risk profile

Sudden-Onset Hazards and the Risk of Future Displacement in Tonga

iDMC internal displacement monitoring centre

Destruction of villages on the island of Niuatoputapu in Tonga. © OCHA, 2009

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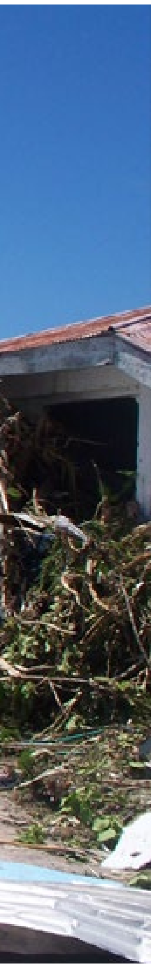


Cover image: Destruction of Hihifo, the main village on the island of Niuatoputapu in Tonga, after a tsunami generated by an 8.0 magnitude earthquake on 29 September 2009. Credit: Tevita Ofahulu © Tevita Ofahulu

Summary

Disaster displacement is one of the world's biggest humanitarian and sustainable development challenges, and climate change and urbanisation serve to aggravate the phenomenon.

IDMC has built upon the risk analysis developed by the United Nations Office for Disaster Risk Reduction to look at future displacement risk associated with sudden-onset hazards such as earthquakes, tsunamis, cyclonic winds and storm surges. The analysis considered a wide range of hazard scenarios, their likelihood and their potential to cause housing damage, which serves as a proxy for displacement. At this stage, our model's current resolution, however, did not enable us to assess the risk associated with riverine floods in small island states.

This technical paper presents the initial results of our efforts to assess the risk of displacement associated with disasters and climate change in Tonga. In addition of risk information, the paper looks more broadly at the social and demographic context, events from the past that triggered internal displacement and government initiatives linked to displacement and more generally to disaster risk reduction.

It examines risk levels and uncertainties for sudden-onset hazards by type to produce a baseline country risk profile via two national-level metrics:

- **Probable Maximum Displacement (PMD)** is the maximum displacement expected within a given time period, and determines outlier events that could occur during it.
- **Average Annual Displacement (AAD)** is a compact metric that represents the annualised accumulated effect of small to medium and extreme events and predicts the likely displacement associated with them on a yearly basis.

Cyclone winds represent Tonga's highest displacement risk. There is a 64 per cent probability that in the next 50 years about **21,400** people will be displaced as a result of cyclonic winds in the archipelago. This is the country's PMD.

About **1,229** people on average are likely to be displaced during any given year in the country by sudden-onset hazards, such as earthquakes, tsunamis and cyclonic winds. This is the **ADD** metric.

Displacement risk is determined by three factors:

1. **Hazard:** the likelihood of different hazards and their intensity
2. **Exposure:** the number of people and assets exposed to hazards
3. **Vulnerability**: the likelihood of exposed houses and buildings being damaged or destroyed

Our global disaster displacement risk model does not consider people's economic and social vulnerability. It covers only the physical aspect by looking at the extent of damage and destruction that hazards of different intensities are likely to cause.

The results it generates provide insight into future disaster scenarios, informing decision-makers in their efforts to reduce the risk of displacement and with it the number of people forced to flee their homes when hazards strike.

The inhabitants of small island developing states in the Pacific are among the world's most exposed to disasters relative to population size. At least 50,000 are at risk of being displaced each year. Almost all human settlements, major services and tourism infrastructure are located in coastal areas, and sudden-onset hazards such as cyclones and flooding pose severe social and economic risks.

This report is divided into four main parts:

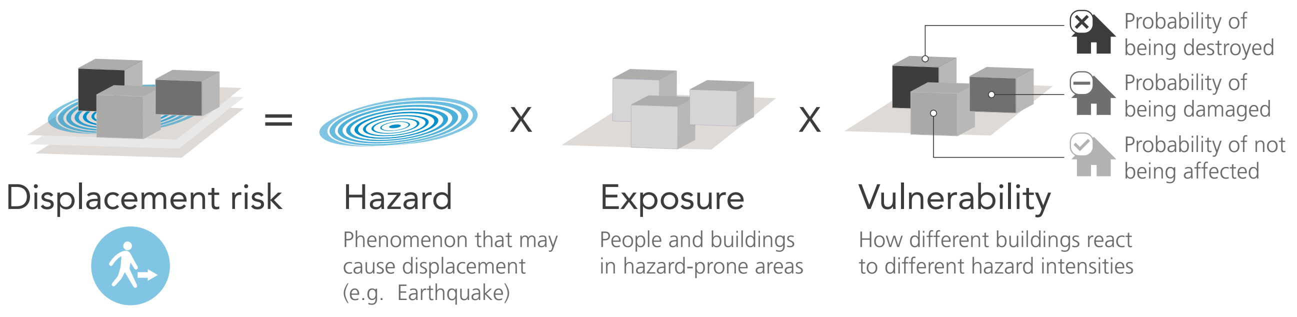
1. Background information on Tonga
2. A baseline for disaster displacement risk in the country
3. Moves toward risk-informed decision-making
4. Information on how our risk model was constructed, caveats and future improvements

What are disaster displacement and its associated risk?

Disaster displacement refers to "situations where people are forced to leave their homes or places of habitual residence as a result of a disaster or in order to avoid the impact of an immediate and foreseeable natural hazard. Such displacement results from the fact that affected persons are (i) exposed to (ii) a natural hazard in a situation where (iii) they are too vulnerable and lack the resilience to withstand the impacts of that hazard".[1]

Disaster risk refers to "the potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity".[2]

Figure 1: Displacement risk: How is it estimated?



Background information

Map 1: Tonga location map

Located to the east of Australia and north of New Zealand, the Kingdom of Tonga has more than 170 islands with a population of 103,000 and a total land mass of 748 square kilometres.

The capital, Nuku'alofa, on the island of Tongatapu, is home to about 70 per cent of the total population. The economy has a significant natural resource base, and GDP per capita is between $5,000 and $6,500. Tourism also makes up a substantial portion of the economy as does remittances from Tongans being employed overseas.[3] Coastal resources such as fisheries are also vital to Tongan livelihoods.

The climate of Tonga is generally categorized as oceanic tropical, with a warm season from December to April and a cooler season from May to November.[4] The wettest period is around February and March. The cyclone season in Tonga is from November to April. The peak time for tropical cyclones in Tonga, however, is from January to March with most events occurring in February. Climate change is expected to affect the country's coastal resources through higher marine temperatures and sea level rise. The country is also prone to El Niño-Southern Oscillation (ENSO) events, and infrastructure may be affected by an increase in the frequency and intensity of tropical storms and rainfall. During an El Niño event, rainfall in Tonga is highly variable from year to year. The country in an El Niño year can usually expect to experience two cyclones. El Niño is a natural occurrence and happens about every three to seven years on the archipelago.[5]

One element of our risk equation is the "exposure" of people and assets in a risk-prone area. Seventy-four per cent of Tonga's population were living in Tongatapu in 2016, in continuation of a trend in which an ever-greater share of the population lives on the main island. The proportion of Tonga's population that lived in Vava'u that year was 14 per cent, compared with six per cent for Ha'apai, five per cent for 'Eua and one per cent for Ongo Niua. These percentages are similar to what was observed in 2011. Locations with dense populations tend to have higher levels of risk. Therefore, risk and urbanisation are linked.[6] Rapid urbanisation, in Tonga but across all the pacific region, is also transforming relations to tenure security and undermining settlements' resilience to disasters.[7]

The latest census from 2016 reveals that 23 per cent of Tonga's population reside in the urban districts of Kolofo'ou, Kolomotu'a and Ma'ufanga, which together form the township of Nuku'alofa, Tongatapu. The urban-rural split in the population has remained stable since 2006.[8] The majority of Tonga's population lives at sea level on the coasts of the larger islands because the higher ground of the country is mountainous and ill-suited for habitation. Several people have already relocated inland or to other Tongan islands as rising seawater overtook their villages (see box 1). The rising sea and more frequent storms means that local infrastructure built at sea level must be rebuilt every year as roads and paths are washed away.[9]

Given that most of the population is situated in coastal areas exposed to cyclones and storm surges, disasters will not only have a human impact, but also an economic one. Fishery resources are critically important in the Pacific islands region as a source of food and employment, a generator of government revenue and a foundation for economic development.[10] More than 80 per cent of the population, both rural and urban, live in coastal areas where the vast majority of services, infrastructure and agricultural production are located.[11]

In many Small Island Developing States (SIDS), exposure to hazards is driven by the growing concentration of people and assets in low-lying coastal areas and the marginalisation of the urban poor in risk-prone areas. This also means disasters affect more urban dwellers with increasingly harmful consequences for employment, housing and critical infrastructure, such as roads, and power and water supplies.[12]

Many Pacific cities have expanded in recent years, with informal settlements on riverbanks, estuaries, and in peri-urban areas, as well as in waste disposal sites and mangrove swamps. This has increased people and assets' exposure and vulnerability to hazards, driving up the risk and potential impacts of displacement.[13] The sea level has risen by about six mm per year, well above the global average. This threatens subsistence agriculture and human habitation.

Tonga has experienced many disasters during the current and previous century. At least 4,650 people were rendered homeless and six killed in 1982 as a result of Cyclone Isaac.[14] The deadliest event occurred in 2009, claiming nine lives in Niuatoputapu, a flat coral island 500 km north of the main island of Tongatapu. The waves reached estimated heights of about six meters at Hihifo and Falehau.[15]

Tonga is situated close to the Tonga Trench, which is 10 km deep at its lowest point. More than 65 per cent of the world's deepest earthquakes happen there.[16] Several earthquakes with a magnitude higher than 7 on the Richter scale have occurred around Tonga, generating tremors and damage. One of the most destructive was the 1977 Tonga earthquake, which measured 8 on the Richter scale.

Box 1: Government initiatives and community relocations in Tonga

Tonga has suffered acutely from coastal erosion and sea-level rise related to climate change over the last decades.[17] The country's higher ground is volcanic and unsuitable for human habitation.[18] The majority of its population, however, lives in low-lying areas on the coasts of the larger islands, and there have been several cases of relocation. There is no law or policy for managing disaster displacement in Tonga.

The earliest documented relocation in the country dates back to 1946 when a massive volcanic eruption at Niuafo'ou and the destruction of a large share of the village prompted the relocation of all 2,500 inhabitants to 'Eua island. This was organised by national and local authorities, following a vote. Relocated communities were offered land on 'Eua. About 700 people returned a few years later to Niuafo'ou, while the remaining 1,800 stayed on 'Eua.[19]

More recently, in 2006, communities from Hihifo district on the western coast of Lifuka island were relocated by the government after a 7.9 earthquake struck the country in May of that year. There were no direct, significant damages from the disaster, but it caused Lifuka to sink by 23 cm, causing instant sea-level rise. Four years later, 20 meters of land where those communities had once lived had been submerged under the sea.[20]

Another resettlement occurred on Niuatoputapu after the 2009 earthquake and subsequent tsunami, that also struck Samoa and Niue. About 68 families were voluntarily relocated to higher ground on the southern part of the island, as was a hospital.[21]

Following these relocations, the country during the last decade implemented resettlement schemes, progressively recognising and administering relocations to respond to climate change and disaster threats. As early as 2005, an official government communication mentions farm relocation as a solution to sea level rise and the risk of farmland flooding.[22] It does not, however, refer to the relocation of communities and infrastructure.

Only after Tropical Cyclone Ian hit the country in January 2014, leading to the forced evacuation of about 3,000 people on Ha'apai island, did the government start considering community relocation as a potential national policy to mitigate disaster risks.[23] A few months later, the **Ha'apai Housing Recovery and Reconstruction Policy** was developed to facilitate the mobilisation of reconstruction support from the World Bank.[24] The policy referred to the need for specific households to relocate because of environmental risks and led to the relocation of public infrastructure to safer ground. This included the Niu'ui Hospital that was relocated to the highest point of the island at the end of 2019 with the help of the Asian Development Bank.[25] Unfortunately, the policy did not stipulate what conditions a place would need to be suitable for relocations.[26]

To push this initiative at the national level, the Ministry of Infrastructure released in 2017 a **Resettlement Policy Framework** developed under the Cyclone Reconstruction and Climate Resilience Project. This included operational guidelines that set out key principles for resettlement planning and implementation. It also emphasized housing replacement on existing sites and allotments, whenever possible.[27]

These guidelines are backed by the country's broader **Climate Change Policy**, which was released in 2016 and promotes the implementation of the recovery and adaptation measures. The policy does not refer to displacement or migration. It does, however, suggest investigating alternative sites for possible settlement relocation from low-lying areas at risk from climate change impacts to protect people, resources and assets.[28]

As a result of plate tectonics, the islands of Tonga are being pushed out of the ocean. In the last hundred years, there have been eruptions at as many as 15 large volcanoes on land. Many more volcanoes have erupted at sea. Several of the submarine volcanoes have risen out of the ocean in just the last ten to 15 years.[29] An undersea eruption at Lateiki Island in late October 2019 has brought new life in the Tonga chain.

Disaster displacement in Tonga: historical trends (2008-2020)

Disasters have triggered about 18,000 displacements in Tonga since IDMC began systematically monitoring data on the phenomenon in 2008. IDMC has detected seven disaster displacement events related to weather, such as storms and floods.

The data on new displacements presented in table 1 corresponds to the estimated number of internal displacement movements that have taken place as the result of an event. Summed up by years or decades, the numbers could include individuals who have been displaced more than once. In this sense, the number of new displacements is not equal to the number of people displaced during a year.

A large number of displacements in Tonga have been triggered by weather-related events. Storms, especially cyclones, are the main triggers of displacement. On April 9 2020, TC Harold started impacting Kingdom of Tonga. Strong winds and storms were felt across Tongatapu, 'Eua, Ha'apai and Vava'u. Sea surge and heavy damaging swell combined with King tide impacted most of the coastal areas. Around 2,700 were sheltered in evacuation centers.[30] In 2018, Tropical Cyclone Gita, the worst cyclone to hit the country in 60 years, led to widespread destruction after striking on 12 February and generated one third of the displacement recorded in the country during the decade (see Box2). There were reports of significant damage on both Tongatapu and 'Eua. The storm affected close to 80,000 people, or about 80 per cent of the country's population, destroyed more than 800 houses and damaged an additional 4,000.[31]

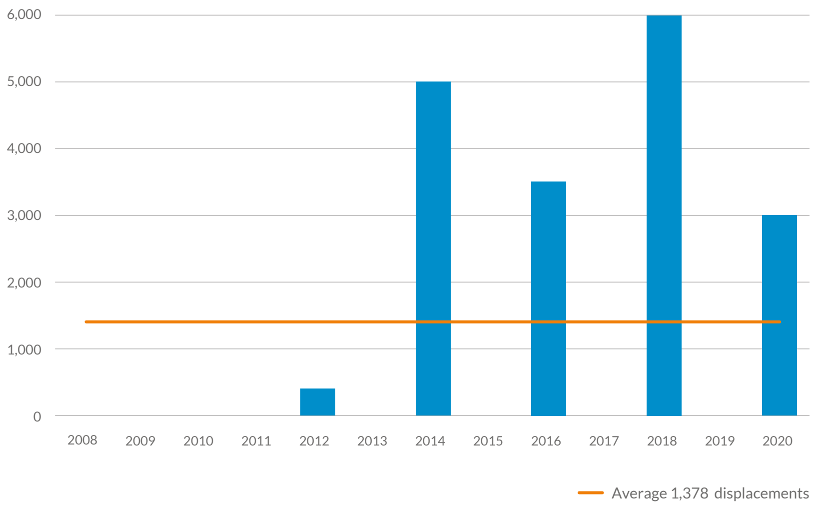
Box 2: The Urban – Rural impact of Tropical Gita

On 12 February 2018, TC Gita, a category 4 event, made landfall on the Tongan island groups of Tongatapu and 'Eua shortly after the country declared a state of emergency. Tongatapu hosts two-thirds of the total population and the country's capital city and main urban centre, Nuku'alofa, which was struck by the strongest part of the storm's eye. The cyclone was the most powerful storm in the country's known history, with average wind speeds of 195 km/hour.[32] Around 4,500 people were sheltered in about 111 evacuation centers. Some more were hosted by friends and families.[33]

Fifteen per cent of the people in the capital city were estimated to live in poverty prior to the cyclone, and half of the population on 'Eua could not afford a basic basket of goods in 2016. The direct and indirect effects of the cyclone were significant, worsening the quality of life and affecting livelihoods. Losses to the economy amounted to about $164 million, the equivalent of nearly 38 per cent of Tonga's GDP. The housing sector was significantly affected, leading to the displacement of five per cent of the population on Tongatapu. On 'Eua, 56% of housing stock was either destroyed or damaged. Damages to the housing sector represented 53 per cent of the total damages to the economy.[34]

Since the cyclone, 17 new houses have been built under the government's Cyclone Gita Recovery Project, which sought to speed construction to enable more families to relocate.[35] The six most recently built houses were constructed on the same islands hit by Gita, namely 'Eua and Tongatapu.

Figure 2: New disaster displacements in Tonga [2008-2020]



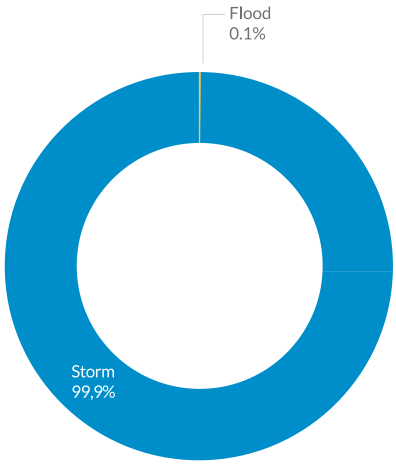


Table 1: Historical displacement events in Tonga 2008-2020

Year	Event Name	Hazard Type	New Displacements
2012		Storm	400
2013		Flood	17
2014	Tropical cyclone Ian	Storm	5,306
2016	Tropical Cyclone Ula	Storm	500
2016	Tropical cyclone Winston	Storm	2,500
2018	American Samoa, New Zealand, Samoa, Tonga: Tropical Cyclone GITA - 9/2/2018	Storm	5,700
2020	Vanuatu, Solomon Islands, Fiji, Tonga: Tropical Cyclone Harold - 01/04/2020	Storm	3,000

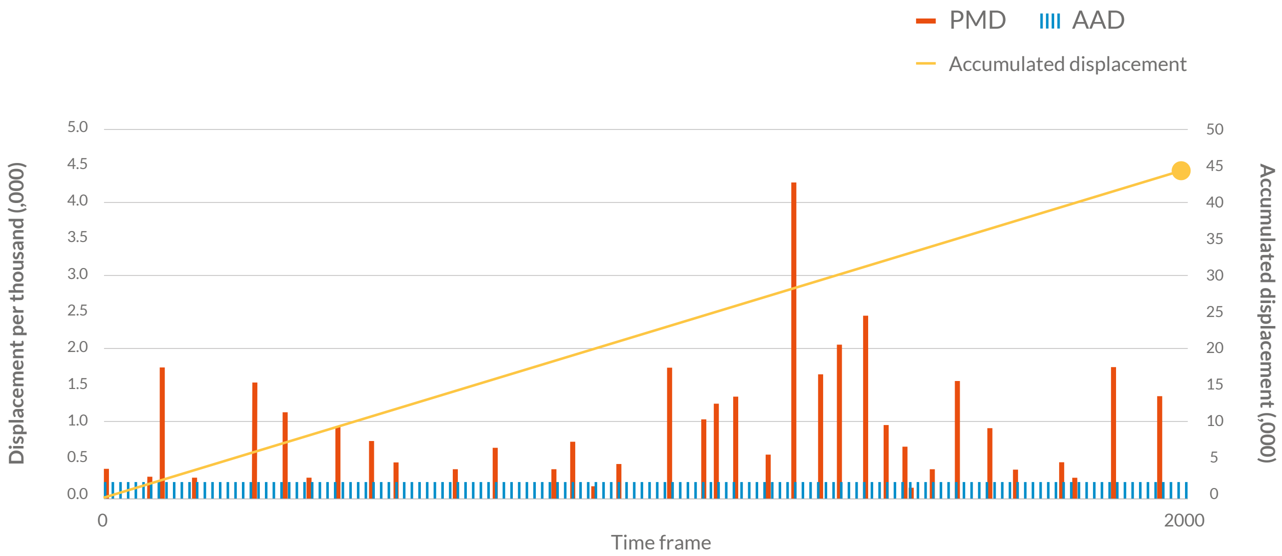
Disaster displacement risk in Tonga

The baseline established by our global disaster displacement risk model presents results at the national level and provides insight into future displacement situations. This analysis of future displacement risk associated with sudden- onset hazards, including earthquakes, tsunamis, storm surges and cyclonic winds, considers a large number of possible hazard scenarios, their likelihood, and the potential damages to housing, which is used as a proxy for displacement.

Displacement risk: two key metrics and how to read them

Our multi-hazard Global Disaster Displacement Risk Model provides two metrics at the national level: the **Average Annual Displacement (AAD)** by hazard and the **Probable Maximum Displacement (PMD)** by hazard. Because these metrics are based on a global model, the granularity of the data is low and estimates should be considered conservative.

Figure 3: How we calculate Probable Maximum Displacement (PMD) and Average Annual Displacement (AAD) by hazard



Source: UNDRR, 2015

Box 3: The concept of risk return periods

The concept of return period is often misunderstood. If a disaster or displacement event has a 500-year return period, that does not mean it will only occur once every 500 years. Nor does it mean that if it occurred today, it would not recur for another 500 years. Rather, it means that it happens once every 500 years on average. If there were four extreme events in the space of a century followed by 19 centuries without any, the return period would still be 500 years.[36]

The longer an event's return period, the less likely it is to occur in any single year. It is also possible for an event with a 500-year return period not to occur at all over five centuries. The most common misconception is that a 100-year flood will only occur once per century. That is not true. There is a small probability that such an intense event could happen every year. If a 100-year flood happened last year, it can happen again before the next century, or even this year. It is also possible for such an event to not occur within a 100-year period.

That said, Houston in Texas experienced 500-year floods for three years in a row between 2015 and 2017, the last one caused by hurricane Harvey. This prompted the city's authorities to revise zoning regulations to account for changes in the flood drainage basins around it.

We expect to see many similar revisions as climate change alters the frequency and intensity of extreme events, and rapid urban sprawl shrinks the natural areas available to absorb floodwater.[37]

The model considers the likelihood of different hazards, as well as their intensity, to estimate the number of people that could be forced to flee from their habitual place of residence as a result of severe damage or destruction that could render housing uninhabitable. Many factors, including insurance penetration and coverage, coping capacity, humanitarian responses and recovery efforts, also influence the duration and severity of displacement.

Probable Maximum Displacement (PMD) by hazard

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.

A hundred years does not mean it will occur every 100 years (see Table 2). There is a common misconception that an event with a 100-year return period will only occur once a century, but that is not the case (see Box 3). There is a small probability that such an intense event could happen much more frequently. PMD for different return periods is best expressed as the probability of a given amount of displacement being exceeded over different periods of time.

Even in the case of a 1,000-year return period, there is a five per cent probability of PMD being exceeded over a 50-year time frame. This metric is relevant to planners and designers of infrastructure projects because investments are often made with an expected lifespan of 50 years.

Average Annual Displacement (AAD) per hazard and multi-hazards

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.

Multi-hazard AAD is calculated by aggregating the figures of each hazard type. This metric encompasses the probability that cyclonic winds and storm surges could destroy one single house, and could be double "counted" when calculating multi-hazard AAD. The probability that double severe damages occur is not nil.

Results - Displacement risk by hazard

As described above, AAD represents the annualized accumulated effect of all the catalogue events. It is a compact metric which accounts for the probable displacement of small to medium and extreme events.

Our Global Disaster Displacement Risk Model highlights that about 1,229 people could be displaced in Tonga in any given year of the future. This is the AAD (see Table 3).

Total: 1,229

EARTHQUAKE

168

CYCLONIC WIND

1,051

TSUNAMI

10

Table 2: Concept of probabilities for different return periods

Return period (years)	Probability of displacement exceedance per year	Probability of displacement exceedance in 20-year timeframe	Probability of displacement exceedance in 50-year timeframe
25	4.0%	56%	87%
50	2.0%	33%	64%
100	1.0%	18%	39%
250	0.4%	8%	18%
500	0.2%	4%	10%
1,000	0.1%	2%	5%

Table 3: Displacement risk by hazard in Tonga

		Return Period in years						
Hazard	ADD	PMD 10	25	50	100	250	500	1,000
Storm Surge								
Cyclonic Wind	1,051	1,300	5,300	21,400	29,000		49,000	
Earthquake	168	250	1,000	1,700	3,000	5,400	9,200	13,000
Tsunami	10				6	48	450	1,800

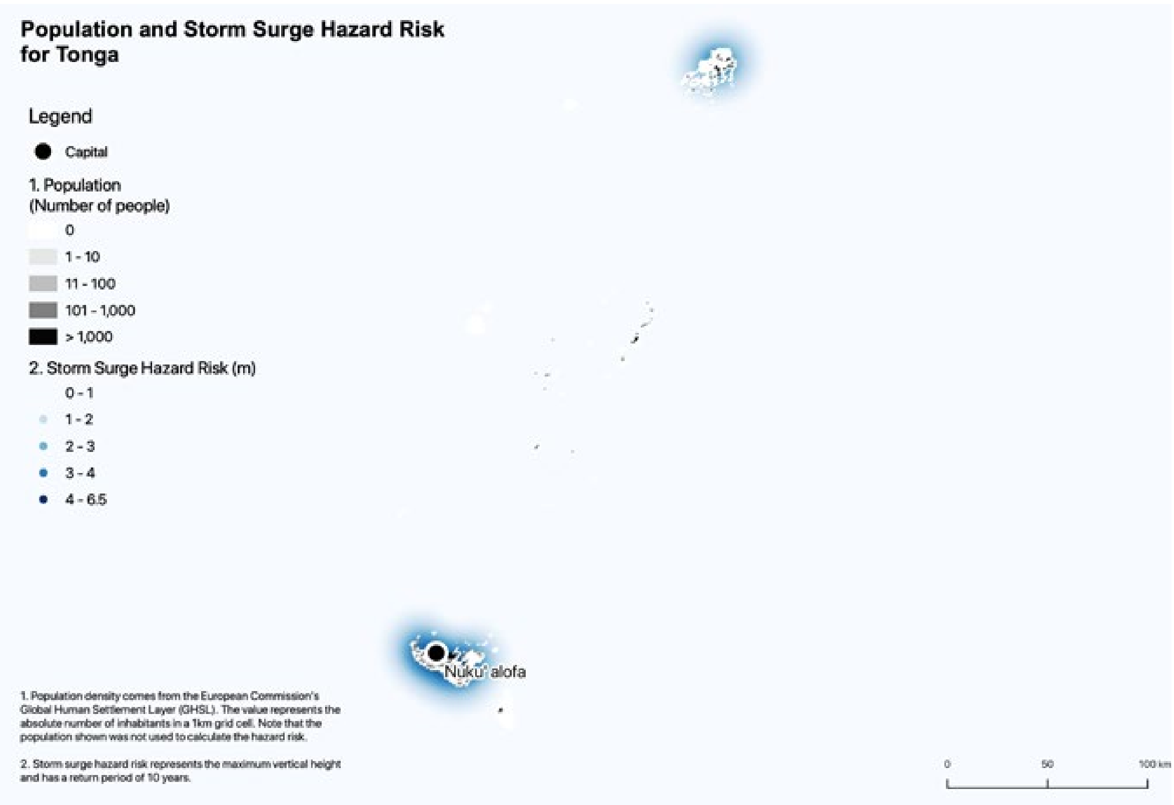
While the AAD is useful for providing a sense of the scale of the annual risk of displacement, it tends to hide potential outliers. High intensity but low frequency events could take place in extremely long spans of time, leading to mass displacement. A category 5 cyclone or a 6.5-magnitude earthquake, for instance, could strike Tonga unexpectedly and cause significant displacement. While such extreme events may not have occurred since record keeping began, they can still occur, and it is important that the country be prepared for them. Cyclones Ian and Gita are examples of disaster at an unprecedented level.

The model for Tonga considers the likelihood of different hazards, as well as their maximum intensity at different return periods (see table 3). The estimate of risk displacement is explained in each hazard section, above). This national level resolution is based on the observations and data at the global level. It provides multi-hazard risk metrics and enables comparisons of risk levels between countries and regions across hazards types. At this scale, the estimates should therefore be considered conservative.

Risk of displacement as a result of storm surges

As a cyclone moves across the Pacific Ocean, its winds push the water into a wall as it moves onshore. The impacts will depend on the coast's topography and the tides. The risk of displacement enters uncharted territory even with king tides, which occur when extreme weather events coincide with uncommonly high tides caused by the alignment of solar and lunar gravitational pulls.[38]

Map 2: Storm surge risk map



While IDMC currently does not have data to calculate displacement risk, the impact of storm surges still exists. For example, severe flooding occurred during Tropical Cyclone Isaac in March 1982. On Tongatapu, the passage of the storm coincided with a high spring tide, resulting in sea level rise about 1.40 m above normal.

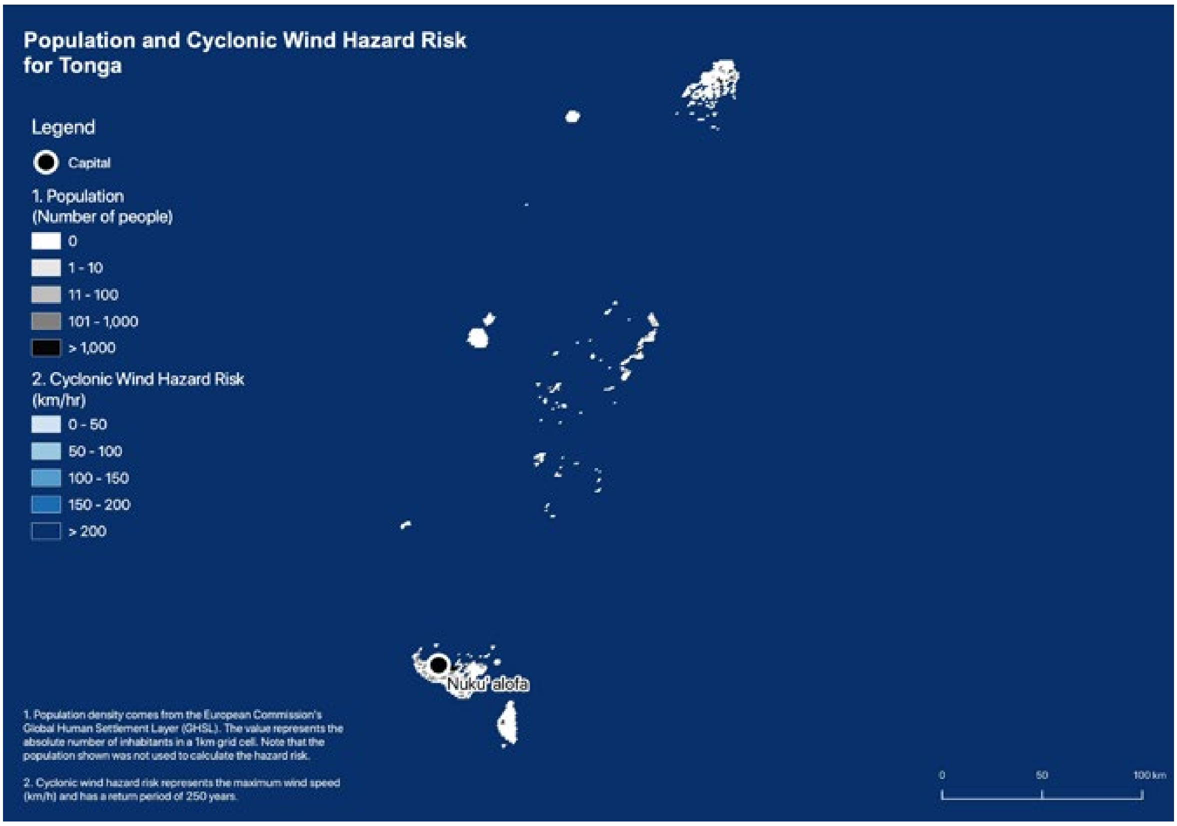
Risk of displacement as a result of cyclonic winds

Cyclonic winds risk in Tonga is very high. The country is located to the south of the equator in an area called the South Pacific Convergence Zone. This is known for the frequent occurrence of tropical cyclones.

Cyclones are like giant engines that use warm and moist air as fuel. That is why they only form over warm ocean waters near the equator. In the South Pacific Convergence Zone, they remain strong for a longer time because they do not face large land masses that would isolate them from the moisture and heat of tropical ocean water and slow them down with greater friction than exists on the sea surface.[39]

On average 1,051 people are expected to be displaced per year considering all the events that could occur over the return period. Surrounded by ocean, the archipelago of Tonga could experience wind speeds greater than 230-240km/h. There is a 64 per cent probability that in the next 50 years about 21,400 people will become displaced by cyclonic winds. That is the probable maximum displacement.

Map 3: Cyclonic wind risk map



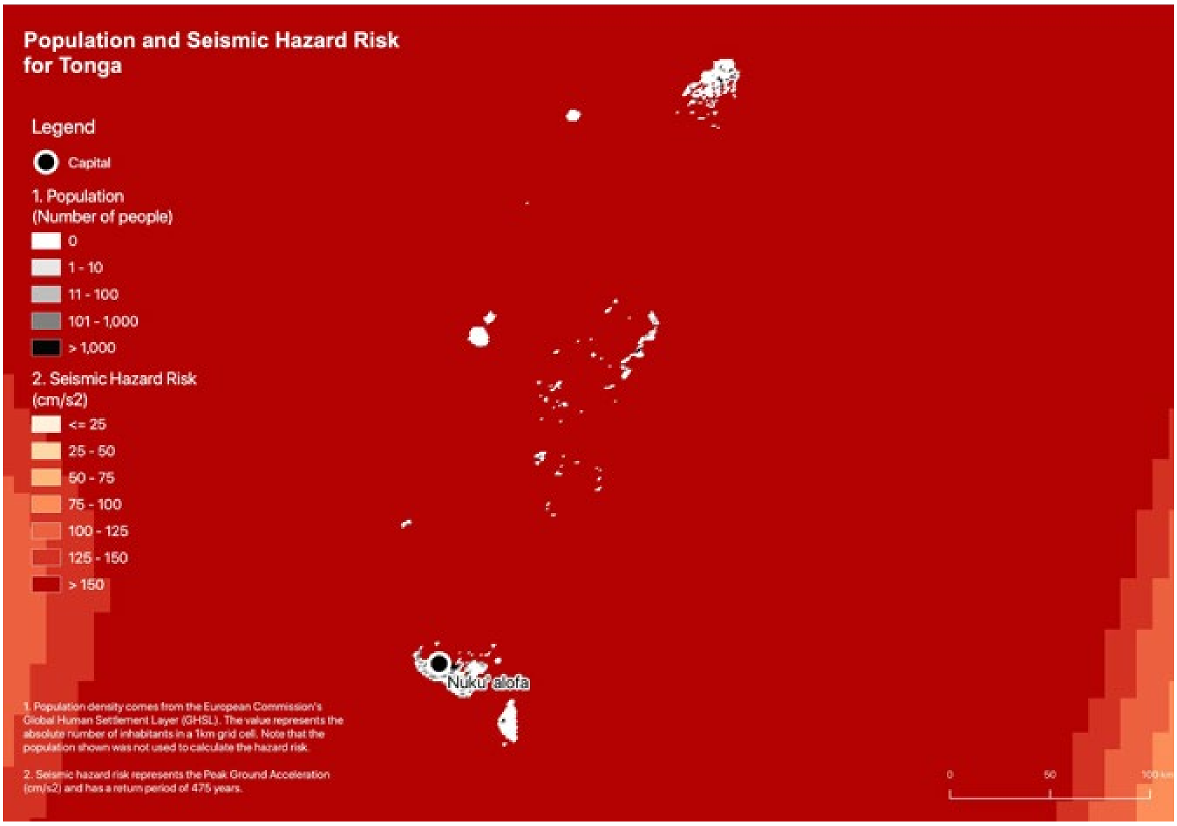
Risk of displacement as a result of earthquakes

Earthquake risk in Tonga is high around the archipelago, which could also experience intense tremors in coming years. The archipelago is located in a seismically active area, the Tonga Trench - a subduction zone known as Tonga – Kermadec, where the Pacific and Australian tectonic plates in the south-western Pacific converge.[40] The Fiji-Tonga region accounts for about 70 per cent of the world's earthquakes with depths greater than 400 kilometres.[41]

On average 168 people are expected to be displaced per year given all the events that could occur over the return period. When it comes to the probable maximum displacement, there is a 39 per cent probability that in the next 50 years about 3,000 people will be displaced by an earthquake in the archipelago.

The map below highlights earthquake intensity zones and indicates where there is a 10 per cent probability that degrees of intensity will be exceeded in 50 years.

Map 4: Seismic hazard risk map

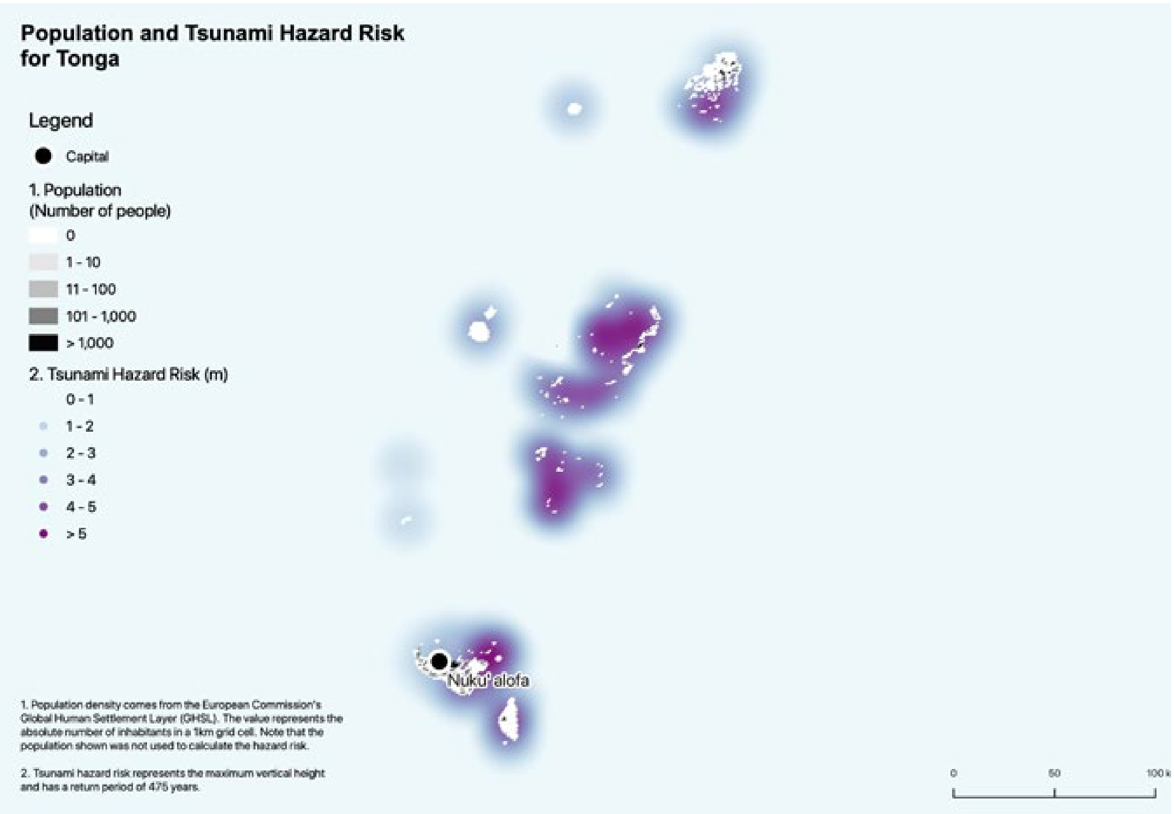


Risk of displacement as a result of tsunamis

The archipelago of Tonga is particularly vulnerable to tsunamis. During a tsunami, waves push a large amount of water above sea level onto the shore. This is known as the run-up, the maximum vertical height above sea level reached by a tsunami onshore. In Tonga, this is estimated to be around five to eight meters for most of the coastal areas at risk. The highest estimated risk is in the Ha'apai island group where waves could rise to more than ten meters. While the archipelago of Tonga is "protected" by coral reefs that can dissipate wave energy, the islands can suffer considerable damage from smaller waves, and the effect can be greatly enhanced by high or king tides.

The most damaging tsunami in Tonga was in 2009. It claimed nine lives in Niuatoputapu and inundated 46 per cent of the land area. The flow height of the tsunami reached a maximum of 16.9 m above mean sea level at Toma, on the southeast coast of Niuatoputapu. Flow heights were typically between eight and 15 m along the eastern, uninhabited coastline of Niuatoputapu and decreased by about half, to between four and seven m above mean sea level along the western, inhabited coastline.[42] Sixty per cent of homes were destroyed and about 850 people made homeless on the island.[43]

Map 5: Tsunami risk map



'Coastal Resilience Project - Tonga' © UNDP, February 2017

Tonga, April 2020: In the aftermath of TC Harold. Three teams from Tonga Red Cross were deployed into different communities to conduct initial damage assessments. ©Tonga Red Cross

Toward risk-informed decision making

Disasters have triggered about 290 million displacements around the world since we began collecting data on the phenomenon in 2008. This is more than three times the figure for conflict and violence displacements. Given its scale, the need to address the risk of disaster displacement has been explicitly recognised in global policy agendas on disaster risk reduction and climate change. The UNFCCC's Warsaw International Mechanism on Loss and Damage associated with Climate Change Impacts has established a task force on displacement, which recognises the need to "avert, minimise and address displacement related to the adverse impacts of climate change".[44]

Global agreements on disaster risk reduction, such as the Hyogo Framework for Action 2005–2015 and the Sendai Framework for Disaster Risk Reduction 2015–2030, have promoted and significantly increased efforts to reduce disaster risk in general. The Sendai framework recognises the importance of addressing displacement risk in particular.[45]

Despite these advances, the number of disaster displacements is likely to increase in the future. Weather-related hazards account for more than 87 per cent of all those recorded to date, and climate change and the increasing concentration of populations in exposed areas mean that ever more people are at risk.

People displaced by disasters face similar challenges to those who flee conflict and violence. Many lose their homes, assets and income. They face insecurity, reduced access to water, food and services such as healthcare and education, and disrupted social networks.

Our data shows that internal displacement is on the rise globally. Addressing the phenomenon will require significant humanitarian and development measures, but resources are becoming increasingly stretched to service a growing number of priorities. This calls for a new and more comprehensive approach to mitigate and reduce the risk of medium and long-term displacement.

Why do we need to understand risks?

Monitoring disaster displacement typically means accounting for the number of people displaced or homes destroyed after a disaster occurs. This information provides a baseline to inform emergency responses and disaster management. Retrospective analysis, however, is only one element of informed planning and decision making, particularly when it comes to mitigation and prevention. It should be complemented with probabilistic analyses and metrics, such as those presented in this report.

As the UN Office for Disaster Risk Reduction (UNDRR) has emphasised: "Catastrophic earthquakes or tsunamis may only happen every 500 or 1,000 years in any given place. As such, even though records may go back centuries, most of the extreme events that could potentially occur have not happened yet.

Box 4: Risk definition

/rɪsk/

The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity (*UNDRR – 2017).* Risk is the possibility of something bad happening.

Ketahi beach. A resort was built here a few years back, but a cyclone destroyed it right before it opened.
© Tobze, August 2010

And, although data on disaster loss provides a guide to the past, it is insufficient to predict and estimate damages that may occur at present and in the future."

The risk of future displacement is determined by the way in which policies and processes influence peoples' exposure and vulnerability to hazards, and many governments and operational stakeholders recognise the need to understand the issue (see Box4). Demand for models and tools to estimate its potential scale and severity is growing, but developing and improving them takes time.

Estimating displacement risk using probabilistic approaches requires highly localised and detailed information. Many governments, however, lack the data needed to validate models and conduct comprehensive quantitative assessments. More capacity building is needed before they will be able to adapt models to their own needs and apply the results to policy development and investment planning.

Investments should be made in understanding disaster risk in all its dimensions: the exposure and vulnerability of people and assets, hazard characteristics, response capacity and environmental factors. Such understanding would also inform preparedness measures and effective responses that build back better.

The initial results from our probabilistic model provide useful baselines for policymakers working to implement the Sendai framework, the Paris Agreement of the UN Framework Convention on Climate Change (UNFCCC), the Warsaw International Mechanism and the Agenda for Humanity.

Methodological considerations and caveats

IDMC's Global Disaster Displacement Risk Model

We began a unique probabilistic modelling exercise in 2017 with our global disaster displacement risk model, which assesses the likelihood of such population movements in the future.

Since 2011 the UN Office for Disaster Risk Reduction (UNDRR), has rigorously analysed the risk of economic losses due to disasters risks in its Global Assessment Report (GAR).[46] One critical gap, however, concerns evidence and analysis of the risk of disaster-related displacement, a problem which hinders the effective reduction of both displacement and disaster risk.

This risk profile for Tonga lays the groundwork for addressing this gap. It presents the first results generated by IDMC's global disaster displacement risk model in 2017, which builds upon and extends the analysis presented in the GARs.[47]

The model's results can be used to inform national and sub-national disaster risk reduction (DRR) measures, identify areas where large numbers of people could be made homelessness by disasters, and calculate evacuation-centre capacities and the amount of investment needed to support displaced people.

In short, they allow decision makers to make risk-informed efforts to prevent displacement happening in the first place and reduce its impacts when it does occur.

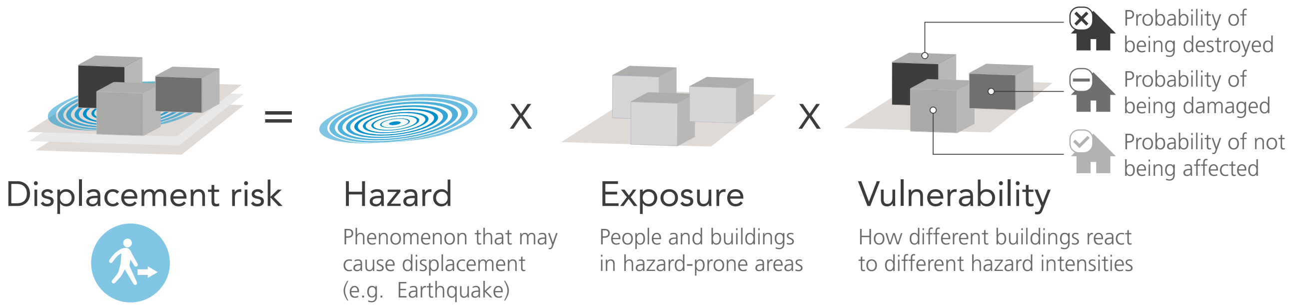
The model can be adapted to support operations in real time by indicating the number and location of homes severely damaged or destroyed by observed and forecasted hazards. This has the potential to make responses more timely and better targeted and ultimately save lives. It also provides a benchmark for measuring progress toward DRR and climate change policy objectives.

Our Displacement risk model is determined by three factors:

1. **Hazard:** the likelihood of different hazards and their intensity
2. **Exposure:** the number of people and assets exposed to hazards
3. **Vulnerability**: the likelihood of exposed buildings being damaged or destroyed

The model does not consider people's economic and social vulnerability. It covers only the physical aspect by looking at the extent of damage and destruction that hazards of different intensities are likely to cause (see figure 4).

Figure 4: Displacement risk: How is it estimated?



The model does not account for pre-emptive evacuations, which means its estimates are inherently conservative. In countries with strong disaster preparedness capacity where such evacuations occur, such as Bangladesh, China, Cuba, Japan and Viet Nam, it underestimates the number of reported displacements significantly. In countries with weaker capacity, and for hazards such as earthquakes for which early warning systems are limited, historical data and the model's estimates are a closer fit.

What about displacement risk associated with slow-onset hazards?

Our global model only considers displacement risk associated with sudden-onset hazards. It is also possible to consider slow-onset phenomena such as drought, desertification, sea level rise and coastal erosion. We have, for example, modelled drought displacement risk in the Horn of Africa.[48]

Such complex exercises, however, need to take many human factors into consideration. They are time-consuming and require historical data on various indicators to validate and generate confidence in the results. We do not yet have such a model for countries in the Pacific, but we would be willing to develop one if there were interest and the resources to do so.

Caveats and future improvements

This risk assessment considers a large number of possible scenarios, their likelihood, and associated damages to housing. Our risk model is informed by and relates to medium to large-scale events, but small and recurrent events still require the daily monitoring of empirical information to understand the true historical scale of displacement.

The results are a probabilistic indication of the potential impact of events, but underlying limitations and simplifications mean the figures for individual events and the calculated impacts on particular assets are unlikely to be precise.

Our global model, presenting results at a national level, aims to provide insight into future displacement situations. It allows decision-makers to take risk-informed decisions that can help prevent and reduce the risk of displacement before it happens. The model calculates how many people will be displaced on average every year by sudden-onset hazards, (earthquakes, tsunamis, floods, cyclonic winds and storm surges). Results are based on the likelihood of housing destruction and show that, globally, 14 million people on average could be displaced in any given year. The model also calculates the probable maximum displacement (PMD) that could be expected within a given return period. (See section Two key metrics and how to read them).

The displacement risk metrics were developed at the global level and so have low granularity, but they are still a useful baseline and guide. The model has analysed more the 4.5 million cells containing proxies for exposed assets and people at a resolution of five square kilometres, and one square kilometre along the coast. Millions of hazard scenarios have also been compiled. The resolution used in 2017, however, did not allow us to run a proper risk assessment for riverine floods in small island states. Nor is its current resolution suitable for informing land use and urban planning decisions.

The model excludes displacements associated with pre-emptive evacuations. This information must be collected in the aftermath of disasters. Where no specific indicators exist to monitor disaster displacement, states could report on other indicators established by the Sendai framework and the Sustainable Development Goals (SDGs) without duplication of effort. Target B of the Sendai framework, for example, includes the "number of directly affected people attributed to disasters". It is linked to SDG targets 1.5, 11.5 and 13.1, which refer to monitoring and reporting on the "number of people whose destroyed dwellings were attributed to disasters". Sendai's target G and particularly G-6 could be also monitored using data on pre-emptive evacuations. These indicators could help to calibrate the next improvements of displacement risk models.

We are working closely with the Swiss Federal Institute of Technology in Zurich (ETHZ), Oxford University and other partners to improve the model's ability to predict displacement risk for sudden-onset hazards, including floods in small island states. Increasing the resolution of the exposure layer from five square kilometres to one allows for a more granular assessment of the people and assets exposed.[49]

This, coupled with a rerun of hazard scenarios using the latest technologies, has produced a more accurate estimate that suggests the number of people at risk of displacement from all hazards is significantly higher than previously thought. Better resolution also allowed the disaggregation of displacement risk figures by urban and rural locations.

Tonga, April 2020: Distributions of root crops to areas of Patangata that were most affected by Tropical Cyclone Harold. © Tonga Red Cross

Destruction of Hihifo, the main village on the island of Niuatoputapu in Tonga, after a tsunami generated by an 8.0 magnitude earthquake on 29 September 2009. © Tevita Ofahulu

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Acknowledgement:

With funding from the European Union, the Internal Displacement Monitoring Centre (IDMC) is collaborating with the International Organization for Migration (IOM) and the Platform on Disaster Displacement (PDD) to generate new evidence to help governments better understand, plan for, prevent and respond to disaster displacement in the Pacific region. The project will contribute to better policy responses, planning and operational tools.

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We would like to extend our gratitude to the Tonga National Disaster Management Office (NDMO) and the International Organisation for Migration (IOM) for reviewing and providing valuable contextual information on displacement to inform this baseline report.

Editors: Steven Ambrus, Steven Kelly, Jeremy Lennard.

Design and layout: Vivcie Bendo.

International Organization for Migration (IOM)
The UN Migration Agency

PLATFORM
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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.

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