Disaster displacement risk in Guatemala

An overview of the risk of future displacement by riverine floods and droughts at the national and sub-national levels

iDMC
internal
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centre

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Cover photo: Guatemalan Red Cross volunteers walk along a flooded street in Guatemala as part of damage assessments and evacuations following heavy rains. Storms and floods account for most of the disaster displacements in the country. © Guatemalan Red Cross

People stand on a flooded street in Guatemala following Hurricane Eta in 2020. Although Eta and Iota did not make landfall in Guatemala, the associated rains and floods triggered 310,000 internal displacements across the country. © UNOCHA/Luis Echeverria

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An aerial view of Guaraquiche, Chiquimula department, Guatemala. The country recorded 939,000 disaster displacements between 2008 and 2024. © UNOCHA/Vincent Tremeau.

Introduction

Every year, floods, droughts, storms, earthquakes and other natural hazards force millions of people to leave their homes. Latest data from the Internal Displacement Monitoring Centre (IDMC) shows that 45.8 million of internal displacements, or movements, associated with disasters were reported in 2024, the highest figure on record and far above the decadal average of 26.5 million.

Fleeing can be the first of many further disruptions to people's lives, however. Not only their livelihoods are affected, but it can take weeks or even months before they are able to return. Those who do return often face unsafe conditions and the prospect of being displaced again by the next disaster.

While understanding historical trends is key, looking at the past is not enough. Producing information and analysis on the risk of future disaster displacement can help reduce risk and build resilience before hazards strike, thereby minimising the impacts of disasters, including displacement. In 2017, IDMC began a unique probabilistic modelling exercise for disaster displacement, assessing the likelihood of population movements in the future at a global level. The model used a state-of-the-art probabilistic approach, like that applied by catastrophe modelers and the insurance industry over the past few decades. It built on a risk analysis developed by the UN Office for Disaster Risk Reduction (UNDRR), which considered a wide range of hazard scenarios, their likelihood, and their potential to cause housing damage, which was used as a proxy to assess the likelihood of people getting displaced.

The model provided disaster displacement risk data at the national level (Admin 0), and defined vulnerability from a purely physical perspective -e.g structural vulnerability of buildings being severely damaged or destroyed by different hazard intensities-, without taking into account other socioeconomic factors including poverty, inequality and access to services, nor how global warming could affect the frequency and intensity of certain weather-related hazards.

Understanding physical impacts alone is not sufficient to fully capture displacement risk, however. Given that people's level of vulnerability and exposure to hazards does much to determine the severity of a hazard, it is important to assess how these aspects may change over space and time, and to unpack the economic, social and environmental factors that affect disaster risk, including optimistic and pessimistic climate change scenarios.

To refine further the granularity and comprehensiveness of its model, IDMC collaborated with several partners to develop an updated version that incorporates the latest hazard scenarios, both optimistic and pessimistic climate change projections affecting their frequency and intensity, new exposure layers, and an enhanced vulnerability component that goes beyond structural building fragility. The model assesses the risk of severe housing damage or destruction, as well as the loss of livelihoods for certain hazards, to estimate the probability of displacement. In essence, it focuses on the risk of medium- to long-term displacement and does not account for or model pre-emptive evacuations. Compared to the previous model, data is provided at Admin 1.

While still work in progress, the first results at a global level were obtained in early 2025, allowing to have a more detailed picture of global disaster displacement risk. As part of a series of papers on disaster displacement risk at a national level, the objective of this report is to advance our collective understanding of the current interlinkages between disasters, displacement and climate change, and better anticipate their future evolution. Given that "riskscapes" are constantly evolving, we need to better understand population and socioeconomic patterns, as well as fluctuations in the frequency and intensity of climate-related hazards in order to act more efficiently and ensure that no one is left behind.

A woman waters newly planted crops in Tierra Blanca, Chiquimula department, Guatemala. The World Food Programme helps communities diversify livelihoods and adapt to the impacts of climate change. Photo: OCHA/Marc Belanger

Disaster displacement in Guatemala: historical trends (2008-2024)

Guatemala is a mountainous country in Central America, bordered by Mexico, Belize, Honduras, and El Salvador, with coasts on both the Pacific Ocean and the Caribbean Sea. It spans roughly 109,000 square kilometres, and features very diverse topography – from coastal plains and tropical forest in the north to steep volcanic highlands in the western interior. A high proportion of the population lives in rural, indigenous areas with slopes and flood-prone terrain, which raises their exposure to disasters.

With a population of around 18 million[1], Guatemala is the most populous country in Central America. Nearly one-fifth of its people live in the Department of Guatemala, which sits at the edge of the volcanic chain [2]. Other densely populated departments include Alta Verapaz, Huehuetenango, Quiché, and Izabal, where vulnerable housing and poor infrastructure increase the risk of recurrent displacement. Rural households, particularly in the Dry Corridor in the east (Jalapa, Jutiapa, Chiquimula, Zacapa) face repeated shocks from drought and rainfall variability that erode livelihoods and contribute to mobility.

Guatemala's environment is shaped by its location along the Central American Volcanic Arc and within both the Pacific and Atlantic hurricane basins. This geographic position exposes it to a wide spectrum of hazards: tropical storms, hurricanes, floods, and landslides are recurrent, while volcanic eruptions and earthquakes occur less frequently but can trigger sudden mass evacuations. Deforestation, soil erosion, and rapid urban growth have compounded these risks, reducing natural buffers and placing more households in harm's way.

In 2024, disaster displacement in Guatemala remained above the historical average, driven by heavy rains that triggered floods and landslides in Alta Verapaz, Huehuetenango, and Izabal. This continued an upward trend since 2020, when hurricanes Eta and Iota struck within weeks of each other, displacing hundreds of thousands and marking one of the largest displacement crises in the country's recent history. Earlier peaks included Tropical Storm Agatha in 2010, which devastated infrastructure across multiple departments, and the 2018 eruption of Volcán de Fuego, which destroyed entire communities and led to long-term displacement.

Disasters have triggered around 939,000 displacements in Guatemala since IDMC began systematically monitoring data on the phenomenon in 2008 (see Figure 1). The data shows fluctuations from year to year, with major peaks linked to tropical storms, hurricanes, and volcanic activity. When hazards strike consecutively or compound one another, displacement figures rise sharply, as in 2020.

IDMC has recorded 244 disaster events that triggered displacement, the overwhelming majority of which have been triggered by weather-related hazards, notably storms and floods (see Figure 2).

Guatemala has experienced repeated waves of disaster displacement over the past 15 years. The country's rugged geography and exposure to multiple hazards – tropical storms, floods, landslides, earthquakes, and volcanic eruptions – mean that many movements are reactive rather than pre-emptive, with housing destruction often prolonging displacement.

In 2010, Tropical Storm Agatha triggered around 112,000 displacements, devastating infrastructure and triggering widespread landslides across several departments. The following year saw further peaks, with an earthquake and volcanic activity combining to trigger 68,000 displacements.

In 2018, the eruption of Volcán de Fuego destroyed entire communities, resulting in tens of thousands of displacements. Many of them were displaced for extended periods of time, given the scale of housing destruction and the need for long-term relocation.

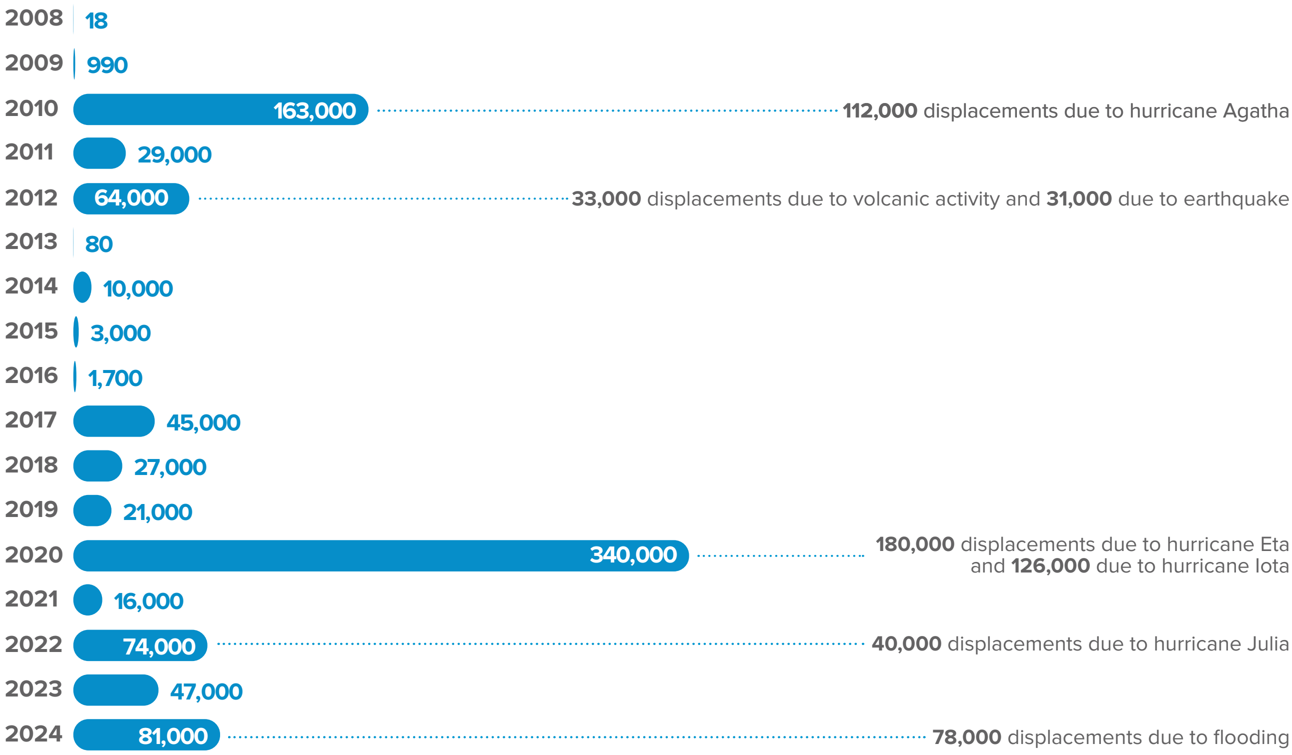
In 2020, hurricanes Eta and Iota struck within weeks of each other, triggering over 300,00 displacements nationwide. This was one of the largest disaster displacement crises in Guatemala's recent history. While many families evacuated temporarily, flood and landslide damage left significant numbers without homes to return to, prolonging displacement.

Subsequent years have continued to see elevated levels of disaster displacement compared to the pre-2020 period. In 2022, Hurricane Julia triggered around 40,000 displacements, while in 2024 heavy rains caused floods that triggered about 78,000 displacements, particularly in Alta Verapaz, Huehuetenango and Izabal.

The government, through its national disaster agency CONRED, has established a legal and institutional framework for disaster risk management that includes multi-level coordination and community-based committees. In recent years, Guatemala has also joined the Early Warnings for All (EW4All) initiative, which seeks to expand multi-hazard early warning coverage and strengthen monitoring and communication systems. These measures demonstrate a proactive approach to preparedness, but gaps remain in turning warnings into effective, timely evacuations and in supporting families whose homes are destroyed and cannot return quickly.

Many of these movements are short-term, as people seek shelter in schools, churches, or community centres until conditions stabilise. However, when homes are destroyed by landslides, hurricanes or volcanic eruptions, displacement is often prolonged. The persistence of high figures since 2020 reflects compounding risk factors such as heavier rainfall, deforestation, rapid urban growth on unstable slopes, and inadequate drainage all of which increase exposure and limit rapid recovery.

Figure 1: Internal displacements by disasters in Guatemala, 2008-2024



112,000 displacements due to hurricane Agatha

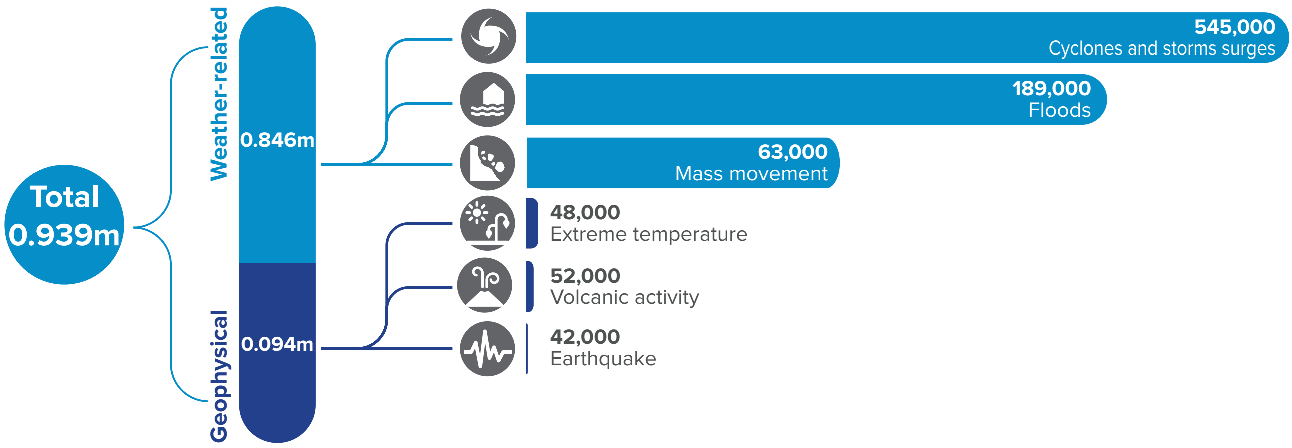
33,000 displacements due to volcanic activity and **31,000** due to earthquake

180,000 displacements due to hurricane Eta and **126,000** due to hurricane Iota

40,000 displacements due to hurricane Julia

78,000 displacements due to flooding

Figure 2: Breakdown of the total number of internal displacements by hazard in Guatemala, 2008-2024



Displacement risk concepts

The need for a broader approach, using probabilistic risk assessment

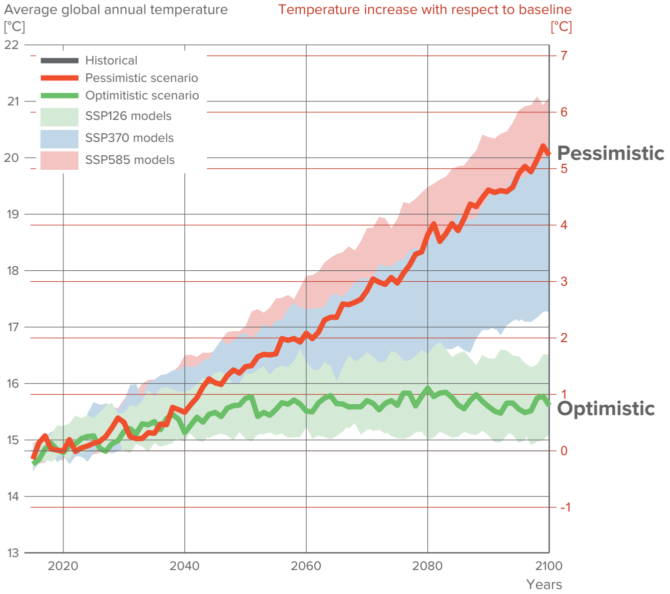
Before diving into the results of the displacement risk model, it is important to first understand key concepts underpinning the modeling approach and how it integrates diverse climate scenarios. These elements are essential to better interpret the outputs.

The baseline established by our new global disaster displacement risk model presents results at the national level downscaled at admin 1 resolution, and provides insight into future displacement situations in a changing climate in Guatemala.

It uses a probabilistic approach, applying statistical methods to estimate the likelihood and potential impact of different hazard scenarios. It accounts for uncertainty by analyzing a range of possible outcomes rather than a single deterministic prediction, and evaluates the risk of severe housing damage or destruction, along with livelihood loss for certain hazards, to estimate the likelihood of displacement. It primarily focuses on the risk of medium, to long-term displacement and does not include or model pre-emptive evacuations which means its estimates are inherently conservative.

The outputs are presented using two key metrics: Average Annual Displacement (AAD) and Probable Maximum Displacement (PMD), disaggregated by hazard type and downscaled to the administrative level 1 resolution.

Figure 3: Illustration of different climate scenarios



The new generation of the Global Displacement Risk Model integrates the potential impact of climate change on the future frequency and intensity of extreme events (see Methodology). To facilitate interpretation of the outputs, we have consolidated the results under three different scenarios:

- Under the **current** climate condition
- "**Optimistic**", corresponding approximately to an average temperature rise of about +1°C by 2100
- "**Pessimistic**", corresponding approximately to an average temperature rise of over +5°C by 2100

Displacement risk metrics

To represent how many people are at risk of displacement in a given country, the commonly used and comparable metric is **Average Annual Displacement (AAD)**, which measures the expected magnitude of future displacement by hazard type that a country is likely to experience. It does not indicate the actual number of displacements that will occur each year, but rather the average annual number projected over a long time period, taking into account all potential events. (See methodology section for more details.)

AAD represents the annualized, accumulated effect of all events in the hazard catalogue. It is a compact metric that captures the expected displacement from both medium and extreme events. The model estimates that under the current climate conditions, 740,000 people could be displaced by riverine floods in Bangladesh in any given year in the future, on average.

While AAD is useful for conveying the scale of displacement risk on an annual basis, it tends to mask potential outliers. High-intensity but low-frequency events, such as a Category 5 cyclone or a magnitude 7 earthquake, could cause mass displacement, even if they occur only rarely.

To better account for such extremes, we also use a second metric: **Probable Maximum Displacement (PMD)**. PMD represents the maximum number of displacements expected within a given return period, capturing the outlier scenarios mentioned above. It is especially useful for preparedness planning, such as determining the size and scope of shelters, infrastructure, and emergency response assets a government may need.

The likelihood or probability of displacement is usually expressed in terms of a return period, which is often misunderstood. A return period is the average time interval in years that separates two consecutive events equal to or exceeding the given magnitude. The most common misconception is that an event with a 100-year return period will only occur once a century. In fact, it means that it has an exceedance probability of 1/100, so events of the same or greater intensity happen once every 100 years on average. It does not preclude more than one event with a 100-year return period happening within a century or even the very small probability of back-to-back events one year after another. Nor does it rule out a century passing without such an event occurring.

AAD

Average Annual Displacement (AAD) is a measure of the magnitude of future displacement by hazard type that a country is likely to experience. It does not reflect the number of displacements it will face each year, but the number it can expect per year considering all the events that could occur over a long timeframe. AAD is a compact metric with low sensitivity to uncertainty.

PMD

Probable Maximum Displacement (PMD) is the maximum displacement expected within a given time period. It answers the question: What is the maximum expected displacement within a range of X years? It represents the outlier event that could occur during a specific time frame. PMD can be used to determine the size of shelters and other assets that a government needs to provide to cope with the potential magnitude of displacement.

Disaster displacement risk in Guatemala: results by hazard type

Looking only to the past is not a reliable guide for understanding what may occur in the future or how best to prepare for it. As climate patterns shift and hazards evolve, it becomes increasingly important to use forward-looking tools, such as predictive modelling to anticipate future displacement risks and inform proactive planning and preparedness efforts.

Riverine floods

The analysis of flood displacement risk at a country level shows an AAD value of around 7,300 people. Looking at the results under optimistic and the pessimistic climate change scenarios, the optimistic pathway suggests only a slight decrease, with AAD values falling to about 7,000, while under the pessimistic scenario AAD falls even further to 6,600.

When downscaling the analysis to the department level, distinct patterns emerge (see Figure 4). Izabal continues to face the highest displacement risk in the country, with an AAD of around 2,600 people. This decreases to about 2,300 under the optimistic scenario, but reduces further to 1,600 under the pessimistic one.

Petén, currently records an AAD of around 400 people, increasing to 700 under the optimistic scenario and to 600 under the pessimistic. Alta Verapaz, with a current AAD of 400 people experiences one of the steepest relative increases rising to 700 under the optimistic scenario and to 600 under the pessimistic.

By contrast, in departments such as Jutiapa, Retalhuleu, and Sacatepéquez, displacement risk remains very low, with AAD values of 100 people or fewer, and no significant change projected across scenarios.

While the AAD reflects the average number of flood-induced displacements over a long time frame, it tends to mask potential outliers. Understanding the impacts of these outliers, and estimating the number of people potentially displaced during frequent (low return period) or rare (high return period) events is essential. It is evident that the number of people at risk of displacement increases significantly with higher return periods.

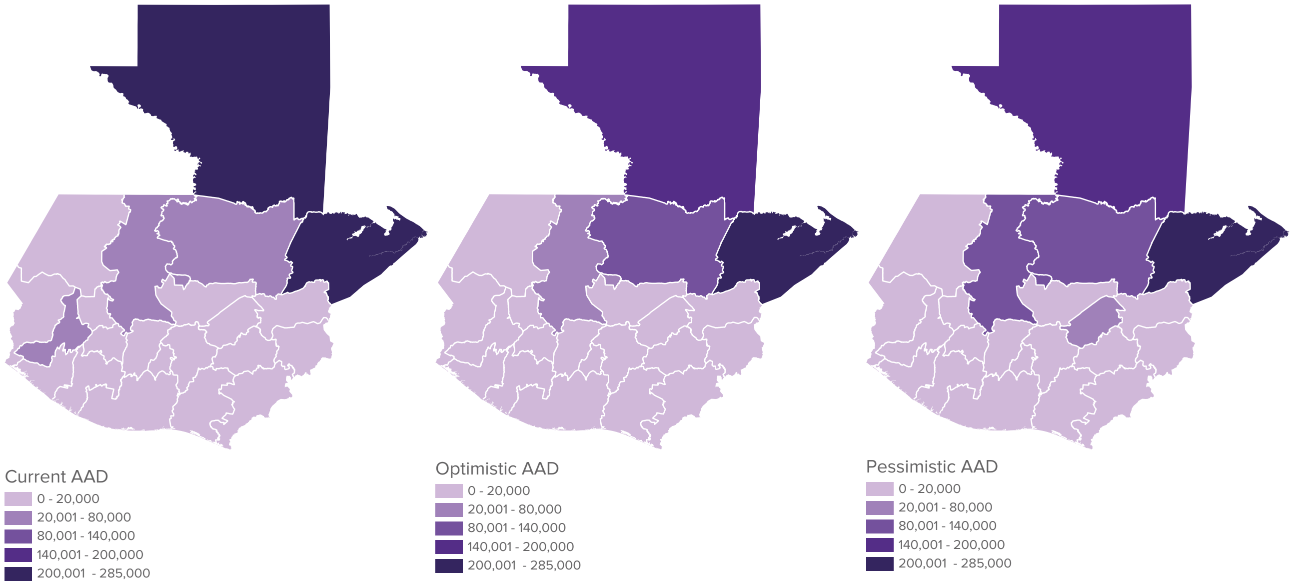
Under current climate conditions, displacement figures rise sharply from frequent events (e.g. a 5-year return period) to rare events (e.g. a 100-year return period).

This trend is observed when analyzing the Probable Maximum Displacement (PMD) under long-term climate scenarios, for both optimistic and pessimistic scenarios. In the latter case, a 100-year riverine flood may result in displacement figures flood event may result in displacement figures that double under the optimistic scenario and triple under the pessimistic one (see Figure 7 in Figure Annex).

Under current climate conditions, a 50 year-return period event, meaning a 2% chance of occurring in any given year, a 33% chance over the next 20 years, and a 64% chance over the next 50 years, could displace approximately 51,000 people in Izabal, 9,700 in Petén and 7,500 people in Quetzaltenango. These numbers highlight how risk is heavily concentrated in a handful of departments.

Looking ahead, the scale of these events intensifies under climate change. By the end of the century, Izabal could see displacement numbers rise well beyond current levels, with both optimistic and pessimistic scenarios pointing to larger impacts. Petén and Quetzaltenango also remain highly exposed, with projected increases that reinforce their position among the country's most at-risk areas.

Figure 4: Average Annual Displacement risk by riverine floods in Guatemala under different climate scenarios



Droughts

Droughts are among the most complex and one of the most catastrophic disasters, causing severe damage to agriculture, food security, and rural livelihoods. In Guatemala, drought risk is concentrated in the Dry Corridor, spanning departments such as Jalapa, Jutiapa, Chiquimula, and Zacapa. However, vulnerability also extends to the western highlands and other areas where rainfall variability, irregular onset of the rainy season, or early withdrawal of rains can trigger drought conditions.

Although there is limited recorded evidence of large-scale drought-induced displacement in Guatemala, past events have often displaced families on a small and localized scale, making them difficult to monitor. To better capture these dynamics, the model incorporates economic, social, and environmental factors, going beyond historical displacement records. This approach provides a more comprehensive picture of potential drought-related displacement and supports resilience planning.

The analysis of drought displacement risk at a country level suggests that drought represents a significant source of displacement in Guatemala, with an AAD of around 29,000 people. Looking to the future, this number more than doubles by mid-century, reaching about 64,000 under both optimistic and pessimistic scenarios. By 2100, it rises further to around 123,000 people.

Downscaling to the departmental level highlights sharp variations. Huehuetenango, San Marcos, Quiché and Quetzaltenango emerge as the most at-risk departments. In Huehuetenango, annual displacement due to drought is projected to rise from around 3,700 today to more than 27,000 by 2100. In San Marcos, the increase is even steeper, from about 2,900 today to more than 26,000 by the end of the century. Quiché grows from around 4,100 to nearly 16,000, while Quetzaltenango rises from about 1,100 to almost 8,800. By contrast, in departments such as Izabal, Retalhuleu and Sacatepéquez, AAD values remain very low, generally under 1,000 across all scenarios. (See Figure 5).

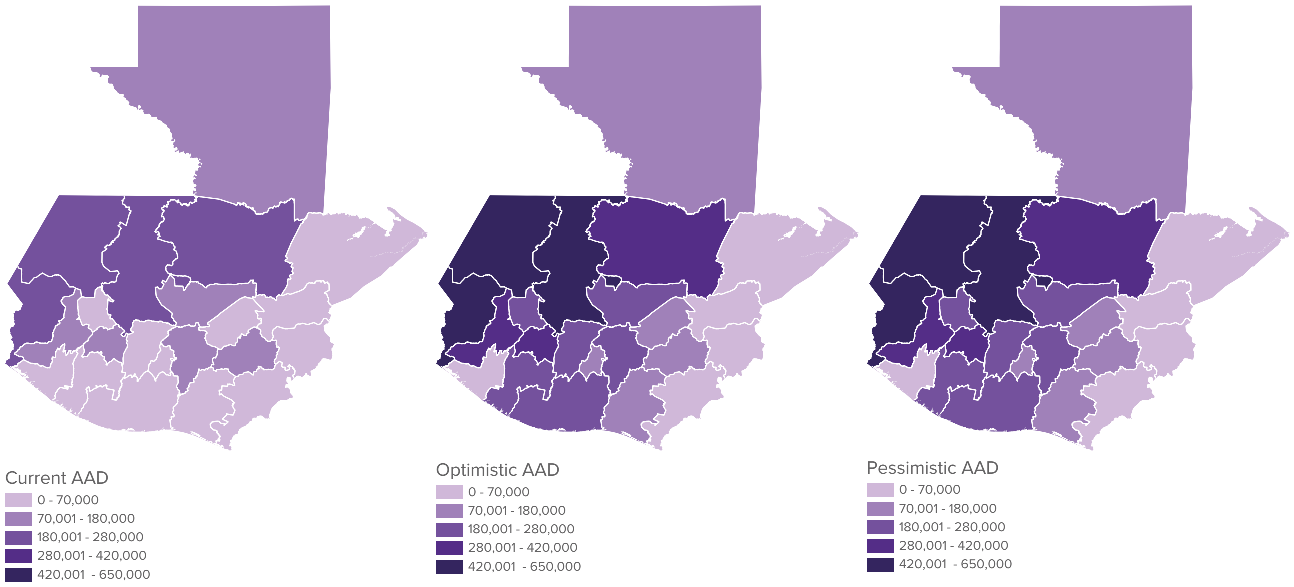
While AAD illustrates long-term averages, it masks the potential impact of outlier drought events. PMD estimates reveal the scale of displacement that could occur during rare, high-intensity events.

Under current conditions, a 50-year drought could displace around 27,600 people in Quiché, 26,300 in Jalapa, and 15,800 in Chiquimula. For a 100-year drought, risks rise sharply, with 27,600 people in Quiché, 26,300 in Jalapa, and 15,800 in Chiquimula potentially displaced.

In the western highlands, extreme scenarios could be particularly severe: in Huehuetenango, displacement during a 100-year drought could increase from around 5,300 today to more than 27,000 people by 2100 under both climate change scenarios. In San Marcos, PMD values rise from about 3,200 under current conditions to more than 26,000 by 2100, highlighting the extreme potential scale of drought impacts (see Figure 8 in Figure Annex).

This demonstrates that while Guatemala's current drought displacement risk is moderate, climate change could dramatically amplify displacement in several departments, particularly in the western highlands and Dry Corridor. Planning efforts therefore need to anticipate not only recurrent seasonal droughts but also high-impact, low-probability events that could overwhelm local and national coping capacity.

Figure 5: Average Annual Displacement risk by drought in Guatemala under different climate scenarios



A farmer works in his maize field in Talquezal, Chiquimula department, Guatemala. Communities in the country's Dry Corridor face recurrent shocks from drought and heavy rains, which damage crops, reduce income and increase the risk of displacement. © UNOCHA/Vincent Tremeau.

Conclusion

Disaster displacement is one of the most significant humanitarian and development challenges we face in the 21st century. Probabilistic risk models underscore the need for proactive policy interventions to anticipate and manage displacement driven by natural hazards in a changing climate. They provide insights into how and where such displacement may occur, helping governments and partners move beyond reactive responses and adopt forward-looking strategies that build resilience in vulnerable communities.

This study applied a multi-hazard displacement risk model that incorporates novel methods for vulnerability assessment. The model quantifies potential displacement from hazards such as floods, droughts, cyclonic winds and storm surges, expressed as Average Annual Displacement (AAD) and Probable Maximum Displacement (PMD) under both current conditions and long-term climate scenarios. While the model has been used previously in Fiji, Vanuatu and the Horn of Africa, this is its first application in Guatemala, where it highlights displacement risks primarily from floods and droughts.

Results at national and subnational levels reveal clear spatial patterns of risk. While Guatemala's AAD values suggest moderate levels of annual displacement, the PMD analysis shows that rare but severe flood or drought events could displace hundreds of thousands to more than a million people. Subnational hotspots emerge as critical areas of concern: Izabal and Petén face the highest risks from floods, while Quiché, Jalapa, Huehuetenango and San Marcos are disproportionately exposed to drought. These findings stress the need for preparedness and resilience-building measures that address both recurrent seasonal shocks and low-probability, high-impact events.

To reduce displacement and its most adverse impacts, tangible steps are required:

- Identify and support vulnerable populations most at risk of displacement, ensuring their rights and well-being are protected.
- Invest in flood- and drought-resilient infrastructure, including improved building standards and early warning systems.
- Integrate displacement risk into broader climate change adaptation and development planning.
- Continue global advocacy and local implementation of climate mitigation measures.

Looking forward, refining these models depends on better data on population, socioeconomic conditions, and hazard frequency and intensity. Leveraging open-access data, refining terrain models, and improving hydrometeorological observations will make projections more accurate and actionable.

The risk of disaster-induced displacement is a global reality, but the tools and data now available create an opportunity for more coordinated action. By building on good practices and investing in evidence-based strategies, Guatemala and its partners can strengthen resilience and ensure that no one is left behind, especially those already enduring the challenges of repeated displacement.

A woman plants seeds in the WFP farming school in Guaraquiche, Chiquimula department, Guatemala. Drought and extreme weather undermine food security and contribute to displacement risk. © UNOCHA/Vincent Tremeau.

Figure Annex

Figure 6: Map of Guatemala by department

Figure 7: Probable Maximum Displacement per department for riverine flood

Legend

Low | | Medium | | High

By Department	Current PMD50	Optimistic PMD50	Pessimistic PMD50
Alta Verapaz	2,600	11,000	9,200
Baja Verapaz	200	200	200
Chimaltenango	200	300	300
Chiquimula	500	600	700
El Progreso	200	3,300	3900
Escuintla	300	400	400
Guatemala	800	1,100	200
Huehuetenango	1,000	1,200	600
Izabal	51,000	46,000	52,000
Jalapa	100	100	100
Jutiapa	200	200	200
Petén	9,700	10,000	8,600
Quetzaltenango	7,500	200	300
Quiché	1,400	2,700	5,400
Retalhuleu	100	100	300
Sacatepéquez	0	900	0
San Marcos	1,100	1,100	800
Santa Rosa	500	600	500
Sololá	0	0	0
Suchitepéquez	500	100	300
Totonicapán	100	100	100
Zacapa	700	1,600	1,500

By Department	Current PMD100	Optimistic PMD100	Pessimistic PMD100
Alta Verapaz	7,900	14,000	12,000
Baja Verapaz	200	300	300
Chimaltenango	200	300	300
Chiquimula	700	1000	800
El Progreso	2,600	4,100	4,300
Escuintla	500	800	500
Guatemala	1,100	1,100	400
Huehuetenango	1,200	1,400	1,500
Izabal	53,000	79,000	76,000
Jalapa	100	100	100
Jutiapa	200	200	300
Petén	11,000	11,000	10,000
Quetzaltenango	9,300	200	3,300
Quiché	1,500	4,300	6,100
Retalhuleu	400	400	400
Sacatepéquez	600	1,400	0
San Marcos	1,300	1,300	900
Santa Rosa	800	900	700
Sololá	0	0	0
Suchitepéquez	600	200	400
Totonicapán	100	100	200
Zacapa	800	1,900	2,000

Figure 8: Probable Maximum Displacement per department for drought

Legend

Low | | Medium | | High

By Department	Current PMD50	Optimistic PMD50	Pessimistic PMD50
Alta Verapaz	72,500	84,600	84,600
Baja Verapaz	24,400	48,000	48,000
Chimaltenango	14,400	43,500	43,500
Chiquimula	7,800	1,200	1,200
El Progreso	16,400	22,500	22,500
Escuintla	13,400	36,500	36,500
Guatemala	22,700	49,500	49,500
Huehuetenango	73,500	234,300	234,300
Izabal	18,600	4,200	4,200
Jalapa	23,300	31,800	31,800
Jutiapa	12,200	16,200	16,200
Petén	27,700	33,400	33,400
Quetzaltenango	21,300	72,700	72,700
Quiché	77,700	191,300	191,300
Retalhuleu	2,600	6,300	6,300
Sacatepéquez	7,100	18,400	18,400
San Marcos	55,500	210,800	210,800
Santa Rosa	5,900	15,800	15,800
Sololá	20,700	63,500	63,500
Suchitepéquez	10,700	28,100	28,100
Totonicapán	9,200	38,100	38,100
Zacapa	18,600	2,600	2,600

By Department	Current PMD100	Optimistic PMD100	Pessimistic PMD100
Alta Verapaz	104,400	116,300	116,300
Baja Verapaz	35,300	63,900	63,900
Chimaltenango	20,800	53,900	53,900
Chiquimula	11,200	4,900	4,900
El Progreso	23,800	32,300	32,300
Escuintla	19,200	41,400	41,400
Guatemala	33,000	64,800	64,800
Huehuetenango	106,400	259,700	259,700
Izabal	26,800	8,900	8,900
Jalapa	33,700	45,800	45,800
Jutiapa	17,700	23,100	23,100
Petén	39,800	45,200	45,200
Quetzaltenango	30,800	77,900	77,900
Quiché	112,100	238,000	238,000
Retalhuleu	3,700	7,200	7,200
Sacatepéquez	10,200	23,800	23,800
San Marcos	80,200	214,800	214,800
Santa Rosa	8,500	19,800	19,800
Sololá	30,000	74,700	74,700
Suchitepéquez	15,200	31,600	31,600
Totonicapán	13,200	38,100	38,100
Zacapa	26,900	5,400	5,400

Methodological Annex

The true benefits of a probabilistic risk assessment are frequently misconstrued because it is regarded as a complex and challenging method to implement and follow, with a communication hurdle when presenting outcomes. A probabilistic disaster displacement risk profile must be seen as a diagnostic tool, because it offers insights into potential hazard occurrences and their consequences.

Such profiles cover all possible risk scenarios in a certain geographical area. Both low-frequency, high-impact events and high-frequency, low-impact events are considered. Their probability of occurrence, all elements of the risk equation (risk = hazard X exposure X vulnerability), and their variability and uncertainty ranges are all included (see Figure 12).

Events that have rarely been recorded but might occur more often under climate projections are thus also considered. This feature is particularly useful because climate change is increasing uncertainty about future hazard patterns. To be prepared, societies need to calculate the worst possible impact. Viewed through this lens, there is no valid alternative to a probabilistic analysis to address such uncertainty in a usable, quantitative way.

Displacement risk information, expressed in average annual displacement (AAD) and probable maximum displacement (PMD), is calculated at the subnational regions and aggregated at country level, allowing for a geographic and quantitative comparison within and between countries. These analyses and comparison exercises are an important step in risk awareness processes and key to pushing for risk reduction, adaptation and management mechanisms to be put in place.

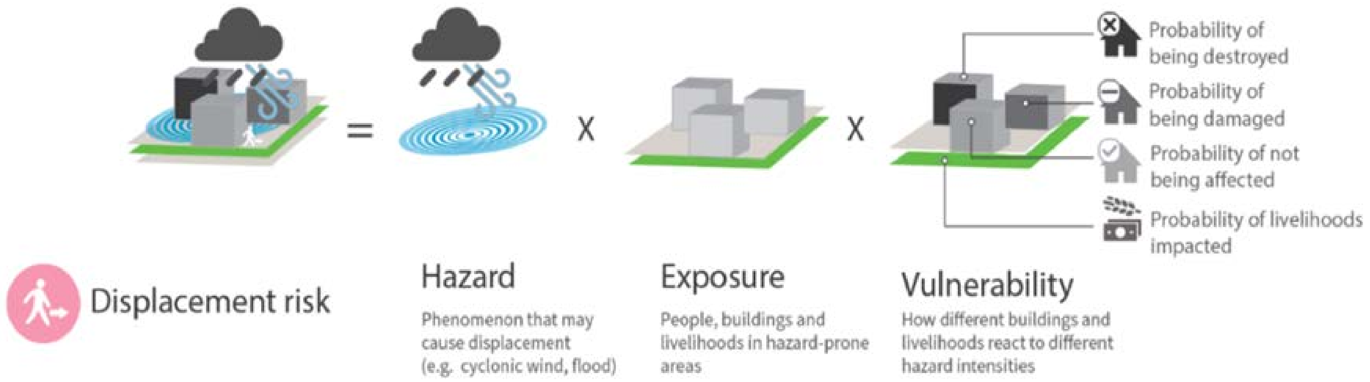
The PMD curve illustrates the probability of a specific scenario leading to an estimated number of displacements. This likelihood is usually measured in terms of return period, which is often misunderstood. A return period is the average time interval in years that separates two consecutive events equal to or exceeding the given magnitude. The most common misconception is that an event with a 100-year return period will only occur once a century, when instead it means that it has an exceedance probability of 1 in 100, so events of the same or greater intensity happen once every 100 years on average. This does not preclude the possibility of several events with a 100-year return period happening within a century, or even the rare chance of consecutive events transpiring in consecutive years. Neither does it eliminate the possibility of an entire century passing without such an event occurring.

Our model assesses the risk of severe housing damage or destruction, as well as the loss of livelihoods for certain hazards such as droughts and floods, to estimate the likelihood of displacement. In essence, it focuses on the risk of medium- to long-term displacement and does not account for or model pre-emptive evacuations. This means the figures presented here are highly conservative. Our approach looks at people who may suffer the consequences of their homes becoming uninhabitable and who are forced to be displaced for weeks, months, or even years.

Using the similar approach of “catastrophe Modeling” CAT assessing economic losses associated with disasters (Average Annual Loss -AAL- and Probable Maximum Loss -PML-), we “humanised” the approach by looking, instead of the monitory value of residential building, how many people lives in it, **to estimate the probability of people getting displaced**. Our outputs are presented under two main metrics: Average Annual Displacement (AAD) and Probable Maximum Displacement (PMD) for each hazard type and downscaled at admin 1 resolution (see section - *Making sense of displacement risk metrics*).

Displacement risk from the four hazards is estimated using two distinct risk modeling framework, one from CIMA foundation for riverine floods and CLIMADA for the other hazards, each of which estimates human displacement resulting from the interplay of the hazard, exposure, and vulnerability data. This consistency allows for a comparative analysis of outputs across models.

Figure 12: The displacement risk equation



Displacement risk from **riverine floods** is assessed using the risk model developed by CIMA foundation, while displacement from **tropical cyclones** (winds) and **coastal floods** (storm surge and sea level rise) is calculated using the Python implementation of CLIMADA under the Weather and Climate Risks at ETH Zürich. Drought-related displacement is modeled using an earlier version of CLIMADA, implemented in Matlab, by United Nations Universities - Institute for Environment and Human Security.

Hazards

River flood hazard maps were generated using a climate-hydrology-inundation framework with bias-corrected CMIP6 projections from 15 global climate models. The Continuum hydrological model simulated river discharge, which was processed through the REFLEX inundation model to produce flood hazard maps. A synthetic 3,000-year event catalogue was created to improve risk estimates. (CIMA foundation)

To capture the spread of possible climate scenarios, we compared 15 models from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP3b), which provides bias-corrected Coupled Model Intercomparison Project Phase 6 (CMIP6) climate scenarios for pre-industrial, historical, SSP1-RCP2.6, SSP3-RCP7.0 and SSP5-RCP8.5 conditions, in terms of temperature and precipitation rise in 2016. Temperature and precipitation trends proved to be highly correlated in the models considered, so we referred only to temperature trends to define representative scenarios, from which we selected, optimistic and pessimistic.

Coastal flood hazard maps were developed based on storm surges and sea-level rise (SLR) projections, considering future scenarios for 2050 and 2100 under SSP1-2.6 and SSP5-8.5. (Disaster Analytics for Society Lab - Nanyang Technological University - NTU Singapore)

Drought hazard conditions were analysed using the Standardized Precipitation Index (SPI_12), which measures long-term precipitation anomalies. Data from the Cordex dataset at a 0.22° resolution were used, incorporating RCP2.6 and RCP8.5 scenarios. Drought intensity and frequency were assessed for return periods of 10 to 100 years. (UNU-EHS – Climate Risk Analytics)

Tropical cyclone wind hazards. We used synthetic tropical cyclone event sets from the MIT model, downscaled from ERA-5 reanalysis data for historical periods and from nine GCMs for future climate scenarios (SSP2-4.5 and SSP5-8.5) for 2041–2060 and 2081–2100. Wind-driven impacts were modelled using the Holland (2008) parametric wind model, with maximum sustained wind speeds serving as the hazard intensity variable. Storm surge effects were categorized under coastal flooding, while rainfall impacts were excluded. (MIT - Weather and Climate Risks at ETH Zürich)

Exposure

We use the Global Building Exposure Model at 1km resolution globally to assess how different hazards impact communities and infrastructure. This model helps us understand which buildings and populations are most at risk from disasters like cyclones, floods, and droughts. By integrating high-resolution data on population, land use, and economic activity, we can better estimate potential displacement and improve disaster response planning. (The GIRI global building exposure model (BEM) - UNEP-GRID-Geneva-CDRI-IDMC).

Vulnerability

In hazard risk modelling, vulnerability is represented through impact functions, which estimate structural damage and displacement risk from hazards like tropical cyclones, floods, and droughts. We use CAPRA impact functions to assess building damage based on wind speed and flood depth, while a separate function estimates livelihood loss due to flooding in agricultural areas. (CAPRA - Comprehensive Approach to Probabilistic Risk Assessment: international initiative for risk management effectiveness and Rossi and al. A new methodology for probabilistic flood displacement risk assessment)

For drought-related displacement, our model considers economic, social, and environmental factors to refine risk estimates at national and subnational levels. This approach ensures a comprehensive understanding of displacement drivers and informs more effective resilience planning.

This risk assessment considers a large number of possible scenarios, their likelihood, and the resulting damage to housing, while also accounting for livelihood damages, mainly from medium- to large-scale events. Small and recurrent events still require daily monitoring of empirical information to understand and capture the true scale of displacement risk by different triggers.

For this iteration, we did not account for changes in exposure between current and future scenarios, although factors such as population growth and distribution—such as rapid urban sprawl reducing natural areas that absorb floodwater—may significantly alter the future "riskscape." However, for drought-related displacement, we explore potential changes in population distribution and dynamics over time using United Nations population projections for 2050 and 2100.

It is important to note that the results exclude individuals involved in pre-emptive evacuations. Our outputs focus on people at risk of medium- to long-term displacement, primarily due to severe damage to homes. For floods, we also explore the risk of loss of livelihoods, incorporating a complex process to avoid double-counting individuals who may experience both housing and livelihood loss in the same scenario. However, since droughts rarely damage built environments, we focus on how they impact agriculture, undermining livelihoods and forcing communities into displacement situation in search of alternatives.

Lastly, even with the use of more accurate exposure layers at a 1 km x 1 km resolution, the resolution of certain hazard datasets did not allow for proper subnational displacement risk assessments. The outputs should be viewed as tools to raise awareness and guide further discussions on disaster risk reduction investments centered on internal displacement. The model and its current resolution are not suitable for informing land use or urban planning decisions. Additional efforts are needed to develop more accurate and higher-resolution data on hazards and exposure, as well as customized vulnerability assessments that incorporate coping mechanisms from different regions within the country. This would enable the design of more detailed and effective measures to actively reduce displacement risk at the local level. Currently, the outputs are intended to support discussions at the national level.

IDMC has been working with numerous partners since the mid-2010s to put our data to use in estimating disaster displacement risk. Collaborating with diverse and respected partners allows us to use the most up-to-date data and methodologies for various components of displacement risk and apply strict scientific rigour and quality assurance in our models.

Our current consortium of partners includes the CIMA Foundation, ETH-Zurich's Weather and climate risk group, the Nanyang Technological University - NTU Singapore, the Potsdam Institute for Climate Impact Research (PIK), The United Nations University's Institute for Environment and Human Security (UNU-EHS).

A view of Talquezal, Chiquimula department, Guatemala. Steep terrain, deforestation and intense rainfall make rural areas highly exposed to landslides and floods, which have repeatedly triggered displacement. © UNOCHA/Vincent Tremeau.

Endnotes

1 UNFPA, https://www.unfpa.org/data/world-population/GT accessed on 18 September 2025

2 Banco de Guatemala, https://banguat.gob.gt/sites/default/files/banguat/Publica/guatemala_en_cifras_2024.pdf accessed on 18 September 2025

A coffee plant in Talquezal, Chiquimula department, Guatemala. Changing rainfall patterns and soil degradation threaten coffee and other crops across the country, heightening communities' vulnerability to displacement. © UNOCHA/Vincent Tremeau.

Every day, people flee conflict and disasters and become displaced inside their own countries. IDMC provides data and analysis and supports partners to identify and implement solutions to internal displacement.

Join us as we work to make real and lasting change for internally displaced people in the decade ahead.

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