Climate Vulnerability Assessment

JJCL-001-MEX-15102024 , ALVARADO, VERACRUZ DE IGNACIO DE LA LLAVE, MÉXICO

CDS
Geoprospective Science

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I. Introduction

This document presents a comprehensive Species Climate Vulnerability and Project Risk Assessment, conducted as part of the classification process under the NAT5 Project Scoring System. This system categorizes projects into six distinct risk and viability classes, ranging from AA+ (very low risk, highly resilient) to E (high risk, low resilience), to inform strategic investment and planning decisions in nature-based climate solutions. The assessments detailed herein are designed to evaluate the ecological and environmental stability of the project area, with a particular focus on its vulnerability to climate-related hazards. The core components of this analysis include:

- Species Climate Vulnerability Assessment, examining the current and projected future suitability for species integrated in the restoration program.
- Project Risk Factors Assessment, which evaluates:
  - Forest Fire Risk
  - Flood Risk
  - Drought Risk

These assessments were conducted using advanced spatial modeling techniques and satellite-based environmental data, ensuring scientifically robust and spatially explicit results. The outcomes are intended to support risk-informed project development, promote long-term sustainability, and enable transparent classification under the NAT5 framework.

II. Species Climate Vulnerability Assessment

This section assesses the climate vulnerability of species proposed for restoration projects by evaluating their distribution across key bioclimatic variables under historical and projected climate conditions. The analysis provides insights into species adaptability and resilience under climate change scenarios.

II.1 Scope and Methodology

The distribution and probability of presence of species found in the project area will be assessed using the **Climpact Data Science (CDS)** tool. Climpact is an integrated modeling platform that allows the evaluation of optimal zones for species distribution and presence, under both current and future climate conditions. The tool uses as its primary input physical, environmental, and biological factors related to each species and its ecological preferences, enabling the spatial identification—across a defined territory—of areas where a species or a community of species is most likely to thrive and persist.

CDS is based on the theory of ecological niches, which are defined as “the position of a species within an ecosystem, describing both the range of conditions necessary for its persistence and its ecological role within that ecosystem.” The model requires calibration of the relationship between the distribution of a species—or, where applicable, a group of species—and the spatial distribution of 20 environmental variables necessary for its development. Among these environmental variables, seven are related to climatic elements considered relevant to the

development and survival of the species, and one variable is directly related to the biological environment to which the species are adapted.

The analysis is conducted on a species-by-species basis. Bioclimatic conditions from WorldClim v2.1 and Net Primary Productivity (NPP) are used to assess species' occurrence and niche suitability. Climate change projections are based on future climate scenarios (e.g. CMIP6 models under SSP2-4.5). This assessment aids in scoring the project's alignment with climate resilience criteria.

The probability of species occurrence is determined by a combination of climatic, biological, structural, and environmental factors that influence the species' ability to adapt and survive (Table 1). This probability is expressed as a percentage, where 100% indicates that all necessary conditions for the species are present in a given area. As the percentage decreases, it reflects suboptimal environmental conditions, requiring the species to expend greater adaptive effort to survive and establish themselves in the new habitat.

II.2 Species Overview

Scientific Names:

1. *Avicennia germinans*
2. *Laguncularia racemosa*
3. *Rhizophora mangle*

Project Area: Alvarado, Veracruz, México

Ecological Role: Wildlife Conservation

Proposed Restoration Use: Ecosystem recovery

II.3 Bioclimatic Variables Used

Table 1 presents the bioclimatic variables analyzed, obtained from WorldClim v2.1 and NPP datasets.

Table 1. Bioclimatic Variables Used in Species Distribution Assessment

Variable	Description	Variable	Description
BIO1	Annual Mean Temperature	BIO11	Mean Temperature of Coldest Quarter
BIO2	Mean Diurnal Range (Mean of monthly (max temp - min temp))	BIO12	Annual Precipitation
BIO3	Isothermality (BIO2/BIO7) (×100)	BIO13	Precipitation of Wettest Month

Variable	Description	Variable	Description
BIO4	Temperature Seasonality (standard deviation ×100)	BIO14	Precipitation of Driest Month
BIO5	Max Temperature of Warmest Month	BIO15	Precipitation Seasonality (Coefficient of Variation)
BIO6	Min Temperature of Coldest Month	BIO16	Precipitation of Wettest Quarter
BIO7	Temperature Annual Range (BIO5-BIO6)	BIO17	Precipitation of Driest Quarter
BIO8	Mean Temperature of Wettest Quarter	BIO18	Precipitation of Warmest Quarter
BIO9	Mean Temperature of Driest Quarter	BIO19	Precipitation of Coldest Quarter
BIO10	Mean Temperature of Warmest Quarter	BIO20	Net Primary Productivity (NPP)

II.4 CLIMATE SUITABILITY AND VULNERABILITY ASSESSMENT

The probability of distribution for the species was modeled using their observed bioclimatic minimum and maximum ranges under both historical and future climate scenarios. Climatic data representative of the broader state of Veracruz, rather than the specific project area, were used for this analysis. As shown in Table 2, the species *Avicennia germinans*, *Laguncularia racemosa* and *Rhizophora mangle* currently demonstrate high suitability (91.76%) on average across the region, with future projections indicating slightly increased suitability (94.76%).

Table 3 provides the classification scheme used to interpret suitability values. Suitability values above 82.6% indicate high alignment between environmental conditions and species' ecological requirements, suggesting strong potential for persistence and minimal impact from future climatic shifts.

The results suggest that these key species retain a robust capacity for survival under anticipated climate scenarios. Overall, the modeled responses reflect the species' resilience to regional changes in temperature and precipitation, aligning with broader warming trends and reinforcing their continued relevance in ecological restoration efforts.

Table 2. Historical and Future Distribution of *Trogon mexicanus*.

Species	Probability of Distribution (%)	
	Historical (Past)	Future (Projected)
Avicennia germinans	91.29	94.66
Laguncularia racemosa	91.99	94.81
Rhizophora mangle	91.99	94.81
Average	**91.76**	**94.76**

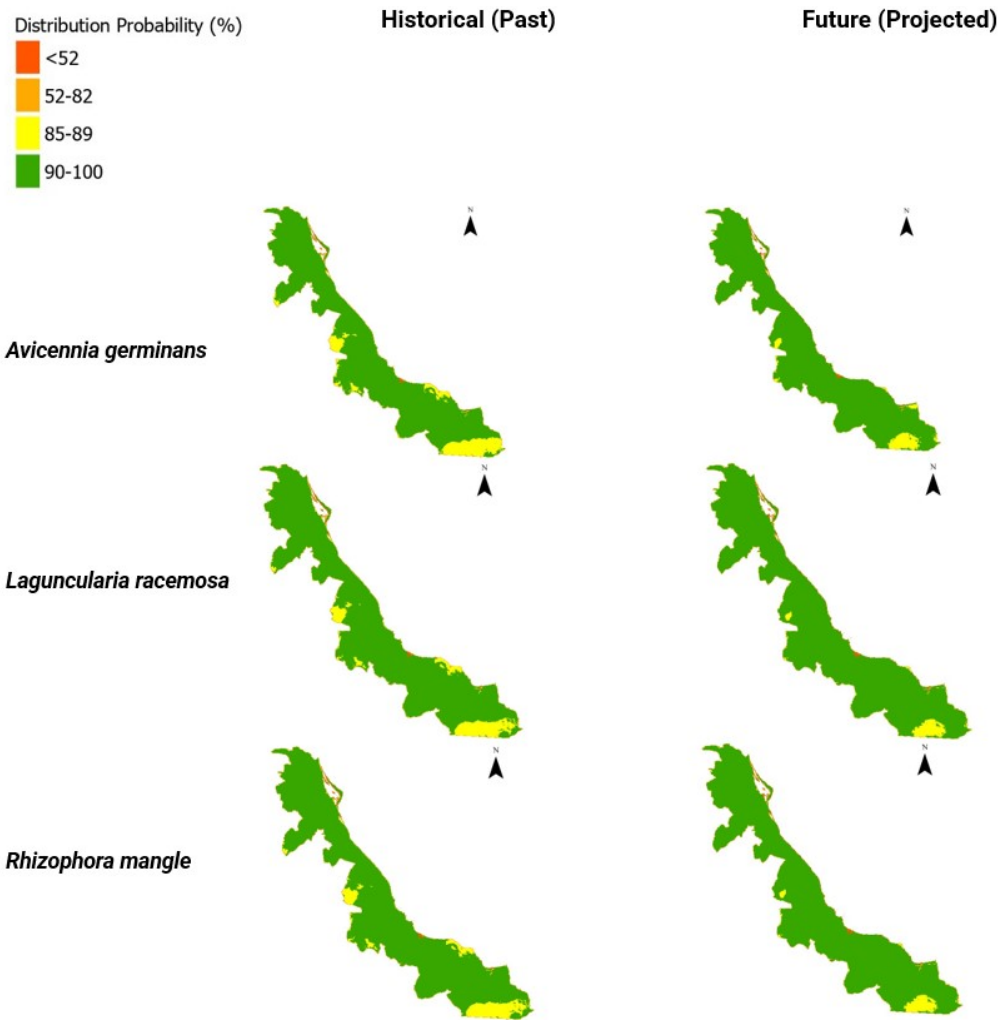


Figure 1. Species Probability Maps of Past and Future Distribution

Table 3. Species Probability Distribution Classifications

Percentage (%)	Interpretation
1-52.16	This range indicates that the area is poorly suited for the development of the species or species community. The environmental conditions are likely to pose significant challenges, and the species' capacity to adapt to future changes is considerably limited.
52.17-82.5	Areas within this range suggest moderate suitability, where the species may need to adjust to altered environmental conditions. Mild stress periods could occur, and there is a higher degree of uncertainty regarding the species' ability to successfully adapt to these changes.
82.6-99	This range reflects high suitability, with environmental conditions closely matching the species' ecological niche. The impacts of climate change in these areas are expected to be minimal, and the species is likely to adapt well to future environmental shifts.
100	A value of 100% indicates full suitability, meaning the environmental conditions perfectly align with the species' ecological requirements. In such areas, the species or community is expected to thrive, with optimal potential for long-term survival and development.

III. Project Risk Factors

In alignment with the aOCP standard for carbon, water, soil, and biodiversity credit certification, comprehensive risk assessment is essential to safeguard project integrity, ensure long-term sustainability, and maximize environmental and community benefits. This process involves the identification, analysis, and evaluation of potential threats that could hinder project implementation or compromise its outcomes.

The identified risk factors related to this project are assessed below.

III.1 Forest Loss Risk

Forest loss risk is evaluated by examining both environmental and anthropogenic factors that may contribute to deforestation or land degradation. The index incorporates variables such as:

- Historical patterns of deforestation
- Proximity to urban centers and infrastructure
- Fire incidence and history of burning

- River and farmland proximity
- Terrain accessibility, including elevation and slope

These indicators collectively inform spatial risk modeling for potential forest disturbance.

III.1.1 Forest Fire Risk Assessment

The Forest Fire Risk assessment utilizes the Fire Weather Index (FWI) to quantify wildfire susceptibility within the project area, based on historical and climatological data. This index integrates multiple variables, including air temperature, relative humidity, wind speed, and fuel moisture content, to evaluate fire danger conditions comprehensively. The analysis draws on a decade of historical fire danger indices to capture temporal variability and long-term fire trends across the region. By aggregating fire danger values over a ten-year period, the model provides a robust estimation of fire risk grounded in climatic and environmental patterns. The cumulative index scores are categorized into three levels: Low, Medium, and High, reflecting the likelihood and potential severity of fire events. Each location within the project area is assigned a numerical risk score, offering a clear, data-driven basis for fire risk mitigation and management planning.

For this project, the assessment identifies a Medium Fire Risk across 73% of the project area, indicating moderate susceptibility to fire-related disturbances. Figure 2 illustrates the spatial distribution of fire risk, highlighting areas of elevated concern. In addition to the Medium Risk area, certain zones were also classified as High Risk (shown in red). Adaptive land management strategies and early warning systems should be considered to address any shifts in vegetation, land use, or climate that may increase vulnerability over time.

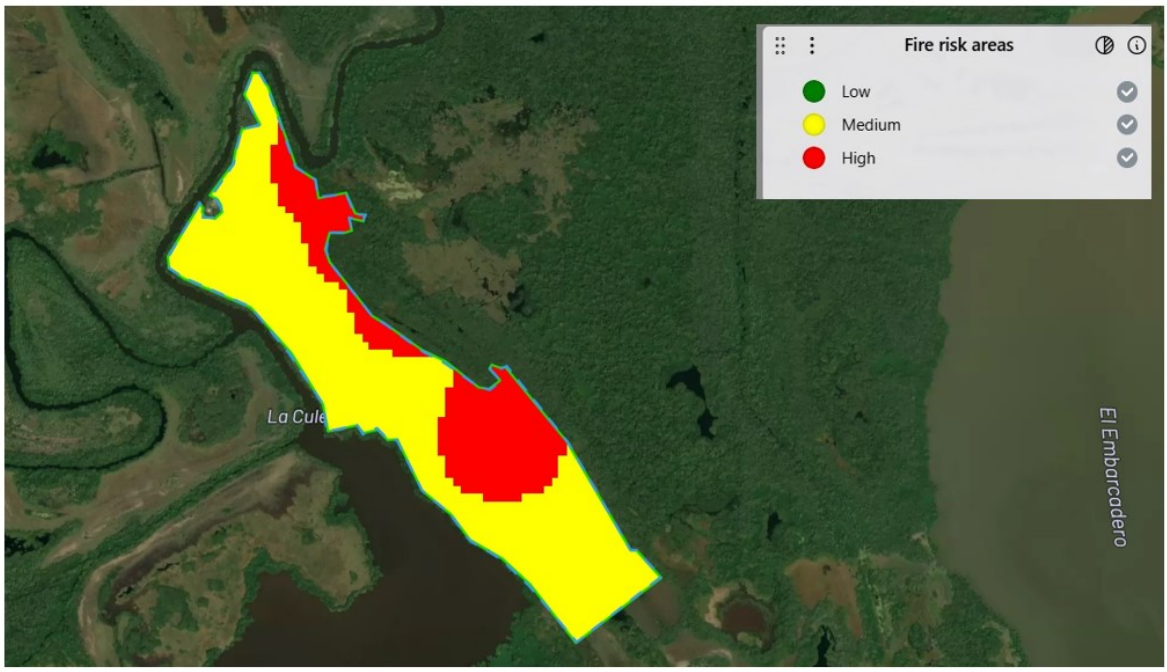


Figure 2. Fire Risk Map

III.2 Drought Risk Assessment

The Drought Risk assessment provides a spatially explicit evaluation of the area's historical exposure to drought conditions, leveraging the Combined Drought Index (CDI), a comprehensive indicator that integrates multiple drought-related variables including precipitation anomalies, soil moisture deficits, and vegetation stress. Each pixel within the project area is evaluated and classified into one of three drought risk categories: Low, Medium, or High, based on historical CDI values. The overall risk score for the project area is determined by calculating the proportion of land area (pixels) that falls within each of the defined risk classes, allowing for a data-driven characterization of drought vulnerability.

The results of the analysis indicate that the project area is predominantly characterized by **Low to Medium** Drought Risk. Figure 3 presents the drought risk distribution map, highlighting minimal spatial variability across the landscape. These findings underscore the importance of incorporating adaptive land and water management strategies, especially in medium-risk zones, to safeguard long-term vegetation health and project sustainability under changing climatic conditions.

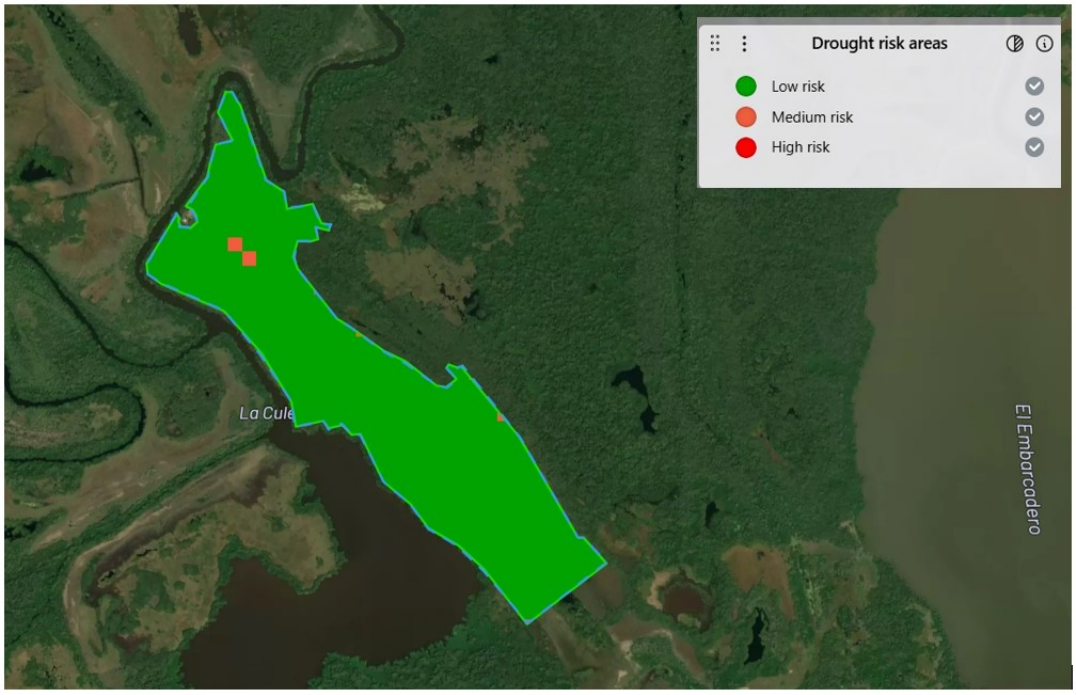


Figure 3. Drought Risk Map

III.3 Flood Risk Assessment

Flood risk is evaluated by integrating multiple environmental and historical parameters, including annual precipitation, the Topographic Wetness Index (TWI), proximity to rivers and flood plains, and records of past flood events. These variables are combined to produce a comprehensive flood risk layer that indicates the spatial distribution and severity of flood susceptibility across the study area.

A key driver in this assessment is precipitation, analyzed using a 35-year dataset of annual values expressed in mm/pentad. This data provides insight into long-term rainfall patterns and potential anomalies. Figure 4 illustrates the distribution of annual precipitation across the region at a resolution of 5.56 km, supporting the identification of flood-prone zones.

Based on the precipitation-driven model outputs, a minimum of 33% of the project area is classified as high flood risk, underscoring the need for targeted mitigation strategies in those zones.

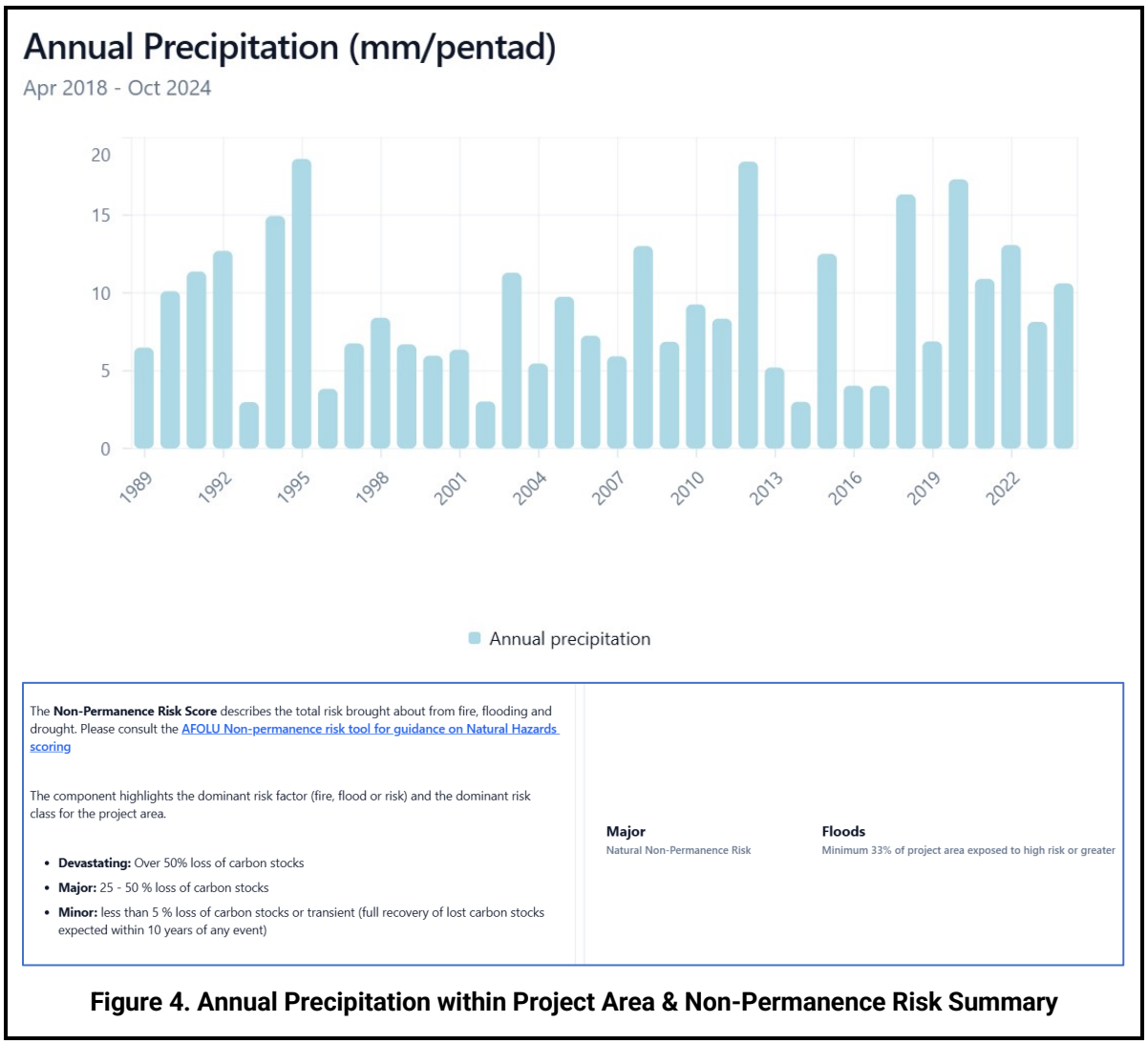


Figure 4. Annual Precipitation within Project Area & Non-Permanence Risk Summary

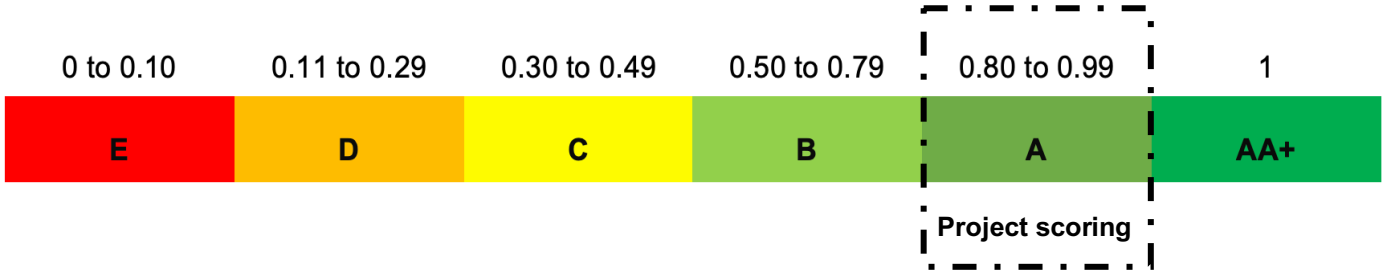
IV. NAT5 SCORING

Scope	Variable	Description	Level	Weighting
Types of credits	Credits	The Pajaro project in Veracruz de Ignacio de la Llave, México, is applying to two types of credits: carbon removal VCC and biodiversity VBBC.	Multi-credit project	1,00
Climatic catastrophes	Forest fires	Given the relationship between various wildfire-related factors—Fire Weather Index (FWI), historical data, and extreme heat risk—the project is classified as having a "mediu to high" wildfire risk. This medium-risk designation highlights the need for continuous monitoring and preparedness for wildfire management interventions.	Medium risk	0,50
	Floods	Given the relationship between various flood-related factors—precipitation, topographic wetness index, presence of rivers, and alluvial plains—the project is classified as having a "medium" flood risk. This medium-risk designation highlights the need for ongoing monitoring and preparedness for flood management interventions.	Medium risk	0,50
	Drought	Given the relationship between various drought-related factors—precipitation, soil moisture, and vegetation health—the project area is not classified under any drought risk level.	No risk	1,00
	Frost risk	The frost risk in the project area is very low.	No risk	1,00

Scope	Variable	Description	Level	Weighting
Climate change	Loss of ecological conditions necessary for the adaptability of reforested species.	Based on the average of each species distribution probability, 91.76% of the ecological conditions required for the reforested species are currently present within the project area. Under future climate change scenarios, the availability of optimal conditions is projected to slightly increase to 94.76%, indicating a continued likelihood of survival and establishment for the reforested individuals.	Very low	1,00
Legal, political and social conditions	Legal risk	All legal documentation is complete, valid, and verified (titles, permits, agreements, etc.).	No risk	1,00
	Political risk	The Government of Mexico has undertaken targeted efforts to meet its climate-related commitments. As part of this, the country has worked on developing various mechanisms aimed at reducing greenhouse gas (GHG) emissions.	Positive outlook toward VCM and in favor of climate action as a national priority	1,00
	Social risk	The project is located on private property, and all stakeholders were consulted.	The project has full social backing, signed agreements, and active participation of local communities.	1,00
Project Developer	Project developer's risk	The project developer carried out the project, which was partly financed by CONAFOR resources, and it was monitored annually with good results.	The developer has previous experience in activities associated with carbon markets or other environmental attributes	0,75
	Strength of the project team	The project developer is a private individual.	The internal team has a combined technical experience of less than 7 years and/or a combined commercial experience of less than 7 years	0,50

Scope	Variable	Description	Level	Weighting
Transparency and communication	Transparency and clarity of project communication	The project developer has shared all non-confidential information in a timely manner as required by the aOCP. Provided a photographic record of the event where the project was socialized, as well as the acceptance agreement with the landowner.	The developer has made all non-confidential project information public and easily accessible in appropriate formats and has adopted appropriate strategies and measures to maintain communication with different stakeholder	1,00
Participation and alliances	Involvement of the local community in the project team	The project developer is a private individual.	The project has seasonal employment for members of the local community	0,50
	Ability of the project to form partnerships	The project has some partnerships and actively engages with relevant organizations across the board	The project has few or no strategic partnerships	0,50
			Total	**0,80**

NAT5 SCORING CLASSIFICATION



For more information about this scoring, please refer to the detailed explanation provided in the *aOCP Project Procedures*[1] document, version 2.3.

[1] https://www.nat5.bio/wp-content/uploads/2025/03/I.3.-aOCP-Project-Procedures-V2.3.pdf