AI Innovation Brief

HARNESSING ARTIFICIAL INTELLIGENCE (AI) AND GEOSPATIAL DATA FOR CLIMATE DISASTER RISK ASSESSMENT IN CAMBODIA

WFP
World Food Programme

NATIONAL COMMITTEE FOR DISASTER MANAGEMENT

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KEY MESSAGES

- Advances in artificial intelligence (AI), geospatial technologies and data are revolutionizing the generation of granular insights into flood and drought risks in Cambodia.
- These insights are transformative for risk-informed planning, budgeting, and targeting of disaster preparedness and response efforts.
- They will strengthen implementing frameworks of Disaster Risk Reduction (DRR), Early Warning for All (EW4All), Anticipatory Actions (AA), and Shock-Responsive Social Protection (SRSP).

TIME TO ACT: THE CLOCK IS TICKING

Cambodia is on the frontline of heightening risks from floods and droughts, both of which have severe socioeconomic impacts. Over the past two decades, these disasters have caused an estimated average annual economic loss of USD 148 million[1].

But the risk does not end there. The cascading socioeconomic repercussions of the COVID-19 pandemic, coupled with volatile global food and fuel prices, have pushed many households to the brink of vulnerability. Climate change is poised to magnify the frequency and severity of these recurring disasters, turning them into existential threats that impede social and economic developments. By 2050, climate change could shrink the national Gross Domestic Product (GDP) by an estimated 3.0% to 9.4%[2].

Now more than ever, a comprehensive understanding of flood and drought risks is not just essential—it is urgent. Risk-informed decision-making is crucial for driving disaster risk reduction and resilience-building to ensure Cambodia can withstand future climate shocks. Yet, current information on disaster risks lacks detailed granularity needed for effective planning at the commune level.

To bridge this gap, the United Nations World Food Programme (WFP) and the National Committee for Disaster Management (NCDM) in Cambodia are harnessing artificial intelligence (AI), and geospatial technologies and data to generate profound insights into household vulnerabilities and the risks they face from floods and droughts across the country.

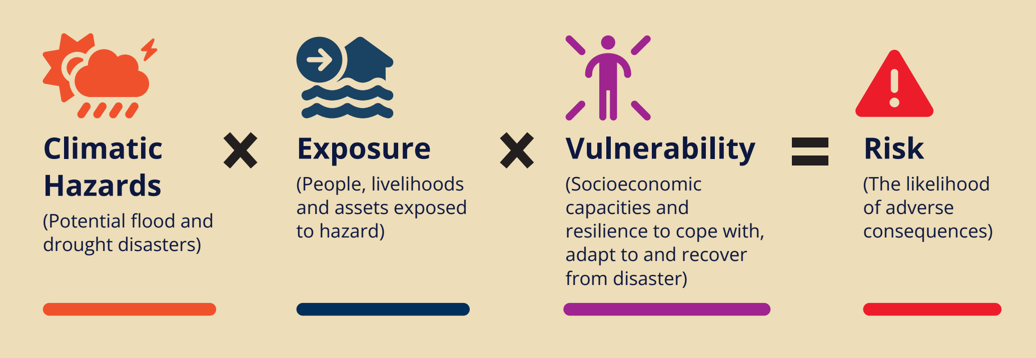
1 Economic impact from the UNDP's Disaster Financial Preparedness Analysis Report, 2023
2 Cambodia Country Climate and Development Report, The World Bank Group, 2023

AI AND GEOSPATIAL TECHNOLOGIES: A NEW FRONTIER IN RISK MODELING

Risk modeling hinges on understanding the interaction between climate hazards, exposure, and vulnerability. This was adapted from the widely recognized risk conceptual framework from the **5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC)**.

A climatic **hazard** is defined as a potentially climate-induced events with the potential to cause loss of life, injury, property and infrastructure damage, or environmental degradation. This assessment focuses on flood and drought probabilities and their spatial distribution. **Exposure** refers to the presence of people, property, livelihoods, or critical infrastructure within flood- and drought-prone areas that could be adversely affected. **Vulnerability** describes the socioeconomic capacities and resilience of household to cope with, adapt to and recover from the impacts of floods and drought.

Recent advancements in geospatial technologies, artificial intelligence (AI), and cloud-based computing platforms such as Google Earth Engine (GEE)



Comprehensive disaster risk assessment framework offer a novel approach to climate disaster risk modeling, allowing for a generation of granular, up-to-date risk information—right down to the localized level—a challenge that the traditional methods struggle to achieve.

Geospatial technologies such as geographic positioning systems (GPS), Geographic Information System (GIS) and Earth observation (EO) satellites and airborne remote sensing platforms, enable increasingly production of high-resolution and quality **geospatial data**, characterizing precise objects, events, and patterns on the Earth's surface.

Artificial Intelligence (AI) is the ability of computer systems to imitate human thinking processes, like learning and solving problems. **Machine Learning (ML)**, a subfield of AI, utilizes statistical algorithms to learn patterns from data, enabling to make accurate predictions in areas where data is missing. One common supervised ML method is the **Random Forest (RF)** algorithm, which creates multiple decision trees by randomly selecting variables and sampling data, enabling accuracy in classifying information from large geospatial datasets. However, using AI and geospatial technologies comes with challenges, such as needing good-quality training data. Without accurate ground data, ML models can produce unreliable results. As well, there is a need for more transparency, ownership, and trust in these technologies among stakeholders.

Additionally, **Google Earth Engine (GEE)** is an open-source, cloud-based computing platform that stores geospatial data from many sources. It enables the upload of external data and includes built-in algorithms, such as the machine learning Random Forest (RF).

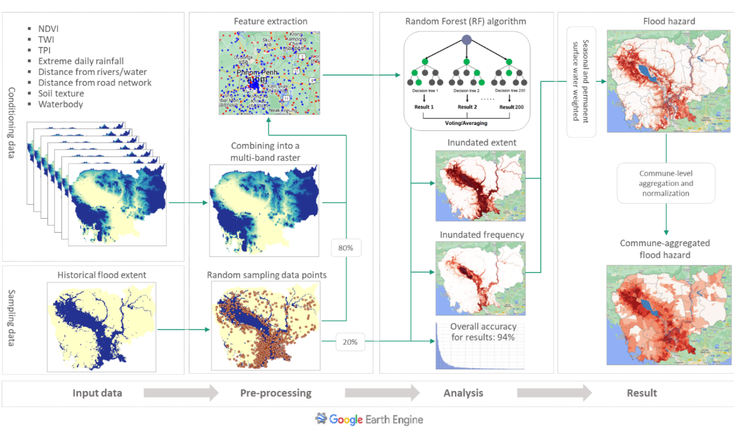
This assessment utilized the machine learning RF model and spatial analysis tools on the GEE platform to process and analyze geospatial and survey-based data, allowing a thorough quantification of flood and drought hazards, exposure, socioeconomic vulnerability, and risk at the commune level.

RECENT ADVANCEMENTS IN GEOSPATIAL TECHNOLOGIES, ARTIFICIAL INTELLIGENCE (AI), AND CLOUD-BASED COMPUTING PLATFORMS SUCH AS GOOGLE EARTH ENGINE (GEE) OFFER A NOVEL APPROACH TO CLIMATE DISASTER RISK MODELING, ALLOWING FOR A GENERATION OF GRANULAR, UP-TO-DATE RISK INFORMATION—RIGHT DOWN TO THE LOCALIZED LEVEL—A CHALLENGE THAT THE TRADITIONAL METHODS STRUGGLE TO ACHIEVE.

FORESEEING FUTURE DISASTERS FROM HISTORICAL EVENTS

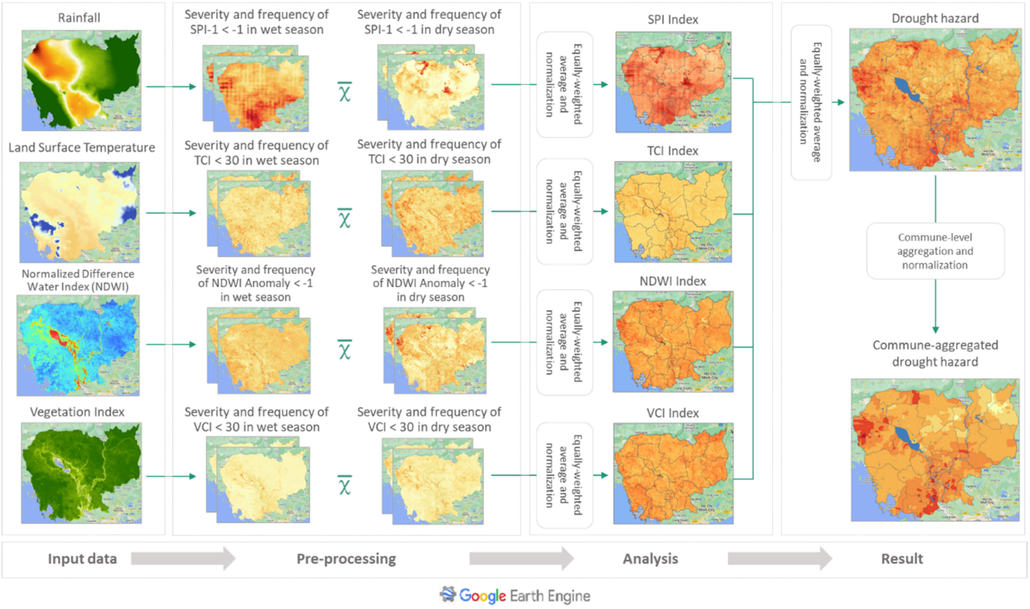
Flooding occurs when water overflows its usual boundaries, such as those of a river or lake, or inundates typically dry land. In this study, flood hazard was assessed using a machine learning model trained on historical flood events and flood susceptibility factors derived from geospatial data such as topography, hydrological networks, rainfall patterns, soil properties, vegetation cover. The assessment focused on the Cambodia's peak flood season (August to November) over the past 11 years, capturing both riverine and flash flood events. The model produced pixel-level indices indicating inundation frequency and locations. The final flood probability index was generated by adjusting for areas with permanent surface water and aggregating results at the commune level.

This Earth observation imagery illustrates flooding along the Mekong River in the provinces of Kratie and Tboung Khmoum in 2024.



The modeling workflow for assessing flood hazard

A drought is defined as a period of abnormally dry weather characterized by a prolonged absence or deficiency of rainfall, leading to a serious hydrological imbalance. Accessible long-term geospatial data on rainfall, temperature, water surfaces, and vegetation enable to quantify drought hazard using indicators such as Standardized Precipitation Index (SPI), Temperature Condition Index (TCI), Vegetation Condition Index (VCI), and Normalized Difference Water Index (NDWI). The assessment considered wet and dry seasonal variability over more than past 20 years. These indicators were normalized and combined to produce probability of a multiple-drought index at the commune level.

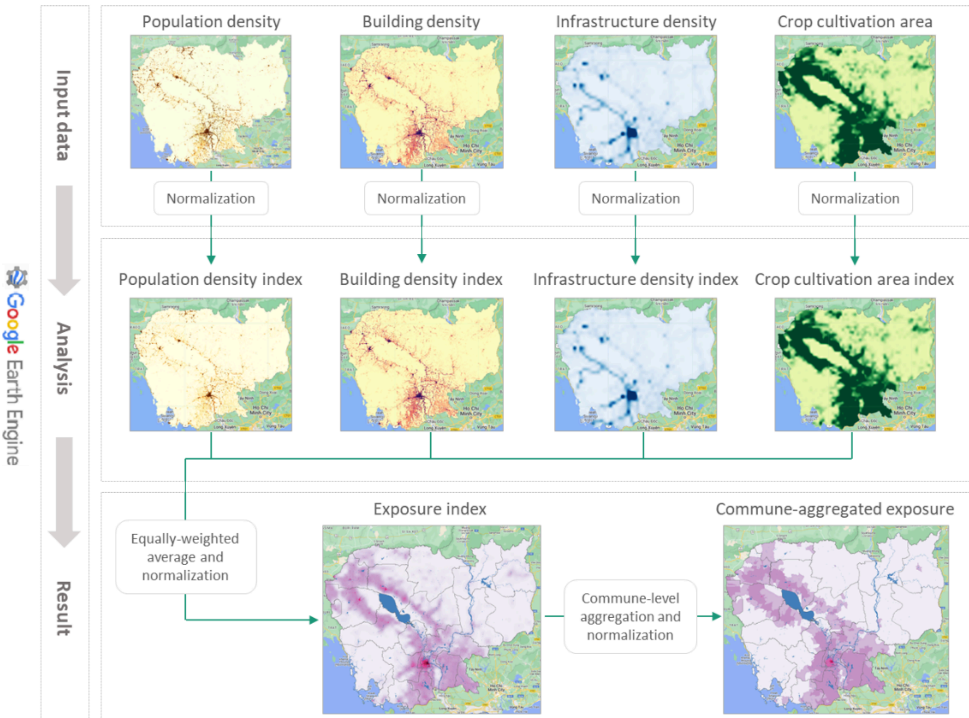


The workflow for assessing drought hazard

PINPOINTING WHO AND WHAT COULD BE AFFECTED

Key attributes, such as population, agricultural land, building footprints, and infrastructure, were essential for identifying those most at risk from floods and droughts in this assessment. Advances in geospatial technologies have enabled the availability of more precise, up-to-date datasets, generated from satellite imagery using machine learning algorithms trained with field reference data. To assess exposure for risk modeling, indices were developed by normalizing and combining these data points into a single index.

This visualizes human settlements in Phnom Penh, extracted from Earth observation imagery, which is critical for understanding exposure.



The workflow for assessing exposure

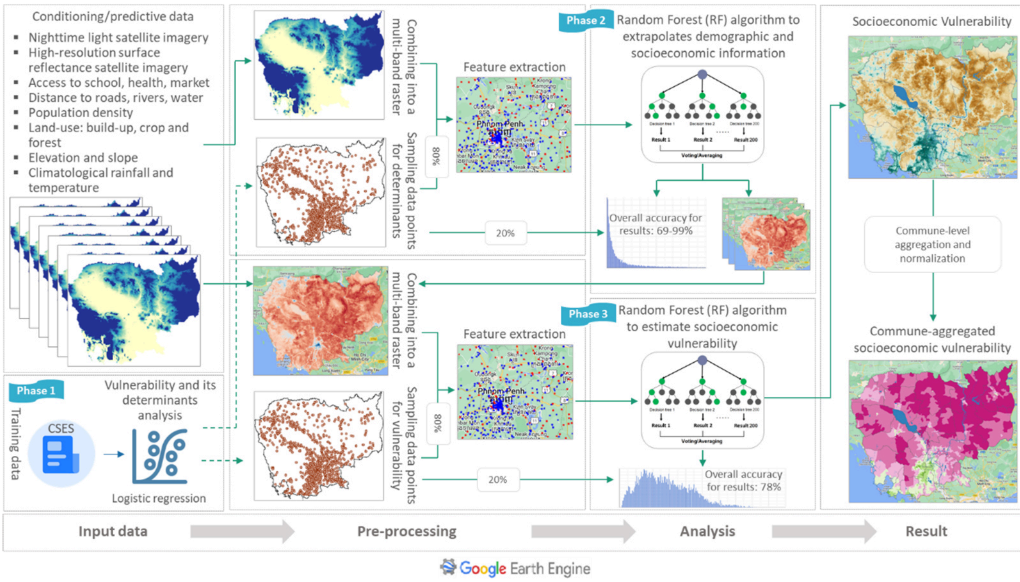
GRANULARITY IN VULNERABILITY ASSESSMENT

Households' social and economic capacities and resilience to cope with, adapt to, and recover from floods and droughts—defining socioeconomic vulnerability—can be measured using national survey data such as the Cambodia Socio-Economic Survey (CSES) [3]. However, such a survey is often not statistically representative at the commune level. To address this gap, the study developed a model for assessing socioeconomic vulnerability in three main phases, estimating information at the commune level where survey coverage was limited:

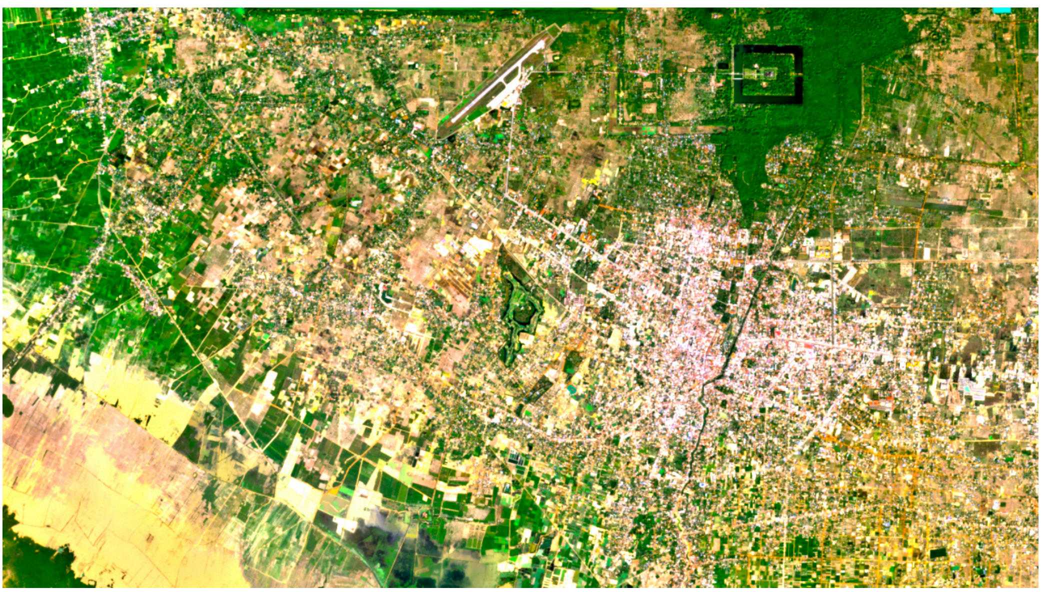
- **Phase 1:** Household vulnerability status was measured by a combination of indicators assessing household economic capacity to meet essential needs, current food consumption, and food- and livelihood-based coping strategies. Relationships between household demographic and socioeconomic characteristics and their vulnerability status were then examined.
- **Phase2:** A machine learning model, trained with the demographic and socioeconomic factors identified in Phase 1, and input with geospatial data (e.g., nighttime light intensity, human settlement patterns, accessibility to essential facilities, land cover, surface water, topography, climatology, etc.) performed geospatial extrapolation of vulnerability determinants.
- **Phase 3:** A nationwide socioeconomic vulnerability model was created by applying a machine learning algorithm to the findings from Phase 1 on household vulnerability status, along with the extrapolated demographic and socioeconomic data and geospatial datasets from Phase 2.

The model output of a pixel-level probabilistic index of socioeconomic vulnerability was aggregated at the commune level.

[3] CSES, conducted by the National Institute of Statistics (NIS) under the Ministry of Planning, provides a wide range of information on households, including demographics, consumption, food security, housing, education, health, employment, agriculture, income, and migration.



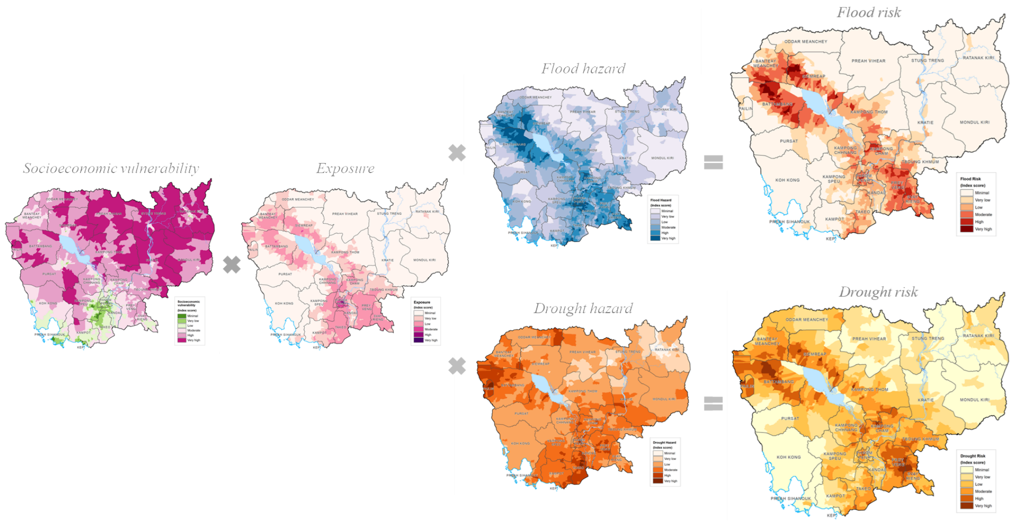
The modeling workflow for socioeconomic vulnerability assessment



This map captures the social and economic dynamics in Siem Reap, observed by satellite, which contribute to understanding vulnerability.

TURNING HAZARD, EXPOSURE, AND VULNERABILITY DATA INTO RISK INSIGHTS

Risk models reveal Cambodia faces significant dual threats from floods and droughts, especially in high-risk communes surrounding the Tonle Sap Lake/ River, along the Mekong River, and in the southern plains. Approximately 15% of the population and 16% of agricultural land are at risk from floods, while 29% of the population and 33% of agricultural land are at risk to droughts. These are more than just statistics—they are a call to action.



Maps visualize modelling of risks to flood (top) and drought (bottom)

THROUGH INNOVATION AND COLLABORATION, WE CAN SAFEGUARD LIVES AND LIVELIHOODS.

FROM INSIGHTS TO ACTION

To reduce risks and strengthen resilience against future disasters, four strategic actions are recommended for the government and development partners to enhance preparedness efforts:

- **Embrace AI and geospatial technologies:** Strengthening the capacity of government institutions to utilize AI/ML and geospatial technologies for data analytics will enable the generation of precise, timely, and actionable insights for disaster preparedness and response activities.

- **Implement dynamic socioeconomic vulnerability assessment:** Adopting the AI-driven vulnerability assessment model outlined in this report as a dynamic modeling approach-integrating near-real-time Earth observation data and on-the-ground socioeconomic data with machine learning predictive analytics enables timely updates to vulnerability data.

- **Enhance reliability of artificial intelligence (AI) in risk modeling:** Embedding geographical reference information in data collection for national surveys, censuses, and assessments will enhance the quality and availability of training data, ensuring reliable results from machine learning (ML) algorithms. Additionally, standardized procedures for capturing accurate, consistent, and interoperable post-disaster loss and damage data can support calibration and validation of risk model.

- **Integrate climate projections into risk assessment:** With escalating climate impacts, incorporating localized climate projection data into assessment of climatic hazards strengthens risk modeling, providing forward-looking information for mitigation and adaptation efforts.

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