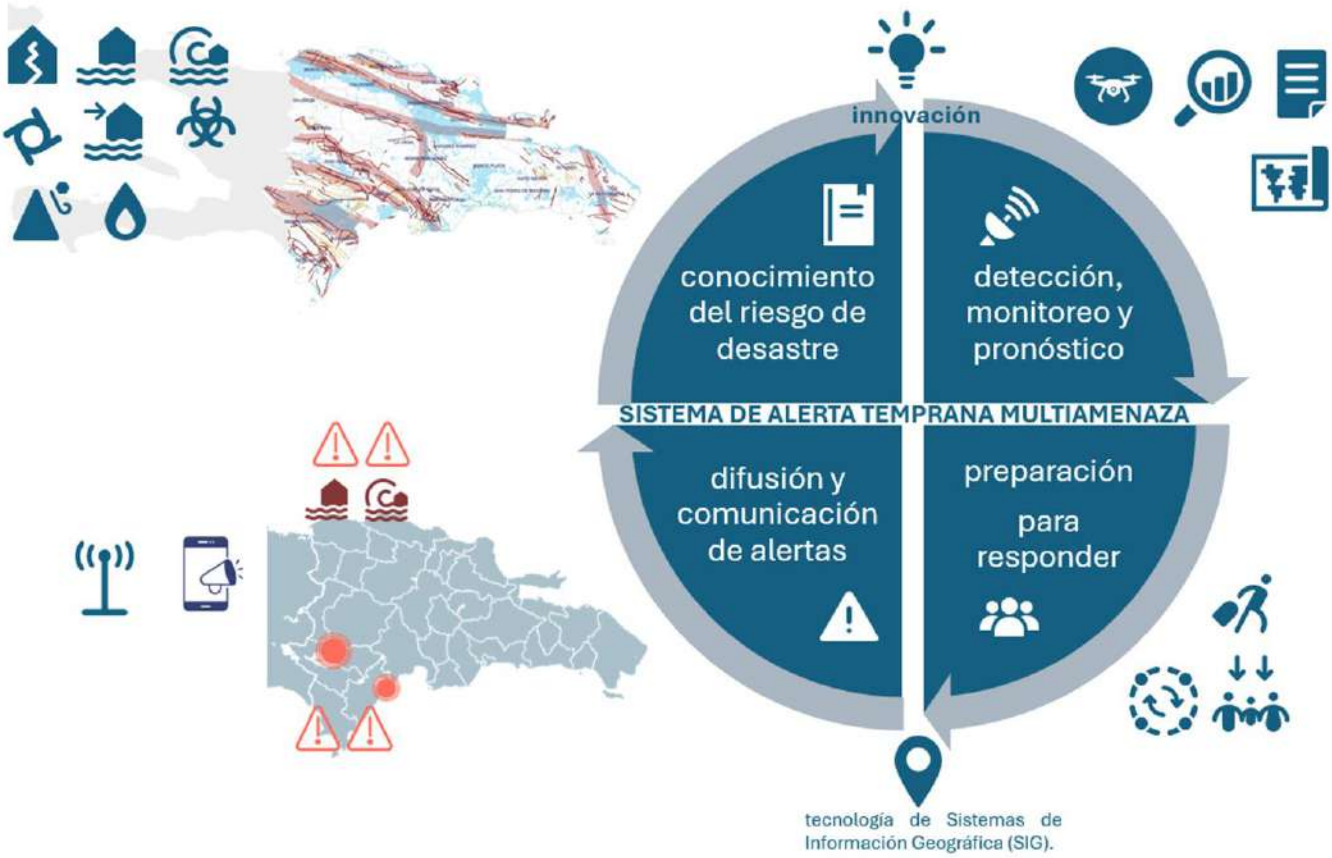
Sistema de Alerta Temprana - Multiamenaza para República Dominicana



CENTRO DE OPERACIONES DE EMERGENCIAS
Presidencia de la República Dominicana
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Gobierno de la República Dominicana
Economía, Planificación y Desarrollo
CDRI Coalition for Disaster Resilient Infrastructure
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Producto 1.3

Hoja de Ruta para la transición hacia un Sistema de Alerta Temprana-Multiamenazas basado en Sistemas de Información Geográfica

CENTRO DE OPERACIONES DE EMERGENCIAS

PRESIDENCIA DE LA REPÚBLICA DOMINICANA
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GOBIERNO DE LA REPÚBLICA DOMINICANA
ECONOMÍA, PLANIFICACIÓN Y DESARROLLO

CDRI
Coalition for Disaster Resilient Infrastructure

IRAF
Infrastructure Resilience Accelerator Fund

IRIS
Infrastructure for Resilient Island States

Executive Summary

This document presents the non-binding Roadmap for the Transition to a Multi-Hazard Early Warning System (SAT-M) centered on Geographic Information System (GIS) tools in the Dominican Republic. Developed between October 2024 and September 2025, the report outlines a roadmap addressing structural, regulatory, and technological challenges as a working and discussion document for the implementation of a Multi-Hazard Early Warning System (SAT-M) capable of effectively responding to the threats facing the country. This document details a transition from current early warning systems to a modern, GIS-based multi-hazard system, aligned with international standards and adapted to the current Dominican context.

The Roadmap for a GIS-based SAT-M (Safety and Maintenance System) provides direct benefits to the infrastructure sectors in the Dominican Republic by integrating up-to-date geospatial data and real-time monitoring systems that enable the identification of critical vulnerabilities in buildings, roads, bridges, and water and energy systems. This facilitates proactive planning of public works, the design of safety protocols, and the prioritization of investments in resilient infrastructure. It also strengthens inter-institutional coordination and information interoperability among entities such as the Ministry of Public Works and Communications (MOPC), the National Institute of Hydraulic Resources (INDRHI), the National Institute of Drinking Water and Sewerage (INAPA), the Ministry of Public Health (MSP), the Ministry of Housing and Urban Development (MIVE), the Ministry of Education (MINERD), and the Dominican Water and Sanitation Company (EGEHID), ensuring that decisions regarding construction, maintenance, and emergency response are based on accurate technical evidence. Overall, the Roadmap reduces physical and economic risks, protects vital infrastructure, and contributes to the continuity of essential services in the face of threats.

The transition to a Multi-Integrated Early Warning System (SAT-M) faces significant governance and inter-institutional coordination challenges. In the Dominican Republic, the governance framework for risk management is fragmented among several institutions, each with responsibilities defined in Law 147-02, which establishes the country's risk management regulations. However, as the report indicates, this distribution of responsibilities lacks a coherent intersectoral structure that would allow for the effective integration of data and technological modernization. Key institutions such as the Emergency Operations Center (COE), the National Council for Climate Change, and the Ministry of Economy, Planning and Development (MEPyD) play fundamental roles, but their efforts are not sufficiently coordinated at the technical and regulatory levels, hindering the efficiency of the early warning system.

At the regulatory level, the diagnosis identifies the need for a hierarchical structure that integrates real-time data management and ensures effective governance at all levels, including local and national. The lack of decentralization in governance limits the participation of local actors in response planning and in alert and communication mechanisms, leading to disparities in community response capacity, particularly in vulnerable areas. Implementing an accessible and up-to-date national risk information repository is crucial to overcoming these challenges and fostering inter-institutional collaboration (Pérez & Gutiérrez, 2020).

International best practices offer a valuable model for the transition to a Rapid Emergency Response System (RERS) in the Dominican Republic. Japan and the United States have made significant progress in implementing early warning systems based on advanced GIS and Internet of Things (IoT) technologies, which enable real-time data integration for decision-making. In Japan, for example, GIS systems facilitate risk visualization and evacuation planning, achieving efficient coordination among local, regional, and national levels (Wang & Kimura, 2021). In the United States, the Federal Emergency Management Agency (FEMA) uses advanced sensors and IoT technologies to improve the detection of natural hazards, enabling a rapid and effective response through integrated, real-time warning systems (FEMA, 2022).

On the other hand, regional experiences such as those of Cuba and Mexico stand out in the implementation of community early warning systems that combine basic technology with active citizen participation. In Cuba, the community acts as the first responder in emergencies, which, together with a technological infrastructure adapted to economic limitations, has significantly reduced the impact of hydrometeorological events on the population (Pérez & Gutiérrez, 2020). Mexico has developed seismic early warning systems that combine advanced technologies and community education, which has strengthened response capacity in urban and rural areas (Ramos & Aguilar, 2021). These experiences suggest that the combination of advanced technology and citizen participation is an effective strategy for strengthening early warning systems in contexts of limited resources, as is the case in the Dominican Republic.

The diagnosis also reveals strengths and weaknesses in the fundamental components of the SAT-M. Regarding Disaster Risk Knowledge, the Dominican Republic has a considerable geospatial database, although its updating and sharing among institutions remains limited. The infrastructure for the detection, monitoring, and forecasting of seismic and hydrometeorological events is uneven, especially in rural and remote areas. The implementation of low-cost seismic and meteorological sensors and emerging technologies could significantly improve detection and monitoring capacity, optimizing the speed and accuracy of emergency response (World Meteorological Organization, 2021).

Regarding the dissemination and communication of alerts, the national system relies primarily on traditional media such as radio and television, complemented by mobile alerts, although the digital divide in remote areas limits the reach of these alerts. Mexico's experience in using mobile applications and community early warning networks offers a viable model for overcoming these barriers in the Dominican Republic, leveraging the access to mobile technologies that are available to most of the population (Garza & Solís, 2019).

Finally, the Preparedness to Respond component reveals a low frequency of regular drills and limited community participation in contingency plans. Although the Emergency Operations Center (EOC) organizes some training programs, their scope is insufficient to guarantee adequate preparedness at the national level. In this respect, Cuba stands out for its focus on community education and the implementation of annual drills, which has demonstrated a significant reduction in the impact of disasters on the population through high citizen participation in risk management (Pérez & Gutiérrez, 2020).

To strengthen the capabilities of the Early Warning System in the Dominican Republic, the report recommends creating a national risk platform that integrates real-time data and allows access to all relevant institutions. Modernizing monitoring and detection infrastructure through the implementation of GIS technologies will improve risk visualization and analysis, thus facilitating informed decision-making. At the community level, it is essential to foster active participation of civil society in early warning processes, replicating successful models such as those in Cuba and Mexico, where the community plays a key role in disaster preparedness and response.

The transition to a robust SAT-M also depends on adequate and sustained funding for technology, training, and governance strengthening. As the Sendai Framework for Disaster Risk Reduction (2015) states, the country needs to take a more active role in financing its SATs, including these systems in public budgets and exploring innovative financing mechanisms, such as disaster insurance and catastrophe bonds, to reduce dependence on international cooperation (United Nations Office for Disaster Risk Reduction, UNDRR, 2015).

The integration of advanced innovations, such as drones, high-resolution satellite imagery, artificial intelligence, and predictive analytics, will transform the accuracy, speed, and responsiveness of disaster preparedness (DPS), enabling institutions to anticipate risks with the precision necessary to significantly reduce human and material losses. These technologies must be implemented progressively and in a culturally appropriate manner, ensuring a multi-level, multi-stakeholder structure that maximizes the use and understanding of these systems at all levels of society. This will solidify the multi-hazard DPS as a key tool in protecting lives and property, enhancing the country's resilience to disasters.

Ongoing training for technicians, decision-makers, and local communities in the use of GIS tools will not only improve response capacity but also foster a culture of risk prevention and mitigation throughout the population. Actively engaging the community through awareness and risk management training programs will transform individuals into active participants in emergency response, strengthening social cohesion in risk management. Strategic coordination among government institutions, NGOs, and the private sector, along with international partnerships, will ensure the financial sustainability and stability of the Early Warning System (EWS), enabling its maintenance, updating, and expansion. This collaborative network will not only boost local resilience but also generate an exchange of knowledge and best practices that will enrich the system and make it more effective.

Regular and rigorous evaluations of the SAT, accompanied by specific performance indicators, will ensure that the system remains aligned with changes in the environment and emerging risks. These indicators will allow for real-time measurement of the SAT's effectiveness, facilitating adjustments that will keep the system at the forefront of disaster management.

In conclusion, the Dominican Republic has a solid foundation for transitioning to a GIS-based multi-hazard early warning system, but this foundation must be strengthened through coherent governance, clear public policies, up-to-date and accessible knowledge production, integration of best practices across different management levels, and investment in technology and training. With these strategies, the country will be better prepared to face future natural hazards, strengthening its resilience and response capacity in a context of high vulnerability.

Abstract

This document presents the *Roadmap for the Transition to a Multi-Hazard Early Warning System (MH-EWS)* , a Multi-Hazard Early Warning System centered on Geographic Information Systems (GIS) tools in the Dominican Republic. Developed between October 2024 and September 2025, the report outlines a strategy addressing structural, regulatory, and technological challenges as a working and discussion document, for implementing an MH-EWS capable of effectively responding to the country's vulnerabilities. It details the transition from the current alert systems to a modern, GIS-based multi-hazard system that aligns with international standards and is adapted to the current Dominican context.

The roadmap for a GIS-based SAT-M brings direct benefits to infrastructure sectors in the Dominican Republic by integrating up-to-date geospatial data and real-time monitoring systems that identify critical vulnerabilities in buildings, roads, bridges, water, and energy systems. This facilitates preventive planning for public works, the design of safety protocols, and the prioritization of investments in resilient infrastructure. It also strengthens inter-institutional coordination and information interoperability between entities such as the MOPC, INDRHI, INAPA, MSP, MIVE, MINERD and EGEHID ensuring that decisions on construction, maintenance, and emergency response are based on accurate technical evidence. Overall, the roadmap reduces physical and economic risks, protects vital infrastructure, and contributes to the continuity of essential services in the face of threats.

The transition to an MH-EWS faces considerable governance and inter-institutional coordination challenges. In the Dominican Republic, the risk management framework is fragmented across various institutions, each with responsibilities defined by Law 147-02, which sets the country's risk management regulations. However, as noted in the report, this distribution lacks a coherent cross-sectoral structure, limiting effective data integration and technological modernization. Key institutions like the Emergency Operations Center (COE), the National Council for Climate Change, and the Ministry of Economy, Planning, and Development (MEPyD) play fundamental roles, but their efforts are not sufficiently coordinated at the technical and regulatory levels, impacting the alert system's efficiency.

On a regulatory level, the assessment identifies the need for a hierarchical structure integrating real-time data management and ensuring effective governance at local and national levels. Limited decentralization restricts the participation of local actors in response planning and alert and communication mechanisms, creating disparities in community response capacity, particularly in vulnerable areas. Implementing a national risk information repository, accessible and up-to-date , is essential to address these issues and promote inter-institutional collaboration (Pérez & Gutiérrez, 2020).

International best practices provide valuable models for transitioning to an MH-EWS in the Dominican Republic. Japan and the United States have significantly advanced in implementing early warning systems based on advanced GIS and Internet of Things (IoT) technologies, allowing real-time data integration for

decision-making. In Japan, for example, GIS systems facilitate risk visualization and evacuation planning, achieving efficient coordination between local, regional, and national levels (Wang & Kimura, 2021). In the United States, the Federal Emergency Management Agency (FEMA) uses advanced sensors and IoT technologies to enhance natural threat detection, enabling rapid and effective response through integrated real-time alert systems (FEMA, 2022).

Regionally, countries like Cuba and Mexico excel in implementing community-based alert systems that combine basic technology with active citizen engagement. In Cuba, communities act as first responders, significantly reducing the impact of hydrometeorological events, supported by a technological infrastructure adapted to economic limitations (Pérez & Gutiérrez, 2020). Mexico has developed seismic alert systems that blend advanced technologies with community education, strengthening response capacity in urban and rural areas alike (Ramos & Aguilar, 2021). These experiences indicate that combining advanced technology with citizen participation is an effective strategy for enhancing EWS in resource-limited contexts, as in the Dominican Republic.

The assessment also reveals strengths and weaknesses in the core MH-EWS components. Regarding *Disaster Risk Knowledge* , the Dominican Republic has a substantial geospatial data repository, although its updating and sharing across institutions remain limited. Infrastructure for *Detection, Monitoring, and Forecasting* of seismic and hydrometeorological events is uneven, particularly in rural and remote areas. Implementing low-cost seismic and meteorological sensors and emerging technologies could significantly enhance detection and monitoring, improving the speed and accuracy of emergency responses (World Meteorological Organization, 2021).

For *Alert Dissemination and Communication* , the national system relies mainly on traditional media, such as radio and television, supplemented by mobile alerts, although digital divides in remote areas limit alert reach. Mexico's experience with mobile applications and community-based early warning networks offers a viable model for overcoming these barriers in the Dominican Republic, leveraging mobile technology accessible to most of the population (Garza & Solís, 2019).

Finally, the *Response Preparedness* component reveals infrequent regular drills and limited community participation in contingency planning. While the COE organizes some training programs, their reach is insufficient for nationwide preparedness. In this regard, Cuba's focus on community education and annual drills has shown a significant reduction in disaster impact through high citizen participation in risk management (Pérez & Gutiérrez, 2020).

To strengthen MH-EWS capabilities in the Dominican Republic, the report recommends creating a national risk platform integrating real-time data accessible to all relevant institutions. Modernizing monitoring and detection infrastructure through GIS technology implementation will improve risk visualization and analysis, facilitating informed decision-making. Community-level engagement is also crucial, replicating successful models from Cuba and Mexico, where the community plays a key role in disaster preparedness and response.

The transition to a robust MH-EWS also requires adequate and sustained financing for technology, training, and governance strengthening. As outlined in the *Sendai Framework for Disaster Risk Reduction (2015)* , the country needs to assume a more active role in EWS funding, incorporating these systems into public budgets and exploring innovative financing mechanisms like disaster insurance and catastrophe bonds to reduce dependence on international cooperation (United Nations Office for Disaster Risk Reduction, UNDRR, 2015).

In conclusion, the Dominican Republic has a solid foundation for transitioning to a GIS-based multi-hazard EWS. Strengthening this foundation through coherent governance, clear public policies, up-to-date accessible knowledge production, integrated practices across management levels, and investment in technology and training will better equip the country to face future natural threats, enhancing its resilience and response capabilities in a highly vulnerable context.

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Acronyms and Abbreviations

INSTITUTIONAL

PUBLIC SECTOR

ANAMAR : National Maritime Affairs Authority
APP: Public-Private Partnerships
APORDOM: Dominican Port Authority
Municipalities : Municipal Government
CAASD: Santo Domingo Water and Sewerage Corporation
CNE: National Emergency Commission
CNS-UASD : National Center for Seismology, Autonomous University of Santo Domingo
CNCCMDL : National Council for Climate Change and the Clean Development Mechanism
COE : Emergency Operations Center
CTE: Emergency Technical Commission
DA: Airport Department
DAEH : Directorate of Out-of-Hospital Emergency Care Services
Civil defense
EGEHID: Dominican Hydroelectric Generation Company
EIGEO: Geospatial Information Team
ETM: Multisectoral Technical Teams
FEDOMU: Federation of Dominican Municipalities
IGN-JJHM : José Joaquín Hungría Morell National Geographic Institute
INDOMET : Dominican Institute of Meteorology
INDOTEL : Dominican Institute of Telecommunications
INDRHI : National Institute of Hydraulic Resources
INAPA : National Institute of Drinking Water and Sewerage
LMD : Dominican Municipal League
MA : Ministry of Agriculture
MARN : Ministry of Environment and Natural Resources
MESCYT: Ministry of Higher Education, Science and Technology
MEPyD : Ministry of Economy, Planning and Development
MIDE: Ministry of Defense of the Dominican Republic
MINERD : Ministry of Education
MINPRE : Ministry of the Presidency
MIVED: Ministry of Housing and Buildings
MOPC : Ministry of Public Works and Communications
ONESVIE : National Office for Seismic Evaluation and Vulnerability of Infrastructure and Buildings
ONE : National Statistical Office
SGN : National Geological Survey
SINI : National Information System
SIUBEN: Single Beneficiary System

PRIVATE SECTOR

To DORA : Dominican Association of Radio Listening
CODIA : Dominican College of Engineers, Architects and Surveyors
OSL : Loyola Seismological Observatory
SODOGEO : Dominican Society of Geology
SODOSISMICA : Dominican Society of Seismology and Earthquake Engineering
CIRRMA Center for Research on Resilience and Multi-Hazard Risks

ACADEMIC SECTOR

INTEC : Technological Institute of Santo Domingo
PUCMM : Pontifical Catholic University Madre y Maestra
UNIBE : Ibero-American University
UASD : Autonomous University of Santo Domingo
UCE: Central University of the East
UNICARIBE: University of the Caribbean

COOPERATION ORGANIZATIONS

AECID : Spanish Agency for International Development Cooperation
IDB : Inter-American Development Bank
BM : World Bank
CRD: Dominican Red Cross
German Cooperation
ECHO : European Civil Protection and Humanitarian Aid Operations
JICA : Japan International Cooperation Agency
WFP : World Food Programme
UNDP : United Nations Development Programme
USAID : United States Agency for International Development
FEMA: Federal Emergency Management Agency
IFRC: International Federation of Red Cross and Red Crescent Societies
FLACSO: Latin American Faculty of Social Sciences
UNDRR: United Nations Office for Disaster Risk Reduction
WFP: United Nations World Food Programme in the Dominican Republic
ITU: International Telecommunication Union

OTHERS

GIRD: Integrated Disaster Risk Management
NASA: National Aeronautics and Space Administration
NHC: National Hurricane Center
NOAA: National Oceanic and Atmospheric Administration
WMO: World Meteorological Organization
SAT: Early Warning System
SAT-M: Early Warning System - Multi-hazard
USGS: United States Geological Survey

1 Introduction

The Latin America and Caribbean (LAC) region faces significant environmental challenges, with climate change being one of the most critical due to its profound physical and economic consequences. Even with a global temperature increase limited to 1.5°C, the region remains highly vulnerable to the effects of climate change. In particular, the Caribbean and Central America are exposed to more frequent and intense extreme weather events, such as tropical storms, hurricanes, and droughts, posing a growing concern for the small island states of the Caribbean. In 2015, the economic cost of climate change in the region was estimated at US$100 billion, and a temperature increase of approximately 2.5°C could reduce economic output by 1.5–5% of GDP.

The Caribbean, largely composed of small island states, faces an increasing number of hydrometeorological events each year. In the Caribbean basin, 1,614 cyclonic systems were recorded over a 169-year period, 20% of which reached hurricane strength. The effects of these disasters have broad implications for the institutional, economic, social, and environmental development of the countries, including the Dominican Republic, whose vulnerability has intensified in recent decades. Between 1980 and 2012, the country experienced 28 hurricanes and storms and 20 floods, resulting in nearly 2,000 deaths. In 2016, more than 2.7 million people were affected by disasters, and in 2022 and 2023, events such as torrential rains and other disasters significantly impacted the population and generated claims for billions of pesos in losses, highlighting the deficiencies of current alert systems to adequately guide the population.

The effects of these phenomena, such as urban flooding in densely populated areas, highlight the urgent need for an effective early warning system. During the intense rains of November 2022 and 2023 in Santo Domingo, the lack of a robust early warning system prevented cities from adequately preparing, exacerbating the impact on people and local economies. According to the Central Bank, the annual fiscal costs associated with weather events represent up to 1.80% of GDP, and approximately 79% of disaster events since 1970 are related to climate risks, such as floods, droughts, and landslides. According to the Germanwatch Global Climate Risk Index (2021), the Dominican Republic is among the countries most affected by extreme weather disasters.

Recognizing the importance of climate action, the Dominican Republic has incorporated risk reduction strategies into planning instruments, such as the National Development Strategy 2030 and the National Multi-Year Public Sector Plan, which are legally enshrined and aligned with the Sustainable Development Goals. In accordance with the Sendai Framework for Disaster Risk Reduction 2015-2030, the country has worked on implementing multi-hazard early warning systems as crucial tools for improving adaptive capacity and resilience, reducing vulnerability, and minimizing losses.

Since 2018, with support from the Regional Fund for Triangular Cooperation in Latin America and the Caribbean, efforts have been made to strengthen early warning systems and improve response capacity. However, many municipalities still face significant challenges in managing climate events, particularly catastrophic floods. As part of the consultancy, a diagnostic study was conducted in the Dominican Republic on the state of early warning systems, and this document is based on that study.

This roadmap report outlines a comprehensive plan that addresses improving institutional arrangements, assessing technological requirements, identifying vulnerable areas, and strengthening monitoring and early warning capacity. Based on the priorities established in the Sendai Framework—such as risk understanding, strengthening governance, investing in risk reduction, and preparing for an effective response—this document charts a path toward creating a Multi-Hazard Early Warning System (MHWS) that combines international approaches and regional experiences adapted to the Dominican context. Developing a GIS-based MHWS in the Dominican Republic represents a fundamental step toward achieving robust and sustainable resilience.

2 Roadmap Objective

The proposed **roadmap** aims to guide the transition to a GIS-based Multi-Hazard Early Warning System (MHWS) in the Dominican Republic, aligned with the principles and guidelines of the United Nations' "Alert for All" initiative, which seeks to "protect and save lives by implementing effective, people-centered, and inclusive early warning systems" (United Nations). Nations , 2022). This document establishes a strategic framework to optimize the effectiveness of the SAT-M using Geographic Information Systems (GIS) technology, which will improve the accuracy of threat detection, facilitate inter-institutional coordination, and ensure the delivery of accessible and timely alerts, especially to vulnerable and high-risk populations.

Purpose and Scope of the Document

The purpose of this roadmap is to outline the steps necessary to develop and strengthen a GIS-based Emergency Response Team (ERT) that meets international standards for risk and disaster management and enables Dominican institutions to respond more quickly and accurately to natural and anthropogenic hazards. By adopting a GIS-based approach, the ERT will be able to:

1. Improve the collection, analysis, and visualization of multi-threat data through advanced mapping and spatial analysis tools (United Nations Office for Disaster Risk Reduction [UNDRR], 2021).
2. Integrate real-time data and forecasts from multiple sources, facilitating a coordinated and effective response at the institutional level.
3. Ensure that alerts reach the entire population, including vulnerable communities, by creating risk maps and georeferenced communication systems that allow for the personalization and targeting of alert information (UNDRR, 2021).

The scope of the document covers:

1. The review and improvement of the four components of SAT-M (Disaster Risk Knowledge; Detection, Monitoring and Forecasting; Dissemination and Communication of Alerts; and Preparedness to Respond), leveraging the capabilities of GIS to optimize decision-making and response planning (UNDRR, 2021).
2. The development of specific recommendations for each prioritized threat (earthquakes, hurricanes, floods, landslides and epidemics), with emphasis on the integration of risk maps, spatial modeling and predictive analysis in a GIS environment.
3. The definition of an effective and sustainable governance for the GIS-based SAT-M, which promotes inter-institutional collaboration and data integration at the local, regional and international levels.

Context of the Diagnosis and Challenges Identified

The initial assessment of the current SAT-M in the Dominican Republic reveals **multiple cross-cutting challenges** that limit responsiveness and anticipation capacity, and hinder the transition to a GIS-based system. According to the goal of the "Alert for All" initiative, which states that SATs should reach everyone by 2027 (United States) , Nations , 2022), the identified challenges are presented as follows:

Limitations in the Collection and Analysis of Geospatial Risk Data : The current SAT-M faces difficulties in obtaining and analyzing accurate spatial data, which is necessary for developing risk maps and conducting real-time threat analyses. The lack of a governing body, the need for advanced technology, and GIS infrastructure affect the capacity for assessment and response (UNDP, 2020). This limits the integration of geospatial data and the generation of detailed risk maps.

Shortcomings in GIS-Based Detection, Monitoring, and Forecasting : Current infrastructure has deficiencies in real-time threat data monitoring and processing. Monitoring systems, such as weather stations and seismographs, are not sufficiently integrated into GIS platforms to enable accurate predictions and timely alert coordination. According to UNDRR (2021), a GIS-based SAT-M requires well-established monitoring networks and a robust technological infrastructure that allows for real-time threat visualization and analysis.

Deficiencies in the Dissemination and Communication of Georeferenced Alerts : There are challenges in transmitting accessible and culturally appropriate alerts to communities at risk. GIS technology offers significant potential to overcome these challenges through the georeferencing of alerts, which allows alert messages to be targeted to specific areas and information to be tailored to the demographic and geographic characteristics of each community (UNDRR, 2022).

Insufficient Coordination and Preparedness for GIS-Based Response : Disaster response is limited by a lack of effective inter-agency coordination and an integrated data infrastructure. The transition to a GIS-based SAT-M will improve preparedness by visualizing risk scenarios, planning drills, and creating optimized response protocols based on geospatial analyses (UNDRR, 2021).

GIS Implementation Financing and Resource Challenges : The transition to a GIS-based multi-hazard early warning system faces financing challenges, which are necessary to ensure training, technology acquisition, and maintenance of advanced geospatial infrastructure. This context limits the Dominican Republic's capacity to meet international standards for an effective and inclusive multi-hazard early warning system (UNDP, 2020).

Part I

3 General Plan for Strengthening the SAT Against All Threats

The first section of this roadmap presents a General Plan for Strengthening the **Multi-Hazard Early Warning System (SAT-M)** , applicable to all prioritized threats in the Dominican Republic. This comprehensive approach is aligned with the international guidelines of the "Alert for All" initiative and the principles of the Sendai Framework for Disaster Risk Reduction, which emphasize the need for inclusive and effective early warning systems to protect all communities from multi-hazard events (UNDRR, 2021).

The General Plan addresses the four fundamental components of the SAT-M: **Disaster Risk Awareness, Detection, Monitoring and Forecasting, Dissemination and Communication of Alerts, and Preparedness to Respond** . Each component has been developed to overcome cross-cutting challenges identified in the diagnostic phase and to strengthen national response capacities to catastrophic events. Through a combination of **advanced technology** , such as Geographic Information Systems (GIS), and **inter-institutional participation** , this plan provides an adaptable framework for building a robust SAT-M that facilitates a rapid, coordinated, and effective response.

This framework, designed to be scalable and sustainable, lays the foundation for an optimized monitoring and response system for each specific threat and fosters a culture of resilience at the community and institutional levels. Taken together, the actions proposed in this section will allow the Dominican Republic to move toward an inclusive and modern Early Warning System (EWS) that meets local needs and international early warning standards.

3.1 Strengthening the Basic Components of the SAT

Strengthening the core components of the Multi-Hazard Early Warning System (SAT-M) is fundamental to improving disaster response and preparedness capacity in the Dominican Republic. This section focuses on optimizing each of the four pillars of the SAT-M—Disaster Risk Awareness; Detection, Monitoring, and Forecasting; Dissemination and Communication of Alerts; and Preparedness to Respond—through the incorporation of advanced technologies and inter-institutional training and collaboration strategies. The key subcomponents for each of these pillars are presented below:

3.1.1 Disaster Risk Awareness

- **Establish a Risk Knowledge Structure with Specialized Personnel, linked to the Technical Committee** : It is essential that the Technical Committee have a stable structure that allows for the assignment of permanent, specialized risk management personnel. This would strengthen the Committee's capacity to produce high-quality information and coordinate actions effectively. It is recommended that this structure include a permanent technical team, comprised of experts on the country's main threats, who can lead research and advise institutional representatives on informed decision-making, as well as collect, systematize, and disseminate all information produced in the country and the region, thereby strengthening the knowledge production capacities of all stakeholders at different territorial levels. This committee will operate independently but in coordination with the SAT-M inter-institutional steering committee (see 3.2.2).

- **Develop Standardized Risk Knowledge and Data Update Procedures:** The lack of clear procedures for updating and sharing data hinders the generation of effective inter-institutional knowledge. Therefore, it is essential to establish systematic and standardized processes for collecting, analyzing, and updating data on threats and vulnerabilities, with a review schedule and a monitoring system managed by each participating institution, including local stakeholders. Institutions must be held accountable for this process, in compliance with the law. This process should be aligned with a standardized risk knowledge approach for Integrated Disaster Risk Management at the national level. To this end, designated governing bodies must issue standardized technical guidelines, promote interoperability, and establish quality controls. Furthermore, stakeholders who apply knowledge to other phases of risk management, such as the Ministry of Economy, Planning, and Development, should be included in the process.

- **Strengthening the Training of Technical Committee Representatives and all Institutional Bodies:** Given staff turnover and a lack of experience in risk management, it is necessary to implement a continuous training program for representatives and staff in each institution. This program should focus on building capacity in risk management, data analysis, and the use of technological tools that enable a greater understanding and management of risk knowledge, with a focus on Early Warning Systems.
- **Formalizing the Inclusion of Key Stakeholders in the Technical Committee:** It is important to review and expand the roles of the institutions participating in the National System for Preventive Medicine and Rehabilitation (SN-PMR) to include key stakeholders that have not traditionally been considered, such as academic organizations, municipal entities, and certain cooperation agencies. It is also important to respect gender quotas and quotas for people with disabilities. All of this would allow for leveraging the specialized knowledge of these entities and improving the quality of shared knowledge. Furthermore, it is suggested that a clear organizational chart be created that defines the roles and responsibilities of each stakeholder, promoting more inclusive and organized participation.
- **Establish an Interoperable Risk Knowledge Information System:** The National Risk Information System (SINI) must evolve into an interoperable platform accessible to all institutions involved in risk management. This entails a comprehensive assessment of SINI's capabilities and its institutional placement, as well as its modernization to enable the real-time collection and consultation of data on threats, vulnerabilities, and response capacity in different regions of the country. Such a platform would facilitate decision-making based on up-to-date information and reduce coordination problems and duplication of effort.
- **Promoting Applied Scientific Research for Risk Assessment:** Finally, to enable the Technical Committee to provide high-quality data and well-founded risk analyses, it is essential to promote applied scientific research on topics such as natural hazards and technological vulnerabilities. This research should be integrated into risk management plans and policies so that its findings are actively used in planning and decision-making at the national and local levels.
- **Improvements in the collection, analysis, and communication of risk data:** To achieve a comprehensive understanding of disaster risks, the collection and analysis of geospatial data will be strengthened, integrating detailed information on hazards, vulnerability, and exposure of at-risk communities. The GEDSI approach will also be of particular importance, collecting data disaggregated by sex, age, and social groups and conducting specific studies to diagnose the vulnerability and impact of disasters on women. This process will involve the implementation of geographic information systems (GIS) that allow for mapping, modeling, and visualizing risk areas, facilitating informed decision-making and the planning of targeted interventions (UNDRR, 2021). Furthermore, communication protocols will be developed to ensure that this information is accessible and understandable to all stakeholders, from government entities to local communities.

3.1.2 Detection , Monitoring and Forecasting

- **Upgrading and maintaining monitoring networks:** The ability to detect and monitor threats in real time depends on upgrading seismological, meteorological, and hydrological monitoring networks, ensuring that equipment is in optimal condition and strategically distributed. Installing monitoring stations in key areas and regularly maintaining this infrastructure will allow for continuous threat monitoring.
- **Integration of advanced technologies (GIS systems, remote sensors):** The incorporation of advanced technologies such as remote sensors and GIS systems will improve forecasting accuracy and enable the early detection of multiple threats. These systems, integrated with high-resolution databases, will allow for real-time monitoring and facilitate the anticipation of catastrophic events. Furthermore, partnerships will be sought with international institutions to access satellite imagery and other resources that enhance analytical and response capabilities.

3.1.3 Dissemination and Communication of Alerts

- **Strategies for effective real-time communication:** The effectiveness of a SAT-M depends largely on the speed and clarity with which alerts are communicated to the population. Multichannel communication strategies will be implemented, including SMS alerts, mobile applications, and community radio, to ensure rapid and accessible real-time transmission (United) . Nations , 2022). The use of GIS will allow alerts to be targeted to specific areas, improving the accuracy of communication and minimizing unnecessary alarms.
- **Expanding alert channels and adapting to local accessibility:** To maximize the reach of alerts, dissemination channels will be expanded through traditional and digital media, as well as the creation of visual and audible alerts in public areas. Alert dissemination should be designed to be tailored to men and women, from different cultural groups, and under different threat contexts. These adaptation strategies will take into account factors such as accessibility, language, and socioeconomic conditions, ensuring that the most vulnerable populations receive and understand the alerts in their particular contexts (UNDP, 2020).

3.1.4 Preparation to reply

- **Action plans and regular drills:** Disaster preparedness involves creating detailed action plans and conducting regular drills focused on the most common types of hazards in the Dominican Republic. These drills will be designed to train both response agencies and communities, taking into account their diversity to meet different needs, evaluating the effectiveness of the procedures, and adjusting them based on the results.
- **Diagnosis of gender-specific needs and impacts:** Considering, among other things, gender roles and how these may intersect with the use of early warning systems, inequalities in access to information and mobility, potential health risks, and other security and economic considerations.
- **Strengthening community and institutional response capacities:** The participation of communities and institutions in preparedness plans is essential for a rapid and coordinated response. Training programs will be implemented for communities at risk, teaching them basic response protocols and self-protection measures. These training programs will be designed to be sensitive to the vulnerabilities and capacities of women and people with disabilities, as well as to potential cultural differences. Furthermore, the infrastructure of first responder institutions will be strengthened, ensuring they have the necessary resources and tools to act effectively in the event of an emergency (UNDRR, 2021).

3.2 Developing Effective Governance in the SAT

To establish **effective governance of the** Multi-Hazard Early Warning System (SAT-M) in the Dominican Republic, it is crucial to clearly define institutional roles and responsibilities, improve inter-institutional coordination, and promote international cooperation aligned with an investment plan. The system's sustainability and scalability depend on a well-defined organizational structure in which all stakeholders can work collaboratively, ensuring the continuity and evolution of the SAT-M over time.

3.2.1 Roles and Responsibilities of Institutions in Each Component of the SAT

- **Defining Key Roles in Disaster Risk Knowledge** : It is essential to assign clear responsibilities to specialized institutions for risk identification and analysis, as well as for coordinating and integrating planning and information. These entities should be responsible for generating geospatial data on hazards and vulnerabilities, as well as producing updated and accessible risk maps. Risk knowledge must be coordinated with the Technical Committee of the National Emergency Commission, strengthened by the previous recommendations, and with the Ministry of Economy, Planning and Development to ensure the standardization of data and risk and vulnerability analyses in all phases of Integrated Disaster Risk Management, including prevention and recovery. To this end, it is proposed to establish a technical working group with sectoral representatives, information authorities, and planners to continue working on the recommendations of this Roadmap, define leadership in risk knowledge management, and determine the institutional location of the interoperable information system.

- **Assignment of Responsibilities in Detection, Monitoring, and Forecasting** : Key institutions for each threat or threat group must coordinate the installation and maintenance of monitoring networks. These institutions, along with the Emergency Operations Center (EOC), will assume responsibility for operating monitoring stations, analyzing real-time data, and activating early warning systems when an imminent threat is detected (UNDRR, 2021).
- **Roles in Dissemination and Communication of Alerts** : Communicating alerts requires an inter-institutional approach, with the COE and INDOTEL assuming coordination of public messages. Local and regional media outlets should be trained in issuing alerts, and collaborative agreements should be developed with technology platforms to disseminate alerts through multiple channels, such as SMS, social media, television, and community radio.
- **Preparedness for Response** : Responsibilities for preparedness for response should be shared by the Ministry of Defense, Civil Defense, and the Emergency Operations Center (COE), who will be in charge of organizing drills, training communities, and activating rapid response protocols. Joint planning for the execution of drills and community training in evacuation and self-protection will strengthen response capacity.

3.2.2 Interinstitutional Coordination and Mechanisms for International Cooperation

- **Strengthening Interinstitutional Coordination:** The effectiveness of the SAT-M depends on continuous collaboration among all relevant institutions. To this end, the creation of a specific interinstitutional steering committee for the SAT-M is recommended, led by the COE and with the participation of all entities responsible for each component of the system (United) . Nations , 2022). This committee will ensure that decisions and actions are aligned and efficiently distributed.
- **Integration of Shared Data Platforms:** Inter-institutional cooperation also requires an integrated data infrastructure, such as a national risk information repository accessible to all institutions. This platform will facilitate real-time information sharing, optimizing detection and monitoring, and enabling each stakeholder in the SAT to work with up-to-date and accurate information.
- **Promoting International Cooperation:** The SAT-M will greatly benefit from collaboration with international organizations, such as the UNDRR, IDB, the World Bank, and the Pacific Tsunami Warning Center, for the exchange of technologies, knowledge, and innovative early warning practices (UNDP, 2020). Cooperation agreements will be promoted to access regional warning systems, training resources, and financing for the development of critical infrastructure.

3.2.3 SAT Sustainability and Scalability Strategies

- **Long-Term Financial and Technical Resource Planning:** The sustainability of the SAT requires a long-term financing strategy, ensuring resources for the maintenance and upgrading of monitoring infrastructure, ongoing training, and expansion of communication networks. National and international funding sources will be explored, including bilateral and multilateral cooperation, as well as partnerships with the private sector.
- **Development of Technical and Human Capacities:** It is essential to ensure the continuous training of technical and operational staff, both in the operation of monitoring equipment and in the interpretation and communication of data. Furthermore, training programs in new technologies will be implemented, especially in the use of GIS and remote sensing, which will strengthen the SAT's capacity to adapt to new technological demands (UNDRR, 2021).
- **Scalability of the Early Warning System to Expand its Coverage and Effectiveness:** The roadmap will include measures for expanding the Early Warning System to rural and remote areas, with technological and operational adaptations that guarantee its effectiveness in low-connectivity contexts. Phased

coverage targets will be established, starting with areas of high vulnerability and prioritizing those that lack access to information and alert services (UNDP, 2020).

3.3 Community Training and Awareness

Community training and awareness are fundamental pillars for the success and sustainability of the Multi-Hazard Early Warning System (SAT-M) in the Dominican Republic. Implementing these training, awareness, and education programs will enable communities not only to receive alerts but also to understand their importance and know how to respond in an emergency. The essential components of this section are detailed below:

3.3.1 Citizen Training Programs on Response Protocols

- **Training in Evacuation and Emergency Response Protocols** : It is essential that organized citizens know the steps to follow in case of an alert. Workshops will be held in which residents will learn about evacuation routes, safe meeting points, and the use of first aid equipment. These multi-level, multi-stakeholder programs will be adapted to the most common types of threats, such as hurricanes, earthquakes, and floods, ensuring specific and contextualized training (UNDRR, 2021).
- **Training in the Use of SAT-M Communication Tools** : Training programs will include the use of technological tools to receive and respond to alerts. The community will be trained in interpreting alerts via SMS, mobile applications, and social media, enabling people to be prepared to act quickly and effectively upon receiving an emergency notification (UNDP, 2020).
- **Community Drills** : Conducting drills in conjunction with the Emergency Operations Center (EOC) and Civil Defense will reinforce learning of response protocols and allow for the evaluation of the effectiveness of evacuation routes and response times. These drills, carried out periodically, will strengthen the communities' capacity to respond in an organized manner to an emergency.

3.3.2 Awareness Campaigns on the Importance of the SAT

- **Development of Mass Communication Campaigns** : Communication campaigns will be implemented through traditional and digital media, such as radio, television, social media, and print media, to educate the population about the importance of the SAT-M. These campaigns will highlight how the SAT-M can save lives and protect communities, and will include messages tailored to the country's diverse demographic and socioeconomic groups.
- **Focus on Citizen Responsibility and Participation** : Awareness campaigns will emphasize the community's shared responsibility in receiving and responding to alerts, promoting a proactive and participatory attitude within the early warning system. Citizen collaboration is vital for an inclusive and effective SAT-M, and these campaigns will foster community engagement with safety and disaster prevention (United) . Nations , 2022).
- **Survivor Testimonials and Success Stories** : To illustrate the importance of the SAT-M, testimonials will be shared from people who have experienced and responded to alerts, demonstrating the concrete benefits of the SAT. These testimonials will serve to raise awareness and foster empathy, reinforcing the message that the system saves lives.

3.3.3 Education Initiatives in Vulnerable Schools and Communities

- **Incorporating Disaster Prevention Education into Schools** : Integrating risk management and disaster prevention education into the school curriculum will allow children and young people to understand from an early age the risks they face and how to respond to them. These lessons will include basic knowledge about different types of hazards, self-protection measures, and how to interpret alerts (UNDRR, 2021).

- **Training Programs in Vulnerable Communities** : The most vulnerable communities, many of which face barriers such as poverty and geographic isolation, will receive targeted training in disaster management and resilience. These programs, which will include first aid and disaster prevention training, will enable residents of these areas to be better prepared to face catastrophic events and reduce their vulnerability.
- **Creation of Community Leaders in Risk Education** : To ensure the sustainability of the SAT-M, community leaders will be identified and trained to act as points of reference and support in case of emergencies. These leaders will receive advanced training in risk management and in the use of SAT tools, so that they can act as liaisons between the authorities and the community, and coordinate emergency responses at the local level (UNDP, 2020).

3.4 Evaluation and Continuous Monitoring of the SAT

Multi-Hazard Early Warning System (SAT-M) in the Dominican Republic is effective, sustainable, and adaptable to changing needs, it is essential to establish a system of continuous evaluation and monitoring. This process will allow not only for measuring the performance of the SAT-M in real time, but also for making adjustments based on the feedback received, maintaining the system's relevance and effectiveness in a context of evolving threats.

3.4.1 Performance Indicators and Continuous Assessment Methods

- **Development of Key Performance Indicators (KPIs) for Each Component of the SAT-M** : To evaluate the performance of the SAT-M, specific indicators will be implemented for each of the system's components: Disaster Risk Awareness, Detection, Monitoring and Forecasting, Dissemination and Communication of Alerts, and Preparedness to Respond. A proposed set of monitoring indicators for the SAT is included in Annex 5. Examples of these indicators include:
    - **Accuracy and coverage of risk data** in the Risk Knowledge component.
    - **Threat detection and forecasting time** in the Detection, Monitoring and Forecasting component.
    - **Speed and reach of alert dissemination** in the Alert Dissemination and Communication component.
    - **Level of participation in drills** and **community response capacity** in the Preparedness to Respond component (UNDRR, 2021).
- **Evaluation Based on Simulated and Real Event Results** : The evaluation methods will include analysis of both simulated (drill) and real events, allowing validation of the SAT-M's responsiveness. The results of these exercises will provide quantitative and qualitative data that will help identify areas for improvement and adjust the system's operating procedures.
- **Continuous Data Collection and Analysis** : A monitoring system will be established to collect real-time data on the performance of the SAT-M and generate periodic reports for review by the authorities. This system will include digital tools and GIS technology to visualize the effectiveness of alerts, response time, and coverage areas, facilitating the identification of gaps and opportunities for improvement.

3.4.2 Feedback and Adjustment Mechanisms of the SAT according to Emerging Needs

- **Community Feedback and Citizen Participation Platforms** : Community feedback is crucial for improving the SAT-M. Online feedback surveys and forms will be implemented, accessible through mobile applications, social media, and community radio stations, allowing citizens to express their experiences, concerns, and suggestions regarding alerts received and the effectiveness of response protocols (UNDP, 2020).
- **Review and Adjustment of the Emergency Response System Based on Institutional Feedback** : Institutional stakeholders, including the Emergency Operations Center (EOC), Civil Defense, and other response agencies, will provide feedback on the system's operability and coordination in each event or

drill. This feedback will be key to adjusting internal protocols and strengthening inter-institutional collaboration.

- **Technology Needs Assessment and Continuous Adaptation** : To respond to emerging threats, the SAT-M must be adaptable and up-to-date with the latest alert and monitoring technologies. Each assessment cycle will include a review of available technology tools and the identification of upgrade or expansion needs, such as incorporating new sensor networks, improving GIS infrastructure, and integrating advanced predictive models (United) . Nations , 2022).
- **Periodic Adjustments Based on Results and International Recommendations** : The SAT-M will be reviewed regularly based on international standards and recommendations, such as those of the Sendai Framework and the United Nations' "Alert for All" initiative. These reviews will help align the system with global best practices, ensuring that it remains effective and people-centered **.**

3.5 Funding and Resource Recommendations

Multi-Hazard Early Warning System (SAT-M) in the Dominican Republic depends on a robust funding strategy and the accurate identification of the necessary technical and human resources. The following are key recommendations to ensure that the SAT-M has the required funding and capabilities to operate continuously and effectively.

3.5.1 Financing Strategies for the Sustainability of the SAT

The optimal combination for the Dominican Republic would be climate grants with concessional loans to cover the investment in SAT-M infrastructure, complemented by a management/PPP model for continuous operation and eventually supported by thematic issues or dedicated budgets for future expansion or improvement.

- **International climate funds (grants):** These stand out as the most attractive option for initial investment, as they do not increase debt and include technical assistance. The Dominican Republic should leverage its eligibility for global adaptation mechanisms to secure grants that cover a large portion of the new SAT-M infrastructure. These funds, aligned with the climate emergency, are designed for countries like the Dominican Republic and have financed SATs in other vulnerable nations .
- **Concessional loans would be the second pillar:** they serve to cover amounts that donations might not reach, under affordable terms. For example, if the SAT-M requires X million and the donation only covers a portion, an IDB/WB loan could complete the financing for major equipment (radars, data centers), with manageable long-term repayments. The conditionality of these loans can also guarantee the incorporation of best practices (maintenance plan, training, and others).
- **Thematic bonds could be considered if more capital is needed and markets are favorable** . The Dominican Republic has already demonstrated capacity with green bonds , so issuing a " resilience bond " or including early warning projects in future sustainable issuances would not be unreasonable . However, given the current debt trajectory , this approach would be used cautiously and preferably after exhausting concessional options. A bond could be particularly useful for financing integral components of climate resilience, of which the SAT-M (for example, a bond that finances both early warning and flood mitigation works).
- **Public-Private Partnerships (PPPs) and Results-Based Programs (RBPs) are seen more as *complementary strategies* than as the primary source of funding.** A well-structured PPP can handle the 24/7 operation and maintenance of the SAT-M (Emergency Monitoring System) once installed—for example, a contract with a company to operate the system for 10 years, paid annually by the government, thus ensuring dedicated resources for its continuous operation. This helps address the challenge of operational sustainability. Meanwhile, results-based financing elements can be incorporated into these contracts or agreements with donors, providing performance incentives (payments or renewals contingent on the SAT-M meeting coverage targets, alert response times, etc.). This will maintain long-term effectiveness, extending beyond the mere execution of civil works.

3.5.2 Identification of Necessary Technical and Human Resources

- **Technological Infrastructure and Maintenance of Monitoring Equipment** : It is essential to have an advanced and well-maintained technological infrastructure for the detection, monitoring, and communication of alerts. This includes seismograph networks, weather stations, remote sensing systems, and GIS platforms for geospatial analysis. Furthermore, planning is required for the periodic maintenance of this equipment, ensuring that it functions correctly and is up-to-date (UNDP, 2020).
- **Training and Development of Technical Skills** : The SAT-M requires trained personnel in all its operational areas, including risk data management, real-time monitoring, alert communication, and emergency response. It is recommended to implement ongoing training programs to ensure staff stay current on the use of advanced technologies and international early warning protocols. Furthermore, it is necessary to train specialists in critical areas such as seismology, meteorology, and geospatial data management.
- **Response Teams and Field Personnel** : Rapid response teams must be composed of qualified personnel and equipped with the appropriate equipment for emergency response. This includes vehicles for rapid access, rescue tools, and portable communication equipment. Investing in trained personnel and adequate field equipment will ensure that the SAT-M response is rapid and effective in crisis situations.
- **Accessible Mass Communication Tools** : To ensure that alerts reach the entire population, it is necessary to have diverse and accessible communication tools. This involves establishing agreements with telecommunications providers for sending SMS alerts, installing siren systems in highly vulnerable areas, and working with community radio and television stations to ensure the transmission of alerts in rural areas.

Part II

4 Specific Roadmap for Prioritized Threats

4.1 Earthquakes and Tremors

4.1.1 Disaster Risk Awareness

- **Challenges** :
  - **Need for updated seismic vulnerability studies** : Structural evaluation of critical buildings (hospitals, schools, response centers) is fundamental, especially in urban and rural areas where buildings may not be prepared to withstand earthquakes (Garcia-Aristizábal et al., 2020).
  - **Limited dissemination of information on seismic risk** : Currently, information on the areas of greatest susceptibility is not distributed effectively, which impacts the perception of risk and the community's ability to prepare (Demeritt & Nobert , 2014).
- **Recommendations** :
  - **Comprehensive seismic risk and vulnerability assessment** : Conduct in-depth studies (microzonation) and map areas of seismic exposure using regularly updated GIS systems. Integrate this data into publicly accessible platforms, in accordance with the United Nations Disaster Risk Reduction (UNDRR, 2021) guidelines.
  - **Creation of a public repository of seismic risk information** : Establish an online database that includes interactive maps, educational resources and risk studies accessible to the public, based on best practices observed in the Japanese model of public risk mapping (UNDRR, 2021).
  - **Community and school awareness** : Implement educational programs in schools and communities that address the region's seismic history and promote a culture of preparedness. In Japan, early education on seismic risks is key to impact reduction (Petal , 2008).
  - **Periodic assessments of essential infrastructure according to R-001.**

4.1.2 Detection , Monitoring and Forecasting

- **Challenges** :
  - **Obsolescence of seismographs and monitoring systems** : The seismograph network requires updating to ensure accuracy in early detection. This also implies improving coverage in high-risk areas (Allen, 2011).
  - **Limited coverage in vulnerable areas** : Some areas with high vulnerability do not have enough monitoring stations, which can affect the ability to detect and respond early (USGS, 2020).
- **Improvement Plan** :
  - **Modernizing equipment and expanding the sensor network** : Replace obsolete seismographs and expand the network at strategic points, following the standards of the U.S. Geological Survey (USGS) and the Japan Early Warning System. These models recommend state-of-the-art monitoring stations in key areas (Allen, 2011). See other options such as Shake. Alert .
  - **Strengthening monitoring infrastructure** : Establish additional stations and improve connectivity with early warning networks at the regional level, ensuring interoperability with international systems (UNDRR, 2021).
  - **Advanced technical training** : Implement ongoing training programs in the interpretation and management of seismological data for technicians, in collaboration with universities and research centers. This approach aligns with the Sendai Recommendations for capacity building at all levels (UNISDR, 2015).
  - **Advanced technology in alert communication** : Integrating real-time monitoring software to facilitate the rapid transmission of alerts, a fundamental component in Japan's seismic alert systems (Petal , 2008).

4.1.3 Dissemination and Communication of Alerts

- **Challenges** :
  - **Limited reach in rural areas** : Remote areas often lack access to reliable communication channels, which limits the effectiveness of alert dissemination (IFRC, 2018).
  - **Variability in the understanding of seismic alerts** : There is a lack of unified understanding about the alerts, which hinders appropriate responses (Demeritt & Nobert , 2014).
- **Recommendations** :
  - **Establishment of clear and standardized communication protocols** : Create a unified and understandable alert communication protocol, following the standards of the International Federation of Red Cross (IFRC) and United Nations (UNDRR, 2021).
  - **Diversification of alert channels** : Use a multimodal alert system that includes mobile applications, SMS, social media, radio, television, and sirens in areas without digital access, based on the multimodal approach of Japan and the USA (Allen, 2011).
  - **Alert interpretation education programs** : Develop educational campaigns on alert interpretation, with drills and social media messages, adapted to different levels of understanding to ensure an appropriate response (Petal , 2008).

4.1.4 Preparation to reply

- **Challenges** :
  - **Shortage of regular drills and specific protocols** : The lack of drills and protocols adapted to different communities and types of infrastructure reduces effectiveness in emergency situations (IFRC, 2018).
  - **Lack of resources for emergency kits, evacuation routes and meeting points** : Some high-risk communities lack emergency kits and marked and equipped meeting points (UNDRR, 2021).
- **Community Preparedness Proposals** :
  - **Organization of regular earthquake drills** : Plan annual drills at the national level, involving the community, educational institutions and businesses, as in the preparedness programs of Japan (Petal , 2008).
  - **Establishment of safe meeting points** : Identify and mark meeting points in each community, especially in areas of high population density (Allen, 2011).
  - **First aid and emergency response training** : Promote community-based first aid and emergency response training programs, especially in high-risk areas. These programs should involve community leaders and be supported by local and national NGOs .
  - **Development of educational materials on earthquake preparedness** : Create practical guides on how to respond to an earthquake, distributed in physical and digital formats (brochures, infographics, videos) through social media, schools, and community centers. This material should align with UN and IFRC risk communication practices (Demeritt & Norbert , 2014).

4.2 Tsunami

This Tsunami SAT aims to optimize tsunami preparedness, monitoring and response, based on the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015) and taking into account the best practices implemented in Japan and other countries with high tsunami exposure.

4.2.1 Disaster Risk Awareness

- **Challenges** :

- **Lack of detailed mapping studies of tsunami inundation zones** : Many coastal settlements lack accurate information on potential impact areas, affecting planning and evacuation capacity (UNDRR, 2021).
    - **Limited dissemination of tsunami risk information in coastal communities** : Local communities may be unaware of the associated risks, which limits the effectiveness of preparedness strategies (Goff et al., 2006).
- **Recommendations** :
    - **Tsunami inundation zone mapping** : Creating detailed tsunami inundation risk maps based on scientific studies and simulations using GIS tools. Japan has been a leader in this practice, generating interactive maps for its coastal communities (UNDRR, 2021).
    - **Establishment of a public tsunami risk data repository** : Make available an online repository with maps, risk studies, and educational resources, accessible to the public and to government and community actors, as implemented in the Japanese model (JMA, 2019).
    - **Community awareness** : Implement education programs in schools and communities, teaching about tsunami risks and warning signs, following the example of Japan, which promotes a culture of preparedness from basic education (UNISDR, 2015).

4.2.2 Detection , Monitoring and Forecasting

- **Challenges** :
    - **Insufficient infrastructure of buoys and underwater pressure sensors** : Many coastal areas lack technology for early tsunami detection, which limits early warning capacity (Dunbar et al., 2010).
    - **Limited coverage of regional monitoring stations** : Offshore areas that are outside the coverage of monitoring stations can make it difficult to detect tsunamis originating in the deep ocean (NOAA, 2018).
- **Improvement Plan** :
    - **Installation of advanced underwater detection buoys and sensors** : Implement a network of underwater pressure buoys and sensors in strategic and high exposure areas, aligned with the standards of the Pacific Tsunami Warning System (PTWC) and the Japan Early Warning System (JMA, 2019).
    - **Improvement of regional monitoring infrastructure and connectivity** : Establish additional monitoring stations and ensure their interconnection with regional tsunami warning networks. This allows for adequate coverage and ensures interoperability in the detection of distant events (NOAA, 2018).
    - **Advanced training in tsunami detection and monitoring** : To train technical staff in the interpretation and management of underwater sensor data, in collaboration with universities and international institutions, following the Japanese model of specialized training (Goff et al., 2006).
    - **Rapid alert transmission technologies** : Integrate advanced communication systems to transmit tsunami alerts in real time, optimizing the flow of information to authorities and communities (UNISDR, 2015).

4.2.3 Dissemination and Communication of Alerts

- **Challenges** :
    - **Lack of access to early warning systems in remote areas** : Rural and hard-to-reach areas often lack reliable communication systems to receive real-time alerts (UNDRR, 2021).
    - **Limited understanding of warning and evacuation signals** : Many communities may be unaware of the meaning of tsunami warnings and fail to act appropriately in an emergency (Goff et al., 2006).
- **Recommendations** :
    - **Establishment of clear and standardized protocols for issuing alerts** : Create a specific communication protocol for tsunamis, aligned with the guidelines of the International Federation of Red Cross (IFRC) and the United Nations, ensuring clear and consistent messages (IFRC, 2018).

- **Diversification of alert dissemination channels** : Employ multiple channels to ensure the reach of alerts, including sirens in coastal areas, SMS, mobile applications, social networks and traditional media, following the model implemented in Japan (JMA, 2019).
- **Educational campaigns on tsunami alert interpretation** : Conduct community awareness campaigns to teach the meaning of siren sounds and other warning signals, with drills and community training (Dunbar et al., 2010).

4.2.4 Preparation to reply

- **Challenges** :
  - **Lack of regular drills and adapted evacuation protocols** : The lack of regular drills limits the effectiveness of evacuation protocols in coastal areas (IFRC, 2018).
  - **Shortage of resources for safe meeting points and emergency kits** : Communities exposed to tsunamis often lack marked meeting points and adequate emergency kits (UNDRR, 2021).
- **Community Preparedness Proposals** :
  - **Regular evacuation drills** : Conduct periodic drills in coastal areas, adapted to the conditions of each community, as practiced in Japan, where these exercises have been shown to improve response capacity in real events (JMA, 2019).
  - **Identification and signage of evacuation routes and safe points** : Establish clear evacuation routes and safe meeting points in each community, with visible signage to guide the population to higher and safe areas (Dunbar et al., 2010).
  - **First aid and community response training** : Invest in community first aid programs and emergency response training to strengthen local response capabilities.
  - **Specific educational materials on tsunamis** : Create educational materials (brochures, infographics, videos) to teach how to react to a tsunami alert, distributed in both physical and digital formats, as recommended by the IFRC to ensure that they reach all audiences (IFRC, 2018).

4.3 Landslides

This Landslide Assessment System (SAT) is designed to optimize the prevention, monitoring and response to landslide events, in line with the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015) and taking as references effective practices implemented in countries with high vulnerability to landslides, such as Colombia and Japan.

4.3.1 Disaster Risk Awareness

- **Challenges** :
  - **Lack of detailed mapping of landslide risk zones** : Many areas with steep slopes or unstable soils lack detailed risk studies, which limits planning and mitigation actions (Lee & Jones, 2004).
  - **Limited dissemination of landslide risk in vulnerable areas** : Communities in risk zones do not always receive adequate information about the danger of landslides and how they can prepare (Fell et al., 2008).
- **Recommendations** :
  - **Conducting studies and mapping risk zones** : Developing landslide risk maps through geological and topographic analyses using GIS tools and remote sensing technologies, aligned with practices in Japan and Colombia, where these maps are public and regularly updated (Sassa et al., 2004).
  - **Creation of a landslide risk data repository** : Establish an accessible database containing interactive maps, risk studies, and educational resources. This data can help local authorities and citizens make informed decisions (UNDRR, 2021).
  - **Community awareness** : Implement educational programs in vulnerable areas on the causes and warning signs of landslides, as has been effective in Japan and Colombia to promote risk awareness from basic education (UNISDR, 2015).

4.3.2 Detection , Monitoring and Forecasting

- **Challenges** :
  - **Limited monitoring infrastructure for soil and slope conditions** : Many landslide risk areas lack sensors and monitoring stations to detect changes in soil and slope (Guzzetti et al., 2020).
  - **Limited coverage in rural and mountainous areas** : Areas most prone to landslides often have little coverage of real-time monitoring systems (Fell et al., 2008).
- **Improvement Plan** :
  - **Installation of motion and soil moisture sensors** : Implement a network of sensors to monitor soil moisture and stability in high-risk areas, following the practices of the landslide warning system in Japan and Colombia (Sassa et al., 2004).
  - **Development of interconnected regional monitoring infrastructure** : Establish additional stations in mountainous and hard-to-reach areas, and improve the connectivity of monitoring data with national and regional networks for more timely detection (UNDRR, 2021).
  - **Technical training in the interpretation of geological data** : Strengthening technical capacity through training in the analysis of soil monitoring data and climatic conditions, in collaboration with universities and research centers (Lee & Jones, 2004).
  - **Implementation of advanced technology for alert transmission** : Use real-time monitoring software that facilitates the rapid and effective communication of alerts to authorities and affected communities (UNISDR, 2015)

4.3.3 Dissemination and Communication of Alerts

- **Challenges** :
  - **Difficulties in disseminating alerts in rural and mountainous areas** : Remote communities often lack access to reliable means of communication to receive real-time alerts (Fell et al., 2008).
  - **Limited understanding of landslide alerts** : Communities may not recognize warning signs or be unaware of the actions to take in case of a landslide (Guzzetti et al., 2020).
- **Recommendations** :
  - **Clear and standardized communication protocols** : Create a communication protocol for landslide alerts, ensuring the clarity and consistency of messages, in line with IFRC and United Nations guidelines (IFRC, 2018).
  - **Diversification of alert dissemination channels** : Use a variety of channels, such as sirens, SMS, mobile applications, social networks and traditional media (radio and television) to ensure that alerts reach all vulnerable areas (Sassa et al., 2004).
  - **Education campaigns on the interpretation of landslide alerts** : Conduct educational campaigns to teach communities to recognize warning signs and act appropriately, supported by drills and local training (Lee & Jones, 2004).

4.3.4 Preparation to reply

- **Challenges** :
  - **Lack of drills and specific protocols for landslides** : Evacuation and response drills in high-risk areas are scarce, which limits the effectiveness of community responses in emergencies (IFRC, 2018).
  - **Limited resources to establish safe points and emergency kits** : In vulnerable areas, communities often lack well-marked meeting points and basic supplies to respond to landslides (UNDRR, 2021).
- **Community Preparedness Proposals** :
  - **Organization of regular evacuation drills in landslide risk areas** : Conduct periodic drills in high-risk communities, such as those implemented in Japan and Colombia, to strengthen response and preparedness in case of landslides (Sassa et al., 2004).

- **Identification and signage of safe evacuation routes and points** : Establish evacuation routes and elevated and safe meeting points, with visible and adequate signage to guide the population during emergencies (Guzzetti et al., 2020).
- **First aid and community response training** : Implement first aid and emergency preparedness programs in affected communities, ensuring the participation of NGOs and local leaders in the training (Lee & Jones, 2004).
- **Development and distribution of educational materials on landslides** : Create practical guides on how to react to a landslide and distribute them in physical and digital format (brochures, infographics, videos) on social networks, schools and community centers, as recommended by the IFRC (IFRC, 2018).

4.4 Floods

This Flood Risk Assessment System (FRAS) is designed to optimize the prevention, monitoring and response to flood events, in accordance with the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015) and taking as references successful practices implemented in countries such as Japan and the United States.

4.4.1 Disaster Risk Awareness

- **Challenges** :
  - **Lack of detailed mapping of flood zones** : Many urban and rural areas with high vulnerability to flooding lack updated risk mapping, hindering planning and mitigation (Jongman et al., 2012).
  - **Insufficient dissemination of information on flood risk** : Communities are often not fully informed about their level of risk or the preventive actions they should take (WMO, 2019).
- **Recommendations** :
  - **Development of flood risk maps** : Carry out a detailed mapping of flood risk areas using GIS systems and historical flood data, similar to the system used in the Netherlands and Japan, where risk maps are public and regularly updated (UNDRR, 2021).
  - **Creation of a flood risk data repository** : Establish an accessible public platform containing interactive maps, data on previous events and educational resources for the population, such as Japan's flood information system (IFRC, 2018).
  - **Raising awareness in schools and communities** : Implementing educational programs on flood risk, warning signs and preventive actions, an effective strategy applied in Japan that involves schools and communities in safety practices (UNISDR, 2015).

4.4.2 Detection , Monitoring and Forecasting

- **Challenges** :
  - **Lack of monitoring and prediction infrastructure in high-risk areas** : Water level monitoring stations and rainfall sensors are often absent or limited in some high-risk areas (Kundzewicz et al., 2014).
  - **Limited coverage of monitoring stations in rural areas** : Many flood-prone areas, especially rural areas, lack monitoring systems that allow for effective early detection (WMO, 2019).
- **Improvement Plan** :
  - **Installation of monitoring sensors in rivers and flood zones** : Establish a network of sensors and monitoring stations in rivers and flood-prone areas, following the models of Japan and the USA, which employ real-time sensors to monitor water levels and rainfall (Jongman et al., 2012).
  - **Strengthening regional monitoring infrastructure** : Implement additional monitoring stations in rural areas and improve connectivity with national and regional early warning systems to ensure interoperability and timely response (WMO, 2019).
  - **Technical training in flood prediction systems** : Providing ongoing training for technical staff in the interpretation of water level and rainfall data, following UN guidelines and the monitoring system of Japan (UNDRR, 2021).

- **Integration of advanced forecasting technologies** : Use climate prediction tools and simulation models to improve the accuracy of predictions and transmit early warnings effectively (Kundzewicz et al., 2014).

4.4.3 Dissemination and Communication of Alerts

- **Challenges** :
  - **Difficulties in disseminating alerts in hard-to-reach areas** : Remote and hard-to-reach areas often lack reliable means of communication to receive real-time alerts (IFRC, 2018).
  - **Limited knowledge about the interpretation of flood alerts** : Communities may not be familiar with the warning signs or the measures to take in case of a flood threat (Jongman et al., 2012).
- **Recommendations** :
  - **Development of clear and standardized communication protocols** : Create a specific protocol for issuing flood alerts, ensuring the clarity and accessibility of the messages, aligned with UN and IFRC standards (UNDRR, 2021).
  - **Diversification of alert dissemination channels** : Employ multiple channels to ensure the reach of alerts, including SMS, social media, sirens in high-risk areas and traditional media (radio, television), as implemented in Japan and the Netherlands (IFRC, 2018).
  - **Educational campaigns on the interpretation of alerts** : Conduct community awareness campaigns to teach how to interpret and respond to flood alerts, supported by drills and community training (UNISDR, 2015).

4.4.4 Preparation to reply

- **Challenges** :
  - **Lack of regular and adapted evacuation drills** : The lack of evacuation drills and specific protocols limits community response capacity (IFRC, 2018).
  - **Insufficient resources to establish meeting points and emergency kits** : In many vulnerable communities, meeting points and emergency kits are not available or are inadequate (UNDRR, 2021).
- **Community Preparedness Proposals** :
  - **Regular evacuation drills in flood-prone areas** : Organize annual drills in high-risk flood zones, such as those conducted in Japan, to strengthen the rapid and effective response of communities (Jongman et al., 2012).
  - **Identification and signage of evacuation routes and safe points** : Establish evacuation routes and safe meeting points in each community, with visible signage to guide the population to higher areas or out of the risk area (WMO, 2019).
  - **First aid and community response training** : Implement first aid and emergency response training programs, involving NGOs and community leaders (Kundzewicz et al., 2014).
  - **Specific educational materials on floods** : Create and distribute practical guides and educational materials on how to respond to a flood, in physical and digital formats (brochures, infographics, videos) to ensure preparedness in all sectors of the community (UNDRR, 2021).

4.5 Hurricanes and Tropical Storms

This SAT for Hurricanes and Tropical Storms is designed to improve prevention, monitoring and response to high wind and precipitation intensity events, in alignment with the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015) and based on good practices from countries such as the United States and Japan.

4.5.1 Disaster Risk Awareness

- **Challenges** :
  - **Need for detailed mapping of areas vulnerable to hurricanes and tropical storms** : Coastal and mountainous areas in particular require accurate risk analysis for planning and damage reduction (Elsner et al., 2019).
  - **Insufficient dissemination of information on hurricane and storm risks** : The lack of accessible information limits the ability of communities to prepare adequately (IFRC, 2018).
- **Recommendations** :
  - **Mapping of areas vulnerable to hurricanes and tropical storms** : Develop risk maps using GIS systems and climate simulations, similar to the risk information systems used in Japan and the United States (UNDRR, 2021).
  - **Creation of an accessible risk data repository** : Establish an online platform that allows access to interactive maps, historical storm data, and educational resources, as in the U.S. hurricane warning and preparedness system (NOAA, 2020).
  - **Raising awareness in schools and communities** : Implementing educational programs in vulnerable communities to explain the nature of hurricanes and storms, as part of the public awareness approach in Japan, which has proven effective in reducing the impact on communities (UNISDR, 2015).

4.5.2 Detection , Monitoring and Forecasting

- **Challenges** :
  - **Insufficient coverage of weather monitoring stations** : Areas prone to severe storms need robust infrastructure for real-time monitoring of critical meteorological parameters (Rappaport, 2014).
  - **Limited forecasting capacity for storm intensity and trajectory** : Improving the accuracy of forecasting models is fundamental for the timely issuance of alerts (Elsner et al., 2019).
- **Improvement Plan** :
  - **Installation and expansion of weather monitoring stations** : Implement a network of weather stations in vulnerable areas and coastal zones, following the models of NOAA in the United States and JMA in Japan, which use advanced technology to measure atmospheric changes in real time (NOAA, 2020).
  - **Improvement of regional monitoring infrastructure and connectivity** : Establish additional interconnected monitoring stations in strategic areas and ensure that data is shared in real time at the national and regional levels for a rapid and effective response (IFRC, 2018).
  - **Advanced training in cyclone prediction** : Providing training for technical staff in prediction models, working in collaboration with research centers and universities, as is common in Japan and the United States (Rappaport, 2014).
  - **Integration of simulation technologies and forecasting models** : Invest in climate simulation models and advanced prediction systems to accurately anticipate the intensity and trajectory of storms, as NOAA and JMA do (Elsner et al., 2019).

4.5.3 Dissemination and Communication of Alerts

- **Challenges** :
  - **Limited dissemination of alerts in rural and hard-to-reach areas** : Communities in remote areas may not receive timely alerts due to limitations in communication infrastructure (IFRC, 2018).
  - **Inequality in the understanding of alerts and response protocols** : Several communities may not know how to interpret alerts and may not be prepared to act in the event of hurricanes (Rappaport, 2014).
- **Recommendations** :

- **Development of clear and unified communication protocols** : Create a standardized communication protocol for hurricane alerts, aligned with UN and IFRC guidelines to ensure consistency of messages and improve public response (UNDRR, 2021).
- **Diversification of alert dissemination channels** : Use multiple channels, such as SMS, mobile applications, social media, radio, television and sirens to ensure that alerts reach all communities, especially in areas without digital access (NOAA, 2020).
- **Education campaigns on interpreting alerts** : Implement community campaigns and drills to teach how to interpret and respond to hurricane alerts, a strategy used effectively in the United States and Japan (IFRC, 2018).

4.5.4 Preparation to reply

- **Challenges** :
  - **Lack of evacuation drills and specific hurricane protocols** : The lack of regular drills limits the ability to respond quickly in high-risk areas (Rappaport, 2014).
  - **Insufficient resources to establish safe meeting points and emergency kits** : Many vulnerable areas lack marked meeting points and basic emergency resources (UNDRR, 2021).
- **Community Preparedness Proposals** :
  - **Regular evacuation drills in hurricane-prone areas** : Organizing annual drills, involving communities and schools in vulnerable areas, is a standard practice in response systems in Japan and the United States (Elsner et al., 2019).
  - **Identification and signage of safe evacuation routes and points** : Establish evacuation routes and meeting points in all vulnerable communities, ensuring their proper signage and maintenance (IFRC, 2018).
  - **Training in first aid and community response** : Implement community programs of first aid and emergency response, supported by NGOs and local response organizations (Rappaport, 2014).
  - **Distribution of educational materials on hurricanes and storms** : Create accessible materials to educate the community on how to act before, during and after a hurricane, distributing them in digital and physical format, as recommended by the IFRC to reach all demographic groups (IFRC, 2018).

4.6 High waves and strong winds

This SAT for Waves and Strong Winds is designed to optimize prevention, monitoring and response to high wave and wind intensity events, following the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015) and effective practices implemented in coastal countries such as Japan and the Netherlands **.**

4.6.1 Disaster Risk Awareness

- **Challenges** :
  - **Lack of risk mapping for extreme waves and winds** : Coastal areas exposed to waves and strong winds require detailed vulnerability studies, especially for coastal and maritime infrastructure (Haigh et al., 2020).
  - **Limited dissemination of information on extreme wave and wind risks** : The lack of accessible information limits the ability of coastal communities to take preventive measures (UNDRR, 2021).
- **Recommendations** :
  - **Mapping areas vulnerable to waves and strong winds** : Use GIS and historical data to develop risk maps of extreme waves and winds, such as those used in Japan for coastal planning (WMO, 2019).
  - **Creation of an accessible risk data repository** : Establish an online platform that includes interactive maps, event history and educational resources, ensuring that the data is available to all affected authorities and communities (UNDRR, 2021).

- **Community awareness in coastal areas** : Implement educational programs that address the risks of waves and winds, focusing on preparedness and self-protection measures, as in the awareness programs of Japan (Haigh et al., 2020).

4.6.2 Detection , Monitoring and Forecasting

- **Challenges** :
  - **Insufficient coverage of wave and wind monitoring systems** : Many coastal areas lack infrastructure for continuous monitoring of wave height and wind speed, which affects the accuracy of alerts (Archer & Caldow , 2017).
  - **Limited ability to predict extreme wave and wind conditions** : The accuracy of wave and wind prediction models must be improved to enable early warnings and reduce the impact on infrastructure and the population (WMO, 2019).
- **Improvement Plan** :
  - **Installation of buoys and weather stations** : Implement a network of buoys and weather stations in areas at high risk of swells and strong winds, following the model of Japan and the National Oceanic and Atmospheric Administration (NOAA) in the United States (NOAA, 2020).
  - **Strengthening regional monitoring infrastructure** : Install additional stations in strategic areas and improve connectivity with national and regional monitoring systems to ensure rapid response to extreme wind and wave events (WMO, 2019).
  - **Technical training in meteorological and oceanographic data analysis** : Training staff in the interpretation of wave and wind data, in collaboration with academic institutions and research centers (Haigh et al., 2020).
  - **Implementation of advanced forecasting models** : Invest in prediction and simulation systems to improve the accuracy of forecasts for extreme waves and winds, following the recommendations of the World Meteorological Organization (WMO, 2019).

4.6.3 Dissemination and Communication of Alerts

- **Challenges** :
  - **Limitations in the dissemination of alerts in remote coastal communities** : Some coastal communities may not receive real-time alerts due to limited communication infrastructure (IFRC, 2018).
  - **Inequality in the understanding of wave and wind alerts** : The interpretation of and response to alerts may not be clear to the entire population, affecting the effectiveness of the community response (Archer & Caldow , 2017).
- **Recommendations** :
  - **Standardized and clear communication protocols** : Develop a specific communication protocol for wave and wind alerts, aligned with IFRC and UN guidelines, to ensure consistent and accessible messages (UNDRR, 2021).
  - **Diversification of alert channels** : Use multiple dissemination channels, such as SMS, mobile applications, coastal sirens, social media and traditional media (radio, television), ensuring that alerts reach vulnerable communities (NOAA, 2020).
  - **Education campaigns on the interpretation of wave and wind alerts** : Conduct awareness campaigns to teach communities how to interpret and respond to wave and wind alerts, with drills and educational materials (WMO, 2019).

4.6.4 Preparation to reply

- **Challenges** :
  - **Lack of regular drills and specific evacuation protocols for wave and wind events** : The absence of regular drills limits the response capacity of coastal communities (IFRC, 2018).

- **Shortage of resources to equip safe meeting points and emergency kits** : Many vulnerable coastal areas lack adequate infrastructure and supplies to respond to extreme wave and wind events (UNDRR, 2021).
- **Community Preparedness Proposals** :
  - **Evacuation drills in coastal risk areas** : Organize annual drills in high-risk areas, involving the community and local authorities, as is common in coastal preparedness systems in Japan (Haigh et al., 2020).
  - **Establishment and signage of evacuation routes and safe meeting points** : Identify and signpost evacuation routes and safe meeting points in each coastal community to facilitate access during an emergency (Archer & Caldow , 2017).
  - **First aid and community response training** : Implement community first aid and training programs in response to extreme wind and wave events, in collaboration with NGOs and local response agencies (IFRC, 2018).
  - **Specific educational materials on waves and wind** : Create and distribute practical guides and educational materials (brochures, videos, infographics) on how to act in response to waves and wind alerts, both in physical and digital format, according to the recommendations of the IFRC (UNDRR, 2021).

4.7 Dengue

This Dengue SAT is designed to improve prevention, monitoring and response to dengue outbreaks, aligned with the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015) and based on good practices implemented in tropical countries with a high prevalence of dengue, such as Brazil and Singapore.

4.7.1 Disaster Risk Awareness

- **Challenges** :
  - **Lack of detailed mapping of high dengue incidence areas** : Many urban and rural areas need accurate dengue risk analysis to identify breeding sites of the vector mosquito (Kotsakiozi et al., 2018).
  - **Insufficient dissemination of information on dengue risk and preventive practices** : In some communities, the lack of information on prevention practices limits the ability to control dengue (WHO, 2020).
- **Recommendations** :
  - **Dengue risk mapping** : Using GIS and epidemiological data to create dengue incidence maps, identifying high-risk areas and facilitating resource prioritization, an effective strategy in Brazil and Singapore (Bhatt et al., 2013).
  - **Creation of an accessible data repository for dengue risk** : Establish a public platform that includes interactive maps, case history and educational resources, allowing authorities and citizens to monitor risk in real time (UNDRR, 2021).
  - **Awareness programs in communities and schools** : Develop educational campaigns focused on the prevention and control of dengue, such as the elimination of breeding sites and the use of personal protection, following the models implemented in Singapore and Brazil (WHO, 2020).

4.7.2 Detection , Monitoring and Forecasting

- **Challenges** :
  - **Limited coverage of vector monitoring systems** : The lack of infrastructure for monitoring mosquito populations and environmental conditions hinders the early identification of dengue outbreaks (Wilder-Smith & Gubler , 2017).
  - **Limited capacity for forecasting dengue outbreaks** : Improving prediction models is key to anticipating incidence peaks and preventing significant outbreaks (Bhatt et al., 2013).

- **Improvement Plan** :
  - **Implementation of vector monitoring stations** : Place mosquito traps and humidity sensors in high-risk areas to monitor vector density and environmental conditions that favor their proliferation, following the Singapore model (Kotsakiozi et al., 2018).
  - **Strengthening epidemiological monitoring infrastructure** : Establish monitoring stations and expand the capacity for real-time epidemiological data analysis, connecting the data with national and regional early warning systems (WHO, 2020).
  - **Technical training in dengue outbreak prediction** : Training public health teams in the analysis of epidemiological and climatic data to improve predictive models of dengue outbreaks, in collaboration with universities and research institutes (Wilder-Smith & Gubler , 2017).
  - **Integration of climate and epidemiological models for prediction** : Investing in advanced prediction technologies that combine climate and epidemiological data, improving the accuracy of outbreak forecasts (Bhatt et al., 2013).

4.7.3 Dissemination and Communication of Alerts

- **Challenges** :
  - **Limited dissemination of dengue alerts in hard-to-reach areas** : Some remote communities may not receive timely alerts due to limitations in communication infrastructure (IFRC, 2018).
  - **Inequality in the understanding of alerts and prevention measures** : The interpretation of and response to dengue alerts may be insufficient in some communities, limiting the effectiveness of interventions (WHO, 2020).
- **Recommendations** :
  - **Standardized and clear protocols for dengue alert communication** : Develop a communication protocol for dengue alerts aligned with WHO and IFRC guidelines, ensuring that messages are understandable and accessible to the entire population (UNDRR, 2021).
  - **Diversification of alert dissemination channels** : Use SMS, mobile applications, social networks, radio and television to disseminate dengue alerts and prevention guides in all communities, as implemented in Brazil and Singapore (WHO, 2020).
  - **Educational campaigns on the interpretation of alerts and prevention** : Conduct awareness campaigns to educate the population on the interpretation of dengue alerts and preventive measures, through simulations and community training (Kotsakiozi et al., 2018).

4.7.4 Preparation to reply

- **Challenges** :
  - **Lack of drills and response protocols for dengue outbreaks** : The lack of regular drills limits the preparedness of the community and authorities to act in case of an outbreak (IFRC, 2018).
  - **Insufficient resources for vector prevention and control kits** : In some vulnerable areas, the distribution of prevention kits and the availability of resources for vector control are inadequate (UNDRR, 2021).
- **Community Preparedness Proposals** :
  - **Dengue risk response drills** : Organize community-based outbreak response drills and exercises, such as those implemented in Singapore, to reinforce actions to eliminate breeding sites and use personal protection (Wilder-Smith & Gubler , 2017).
  - **Establishment of prevention and control kit distribution points** : Identify points in each community to distribute prevention materials (repellents, mosquito nets) and education on vector control (WHO, 2020).
  - **Training in first aid and dengue outbreak management** : Implement community training programs in first aid and outbreak management, in collaboration with NGOs and public health agencies (IFRC, 2018).
  - **Specific educational materials on dengue prevention** : Create informative materials and practical guides on dengue prevention and outbreak response, distributing them in physical and digital format (brochures, infographics, videos) through community communication channels (UNDRR, 2021).

4.8 Forest and Urban Fires

This Early Warning System (EWS) for Forest and Urban Fires is designed to optimize fire prevention, monitoring, and response, in alignment with the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015) and based on best practices implemented in countries such as the United States and Australia.

4.8.1 Disaster Risk Awareness

- **Challenges** :
  - **Lack of detailed risk mapping of forest and urban fires** : Areas with high exposure to fires require risk maps that identify vulnerable areas and urban-forest transition zones (Moritz et al., 2014).
  - **Limited dissemination of information on fire risk** : In some communities, the lack of information on prevention practices and fire risks limits response capacity and preparedness (UNDRR, 2021).
- **Recommendations** :
  - **Mapping of forest and urban fire risk zones** : Create risk maps with historical fire data and propagation models, following the examples of the United States and Australia, where GIS systems are used for emergency planning (Bowman et al., 2017).
  - **Creation of an accessible risk data repository** : Establish an online platform that includes interactive maps, fire history and educational resources on fire prevention and control (UNDRR, 2021).
  - **Awareness programs in schools and communities** : Implement educational campaigns that teach prevention and safety practices in forest and urban fires, such as the model applied in Australia that includes school and community activities (Moritz et al., 2014).

4.8.2 Detection , Monitoring and Forecasting

- **Challenges** :
  - **Limited coverage of fire detection systems** : The lack of monitoring infrastructure in forest areas and vulnerable urban areas hinders early fire detection and makes timely response difficult (Bowman et al., 2017).
  - **Limited ability to predict conditions favorable for fires** : Improving the accuracy of climate and environmental prediction models is fundamental to anticipating the occurrence of fires (Finney , 2018).
- **Improvement Plan** :
  - **Implementation of fire detection and climate monitoring systems** : Place watchtowers, cameras and temperature and humidity sensors in high-risk areas, following the model of the United States and Australia, where detection systems are key in the rapid identification of fires (Bowman et al., 2017).
  - **Strengthening regional monitoring infrastructure** : Expand the coverage of monitoring stations in vulnerable areas and ensure connectivity with national and regional early warning systems (UNDRR, 2021).
  - **Technical training in meteorological and fire propagation data analysis** : Training emergency management teams in the analysis of weather conditions and early fire detection in collaboration with universities and research centers (Finney , 2018).
  - **Use of advanced fire prediction and simulation models** : Investing in simulation technology to predict fire spread and support evacuation decisions is a common practice in Australian fire management systems (Moritz et al., 2014).

4.8.3 Dissemination and Communication of Alerts

- **Challenges** :
  - **Limited dissemination of alerts in rural and remote areas** : Some hard-to-reach communities may not receive timely alerts due to a lack of communication infrastructure (IFRC, 2018).
  - **Inequality in understanding fire alerts** : The interpretation and response to alerts may be insufficient in vulnerable communities, affecting the effectiveness of evacuations and safety measures (UNDRR, 2021).
- **Recommendations** :
  - **Standardized communication protocols for fire alerts** : Develop a clear and standardized communication protocol for fire alerts, following IFRC and UN guidelines to ensure consistency in messages and coverage in all areas (UNDRR, 2021).
  - **Diversification of alert dissemination channels** : Use SMS, mobile applications, sirens, social media, radio and television to ensure that alerts reach all communities at risk, as implemented in Australia and the United States (Bowman et al., 2017).
  - **Educational campaigns on the interpretation of fire alerts** : Conduct community awareness campaigns to teach how to interpret and act upon fire alerts, using drills and educational material (Finney , 2018).

4.8.4 Preparation to reply

- **Challenges** :
  - **Lack of regular drills and specific protocols for fires** : The lack of drills and evacuation exercises limits the preparedness of communities and authorities for an effective response (IFRC, 2018).
  - **Insufficient resources for meeting points and emergency kits** : In many vulnerable areas, evacuation infrastructure and emergency supplies are inadequate (UNDRR, 2021).
- **Community Preparedness Proposals** :
  - **Regular evacuation drills in fire-risk areas** : Conduct evacuation drills in vulnerable urban and rural areas, following the example of Australia, where drills are part of the fire response strategy (Moritz et al., 2014).
  - **Identification and signage of evacuation routes and safe meeting points** : Establish clearly marked and safe evacuation routes and meeting points in each community, especially in areas of high vulnerability (Bowman et al., 2017).
  - **First aid and fire response training** : Implement community training programs in first aid and fire management, in collaboration with NGOs and local response teams (IFRC, 2018).
  - **Specific educational materials on fire prevention and response** : Create and distribute informational materials on fire prevention and response measures, in physical and digital formats (brochures, infographics, videos) (UNDRR, 2021).

5 Conclusions

multi-hazard Early Warning System (EWS) integrated into a Geographic Information System (GIS) represents a significant advance in response capacity and resilience to natural and man-made hazards. This roadmap summarizes the priority actions necessary for this transition, highlighting the importance of a multi-level, multi-stakeholder system based on GIS technology to improve the accuracy, speed, and effectiveness of risk management. This chapter presents the general priority actions to strengthen existing EWS and long-term recommendations to ensure a sustainable transition process adapted to future needs.

5.1 Summary of Prioritized Actions for the GIS-Based Multi-Threat SAT

During the sessions with the SAT-M Sectoral Working Group, members highlighted the need for investment in scientific research, the lack of governance of risk knowledge, the lack of systematization of existing information, and the lack of support for sectoral institutions in these processes. They emphasized the need to align the current roadmap with the National Policy on Early Warning Systems, which is currently under development. However, they also stressed that the development of technical solutions cannot wait until the challenges in Risk Governance are resolved.

Taking this feedback into account, the development of a GIS-based, interoperable, and integrated SAT-M system, coordinated with other actors in the Disaster Risk Management (DRM) framework, is recommended. In this case, its development should focus on the use of the Emergency Operations Center (EOC) for response preparation, coordination during emergencies, and alert issuance.

The following table summarizes the priority actions for strengthening the SAT in each key component, leveraging the capabilities of GIS systems for efficient data integration and management. For more details on the challenges in each component, the actions, and the necessary resources, see Annex 1.

SAT COMPONENT	GENERAL PRIORITIZED ACTIONS
Disaster Risk Awareness	- Conduct vulnerability studies and risk mapping specific to each threat, integrated into GIS platforms for public consultation. - Create an interoperable data repository accessible to all institutions and citizens, with regular updates of risk maps and educational materials. - Develop awareness and education campaigns in communities and schools, focused on risk understanding and preparedness, using interactive GIS-based materials.
Detection, Monitoring and Forecasting	- Expand and modernize the monitoring infrastructure (seismographs, weather stations, sensors) in strategic areas, with real-time interconnection to a centralized GIS system. - Train technical personnel in the use of GIS tools for the interpretation of monitoring and forecasting data, optimizing the accuracy of forecasts. - Develop predictive models and GIS simulations that combine climatic, geological, and socioeconomic data to anticipate the effects of each hazard and its spread.
Dissemination and Communication of Alerts	- Implement a standardized alert communication protocol tailored to each type of threat and accessible in real time, integrating multiple channels such as mobile applications, sirens, social media, and radio, all georeferenced in GIS. - Develop educational campaigns on alert interpretation and appropriate response, focused on vulnerable areas with limited access to digital media. - Configure automatic and customizable notifications via GIS for early warnings, adapting the message according to the location and risk level of the population.
Preparation to Respond	- Organize GIS-based evacuation drills in high-risk areas, considering evacuation routes, safe zones, and response times. - Train the community and first responders in the use of GIS platforms and mobile applications that facilitate navigation and communication during emergencies.

	- Create a network of volunteers and community leaders trained in response techniques and the use of GIS tools to coordinate and guide evacuations and damage control.

Description of Key Stakeholders and Responsibilities

1. **The COE (Emergency Operations Center**) will be responsible for coordinating the implementation of the Multi-Hazard SAT (Emergency Alert System), managing monitoring teams, and developing preparedness and response plans. They collaborate with other institutions in integrating data into the GIS (Geographic Information System) and are responsible for implementing alert protocols.
2. **Meteorological, seismological, epidemiological, and other institutes, as well as universities** : These technical and academic organizations play a fundamental role in generating forecast models and analyzing scientific data. They contribute research and collaborate in training technical personnel and community leaders, in addition to providing support in interpreting early warnings.
3. **National Statistics Office and National Geographic Institute:** These institutions validate statistical and geographic processes to ensure they comply with national and international standards. They are fundamental to the standardization of data and processes.
4. **Local governments and NGOs** : They act as liaisons between the SAT and communities, supporting information dissemination and awareness-raising activities. Local governments are responsible for organizing drills, coordinating first response teams, and facilitating community training in the use of GIS.
5. **INDOTEL** : It is responsible for developing alert communication protocols in collaboration with the COE and for managing the alert dissemination infrastructure. It also coordinates the diversification of communication channels to ensure that alerts reach all communities.

Investment Outlook and Implementation Schedule

Strengthening the GIS-based SAT (Tax Administration Service) envisions an estimated timeline of 3 to 5 years for full implementation, with a focus on long-term sustainability. Costs are rough estimates (each institution should prepare its own budget) and include the following ranges:

- **Model Development and Data Repository Maintenance** : $1,200,000 - $1,300,000 for disaster risk research, the creation of an accessible data system, and the development of predictive models integrated into the GIS.
- **Infrastructure and Technology Costs** : $1,500,000 - $1,800,000 for the acquisition of monitoring equipment, GIS infrastructure, and upgrade of communication platforms.
- **Community Training and Awareness Costs** : $2,100,000 - $2,200,000 allocated to technical training, plans, routes, and the organization of drills and awareness activities for the community.

Annex 2 contains a proposed timeline for strengthening the components of the SAT-M with key stakeholders and high-level costs, and Annex 3 contains a detailed action plan for the implementation of a SAT-M.

The following is a summary of the essential actions recommended for each prioritized threat, organized in a table that highlights the main interventions required. Annex 4 contains a timeline for implementing the actions for each threat.

THREAT	PRIORITY ACTIONS
Earthquakes and Tremors	- Upgrading seismographs and expanding the monitoring network in high-vulnerability areas. Shake Alert . - Advanced training for technical staff in seismic data analysis. - Implementation of community drills to strengthen preparedness and response at the local level.
Tsunamis	- Creation of evacuation routes and clearly marked safe meeting points in coastal communities. - Clear and standardized communication protocols for tsunami alerts, diversifying communication channels. -Implementation of community drills to strengthen preparedness and response at the local level.
Landslides	- Installation of moisture sensors and slope monitoring in vulnerable areas. - Technical training in the interpretation of geological and climatic data. - Community awareness campaigns and drills in mountainous areas for landslide preparedness and response.
Floods	- Expansion of water level monitoring infrastructure in rivers and flood-prone areas. - Creation of flood risk maps and their dissemination through accessible platforms. - Educational campaigns for the population on interpreting alerts and evacuation procedures.
Hurricanes and Storms	- Installation of weather stations in vulnerable areas and expansion of forecasting capacity. - Coordination for the diversification of alert channels (SMS, mobile applications, social media, radio, sirens). - Implementation of annual evacuation drills in at-risk communities.
High waves and strong winds	- Installation of monitoring buoys and coastal wind and wave measurement stations in at-risk areas. - Communication protocols and awareness campaigns in coastal areas on how to respond to extreme waves. - First aid training and organization of safe evacuation points in coastal areas.
Dengue	- Implementation of vector monitoring stations and humidity sensors to anticipate outbreak conditions. - Ongoing community education on eliminating mosquito breeding sites. - Training in dengue outbreak management and distribution of prevention kits.
Forest and Urban Fires	- Installation of watchtowers and early detection sensors in high-risk fire areas. - Conducting response drills in vulnerable forest and urban areas. - Creation of evacuation routes and signage indicating safe meeting points in risk zones.

The following table summarizes the priority actions for the different roles of the infrastructure sectors in each of the four components of the SAT-M. These measures aim to guarantee the necessary infrastructure for the sustainability of the SAT-M itself, address governance aspects, and promote preparedness for the response that allows for the continuity of essential services and resilience to disasters and emergencies.

SAT COMPONENT	PRIORITY ACTIONS FOR THE INFRASTRUCTURE SECTORS
Disaster Risk Awareness	- Develop georeferenced inventories of critical infrastructure. - Implement a unified regulatory framework that standardizes methodologies, data formats, and structural vulnerability indicators. - Integrate risk analysis into the planning, design and maintenance of public and private infrastructure works. - Strengthen interoperability between sectoral databases with technical support from information technology and spatial data sectors.
Detection, Monitoring and Forecasting	- Modernize and expand hydrometeorological, seismic, geotechnical and ocean monitoring networks. - Gradually replace analog networks with automated digital platforms. - Install and maintain ocean buoys for tsunami detection and coastal warning systems. - Establish maintenance and periodic calibration protocols for monitoring equipment and ensure technical and financial sustainability.
Dissemination and Communication of Alerts	- Develop a multi-channel system segmented by type of infrastructure (e.g., road, energy, water, housing, port, telecommunications). - Implement direct inter-institutional communication protocols and enable the necessary tools for this. - Ensure channel redundancy (SMS, radio, sirens, apps , social networks). - Strengthen technical training for the interpretation and transmission of sectoral alerts.
Preparation to Respond	- Develop and update sectoral contingency plans integrated into the SAT-M. - Implement intersectoral coordination drills and regular training. - Incorporate GIS tools for logistics planning, scenario simulation and safe routes. - Include specific budget items and explore public-private partnerships to support monitoring systems, maintenance and control centers.

5.2 Long-Term Perspectives and Recommendations for the GIS-Based Multi-Hazard SAT

The sustainability and adaptability of the GIS-based multi-hazard SAT depend on a continuous strengthening strategy that ensures its ability to respond to new threats and adapt to technological advancements. The following are recommendations for maintaining and improving the system in the long term:

- **Incorporation of Technological Innovations** :

Integrating advanced technologies such as drones, high-resolution satellite imagery, artificial intelligence, and predictive analytics into the SAT (System for the Analysis of Risks) will improve the accuracy and speed of detection and monitoring. Collaboration with research centers and continuous system updates with new technological advancements will ensure that the GIS-based SAT remains at the forefront of risk management. **Continuous and progressive adaptation to technological advancements,** in accordance with cultural appropriation, is essential. This approach must be multi-level and multi-stakeholder .

- **Development of Technical Capacities and Interinstitutional Coordination**

multi-stakeholder Training and Capacity Development Strategies

Implement ongoing training programs in the use of GIS tools and data analysis for technicians and decision-makers. Training in new monitoring systems and the creation of collaborative networks among government, academic, and community institutions are fundamental for a resilient multi-hazard SAT (Emergency Warning System).

Establish coordination protocols between the institutions involved in disaster management, so that the use of GIS is uniform and facilitates coordinated decision-making during emergency events.

- **Strengthening Community Participation** :

Awareness programs and the creation of volunteer networks can strengthen local resilience, enabling the community to play an active role in emergency prevention and response.

Community participation is essential for the success of a multi-hazard SAT . Implementing awareness programs about the importance of GIS and its use in emergency preparedness and response will help communities become active participants in risk prevention and mitigation.

Create networks of volunteers trained in the use of GIS, who can collaborate with the authorities during critical events and ensure an efficient response.

Municipal networks

- **Financial Sustainability and Strategic Alliances** :

The sustainability of the multi-threat SAT requires ongoing investment in equipment maintenance, infrastructure upgrades, and staff training. To achieve this, it is recommended to establish strategic partnerships with the private sector, NGOs , and international organizations, as well as to secure funding through national and international programs.

- **Evaluation and Continuous Improvement of the System** :

Conducting periodic assessments of the SAT, with a comprehensive review every 3 to 5 years, allows for adjusting protocols and technology to changes in the environment and emerging risks. These assessments should be based on the analysis of recent events, technological advancements, and the integration of lessons learned.

Incorporate specific performance indicators that evaluate the effectiveness of the GIS system in detecting, monitoring, and responding to each threat, providing a solid foundation for continuous improvement.

- **Connections with International Early Warning Networks** :

Establishing an international collaboration network allows for the exchange of experiences and the adoption of successful risk management practices. Cooperation with other GIS-based early warning systems will enable countries to address common threats and strengthen their capabilities through knowledge and technology sharing.

In conclusion, the sustainability and adaptation of the GIS-based multi-hazard Early Warning System (EWS) in the Dominican Republic require a strategy of continuous strengthening, tailored to the complexities of a country exposed to multiple natural hazards and undergoing constant technological evolution. The integration of advanced innovations, such as drones, high-resolution satellite imagery, artificial intelligence, and predictive analytics, will transform the accuracy, speed, and responsiveness of the EWS, enabling institutions to anticipate risks with the precision necessary to significantly reduce human and material losses. These technologies must be implemented progressively and in a culturally appropriate manner, ensuring a multi-level and multi-stakeholder structure that maximizes the use and understanding of these systems at all levels of society. This will consolidate the multi-hazard EWS as a key tool in protecting lives and property, enhancing the country's resilience to disasters.

Ongoing training for technicians, decision-makers, and local communities in the use of GIS tools will not only improve response capacity but also foster a culture of risk prevention and mitigation throughout the population. Actively engaging the community through awareness and risk management training programs will transform individuals into active participants in emergency response, strengthening social cohesion in risk management. Strategic coordination among government institutions, NGOs, and the private sector, along with international partnerships, will ensure the financial sustainability and stability of the Early Warning System (EWS), enabling its maintenance, updating, and expansion. This collaborative network will not only boost local resilience but also generate an exchange of knowledge and best practices that will enrich the system and make it more effective.

Periodic and rigorous evaluations of the Early Warning System (EWS), accompanied by specific performance indicators, will ensure that the system remains constantly aligned with changes in the environment and emerging risks. These indicators will allow for real-time measurement of the EWS's effectiveness, facilitating adjustments that will keep the system at the forefront of disaster management. In this process of continuous improvement, the Dominican Republic's EWS is becoming a benchmark in the region, contributing to the country's sustainable development and strengthening its position as a leader in comprehensive risk management. The combination of advanced technology, community participation, and inter-institutional collaboration guarantees not only the protection of lives and property, but also a safer and more resilient future for generations to come, promoting an environment where the capacity to adapt to and respond to disasters is constantly evolving.

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KEY DOCUMENTS

1. **"Roadmap for the Development of a Monitoring and Early Warning System for Concessioned Urban Drinking Water Services"** : This document, prepared in Chile, offers a detailed guide for the implementation of an early warning system using GIS technologies, focusing on the management of drinking water in urban areas.

DIRPLAN Repository

2. **Multi-Hazard Early Warning Systems (EWS) in Uruguay"** : This report presents a national diagnosis and recommendations for the design and implementation of a multi-hazard EWS in Uruguay, highlighting the integration of GIS tools to improve detection and response to natural disasters.

UNDP

3. **"GIS Application for the Development of Multi-Hazard Maps and their Application in the Urban Expansion of the Guadalupe Parish-Zamora Canton"** : This case study in Ecuador analyzes how the application of GIS can contribute to the development of multi-hazard maps , facilitating urban planning and risk mitigation in disaster-prone areas.

UTPL DSpace

4. **"The CRGR Presents its Interactive Multi-Hazard Map to Strengthen Networking Within It "** : The Regional Coordination for Risk Management in Central America has developed an interactive multi-hazard map based on GIS, intended to strengthen collaboration and disaster response in the region.

CRGR Central America

These documents offer valuable insights into the strategies and best practices adopted in different contexts for the transition to GIS-based multi-hazard SATs. Analyzing these experiences can provide useful guidance for the development and implementation of similar systems in other regions.

1. **Secretary-General 's Roadmap for Digital Cooperation"** : This document emphasizes the importance of digital cooperation and the adoption of advanced technologies, including GIS, to improve risk management and disaster response.

United Nations

2. **"United Nations Development Programme (UNDP) Digital Strategy 2022-2025" : This strategy builds on the** Secretary-General 's Roadmap for Digital Cooperation and defines UNDP's role in implementing digital technologies, such as GIS, to strengthen multi-hazard SATs .

Digital Strategy

3. **"Early Warnings for All People"** : An initiative of the UN Secretary-General that seeks to ensure that all people are protected by multi-hazard early warning systems within the next five years, promoting the use of technologies such as GIS to improve disaster detection and response.

UNDRR

Regional Comprehensive Disaster Risk Management Plan (PRGIR) 2024-2030 : This plan establishes a roadmap for comprehensive disaster risk management in the region, incorporating the use of technologies such as GIS to improve detection and response to multiple threats.

CEPREDENAC

Central American Policy for Comprehensive Disaster Risk Management (PCGIR) : This document guides the efforts of SICA and CEPREDENAC in disaster risk reduction and prevention, promoting the adoption of advanced technological tools to strengthen multi-hazard SATs .

UNDRR

Circular Caribbean Project : Implemented by the Central American Commission for Environment and Development (CCAD) of SICA, this project seeks to prevent the entry of plastic waste into the Caribbean Sea and promotes regional exchange and cooperation with the private sector through the circular economy.

SICA

Sendai Framework for Disaster Risk Reduction 2015-2030

- Published by the UN, the Sendai Framework is essential for guiding disaster risk reduction globally. It includes recommendations for the creation of multi-hazard disaster risk assessment tools and promotes community participation, the use of GIS, and multi-level collaboration.
- **Access** : un.org

"Multi-Hazard Early Warning Systems: A Checklist" (UNDRR)

- This UNDRR checklist is a practical resource for developing multi-hazard early warning systems (EWS). It includes critical steps for integrating GIS and improving the efficiency of early warning and response systems, with an emphasis on monitoring and effective communication.
- **Access** : undrr.org

"Public Awareness and Public Education for Disaster Risk Reduction: Action-Oriented Key Messages" (IFRC)

- This document from the International Federation of the Red Cross contains key messages for public education in disasters, with guidelines on communication and community involvement, essential for the success of a SAT.
- **Access** : ifrc.org

"Guidelines for Landslide Susceptibility, Hazard, and Risk Zoning for Land-Use Planning" (Fell et al., 2008)

- This technical document provides detailed methods for landslide risk assessment and zoning, which is important for the implementation of early warning systems in vulnerable areas. It includes a GIS approach to improve the accuracy of landslide monitoring.

- **Reference** : Engineering Geology , 102(3), 85-98.

"Global Assessment Report on Disaster Risk Reduction" (UNDRR, 2022)

- The UNDRR report analyzes the global state of risk management and highlights the use of GIS in multi-hazard risk assessments . It presents case studies from countries that have implemented successful risk assessments, providing lessons applicable in other contexts.
- **Access** : undrr.org

"Tsunami Early Warning Systems" (Japan Meteorological Agency, JMA)

- This technical document from the Japan Meteorological Agency (JMA) provides a detailed overview of tsunami early warning systems in Japan, a global leader in this field. It includes the use of GIS and predictive models, which are useful for planning tsunami early warning systems in coastal areas.
- **Access** : jma.go.jp

"Integrated Flood Management Tools Series: Community-Based Flood Management" (WMO, 2019)

- Published by the World Meteorological Organization (WMO), this resource describes how to integrate communities into flood management and use GIS to improve planning and response.
- **Access** : wmo.int

"Digital Strategy 2022-2025" (UNDP)

- The UNDP's digital strategy presents a broad approach to the use of digital tools in risk management. It is relevant to the implementation of a GIS-based risk assessment tool, with an emphasis on inter-agency cooperation.
- **Access** : digitalstrategy.undp.org

"Sendai Framework Words into Action: Developing National Disaster Risk Reduction Strategies" (UNDRR)

- multi-hazard risk assessment roadmaps .
- **Access** : undrr.org

"Early Warnings for All: Executive Action Plan on Early Warnings for All" (United Nations, 2022)

- This UN action plan aims to ensure that all countries implement multi-hazard early warning systems (EWS) within the next five years. It promotes the use of GIS for early threat detection and monitoring, aligned with the Sustainable Development Goals.
- **Access** : un.org

Annexes

Annex 1. Main challenges and actions for the transformation towards a GIS-based SAT-M

GIS-based Multi-Hazard SAT Roadmap

SUPPLIES	CHALLENGES ENCOUNTERED	ACTIONS FOR THE TRANSITION TOWARDS A GIS-BASED MULTI-HAZARD SAT	REQUIRED RESOURCES	TEMPORALITY
DISASTER RISK AWARENESS				
Regulatory, institutional and governance framework for risk awareness.	Fragmentation in institutional roles and limitations in the interoperability of systems.	Create a coordinated inter-institutional structure to consolidate and standardize roles and responsibilities in disaster risk management.	Specialized personnel in governance and regulatory framework; inter-institutional collaboration platform	Short term
Progress of the national risk information repository (risks, exposure and vulnerability maps, formats, accessibility, maintenance).	Lack of updating and accessibility to the national information repository.	Establish a centralized and accessible geospatial information management system, with regular updates and clear maintenance protocols.	Centralized GIS platform, IT staff and data analysts	Short-medium term
Metadata and methodologies for the geographical assessment of risk (Hazard, Exposure, Vulnerability, with disaggregated data).	Inconsistencies in the data and lack of standardization in the collection and disaggregation of information.	Develop geospatial evaluation methodologies and disaggregation standards that ensure the accuracy and comparability of data in a GIS environment.	Consultants in risk methodologies, GIS software, geospatial analysts	Medium term
National and international standards for risk assessment.	Difficulty in integrating international standards due to limitations in resources and technology.	Implement a regulatory framework that allows alignment with international standards, and offer training in risk assessment standards and regulations.	Regulatory staff and international advisors; training workshops	Short term
Risk knowledge assessment for integration in SAT-M with GIS (SWOT).	Lack of identification of weaknesses and opportunities to strengthen the current system.	Conduct a thorough SWOT analysis to guide the integration of risk knowledge into GIS and enable the improvement of critical areas and the leveraging of strengths.	Specialists in SWOT analysis and geoinformation; geospatial analysis tools	Short term
DETECTION, MONITORING AND PROGNOSIS				
Regulatory, institutional and governance framework for detection and monitoring.	Poor coordination in the flow of information between entities responsible for threat detection and monitoring.	Create inter-institutional communication and collaboration protocols, facilitating the exchange of information in real time	GIS collaboration system; training in communication protocols	Short term

SUPPLIES	CHALLENGES ENCOUNTERED	ACTIONS FOR THE TRANSITION TOWARDS A GIS-BASED MULTI-HAZARD SAT	REQUIRED RESOURCES	TEMPORALITY
		through shared GIS platforms.		
Monitoring and tracking networks (processes, technologies, reception times, processing, information availability).	Limited monitoring network, with deficiencies in coverage and response times to threats.	Strengthen and expand monitoring networks with advanced technologies, ensuring the integration of GIS for real-time visualization and analysis.	Monitoring equipment, remote sensors, weather stations; real-time data analysts	Medium to long term
Forecasting and alert generation (methodologies, protocols, technical staff).	Inequality in technical capacity and lack of standardized methodologies for generating alerts.	Train staff in forecasting methodologies and use GIS to standardize and optimize the generation and dissemination of alerts in a uniform manner.	Experts in forecasting, GIS platforms; training in alert protocols	Medium term
Evaluation of detection systems for integration into SAT-M with GIS (SWOT).	Lack of a systematic analysis of the strengths and weaknesses in current detection and monitoring systems.	Conduct a SWOT analysis focused on identifying how to improve detection systems to facilitate integration with GIS tools.	Specialists in detection analysis and GIS, geospatial analysis tools	Short term
DISSEMINATION AND COMMUNICATION OF ALERTS				
Systems and equipment for the dissemination of alerts (communication channels, adaptation to communities, verification of receipt, user understanding).	Lack of public trust in the system and poor adaptation of alerts to different communities.	Implement a georeferenced alert communication system using GIS, adapted to local needs and including feedback on its effectiveness.	Digital communication tools, community radio stations, SMS platforms; social communication staff	Short-medium term
Evaluation of the dissemination of alerts for integration in SAT-M with GIS (SWOT).	Limited capacity to assess the effectiveness of alerts in different contexts and populations.	Integrate a GIS monitoring system that allows continuous feedback and analysis of the effectiveness of alert communication in all areas.	Assessment and GIS consultants; perception measurement tools	Medium term
PREPARATION TO ANSWER				
Regulatory, institutional and governance framework for disaster response.	Weak governance structure and lack of clarity in roles and responsibilities during the response.	Establish a clear and updated governance framework for disaster response, integrating a role communication system through GIS platforms.	Administrative and legal staff, collaboration platforms; regulatory training	Short term

SUPPLIES	CHALLENGES ENCOUNTERED	ACTIONS FOR THE TRANSITION TOWARDS A GIS-BASED MULTI-HAZARD SAT	REQUIRED RESOURCES	TEMPORALITY
Response plans and procedures (safe zones, focus on people and assets).	Limited identification of safe zones and lack of evacuation plans that consider specific vulnerabilities.	Create evacuation maps and safe zones using GIS, integrating socioeconomic and critical infrastructure data for inclusive response plans.	Personnel trained in risk mapping and GIS, mapping software, response plan guides	Medium term
Assessment of preparedness to respond in SAT-M with GIS (SWOT).	Lack of systematic evaluation of response capabilities and feedback on areas for improvement.	Implement a continuous assessment process that uses GIS to map vulnerabilities and analyze response readiness, adjusting actions based on the data obtained.	Specialists in response preparedness and GIS; continuous feedback system	Short-medium term
GOVERNANCE				
Interinstitutional coordination for roles in the SAT-M	Lack of integration of institutional roles and deficiency in collaboration between entities.	Create a National SAT Committee to coordinate roles and functions in alert management, ensuring effective collaboration at every stage of the system.	Government personnel and SAT experts; inter-institutional collaborative training	Short term
SUSTAINABILITY AND FINANCING				
Financial sustainability strategies and necessary technical and human resources.	Limited funds for ongoing maintenance and expansion of the system.	Develop a long-term financing plan, including public-private partnerships and access to international cooperation for the sustainability of the SAT-M.	Financial staff, international partners, APP resources	Long term

Annex 2. Prioritized actions for the SAT-M based on GIS with responsible parties, activities, schedule and high-level cost estimates.

GENERAL PRIORITIZED ACTIONS	KEY STAKEHOLDERS	RESPONSIBLE PARTIES	MAIN ACTIVITIES	SCHEDULE	COST ESTIMATE (US DOLLAR)
Disaster Risk Awareness					
- Conduct vulnerability studies and risk mapping specific to each threat, integrated into GIS platforms. - Create a centralized data repository accessible to all institutions and citizens, with regular updates. - Develop awareness and education campaigns in	PUBLIC INSTITUTIONS PRIVATE INSTITUTIONS ACADEMY COOPERATION ORGANIZATIONS	COE CN-PMR	- Budget for improving institutional capacities for risk studies. - Design and develop the data repository. - Implement awareness campaigns in collaboration	12-24 months	$1,300,000 - $1,500,000

communities and schools about risk and preparedness.			with NGOs and universities.		
Detection, Monitoring and Forecasting					
- Expand and modernize the monitoring infrastructure (seismographs, weather stations, sensors) and connect it to a centralized GIS. - Train technical staff in GIS tools for monitoring data analysis and forecasting. - Develop predictive GIS models that combine climatic, geological, and socioeconomic data.	PUBLIC INSTITUTIONS PRIVATE INSTITUTIONS ACADEMY COOPERATION ORGANIZATIONS	COE CN-PMR	- Acquire and upgrade monitoring equipment. - Configure interoperability with the centralized GIS system. - Train staff in GIS and predictive analytics.	18-36 months	$1,500,000 - $1,800,000
Dissemination and Communication of Alerts					
- Implement a standardized alert protocol tailored to each threat and accessible in real time, using multiple channels. - Develop educational campaigns on interpreting alerts in vulnerable areas. - Configure customizable automatic notifications through GIS for early warnings.	PUBLIC INSTITUTIONS PRIVATE INSTITUTIONS ACADEMY COOPERATION ORGANIZATIONS	COE INDOTEL	- Create and standardize alert protocols in multiple formats. - Collaborate with local governments to distribute educational materials. - Configure automatic notifications in the GIS.	12-24 months	$150,000 - $250,000
Preparation to Respond					
- Organize evacuation drills in high-risk areas, considering evacuation routes and safe points based on GIS. - Train the community and first responders in the use of GIS platforms. - Create networks of volunteers and community leaders trained in GIS to coordinate emergency response.	PUBLIC INSTITUTIONS PRIVATE INSTITUTIONS ACADEMY COOPERATION ORGANIZATIONS	COE Ministry of Defense Civil Defense and Local Governments	- Plan and conduct community drills. - Train staff and volunteers in GIS for emergency support. - Develop and distribute educational materials. GdR Plans in all municipalities. Updating and creation.	18-36 months	$1,500,000 - $1,800,000

Annex 3. Proposed Implementation Schedule

GIS-based Multi-Hazard SAT Roadmap

PHASE	GENERAL ACTIONS	SCHEDULE
Phase 1: Planning and Design (Months 1-6)	- Detailed design of the GIS-based multi-threat SAT. - Coordination meetings with all stakeholders to define roles and responsibilities. - Assessment of existing infrastructure and upgrade needs. - Development of the training plan and selection of technologies to be implemented. - Detailed estimate of the budget and resources required. - Development of a schedule of specific activities for each prioritized threat.	Months 1-6
Phase 2: Infrastructure and Initial Training (Months 7-18)	- Acquisition of equipment and upgrade of GIS infrastructure. - Installation of monitoring systems and detection	Months 7-18

PHASE	GENERAL ACTIONS	SCHEDULE
	stations in high-risk areas. - Development of the data repository and the centralized GIS system. - Training of technical personnel in GIS use, data analysis, and operation of the SAT (Automatic Monitoring System). - Integration of alert communication protocols and coordination with local stakeholders.	
Phase 3: Implementation of Predictive Models and Testing (Months 19-30)	- Development of specific predictive models for each threat in the GIS. - Conducting alert and community response drills. - Adjustments and improvements to the system based on test results. - Optimization of communication channels for disseminating alerts and raising awareness in the community.	Months 19-30
Phase 4: Evaluation and Final Adjustments (Months 31-36)	- Comprehensive evaluation of the SAT and GIS models based on the results of recent drills and events. - Review and update of protocols, training, and equipment. - Adjustments to the data repository and alert systems, according to needs and recommendations.	Months 31-36
Phase 5: Sustainability and Continuous Monitoring (Starting in Month 37)	- Ongoing maintenance of the GIS system and technological updates. - Annual staff training and procedure updates in accordance with new knowledge and technologies. - Continuous monitoring of the SAT and its effectiveness, incorporating lessons learned and improvements based on events.	Months 37 and onwards

Annex 4. Detailed Schedule of Specific Actions by Priority Threat

1. EARTHQUAKES AND SEISMIC ACTIVITY

Specific Actions	**Schedule**
Evaluation of existing seismograph networks and acquisition of new equipment	Months 7-12
Installation of additional stations in high-risk areas	Months 13-18
Advanced training in seismic data analysis	Months 10-18
Development of drills and community evacuation routes	Months 19-24

Testing and adjusting the seismic prediction model in the GIS	Months 25-30

2. TSUNAMIS

Specific Actions	Schedule
Installation of monitoring buoys and pressure sensors in coastal areas	Months 7-12
Development of evacuation routes and signage in coastal communities	Months 13-18
Community training in interpreting alerts and evacuation	Months 15-20
Implementation of tsunami warning tests and drills	Months 21-24
Adjustment and optimization of the tsunami propagation model in GIS	Months 25-30

3. LANDSLIDES

Specific Actions	Schedule
Installation of humidity sensors and slope monitoring	Months 7-12
Creation of risk maps in mountainous and vulnerable areas	Months 13-18
Training in geological and climatic data analysis	Months 15-20
Conducting evacuation drills and community training	Months 19-24
Adjustments and calibration of the landslide risk model in GIS	Months 25-30

4. FLOODS

Specific Actions	Schedule
Installation of monitoring stations in rivers and high-risk areas	Months 7-12
Development of flood maps and GIS updates	Months 13-18
Training in the use of GIS tools for flood prediction	Months 15-20
Development of evacuation drills in vulnerable areas	Months 19-24
Tests and adjustments to the flood prediction model	Months 25-30

5. HURRICANES AND TROPICAL STORMS

Specific Actions	Schedule
Installation of weather stations in strategic areas	Months 7-12
Creation of storm and hurricane vulnerability maps	Months 13-18
Training in hurricane trajectory and intensity prediction	Months 15-20
Conducting evacuation drills and community training	Months 19-24
Development and adjustment of the forecasting model in GIS	Months 25-30

6. High waves and strong winds

Specific Actions	Schedule
Installation of monitoring buoys and coastal stations	Months 7-12
Creation of communication protocols for wave and wind alerts	Months 13-18
Training in the interpretation of wind and wave data in GIS	Months 15-20
Organization of evacuation drills and community exercises	Months 19-24
Optimization of the prediction model in GIS	Months 25-30

7. DENGUE

Specific Actions	Schedule
Installation of vector monitoring stations and humidity sensors	Months 7-12
Creation of a repository of dengue incidence data and maps	Months 13-18
Training in vector data analysis and environmental factors	Months 15-20
Development of prevention and training campaigns in vulnerable areas	Months 19-24
Adjustments to the predictive model of outbreaks in GIS	Months 25-30

8. Forest and Urban Fires

Specific Actions	Schedule
Installation of surveillance towers and temperature sensors	Months 7-12
Mapping of risk zones and development of evacuation routes	Months 13-18
Training in monitoring conditions favorable for fires	Months 15-20
Implementation of evacuation drills in vulnerable communities	Months 19-24
Optimization of the fire risk model in GIS	Months 25-30

Summary of the Complete Schedule

- **Months 1-6** : Planning and design, including defining roles, assessing needs, and developing the schedule.
- **Months 7-18** : Installation of infrastructure and initial training of staff and communities.
- **Months 19-30** : Development and testing of specific GIS models, simulations and technical adjustments.
- **Months 31-36** : Final evaluation and adjustments, with feedback from all stakeholders.
- **Months 37+** : Sustainability, monitoring and continuous updates.

Annex 5. Evaluation and Monitoring Indicators

Note: These indicators must be adjusted once defined and accepted by all parties.

Disaster Risk Awareness

Subcategory	Indicators
Indicators of risk understanding	% of institutions strengthened in SAT Percentage of population trained on specific threats. Number of risk studies conducted/updated in the last 5 years. Coverage of updated hazard maps (% of national territory).
Knowledge dissemination indicators	Frequency of community drills by type of threat. Number of awareness campaigns carried out annually. Level of community participation in risk workshops (% attendance).

Detection, Monitoring and Forecasting

Subcategory	Indicators
Technical capability indicators	Average time to detect critical events. Percentage of national coverage of meteorological stations and seismographs. Frequency of equipment maintenance and calibration (annual percentage).
Accuracy indicators	Average error in event forecasts (in magnitude, intensity, or location). Percentage of events correctly detected before their impact.
Sustainability indicators	Percentage of annual budget allocated to maintenance and improvement of the monitoring system. Relationship between identified needs and funding obtained.

Dissemination and Communication of Alerts

Subcategory	Indicators
Scope indicators	Percentage of population receiving real-time alerts. Number of active communication channels (radio, TV, social media, SMS, etc.).
Effectiveness indicators	Average time between event detection and alert issuance. Percentage of the population that acts according to established protocols upon receiving an alert.
Accessibility indicators	Percentage of messages adapted for people with disabilities and local languages. Frequency of evaluation of alert messages to ensure clarity.

Preparation to Respond

Subcategory	Indicators
Indicators of operational capacity	Average activation time of emergency teams after an alert. Percentage of strategic resources pre-positioned in risk zones.
Coordination indicators	Frequency of inter-institutional coordination meetings (% monthly or annually). Level of compliance with emergency plans in drills (%).

Governance

Subcategory	Indicators
Indicators of institutional articulation	Number of active inter-institutional agreements related to SAT. Percentage of municipalities integrated into the national early warning system.
Performance evaluation indicators	Frequency of independent audits and reviews of the SAT. Percentage of audit recommendations implemented within the expected timeframe.

Annex 5. List of Key Actors and their Responsibilities

Note: These responsibilities must be adjusted and expanded once defined and accepted by all parties.

Key Actor	Main Responsibilities
Emergency Operations Center (EOC)	- General coordination of the implementation of the multi-threat SAT . - Supervision of monitoring mechanisms and equipment in conjunction with the governing institution. - Development and execution of preparedness, response, and recovery plans. - Implementation of alert protocols and supervision of drills. - Inter-institutional coordination for SAT interoperability.
Ministry of Economy, Planning and Development	- Integration of risk knowledge with other phases of the GIRD, specifically prevention, mitigation and recovery.
Meteorological, Seismological, Epidemiological Institutes and Universities	- Development and maintenance of forecasting models for specific threats. - Generation and analysis of scientific data. - Training of technical staff and community leaders. - Conducting applied research. - Technical support in the interpretation of alerts.
Dominican Institute of Telecommunications (INDOTEL)	- Development and updating of alert communication protocols. - Management of technological infrastructure for alert dissemination. - Diversification of communication channels. - Monitoring the effectiveness of alert messages.
Local Governments and NGOs	- Act as a liaison between the SAT and the communities. - Organize and conduct community drills. - Disseminate key information about threats. - Mobilize first response teams. - Identify local vulnerabilities.
National Statistics Office	- Formulation and validation of processes and statistical data.
National Geographic Institute	- Formulation and validation of geographical standards.
Civil defense	- Coordination of the mobilization of human and material resources. - Training of community brigades. - Supervision of compliance with safety regulations. - Participation in drills and emergency planning.

Ministry of Education	- Incorporation of risk management content into educational plans. - Organization of drills in schools. - Dissemination of alert protocols and self-protection measures.
Ministry of Public Health	- Monitoring of alerts related to biological risks. - Implementation of preventive campaigns on health risks. - Coordination of the response to outbreaks or epidemics.
National Geological Survey (SGN)	- Generation of geological hazard maps. - Earthquake monitoring and issuance of early warnings. - Integration of geological data into the GIS system.
Media and Technology Companies	- Collaboration in disseminating alerts through mass media. - Design of communication strategies to maximize the reach of alerts. - Innovation in technological tools.
Community	- Active participation in awareness and training workshops. - Acting as information multipliers in their communities. - Following established protocols upon receiving alerts.

ABOUT THE GLOBAL GREEN GROWTH INSTITUTE

The Global Green Growth Institute was founded to support and promote a model of economic growth known as "green growth", which targets key aspects of economic performance such as poverty reduction, job creation, social inclusion, and environmental sustainability.

The Global Green Growth Institute

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