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DISASTER RISK MANAGEMENT GUIDE CASE STUDY: APPLIED TO FONABOSQUE

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ABSTRACT

The National Forest Development Fund (FONABOSQUE) is an autonomous public entity in Bolivia, created on July 12, 1996, under Forestry Law Nº 1700. It operates under the Ministry of Environment and Water, and its mission is to finance initiatives for sustainable forest management, integrated watershed management, soil conservation, and fire management. Over the years, it has promoted various forestry projects, but without a clear Disaster Risk Management (DRM) approach, which has resulted in vulnerability to forest fires, floods, and droughts. This gap also implied non-compliance with Law Nº 602 and Ministerial Resolution Nº 115 of 2015, which require risk analysis in public investment projects.

Focusing to this need, a technical DRM guide was developed containing methodologies to identify hazards, assess vulnerabilities, and reduce risks. The guide was validated through FONABOSQUE-funded projects, and as an application example, the Pre-Investment Technical Design Study (EDTP by its Spanish acronym) of the project "Strengthening Sustainable Productive Associations" in Apolo is presented, where analytical methodologies such as the Saaty matrix and Bayesian analysis were applied. This guide is a valuable tool to strengthen future projects, promoting safer and more sustainable planning aligned with the Sendai Framework for Disaster Risk Reduction and the Sustainable Development Goals (SDGs).

Keywords: Disaster Risk Management (DRM), vulnerability, risk analysis, Saaty matrix, Bayesian analysis

1. INTRODUCTION

Disaster Risk Management (DRM) is an essential component for ensuring the sustainability of projects, particularly in contexts with high exposure to natural hazards such as forest fires, floods, droughts, and others. In the case of the National Forest Development Fund (FONABOSQUE), although current regulations—specifically Ministerial Resolution No. 115 of May 12, 2015, establish the obligation to include the analysis and design of prevention and risk management measures in the Preliminary Conditions Technical Report (ITCP by its Spanish acronym) and in the Pre-Investment Technical Design Studies (EDTP by its Spanish acronym).

In addition to exposing projects to material, environmental, and social impacts, this institutional the lack of the DRM carries the risk of regulatory non-compliance, which may affect the legality and eligibility of funded initiatives. In this context, a DRM guide adapted to FONABOSQUE's requirements was developed, establishing a methodology for carrying out the four key steps of the process: hazard analysis, vulnerability analysis, risk assessment, and the formulation of intervention measures. This guide proposes the complementary use of two

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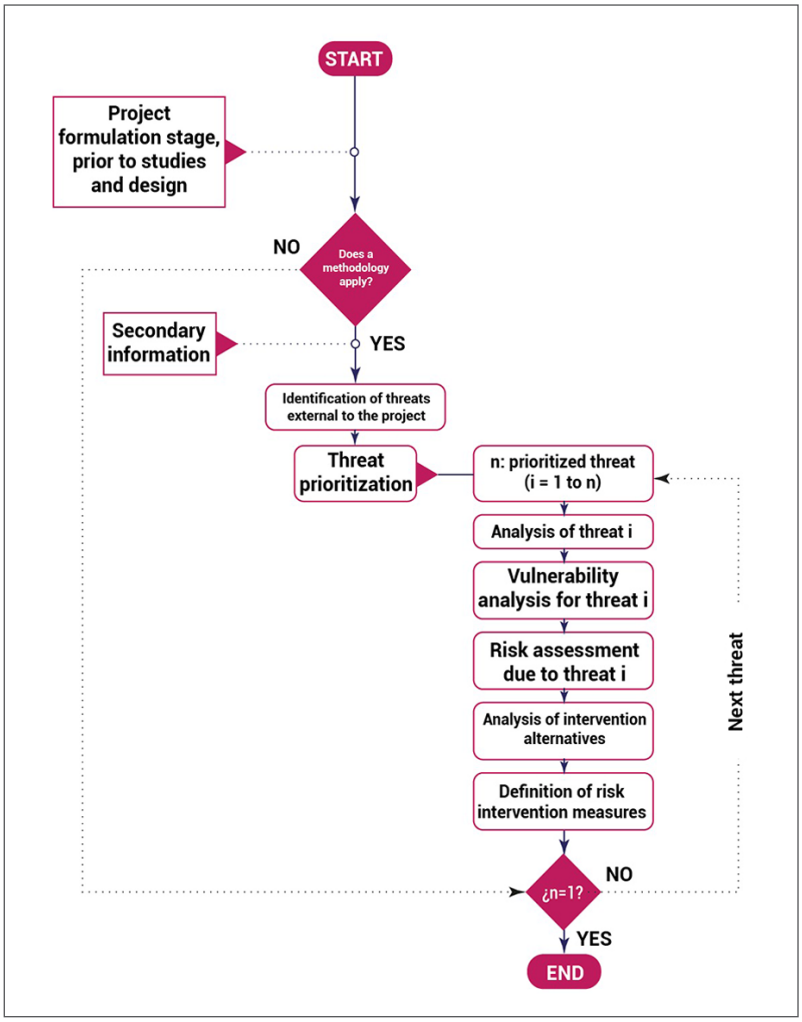
approaches: an analytical one, which incorporates tools such as the Saaty matrix (Saaty, 1980) and Bayesian analysis (UDAPE, 2024), and another based on digital platforms, which facilitates the processing of informational data.

The guide was applied in projects funded by FONABOSQUE, and in this work the following example was used: the Pre-Investment Technical Design Study TPDS of the project "Strengthening Sustainable Productive Associations: Promoting Conservation, Livelihoods, and Market Consolidation in the Municipality of Apolo" (FONABOSQUE, 2024). The analysis identified forest fires, floods, and droughts as the priority hazards.

2. MATERIALS AND METHODS

The flowchart of the proposed methodological procedure is presented. The guide proposes a structured process composed of four fundamental steps: (1) hazard analysis, (2) vulnerability analysis, (3) risk assessment, and (4) formulation of intervention measures (see Figure 1).

Figure 1. General methodological process



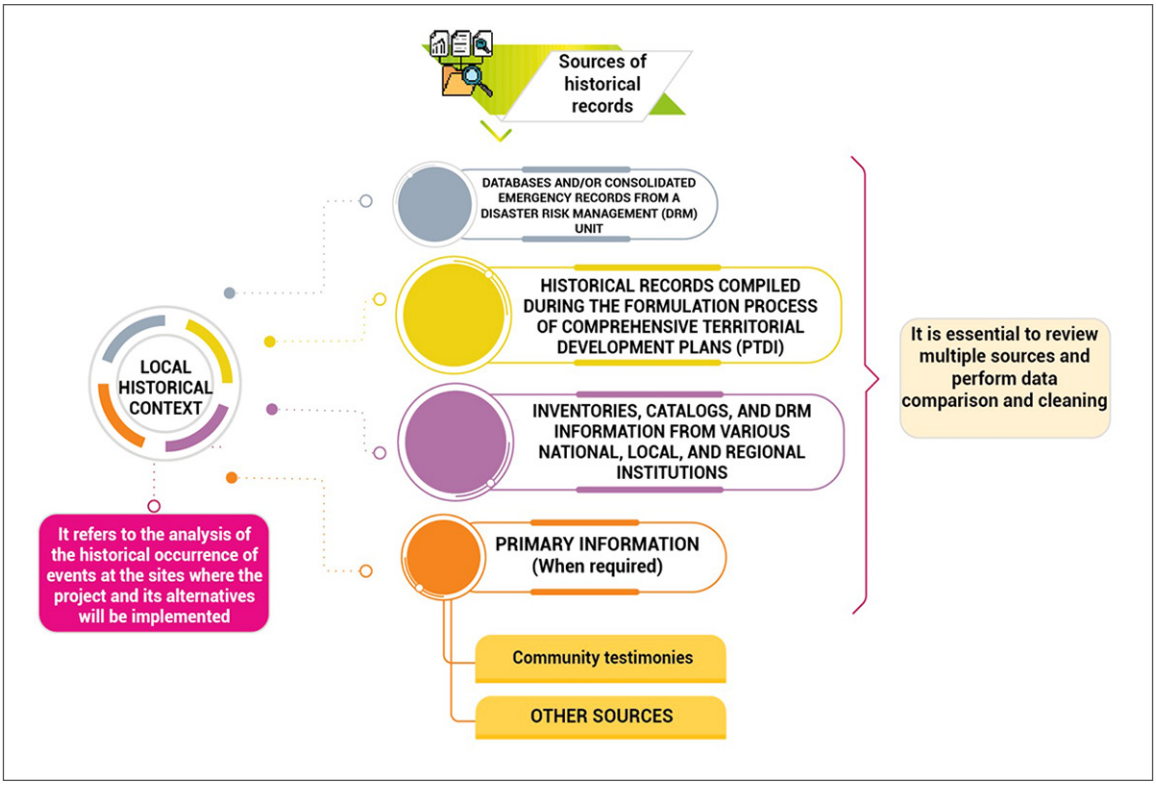
Source: Siles C., (2025)

a) Input information

The process begins with the project data, which must have the appropriate level of detail according to the formulation phase it is in. Having accurate information is essential to carry out the work effectively. Within the framework of this methodology, it is recommended to use the most detailed information available.

Once the project is placed within its general hazard context, it is crucial to investigate and analyze past events recorded at the local level. The study of these historical records is key to understanding the hazards, as it provides the essential information needed and, in many cases, the only available source to conduct an accurate assessment (see Figure 2).

Figure 2. Analysis of the local historical event context



Source: Siles C., (2025)

b) Hazard Analysis

A hazard is defined as "the probability that a natural, socio-natural, or anthropogenic event will occur at a specific time or place" (Law No. 602/2014).

To properly understand and manage the hazards a project may pose, either to its surroundings or within its own structure, it is essential to analyze the historical context of similar projects. This allows learning from past situations by identifying relevant events and the damage they caused.

These hazards should be classified according to their priority level (high, medium, or low), taking into account factors such as frequency and potential damage. It is recommended to focus the analysis on hazards considered high or medium priority. However, if the necessary resources are available, ideally all possible hazards should be assessed.

Tables 1 and 2 provide criteria to evaluate the frequency and potential damage of each hazard, which facilitates their prioritization in a clearer and more structured manner.

Table 1. Frequency criteria for hazard prioritization

Description	Frecuency criterion
It occurs frequently, once every 1 to 5 years	HIGH
Limited possibility of occurrence or happens sporadically; once every 5 to 20 years	MEDIUM
Expected to occur rarely, once or less in 20 years	LOW

Source: Siles C., (2025)

Table 2. Damage potential criteria for hazard prioritization

Description	Damage potential criterion
Can severely affect physical elements (destruction) and people (deaths), as well as disrupt activities in the area	HIGH
Can moderately affect physical elements, activities, and people, without causing human deaths	MEDIUM
Only minor physical damages would occur	LOW

Source: Siles C., (2025)

Figure 3 visually presents the suggested combination of these criteria to establish the priority order in the analysis.

Figure 3. Combination of criteria for hazard prioritization

		DAMAGE POTENTIAL		
		HIGH	MEDIUM	LOW
FRECUENCY	HIGH	High Risk	High Risk	Medium Risk
	MEDIUM	High Risk	Medium Risk	Medium Risk
	LOW	Medium Risk	Medium Risk	Low Risk

Source: Siles C., (2025)

c) Vulnerability Analysis

Vulnerability refers to the conditions of elements exposed to a hazard that make them susceptible to damage. It can occur:

- Due to exposure to the hazard.
- Due to fragility when in contact with the hazard, which reflects intrinsic conditions such as the fragility of people, communities, activities, relationships, and functions.
- Due to resilience, that is, the ability to absorb or recover from the impact of the hazard.

Vulnerability varies depending on the hazard being analyzed. Therefore, it is necessary to conduct a specific analysis for each prioritized hazard.

Depending on the information available, there are various methodologies for vulnerability analysis. The guide provides some methodologies based on secondary information analysis. However, a more detailed analysis involving community participation would allow for a more accurate assessment of vulnerability.

If the technical team deems it necessary, primary data can be collected to achieve a more precise evaluation.

d) Risk Assessment

Risk is defined as "The estimated magnitude of loss of life, injured persons, affected property, damaged environment, and paralyzed economic activities, as well as affected goods and services in a given location, during a defined period of exposure to a particular hazard, considering the vulnerability conditions of the threatened sectors and population" (Law No. 602, Risk Management Law, November 14, 2014).

Risk analysis comprises two essential elements: Hazard and vulnerability. This analysis focuses on evaluating how both factors interact to estimate the potential impact that could result from the occurrence of a hazard in a vulnerable environment.

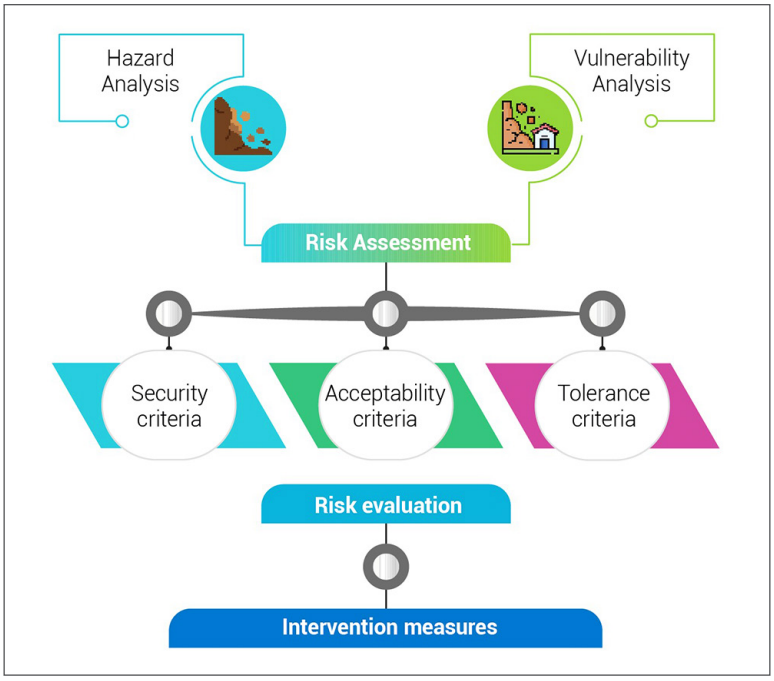
To do this, it is necessary to categorize the risk, which is based on the interaction between the hazard and vulnerability. The following matrix is suggested for this purpose (see Figure 4).

Figure 4. Risk criteria

		VULNERABILITY		
		HIGH	MEDIUM	LOW
THREAT	HIGH	High Risk	High Risk	Medium Risk
	MEDIUM	High Risk	Medium Risk	Medium Risk
	LOW	Medium Risk	Medium Risk	Low Risk

Source: Siles C., (2025)

Figure 5. Risk evaluation



Source: Siles C., (2025)

e) Formulation of Intervention Measures

After assessing the risk, it is essential to integrate the necessary DRM actions into the project and recommend those appropriate for the specific context. In this regard, intervention measures may differ in nature, following a process such as the one described below:

- Analysis of alternatives for risk reduction and climate change adaptation.
- Evaluation of the alternatives and selection of the most suitable intervention or mitigation measures.

Safety, acceptability, and tolerance criteria

i) Safety criterion

Involves protecting lives and property against disasters, ensuring that the measures adopted are effective in mitigating risks.

ii) Acceptability criterion

Defines the level of loss a community is willing to tolerate without compromising its economic or social integrity. this includes considering local expectations and needs.

iii) Tolerance criterion

Related to a community's capacity to recover after a disaster. This involves evaluating not only the immediate impact but also how pre-existing conditions can be restored or long-term resilience improved.

3.1. Analysis of Historical Records

3.1.1. Climate Risks

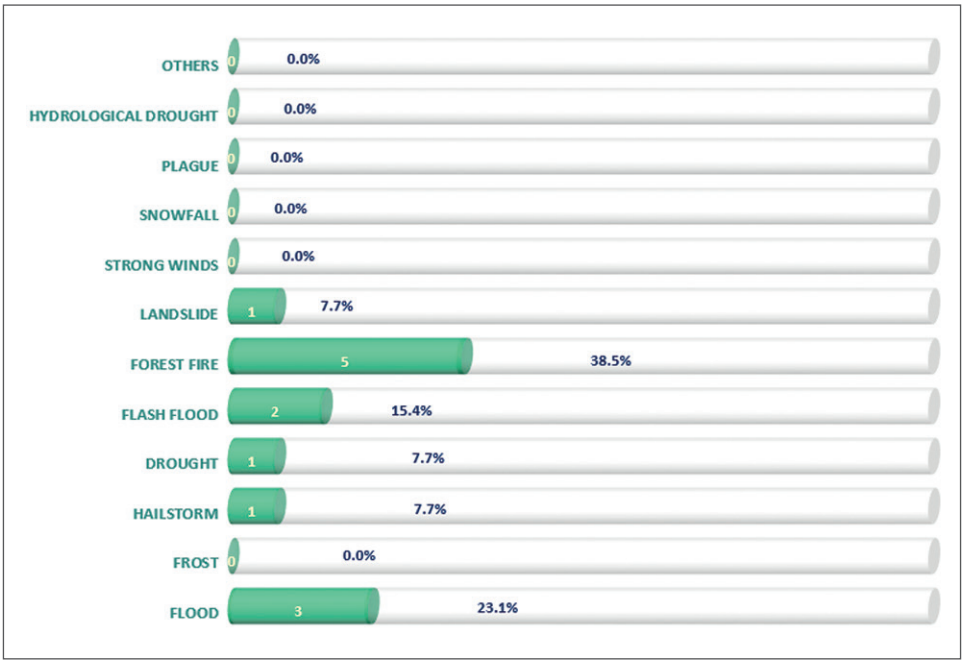
i. Relevant Adverse Events Recorded in Apolo

The events recorded during the period 2013 - 2023 include floods, frosts, hailstorms, droughts, landslides, forest fires, and others (thunderstorms, heavy rains, overflows, epidemic quarantines, human avalanches, collapses, mudflows, explosions, drownings).

During the study period, 13 events were recorded. Regarding disaster events, 38.5% corresponded to forest fires (5), ranking first among the most frequent events in Apolo; the second place with 23.1% corresponds to floods (3); and the third place with 15.4% corresponds to landslides (2).

Figure 6 shows the events that occur most frequently, which have a negative impact on various socioeconomic activities in the region.

Figure 6. Cumulative records by type of event occurring in Apolo (2013–2023)



Source: Siles C., based on information provided by SINAGER, 2024

ii. Impact of Disasters in the Municipality of Apolo

For the period 2013–2023, disaster activity shows an irregular pattern, with a total of 13 events concentrated in the years 2014, 2018, 2019, 2020, 2021, and 2022. Affected population. include a total of 2,003 people affected and 3,956 impacted, although there were no reported cases of injuries or missing persons, and only one death was reported in 2020.

Regarding material damage, 21 homes were affected, with the biggest losses recorded in the agricultural sector, where 15340.148 hectares were affected and 1846 hectares lost, mainly in 2019 and 2021.

Years without events indicate possible variability in disaster incidence, with significant peaks in specific years, which could be linked to particular climatic or social phenomena (see Table 3).

Table 3. Events and damages recorded in the Municipality of Apolo, period 2013 - 2023

YEAR	Nº OF EVENTS	PERSONAL DAMAGES					MATERIAL DAMAGES			
							HOUSING		CROPS [Ha]	
		VICTIMS	AFFECTED	MISSING	INJURED	DECEASED	AFFECTED	DESTROYED	AFFECTED	LOST
TOTAL	**13**	**2003**	**3956**	**0**	**0**	**1**	**3**	**18**	**15340.15**	**1846**
2013	0	0	0	0	0	0	0	0	0	0
2014	1	0	486	0	0	0	0	0	1600	0
2015	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0
2018	1	278	278	0	0	0	0	0	0	0
2019	3	599	300	0	0	0	3	18	8500	0
2020	4	0	1	0	0	1	0	0	0	0
2021	2	726	2491	0	0	0	0	0	4740.15	1296
2022	2	400	400	0	0	0	0	0	500	550
2023	0	0	0	0	0	0	0	0	0	0

Source: Siles C., based on information provided by SINAGER, 2024

Table 4. Damages recorded by type of event in the Municipality of Apolo, period 2013 - 2023

EVENT	Nº OF EVENTS	PERSONAL DAMAGES					MATERIAL DAMAGES			
							HOUSING		CROPS [Ha]	
		VICTIMS	AFFECTED	MISSING	INJURED	DECEASED	AFFECTED	DESTROYED	AFFECTED	LOST
Total	**13**	**2003**	**3956**	**0**	**0**	**1**	**3**	**18**	**15340.15**	**1846**
Flood	3	1004	3255	0	0	0	0	0	3627.73	1296
Frost	0	0	0	0	0	0	0	0	0	0
Hailstorm	1	199	0	0	0	0	0	0	0	0
Drought	1	400	400	0	0	0	0	0	500	500
Flash flood	2	0	1	0	0	1	0	0	0	0
Forest fire	5	0	0	0	0	0	0	0	2712.42	50
Landslide	1	400	300	0	0	0	3	18	8500	0
Strong winds	0	0	0	0	0	0	0	0	0	0
Snowfall	0	0	0	0	0	0	0	0	0	0
Plague	0	0	0	0	0	0	0	0	0	0
Hydrological drought	0	0	0	0	0	0	0	0	0	0
Others	0	0	0	0	0	0	0	0	0	0

Source: Siles C., based on information provided by SINAGER, 2024

3.2. Hazard Analysis

It can be observed that the results of the analysis conducted using two approaches—one based on the database provided by SINAGER (SINAGER, 2024) in the analytical approach—coincide with those obtained by UDAPE (UDAPE, 2024) in the platform-based approach, despite using different methodologies.

Once the hazards are identified and prioritized according to the presented methodology, the following events are considered: flood, landslide, forest fire, landslide, and hailstorm. On the other hand, droughts will not be included in the subsequent analysis, as they have been classified as LOW priority (see Table 5).

Table 5. Project hazards

EVENT HAZARD	HAZARD IDENTIFICATION AND PRIORITIZATION			HAZARD	
	Frequency Criterion	Ptential Criterion	Analysis Criterion	Analysis with SINAGER Database	UDAPE
Forest fire	MEDIUM	MEDIUM	MEDIUM RISK	HIGH	
Flood	HIGH	MEDIUM	HIGH RISK	HIGH	HIGH
Drought	LOW	LOW	LOW RISK	LOW	LOW
Landslide	MEDIUM	MEDIUM	MEDIUM RISK	MEDIUM	
Flash flood	MEDIUM	HIGH	HIGH RISK	HIGH	
Hailstorm	MEDIUM	MEDIUM	MEDIUM RISK	MEDIUM	LOW

Source: Siles C., based on information provided by SINAGER and UDAPE, (2024)

3.3. Vulnerability Analysis

At this stage, the vulnerability of the previously prioritized hazards is analyzed. This analysis is carried out using two approaches: an analytical approach and a platform-based approach, both of which have databases and provide a result or vulnerability range.

Depending on the available information and the chosen approach, there are various methodologies for vulnerability analysis; the guide suggests several, and the choice will depend on the designer's criteria. For the analysis presented below, two methodologies were used: an analytical approach using the Saaty matrix for multicriteria evaluation, and the Bayesian Method, used in the UDAPE platform (UDAPE, 2024).

Table 6. Vulnerability analysis results for floods, droughts, and hailstorms

Hazard	Population Vulnerability
Flood	HIGH
Drought	VERY LOW
Hailstorm	VERY LOW

Source: Siles C., based on information provided by SINAGER and UDAPE, (2024)

3.3.1. Site analysis based on exposure (micro-location)

This analysis consists of assessing the exposure of the site where the project is intended to be implemented. Project exposure is closely related to its location within the territory and the type of project.

The following components are evaluated: bioclimatic, geological, ecosystem, built environment, pollution, and institutional–social. For each of these components, Tables 7 through 12 must be completed, considering the variables for each component.

3.3.1.1. Bioclimatic Component

Table 7. Multicriteria Evaluation Matrix (Saaty Method) for the Bioclimatic Component

Nº	VARIABLES	N/A	1	2	3
1	**Hygrothermal comfort**	X			
	1. The land has good thermal conditions for human habitat				
	2. The land has unfavorable but not extreme comfort conditions for human habitat				
	3. The land has very unfavorable thermal comfort conditions, with temperatures, relative humidity and heat waves greater than normal conditions				
2	**Orientation**	X			
	1. The longitudinal axis of the land is oriented east-west				
	2. When the land is rectangular or irregular, but its longitudinal axis is oriented north-east or north, up to 22 degrees from north				
	3. When the land is rectangular or irregular but its longitudinal axis is oriented north-south, southeast or southwest				
3	**Wind**				
	1. Winds with average annual speeds below 5.5 m/s (20 km/h)				
	2. Winds with average annual speeds between 5.5 and 7.9 m/s (28 km/h)			X	
	3. Winds with average annual speeds above 10.8 m/s (36 km/h) that may affect the project				
4	**Precipitation**				
	1. Dry regime or normal precipitation with occasional effects				
	2. Rigorous precipitation or drought regime not exceeding the territory's average, with distinct periods and non-significant effects				
	3. Severe precipitation regime exceeding the territory's average, with poorly differentiated periods during the year; precipitation may cause significant effects on the project or environmental factors				X
5	**Noise**	X			
	1. Insignificant noise below 40 decibels, a quiet urban environment				
	2. Acceptable noise, between 40 and 60 decibels, isolated noise sources that do not affect the project				
	3. High noise levels, above 65 decibels, or the land is located less than 60 meters from: industries, airports, heavily trafficked roads, churches, markets, etc.				
6	**Air quality**				
	1. Little or no effect from air pollution		X		
	2. Moderate effect from air pollution, presence of some sources (bad odors or suspended dust may occasionally occur) between 20 and 40 meters away				
	3. Strong effect from high air pollution (bad odors and suspended dust are permanently present), pollution sources less than 20 meters away				

Source: Siles C., based on the methodology of SEGEPLAN, (2013)

3.3.1.2. Geological component

Table 8. Multicriteria Evaluation Matrix (Saaty Method) for the Geological Component

Nº	VARIABLES	N/A	1	2	3
7	**Seismicity**				
	1. The land is located in a low-hazard area on rocky ground, with no tall buildings nearby or slopes close to the site		X		
	2. The land is not close to seismic faults, but there are tall buildings nearby, transformer banks, rotten trees within 20 to 30 meters, and slopes under 2 meters in height				
	3. The land is located on one or more seismic faults, or faults exist less than 20 meters away; or tall buildings, transformer banks, rotten trees, etc. are within 1/3 of their height				
8	**Erosion**				
	1. There is no visual evidence of erosion on the land				
	2. The land shows signs of a moderate erosion process with vegetation cover predominant over most of the area (presence of small gullies at 2-meter intervals or numerous drainage lines)			X	
	3. The land shows signs of a pronounced erosion process (no vegetation cover, exposed roots, gullies 7 to 15 cm deep, numerous drainage lines)				
9	**Landslide or Collapse**				
	1. There is no risk of landslide or collapse on the land				
	2. There is a landslide risk on the land, but no effects on the site are expected due to the position of the slope			X	
	3. The land is located in zones of high danger from partial or mass landslides (due to loose soils, slopes greater than 15%)				
10	**Volcanism**				
	1. There are no nearby volcanoes, or if any exist, they are far enough that their activity would not affect the project		X		
	2. There are active volcanoes near the site and their volcanic activity could damage the project				
	3. The land is very close to inactive volcanoes and/or volcanoes with frequent activity that could seriously affect the project (ash, gases, lava, lahars, earthquakes, pyroclastics, etc.)				
11	**Slope ranges**				
	1. The land has slopes between 1 and 5%, or optimal ranges for the type of project				
	2. The land's slopes are between 5 and 15%			X	
	3. The land's slopes are greater than 15%				
12	**Soil quality (field test, laboratory, or expert opinion)**				
	1. Soils with strength or bearing value greater than 1.5 kg/cm2 (fine dry sand, hard clay, coarse dry sand, gravel, cemented gravel and sand, medium rock, solid rock) or a water table deeper than 6 meters		X		
	2. Soils with strength or bearing value between 1 and 1.5 kg/cm2 or a water table shallower than 5 meters, or without plastic or expansive clays				
	3. Soils with strength or bearing value equal to or less than 1 kg/cm2 or a water table at or above the depth of the foundations, or presence of clays with a high plasticity index or expansive clays				
13	**Land use**				
	1. The zoning plan indicates that land use is compatible with the type of project proposed		X		
	2. Land use is compatible with the type of project proposed, even though the zoning plan does not indicate it				
	3. Land use is not compatible with the type of project proposed				
14	**Geological formation (review Bolivia's geological map and verify in the field with weathering, consolidation, and fragmentation tests)**				
	1. The site is located on a geological formation of rock and deposits (sound rock and consolidated deposit)		X		
	2. The site is located on a moderately consolidated and weathered geological formation (sandy formation - slightly eroded ash)				
	3. The site is located on a rocky geological formation or deposits (poorly consolidated, highly weathered and fractured)				

Source: Siles C., based on the methodology of (SEGEPLAN, 2013)

3.3.1.3. Ecosystem Component

Table 9. Multicriteria Evaluation Matrix (Saaty Method) for the Ecosystem Component

Nº	VARIABLES	N/A	1	2	3
15	**Agricultural soils**				
	1. There are nearby agricultural lands but farming techniques are not harmful, or there are no agricultural lands within a 400-meter radius				
	2. Burning or fumigation farming practices are used nearby, but the effect on the proposed project is minor			X	
	3. Nearby (less than 20 meters from the land) there are agricultural lands where burning or pesticide fumigation practices are used, which may affect people's health or the activities of the proposed project				
16	**Surface hydrology**				
	1. Due to its location, the land is not susceptible to flooding according to historical records				
	2. Flooding may exceptionally occur, but without the possibility of damage to the proposed project			X	
	3. The flood hazard is evident due to the existence of nearby water bodies, historical records, or the project encroaching on the natural right-of-way of a water body				
17	**Groundwater hydrology**				
	1. There is no historical evidence of groundwater flows in the land's area that could affect the project				
	2. Near the land, within less than 20 meters, there are groundwater sources at depths between 10 and 40 meters. Soils with low infiltration rates.			X	
	3. Near the land there are significant groundwater flows at depths less than 10 meters (soils with high infiltration rate)				
18	**Lakes**				
	1. The land is located more than 3 meters above the overflow elevation		X		
	2. The altitude difference is equal to or less than 1.50 m				
	3. The land is within the natural right-of-way elevation				
19	**Fragile areas**				
	1. The land is far from environmentally fragile areas, at distances greater than 1 km				
	2. The land is between 250 and 500 m from environmentally fragile areas			X	
	3. The land is within or very close to (less than 200 meters) environmentally fragile areas				
20	**Sedimentation**				
	1. There is no risk of deposit accumulation on the land where the project will be located				
	2. On the land where the project will be located, deposit accumulation may occasionally occur in insignificant amounts that do not affect the project and/or alter the land's topography			X	
	3. The land is within zones of deposit or soil accumulation, which may alter the site's topography or affect the proposed project during intense rains				

Source: Siles C., based on the methodology of (SEGEPLAN, 2013)

3.3.1.4. Built Environment Component

Table 10. Multicriteria Evaluation Matrix (Saaty Method) for the Built Environment Component

Nº	VARIABLES	N/A	1	2	3
21	**Range of action**				
	1. Less than 25% of the population using the proposed project is located more than 5 km on foot or one hour by bus				
	2. Between 25 and 49% of the population using the project is more than 5 km on foot or one hour by bus			X	
	3. More than 50% of the population using the project is more than 5 km on foot, or one hour by bus, from the project's area of action				
22	**Accessibility**				
	1. There is no difficulty accessing the site at any time of year				
	2. There are roads usable only in certain seasons, or access construction is required for certain types of transport			X	
	3. Accessibility is difficult at certain times and impossible during the rains due to lack of infrastructure, means of transport (land and water)				
23	**Access to services**				
	1. Basic services exist at the site where the project will be located and it is possible to connect to them				
	2. At the site where the project will be located, at least two of the four services exist, or it is at least possible to connect to two of them			X	
	3. At the site where the project will be located, the services do not exist or the project cannot connect to them due to insufficiency or incapacity of the service systems				
24	**Urban and rural considerations**				
	1. When a territorial development plan (urban-rural) exists at the site where the project will be located and is compatible with the population growth and services it will require				
	2. When there is no development plan (urban and rural) for the land where the project will be located, or if it exists it is elementary, but there are alternatives to integrate the site with population growth and the services it requires			X	
	3. When there is no territorial development plan (urban and rural) at the site where the project will be located, and the project is not compatible with existing population growth and services, which hinders its future integration into urban or rural growth				
25	**Land uses and pollution sources**				
	1. The land is far from pollution sources		X		
	2. The land is moderately close to pollution sources, and historically pollution sources existed at the site				
	3. The land is close to pollution sources or shows evidence of contamination				
26	**Urban and rural regulations**				
	1. Municipal regulations or ordinances exist and the site is compatible with urban and rural development				
	2. There are no municipal regulations or ordinances, or if they exist they are not enforced, or the proposed project will moderately affect urban and rural development			X	
	3. There are no municipal regulations or ordinances, or if they exist they are not enforced, and the site where the project will be located will considerably affect urban and rural development				
27	**Communal areas**				
	1. There is coverage of services and communal areas				
	2. There are no communal areas or basic facilities, but these will be provided by the project			X	
	3. There are no communal areas or basic facilities				
28	**Waste treatment facilities**				
	1. There is appropriate space at the site and the soils are suitable for treating liquid and solid waste		X		
	2. There is the possibility of applying preliminary treatment, but on a restricted basis				
	3. There is no space and/or the soils are not suitable for building adequate treatment systems. There is no final effluent disposal system, or effluents are discharged into the watercourse				
29	**Project dimensionality**				
	1. The land's dimensions are sufficient to meet the type of project		X		
	2. The land's dimensions are just enough for the project but will not allow its expansion or modification				
	3. The land's dimensions are insufficient				

Source: Siles C., based on the methodology of SEGEPLAN, (2013)

3.3.1.5. Pollution Component

Table11. Multicriteria Evaluation Matrix (Saaty Method) for the Pollution Component

Nº	VARIABLES	N/A	1	2	3
30	**Solid and liquid waste**				
	1. The land is more than 1000 meters from open-air solid and liquid waste dumps in the same wind direction, or opposite the wind direction but with tree masses that filter the polluted air.		X		
	2. The land is between 800 and 1200 meters from pollution sources (500-800 m, sanitary landfills; 800-1000 m, open-air solid waste dumps; 1200 m from cemeteries.)				
	3. The land is at distances of less than 100 to 800 meters from pollution sources (less than 500 m, sanitary landfills; less than 800 m, open-air solid waste dumps; less than 100 m from cemeteries)				
31	**Polluting industries**				
	1. The land is located more than 1000 meters from polluting industries (paint factories, nitrogen acids, leather processing); 500 m from polluting industries (construction material yards and asphalt plants); 300 m from slaughterhouses and plant fiber processing plants; and 100 m from glass, dairy, canned fish, gypsum, and clay factories		X		
	2. The land is located below the above standards, but very close to the limit of the standard, and there are mitigating factors such as tree masses				
	3. The land is located less than 1000 m from the limit of the standards and there are no tree masses				
32	**High-voltage lines or electromagnetic equipment**				
	1. The land is located more than 80 meters from high-voltage power transmission lines, electrical or electronic equipment (telephone antennas), etc.		X		
	2. The land is between 70 and 80 meters from high-voltage power transmission lines, electrical or electronic equipment (telephone antennas), etc.				
	3. The land is less than 70 meters from high-voltage power transmission lines, electrical or electronic equipment (telephone antennas), etc.				
33	**Danger of explosions and fires**				
	1. The land is more than 25 m from flammable structures (wood, straw, wattle-and-daub buildings) and/or more than 180 m from structures with explosion hazards (gas stations, material warehouses, explosive gas warehouses). At distances of less than 60 m from underground or above-ground fuel storage and gas plants		X		
	2. The land is at or below the limits of the above standards				
	3. The land is well below the above standards or adjacent to flammable structures or structures with explosion hazards				
34	**Vice establishments**				
	1. There are no nearby vice establishments to the land		X		
	2. The land is located at a sufficient distance from vice establishments				
	3. The land is adjacent to or extremely close to vice establishments (bars, nightclubs, etc.)				
35	**Solid and liquid waste collection services**				
	1. The land has coverage of these services and there is capacity to collect solid and liquid waste				
	2. The land is located in an area where solid and liquid waste collection services are planned to be provided			X	
	3. Strong effect from high air pollution (bad odors and suspended dust are permanently present), pollution sources less than 20 meters away				

Source: Siles C., based on the methodology of SEGEPLAN, (2013)

3.3.1.6. Institutional and Social Component

Table 12. Multicriteria Evaluation Matrix (Saaty Method) for the Institutional and Social Component

Nº	VARIABLES	N/A	1	2	3
36	**Territorial conflicts**				
	1. There are no territorial conflicts or disputes in the area where the proposed project will be located		X		
	2. There are territorial claims, but there is consensus among the population on the legitimacy of the site for the proposed project				
	3. There are territorial conflicts or disputes in the area where the proposed project will be located, and/or the project's location at the site may trigger or intensify territorial disputes				
37	**Public safety**				
	1. There is security near the land where the proposed project will be located		X		
	2. In the surroundings of the land where the proposed project will be located, common criminal behavior has occurred, but it is isolated and infrequent				
	3. The land where the project will be located is in areas with high rates of common crime, armed confrontations, kidnappings, or vandalism				
38	**Legal framework**				
	1. The land complies with the provisions of the legal framework (registered with a property title)		X		
	2. The land is in the process of being legalized				
	3. The land does not comply with legal regulations				
39	**Citizen participation**				
	1. There are communal organizations that actively participate in the proposal, planning, execution, and maintenance of the proposed project		X		
	2. There is organization but it does not actively participate in all phases of the project				
	3. There is no community organization, or one exists but is not taken into consideration				
40	**Socioeconomic importance**				
	1. The project is the main source of socioeconomic accessibility		X		
	2. Other routes exist, but the project is necessary				
	3. The project has low economic and social significance				
41	**Quality of life**				
	1. The project seeks to improve the quality of life of the population in impoverished neighborhoods		X		
	2. The project affects a sector of the population, but does not positively impact their quality of life				
	3. The project does not represent a significant contribution to quality of life				
42	**Local conduct**				
	1. The population has habits of using public space				
	2. There are limitations that can be overcome through education and citizen participation			X	
	3. The population does not have habits of using public space				

Source: Siles C., based on the methodology of SEGEPLAN, (2013)

This rating represents the site exposure index in relation to the proposed project and the threats that could affect it. It also allows for decisions to be made regarding whether the analyzed site location is appropriate for the implementation of the proposed project.

The site exposure rating was calculated, and the weights were determined using the Saaty method (see Table 13).

Table 13. Determination of Weights Using the Saaty Method

	C1	C2	C3	C4	C5	C6	Ci
C1	1	1	1	3	5	1	0.24
C2	1	1	3	3	3	1	0.26
C3	1	1/3	1	5	1	1	0.17
C4	1/3	1/3	1/5	1	1	1	0.08
C5	1/5	1/3	1	1	1	1	0.10
C6	1	1	1	1	1	1	0.15

The summary of the ratings, taking into account the variables of each component and their relative weights, is presented in the following table (see Table 14).

Table 14. Structure of Vulnerability Analysis by Exposure

Site exposure							
	Component/variable	**Rating**	**Relative weight**		**Component/variable**	**Rating**	**Relative weight**
	Bioclimatic Component	**2**	**0.24**		**Built Environment Component**	**2**	**0.08**
1	Hygrothermal comfort	N/A		21	Range of action	2	
2	Orientation	N/A		22	Accessibility	2	
3	Wind	2		23	Access to services	2	
4	Precipitation	3		24	Urban considerations	2	
5	Noise	N/A		25	Land uses and pollution sources	1	
6	Air quality	1		26	Urban regulations	2	
	Geology Component	**1**	**0.26**	27	Communal areas	2	
7	Seismicity	1		28	Waste treatment facilities	1	
8	Erosion	2		29	Project dimensionality	1	
9	Landslides	2			**Pollution Component**	**1**	**0.10**
10	Volcanism	1		30	Solid and liquid waste	1	
11	Slope ranges	2		31	Polluting industries	1	
12	Soil quality	1		32	High-voltage lines or electromagnetic equipment	1	
13	Land use	1		33	Danger of explosions and fires	1	
14	Geological formation	1		34	Vice establishments	1	
	Ecosystem Component	**2**	**0.17**	35	Waste collection services	2	
15	Agricultural soils	2			**Institutional and Social Component**	**1**	**0.15**
16	Surface hydrology	2		36	Territorial conflicts	1	
17	Groundwater hydrology	2		37	Public safety	1	
18	Lakes	1		38	Legal framework	1	
19	Fragile areas	2		39	Citizen participation	1	
20	Sedimentation	2		40	Socioeconomic importance	1	
				41	Quality of life	1	
				42	Local conduct	2	

Source: Siles C., based on the methodology of SEGEPLAN, (2013)

3.4. Site Exposure Vulnerability Rating

Next, the site exposure rating is estimated, which is the result of the sum of the products obtained by multiplying the rating of each component by its respective relative weight, according to the methodology proposed by SEGEPLAN, (2013). The formula to follow is:

$$C_{VES} = (C_{CB} * PR_{CB}) + (C_{CG} * PR_{CG}) + (C_{CE} * PR_{CE}) + (C_{CMC} * PR_{CMC}) + (C_{CC} * PR_{CC}) + (C_{CIS} * PR_{CIS})$$

Where:

C: Rating, ***PR:*** Relative Weight, ***ES:*** Site Exposure, ***CB:*** Bioclimatic Component,
CG: Geological Component, ***CE:*** Ecosystem Component, ***CMC:*** Built Environment Component,
CC: Pollution Component, ***CIS:*** Institutional and Social Component.

The site exposure rating is used to make decisions, as suggested in the weighting scale for the level of vulnerability by site exposure of the proposed project.

By applying the indicated formula and analyzing the data from Table 7, it was determined that the Site Exposure Vulnerability is:

$$C_{VES} = \mathbf{1.49}$$

Which corresponds to a medium vulnerability

According to the weighting scale, this value places the site in the medium exposure category (see Table 15).

Table 15. Weighting Scale for Site Exposure Level

Exposure level	Range	Recommendation
Highly exposed sites	**2:00 to 3:00**	Look for a new site, or in special cases where a new site is not an option, an in-depth analysis of fragility and resilience should be carried out, considering the exposure elements
Moderately exposed sites	**1:00 to 1:99**	Continue the vulnerability analysis of the proposed project, considering the exposure elements that could affect the project
Sites with low exposure	**0:0 to 0:99**	Continue the vulnerability analysis of the proposed project

Source: Siles C. Based on the Saaty methodology, (1980)

3.5 Risk Analysis and Evaluation

Risk analysis considers two fundamental components: hazard and vulnerability. Based on the analyses and results obtained in the previous sections, step 3 is carried out: risk evaluation, which includes completing the risk matrix. Using the risk criteria table, the corresponding rating for each hazard was determined (see Table 16).

Table 16. Risk Evaluation

Event	Hazard	Vulnerability	Risk Evaluation
Forest fire	MEDIUM	MEDIUM	MEDIUM RISK
Flood	HIGH	HIGH	HIGH RISK
Drought	LOW	LOW	LOW RISK
Landslide	MEDIUM	MEDIUM	MEDIUM RISK
Flash flood	HIGH	MEDIUM	HIGH RISK
Hailstorm	MEDIUM	LOW	MEDIUM RISK

Source: Siles C., based on information provided by SINAGER, VIDECI, and SEGEPLAN, (2024)

The table shows the identified risks. Various types of threats were analyzed (natural, socio-natural, and anthropogenic), highlighting events such as forest fires, floods, droughts, landslides, flash floods, and hailstorms.

High Risk: Floods and flash floods present a high risk due to the combination of a high hazard level and high or medium vulnerability. This suggests that these events are a priority for mitigation and adaptation actions.
Medium Risk: Threats such as forest fires, landslides, and hailstorms have a medium risk rating, indicating that although they are not the highest priority, they require monitoring and control measures to reduce potential impacts.
Low Risk: Drought is classified as low risk, as both the hazard and vulnerability are low. However, monitoring remains important due to potential climate changes that could alter these conditions.

3.6. Formulation of Intervention Measures

- Floods and flash floods should be addressed through specific action plans, such as strengthening infrastructure, implementing early warning systems, and promoting community awareness.
- Forest fires and landslides require preventive management strategies, including reforestation, soil management, and contingency plans.
- For hailstorms, it is recommended to work on agricultural protection systems and insurance mechanisms to reduce impacts on communities.
- Continuous monitoring of droughts is essential to detect potential upward trends in the level of hazard.

This risk prioritization is essential for allocating resources efficiently and minimizing impacts in the region.

4. CONCLUSIONS

- The project "Development of a Disaster Risk Management (DRM) Guide for FONABOSQUE" successfully met all the established objectives.

- A DRM guide was designed that can be implemented throughout the life cycle of projects financed by FONABOSQUE, strengthening their focus on sustainability and resilience.

- The guide was applied to FONABOSQUE projects, and in this work the following was used as an example: the Technical Pre-Investment Design Study (TPDS) of the project "Strengthening Sustainable Productive Associations: Promoting Conservation, Livelihoods, and Market Consolidation in the Municipality of Apolo."

- The results obtained from the practical case were evaluated, allowing for adjustments and improvements to ensure its applicability and efficiency in future projects.

- Clear objectives were established, aligned with FONABOSQUE's mission, and current legal and international regulations were identified, ensuring regulatory compliance.

- Historical data, common risks, and best practices were compiled, grounding the guide in solid evidence and real-world context.

- During the vulnerability analysis carried out in the municipality of Apolo, the results obtained were significant:
  - The main risks associated with the project were identified, including forest fires, deforestation, and droughts, which are the most frequent threats in the region.
  - Using tools such as the Saaty Matrix and the Bayesian method, vulnerability levels were quantified in key areas, which made it possible to propose concrete mitigation and prevention measures.
  - The case analysis demonstrated that the implementation of measures based on the guide can significantly reduce the risks to which projects and beneficiary communities are exposed.

- Impact of the Guide on FONABOSQUE's Risk Management
  - The guide provided a structured and systematic approach to risk identification, analysis, and mitigation, strengthening FONABOSQUE's capacity to address disaster-related challenges.
  - Its application in FONABOSQUE projects made it possible to validate the relevance and usefulness of the guide, demonstrating its potential to be integrated into project selection, evaluation, and monitoring processes.
  - The results of the practical case showed that the guide not only complies with national regulations, such as Ministerial Resolution No. 115, but is also aligned with international commitments such as the Sendai Framework and the Sustainable Development Goals (SDGs).

- Institutional Strengthening and Benefits for Projects. The implementation of the guide in projects financed by

- FONABOSQUE will make it possible to:
  - Significantly reduce vulnerability to natural disasters, decreasing the risk of economic, environmental, and human losses.

• Ensure regulatory compliance, enhancing FONABOSQUE's credibility as a financing entity for sustainable projects.
•Promote a culture of prevention and resilience, both within the institution and among beneficiary communities.

- This project represents a significant advancement in disaster risk management within the context of projects financed by FONABOSQUE. The developed guide is a comprehensive, adaptable, and effective tool that not only improves project planning and implementation, but also strengthens their sustainability, contributing to the conservation of natural resources and the well-being of the communities involved. Its implementation will continue to generate tangible and sustainable benefits in the long term.

5. RECOMMENDATIONS

- It is recommended to incorporate Disaster Risk Management (DRM) as a subject or cross-cutting content within the Environmental Engineering curriculum, considering that this topic is currently not formally addressed, despite its importance for comprehensive and context-based training.

- FONABOSQUE should institutionalize the use of the Technical Guide, ensuring that all projects it finances apply DRM criteria from the design phase onward.

- It is suggested to train technical staff from FONABOSQUE and implementing entities in the use of analytical methodologies for vulnerability and risk analysis, such as the Saaty Matrix and Bayesian analysis.

- It is advisable to promote agreements with universities and research centers to update and enhance the technical guide with new approaches, geospatial tools, and case studies.

- It is strongly encouraged to integrate risk monitoring and evaluation processes throughout the project life cycle, thereby strengthening the sustainability and resilience of investments.

6. REFERENCES

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