Chapter 1

Uses of Free Geoinformatics for Disaster Risk Reduction in Small Island Developing States – A Case Study from Honiara, Solomon Islands

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Abstract

An increasingly wide range of geoinformatic data and software is available for the mapping and monitoring of hazard zones, vulnerable/exposed features and areas of risk. Unfortunately, there is a major cost barrier: high-resolution satellite imagery and the commercial geographic information system (GIS) software to process that data, can each cost many thousands of dollars. This study provides examples of low-cost or freely downloadable remotely sensed data and free Open Source GIS mapping software, applied to disaster risk reduction in small island developing states (SIDS). Examples are presented from Solomon Islands of hazard and vulnerability mapping based on free satellite data, with the data processing carried out using GIS freeware (QGIS). Strategies are discussed for improving the capacity in SIDS for accessing and effectively utilising free geoinformatics data and GIS freeware. The benefits of Open Data Cubes and their Analysis Ready Data layers for disaster risk reduction applications are considered, with particular regard to the challenges that many SIDS face. Universities, colleges and secondary schools are highlighted as being central to both improved capacity and improved outreach to remote communities.

1.1 Introduction

The annual cost of natural hazards has increased notably in recent decades, driven by pressures from growing populations, particularly in urban environments, as well as increases in the frequency and magnitude of climate-driven hazards (Hyndman 2017; Tomás and Li 2017). Improved decision-making for disaster risk reduction and climate change adaptation requires better knowledge to characterise, monitor and model geohazards and then mitigate their impacts on people and the environment (Pandian, Yarrakula and Chaudhury 2018).

The effects of global warming are uneven, with poor regions in the tropics and subtropics being most vulnerable, particularly small island developing states (SIDS). SIDS tend to have limited financial and human resources to prepare for shifts in temperature, precipitation and sea-level rise, yet they are expected to face bigger climate changes than mid-latitude countries and experience those changes earlier (Mora et al. 2013; Storlazzi, Elias and Berkowitz 2015; Schiermeier 2018). Future extreme sea level (ESL) events, such as storm surges, pose a further challenge to SIDS because ESL events occur randomly, and precise forecasts are limited to days or hours.

With regard to disaster risk reduction, urban areas are of particular concern, partially because of an increased urbanisation because of population growth and social-economic pressures, but also because of the associated growth of informal communities that are often located in hazardous terrain, such as floodplains. A further pressure comes from migration caused by climate change. In the Pacific, Fiji, Kiribati and Solomon Islands have several examples of climate change-related relocations from small islands to bigger islands (Locke 2009; Barnett and McMichael 2018; Newark and Reuters 2007; Gharbaoui and Blocher 2018). Moreover, due to challenging land-ownership systems, urban areas are likely to experience an increased amount of unplanned developments.

Satellite remote sensing, also termed Earth Observation (EO), has been widely applied to risk management at the preparedness, response and recovery stages of the disaster cycle. However, there has been a tendency to focus on disaster response (reactive approaches) rather than disaster preparedness (proactive approaches), with little attention paid to post-disaster recovery and rehabilitation, such as the design of effective ‘build back better’ strategies. This chapter examines how satellite remote sensing can assist with disaster risk reduction and climate change adaptation within SIDS, focusing on challenges associated with the ease of data supply, data management and public understanding of satellite-derived information. Those challenges will be discussed with regard to the example of Honiara, the capital of Solomon Islands.

1.2 Case Study: Honiara, Solomon Islands

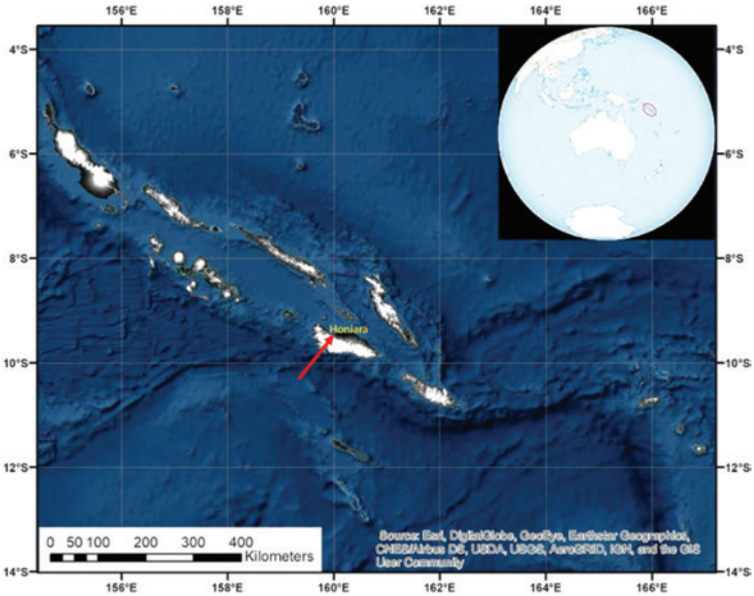
1.2.1 Location and hazard setting

Solomon Islands is a Pacific state consisting of six major islands and more than 900 smaller islands (Figure 1.1). With a population of about 620,000 (Worldmeters 2018) spread across 28,000 km^2, Solomon Islands are among the most sparsely populated of the Pacific SIDS. Despite this low population density, the majority of human settlements are located in low-lying coastal areas, which are becoming increasingly densely populated (Albert et al. 2016). Solomon Islands capital, Honiara, located on the north coast of Guadalcanal island, had a population of 84,520 in January 2017 (Countrymeters 2018). Figure 1.2 illustrates the rapid growth of Honiara’s urban and peri-urban areas since 2008.

1.2.2 Data access

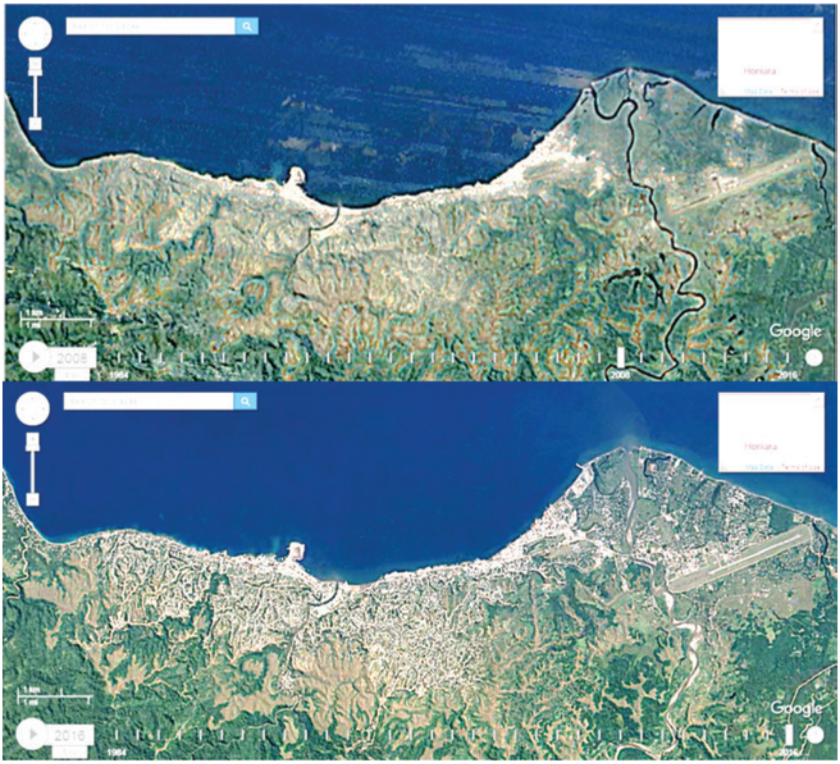
A needs assessment and gap analysis were carried out in Honiara during March 2018, regarding availability of geospatial data for Solomon Islands, via interviews with geoinformatics practitioners. The main data challenges were found to be: a widespread lack of digital maps; limited sets of thematic maps, such as geological

Figure 1.1 Location of Solomon Islands and the capital city, Honiara (arrow)



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 1.2 Landsat imagery of Honiara, illustrating the rapid urbanisation from 2008 (top) to 2016 (bottom), as seen on Google Earth Engine. Such rapid urbanisation inevitably leads to a number of informal settlements



maps, many of which were colonial-age printed maps; limited Internet access; minimal sharing of geospatial data between organisations; and the much more limited access to geospatial information in the smaller islands of the archipelago. Topping the list of geospatial needs in Solomon Islands were requests for a national digital elevation model (DEM), at a scale that could be of use at the district and community levels; next were requests for land-use and land-cover (LULC) change maps; then maps of hazards, vulnerability and risk. Another fundamental problem was a lack of geoinformatic expertise regarding GIS applications and, particularly, remote sensing (from image interpretation, through to data processing). Geoinformatic capacity building, via awareness raising and technical training, is a major need among Solomon Island government agencies, non-governmental organisations (NGOs), education establishments and businesses.

Solomon Islands' lack of digital maps, along with the limited or slow internet access, results in severe 'data poverty' (Leidig and Teeuw 2015; Leidig et al. 2016); geospatial data poverty is a major challenge for disaster risk reduction activities which hinders sustainable development (Teeuw et al. 2012).

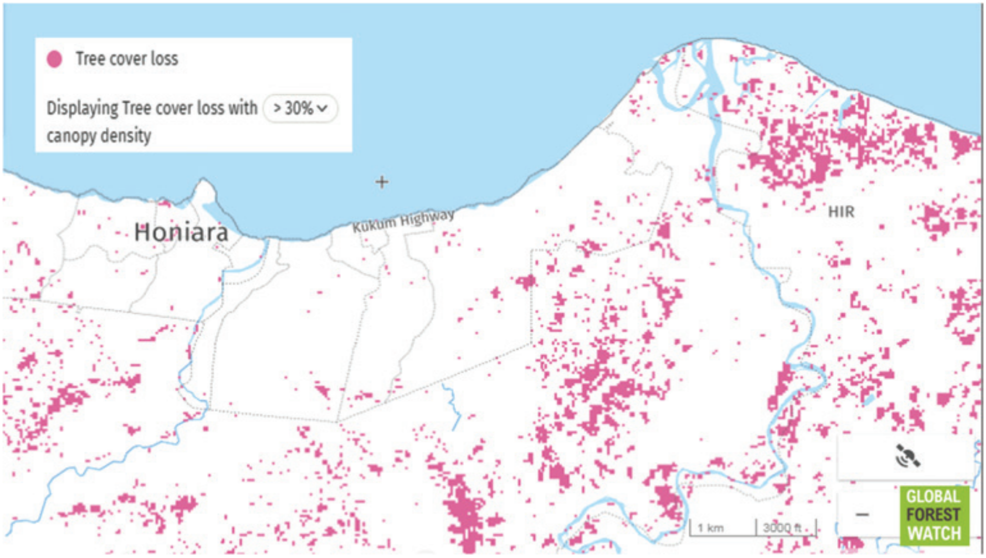
A freely available new technology that has great potential for reducing data poverty and assisting disaster risk reduction activities, is the development of Open Data Cubes derived from satellite imagery (CEOS 2017). Tens (or even hundreds) of satellite images covering a given area are automatically processed ('sieved' or 'diced') to remove unwanted features, such as cloud cover (Figure 1.3). Various algorithms are then run on those imagery data layers to produce sets of Analysis Ready Data, which form the basis for further layers such as maps showing areas of deforestation. As part of an international initiative to develop Open Data Cubes for all countries, the source code of algorithms for mapping has been made open and freely available for the following features: cloud-free mosaics, vegetation cover, urbanisation, surface water detection, surface water quality (turbidity), landslides and coastal changes, such as erosion or deposition (CEOS 2017).

One of the most effective systems for data cube processing of large archives of satellite imagery, such as NASA's four decades of global Landsat data, is Google Earth Engine

Figure 1.3 Schematic illustrating how satellite image data cubes work

Source: https://www.opendatacube.org/ceos

Figure 1.4 An Analysis Ready Data layer: tree cover loss in Honiara region (2001–17)



HIR: Honiara International Airport.
Source: Global Forest Watch, available at: https://www.globalforestwatch.org/dashboards/global

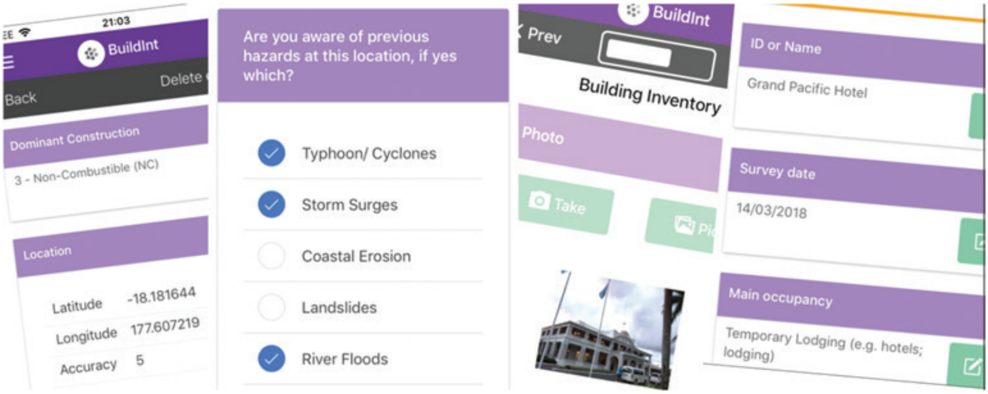
(available at: https://earthengine.google.com/), which was used to examine the recent rapid urban expansion of Honiara (Figure 1.2). An example of the application of Google Earth Engine, in conjunction with other data sources, is Global Forest Watch (available at: https://www.globalforestwatch.org/), which produced a map showing deforestation in Honiara district from 2001 to 2017 (Figure 1.4).

1.3 Methodology

A wide range of free satellite imagery has been used in this project, with district-level land-cover mapping based on the visible and infra-red wavelengths of Landsat and Sentinel-2, as well as analysis of digital elevation models (DEMs) from the shuttle radar topography mission (STRM: 30m pixels) and ALOS-PALSAR (12.5m pixels). To get an impression of the risk situation and the exposure of Honiara to hazards such as storm surges or tsunami, the DEM data were processed to map elevation, slope steepness and potential coastal inundation areas, with assumed wave heights of 5m and 10m (Figure 1.6). Free satellite images from Landsat-8 and Sentinel-2 (with 30m and 10m pixels respectively), as well as commercial high-resolution images from Planet.com (with 3.5m pixels), were processed to map near-shore relative bathymetry, using a bottom albedo-independent bathymetry algorithm developed by Stumpf and Holderied (2003).

The availability of vector data is limited and is primarily based on OpenStreetMap data and information digitised from scanned and georeferenced tourist maps. The OpenStreetMap data were simplified by removing all empty columns from the

Figure 1.5 Example outputs from the prototype mobile phone app for collecting COPE building details and information about local geohazards, for the Honiara GIS archive



Dominant Construction: 3 - Non-Combustible (NC)

Location

Latitude	-18.181644
Longitude	177.607219
Accuracy	5

Are you aware of previous hazards at this location, if yes which?

- ☑ Typhoon/ Cyclones
- ☑ Storm Surges
- ☐ Coastal Erosion
- ☐ Landslides
- ☑ River Floods

ID or Name: Grand Pacific Hotel

Survey date: 14/03/2018

Main occupancy: Temporary Lodging (e.g. hotels; lodging)

attribute table and summarising others to end up with only ‘osm_ids’, ‘occupancy’, ‘construction’ and ‘stories’. Not only could the missing information for these elements be easily collected by local authorities, via volunteered geographic information (VGI) campaigns, or via university and secondary school courses, but it also provides some essential vulnerability and exposure information for disaster risk reduction assessments.

The insurance industry COPE (‘construction, occupancy, protection, exposure’) classification system was used to classify the buildings entered into the GIS archive. A prototype mobile phone app was created for the collection of geospatial information about hazard zones, buildings and infrastructure in Honiara (Figure 1.5). The app could enable crowd-sensing verification of hazard zones and vulnerable features. Because the app is not dependent on internet access or phone networks, off-line data storage should enable the app to be utilised in remote locations.

At the time of this study, there were no digital maps available from official Solomon Islands sources. To assess risk-related features in and around Honiara, the available data sets, obtained from the internet and scanned paper maps, were combined in a GIS inventory (Table 1.1). To ensure maximum compatibility with Open standards, QGIS was selected as the GIS software. Ground-truth surveys to verify the resultant maps were carried out during March 2018.

1.4 Results

The use of freely available data in conjunction with freely available GIS software, such as QGIS, enables the mapping, visualisation and communication of critical infrastructure and building locations, both formal and informal, in low-lying coastal areas that might be prone to coastal flooding.

Relative coastal bathymetry can be extracted using freely available satellite data, such as Sentinel-2 (Figure 1.6). That satellite-derived bathymetry map provides a

Table 1.1 Datasets used in the initial GIS archive for Honiara

Dataset	Spatial resolution	Application/derived product
Digital elevation models		
SRTM https://earthexplorer.usgs.gov	30m and 90m	– slope hazard maps
ALOS PALSAR https://vertex.daac.asf.alaska.edu	12.5m	
Optical satellite data		
Landsat-8 https://earthexplorer.usgs.gov	15m to 30m	– nearshore bathymetry for run-up hazard maps
Sentinel-2 https://scihub.copernicus.eu/dhus/	10m	– land use and land cover
Planet https://www.planet.com/products/planet-imagery/	3.5m	
Scanned maps		
Honiara geological map	1:50,000	
Tourist map	ca. 1:10,000	– with some COPE annotations
Base-map		
OpenStreetMap https://www.openstreetmap.org	Variable, from 1:10,000	– vector files containing e.g. digitised building locations, infrastructure locations

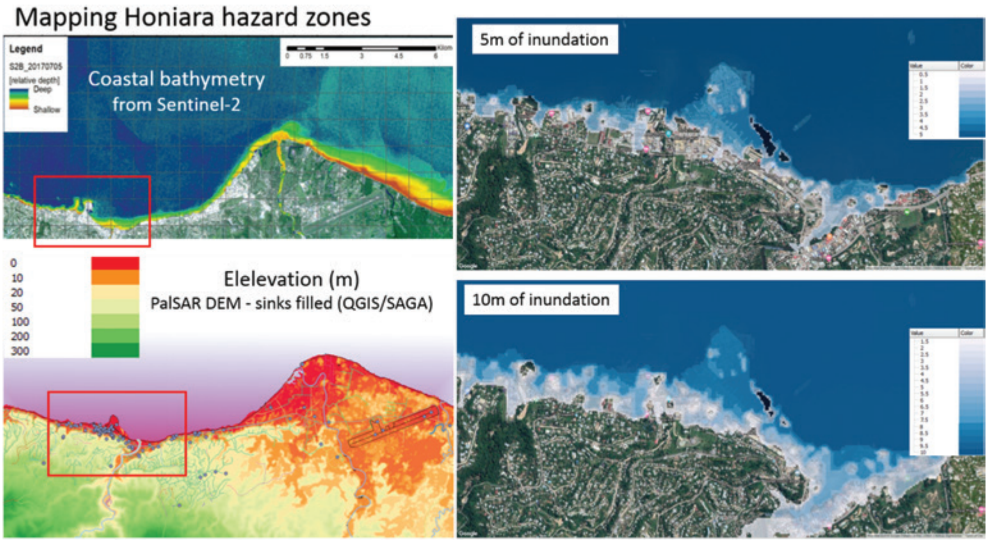
useful indication of the coastal geohazards, although it is not suitable for navigation purposes (Collin et al. 2017; Parente et al. 2018). If there are extensive coastal areas with shallow water and low gradients, then the run-up effects with storm surge waves or tsunami waves will be exacerbated. With reference to Figure 1.6, the coastline to the east of Honiara city has a more severe run-up hazard.

Of the features at risk of coastal flooding, Honiara's main hospital is of particular concern: it is located on the seafront in the low-elevation coastal zone. Also at high risk are the prime minister's office, the Japan International Cooperation Agency (JICA) office, many embassies, as well as the National Disaster Management Office (NDMO). Moreover, considering the rapid urbanisation of Honiara in the past decade (Figure 1.2), there are many informal urban developments in flood-prone low-elevation coastal zones, notably along the Mantaniko River, where flooding killed almost 20 people in 2014.

1.5 Discussion

Honiara provides an example of the limitations that severe data poverty places on disaster risk reduction activities. There is a lack of up-to-date digital maps at the local or district scales, a very limited number of geoinformatics experts (especially with regard to remote sensing), limited finances, and limited resources for mapping and

Figure 1.6 Use of geoinformatics to map Honiara's hazard zones. Bottom left: Elevation map derived from ALOS PALSAR DEM data, with some examples of critical infrastructure locations and areas flooded by the Mataniko River in 2014. Top left: Honiara coast: relative near-shore bathymetry (red: shallow water; to blue: deep water), derived from Sentinel-2 imagery of 5 July 2017. Right: Use of QGIS to map areas of coastal flooding, for 5m and 10m of inundation (detail of the area indicated by the red box)



risk assessments. Unfortunately, such a situation is typical in many SIDS and low-income countries. Furthermore, as soon as rural areas or remote islands in SIDS are considered, the situation with regard to any type of maps, data and information tends to be even worse.

The distinction of settlements as being 'formal' and 'informal' is not always possible by satellite remote sensing: such assessments require local expert knowledge. Some of the required local expert knowledge could be collected via volunteered geographic information (VGI) and crowd-sensing, as illustrated in the mobile app developed for this project (Figure 1.5). The approach presented facilitates monitoring areas of fast urban growth, which may be in areas previously avoided for settlement because of geohazards, such as steep slopes or floodplains.

With an increasing amount of freely available satellite remote sensing data, analysed using freely available software, there are now many ways to rapidly map the elevation, coastal bathymetry and land-cover types of previously poorly-mapped districts. That can greatly assist climate change adaptation and disaster risk reduction initiatives, by highlighting geohazard zones, vulnerable features and high-risk locations, assisting decision-makers in the preparedness phase of emergency management by targeting often limited resources towards areas at greatest risk of disaster (e.g. Teeuw et al. 2012; van Westen 2013; UNOOSA 2017; UN ESCAP 2017; World Bank 2018). The data collected for risk assessments also support disaster response and provide a baseline for damage assessment and reconstruction, or more generally for risk-informed planning (Deichmann et al. 2011).

The freely available datasets considered here could potentially be incorporated in an Open Data Cube (ODC) for Fiji, which is currently being developed by the CommonSensing project, funded by the UK Space Agency (Reliefweb 2018), with follow-on ODCs envisaged for Vanuatu and Solomon Islands. An ODC is also being developed for Samoa by Australia's Commonwealth Scientific & Industrial Research Organisation (CSIRO). Two of the satellite-derived Analysis Ready Data layers being tested in the CommonSensing project could become new additions to the Open Data Cube family: (i) a DEM layer, from which slope-related hazard zones (i.e., landslides and flooding) can be mapped; and (ii) satellite-derived nearshore bathymetry data, from which run-up hazard maps can be produced.

This preliminary study, using freely available geospatial data along with local expert knowledge, provides a promising outlook for the continuation of this work. Ensuing research aims to update the initial Honiara GIS archive with relevant data for disaster preparedness, mapping the exposure of properties to coastal geohazards, selecting safe sites for shelters, and helping emergency planners to make informed decisions about future developments of critical infrastructure and settlements.

As illustrated above, free satellite imagery, particularly when provided as Analysis Ready Data (ARD) layers within Open Data Cubes (ODCs), offers many rapid and cost-effective ways of detecting and monitoring features of use in disaster risk management. However, there are some limitations, as mentioned by Guiliani et al. (2017). In general, there are the Big Data management issues, the complex system architecture and the associated high costs of building an ODC.

There are also some geographical limitations in the availability of satellite data coverage that are common to SIDS: mountainous islands often have cloud cover, or at least frequently cloud-covered hinterland hills, which limits applications dependant on visible and infra-red sensors. Some SIDS are in remote settings relative to the main land masses to which most satellite data capture is focused. Satellite data coverage is a particular problem for Pacific SIDS, where there is very limited Landsat data coverage during 1987 to 1999 for Vanuatu, Nauru and Solomon Islands (Guiliani et al. 2017). There is also a challenge with ODCs and ARD layers being a new technology for which capacity building is needed: this is an issue that the CommonSensing project will address in Fiji, Vanuatu and Solomon Islands, via workshops for awareness raising and technical training.

Another limitation is a given country's access to digital data and the issue of relative data poverty (Leidig et al. 2015). As of 2019, both Fiji and Vanuatu have high-speed/high-volume data links via submarine fibre-optic cables, but Solomon Islands is limited to relatively slow, low-volume satellite data links. Joining Solomon Islands to regional submarine fibre-optic cables, such as the Coral Sea Cable System or the Interchange Cable Network 2, both expected by 2020, should help to alleviate this issue and enable greater use of geoinformatics for disaster risk management applications.

Even with access to internet-deliverable Analysis Ready Data, from data cubes and other geoinformatics data archives, there are still data poverty issues with regard to remote communities, particularly those on small islands in archipelago states, located far from islands with cities that have easy access to the internet and phone networks. Recent discussions with emergency planners and representatives of NGOs involved with disaster risk reduction, in Pacific SIDS (Fiji, Samoa, Solomon Islands, Vanuatu), Caribbean SIDS (Barbados, Dominica) and low-income small states (Sierra Leone, El Salvador), have highlighted that local universities, colleges and secondary schools are central to both improved geoinformatic capacity and better outreach to remote communities.

1.6 Conclusion

An increasingly wide range of geoinformatic data and software is available for the mapping and monitoring of hazard zones, vulnerable/exposed features and areas of risk. Unfortunately, there is a major cost barrier: high-resolution satellite imagery and the commercial GIS software to process that data, can each cost many thousands of dollars.

This study provides examples of freely downloadable remotely sensed data and free Open Source GIS mapping software, applied to disaster risk reduction in Solomon Islands, a low-income island state. Moderate resolution satellite imagery, with pixel sizes ranging from 10m to 30m, was used to map hazardous terrain and vulnerable features in the district around the capital city, Honiara. Google Earth Engine has been used to monitor and map changes in urban area and tree cover since 2008.

A dedicated Open Data Cube (ODC) is currently being developed for Fiji by the UKSA-funded *CommonSensing* project, with further ODCs envisaged for Vanuatu and Solomon Islands. An ODC is also being developed for Samoa via Australian technical assistance. Two new data layers for use in ODCs have been tested on Honiara district, a DEM-based slope hazard layer and a coastal run-up hazard layer based on satellite-derived bathymetry – the preliminary results of this are encouraging.

Acknowledgements

This research was carried out as part of the *CommonSensing* project, funded via the International Partnerships Programme of the UK Space Agency.

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