15 January 2022 Volcanic Eruption and Tsunami. Preliminary Satellite-Based Comprehensive Damage Assessment Report

Tongatapu, Eua, and Ha'apai divisions of the Kingdom of Tonga

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Prepared By
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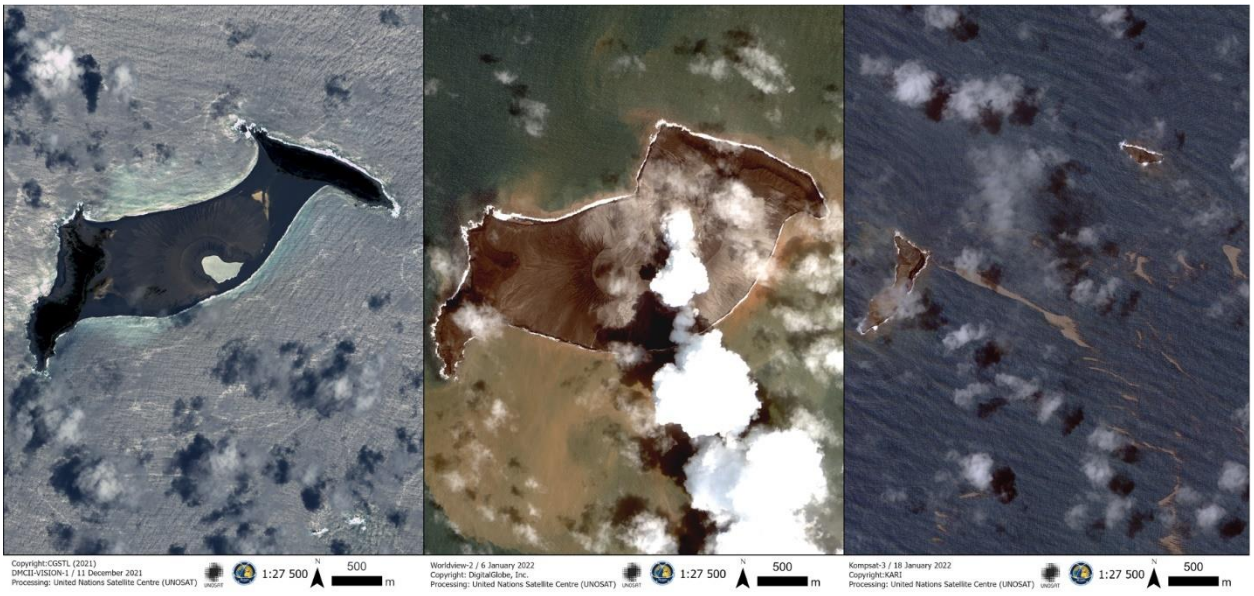
Overview

A volcanic eruption triggered a tsunami on 15 January 2022, causing damage, devastation, and destruction on islands in the Kingdom of Tonga. The volcano erupted about 70km northwest of the capital city of Nuku'alofa, sending clouds of ash into the atmosphere and tsunami waves from the volcanic origin.



The Government of Tonga has stated that the volcanic eruption affected 84,000 in the Tongatapu, Eua, and Ha'apai divisions of the Kingdom of Tonga. About 80% of the total population in the country needs emergency humanitarian assistance.

According to the OCHA, three fatalities have been confirme. More than 80 percent of the affected population resides in the Tongatapu, Eua, and Ha'apai divisions of the Kingdom of Tonga. These figures are likely to rise as the after-effects of the eruption, along with the effects of the tsunami, are fully realised. The eruption triggered tsunamis that severely impacted the islands of Mango, Fonoifua, and Nomuka and destroyed nearly all buildings and residences on the islands.

- Preliminary assessment has shown devastating damages to houses, roads, and bridges disrupting aid movement into the affected areas.

- This report summarizes satellite-derived damaged analysis covering the most affected areas within the divisions of Tongatapu, Ha'apai, Eua of Tonga.

Comprehensive Satellite-Detected Building Damage Assessment: Overview Map, Methodology and Considerations

The United Nations Satellite Centre (UNOSAT), on behalf of the United Nations Office for the Coordination of Humanitarian Affairs (OCHA) | Regional Office for Asia and the Pacific, activated the International Charter on Space and Major Disasters on 15 January 2022 to support the planning and coordination of emergency response operations with satellite analysis, covering the areas affected by the volcanic eruption and tsunami. Other organizations such as the Government of Tonga have also requested the activation of the International Space Charter. The Project Manager (PM) nominated for this Charter Call is UNOSAT, along with other satellite mapping groups (Copernicus EMS), who are supporting the Charter Call by providing (satellite-derived) value-added analysis and mapping products. To support the planning and coordination of emergency response operations, UNOSAT has released a Preliminary Satellite-Based Damage Assessment report for the Kingdom of Tonga. In addition, UNOSAT has released a webmap of satellite-based analysis related to the volcanic eruption and tsunami and a damage assessment for the Tongatapu, Eua, and Ha'apai divisions of Tonga.

Copernicus Emergency Management Service has also been working to provide a coherent and broad overview of the damage caused by the volcanic eruption and tsunami. In addition, efforts have been made to estimate the overall damage caused by the disaster, particularly concerning the number of damaged buildings in Tonga. This report will focus on the three most affected divisions: Tongatapu, Eua, and Ha'apai. The building damage assessment was conducted using pre- and post-event satellite data covering different areas of interest shown on the GDACS Satellite Mapping Coordination System (SMCS) page. The SMCS is a coordination platform, used by organisations to monitor mapping activities for ongoing emergencies.

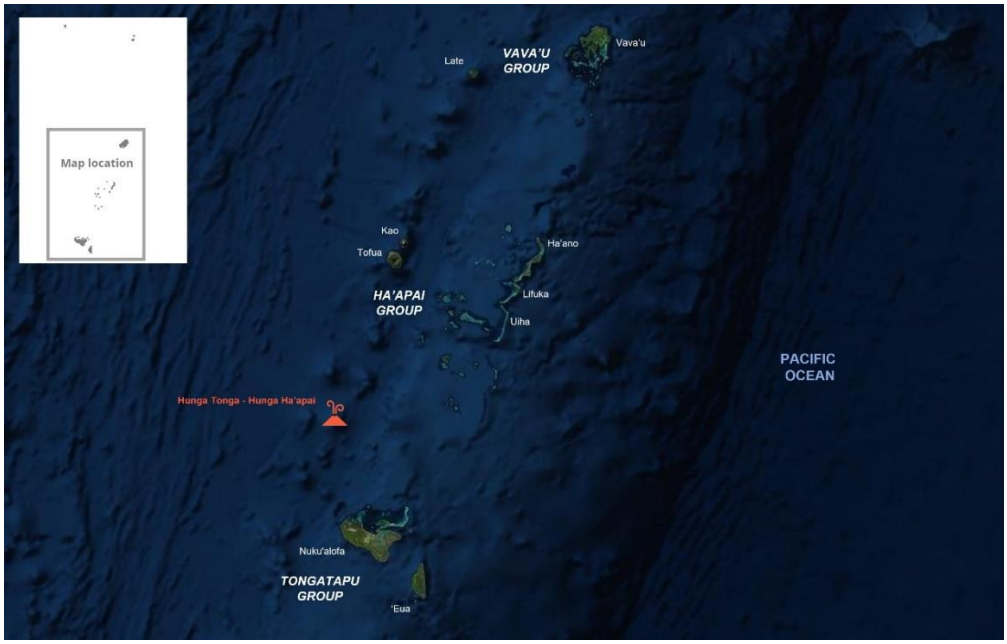


Figure 1, Physical map of Tonga's southern island

Satellite-derived analysis

This report describes preliminary building damage analysis covering the divisions of Tongatapu, Eua, and Ha'apai of Tonga, for a total area of approximately 366 Km^2. A building damage analysis and a rapid assessment of transportation network conditions were conducted by comparing a series of satellite imageries acquired from the International Charter Space and Major Disasters before and after the volcanic eruption.

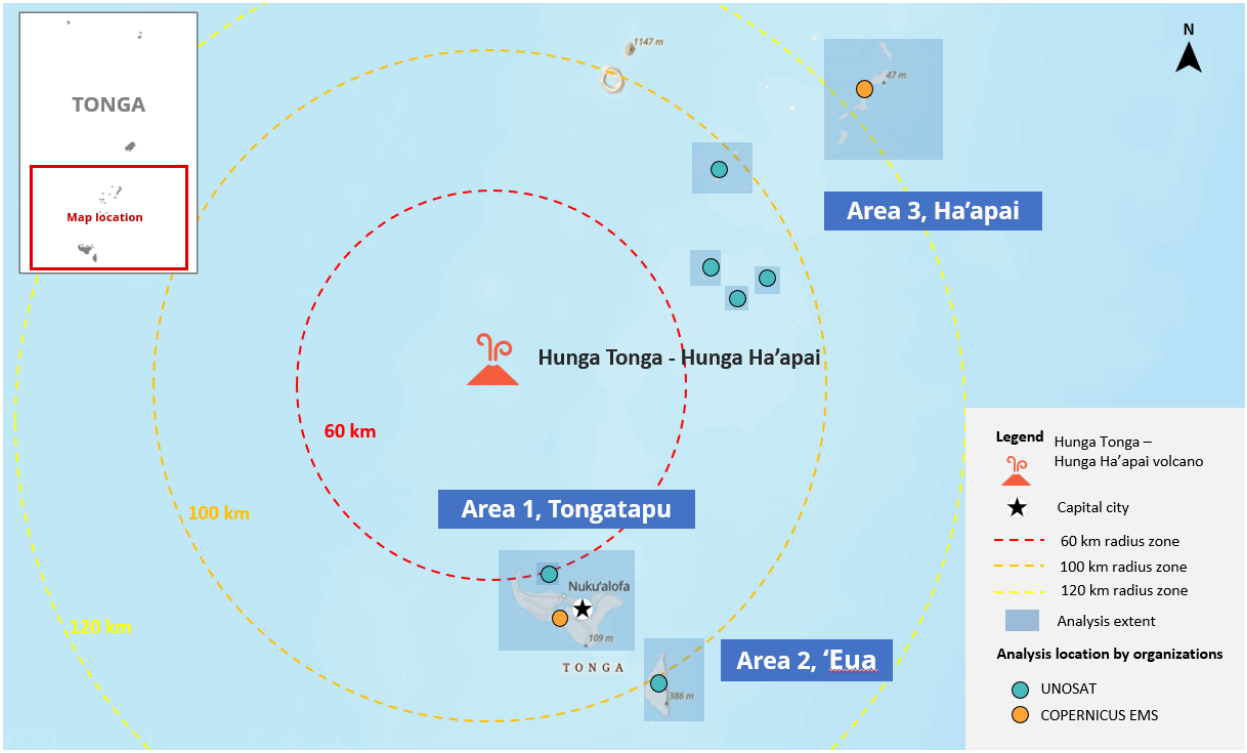


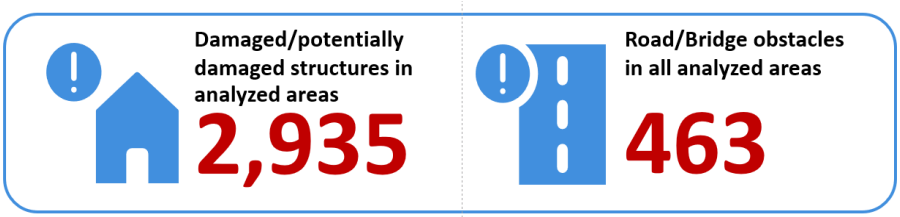
Figure 2. This map depicts the analysis extents in the Tongatapu, Eua, and Ha'apai divisions of Tonga examined by UNOSAT and Copernicus EMS to determine infrastructure damage caused by the volcanic eruption and tsunami on 15 January 2022, The map also identifies the location of the volcano.

Area of interest	Name of analysed extent	Post event satellite data	Pre event satellite data
Area 1, Tongatapu division	Kolofo'ou, Kolomotu'a, Kolovai, Lapaha, Nukunuku, Tatakamotonga, and Vaini districts	Pléiades, 17 Jan 2022	Pléiades, 17 Apr 2020
	Atata Island, Kolovao District	Pléiades, 17 Jan 2022	ESRI Basemap
Area 2, 'Eua division	Eua fo'ou and 'Eua Prope districts	Pléiades, 19 Jan 2022	Worldview-3, 14 Sep 2021
		Pléiades, 20 Jan 2022	
		Pléiades, 24 Jan 2022	
Area 3, Ha'apai division	Nomuka, Mu'Omu'A district	Pléiades, 16 Dec 2021	WorldView-2, 13 Nov 2021
		Pléiades, 17 Dec 2021	WorldView-2, 21 Nov 2021
	Lulunga district	Worldview-3, 26 Jan 2022	ESRI Basemap
	Ha`ano, Pangai, and 'Uiha districts	Pléiades, 16 Jan 2022	Pléiades, 19 Apr 2022

Table 1. Overview of satellite imageries that has been used for the damage assessment, the analysis zones and the corresponding acquisition date.

Analysis summary

This comprehensive damage analysis identifies 2,935 buildings/structures with visible damages and 463 road/bridge obstacles in the divisions of Tongatapu, Eua, and Ha'apai of Tonga.



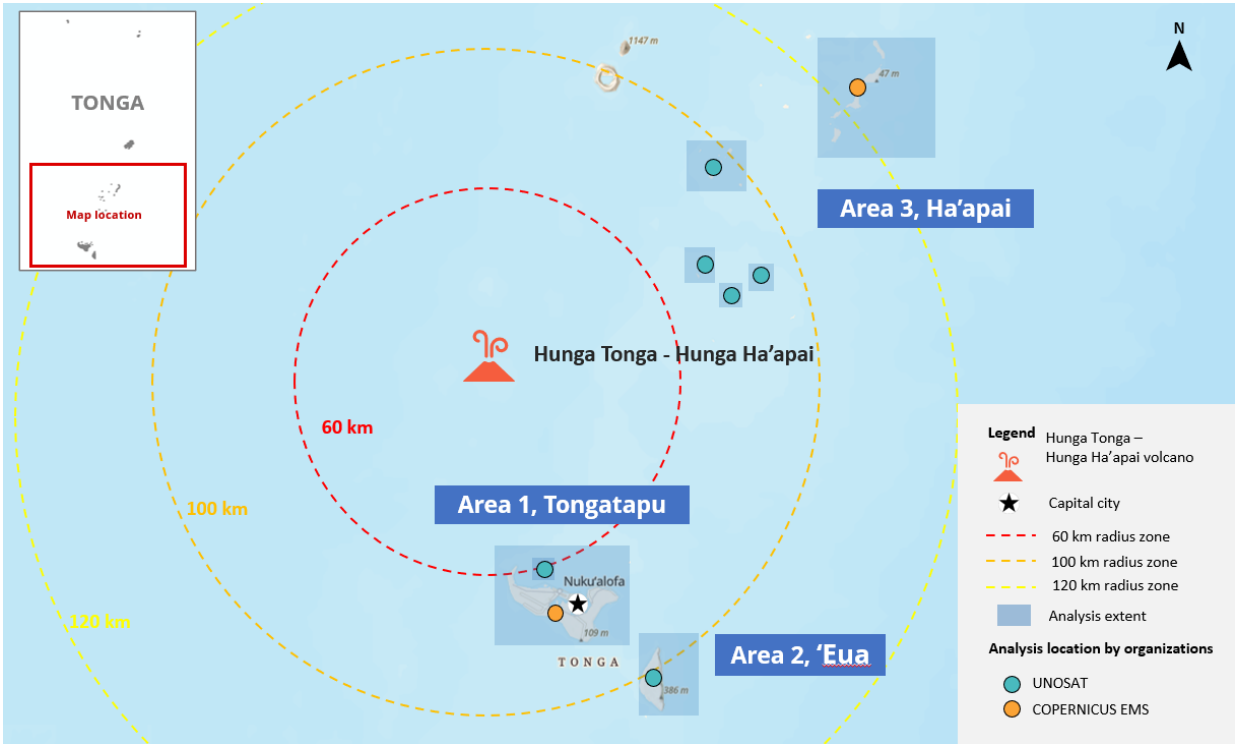


Figure 3. This map depicts the analysis extents in the Tongatapu, Eua, and Ha'apai divisions of Tonga examined by UNOSAT and Copernicus EMS to determine infrastructure damage caused by the volcanic eruption and tsunami on 15 January 2022.

Division	Area of interest (km^2)	Analysis Extent		Building damage assessment			Road/ bridge obstacles assessment		
		Analyzed Extent (km^2)	Percentage of Area in Analyzed Extent	Damaged Buildings	Potentially Damaged Buildings	Total of Damaged and Potentially Damaged Buildings	Road/bridge Obstacles	Potentially Road Obstacles	Total of Road Obstacles and Potentially Road Obstacles
Eua Division	87.50	87.50	100%	140	3	143	6	-	6
Ha'apai	22.23	17.89	80%	160	557	717	17	14	31
Tongatapu	262.88	261.03	99%	301	1,774	2,075	201	225	426
Total	**372.61**	**366.42**	**98%**	**601**	**2,334**	**2,935**	**224**	**239**	**463**

Table 2. Overview of building/structure damage assessment conducted by UNOSAT and Copernicus EMS. The table gives an overview of each affected department's total area and analysed area and the potentially damaged and damaged buildings and roads identified during the analysis.

Area 1: Tongatapu Division

The Tongatapu Island has approximately 74,500 people and an area of 263 km^2. According to Humanitarian Open Street Map data, the pre-event building footprint of the Tongatapu Island was 31,500 buildings, with 31,300 of those buildings within the Areas of Interest (AOIs) analysed by emergency response teams.

Area 1 has one AOI covering approximately 260 km^2 in seven districts, including Kolofo'ou, Kolomotu'a, Kolovai, Lapaha, Nukunuku, Tatakamotonga, and Vaini. Analysts conducted satellite-analysis by comparing the post-disaster satellite images with available pre-disaster images.

UNOSAT and partners' preliminary analysis shows 2,075 buildings/structures with visible damages and ash deposits (7% of the total building in AOIs) and approximately 426 locations with visible road obstacles and access constraints.

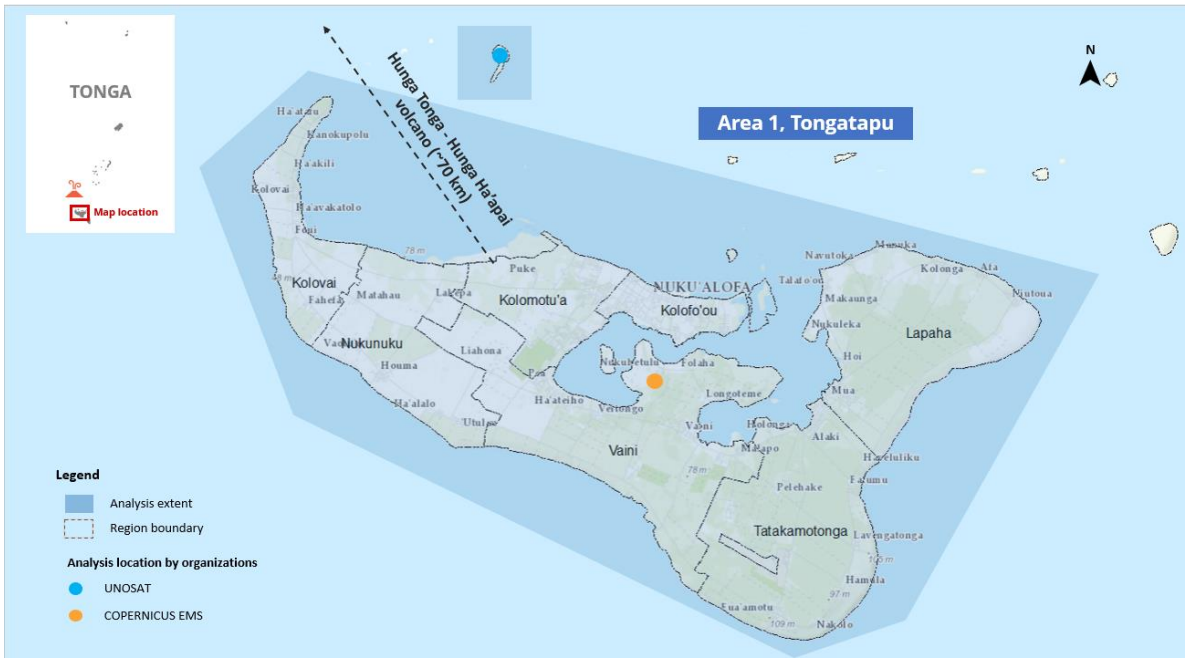


Figure 4. This map depicts the analysis extent in the Tongatapu Island of Tonga examined by Copernicus EMS and UNOSAT to determine infrastructure damage caused by the Volcanic eruption and tsunami on 15 January 2022.

Division/District	Area of Division/ District (km2)	Analysis Extent		Building damage assessment			Road/ bridge obstacles assessment		
		Analysed Extent (km^2)	Analysis extent coverage percentage	Damaged Buildings	Potentially Damaged Buildings	Total of Damaged and Potentially Damaged Buildings	Road/bridge Obstacles	Potentially Road/bridge Obstacles	Total of Road Obstacles and Potentially Road Obstacles
Tongatapu	**262.88**	**261.03**	**99%**	**301**	**1,774**	**2,075**	**201**	**225**	**426**
Kolofo'ou	12.53	12.03	96%	72	627	699	70	99	169
Kolomotu'a	23.10	23.10	100%	11	523	534	46	21	67
Kolovai	20.80	20.80	100%	194	85	279	53	29	82
Lapaha	52.23	50.88	97%	14	439	453	29	47	76
Nukunuku	35.02	35.02	100%	3	20	23	-	3	3
Tatakamotonga	54.20	54.20	100%	3	66	69	2	10	12
Vaini	65.00	65.00	100%	4	14	18	1	16	17

Table 3. Overview of building/structure damage assessment in the Tongatapu division. The table gives an overview of the total area and analysed area of each affected district of the division and the potentially damaged and damaged buildings and roads identified during the analysis

Building/Structure damage assessment in Tongatapu Division

Preliminary building/structure damage assessments were conducted through visual interpretation by UNOSAT and partners, utilising before and after very high-resolution satellite images. The post-disaster satellite images were acquired after the volcanic eruption on 15 January 2022, along with available pre-disaster images. 2,075 buildings were identified with visible damage and ash deposits within the analysed areas. Kolovai district had the highest number of affected buildings, with over 194 damaged buildings detected.

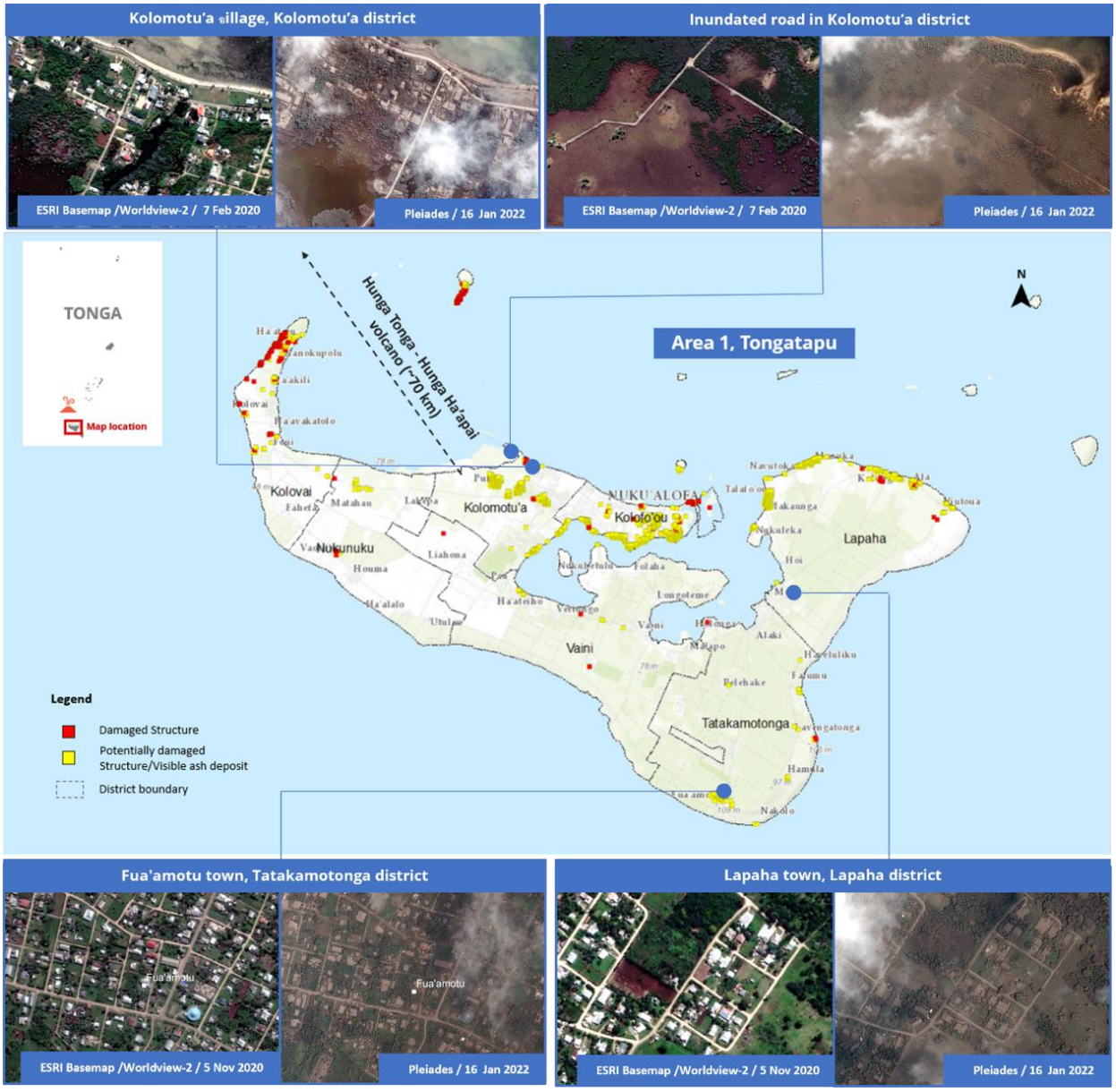


Figure 65. This map depicts the analysis extent in the Tongatapu division of Tonga examined by UNOSAT, and Copernicus EMS to determine infrastructure damage caused by the volcanic eruption and tsunami on 15 January 2022.

Area 2: Eua Division

Eua has a population of approximately 4,900 people and an area of 88 km^2. According to Humanitarian Open Street Map data, the pre-event building footprint of the Eua division was 1,890 buildings buildings within the areas of Interest (AOIs) analysed by emergency response teams.

Area 2 has one AOI covering approximately 88 km^2 in two districts, including Eua fo'ou, and Eua Prope. Analysts conducted satellite-analysis by comparing the post-disaster satellite images with available pre-disaster images.

UNOSAT and partners' preliminary analysis identifies a total of 143 buildings/structures with visible damages and ash deposits (8% of the total building in AOI) and approximately six locations with visible road obstacles and access constraints.

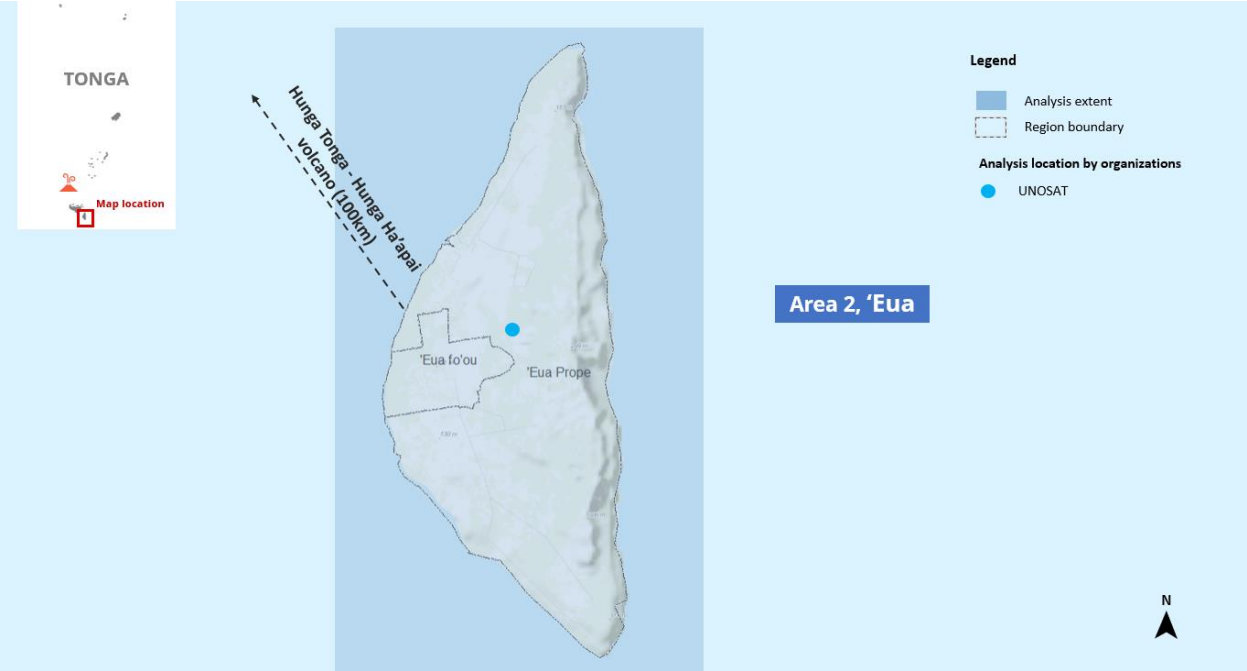


Figure 6. This map depicts the analysis extent in the Eua division of Tonga examined by UNOSAT, and Copernicus EMS to determine infrastructure damage caused by the volcanic eruption on 15 January 2022.

Division/District	Area of Division/ District (km^2)	Analysis Extent		Building damage assessment			Road/ bridge obstacles assessment		
		Analysed Extent (km^2)	Analysis extent coverage percentage	Damaged Buildings	Potentially Damaged Buildings	Total of Damaged and Potentially Damaged Buildings	Road/bridge Obstacles	Potentially Road/bridge Obstacles	Total of Road Obstacles and Potentially Road Obstacles
Eua Division	**87.50**	**87.50**	**100%**	**140**	**3**	**143**	**6**	**-**	**6**
Eua fo'ou	8.10	**8.10**	100%	1	-	1	-	-	
Eua Prope	79.40	79.40	100%	139	3	142	6	-	-

Table 4. Overview of building/structure damage assessment in 'Eua Division of Tonga. The table gives an overview of the total area and analysed area of each affected division. The table also gives an overview of the department and the potentially damaged buildings, damaged buildings and roads identified during the analysis.

Building/Structure damage assessment in Eua Division

Preliminary building/structure damage assessment was conducted through visual interpretation by UNOSAT and partners utilizing before and after very high-resolution satellite imageries. The post-disaster satellite images were acquired after the volcanic eruption on 15 January 2021 with available pre-disaster images. A total of 140 buildings were identified to have suffered prominent visible damages and ash deposits within the analysed areas. Eua Prope district had the highest number of affected buildings, with over 139 damaged buildings detected.

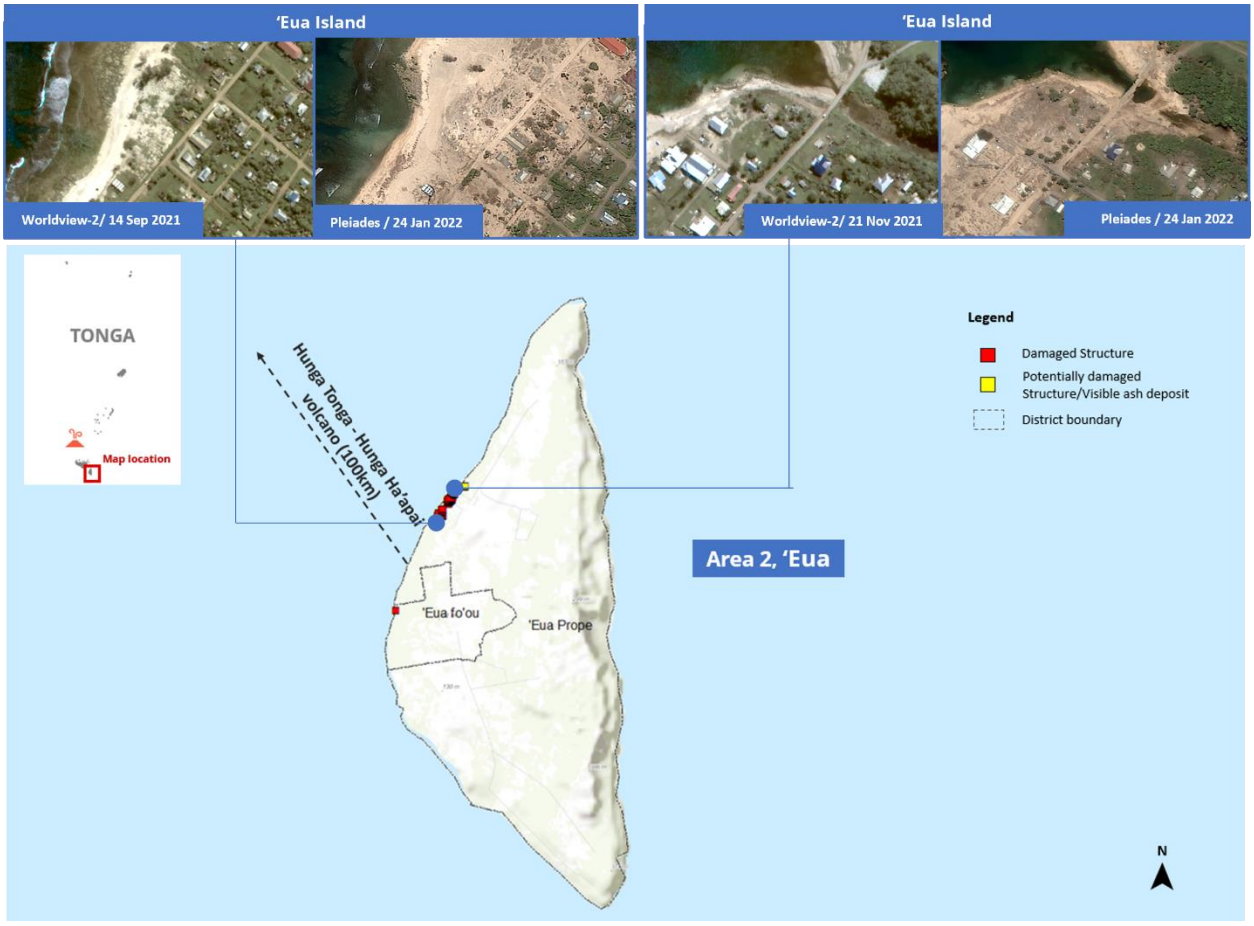


Figure 7. This map depicts damaged buildings in the 'Eua Division of Tonga. Additional inset images from the WorldView-2 and Pleiades satellites acquired before and after the volcanic eruption on 15 January 2022 highlight and visualise the extent of damage to buildings within 'Eua Island.

Area 3: Ha'apai Division

Ha'apai has a population of approximately 5,400 people and an area of 22km^2. According to Humanitarian Open Street Map data, the pre-event building footprint of the Ha'apai division was 3,200 buildings, with 2,500 of those buildings within the areas of interest (AOIs) analysed by emergency mapping response teams.

Area 3 has five AOIs covering approximately 18km^2 in six districts, including Foa, Ha`ano, Lulunga, Mu'omu'a, Pangai, and Uiha. Analysts conducted satellite-analysis by comparing the post-disaster satellite images with available pre-disaster images.

UNOSAT and partners' preliminary analysis identifies a total of 717 buildings/structures with visible damages and ash deposits (29% of the total building in AOIs).

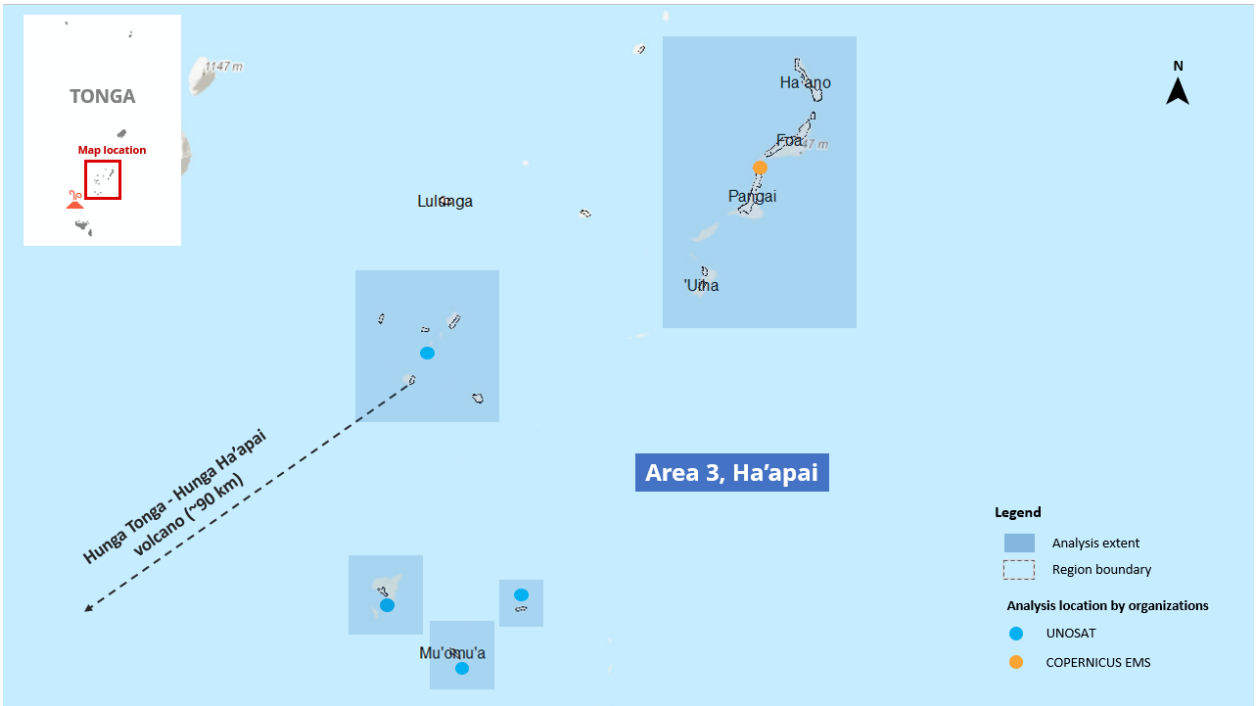


Figure 8. This map depicts the analysis extents in the Ha'apai division of Tonga examined by UNOSAT and Copernicus to determine infrastructure damage caused by the volcanic eruption and tsunami on 15 January 2022.

Division/District	Area of Division/ District (km2)	Analysis Extent		Building damage assessment			Road/ bridge obstacles assessment		
		Analysed Extent (km^2)	Analysis extent coverage percentage	Damaged Buildings	Potentially Damaged Buildings	Total of Damaged and Potentially Damaged Buildings	Road/bridge Obstacles	Potentially Road/bridge Obstacles	Total of Road Obstacles and Potentially Road Obstacles
Ha'apai	**22.23**	**17.89**	**80%**	**160**	**557**	**717**	**17**	**14**	**31**
Foa	5.27	5.27	100%	-	251	251	-	2	2
Ha`ano	4.25	3.92	92%	-	75	75	-	5	5
Lulunga	3.98	0.41	10%	11	63	74	-	-	-
Mu'omu'a	1.80	1.80	100%	145	8	153	14	-	14
Pangai	5.37	5.37	100%	-	145	145	3	3	6
'Uiha	1.56	1.12	72%	4	15	19	-	4	4

Table 5. Overview of building/structure damage assessment in Ha'apai Division. The table gives an overview of the total area and analysed area of each affected district of the division and the potentially damaged and damaged buildings and roads identified during the analysis

Building/Structure damage assessment in Ha'apai Division

Preliminary building/structure damage assessment was conducted through visual interpretation by UNOSAT and partners utilising before and after very high-resolution satellite imagery. The post-disaster satellite images were acquired after the volcanic eruption on 15 January 2022 with available pre-disaster images. 160 buildings were identified with visible damage within the analysed areas. Mu'omu'a district had the highest number of affected buildings, with over 145 damaged buildings detected.

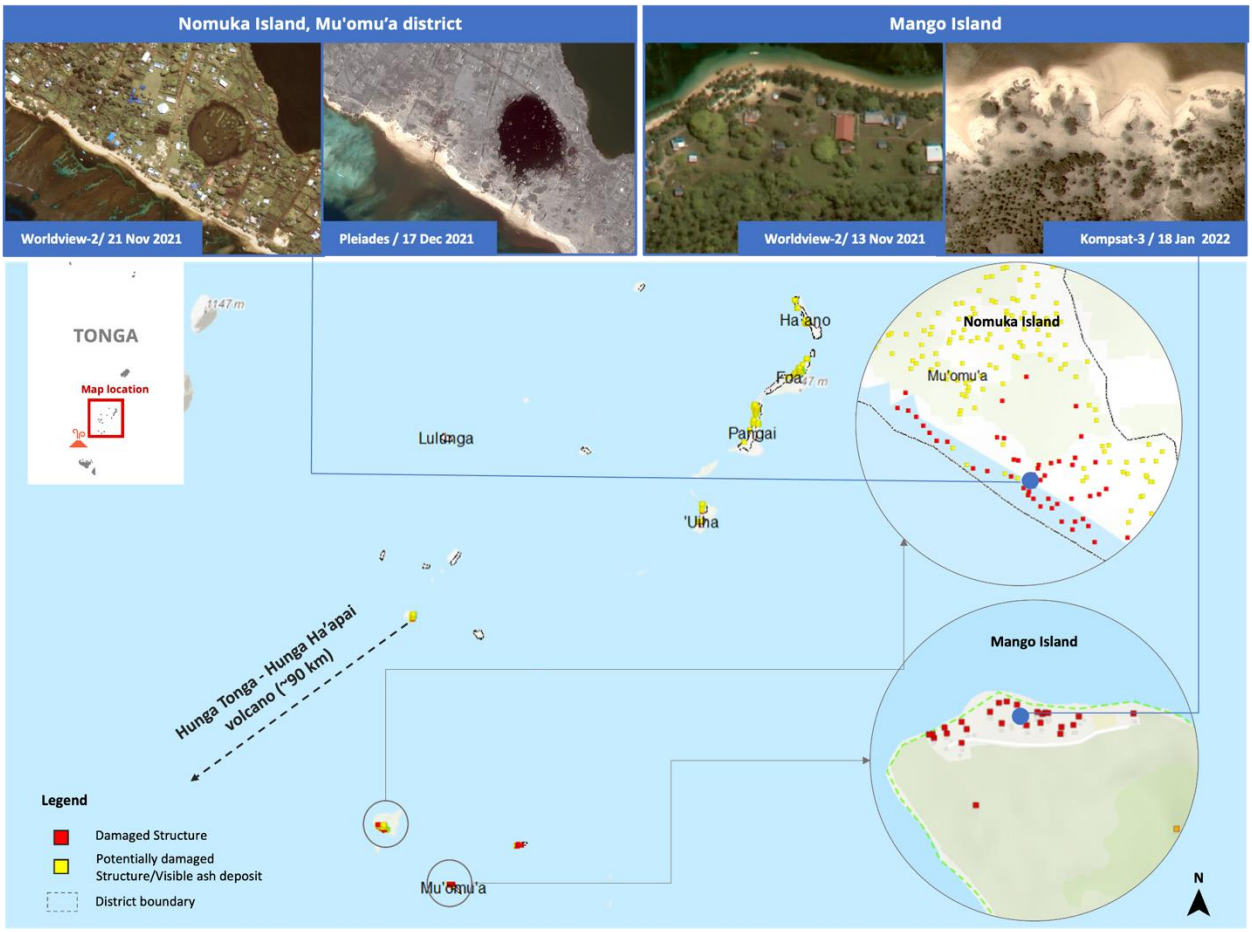


Figure 9. This map depicts damaged buildings in the Ha'apai division, specifically in Mango and Nomuka Islands. Additional inset images from the Worldview-2, Pleiades, and Kompsat satellites acquired before and after the volcanic eruption on 15 January 2022 highlight and visualise the extent of damage to buildings within the Mango and Nomuka Islands.

Vegetation damage assessment on Mango and Nomuka Islands, Ha'apai Division.

UNOSAT conducted a preliminary vegetation assessment by calculating the Normalized Difference Vegetation Index (NDVI) before and after the volcanic on Mango and Nomuka islands. The post-disaster satellite images were acquired between 15 January 2022 and 26 January 2022 after the volcanic eruption on 15 January 2022, with available pre-disaster images acquired between 01 December 2021 and 14 January 2022. The vegetation on Mango Island has declined by 78% following the volcanic eruption on 15 January 2022, which covered the island in volcanic ash. The vegetation on Nomuka Island has been reduced by 76% following the volcanic eruption on 15 January 2022, which covered portions of the island in volcanic ash.

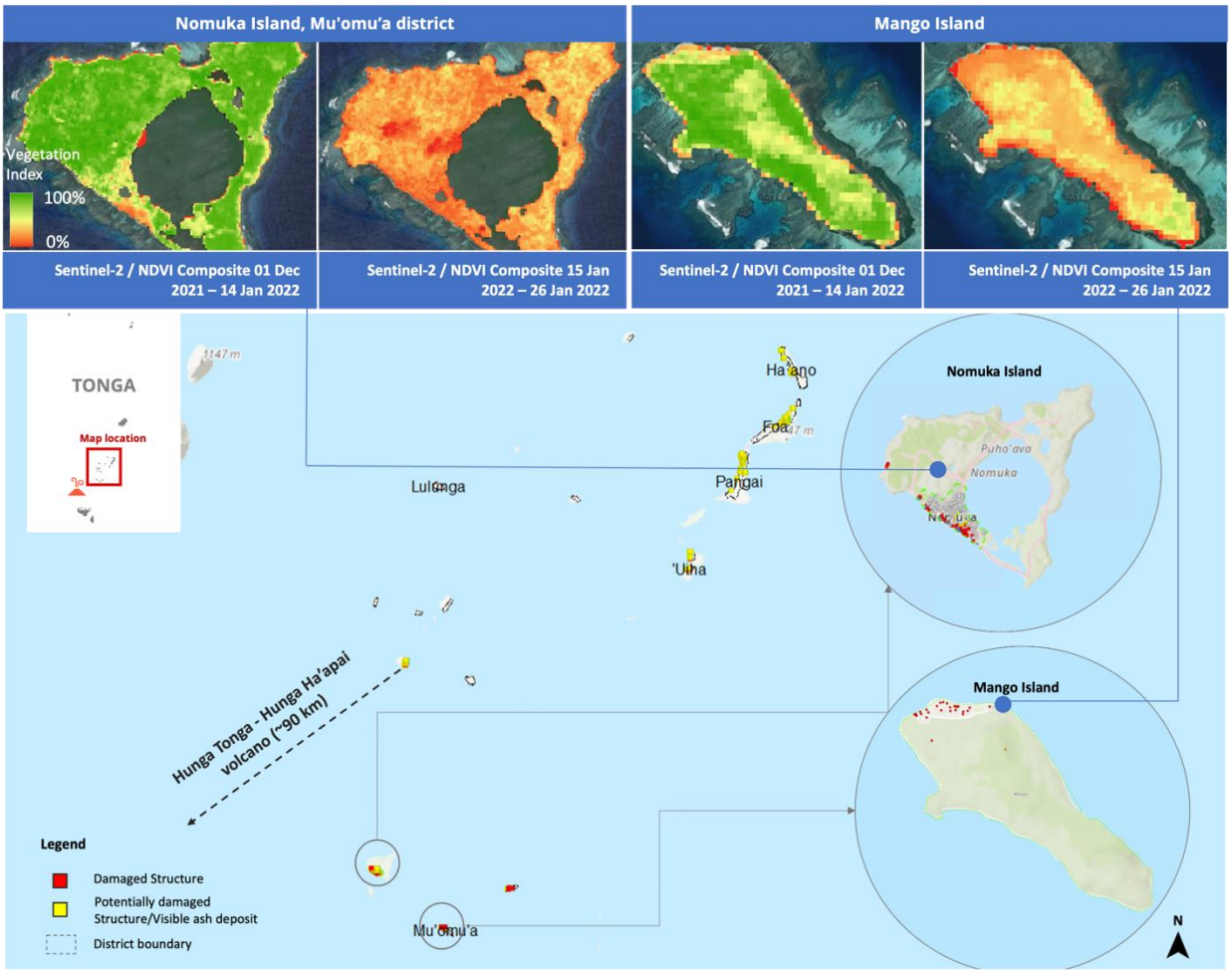


Figure 10. This map depicts Nomuka and Mango Islands damaged vegetation following the volcanic eruption on 15 January 2022.

Sentinel-2 image Copyright: Contains modified Copernicus Sentinel Data [2021]

Source: ESA

UNOSAT LIVE Web map

UNOSAT Live maps are created by the United Nations Satellite Centre (UNOSAT) and deliver an overview of a situation by providing information on damage assessments conducted by the UN Satellite Centre (UNOSAT) and partner organisation (Copernicus EMS). All analysis results are shared in the webmap in a geographic format. The added benefit of the live web map is the ability to host data from different sources and deliver up-to-date information publicly available across browsers and operating systems by citizens and emergency response staffs including on their smartphones and tablets.

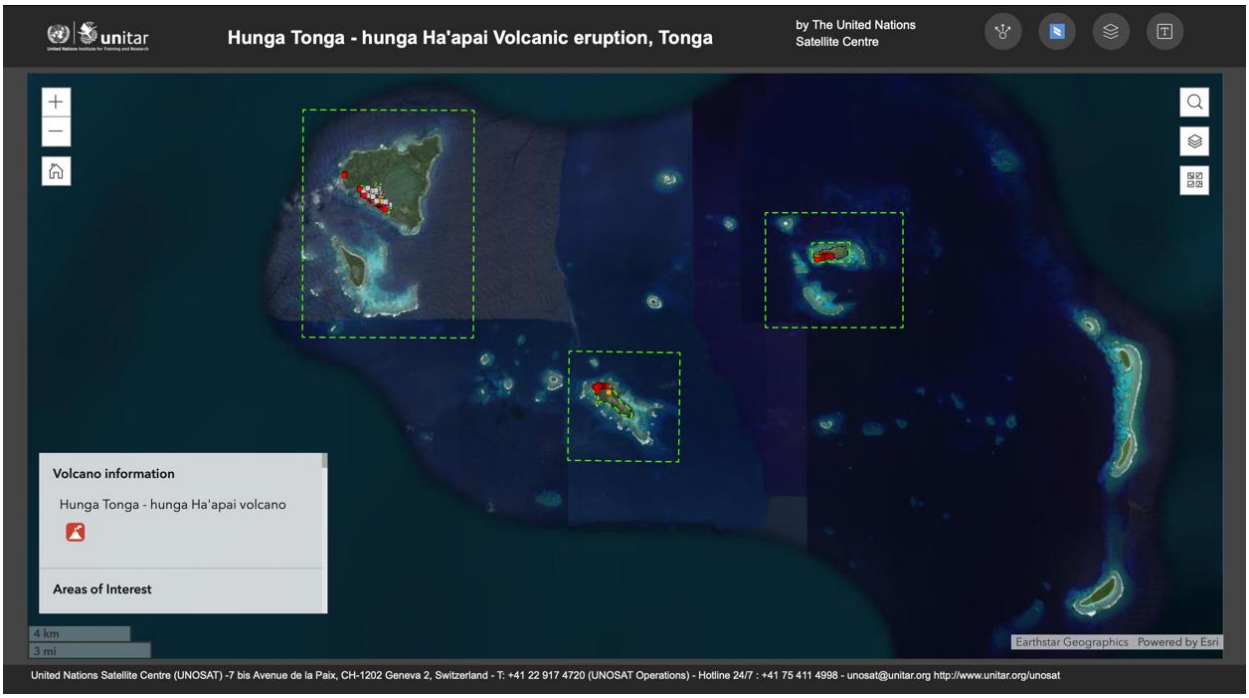


Figure 10. A snapshot of the UNOSAT web map interface displaying areas identified as damaged (red) and potentially damaged (orange) following the Volcanic Eruption in Tonga of all analysed areas (green).

Reference Ancillary data;
Administrative boundaries: Secretariat of the Pacific Community, Statistics for Development Division
Populated place: OpenStreetMap

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