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TOPICAL COMMUNICATIONS

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Assessing hazards and disaster risk on the coast for Pacific small island developing States: the need for a data-driven approach

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Abstract

Small island developing States, such as those in the Pacific, are often prone to multiple hazards that have potential to result in disaster and / or restrict development. Hazard data can be limited in resolution or omitted in or near SIDS' coasts, but a growing and improved range of datasets are becoming available. Through an analysis of approximately 100 policy documents on hazards and disaster risk management in Pacific island nations, we found: limited information on hazards and how they manifest to disasters at local levels, thus not fully connecting drivers and subsequent risk; at times a non-specific multi-hazard approach prompting the need to address more specific hazards; and restricted temporal and spatial scales of analysis that potentially limit continuity of actions where mitigation methods evolve. These limitations suggest that appropriate and timely high resolution hazard data is needed from the top-down to underpin the design and development of local disaster risk management plans, simultaneous to local, bottom-up knowledge and interpretation to bring the realities of such hazard data to life. Developing and ensuring openly available hazard data will enable island States to develop more robust, inclusive disaster risk management plans and mitigation policies, plus aid inter-island comparison for communal learning.

Keywords: Data, Small islands, Hazard, Disasters, Risk, Risk management, Disaster planning

1 Hazards and disaster risk in small island developing States

Environmental hazards on Pacific small island developing States (SIDS) include tectonic (tsunami, earthquake, volcanic), meteorological (storm surges, monsoons, cyclones, fluvial flooding) and associated geomorphic (landslide, sedimentation, erosion) processes (e.g., Brown et al., 2020; Duvat et al., 2021; Hay et al., 2019; Terry and Goff, 2012). Hazards, such as the 2022 Tonga earthquake and associated tsunami can be locally catastrophic (BBC, 2022) and felt world-wide, leading to a growing need for high performance computing to understand subsequent disasters and impacts (Yuen et al. 2022). Climate change is projected to exacerbate many impacts (IPCC, 2021; Mycoo et al. 2022). Consequently, amid increasingly complex interactions with the human system, there is a need to understand what, where and how hazards occur, their potential impacts and local risks. This is especially important where it could affect livelihoods and limit growth and development (IPCC, 2021, 2018; United Nations, 2015, 2014). For example, multiple hazards have hampered Vanuatu's efforts to graduate from the Least Developed Countries list since it was identified as a candidate in 2006 (United Nations, 2017). Presently there is limited consistent hazard, exposure and vulnerability data in Pacific SIDS, making disaster risk management (DRM) more challenging, yet determining key methods and intervention points to reduce a hazard's impact (Vakis, 2006) can aid disaster management

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(Asian Development Bank, 2014). Risk management plans are central to achieve global targets such as the Sustainable Development Goals (SDG) (United Nations Development Programme, 2021) and the Sendai Framework for Disaster Risk Reduction (United Nations, 2015). This Topical Communication reviews hazard-based data needs for improved DRM and subsequent mitigation at strategic levels by (i) identifying hazard data (in Section 2); (ii) reviewing existing DRM documents across 21 Pacific SIDS to determine gaps in current DRM documents in terms of how hazard data is used (in Section 3); and (ii) suggesting a route forward (in Section 4). It is noted that improved vulnerability data is also required to improve risk metrics, however the focus here is on hazards.

2 Identifying hazard data

Historically, hazard data and events in Pacific SIDS is often limited to national level and at coarse resolutions, but this is improving (Asian Development Bank, 2014). In the last decade, access to global spatial inventories of hazards and impacts have increased (Wirtz et al., 2012). For example, many organisations share hazard, exposure, vulnerability and impact data. These include: Munich Re's NatCatSERVICE (Munich Re, 2021), Swiss Re's Sigma (Swiss Re Institute, 2021), ThinkHazard! (Global Facility for Disaster Reduction and Recovery, 2020), Global Risk Data Platform (UNEP/GRID-Geneva, 2013), National Oceanic and Atmospheric Administration (2021), Pacific Data Hub (Pacific Community, 2021), SPC Statistics for Development Division (2022), Wirtz et al. (2012) and the Centre for Research on the Epidemiology of Disasters EM-DAT database (Centre for Research on the Epidemiology of Disasters, 2021). Despite these resources, SIDS do not feature prominently in global hazard and climate change projection databases (e.g. Vafeidis et al. 2008) as they are often too small in comparison to data resolution (e.g., areas of inland high elevation not identified within a lower spatial data sub-set or missing entirely), remote (meaning they are not well represented on land based global datasets as the data in the cell can be considered as ocean), have limited in-situ measurements or lack infrastructure and resources to monitor all hazards. Nevertheless, the need for robust and timely high-resolution hazard data remains (Berg et al., 2015) so SIDS have a wider picture of hazards and further develop local and regional partnerships and DRM plans.

3 Risk framing and analysis of disaster risk documents

This section considers findings from an analysis of disaster risk documents.

3.1 Disaster risk

Disaster risk reduction (DRR) is explicitly mentioned in SDGs: (1) No poverty, (2) Zero hunger, (11) Sustainable cities and settlements, and (13) Climate action, and implicitly in many others (UNISDR, 2015; United Nations Development Programme, 2021). The Sendai Framework for Disaster Risk Reduction (United Nations, 2015) argued that DRR be built into 'policies, plans, programmes and budgets at all levels'. This reinforced the 2014 Small Island Developing States Accelerated Modalities of Action (SAMOA) Pathway (United Nations, 2014), with the SAMOA Pathway's 2019 mid-term review indicating the need for improved data collection and national statistics, financing and partnerships to implement these frameworks (United Nations, 2019). DRR and climate change adaptation have overlapping priorities (Gero et al., 2011). National Adaptation Plans were introduced in 2011 (UNFCCC, 2021) to identify medium and long-term adaptation needs using a progressive and iterative process which follows a country-driven, gender-sensitive, participatory and fully transparent approach. Additionally, the Pacific Community (SPC) provides guidance for individual SIDS to create their own plans and policies (e.g., 'Framework for resilient development in the Pacific (2017–2030)' (Pacific Community et al., 2016), encouraging the transfer of knowledge and skills, and identifying where coordinated actions would be beneficial. Despite this, adaptation to climate change is occurring at different rates within Pacific SIDS (Robinson, 2020).

Disaster risk can be framed as the product of hazard, exposure and vulnerability (IPCC, 2012, 2022), requiring prevention, mitigation, preparedness, response, recovery and rehabilitation strategies (United Nations, 2015). These strategies need a data driven understanding of the local risk drivers (Fig. 1) to better coordinate DRM and actions plans (Berg et al., 2015). This includes exploring the relationship of hazard to disasters, monitoring and early warning, assessment methods, scenarios, open communication and reporting metrics. Mitigating for and adapting to disasters means assessing how risk varies through time and space. For example, increased exposure due to growing populations (Mason et al., 2020), or increased value of assets on SIDS' coasts, mean risk is enhanced, especially in highly interconnected coastal communities. Hence changing exposure needs to be considered over long-term disaster risk plans to determine best ways to adapt.

3.2 Methods

In light of the data requirements for the development of plans, we analysed approximately 100 policy documents on DRM published over two decades downloaded from national government websites,

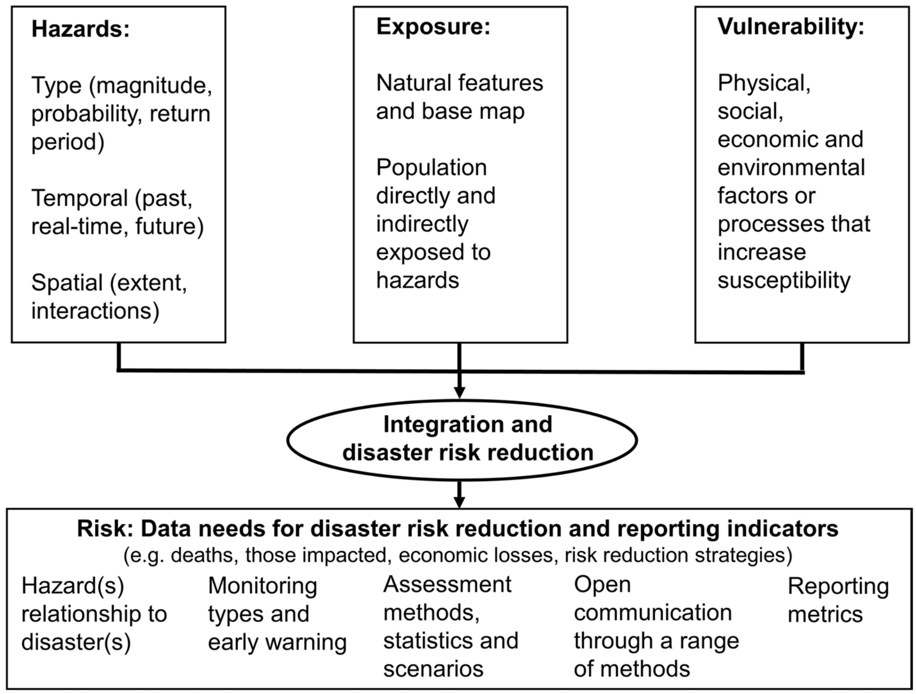

Fig. 1 Data needs portrayed in a risk framework (IPCC, 2012) mapped against data needs identified in the Sendai Framework for Disaster Risk Reduction (United Nations, 2015)

development banks, the Pacific Community and disaster risk prevention websites in 21 small island Pacific nations (Table SM1. See SM1.1 for selection criteria of materials and SM1.2 for methods). These set out responsibilities, processes, infrastructure, emergency response and recovery processes to disasters. Whilst we acknowledge that not all plans are online and some are not in English, those that were available provided a representative overview of the current position as multiple searches were undertaken until no more reports were found, with sector specific plans cross referenced with generic plans. As many reports came from similar aid or disaster prevent organisations, their websites were checked for any missed plans and how plans evolved over time.

They were analysed to determine if nations had (i) policies or legislation that is hazard and/or climate related; (ii) hazard management and/or hazard action plans; (iii) specific management of a hazard(s) or generic; (iv) disaster risk assessments including risk reduction strategies. These features specifically related to indicators of the SDG (United Nations Development Programme, 2021) and the Sendai Framework for Disaster Risk Reduction (United Nations, 2015). Rather than look for the details of hazards or plans, the goal was to ascertain whether policies, plans or DRR strategies were present from a strategic perspective and identify their underlying data.

3.3 Planning and responding to hazards

From the DRM plans available, challenges were identified with respect to how hazard data has been used and the development of robust DRM strategies:

- Limited hazard information: Whilst appreciating that detailed sources of hazard information are not be included as DRM plans as they not data repositories, some plans showed limitations in hazard detail (e.g., magnitude, frequency, duration) within a country (e.g. Pitcairn Islands, Tonga). Thus, how a hazard could manifest into a disaster did not appear to be fully explored. For instance, where climate change was listed as a hazard, only global or sub-global data sources and projections were available (e.g., from the Intergovernmental Panel on Climate Change or CSIRO as seen in the 2019 in Kiribati (Government of Kiribati, 2019) and in 2014 in the Marshall Islands (Republic of the Marshall Islands, 2014), as only a few places were reported in country or local data does not exist). This means potentially important regional or local variations in the impact of hazards (e.g. due to topography) and therefore

risk connections were not fully made and could be a limiting factor when undertaking larger scale strategic decision making. Consistency in data sources across different sectors was difficult to determine.
- Multi-hazard approach: Emergency response plans were similar across a range of hazards (e.g., Cook Islands, Niue and Palau), suggesting related responses in DRR. Others were more forthright on committing to multi-agency and multi-hazard approaches, such as Vanuatu's climate change and DRM policy (Government of the Republic of Vanuatu, 2015). The integration of planning and response across both hazards and affected sectors could evolve to take a more complementary approach.
- Temporal evolution: Funding streams were often from global or regional organisations and consequently supported the use of use external expertise (e.g., Palau working with the government of Japan and the Romanian Agency For International Development Cooperation (UNDP, 2021)). Plans and responses were therefore often time limited, with revisions or updates not automatically planned for, particularly in subject specific plans. This has the potential to limit continuity of actions where hazards evolve.
- Spatial scales: Whilst acknowledging in SIDS that national can also mean local, only a few nations considered sub-national or local planning strategies (e.g., the Federated States of Micronesia had sub-regional plans published online covering Chuuk (Chuuk State Government, 2017), Kosrae (Secretariat of the Pacific Community, 2015), Pohnpei (Pohnpei State Government, 2016) and Yap (Secretariat of the Pacific Community, (2015)). This can mean that important localised variations in risk are missed. Where local science or DRM plans exist, these may only be specific to certain types of hazard (e.g., tsunami risk in New Caledonia (Thomas et al., 2021). Hence, targeted support, capacity building and funding is required to bring local level information and local populations into disaster risk strategies.

These issues point towards the need for extensive local hazard data which may need to be internationally sourced but locally interpreted, addressing exposure and vulnerability. The latter two were often addressed separately from the DRM plans, such as through national strategic plans that transverse longer timescales than more shorter scale DRM plans.

4 A route forward

Given the challenges presented, this section considers their implications.

4.1 Meeting the sustainable development goals

Indicators of the SDGs (United Nations Development Programme, 2021) state the need for national and local disaster risk reduction strategies, and the proportion of governments that adopt those strategies plus additional disaster related statistics. Furthermore, SDG 13 (Climate Action) targets the need to strengthen resilience and adaptive capacity, and part of this is a greater understanding as to when and where hazards occur and their impact. Despite this, many Pacific SIDS do not have the capacity to provide statistical evidence to illustrate progress on these components of the SDGs (e.g., Lal, 2020) and need support to augment existing resources (United Nations, 2015).

SIDS are in a unique situation: although surrounded by water and many being geographically remote, they are not remote in themselves as they are integrated into a much wider and connected terrestrial and marine socio-ecological system. Integration into the wider system is therefore essential for successful risk reduction planning, particularly as their economies change and develop. Communication between SIDS allows for generic lessons to be learnt about drivers of vulnerability and exposure (Petzold and Magnan, 2019) that can inform adaptation and mitigation needs. As development occurs, particularly in highly populated coastal zones (Andrew et al., 2019), better integration of information on risks into development planning is needed (e.g. sharing of data, propagate of disasters, successful mitigation measures), especially as climate and risks evolve.

Given these challenges, the need for robust and timely high-resolution (0.50 m to 1,000 m depending on the type of information or infrastructure system at risk) hazard data in SIDS remains (Berg et al., 2015) to further develop local and regional partnerships and disaster risk action plans. Improved DRM cannot be achieved without an improved understanding of the first-order drivers of hazards, acknowledging these may not originate on the coast but affect coastal populations and infrastructure. Data and a stronger evidence base is needed to better understand risk drivers. Wider social risk management approaches could help, especially from the international community given the bespoke needs and specialist high-resolution data required. Capacity building in the medium to long-term can help so that Pacific SIDS (and others) are able to facilitate and be more self-reliant on DRR data collection and interpretation themselves, away from or in addition to external projects that can be of short-term duration.

4.2 Top-down and bottom-up approaches

Conway et al. (2019) argued that top-down and bottom-up approaches are needed to assess climate risk. The same can be argued in managing hazards and disaster risk through improved understanding of hazards, exposure and vulnerability. Top-down approaches guide where large-scale disasters may arise, whereas bottom-up approaches with local data and expertise provide details of potential cascades of hazards and impacts identifying where local social risk management is required to prevent a disaster from unfolding.

Present top-down datasets (e.g., Pacific Community, 2021; Secretariat of the Pacific Regional Environment Programme, 2020; SPREP, 2021) include SIDS (national) level or administrative district level population data, including national earthquake maps and environmental indicators (see Section 2), but would benefit from being of a higher resolution (e.g., Berg et al., 2015). Presently, these data are focused on hazard and exposure assessment rather than vulnerability at local levels (for the latter, examples are apparent, such as shelters or evacuation routes for tsunamis). Further exploration is needed to encompass this aspect of risk evaluation (Fig. 1) quantitatively or qualitatively. This would be in line with the Sendai Framework for Disaster Risk Reduction (United Nations, 2015) which aims to use data to integrate all risk components.

Bottom-up approaches and involvement is crucial as high-resolution data has limited meaning unless there is local community interpretation and local/traditional knowledge, particularly as vulnerabilities are currently difficult to quantify. When a disaster does occur, and even taking account of emergency response organisations and international aid (which can be significant as compared with the size of their economies, aid in general is large against international standards (Feeny and McGillivray, 2008), it is also the individuals at the local level and at the heart of the emergency who respond first, working closest to those people they are striving to protect. Hence, a shared understanding of the propagation of hazards is critical to prevent a disaster. Initiatives, such as the Small Island States Resilience Initiative (Global Facility for Disaster Reduction and Recovery, 2021), channelling support for investment, technical and operational support and knowledge exchange, are vehicles to achieving these aims.

For both approaches, the key is an enhanced provision of risk data:

- Top-down risk approaches: Increased high resolution and currency in maintained databases funded by the international community as a pooled resource. Increasing high-resolution data (see Section 2) needs to be openly available with international cooperation for nations who cannot produce their own without help. If a standardised approach were used, wider integration, understanding and inter-island comparisons (Robinson, 2018) can be undertaken, which is important when considering social protection measures. For example, consistency could be a standard data format, layout, method, resolution or return period, and could include national providers and international datasets with strict quality control (Jevrejeva et al., 2019). Hazard information could be displayed in an open, user-friendly (e.g., data driven and graphically driven depending on the expertise and needs of the end user) way co-designed with local communities and relevant for experts and non-experts to enhance communication and knowledge exchange and to enhance decision making (GFDRR, 2015). Monitoring and early warning systems, and reporting of metrics could enhance this process (Fig. 1).
- Bottom-up risk approaches: Continuous local investment, support and knowledge exchange. The potential for top-down, high quality, high resolution information is limited unless there is continued investment in local interpretation, technical and research expertise alongside local knowledge. Investment is needed for continuity in data, statistics and information supply, in understanding and acting on hazards to avoid fragmentation, drawing on a range of technical and operational support (Global Facility for Disaster Reduction and Recovery, 2021). This is particularly important to determine how a hazard turns to disaster, and where social risk management through mitigation and/or adaptation policies may be applied.

Disasters can be prevented more by socio-economic factors than political factors (Tselios and Tompkins, 2020). Investing in risk data that provides evidence for the outcomes of socio-economic decisions, has the potential to reduce disaster risk through mitigation and/or adaptation, but only when combined with local knowledge.

5 Conclusion

In an increasingly data rich world, there remains limited but growing knowledge of how hazards propagate to disasters in SIDS, including in the Pacific. Limited spatial resolution limits further understanding on the manifestation and action into disasters. From analysing approximately 100 DRM related documents in 21 Pacific small islands nations, it was found that at times there was limited information on specific hazards, how multi-hazards are considered in practice, plus temporal and spatial changes in hazards within DRM. Despite some individual examples of best practice e.g., for Apia, Samoa or the Federated States of Micronesia, many SIDS were not reporting that they plan for DRR at regional or local levels (although they may be in practice), or which components of the DRR cycle are strongest to action regional mitigation actions.

With some SIDS held back from development due to hazards, greater scientific endeavour is needed to provide top-down high-resolution risk data (including hazard, exposure and where possible metrics of vulnerability) in an easy to access manner. From the bottom-up, continuous investment, support and knowledge exchange is needed so the data can be used to better inform the drives disasters, thus better informing mitigation and/or adaptation needs. Thus, we argue that a greater data-driven approach from both top-down and bottom-up perspectives are needed to reduce disaster risk and enhance disaster risk planning.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1007/s44218-022-00005-3.

Additional file 1.

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Authors' contributions
SB and DS conceived the study, with help from SEH. SEH with help from SB analysed the policy documents. SB and SEH drafted the article, with input from DS, CH and CWH. The author(s) read and approved the final manuscript.

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Availability of data and materials
All data is publicly available, with broad frameworks and resources used in Table SM1.

Declarations

Competing interests
None to declare.

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