Atmospheric Administration. (2017). Precipitation measurement. https://www.ncdc.noaa.gov/monitoring-references/faq/precipitation-measurements.pdf

Neyman, J. (1934). On the two different aspects of the representative method: The method of stratified sampling and the method of purposive selection. Journal of the Royal Statistical Society, 97(4), 558–625.

Organización Mundial de la Salud. (2017). Directrices de calidad del agua potable. https://www.who.int/water_sanitation_health/publications/2017-wq-guidelines.pdf

Pizarro, R., Flores, J., Sangüesa, C., & Martínez, E. (2004). Zanjas de infiltración. Universidad de Talca. https://www.cuhs.utalca.cl/exctha/Docs/pdf/Publicaciones/libros/Zanjas.pdf

Proyecto LIFE MedWetRivers. (s. f.). Anexo: Tabla de impactos Planes básicos vs. PYA UE. https://www.lifemedwetrivers.eu/sites/default/files/documentos/anexo1_tabla_impactos_planes_basicos_vs_pya_ue_0.pdf

Secretaría de Medio Ambiente y Recursos Naturales. (2017). Control de nutrientes en cuerpos de agua: Estrategias para prevenir la eutrofización. https://www.gob.mx/medioambiente/documentos/control_de_nutrientes.pdf

The Nature Conservancy. (s. f.). Fondos de agua: Invirtiendo en la naturaleza para la seguridad hídrica. https://www.conservationgateway.org/Documents/LAWFP-ESP-low%20050312.pdf

UICN. (2014). Restauración funcional del paisaje rural: Manual de técnicas. https://portals.iucn.org/library/sites/library/files/documents/ST-GFE-no.03.pdf

UN-Water. (2015). Water security and the sustainable development goals. https://www.unwater.org/publications/water-security-and-sdgs.pdf

Wischmeier, W. H., & Smith, D. D. (1978). Predicting rainfall erosion losses—A guide to conservation planning (Agricultural Handbook No. 537). USDA. https://www.fao.org/3/X0560E/X0560E00.pdf

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Type of document

Methodological document. Methodology for quantification of net water gains due to increased infiltration in watersheds.

Version	Date	Nature of the document
Version for Public Consultation	June 27, 2025	Initial version
Version 1.0	September 22, 2025	Includes the answers to comments received during public consultation, as well as some minor modifications to improve the process of quantifying water credits, and to shed some light on some variables and procedures.