ASES ON-CHAIN PROTOCOL V2.0

BASELINE FIELD REPORT

Santa Isabel Water and Soil Credits

LT-012-MEX-210823 CHIHUAHUA, MÉXICO
Santa Isabel, Chihuahua, México
Type B Project

November 2023

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On-Chain Protocol

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EXECUTIVE SUMMARY

The baseline report for the projects is an essential undertaking for their certification process. This step is vital as it lays the groundwork for determining the initial metrics of biomass production, subsequent carbon sequestration, soil erosion, and soil water management in each project. The report encompasses the calculation of NDVI along with an evaluation of soil erosion within the project area. These assessments are conducted using a specific methodology that utilizes satellite imagery and high-resolution ortho mosaics.

The ecological restoration of a plot devoid of vegetation due to overgrazing in Santa Isabel, Chihuahua (Mexico) entailed planting a total of 4,232 *Prosopis glandulosa* (sweet mesquite) plants, mainly native to the region and well-suited for adverse environmental conditions. The project area, situated in the limits of the Santa Isabel community, municipality of Chihuahua, covered 79,118.08 square meters.

The moderate-density technique was employed, providing numerous benefits such as improved yield and efficient resource utilization. The average planting density within the plot was one tree per 19.2 square meters, equivalent to an average of 521 trees per hectare in the plot.

The total soil loss within the restored parcel prior to project implementation was 89.61 tons in 2021. After project implementation soil loss rates reduced to 33.95 tons in 2022 and it is anticipated to further reduce to 5.14 tons in future by 2052. These figures underscore the project's significant contribution to soil erosion management and overall environmental restoration.

The successful reforestation endeavor in Chihuahua demonstrates the positive impact of employing dense planting techniques and strategically selecting native species to reclaim and revitalize degraded landscapes, providing ecological, economic, and social benefits for the region and its communities.

I. Project Design

This section is based on the information compiled in the PSF Format - Project Submission Form prepared by the project developer.

I.1. Project location

The project is located in the Santa Isabel community, municipality of Chihuahua, (Mexico). The afforested plot lies close to adjoining Grassland and Shrubland areas. A project location map is illustrated in Figure 1. Table 1 shows the coordinates of the reforested Plots.

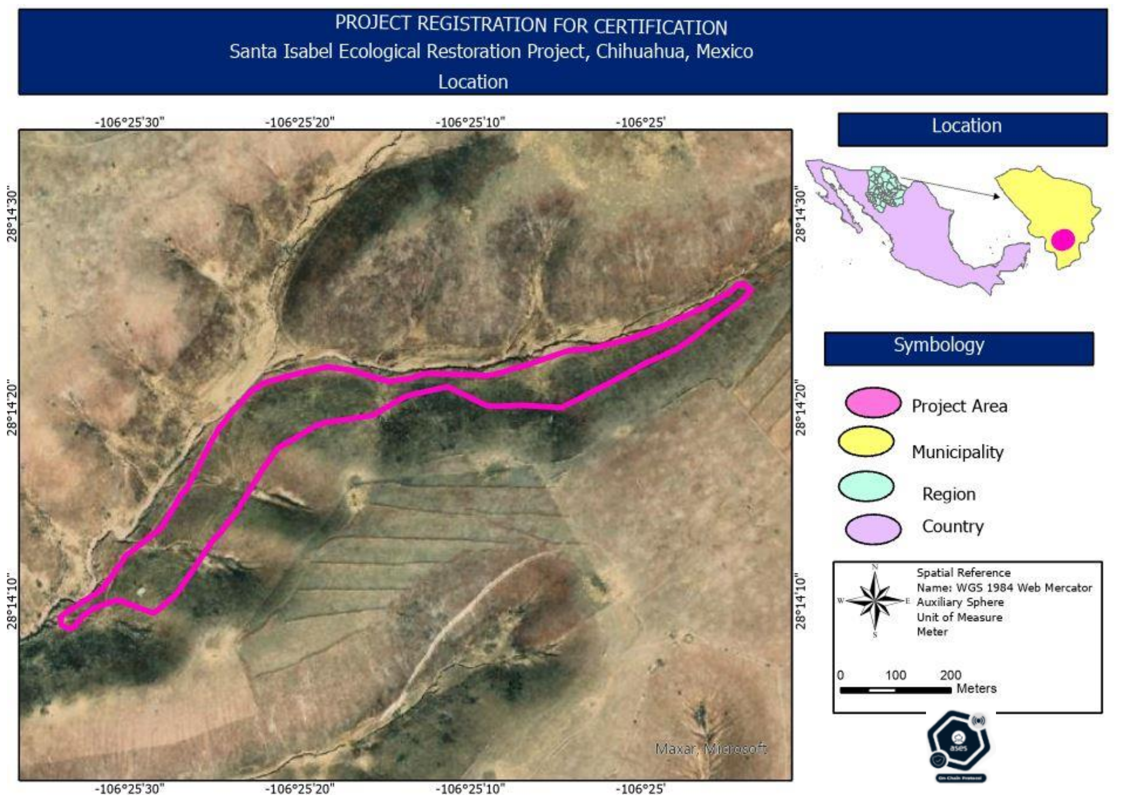

Figure 1. Project location

Table 1. Project area location

Plot	Coordinates	
1	**Latitude**	**Longitude**
	28.2384364°N	106.4214020°W

I.2. Administrative specifications

This section introduces the project developer and provides a clear understanding of the roles and responsibilities assigned to each party involved. It also addresses the status of land ownership, ensuring transparency and certainty regarding the agreements made with the landowners.

I.2.1. Project developer

Key project	LT-012-MEX-210823 CHIHUAHUA, MÉXICO
Project name	Santa Isabel Water and Soil Credits
Company	Life Terra (foundation)
Person responsible	Sven Kallen
Fiscal address	1043 CR Ámsterdam – The Netherlands
Telephone	+31.20 2620240
Mail of the person authorized to receive notifications	sven@lifeterra.eu

I.2.2. Type of project

Type	☐ Forest management ☐ Regenerative agriculture ☐ Silvopastoral management ☐ Individual tree-based climate action / urban forest ☒ Water flow restoration ☐ Biochar

I.2.3. VNPCs the project is applying to

Type of VNPCs the project is applying for	☐ Carbon Removals (VCRm) ☐ Carbon Emission Reductions (VCRd) ☐ Biodiversity Based Credit (VBBC) ☒ Water Credits (VWC) ☒ Soil Credits (VSC) ☐ Climate action bond

II. PROJECT AREA BASELINE

An evaluation of the ESA-worldcover-v200 for 2021, focusing on land use and land cover, revealed that the project site was situated within a predominantly Grassland area. Adjoining land covers include Shrubland and Grassland areas extending a few kilometers from the site.

II.1. SPECTRAL RESPONSE

When solar radiation interacts with an object, one of three situations can occur, either individually or in combination:

Reflection: The radiation can bounce off the object partially or entirely, resulting in reflection.

Absorption: The object can absorb the radiation, taking in its energy.

Transmission: Radiation can pass through one object and reach another, known as transmission.

The extent to which radiation is reflected, absorbed, or transmitted depends on the specific physicochemical characteristics of the objects involved. However, for object identification purposes, our primary interest lies in the reflected light or radiation at different wavelengths. For instance, vegetation exhibits low reflectance in the visible range, but the presence of chlorophyll in plants increases reflectance in the green channel. On the other hand, plants demonstrate the highest reflectance in the near-infrared region of the electromagnetic spectrum.

II.1.1. INDEX

Vegetation indices (VI) are extensively employed for monitoring and detecting changes in vegetation and land cover. These indices are created by considering the contrasting absorption, transmittance, and reflectance of energy by vegetation across the red and near-infrared portions of the electromagnetic spectrum. Numerous studies have demonstrated that the Normalized Difference Vegetation Index (NDVI) is particularly resilient against the influence of topographic factors. NDVI is commonly utilized as a broad indicator of photosynthetic activity in plants and the corresponding aboveground primary production.

The calculation of NDVI was performed using Sentinel-2 satellite images in the Google Earth Engine platform. Images with less than 20% cloud cover were selected for each month. The assessment focused on the average monthly NDVI time series spanning from January 1, 2021, to October 30, 2023. The findings are presented in Figure 2, which covers both pre- and post-project implementation periods. To delineate the pre- and post-project implementation periods, it is important to note that the reforestation activities took place between July and September 2021. Consequently, all months before these dates are considered the pre-project implementation period, while months after are regarded as the post-project implementation period for this analysis. Analyzing the NDVI values within the plot reveals a spectrum ranging from 0.13 to 0.18 before the project's initiation with the lowest NDVI observed in March 2021.

Given the known information a healthy, dense vegetation canopy typically exhibits NDVI values above 0.5, while sparse vegetation generally falls within the range of 0.2 to 0.5. The current assessment indicates that the reforestation project has the potential to foster an ascending trend in the plot's NDVI as it transitions to a forested area. With the project in place, it is anticipated that the NDVI will continue to rise further, eventually reaching a level indicative of a healthy and thriving vegetation cover.

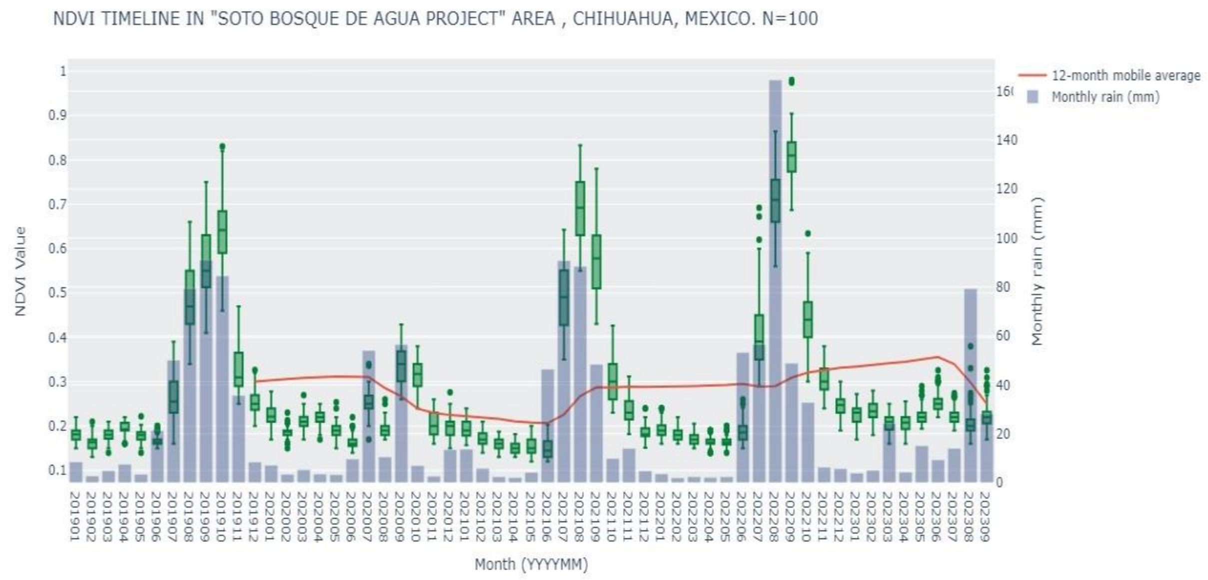

FIGURE 2. RAINFALL AND NDVI TIMESERIES IN THE AREA OF INTEREST

II.2. IMPACT ON THE LANDSCAPE

The project site had experienced decreased biodiversity, and reduced ecosystem services prior to undergoing reforestation efforts. However, this ecological restoration initiative plays a pivotal role in safeguarding various plant and animal species by establishing new habitats and reinstating wildlife corridors as healthy vegetation is crucial for the survival of many species. Furthermore, reforestation contributes to the re-establishment of natural hydrological cycles, by slowing down runoff, enhancing water infiltration, and reducing soil erosion. This helps regulate water flow, improve water quality, and mitigate the impacts of flooding.

An added advantage is the reforested landscapes offering aesthetic beauty and recreational opportunities. They can provide green spaces for leisure activities, such as hiking, wildlife observation, and eco-tourism, enhancing the well-being of local communities and visitors. The implemented project is therefore poised to amplify the effectiveness of these endeavors.

FIGURE 3. SATELLITE AERIAL VIEW OF PROJECT AREA BEFORE (2021) AND AFTER (2023) PROJECT IMPLEMENTATION

III. TECHNICAL SPECIFICATIONS

III.1. GROUND WORKS

Soil restoration works are those actions carried out to recover the quality and productivity of soils that have been degraded. In general, they are focused on the following objectives:

- **Improve soil structure:** This can be achieved by incorporating organic matter, reducing compaction and building drainage structures.
- **Reduce erosion:** This can be achieved by planting trees and shrubs, constructing barriers and implementing appropriate management practices.
- **Protect soil biodiversity:** This can be achieved through the conservation of vegetation cover, the creation of wildlife refuges and waste management.

The soil works carried out in the **Soil regeneration project in Soto, Ángel Trías, Chihuahua** were mainly focused on reducing soil erosion and promoting forest cover regeneration. The design of the works followed the "trench-board" methodology.

The "trench-board" works are a practice implemented to control laminar erosion, its benefits are focused on:

- Retain soil and sediment;
- Decrease the degree and length of slope;
- Prevent the formation of gullies;
- Reduce sediment content in runoff water;
- Capture rainwater, promoting water infiltration;
- Intercept runoff and reduce its velocity;
- Increase soil moisture, which helps the establishment of forest vegetation;
- Improve water quality.

According to the Comisión Nacional Forestal (CONAFOR), the " trench-board" works are a set of ditches and berms, as the name implies, which are built on contour lines, placing the product of excavation downstream of the ditch to form the board. The ditches are constructed with dividing dikes to section off the water storage.

Activities conducted in the **Soil regeneration project in Soto, Ángel Trías, Chihuahua,** included drawing contour lines across a 13.4-hectare area using a laser level to prepare for ditch opening. This contouring followed a board ditch design, with a 6-meter separation between lines, to facilitate soil retention and expedite water capture and infiltration. Soil works conducted included excavating a trench board with dimensions: 30 cm deep and 40 cm wide. This trench was designed to enhance rainwater retention and infiltration, as well as to create access roads for various reforestation tasks. Finally, 4,232 *Prosopis glandulosa* (Mesquite) plants were transported to the project site for planting.

FIGURE 6. DRAWING CONTOUR LINES

FIGURE 5. FLAG FOR MARKING

FIGURE 4. DRAWING CONTOUR LINES

FIGURE 7. DRAWING CONTOUR LINES

FIGURE 8. GROUND WORKS LAYOUT

FIGURE 9. AERIAL PHOTO OF THE CONSTRUCTION SITE LAYOUT IN THE PROJECT AREA

Source: Google Earth 2023

III.1.1. METHODOLOGICAL PROCESS OF GROUND WORKS

The first step consists of drawing contour lines based on the amount of runoff to be captured. Their construction should consider the excavation necessary to capture 50% and up to the total runoff produced in a return period of 5 years.

The second step consists of excavating the land and shaping the embankment. The excavation of continuous trenches 40 cm wide by 40 cm deep is started on the contour lines that have been dug. The product of the excavation is placed downstream of the trench and must be separated from it by at least 20 cm to prevent the material from returning to the excavation.

The third step consists of building a 50 cm dividing dike approximately every four or five meters. This dike is built to section off the stored water and prevent it from concentrating at certain points, thus reducing the risk of breaking the embankment.

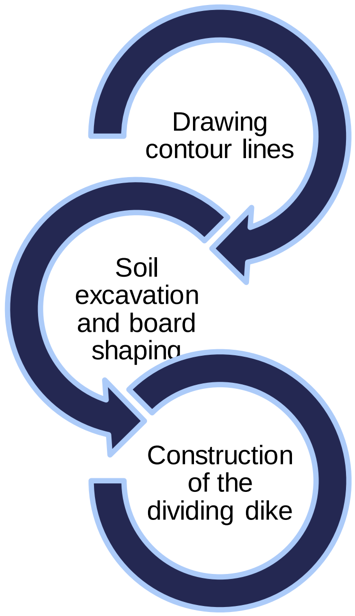

FIGURE 10. PROCESS OF THE CONSTRUCTION OF THE WORKS TRENCH-BOARD

III.2. REFORESTATION

The project encompasses a plot with a total surface of 8.05 hectares, situated in Santa Isabel community, municipality of Chihuahua, (Mexico). The demarcated plot is shown in Figure 3.

III.2.1. SPECIES

The reforestation project successfully planted a total of 4,232 trees, encompassing one plant species. The number of individuals is shown in Table 2. The selection of species was based on a preliminary assessment of the region, considering available bibliographic information, as well as the prevailing climatic, vegetational, and meteorological conditions. The species chosen is indigenous to the area and well-suited to the local climate and environmental conditions.

Out of the total number of trees planted (4,232), the percentage by species is presented in Table 2.

TABLE 2. NUMBER OF TREES BY SPECIES

Species	Number of trees	Percentage (%)
Prosopis glandulosa	4,232	100
Total	4,232	100%

The assessment revealed an average planting density of one tree per 19.2 square meters, equivalent to an average of 521 trees per hectare in the plot (figure 4). This moderate density approach offers several ecological, environmental, and economic advantages. The moderate tree density, combined with the implementation of various tree species, will foster biodiversity, and enhance ecological resilience within the restored ecosystem. Moreover, the density will expedite canopy closure, creating a continuous cover as the tree canopies interlock. This canopy closure plays a crucial role in weed suppression, creating improved microclimates, moisture retention and reducing soil erosion. However, it's important to note that high planting densities can also lead to competition for resources among trees, which may result in stunted growth, reduced health, and increased mortality of some trees. In addition, the proximity between trees can facilitate the rapid spread of diseases and pests. Controlling and managing these issues becomes more complex in densely planted areas.

As a result of this moderate-density with “wide spacing" planting strategy, the reforestation project is well-positioned to maximize carbon sequestration potential, promote wildlife habitat, and provide essential ecosystem services. The management of this densely planted plot will be critical to ensure the continued success and long-term sustainability of the reforestation efforts. Figure 4 shows the mapped planting density of the geolocalized trees within the plots with the location of each tree represented by dot symbols.

The technical data sheets providing detailed information about the species utilized for the reforestation project are included in Table 3. These sheets offer comprehensive insights into the characteristics, growth patterns, environmental requirements, and other relevant details of the selected plant species. These data sheets serve as valuable references for understanding the specific attributes and suitability of each species for the reforestation efforts.

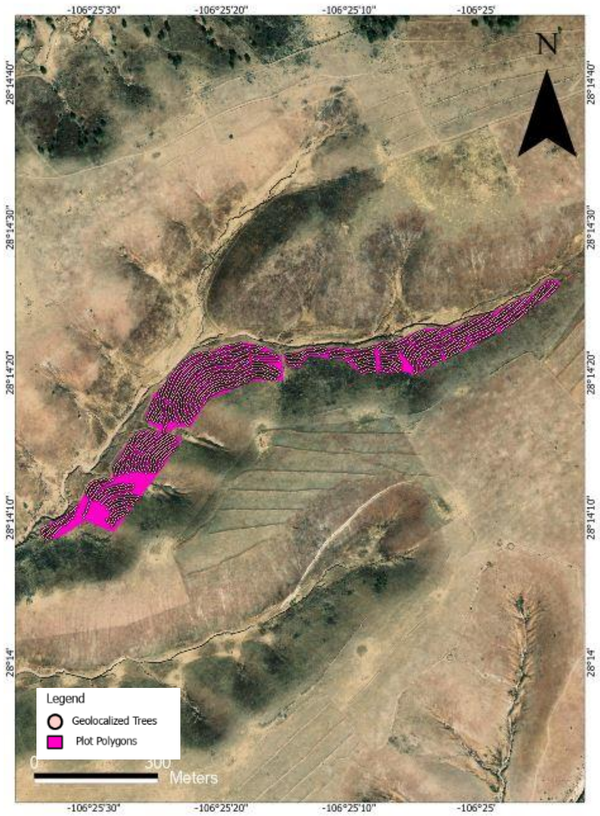

FIGURE 11. TREE PLANTING DISTRIBUTION

TABLE 3. TECHNICAL DATA SHEETS OF SPECIES USED FOR REFORESTATION

Prosopis glandulosa • *Prosopis glandulosa*, commonly known as honey mesquite, is a species of small to medium-sized, thorny shrub or tree in the legume family. • The plant is primarily native to the Southwestern United States and Northern Mexico. • This tree normally reaches 20–30 ft (6.1–9.1 m), but can grow as tall as 50 ft (15 m) and is considered to have a medium growth rate. • *Prosopis glandulosa* shrubs and trees provide shelter and nest building material for wildlife, and produce seed pods in abundance containing beans that are a seasonal food for diverse birds and small mammal species. • Honey mesquite is a honey plant that supports native pollinator species of bees and other insects, and cultivated honey bees.	

III.2.2. Reforestation technique

The reforestation technique implemented is the wide spacing or moderate-density Planting technique. Wide spacing or moderate density planting is a reforestation technique where tree seedlings are planted with relatively larger gaps between them. This approach contrasts with high-density planting, where seedlings are placed closer together. The wide spacing technique aims to provide individual trees with more access to essential resources such as sunlight, water, and nutrients, allowing them to grow with reduced competition. The goal of this technique is to optimize the use of available resources, such as sunlight, water, and nutrients, by creating a more efficient growing environment as trees have ample room to establish strong root systems and develop healthier canopies, potentially leading to better long-term growth. Additionally with wider spacing, there's a reduced risk of disease transmission between trees compared to denser plantings.

Nonetheless, it is important to note that the suitability of wide spacing depends on factors like soil type, climate, and water availability. Also, choosing tree species adaptable to wider spacing is crucial for successful establishment. It is a balance between optimizing individual tree growth and considering the overall ecosystem dynamics.

III.2.3. Methodological process of reforestation

The operational phase is divided into three steps shown in Figure 12.

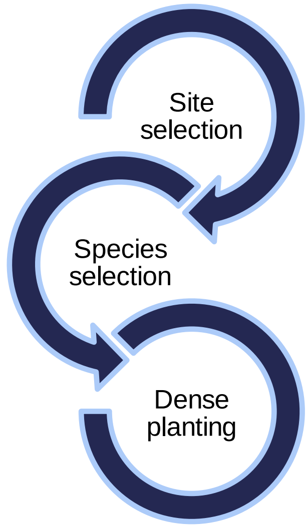

Figure 12. Methodological process of reforestation

The reforestation process involved a well-defined series of steps. Firstly, a thorough evaluation was conducted to select the most suitable reforestation area, considering restoration needs, climatic and soil feasibility, permit requirements, and cost considerations. It ensured that the chosen location was conducive to successful reforestation. To preserve the ecological integrity of the region, afforestation was not carried out on scarified ground. This approach aimed to leverage the existing ecosystem to facilitate the growth and development of the newly planted trees, promoting biodiversity and increasing the chances of successful reforestation. Local community stakeholders were actively involved in the process, fostering a sense of ownership and sustainability in the reforestation initiative.

IV. Soil Erosion Assessment

This section presents the outcomes of a soil erosion assessment conducted in the Micro Basin where the Project area is located, including a designated restoration area. The findings from this assessment will have a significant impact on the allocation of soil credits for the project under consideration.

The RUSLE methodology for erosion assessment was used in this analysis. To delineate the pre- and post-project implementation periods, it is important to note that the reforestation activities took place between July and September 2021. Consequently, all months before these dates are considered the pre-project implementation period, while months after are regarded as the post-project implementation period for this analysis.

The evaluation covered four distinct periods:

Table 4. Evaluation periods

Period	Date range
Pre-project	July 2019 to June 2021
1st year monitoring	October 2021 to October 2022
Year 10 projection	October 2030 to October 2031
Year 40 projection	October 2060 to October 2061

Of the 5 factors influencing hydric erosion, only the R-, C- and P-factors are considered to considerably change over time. Table 5 shows the combination of these factors used to compute soil loss rate for the assessed periods.

Table 5. Combination of datasets used to represent the four scenarios for erosion modelling

Scenario	C - Factor	P- Factor	R-factor
Before Project	Pre-project	Without soil management practices	Yearly rain in pre-project period
After Project Year 1	Monitoring	With soil management practices	Yearly rain in monitoring period
After Project Year 10	Pre-project & Maximum*	With soil management practices	Yearly rain in year 10 after implementation
Project's last year	Pre-project & Maximum*	With soil management practices	Yearly rain in year 40 after implementation

*See detailed description on *Vegetation Cover (C) factor* subsection below.

By integrating these RUSLE parameters, the assessment provides valuable insights into the soil erosion dynamics within the study area and offers essential guidance for sustainable land management practices and erosion control strategies

IV.1. RUSLE Parameters Extraction

All processing was executed in Google Earth Engine.

Rainfall Erosivity (R) Factor

R-factor is a measure used to quantify the erosive force of rainfall and its impact on soil erosion. This was computed from the equation from Renard, Fremund, (1994) R factor equation for Conterminous US. This was chosen as the project area falls within this region. Annual rainfall for each assessed period was acquired from the CHIRPS database and used in this computation. For the 10 and 40^{th} years projections, rainfall data was obtained from the *NASA Earth Exchange Daily Downscaled Climate Projections (NEX-GDDP-CMIP6)* (Thrasher et al., 2012), retrieved from the GEE catalog. These CMIP6 GC Models were developed in support of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR6) based on two of the four “Tier 1” greenhouse gas emissions scenarios. The SSP245 CMIP6 scenario was used for the analysis. The SSP245 scenario builds upon the RCP4.5 scenario, with an additional radiative forcing of $4.5W/m^2$ by the year 2100, representing the medium pathway of future greenhouse gas emissions. This scenario assumes that climate protection measures are being taken.

Slope Length and Slope steepness (LS) Factor

The effect of topography in erosion processes is represented in RUSLE as the slope length and slope steepness (LS) factor. The LS factor for the area was derived from the Shuttle Radar Topography Mission digital elevation data, SRTM V3 product (SRTM Plus) is provided by NASA JPL at a resolution of 1 arc-second (approximately 30m) (Farr et al., 2007).

The LS-factor method from the “soil-erosion-watch“ repository, developed and published by Global Soil Watch (Ouellettev, 2021), was applied.

Vegetation Cover (C) factor

The effect of vegetation cover erosion management is represented by the C-factor. The C_{VK} equation, adapted to European climates, was employed in this case due to the climatic conditions of the Project area.

It was derived from yearly mean NDVI calculated from Sentinel 2 images acquired for the pre-project and monitoring periods. To determine the future C factor, the maximum pixel value for the annual NDVI found within the microbasin was used to establish the future NDVI that the Project area is expected to achieve once the planted trees mature and the ground works reach their full potential. The rest of the microbasin was assumed to maintain the same yearly NDVI as in the pre-project period.

Conservation Practice (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 table for contour strip cropping (David & P., 1988) was used as this was the support practice implemented in the area under study.

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

Soil Erodibility (K) Factor

K-factor represents the susceptibility of soil to erosion by runoff. It incorporates soil properties such as texture, structure, permeability, bulk density and organic matter content, which influence the capability of soil to resist detachment and subsequent transport of eroded particles.

The K-factor method from the “soil-erosion-watch“ repository, developed and published by Global Soil Watch (Ouellettev, 2021), was applied.

IV.2. Erosion Assessment Results

Erosion rates and percent change over the years in the microbasin and the Project area are depicted in Tables 5 and 6 respectively. Between pre-project and monitoring periods, the soil loss rate in the Project area decreased 23.2%, from -212 to 163 mm. In the same period, the counterfactual area also experienced an in decline, from 9.3 to 7.1 t ha^{-1} y^{-1}, equivalent to a 24.2% decrease. The rest of the microbasin also experienced a decline, from 5.5 to 3.7 t ha^{-1} y^{-1}, equivalent to -31.8%, similar to the Project area. At this first year after project implementation, its effects are not so notorious.

However, when observing the results expected at year 10 and 40, the project’s impacts on soil erosion reduction are more evident. The change in soil erosion rate from the pre-project period up to year 40 are: 58% decrease in the Project area, 9.4% increase in the counterfactual area and 11.2% decrease in the rest of the microbasin. The notorious difference between the counterfactual and the rest of the microbasin, considering both remain “unchanged”, can be due to differences in vegetation types, soil texture and slope. On the other hand, the difference between the Project area and the counterfactual, where both have similar ecological characteristics, can be attributed to the implementation of Project activities.

Table 6. Estimated soil erosion rates in the project area (8.05 ha), counterfactual (8.03 ha) and microbasin (827.03 ha) at the assessed periods

Period	Erosion Rate (t ha^{-1} y^{-1})			Total Soil loss (T y^{-1})		
	Project area	Counterfactual	Microbasin	Project area	Counterfactual	Microbasin
Pre-project	7.8	9.3	5.5	62.6	74.9	4528.8
Monitoring	5.3	7.1	3.7	42.8	56.8	3090.2
Year 10	3.0	9.3	4.4	24.0	74.7	3664.3
Year 40	3.3	10.2	4.9	26.3	82.0	4021.6

TABLE 7. PERCENTAGE CHANGE IN TOTAL SOIL EROSION RATE AND SOIL LOSS DIFFERENCE IN THE PROJECT AREA (8.05 HA), COUNTERFACTUAL (8.03 HA) AND MICROBASIN (827.03 HA) OVER THE ASSESSED PERIODS

Period	Percent change (%)			Soil loss difference (T y^{-1})		
	Project area	Counter-factual	Microbasin	Project area	Counter-factual	Microbasin
Pre-project to Monitoring	-31.7	-24.2	-31.8	-19.8	-18.1	-1440.2
Pre-project to Y10	-61.7	-0.3	-19.1	-38.6	-0.2	-865.0
Pre-project to Y40	-58.0	9.4	-11.2	-36.3	7.0	-507.2

Notably, project implementation leads to reduced erosion rates, compared to a scenario without restoration efforts. This can be attributed to the project's implementation of soil conservation measures, including contouring, the restoration of climate-resilient vegetation species and induction of vegetation natural regeneration by soil works. These measures collectively enhance ecosystem's resistance to erosion, contributing to the preservation of soil and the ecological functions it supports.

IV.3. SOIL CREDITS CALCULATION

As shown in table 7, the modelled change in the project scenario from year 0 to 40 is -58.0 %, whilst in the control area with a BAU scenario it is 9.4 %. Pre-project soil loss rate in the Project area is 7.78 t ha^{-1} yr^{-1}, according to the modelled Project scenario trajectory, its soil loss at year 40 will be 3.27 t ha^{-1} yr^{-1}. Contrastingly, if the Project area follows the modelled BAU trajectory, its soil loss at year 40 will be 8.5 t ha^{-1} yr^{-1}.

Two project scenarios were computed: conservative and optimistic. The conservative scenario assumes that the full impact of the project will be achieved until year 40. It is represented as a lineal progression from the Pre-project (year 0) until the Future (year 40) erosion rate. The optimistic scenario assumes that planted trees will mature and reach the maximum impact since year 10, maintaining the benefits until the end of the project.

Consequently, 3 scenarios were computed as follows:

- Project conservative scenario: linear change from year 0 until 40.
- Project optimistic scenario: linear change from year 0 until 10, then linear change from year 11 until 40.
- No project scenario: linear change from year 0 until 40.

Project's impact was calculated as the difference between the BAU and each of the project scenarios. The additional soil loss reduction that the Project could potentially achieve during its life was calculated as the sum of each year's impact. Table 7 compares the annual erosion rates in the Project area for the 3 assessed scenarios over the 40 years following project implementation.

Figure 12 illustrates Project area's modelled erosion rate for the 3 scenarios. The accumulated additional soil loss reduction at year 40, attributable to Project activities, is estimated to be between 107.21 and 180.66 t ha^{-1}. Considering the whole Project area (8.05 ha), the total mass of soil that can be prevented from eroding due to implementation of Project activities is between 863.06 and 1454.35 tons. Since 1 ton of soil prevented from being lost to erosion equals 1 Soil Credit, the total number of **Soil Credits the Project can generate is between 863 and 1454** (figure 14).

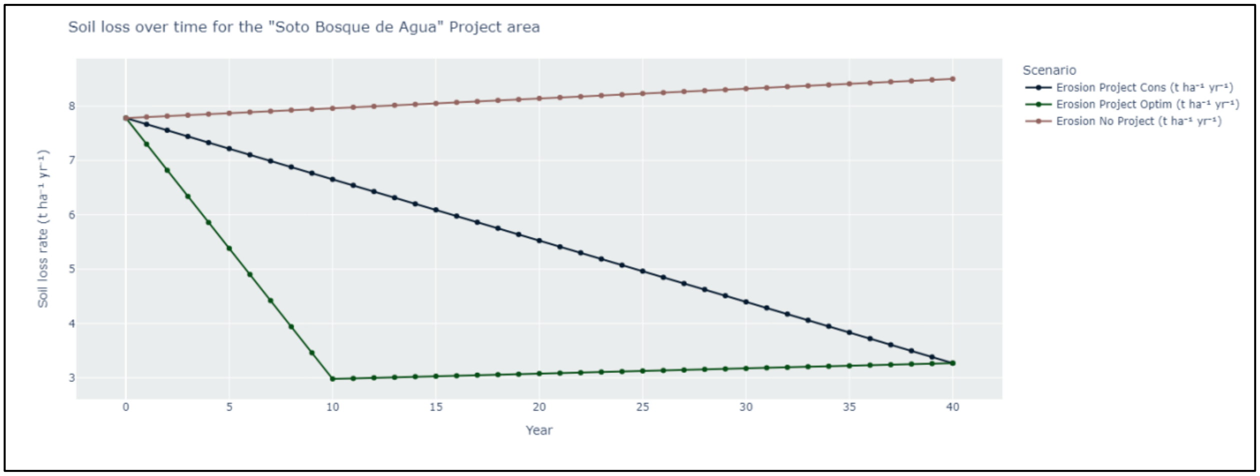

FIGURE 13. PROJECT AREA'S MODELLED EROSION RATE FOR THE 3 SCENARIOS

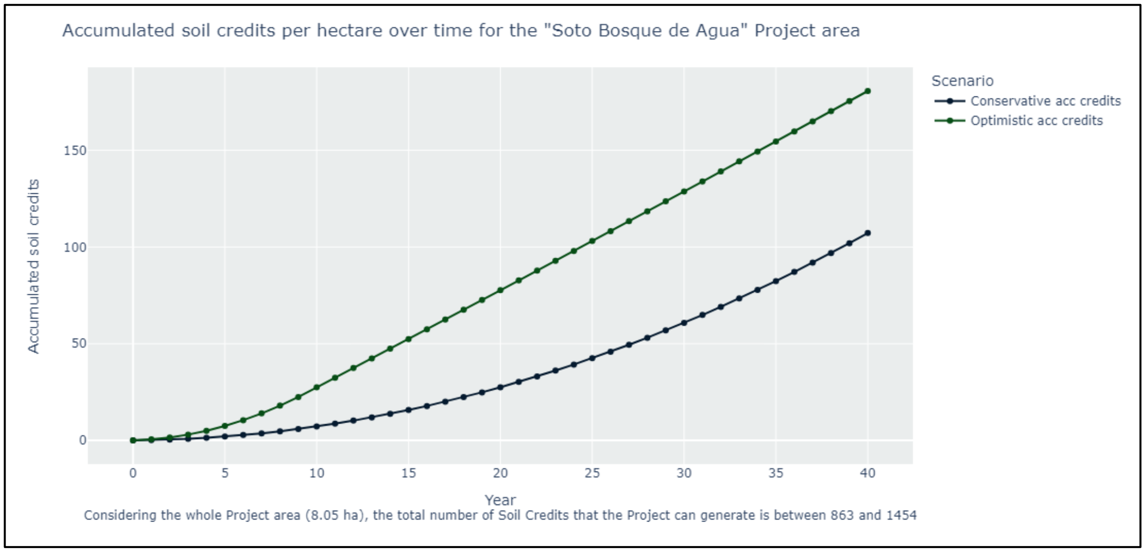

FIGURE 14. YEARLY ACCUMULATED NUMBER OF SOIL CREDITS PER HECTARE FOR BOTH THE CONSERVATIVE AND OPTIMISTIC SCENARIOS

TABLE 8. MODELLED YEARLY SOIL EROSION RATES IN THE PROJECT AREA AND ACCUMULATED NUMBER OF CREDITS PER HECTARE. (SEE NEXT PAGE)

Year	Erosion Project Cons (t/ha)	Erosion Project Optim (t ha^{-1})	Erosion No Project (t ha^{-1})	Impact Cons (t ha^{-1})	Impact Optim (t ha^{-1})	Conservative accumulated impact (t ha^{-1})	Optimistic accumulated impact (t ha^{-1})
0	7.8	7.8	7.8	0.0	0.0	0	0
1	7.7	7.3	7.8	0.1	0.5	0	0
2	7.6	6.8	7.8	0.3	1.0	0	1
3	7.4	6.3	7.8	0.4	1.5	1	3
4	7.3	5.9	7.9	0.5	2.0	1	5
5	7.2	5.4	7.9	0.7	2.5	2	7
6	7.1	4.9	7.9	0.8	3.0	3	10
7	7.0	4.4	7.9	0.9	3.5	4	14
8	6.9	3.9	7.9	1.0	4.0	5	18
9	6.8	3.5	7.9	1.2	4.5	6	22
10	6.7	3.0	8.0	1.3	5.0	7	27
11	6.5	3.0	8.0	1.4	5.0	9	32
12	6.4	3.0	8.0	1.6	5.0	10	37
13	6.3	3.0	8.0	1.7	5.0	12	42
14	6.2	3.0	8.0	1.8	5.0	14	47
15	6.1	3.0	8.1	2.0	5.0	16	52
16	6.0	3.0	8.1	2.1	5.0	18	57
17	5.9	3.0	8.1	2.2	5.0	20	62
18	5.8	3.1	8.1	2.4	5.0	22	68
19	5.6	3.1	8.1	2.5	5.1	25	73
20	5.5	3.1	8.1	2.6	5.1	27	78
21	5.4	3.1	8.2	2.7	5.1	30	83
22	5.3	3.1	8.2	2.9	5.1	33	88
23	5.2	3.1	8.2	3.0	5.1	36	93
24	5.1	3.1	8.2	3.1	5.1	39	98
25	5.0	3.1	8.2	3.3	5.1	42	103
26	4.8	3.1	8.2	3.4	5.1	46	108
27	4.7	3.1	8.3	3.5	5.1	49	113
28	4.6	3.2	8.3	3.7	5.1	53	118

Year	Erosion Project Cons (t/ha)	Erosion Project Optim (t ha^{-1})	Erosion No Project (t ha^{-1})	Impact Cons (t ha^{-1})	Impact Optim (t ha^{-1})	Conservative accumulated impact (t ha^{-1})	Optimistic accumulated impact (t ha^{-1})
29	4.5	3.2	8.3	3.8	5.1	57	124
30	4.4	3.2	8.3	3.9	5.1	61	129
31	4.3	3.2	8.3	4.1	5.2	65	134
32	4.2	3.2	8.4	4.2	5.2	69	139
33	4.1	3.2	8.4	4.3	5.2	73	144
34	3.9	3.2	8.4	4.4	5.2	78	149
35	3.8	3.2	8.4	4.6	5.2	82	155
36	3.7	3.2	8.4	4.7	5.2	87	160
37	3.6	3.2	8.4	4.8	5.2	92	165
38	3.5	3.3	8.5	5.0	5.2	97	170
39	3.4	3.3	8.5	5.1	5.2	102	175
40	3.3	3.3	8.5	5.2	5.2	**107**	**181**

Such significant reductions in soil loss are of paramount importance for the overall health and sustainability of the basin's ecosystem. By mitigating erosion rates, the restoration project contributes to the protection of valuable soil resources, supports sustainable land use practices, and helps maintain water quality in the region. These results underscore the effectiveness of the implemented conservation practices and provide valuable evidence for guiding future land management decisions and restoration initiatives in similar regions.

Moreover, the modeled changes in erosion rates serve as crucial data for monitoring and evaluating the long-term success of the restoration project and its influence on the local ecosystem.

IV.3.1. Contingent table of Verified Soil credits (VSCs)

As established in section *III.1.2.* of the *Procedures document version 2.0*, **20%** of the credits generated by the project will be withdrawn for the buffer pool as a measure to guarantee the permanence of the project benefits (291 credits), resulting in a total of **1,164 Verified Soil Credits** to be issued according to the Contingency Table (Table 9).

Table 9. Contingent table of verified soil credits (VSCs)

Year	Number of VSCs issued on each year
After project implementation	19
2025	13

Year	Number of VSCs issued on each year
2026	16
2027	19
2028	23
2029	26
2030	30
2031	32
2032	32
2033	32
2034	32
2035	32
2036	32
2037	32
2038	32
2039	32
2040	33
2041	33
2042	33
2043	33
2044	33
2045	33
2046	33
2047	33
2048	33
2049	33
2050	33
2051	33
2052	33
2053	33
2054	33
2055	33
2056	33
2057	33
2058	33
2059	33
2060	33
2061	33
Total	**1164**

V. GROUNDWATER RECHARGE

V.1.GROUNDWATER RECHARGE METHOD

The project area has been assessed according to the *aOCP Methodology for the assessment of groundwater recharge restoration*. Ground water storage was assessed for the same periods as soil erosion.

The methodology establishes the Soil Conservation Service Curve Number (SCS-CN) Method for the assessment of infiltration, which is then used as input for the Thornthwaite-Mather water balance model. The process of implementing the SCS-CN is outlined below, including its integration with the water balance method. This approach has the potential to track the evolution of restoration projects since it is based on satellite imagery from Sentinel-2, which has a temporal resolution of 5 days.

The methodology was implemented in Google Earth Engine (GEE), following the next steps for the calculation of ground water storage (GWS):

1. Use the LSMA method to calculate the proportion of impervious surface, vegetation and soil of each pixel in a Sentinel-2 image of the microbasin where the study area is located. This step is performed with the "unmixing" function, which is a supervised *soft classification.* To train the classifier polygons were hand-drawn for soil and vegetation, using as reference NDVI and BSI (bare soil index); for impervious surface, the *Open Buildings V3 Polygons* dataset (Sirko et al., 2021) from the GEE catalog was used.
   The bands/layers used for the unmixing classification were 'B2', 'B3', 'B4', 'NDVI', 'BSI', 'BRBA', 'NDWI' and 'DEM'.
2. Calculate the composite curve number (CNc) (Fan et al., 2013), as the weighted* average of:
   a. Soil CN: based on the hydrologic soil group, defined by soil texture. Hydrologic soil group is defined following soil texture classification and values of CNsoil in AMC-I by Li et al. (2018), based on sand and clay content retrieved from OpenLandMap (Tomislav Hengl, 2018; Tomislav Hengl., 2018).
   b. Impervious CN: given a fixed value of 98, according to literature (USACE Hydrologic Engineering Center, n.d.).
   c. Vegetation CN: determined by NDVI class and percentage of vegetation in the pixel, according to Bera et al. (2022).

*The weights correspond to the proportion of each land cover class, obtained from the LSMA.

3. Calculate slope corrected CN (CNsc) (Huang et al., 2006).
4. Calculate runoff and infiltration.
5. Obtain evapotranspiration (ET) from the *MOD16A2 Version 6.1 Evapotranspiration/Latent Heat Flux product* (Running et al., 2021) in the GEE catalog.
6. Mean annual precipitation for the pre-project and monitoring periods was 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). For the

future scenarios (years 10th and 40th), rainfall was obtained by averaging the 34 *NEX-GDDP-CMIP6* models (Thrasher et al., 2012), retrieved from the GEE catalog.

7. Compute delta ground water storage (dGWS), using runoff from step 4, ET from step 5 and mean annual precipitation (P) from step 6.

dGWR assessment covered four distinct periods:

TABLE 10. ASSESSMENT PERIODS

Period	Date range
Pre-project	July 2020 to June 2021
1st year monitoring	October 2022 to September 2023
Year 10 projection	October 2030 to September 2031
Year 40 projection	October 2061 to September 2062

NDVI, land cover fractions, precipitation and ET are the independent variables considered to significantly change over time. Table 10 and 11 shows the combination of these factors used to compute dGWR for the assessed periods.

TABLE 11. COMBINATION OF DATASETS USED TO REPRESENT THE FOUR SCENARIOS FOR DELTA GROUND WATER STORAGE (DGWS) MODELLING, PART 1

Scenario	NDVI	Land cover fractions (LCF)
Before Project	Mean annual NDVI from pre-project period	Unmixing on S-2 image from 2021-09-10
After Project Year 1	Mean annual NDVI from monitoring period	Unmixing on S-2 image from 2023-09-05
Year 10 projection	Monitoring & Maximum*	Based on LCF from monitoring: • Impervious: unchanged • Vegetation: Multiplied 2x and limited to 1.0 • Soil: computed as 1-impervious-vegetation
Year 40 projection	Same as Year 10	Same as Year 10

* Mean annual NDVI for future scenarios was assumed to remain the same as in the monitoring period for the rest of the microbasin, while in the project area it would reach up to the maximum (mean annual) NDVI value found in the microbasin.

TABLE 12. COMBINATION OF DATASETS USED TO REPRESENT THE FOUR SCENARIOS FOR DELTA GROUND WATER STORAGE (DGWS) MODELLING, PART 2.

Scenario	Precipitation	ET
Before Project	Yearly rain in pre-project period from CHIRPS	ET from pre-project period
After Project Year 1	Yearly rain in monitoring period from CHIRPS	ET from monitoring period
After Project Year 10	Yearly rain in year 10 after implementation from NASA *NEX-GDDP-CMIP6*	ET from monitoring period
Project's last year	Yearly rain in year 40 after implementation from NASA *NEX-GDDP-CMIP6*	ET from monitoring period

V.2. GroundWater Recharge Results

GroundWater Recharge and percent change over the years in the microbasin and the Project area are depicted in Tables 10 and 11, respectively. Between pre-project and monitoring periods, infiltration in the Project area increased 23.2%, from -212 to -163 mm. In the same period, the counterfactual area also experienced an increase, from -278 to -213 mm, equivalent to 23.1%. Infiltration in the rest of the microbasin also increased, from -185 to -126 mm, equivalent to 32.0%, similar to the Project area. Negative values indicate that the area is subject to water deficit, where the volume of water that is lost due to runoff and evapotranspiration is higher than the volume of precipitation. This situation is leading to the depletion of the aquifer, jeopardizing ecosystem functions and people's vital needs satisfaction.

In this first year after project implementation, its effects are not so notorious. However, when observing the results expected at years 10 and 40, the project's impacts on rainfall water infiltration are more evident. The change in dGWR from the pre-project period up to year 40 is a 60.2% increase in the Project area, a 35.0% increase in the counterfactual area, and a 38.6% increase in the rest of the microbasin. The difference between the counterfactual and the rest of the microbasin, considering both remain "unchanged", can be due to vegetation types, soil texture, and slope. On the other hand, the difference between the Project area and the counterfactual, where both have similar ecological characteristics, can be attributed to the implementation of Project activities. It is expected that, as planted trees grow and natural regeneration takes place, vegetation will reduce runoff, increasing the volume of water being infiltrated underground. According to the modeling results, it is expected that when the restoration reaches maturity, the Project area will infiltrate an additional volume of 10,279 m^3 per year, compared to the pre-project period, depending also on the volume of rainfall for each given year.

Table 13. Estimated dGWR in the project area (8.05 ha), counterfactual (8.03 ha) and microbasin (827.03 ha) at the assessed periods

Period	dGWR (mm = L m^{-2})			Total Infiltration (m^3)		
	Project area	Counterfactual	Microbasin	Project area	Counterfactual	Microbasin
Pre-project	-212	-278	-185	-17075	-22293	-1528301
Monitoring	-163	-213	-126	-13110	-17140	-1038896
Year 10	-84	-181	-114	-6799	-14527	-939376
Year 40	-84	-181	-114	-6793	-14500	-938314

Table 14. Percentage change in infiltration and dGWR in the project area (8.05 ha), counterfactual (8.03 ha) and microbasin (827.03 ha) over the assessed periods

Period	Percent change (%)			dGWR change (m^3)		
	Project area	Counter-factual	Microbasin	Project area	Counter-factual	Microbasin
Pre-project to Monitoring	23.2	23.1	32.0	3961	5150	489056
Pre-project to Y10	60.2	34.8	38.5	10279	7758	588396
Pre-project to Y40	60.2	35.0	38.6	10279	7803	589924

V.3. WATER CREDITS CALCULATION

The modelled change in the project scenario from year 0 to 40 is: 60.2 %, whilst in the control area with a BAU scenario it is 35.0 %. Pre-project dGWR in the Project area is: -212.1 mm, according to the modelled Project scenario trajectory, its dGWR at year 40 will be -84.4 mm. Contrastingly, if the Project area follows the modelled BAU trajectory, its dGWR at year 40 will be -137.9 mm.

Two project scenarios were computed: conservative and optimistic. The conservative scenario assumes that the full impact of the project will be achieved until year 40. It is represented as a lineal progression from the Pre-project (year 0) until the Future (year 40) infiltration. The optimistic scenario assumes that planted trees will mature and reach the maximum impact since year 10, maintaining the benefits until the end of the project.

Therefore, 3 scenarios were computed as follows:

- Conservative scenario: linear change from year 0 until 40.
- Optimistic scenario: linear change from year 0 until 10, then linear change from year 11 until 40.
- No project scenario: linear change from year 0 until 40.

Project's impact was calculated, in mm, as the difference between the BAU and the project scenario. Then it was converted into m^3/ha by multiplying by 10 the impact in mm, since mm = L/m^2. The additional water infiltration the Project can potentially lead to was calculated as the sum of each year's impact. Table 12 compares the annual infiltration in the Project area for the 3 assessed scenarios over the 40 years following project implementation.

Figure 8 illustrates Project area's modelled infiltration for the 3 scenarios. The accumulated additional water infiltration at year 40, attributable to Project activities, is estimated to be between 10968.0 and 30123.0 m^3/ha. Considering the whole Project area (8.05 ha), the volume of water that total is expected to be infiltrated due to the implementation of Project activities is between 88297 and 242502 m^3. Since 1 water credit equals 1 m^3 of water that is infiltrated due to implementation of Project activities, the number of **Water Credits the Project can generate is between 88,297 and 242,502** (figure 15).

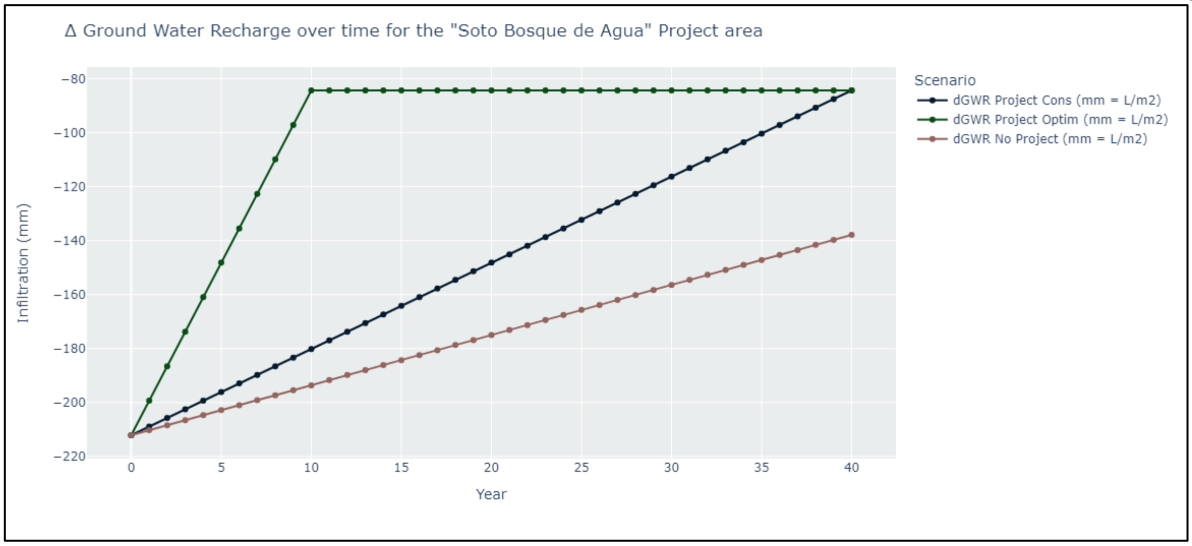

FIGURE 15. PROJECT AREA'S MODELLED INFILTRATION FOR THE 3 SCENARIOS

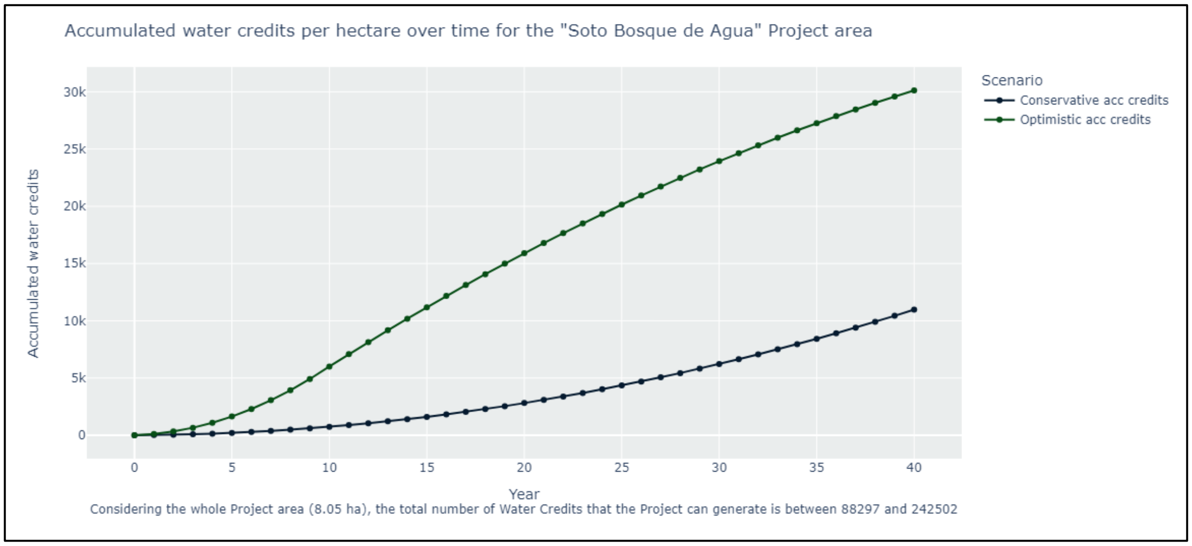

FIGURE 16. YEARLY ACCUMULATED NUMBER OF WATER CREDITS PER HECTARE FOR BOTH THE CONSERVATIVE AND OPTIMISTIC SCENARIOS

TABLE 15. MODELLED YEARLY INFILTRATION FROM PRECIPITATION IN THE PROJECT AREA AND ACCUMULATED NUMBER OF CREDITS PER HECTARE

Year	dGWR Project Cons (mm = L/m2)	dGWR Project Optim (mm = L/m2)	dGWR No Project (mm = L/m2)	Impact Cons (mm = L/m2)	Impact Optim (mm = L/m2)	Impact Cons (m3/ha)	Impact Optim (m3/ha)	Conservative acc credits	Optimistic acc credits
0	-212	-212	-212	0	0	0	0	0	0
1	-209	-199	-210	1.3	10.9	13	109	13	109
2	-206	-187	-208	2.7	21.8	27	218	40	327
3	-203	-174	-207	4	32.7	40	327	80	654

Year	dGWR Project Cons (mm = L/m2)	dGWR Project Optim (mm = L/m2)	dGWR No Project (mm = L/m2)	Impact Cons (mm = L/m2)	Impact Optim (mm = L/m2)	Impact Cons (m3/ha)	Impact Optim (m3/ha)	Conservative acc credits	Optimistic acc credits
4	-199	-161	-205	5.4	43.7	54	437	134	1091
5	-196	-148	-203	6.7	54.6	67	546	201	1637
6	-193	-136	-201	8.1	65.5	81	655	282	2292
7	-190	-123	-199	9.3	76.4	93	764	375	3056
8	-187	-110	-197	10.7	87.4	107	874	482	3930
9	-183	-97	-195	12	98.2	120	982	602	4912
10	-180	-84	-194	13.4	109.2	134	1092	736	6004
11	-177	-84	-192	14.7	107.3	147	1073	883	7077
12	-174	-84	-190	16	105.4	160	1054	1043	8131
13	-171	-84	-188	17.4	103.6	174	1036	1217	9167
14	-167	-84	-186	18.7	101.7	187	1017	1404	10184
15	-164	-84	-184	20.1	99.9	201	999	1605	11183
16	-161	-84	-182	21.4	98	214	980	1819	12163
17	-158	-84	-181	22.8	96.2	228	962	2047	13125
18	-155	-84	-179	24.1	94.3	241	943	2288	14068
19	-151	-84	-177	25.5	92.5	255	925	2543	14993
20	-148	-84	-175	26.8	90.6	268	906	2811	15899
21	-145	-84	-173	28	88.7	280	887	3091	16786
22	-142	-84	-171	29.4	86.9	294	869	3385	17655
23	-139	-84	-169	30.7	85	307	850	3692	18505
24	-136	-84	-168	32.1	83.2	321	832	4013	19337
25	-132	-84	-166	33.4	81.3	334	813	4347	20150
26	-129	-84	-164	34.8	79.5	348	795	4695	20945
27	-126	-84	-162	36.1	77.6	361	776	5056	21721
28	-123	-84	-160	37.5	75.8	375	758	5431	22479
29	-120	-84	-158	38.8	73.9	388	739	5819	23218
30	-116	-84	-156	40.1	72	401	720	6220	23938
31	-113	-84	-155	41.5	70.2	415	702	6635	24640
32	-110	-84	-153	42.8	68.3	428	683	7063	25323
33	-107	-84	-151	44.2	66.5	442	665	7505	25988
34	-104	-84	-149	45.4	64.6	454	646	7959	26634
35	-100	-84	-147	46.8	62.8	468	628	8427	27262
36	-97	-84	-145	48.1	60.9	481	609	8908	27871

Year	dGWR Project Cons (mm = L/m2)	dGWR Project Optim (mm = L/m2)	dGWR No Project (mm = L/m2)	Impact Cons (mm = L/m2)	Impact Optim (mm = L/m2)	Impact Cons (m3/ha)	Impact Optim (m3/ha)	Conservative acc credits	Optimistic acc credits
37	-94	-84	-144	49.5	59.1	495	591	9403	28462
38	-91	-84	-142	50.8	57.2	508	572	9911	29034
39	-88	-84	-140	52.2	55.4	522	554	10433	29588
40	-84	-84	-138	53.5	53.5	535	535	10968	30123

V.3.1. CONTINGENT TABLE OF VERIFIED WATER CREDITS VWCS

As established in section *III.1.2.* of the *Procedures document version 2.0*, **20%** of the credits generated by the project will be withdrawn for the buffer pool as a measure to guarantee the permanence of the project benefits (48,498 credits), resulting in a total of **193,992 Verified Water Credits** to be issued according to the Contingency Table (Table 16).

TABLE 16. CONTINGENT TABLE OF VERIFIED WATER CREDITS VWCS

Year	Number of VWCs issued on each year
After project implementation	4212
2025	2814
2026	3516
2027	4218
2028	4920
2029	5629
2030	6324
2031	7032
2032	6910
2033	6788
2034	6672
2035	6549
2036	6434
2037	6311
2038	6195
2039	6073
2040	5957
2041	5835
2042	5712
2043	5596

Year	Number of VWCs issued on each year
2044	5474
2045	5358
2046	5236
2047	5120
2048	4997
2049	4882
2050	4759
2051	4637
2052	4521
2053	4399
2054	4283
2055	4160
2056	4044
2057	3922
2058	3806
2059	3684
2060	3568
2061	3445
Total	**193,992**

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