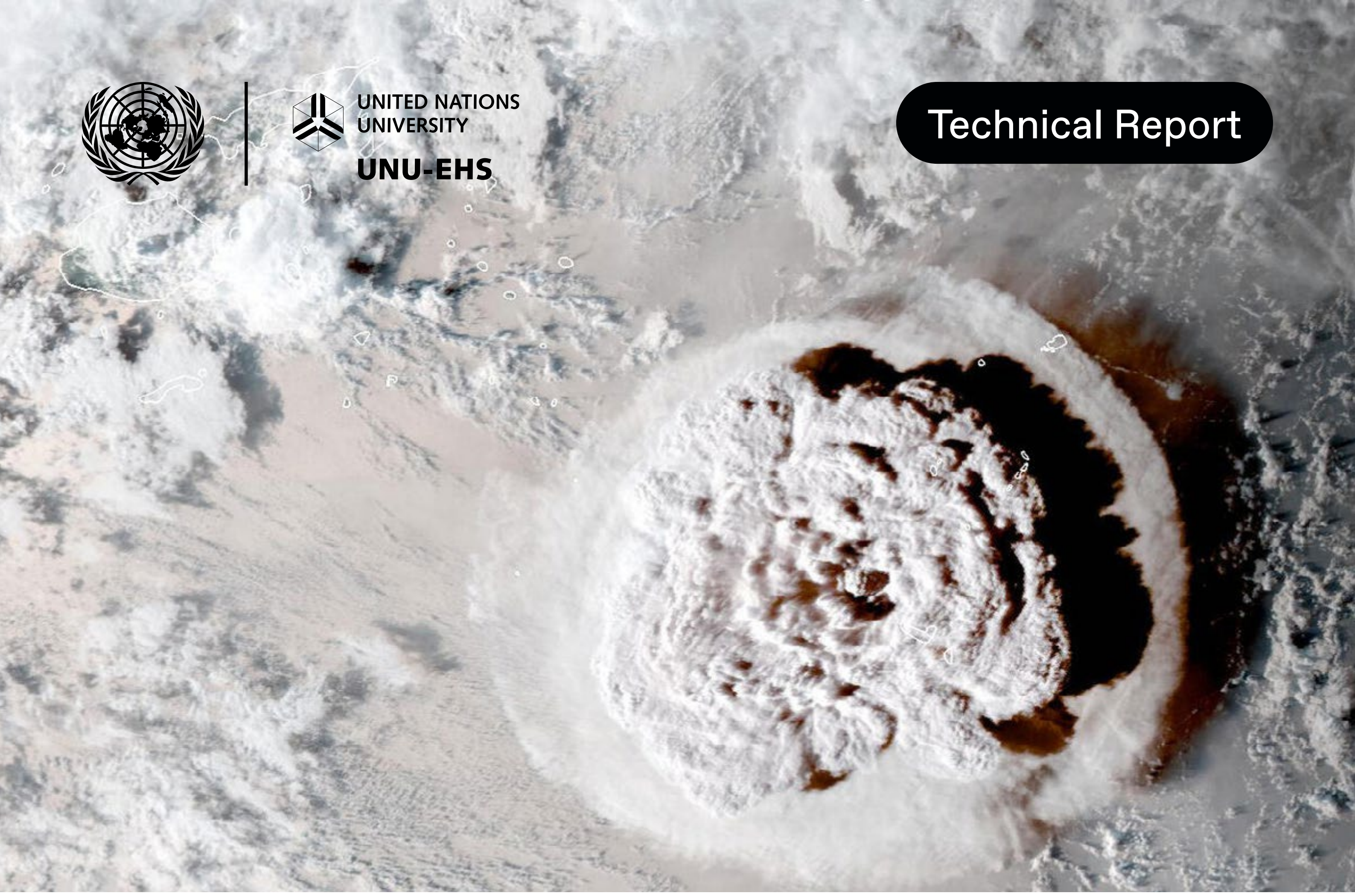

UNITED NATIONS UNIVERSITY
UNU-EHS

Technical Report

Tonga volcano eruption

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2021/2022

Interconnected Disaster Risks

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1. Introduction

On 15 January 2022, a violent eruption of the "Hunga Tonga-Hunga Ha'apai" submarine volcano sent a plume of ash half the size of France into the upper atmosphere. The powerful "Big Bang" triggered a tsunami and shock waves that were felt across the Pacific Ocean and beyond. Comparing with historic seismic records, this eruption is considered the largest and most explosive one of the twenty-first century. It released mechanical energy equivalent to hundreds of the Hiroshima nuclear explosion (Voiland, 2022), and generated supersonic air pressure waves observed from space (Witze, 2022).

In the archipelago Kingdom of Tonga, the ashfall, tsunami and shock waves caused widespread devastation on several islands, affecting 84 per cent of Tongans with an estimated $90.4 million in damage (around 18.5 per cent of Tongan Gross Domestic Product (GDP) Burki, 2022; World Bank, 2022a). The only fibre-optic cable that connects the islands with the rest of the world was severely damaged, leaving the entire country offline for more than three weeks. Disruption of internet connectivity had serious implications on the economy of the country, as about 30 per cent of household consumption and 40 per cent of national GDP depends on remittances from international migrants sent via the internet (Jalil, 2022). The disruption particularly affected women, generally highly dependent on remittances, who had to deal with an increase in water and food prices during the emergency.

Tonga: Where in the world?

The Kingdom of Tonga is an archipelago of more than 175 islands, located in the south-western Pacific Ocean, some 3,220 kilometres to the east of Australia and some 1,800 kilometres to the north-east of New Zealand. The archipelago counts a territory of about 750 km2 of land. It has a population of about 105,000 people, inhabiting 36 islands. The main island, Tongatapu, contains around 100,000 people and the capital Nuku'alofa. The climate of Tonga is subtropical, with annual temperatures between 17°C and 30°C and annual rainfall of approximately 2,700 mm. On average, at least two cyclones affect Tonga per year, and due to its geological setting, earthquakes, volcanic eruptions and tsunamis are a common phenomenon for Tongans.

The volcano: What is the Hunga Tonga-Hunga Ha'apai volcano?

The Hunga Tonga-Hunga Ha'apai volcano is one of six active volcanoes in the Kingdom of Tonga and is located about 65 km north of the Tongatapu island. It sits in the tectonically active so-called "ring of fire"[1] region in the Pacific Ocean, and it is the result of the interaction between the Indo-Australian and Pacific plates. Hunga Tonga and Hunga Ha'apai, originally two separate islands until 2014, were joined through a volcanic eruption in 2015, which produced enough material to merge both territories into one single island (*link to photo where we can see the single island before the January eruption)*. By January 2022, this resulting island was approximately 2 km in diameter, with a central crater rising around 120 m above sea level. However, under the surface, the massive submarine volcano known as Hunga rises more than 2,000 m from the surrounding seafloor (Cronin and others, 2017).

[1] This is the name for the tectonic and volcanic area that stretches around the Pacific Ocean, from New Zealand crossing the Philippines and Japan and covering almost the entire western coastline of the American continent.

The eruption: What happened?

Although the Hunga Tonga-Hunga Ha'apai volcano started to show signs of low-level volcanic seismicity on December 15 2021, the main phase of imminent explosive eruptions started on January 14 2022, with a major emission of ash[2] and steam (water vapour) accompanied by an earthquake of 5.8 in magnitude located at a depth of 5 km (Kusky, 2022). On January 15 2022, eruptions peaked when the continuous volcanic activity is believed to have destabilized the parts of the island above the surface, which triggered a collapse of the crater underwater. This put new hot magma in contact with cold seawater, causing a major steam explosion. This type of volcano style or eruption is known as Surtseyan[3]; however, due to its abnormal intensity, scientists are referring to the Tongan phenomena as an "ultra Surtseyan eruption" (Voiland, 2022). The "ultra Surtseyan eruption" caused a sonic blast that was detected by different instrumentation networks around the world, both ground-based and space-borne (e.g. infrasound, seismic, hydroacoustic satellites and atmospheric pressure sensors, to name a few). On the Volcanic Explosivity Index (VEI), which goes from 1 to 8, this eruption ranked as 5.8, becoming one of the most energetic events recorded during the past century (Vergoz and others, 2022). The mushroom-shaped ash cloud reached an altitude of 30 km and spread across a diameter of around 600 km within 2 hours (Global Volcanism Program (GVP), 2022).

The tsunami: What else happened?

The Hunga Tonga-Hunga Ha'apai eruption triggered a tsunami, with waves of 15 m reaching the Tongan shore with devastating impacts (Kusky, 2022). Just like with the eruption, the tsunami was quite exceptional, as only ~5 per cent of tsunamis are caused by volcanic eruptions (National Oceanic and Atmospheric Administration (NOAA), 2022). Most tsunamis are linked to earthquakes, where displacement on the seabed forces water out of the way and forms huge fast-moving waves, which increase in size and velocity depending on depth. The explosive nature of the Hunga Tonga-Hunga Ha'apai volcano eruption added another element to the already unique origin of this tsunami: atmospheric gravity waves. These atmospheric gravity waves seem to have resulted in a faster and longer-lasting tsunami compared to the waves caused by the seismic activity, making it difficult to predict (Kusky, 2022; Vergoz and others, 2022). Indeed, the tsunami-like waves generated by the atmospheric pulses hit the shore almost one hour before the predicted tsunami waves calculated for volcanic eruptions (Matoza and others, 2022). Atmospheric disturbance is also believed to have caused the small tsunami waves observed as far away as in the Caribbean Sea, the Azores in the Atlantic and Mauritius in the Indian Ocean (Andrews, 2022).

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[2] In geology, ash is defined as small fragments up to 20 mm of broken rock, volcanic glass and minerals.
[3] In geology, this volcanic style is described as a high-energy volcanic eruption that occurs when seawater or lake water floods into the top of an active open vent, allowing the mixture with hot magma

2. Impacts

2.1 Loss of life

In Tonga, three people died due to the tsunami, two of them Tongan citizens, one in Mango and the other in the Nomuka islands; the third victim, a British citizen, died in the main island of Tongatapu (Frost, 2022; Gersony, 2022). Although the nation suffered a lot of damage in terms of infrastructure as explained above, the death toll was surprisingly low considering the severity of the volcanic explosion. According to the government, this is a result of the familiarity with tsunami drills in the nation, which can be considered a success in terms of preparedness (Wright, 2022). In Peru, the authorities reported that two elderly women lost their lives due to the tsunami waves (Sarkar, 2022).

2.2 Displacement

Around 211 people living in the islands of Nomuka, Mango and Fonoifua were evacuated to the main island of Tongatapu in the aftermath of the volcanic eruption and tsunami. Due to their closeness to the volcano, these three islands in particular suffered the most impacts in terms of houses destroyed and disruption to all types of fishing and agriculture activities (World Bank, 2022a). Furthermore, according to the International Organization for Migration (IOM), three weeks after the volcanic eruption and tsunami, at least 465 households (some 2,390 people) were counted as displaced; around 54.41 per cent of them were found in the main island of Tongatapu and the rest were distributed between Ha'apai (30.54 per cent) and Eau (15.05 per cent) islands (United Nations Office for the Coordination of Humanitarian Affairs (OCHA), 2022a).

2.3 Infrastructure damage

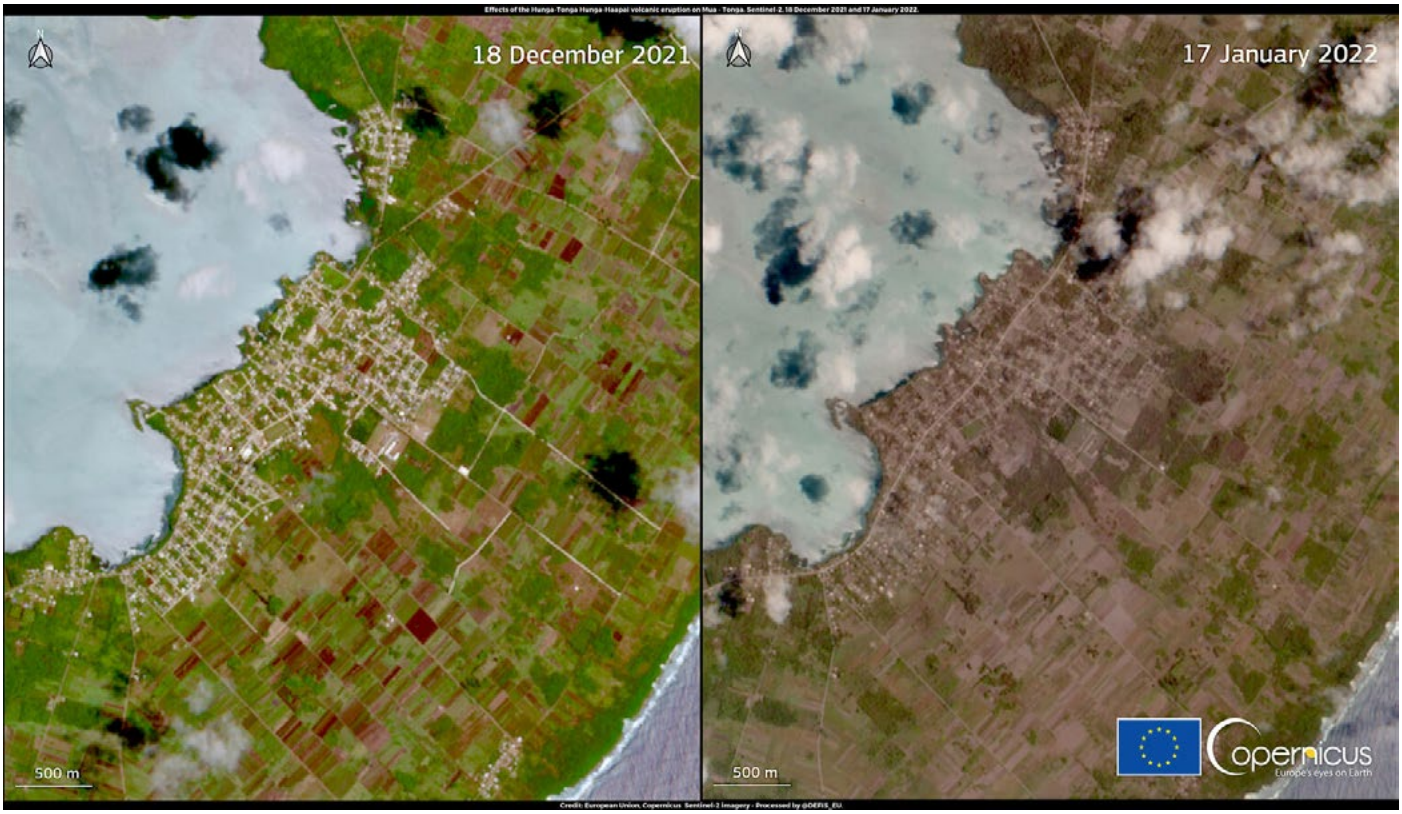
The volcano's eruption and associated tsunami damaged the only underwater fibre-optic cable that connects Tonga to the outside world, via Fiji, meaning the internet was interrupted for at least 105,000 people who had to face "digital darkness" (Miller, 2022). This single cable was completed in 2018 with a length of 827 km and 5 cm in diameter. Communication among the 36 inhabited islands was also severely disrupted, affecting the assessment of damage in the aftermath of the eruption and tsunami. Because the situation was not considered safe due to the continued volcanic activity and gases in the water, reparations were delayed. Overall, it took around one month for the main cable to be fully repaired but even five months later, communication among the islands was still not completely re-established. Communication via satellite was only accessible to government officials and a few private companies, and this was also compromised, due to the huge amounts of ash suspended in the air (Reuters, 2022).

Sea and air transportation were affected for several days after the eruption. The Fua'amotu International Airport was closed for several days due to a layer of ash covering the airport's runways. This delayed the arrival of aid, which could only enter some five days after the eruption and disrupted air traffic for almost two weeks (Anthony, 2022).

An estimated 600 structures were damaged or destroyed by the tsunami, including the capital's port on the main island of Tagatapu (British Broadcasting Corporation (BBC), 2022b). Around 300 residential buildings were reported to be damaged, with at least hundreds of homes completely destroyed in the islands of Nomuka, Mango and Fonoifua, where the tsunami was particularly high and reached 15 m in (compared to the main island of Tongatapu, where waves only reached 1.2 m) (Frost, 2022). In Mango the school and church were also destroyed. Furthermore, in Tongatapu at least seven resorts were wiped by the tsunami waves (Enoka, 2022).

Finally, the abrasive and corrosive nature of ash also compromises other types of infrastructure, including road networks, storm water and sewerage systems and water and electricity plants (Stewart and others, 2006), resulting in important economic costs. Initial reports by the World Bank estimated the clean-up of volcanic ash on buildings and road infrastructure at $5 million (World Bank, 2022a). The size of the suspended ash particles also affects assets, such as cars, which was particularly reported on Tonga's main island.

A search and rescue team looking for missing British woman Angela Glover through tsunami damage in Ha'atafu on the western coast of Tonga's main island Tongatapu following the January 15 eruption of the nearby Hunga Tonga-Hunga Ha'apai underwater volcano. (Image credit: Pesi Fonua /Matangi Tonga/ AFP)



On 18 January 2022, the impact of the eruption of Hunga Tonga-Hunga Ha'apai and tsunami on Mu'a, on Tongatapu island, can be seen when comparing Copernicus Sentinel-2 images acquired on 18 December 2021 (before the event) and 17 January 2022 (after the event). (Images credits: EU Copernicus Sentinel-2 / UNICEF)

2.4 Livelihood loss

The main source of livelihood on the island relates to the ocean, either through fishing (for both consumption and income) or tourism (as a source of profit) (Dickie, 2022). Weeks after the disastrous event, fishermen were still not allowed to carry out their activities; it was not safe to enter the ocean due to the uncertainty regarding a possible subsequent explosion, and the fish were contaminated (UN News, 2022). In terms of tourism, Tonga's main attraction is its coral reefs; however, the ash buried and smothered several km of corals, which will take considerable time to recover (Dickie, 2022). Furthermore, tourist accommodation was either destroyed or severely damaged (World Bank, 2022a).

The volcanic ash and tsunami also affected around 85 per cent of agricultural households nationwide (approximately 60,000 people) through damage to crops, livestock loss, and shallow reef fisheries, which were initially estimated to amount to $20.9 million (World Bank, 2022a).

2.5 Ecosystem damage and biodiversity loss

In the aftermath of the volcanic eruption and the tsunami, coastlines were eroded, trees were uprooted and ash covered a huge part of the once green vegetation in some of the Tongan islands (Gersony, 2022). Additionally, the mixture of emitted gases with oxygen resulted in acid rain in some areas, which can damage not only crops, but also the soil and plants, as well as harming animals (Dickie, 2022).

Suspended ash and gases polluted the ocean, particularly near the volcano, where the water turned murky. This probably deprived fish from access to food and disturbed spawning grounds, fragmenting their habitat and possibly inducing migration of those that didn't die (Di Prinzio and others, 2021; Dickie, 2022). Besides the damage to corals mentioned above, volcanic eruptions normally increase the levels of iron in the water. Higher iron concentrations favour the growth of blue-green algae and sponges, which affect the habitat of corals and their ability to grow (Schils, 2012). There is, therefore, reason for concern about the long-term effects on Tonga's corals.

Environmental impacts might have included the long-distance effects of the tsunami, such as the spill of approximately 12,000 barrels of oil off the Peruvian coast near the "La Pampilla" refinery, owned by the private company Repsol and located 30 km north of Lima (Sierra Praeli, 2022), although at the time of writing this report, there remains a controversy over the attribution of the oil spill to the tsunami. The environmental damage in Peru has been classified as the country's worse ecological disaster in the past few decades (Bazo Reisman, 2022; Infobae, 2022). The oil spill covered 18,000 m2 of sea, 17 beaches, and plenty of protected areas, affecting marine and coastal life, including plankton, crabs, molluscs, fishes, birds and aquatic mammals (e.g. seals, dolphins and otters), among others (Sierra Praeli, 2022).

2.6 Health impacts

The massive emission of volcanic ash and toxic gases associated with the volcanic eruption on 15 January represented a major threat to the health of Tongans. Volcanic ash can be suspended in the air for several days and has the capacity to inflame and damage both heart and lung tissue, causing, for example, suffocation and affecting those with pre-existing respiratory conditions (e.g. asthma). Additionally, depending on the ash chemical composition and gases mixture, people coming into contact with it can experience moderate to severe irritation of the skin and eyes. On the main island of Tongatapu, the layer of ash reached 20 mm in thickness, and in some places, ash fragments of up to 2 cm in diameter were reported. This resulted in air pollution and reduced visibility, which is why residents were advised to use face masks and stay indoors as much as possible, following the eruption (Wetzel, 2022; Burki, 2022; Anthony, 2022). Salt water brought by the tsunami increased the risk of cholera, and due to prolonged standing water in some locations, some cases of dengue were registered in Tongatapu (Lourens, 2022).

Aerial view showing cleaning crews work to remove oil from a beach in the Peruvian province of Callao on January 17, 2022, after a spill which occurred during the unloading process of the Italian-flagged tanker "Mare Doricum" at La Pampilla refinery caused by the abnormal waves recorded after the volcanic eruption in Tonga. (Image credit: Cris Bouroncle/ AFP)

The disastrous event indirectly also caused a spike in the outbreak of the COVID-19 pandemic. As a likely consequence of the arrival of international aid in the country, the number of COVID-19 positives increased in the aftermath of the event, although initially the government restricted the international aid as a precautionary measure. By mid-April 2022, the number of cases was around 8,500; the country had managed to keep the numbers of cases very low for almost two years thanks to travel restrictions. Consequently, strict lockdown measures had to be put in place on the islands of Tongatapu, Vava'u and Ha'apais (Lourens, 2022).

Another health impact was related to the psychological effects of the disasters (Anthony, 2022). According to Tonga's prime minister, the mental health costs for Tongans are yet to be measured; many families will have to deal with trauma after the devastation of their homes, and some of them will also have to undergo relocation so they can start over, leaving some of their dear memories behind (Vaswani, 2022).

2.7 Food insecurity

Tongans heavily depend on the agricultural sector in order to meet their own food needs. Therefore, damage to crops and loss of livestock represented a major threat to their food security (World Bank, 2022a). The ash covered ha of crops, causing acid damage or physical abrasion to vegetation leaves and fruits, thus affecting the harvesting of lettuces, cabbages, tomatoes, pineapples, coconuts, watermelons and yams for both local consumption and exports.

Additionally, most Tongans get their protein intake from fishing in the ocean, but the toxic mixture of ash and gases injected into the seawater contaminated marine life. Fishermen were consequently banned from fish consumption, as the Tongan Geological Service warned about potential poisonous fish (Dickie, 2022).

2.8 Water insecurity

The main sources of fresh water in Tonga are harvested rainwater and groundwater. In the days following the volcanic eruption, ashfall contaminated most of the fresh water reservoirs in the nation, especially rain barrels that collect water from roofs (Miller, 2022). In addition, the tsunami resulted in salt water infiltrating the ground, partially contaminating the groundwater reservoirs. As a precautionary measure, the government advised the locals to drink bottled water, but soon due to the demand, prices increased (Jalil, 2022). Consequently, availability of safe drinking water for tens of thousands of people was among the most urgent needs in the aftermath of the eruption (OCHA, 2022b; Menon and others, 2022).

3. Drivers

3.1 Remittance dependency

By 2021, the diaspora of Tongans living overseas counted nearly 150,000 people (BASE, 2022). As is the case for many Pacific Island states, most of the Tongans living abroad are men who moved mainly to Australia, New Zealand and the U.S. with the aim of finding other sources of income to support their families back home (Connell, 2006). Nowadays, four out of five Tongan households heavily depend on the remittances sent by their family members living abroad, making remittances are the largest contributor to Tonga's economy, responsible for 40 per cent of their GDP (BASE, 2022; Jalil, 2022). In 2019, Tonga ranked first worldwide in income received from international remittances (International Finance Corporation (IFC), 2020). Due to the male migration dynamics and the gender inequality background (see root cause on inequality), Tongan women are normally in charge of taking care of their children, their parents and their in-laws, consequently becoming the appointed recipient of such inflows of money (Collins, 2022).

Against such a background, losing internet connectivity as a consequence of the described damage to the submarine cable represented a major economic crisis for numerous families; female households were unable to receive their usual financial support in the form of remittances for almost a month. In the aftermath of the volcanic eruption and the tsunami, many families could access neither financial relief nor resources. Due to not having alternative income options and due to increasing commodity prices (e.g. drinking water and food), many families were unable to rebuild their homes (BASE, 2022).

3.2 Deforestation

Tonga's coastal forests were traditionally protected by farmers for their buffering capacities, defending cultivated areas from the sea, in terms of reducing damage related to storms and cyclones, and controlling salt spray and saltwater intrusions. However, in the last 50 years, particularly in the islands with human settlements, extensive areas of native coastal forests, including mangrove forests, have systematically been cleared for agricultural expansion (e.g. cropping and introduction of domestic animals, such as cattle, pigs and horses), touristic purposes (e.g. hotels and resorts), and timber and firewood (Thaman and others, 2011). According to Food and Agriculture Organization (FAO), by 2020, the percentage of forest cover was 12.4 per cent of total land area (about 9,000 ha) with only 4,000 ha of native hardwood forest remaining, mostly on uninhabited islands (FAO, 2020). Consequently, erosion has increased in coastal areas, leaving shorelines exposed to several environmental threats, including sea level rise and tsunamis, as in evidence with the volcanic explosion of the Hunga Tonga-Hunga Ha'apai volcano.

3.3 Vulnerable infrastructure

Most global data transfer is carried out through fibre-optic submarine cables. By late 2021, an estimated total of 436 cables were dispersed along the ocean floors (TeleGeography, 2022). Most countries around the world are connected through several cables, meaning that, in case of damage to one of their cables, they have a backup until reparations are completed. However, for small island states like Tonga, there is no such backup; Tonga is connected to the rest of the world by one single 827 km cable. Not having a backup connection cable, makes Tonga very vulnerable, not just to volcanic events or tsunamis, such as was seen with the case of the Hunga Tonga-Hunga Ha'apai (leaving Tongans "offline" for almost a month), but also to other more recurrent threats, such as tropical cyclones or even fishing boats, which surprisingly are responsible for at least 200 incidents per year regarding this submarine cable network. (Wakefield, 2022).

Outdated water infrastructure and lack of regular maintenance represent a major driver of vulnerability in Tonga. On the one hand, transportation of groundwater sources is linked to pipeline leakages and contamination from septic leakages (Secretariat of the Pacific Regional Environment Programme (SPREP), 2019), and on the other hand, rainwater sources (e.g. rain tanks/barrels) are more exposed to ashfall threats, as proven by the volcanic eruption and tsunami impacts described above. A study based on household consumption revealed that by 2020, rain tanks were the preferred source of drinking water (over 60 per cent of households) and piped water supply (mostly groundwater) is preferred for washing, bathing and sanitation (over 80 per cent of households) (White and others, 2020).

On 22 January 2022, Sione Falani Kuli Ha'apai, 18, stands in front of his home in Sopu on Tongatapu, Tonga's main island, showing the damage caused by the Hunga Tonga-Hunga Ha'apai underwater volcano eruption and tsunami. (Image credit: Malani Wolfgramm / UNICEF)

3.4 Insufficient volcano and tsunami forecasting

Considering the magnitude of the volcanic explosion and the tsunami, the death toll in Tonga was low, which was attributed by the authorities to the familiarity with tsunami drills and, therefore, a reward in terms of preparedness actions (Wright, 2022).

However, volcano forecasting is limited in Tonga, particularly in terms of submarine volcanoes. In the case of the Hunga Tonga-Hunga Ha'apai eruption, there was no clear precursor seismic activity (i.e. a group of small earthquakes with particular characteristics that hint at a possible major tectonic event) recorded. This could be either because the volcano didn't "show" any type of signal before the explosion, or because there were not enough seismic stations near the volcano that could have recorded the subtle signals. For some experts, the latter could be applied to Tonga, which gives room for improving the monitoring of this type of volcano (Retailleau, 2022).

4. Root causes

4.1 Undervaluing environmental costs

The undervaluation of the environmental costs of our choices and actions strongly contributed to a degradation of Tonga´s coastal ecosystems and thus to the impacts of the volcanic eruption and tsunamis. Socioeconomic development, in terms of agricultural expansion and increasing urbanization, have led to environmental degradation in Tonga, resulting in deforestation (see section 3.2).

Tonga's natural resources, especially forest cover, were already compromised before the volcanic eruption, and its limited land combined with a high population growth rate in the past 50 years has triggered extensive deforestation practices, mainly in the islands with human settlements (World Rainforest Movement (WRM), 2001). For example, in the early 1990s, extensive areas of native forest were cleared in favour of squash agriculture, which is one of the main export goods of Tonga (SPREP, 2019). Along with population growth and expansion of settlements and infrastructure, the construction sector has also pushed the extraction of beach sand (sand mining) in Tonga, exacerbating beach erosion. In Tongatapu, for instance, it is estimated that the main beaches have retreated by at least 50 m due to extraction of sand during the early 1990s (SPREP, 2019; United Nations Development Programme (UNDP), 2007).

The undervaluation of environmental costs is also visible in terms of pollution, which undermines ecosystems and their ability to protect the archipelago. Pollution, linked to increasing urbanization and inadequate wastewater treatment (e.g. of agricultural chemicals) has led to contamination of the ocean areas. Increased concentrations of agricultural pollution favour algal blooms, which in turn affect coral reef ecosystems, that are already threatened by overfishing practices (SPREP, 2019). Healthy corals are well known for providing storm surge mitigation, which is key for coastal protection against cyclones. Depending on their structure and location, reefs can also help to mitigate the impacts of sea level rise and to attenuate tsunami waves (Wanger and others, 2020; Salcone and others, 2015; Ferrario and others, 2014). Degradation of Tonga's natural defences has reduced its ability to cope with hazards. Considering that Tonga ranked third, only after Vanuatu and Solomon Islands (among 181 nations), in the list of countries with the highest disaster risk in 2021 (Aleksandrova and others, 2021), the undervaluation of environmental costs and the resulting gradual loss of critical ecosystems is particularly concerning.

4.2 Inequality of development and livelihood opportunities

Livelihoods in Tonga build around the ocean in terms of fishing and tourism, as well as agriculture. Such limited options have pushed many Tongans, especially males, to find other livelihoods abroad, leaving the country with a population based on elders, females and children (Australian Council for International Development (ACFID), 2020).

Tonga's strong traditional hierarchical values are reflected within several societal aspects; for example, inequality between genders. As such, only men inherit land and the land ownership rights pass through male hands, meaning women have no right to their family homes or land, unless they become a widow (ACFID, 2020). These sociocultural norms also represent additional limitations for Tongan women; for example, according to UNDP, by 2019, the female working population was 45.3 per cent against 74.1 per cent of males (ACFID, 2020). Consequently, women take up roles that imply caring for children or elders, making them more dependent on the flow of remittances, as mentioned above (Collins, 2022).

4.3 Insufficient risk governance

By 2020, around 27 per cent of the population of Tonga was considered to be poor (Government of Tonga, 2020). This situation has been historically exacerbated by external shocks, including climate related hazards and geohazards (Burton and others, 2015). Weak institutional coordination in implementing approaches that help build resilience within the archipelago and learned experiences, have been highlighted as part of the problem (Government of Tonga, 2017). Additionally, the lack of so-called social safety nets or social welfare services created to eliminate or avoid poverty in terms of housing and job challenges (United Nations Economic and Social Commission for Western Asia (UNESCWA), 2015), as well as limited livelihoods opportunities, influences response during and after emergencies (Burton and others, 2015), as shown by the volcanic eruption of the Hunga Tonga-Hunga Ha'apai volcano and related tsunami.

In terms of land use, one major issue in Tonga is related to the lack of regulations for both land expansion and compensation for lost land. Partially, this is related to monarchy dynamics in the country, where basically the Crown is the rightful owner and the people are considered "landholders," either through allotments or leases, creating in some cases an unfair distribution of resources (Niu, 2013), in addition to the inequalities between males and females addressed above (see section 4.2).

A woman carries a refilled gas container in the centre of the capital Nuku'alofa ahead of the country's first lockdown on February 2, 2022, after Covid-19 was detected in the previously virus-free Pacific kingdom as it struggles to recover from the deadly January 15 volcanic eruption and tsunami. (Image credit: Mary Lyn Fonua/AFP)

5. Big picture

In a world highly interconnected by communication and technology, the case the Hunga Tonga-Hunga Ha'apai volcano eruption showed that the inability to "be online" becomes a vulnerability in the context of extreme events. Considering that approximately 800 million people live within 100 km of an active volcano (Burki, 2022), questioning how vulnerable are our communication systems becomes a major priority for many nations around the world. As such, island countries such as Vanuatu, Samoa and New Caledonia also heavily depend on only a single submarine cable while satellite services are restricted and insufficient to cover basic connectivity needs. Damage to critical telecommunications infrastructure not only can hinder response actions, but can also can minimize the effectiveness of early warning systems, compromising disaster risk management strategies, and triggering offline scenarios, as happened in Tonga.

Destroyed beach resorts in the Hihifo district of Tonga's main island Tongatapu following the January 15 eruption of the nearby Hunga Tonga-Hunga Ha'apai underwater volcano. (Photo by Mary Lyn Fonua/ Matangi Tonga/ AFP)

6. Solutions

6.1 Let nature work

Coastal ecosystems, including mangroves and other coastal forests, seagrasses and coral reefs to name a few, provide numerous types of services, including the protection of coastal areas against adverse climate impacts, such as cyclones and sea level rise (Bengen, 2022), and the reduction of the energy of tsunami waves (Danielsen and others, 2005; Tanaka and others, 2007; Gelfenbaum and others, 2011; Takabatake and others, 2022). In terms of volcanic risk reduction, ecosystems, and particularly healthy forest cover, provide shelter (e.g. to hide or take cover under) and reduce diffusion (e.g. by air dispersion) of ash, which is in turn beneficial to control air quality in the aftermath of volcanic eruptions (Ágústsdóttir, 2015). Scientific evidence of the effectiveness of coastal ecosystems for risk reduction and adaptation is growing as they serve as natural barriers against coastal hazards, often come with moderate investment and maintenance costs compared to other engineered interventions, but while also provide co-benefits (for example, opportunities for related to ecotourism) (Guerry and others, 2012; Grabowski and others, 2012; Barbier and others, 2013; Spalding and others, 2014; Guannel and others, 2016).

In Tonga, examples of “Let nature work” are already in place. The restoration of ecosystems, especially those that support the growth of native species, which are considered to be more robust compared to introduced species that are not so well adapted to Tonga’s weather (SPREP, 2019), is one such example. Past projects, such as the 2011-2014 MESCAL – Mangrove Ecosystem for Climate Change Adaptation and Livelihoods, supported by the International Union for the Conservation of Nature (IUCN), focused on mangrove conservation and community livelihoods, drawing attention to the 10 species of mangroves that could provide coastal protection to the archipelago (Government of Tonga, 2017). Since 2019, a project led by the Tongan government and funded by the European Union has focused on coastal protection along the northern coast of Tongatapu, exploring hybrid solutions such as marsh-levee systems and dune-dyke systems. The project aims to establish a “green belt” of replanted mangroves with sea walls or dykes behind them in order to protect coasts from wave action, storm surge and tsunami, bringing co-benefits for the community in the form of carbon sequestration, high fishing productivity and biodiversity recovery (Government of Tonga, 2021).

6.2 Plan for risks

In order to reduce its vulnerability in terms of connectivity, Tonga could benefit from diversifying its telecommunications systems, considering that currently only a single undersea cable connects it to the world. Submarine cables are susceptible to suffer damage from different environmental and anthropogenic threats, as evidenced by the Hunga Tonga-Hunga Ha’apai volcanic eruption on 15 January 2022 (see section 3.3). A diversification of communication sources, for instance via satellite services, could help to ensure redundancy by having a backup system when a disaster strikes (Dominey-Howes, 2022). The government of Tonga has already signed a contract of US$5.7 million with the company Kacific in 2019, to provide satellite backup for 15 years. Unfortunately, delays in the payment and a series of legal issues between the involved parties have interrupted the implementation of this solution (Burkitt-Gray, 2022). Further initiatives should, therefore, consider potential dependencies on companies.

6.3 Boost early warning

Enhancing people-centred, multi-hazard early warning system capacities in Tonga is one of the solutions that could help in light of current and future volcano and tsunami risk. It starts with education at the community level and stretches all the way to government investments and international cooperation strategies. Investments in satellite and ground-based in situ observation technologies would be particularly important for the continuous monitoring of volcanic activities in the region (e.g. seismic signals, gas emissions, heat flux and ground deformation), with the advantage of early warning. Obtaining early signals through improved observation technologies and having the population prepared to act effectively through education in turn translates into saving lives and reducing related damage (Poursanidis and Chrysoulakis, 2017; World Meteorological Organization (WMO), 2022; Anticipation Hub, 2022).

Initiatives to strengthen Tonga's early warning systems, particularly for tsunami alerts, have been a focus of the national government during the past few years. These initiatives, as mentioned above, are considered part of the reason for the low death toll despite the powerful nature of the volcanic eruption (Wright, 2022). Still, Tonga, like many other Pacific Island states, could further improve in terms of volcanic activity monitoring and forecast and strengthen its international cooperation, joining already existing international networks (Pultarova, 2022). Indeed, it is crucial to combine the solutions Boost early warning with Working together as a collaborative planning effort that enhances knowledge sharing without borders (Tupper, 2022) (see 2021/2022 IDR report). This combination is beneficial for both the Tongans, who can learn from the international community how to better understand and reduce disasters triggered by geological settings, and the international community, which can benefit through understanding the particularities of exceptional events such as the volcanic eruption of the Hunga Tonga-Hunga Ha'apai volcano (e.g. air-sea coupling waves), which should be considered in future scenarios for tsunami early warning to increase resilience for people in every corner of the planet (Kusky, 2022).

6.4 Secure livelihoods

For Tongans, an important solution is to support livelihood diversification as well as access to better social protection schemes to increase their response capacity to disasters. The lack of social protection (social safety nets; see section 4.3) in the country has been found to increase the impacts of disasters on female headed households, the elderly, the youth, children, people with disabilities and those living on outer islands (Burton and others, 2015). As a consequence, there is a need for projects that foster development outcomes for those vulnerable groups; for example, in terms of access to quality and safe education conditions for the youth, as in the case of the project "Tonga Climate Resilient Project 2021-2029," supported by the World Bank, which aims to boost climate and disaster resilience for Tongan schools, ports and roads (World Bank, 2022b).

Another pathway of action is linked to fighting gender inequality, which is present in all aspects of Tonga's society (see section 4.2). Projects that include financial support for women in Tonga could help to address the lack of opportunities for this vulnerable group and transform their "passive" role into leaders of recovery and resilience in the country (Maykin and others, 2022). As such, there are already initiatives in place, such as the Shifting the Power Coalition, which aims to empower women in the region to enhance their engagement in national disaster coordination mechanisms, challenging patriarchal and traditional gender norms (Australian Aid, 2021).

6.5 Conclusion

The four solutions described above are just some of the examples of integrated approaches that could help to reduce disaster risk in small island states exposed to volcanic and tsunami threats, as in the case of Tonga. Additionally, these solutions would provide benefits in the face of climate related hazards, such as cyclones, and sea level rising, as illustrated through the advantages of working with ecosystem-based approaches that could help to reduce disaster risk and to adapt to climate change. Furthermore, although applied individually, as these solutions could address some of the root causes and drivers discussed above, the aim of including them in this report is to think about them as part of a solution package (see 2021/2022 IDR report). As such, these solutions in appropriate combination could act as a robust and comprehensive risk management strategy, bringing co-benefits and synergies, and at the same of minimizing potential trade-offs.

7. References

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Cover Image Credit: NOAA / UNICEF
On 15 January 2022, a satellite image captures another explosive eruption of the Hunga Tonga-Hunga Ha'apai volcano, located in the South Pacific Kingdom of Tonga.