frontiers in Climate

DATA REPORT
published: 19 March 2021
doi: 10.3389/fclim.2021.591020

Toward an Interoperable National Hazards Events Database for South Africa

Claire Davis-Reddy†* and Amelia Hilgart*†*

uLwazi Node, South African National Observation Network, Cape Town, South Africa

Keywords: South Africa, disaster risk reduction, disaster loss data, interoperability, events database, disaster loss database

Edited by:
Andrew John Dougill, University of Leeds, United Kingdom

Reviewed by:
Anna Steynor, University of Cape Town, South Africa
Stavros Afionis, Cardiff University, United Kingdom

***Correspondence:**
Claire Davis-Reddy
claire@saeon.ac.za

†These authors have contributed equally to this work

Specialty section:
This article was submitted to Climate Services, a section of the journal Frontiers in Climate

Received: *03 August 2020*
Accepted: *04 February 2021*
Published: *19 March 2021*

Citation:
Davis-Reddy C and Hilgart A (2021) Toward an Interoperable National Hazards Events Database for South Africa. Front. Clim. 3:591020. doi: 10.3389/fclim.2021.591020

INTRODUCTION

At the global scale, the frequency, extent and severity of natural disasters have increased notably over the last several years (Sapir et al., 2004; Field et al., 2012; McPhillips et al., 2018; Coronese et al., 2019). Climate-related disasters (floods, storms, droughts, wildfires, and heat waves) have come to dominate the disaster risk landscape accounting for upwards of 91% of the major-recorded events worldwide between 1998 and 2017 (Wallemacq, 2018). South Africa has faced a number of climate-related disasters over the last few decades including the 2014–2016 drought in which the country experienced the lowest annual rainfall amount on record (AgriSA, 2016; Engelbrecht et al., 2018). More frequent and intense events combined with a growing and urbanizing population, poor land-use practices, and an increasing number of people residing in informal settlements and high-risk areas, are likely to exacerbate the vulnerability of communities to climate-related events (Vermaak and Van Niekerk, 2004; Van Huyssteen et al., 2013; Thornton et al., 2014).

The shift toward proactive planning and preparedness that is closely tied to climate change adaptation requires reliable records of disastrous events to be collected, maintained, and managed (Kar-Purkayastha et al., 2011). Despite increasing access to data from a wide variety of sources, integration and reuse remains difficult due to a number of interoperability barriers to working with disaster data (Migliorini et al., 2019). Interoperability refers to the ability to create, exchange and consume data with common understanding of context and meaning of the data (Wilkinson et al., 2016). Barriers to interoperability of disaster databases include issues such as the lack of geospatial data that is comparable across communities, districts, and countries and which is consistent over time (Department of Environmental Affairs, 2014; Storiea, 2017; Li et al., 2019; Valachamy et al., 2020). Other issues include the use of different disasters classification systems and the lack of standardization in associated definitions. These inconsistencies are a result of the variations in how disaster data has been collected over time by a variety of countries and organizations, the types of disasters reported, spatial, and temporal data aggregations (Tschoegl et al., 2006; Integrated Research on Disaster Risk, 2014; Osuteye et al., 2017).

Due to the cross-sectoral nature of the disaster domain the exchange of data and the fulfillment of interoperability requirements is particularly critical. The minimum system requirements for an interoperable disaster loss database are outlined in South Africa's National Disaster Management Framework (Republic of South Africa, 2005). A shared disaster risk system must facilitate: "interoperability between systems and system components; sharing of common system components; common infrastructure components and common data/information; and reuse and customization of system solutions or components" (Republic of South Africa, 2005, p. 73).

This paper will consider some of the available sources of disaster data for South Africa and present a comparison between the recorded deaths as a result of natural disasters in South Africa from 1997 to 2016 based on data from the South African Vital Statistics and Emergency Events Database (EM-DAT) to demonstrate some of the challenges with existing databases. We then present our recommendations built into a prototype National Hazards Events (NHE) online reporting system. The proposed open-access system presents a standardized, scalable design method and implementation of a database that can be used to improve data collection and reporting.

STATUS OF DISASTER LOSS DATABASES FOR DISASTER RISK REDUCTION IN SOUTH AFRICA

International Databases

Currently, there are six major global open-access disaster loss databases that can be used to derive the baseline data for disasters in South Africa: United Nations Desinventar Sendai (United Nations Disaster Risk Reduction, 2020), Global Sustainable Development Goal Indicators Database (United Nations Disaster Risk Reduction, 2020), NatCatSERVICE (Munich Re)[1], Sigma (Swiss, 2020), Global Disaster Identifier Number (Asian Disaster Reduction Center, 2004), Global Risk Data Platform (United Nations Environmental Program, 2013), and EM-Dat [CRED (Centre for Research on the Epidemiology of Disasters), 2020]. Each of these databases provides access to records about disaster occurrence, damages, losses, and impacts, compliant with the Sendai Framework for Disaster Risk Reduction 2015–2030 (SFDRR) monitoring minimum requirements (UNISDR, 2017).

The data available in these international databases varies between sources and calendar years resulting in inconsistencies between data outputs. For example, differences exist in the date of events in different databases. NatCatService and Sigma usually record a period for the disaster with a start and end date whereas EM-DAT records the day the event was declared a disaster or emergency. Moreover, international databases tend to record losses only from large scale events. In the cases of EMDAT and DesInventar this means that events are only recorded if 10 or more people are reported killed; 100 or more people need to be evacuated, provided with humanitarian assistance or otherwise affected; countries declare an emergency or call for international assistance (Osuteye et al., 2017). This conceals the diversity of the hazard landscape in South Africa, which experiences a far broader range of small hazards. These include mini-tornados, localized flooding and slow-onset flooding events, deaths due to lightning strikes and fires in informal settlements. Consequently international databases tend to underestimate the scope and prevalence of hazard events in South Africa.

National Database

There is currently no internationally standardized database on loss or damage of disaster events for South Africa (UNISDR, 2019). In 2018, the National Disaster Management Center (NDMC) released an online Disaster Atlas Application (National Disaster Management Centre, 2018) to serve as the national disaster database. The portal enables users to view records of declared or gazetted disasters for the period of February 2006 to March 2017. The data is not currently available for download and the database has not been updated since March 2017 for more recent disasters. Events presented in this database were declared either local, provincial or national disasters and met the criteria laid out Section 1(1) of the Disaster Management Act No. 57 of 2002 (Republic of South Africa, 2002):

"Disaster" means a progressive or sudden, widespread, or localized, natural or human-caused occurrence which-

(a) causes or threatens to cause-
  (i) death, injury or disease;
  (ii) damage to property, infrastructure or the environment; or
  (iii) disruption of the life of a community; and
(b) is of a magnitude that exceeds the ability of those affected by the disaster to cope with its effects using only their own resources;"

While understanding that not all extreme or hazardous events are declared a disaster (see Van Niekerk, 2014), there are inconsistencies in reporting that make it difficult for practitioners and researchers to access consistent information to inform Disaster Risk Reduction (DRR). For example, a fire in Joe Slovo, Langa in 2000 was declared a national disaster but subsequent fires in Hout Bay in 2004 and in Joe Slovo in 2005 were not declared disasters despite impacting more people than the fire in 2000 (Smith, 2005; Stewart, 2008). Furthermore, a number of important events, including the 2017 wildfires in Knysna (Forsyth et al., 2019), are excluded from this database.

To fill some of these data gaps, national sector departments and various organizations have created their own databases. The South Africa Weather Service (SAWS) maintains the CAELUM weather events database, a restricted commercial product, that provides a description of historical extreme weather events. Other sector departments such as the Department of Health, and the Department of Agriculture, Land Reform and Rural Development collect disaster-related data for monitoring and reporting purposes. Statistics South Africa (StatsSA) releases information on mortality and causes of death, which includes those attributed to natural disasters. For a full review of these see Storiea (2017).

Private insurance companies are also a source of data on the costs of recovery from disasters and the overall economic impact, but access to data and collaboration on disaster research is often limited by lack of public-private partnerships (Department of Environmental Affairs, 2014). Currently, insured properties are unlikely to be recorded as part of the pool of impacted stocks as disaster recovery is handled through private insurance agencies rather than the government, with no requirement for a disaster declaration.

[1] The NatCatSERVICE analysis tool became a paid for service in mid-2020.

Issues of Interoperability: A Case Study Comparing Disaster-Related Mortality From EM-DAT and South Africa's Vital Statistics

The authors noted a number of key differences between the natural disaster deaths reported by the Statistics South Africa Vital Statistics (StatsSA, 2019) and EM-DAT [CRED (Centre for Research on the Epidemiology of Disasters), 2020] for South Africa between 1997 and 2016 (**Figure 1**). Firstly, the total number of deaths over the 20 years was markedly different between the two datasets and between the number of deaths per disaster class. The data from EM-DAT shows that the highest number of deaths were a result of epidemics (e.g., cholera, diarrheal disease, and SARS) and floods whereas the data from StatsSA shows that lightning strikes are the most common cause of disaster-related deaths with cold extremes being second. These differences are a result of the source of the data and how deaths are defined and classified in each of the databases.

The purpose of StatsSA Vital Statistics data is to report on national-recorded live births, marriages, and divorces as well as mortality and causes of death, based on civil registration data. The use of the mortality data to assess deaths due to natural disasters is secondary and has been used in the 2019 South African Sustainable Development Goal Country Report to describe the "number of deaths as a result of natural disasters" to provide evidence for Indicator 13.1.1D. As an international database, EM-DAT scrapes various sources for disaster data including, UN databases, national government repositories, inter-government organizations, reinsurance companies, and media sources [CRED (Centre for Research on the Epidemiology of Disasters), 2020]. Gaining access to accurate data, verified reports, and updated information as a disaster progresses is a key challenge and, as such, EM-DAT often underestimates the impact of events (Green et al., 2019).

Secondly, differences in the classification of disaster types by the two databases are evident where disasters such as "sunlight,", "lightning," "epidemics," and "forest fires" are reported in one database but not the other. EM-DAT uses the 2014 Integrated Research on Disaster Risk (IRDR) framework for hazard definitions (Integrated Research on Disaster Risk, 2014), putting it in line with the SFDRR. This is a five-tiered hazard classification framework with 46 "natural" hazards across the tiers and is extensible for specific descriptions of hazards such as "epidemics" which can be caused by a number of pathogens. StatsSA Vital Statistics uses the UN WHO International Classification of Disease (ICD) codes which define 8 hazards with a ninth catchall "other category." The ICD-10 codes for vital statistics define disaster mortality as death from "exposure to forces of nature" (Haagsma et al., 2016). This indicates that the data in this database references particular deaths rather than the actual disaster event.

The spatial resolution differs between the datasets where EM-DAT provides deaths at a location (provided by XY co-ordinates) whereas mortality statistics from StatsSA is provided at the provincial level. Publicly available vitality statistics in South Africa state the province in which the death occurred and as such, this is the highest spatial resolution of data available from this source. Due to the wide variety of data sources supplying EM-DAT, the records are highly variable in their spatial resolution and include anything from a specific suburb to the entire country for an individual event [CRED (Centre for Research on the Epidemiology of Disasters), 2020].

Lastly, the temporal resolution of the data (not shown here) is also quite different between the two sources. Mortality statistics record the day a person died while EM-DAT data is concerned with the date of the disaster event. Thus when comparing dates, those in EM-DAT may not be the date of death and the death date recorded in vital statistics may not indicate the date the disaster started.

CREATING ENABLING TECHNOLOGIES FOR DISASTER RISK REDUCTION IN SOUTH AFRICA

A Prototype of a Web-Based National Hazards Events Database for South Africa

A team of programmers and researchers at South Africa Environmental Observation Network (SAEON) have developed a framework for an interoperable web-based National Hazards Events Database (NHE) for South Africa in order to address the gaps in national and international disaster reporting. The open-access database is aimed at facilitating a better understanding of how people, infrastructure and different economic sectors are impacted by an event.

The data can be viewed in a dashboard containing location maps, charts, and other views which specify the areas impacted, the total number of disasters, the funding directed toward a specific disaster, and the breakdown of the total number of injuries and fatalities. The historical events are displayed on a timeline for a geographic region and are intended to give perspective on the frequency and impact of hazardous events over a period of time. The prototype landing page of the NHE is provided in **Supplementary Figure A**. At the time of writing, the data in the NHE consists of declared disasters from the NDMC database (National Disaster Management Centre, 2018). A key next step in the development of the database will be securing data sharing partnerships with both government departments, including the NDMC, as well as the private sector insurance companies.

Developing an Interoperable Disaster Reporting Lifecycle

Disaster Reporting Lifecycle

A disaster reporting lifecycle should encompass actions or inactions of various parties at intermediate stages before, during and after a disaster occurs and link the stages throughout. Under the South African Disaster Management Act (Republic of South Africa, 2002) and the National Disaster Management Framework (Republic of South Africa, 2005) the three tiers of government (national, provincial, and municipal) are required to develop Disaster Management Plans (DMP). The Key Performance Areas (KPAs) of these plans align with aspects of the reporting lifecycle

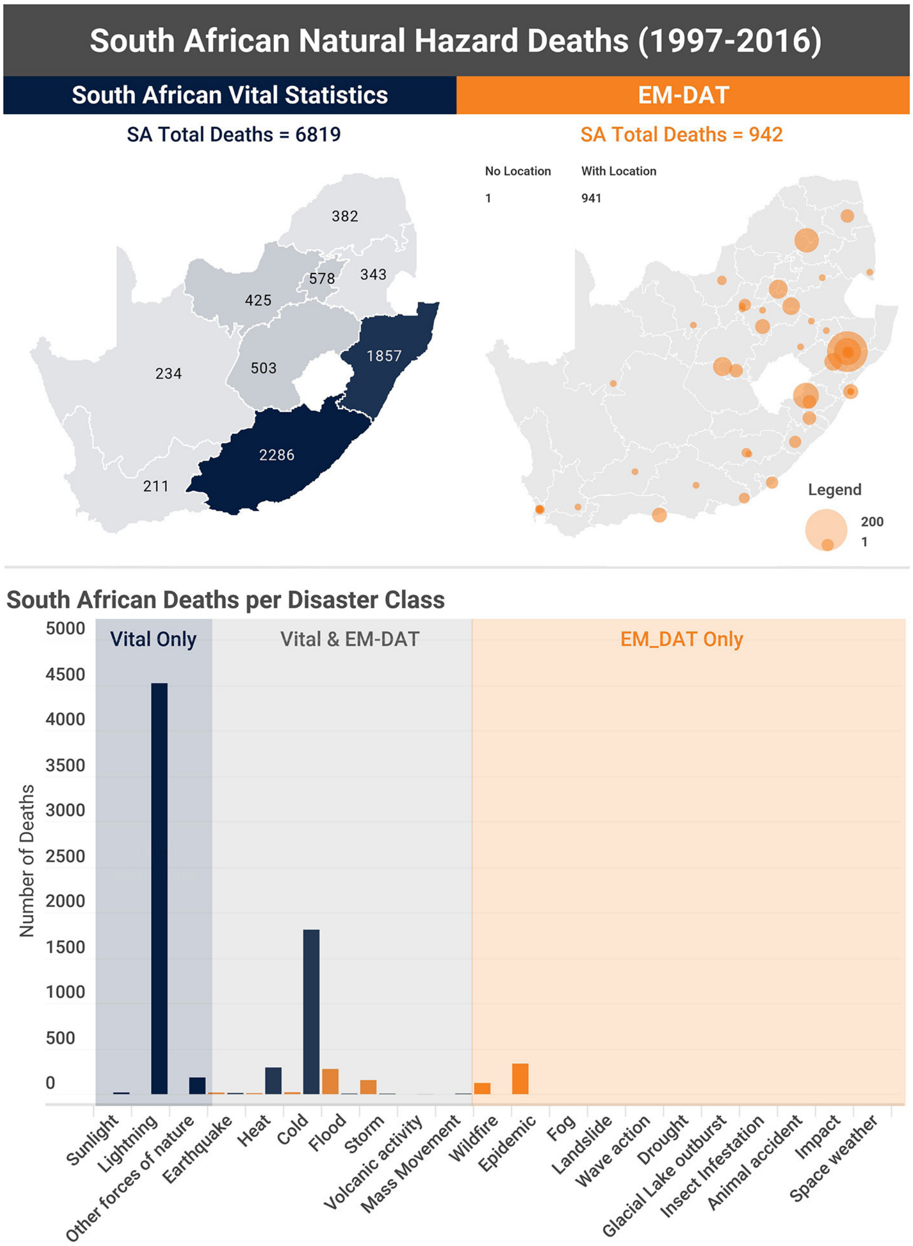

FIGURE 1 | Comparison of the number of disaster-related deaths for South Africa between 1997 and 2016 obtained from the South African Vital Statistics (left) and EM-DAT (right).

actions, outlined in **Table 1**. In order for responsible parties to be assigned to actions, the responses must be accessible and centralized.

The NHE was specifically designed to facilitate information uptake during the "Recovery and Rehabilitation" stage of the reporting life cycle. This is the stage in which impacts are effectively recorded as accounts are tallied during disaster recovery and rehabilitation. Ultimately, impact reporting underpins the rest of the lifecycle and helps to define future priorities. This is also the stage when disaster declarations occur.

Hazard Type Classification

A standardized hazard classification system with associated definitions should be used between the different national databases so that data for a hazard type can be compared across years and regions and the reporting lifecycle. The first step is to ensure that reporting agencies agree on a common classification so that references made across a database correspond to the same hazard type (e.g., flood vs. riverine flood vs. storm). In the NHE, these definitions are actioned through controlled vocabularies such that only options from the list can be selected for entry.

In the NHE, we propose the use of a hazard classification system which integrates schemes provided by SFDRR Integrated Research on Disaster Risk (IRDR) with those used by the NDMC and the WHO International Classification of Disease (ICD) codes for natural disaster deaths. Hazards common to the South African context, such as mini-tornadoes and fires in informal settlements, are also included in the database. Hazard definitions are based on the SFDRR Hazard Definitions covering natural, environmental, biological, and man-made hazards but linked to the definitions outlined in the National Disaster Management Act.

Disaster Impact Classification

Disasters are frequently classified according to their impact, measured by number of victims and economic damage. In order to consistently report on what losses have occurred as a result of a disaster, a standard impact classification system needs to be developed for South Africa and adopted by all reporting structures. We propose two impact units for South African disaster loss databases—economic loss at 2010 South Africa Rand (ZAR) value and the numbers of people affected. A common monetary value allows for quick and easy translation into national and international disaster reporting frameworks and makes data comparable across databases. In accordance with the SFDRR the number of people would extend to the number of people killed, injured, mising, homeless, affected, relocated, or displaced by a disaster.

The DMP planning KPA on "Preparation," includes "personal injury, health, loss of life, property, infrastructure, environments and government services." In the NHE questionnaire, this has been expanded to include data for indicators from SFDRR Targets A (reduce global mortality), B (reduce the number of people affected), C (reduce economic loss), and D (reduce damage to critical infrastructure and basic services) and broadly cover four key sectors:

- Human health and wellbeing (e.g., StatsSA, 2007, 2020a): based on census and vital statistics as well as UN reporting standards for demographic data that provides an output of the number of people.
- Ecosystems and ecosystem services (e.g., Reyers et al., 2015; Sitas et al., 2019): based on South African natural capital accounting reports that provide an output in ZAR.
- Human settlements and infrastructure (e.g., StatsSA, 2020b): based on national accounts that provide an output in ZAR of the value to replace or repair buildings and equipment.
- Economic sectors and workers (e.g., StatsSA, 2020c,d,e,f): based on national accounts and provides an output in ZAR of the loss of production or of lost revenue.

In the NHE, data inputted for these four sectors are automatically converted to a corresponding ZAR value by leveraging national statistics reports from relevant sectoral departments. As an example, a user might indicate that 50 hectares of maize were destroyed in a drought in a particular year and the incorporated national accounting-based calculator would indicate the value in rands for that region, for that crop, for that year. The database thus collects data through a questionnaire in great detail using units suited for the particular purpose or industry but provides a platform for interoperability across sectors. As the user is not responsible for an evaluation of the impact units, the results are based on consistent calculations across the framework.

Evaluation of the Interoperability of the NHE

While the NHE faces the same challenges of data access as other efforts, it offers a platform where local, district, and provincial managers can capture hazardous events at local level occurring across South Africa and their impacts on urban and rural populations. The questionnaire design ensures that impacts to human health and habitation, various sectors of the economy and infrastructure are documented in a quantifiable and relevant way. The NHE's controlled vocabularies for South African sectoral accounts, vital statistics, and census practices and infrastructure reporting allow for impacts to be calculated directly within the data framework with the latest publicly available data.

Core interoperability literature for information systems is generally based on four dimensions: technical, semantic, syntactic, and organizational:

- Technical interoperability refers to the ability of the data to be easily accessed and shared through common protocols. The NHE is a web based interface for a Postgresql database making it technically interoperable.
- Syntactic interoperability refers to the packing and sharing methods for a dataset. Optimal syntactic interoperability indicates that data can be downloaded in an open source, machine readable format. As data from the NHE can be downloaded as csv files, the NHE is syntactically interoperable. Events are also georeferenced using GeoJSON such that events can be spatially recorded within current municipal boundary polygons.
- Semantic interoperability refers to the ability for databases to exchange relevant information through a common framework of understanding. In the NHE, APIs have been used for controlled vocabularies common to other systems including the National Climate Change Information System (NCCIS) (Department of Environment Forestry Fisheries, 2020) and the South African Risk and Vulnerability Atlas (SARVA) (Department of Science Innovation, 2020) making these bespoke government systems semantically interoperable.
- Organizational interoperability refers to the exchange of information between organizations. This includes data sharing agreements and data licensing. The data and codebase for the NHE are open source and shared under a creative commons (CC-BY) license.

DISCUSSION

Open access to disaster-related data is critical to achieve Action Priorities 1 and 2 of the Sendai Framework for Disaster Risk Reduction for years 2015–2030 as well as the United Nations Sustainable Development Goals (SDGs) and the Paris Agreement to reduce climate change and its impacts. While data gaps and inconsistencies between datasets are issues not unique to South

TABLE 1 | A South African disaster reporting lifecycle: Integrating disaster reporting into South African Disaster Management Plan planning.

#	1	2	3	4	5	6
Phase	**Preparation (mitigation)**	**Monitoring**	**Early warning**	**Response**	**Recovery and Rehabilitation**	**Disaster risk reduction linked to climate change adaptation**
Definition	Each municipality is responsible for 'development and adoption of integrated disaster risk management policy' as part of larger integrated Development Plan planning.	Principally, municipalities coordinate directly with the South African Weather Service and other sectoral departments.	The South Africa Weather Service is currently deploying an impact early warning system to municipalities.	Relief groups respond to the immediate impacts on the community.	The community is rehabilitated, rebuilt or redeveloped.	Measures are initiated by the municipal government in consultation with the community to adapt to future events through IDP planning. (Different from mitigation in that it is a response to a specific event).
Technology needed	Consolidated disaster database including occurrence and impact as well as the risk of recurrence	Databases of seasonal trends to indicate when and where problems are likely to occur and what signals to be monitored.	Real time database of current environmental conditions with automated threat assessments delivered to municipalities.	Database of logistics information for relocation and resupply for different scales of disasters	Database of disaster impacts and their costs.	Database of new and past adaptation measures and evidence of their success linked to specific hazard occurrences.
Contributing party	SAWS, NDMC, Other sectoral departments	SAWS and Sectoral departments	SAWS, sectoral early warning systems, research institutions, and private-public partnerships.	Three spheres of government, Sectoral departments, Emergency response units	Three spheres of government, insurance agencies, StatsSA (vital statistics)	Three spheres of government, private sector, researchers
Critical access groups	Three spheres of government, NDMC, Sectoral departments	Three spheres of government, NDMC, Sectoral departments	Three spheres of government, NDMC	Three spheres of government, NDMC, Emergency response units	Municipal government	Three spheres of government, DEFF, NDMC
Disaster management plans	*KPA2 Risk Assessment KPA3 Disaster Risk Reduction plans and programmes KPA4a Preparedness Plans that include the dissemination of early warnings and averting or reducing the potential impact*	*KPA1 Integrated Institutional Capacity—"Coordinate and align the implementation of its plan with other organs of state and institutional role players"*	*KPA1 Integrated Institutional Capacity—"Coordinate and align the implementation of its plan with other organs of state and institutional role players"*	*KPA4b Response—"implementing immediate integrated and appropriate response measures when significant events or disasters occur or are threatening to occur"*	*KPA 4c Recovery—"implementing all rehabilitation and reconstruction strategies following a disaster in an integrated and developmental manner"*	Regular testing and review of DMP

The blue indicates where the prototype National Hazards Events Database fits into the cycle.

Africa, the country faces a number of challenges regarding the interoperability of national datasets. Multiple sources of data, the lack of consistency in output data as well as data gaps in these international databases has the potential to lead to confusion in the evaluation of the impact of a disaster situation by researchers and policy-makers.

The development of a database system that meets the requirements of users needs to consider findability, accessibility, interoperability, and reuse (Wilkinson et al., 2016). In this paper, we have identified various key factors where data can be harmonized and how interoperability in disaster databases can be achieved. This includes a common framework for a disaster reporting life cycle and a standard classification system for hazards and impacts metrics. With this minimum set of information, disaster data can facilitate risk-informed sustainable development.

To support this approach to disaster data management, we have developed a National Hazard Events database framework that guides data providers to enter data in such a format that becomes consistent with other databases in terms of interoperability aspects. The proposed system supports data compatibility and interoperability with data collected by the NDMC but also with international databases such as EM-DAT. The NHE is open access, user-friendly database that provides data and information on the spatial and temporal occurrence of hazardous events including risks such as floods, fires, droughts, sea storm surges, lightning strikes, landslides, heat waves, hail storms, wind storms, and tornadoes. Ultimately, the proposed NHE has the potential to substantially increase the value of disaster data to a wider range of researchers and applications and to better inform future disaster risk management at the local level.

Critical Success Factors for the Implementation of NHE in South Africa

The NHE presented in this paper is a proof of concept and represents an investment of effort and goodwill by SAEON in the disaster response domain of South Africa. There are a number of critical success factors for the successful implementation of the NHE as a national resource and ensure that the information is regularly updated and system maintained. For the NHE to be completely interoperable, there needs to be the development and implementation of a standardized disaster classification system (e.g., IRDR framework for hazard definitions) across all national and sector departments. Such a process will be time consuming and will require substantial effort engaging the disaster management sector in South Africa.

Additional collaboration with National Sectoral Departments and partnerships with private sector insurance companies will need to be established to ensure open data sharing. Future plans for NHE also include the incorporation of tools such as events detected *via* remote sensing, social media, crowdsourced contributions, and online news items to give users a more complete view of the scope of disastrous events occurring in South Africa. This will assist in supplementing the information housed in the NHE as well as serving as a verification process. To facilitate collaboration, all the development code and algorithms are open source projects. The web-based NHE and associated databases and vocabulary services have been developed with re-usable open source code and support the ability to directly embed components into another website or to modify the source code and reuse in a website.

A comprehensive review of information needs in terms of policy makers, disaster management practitioners, and researchers will need to take place to ensure that the NHE meets the expectations of the users. This would include an assessment of local and district integrated development plans and associated key performance indicators to ensure that the information and data from the NHE serves a practical purpose. Engagement with local stakeholders such as the South African Local Government Association (SALGA), local NGOs working with municipalities and farmers are consulted to ensure not only the uptake of the NHE but also the bottom-up process of information gathering on local disasters. These engagements and partnerships will need to be on-going and iterative throughout the lifespan of the NHE.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are publicly available. This data can be found here: https://search.datacite.org/works/10.15493/sarva.270121-1.

AUTHOR CONTRIBUTIONS

CD-R and AH have read and agreed to the published version of the manuscript. All authors contributed to the article and approved the submitted version.

FUNDING

This research was made possible by the South African Department of Environment, Forestry and Fisheries (DEFF) and the South African Department of Science and Innovation (DSI).

ACKNOWLEDGMENTS

The authors would like to acknowledge the software developers, Alex Pfeiffer and Andre Engelbrecht who built the prototype version of the National Hazards Events Database and contributions made by Wim Hugo on the initial design of the database structure. The authors would also like to thank Dr. Nicky Allsopp and Leo Chiloane for reviews on earlier drafts of this paper.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2021.591020/full#supplementary-material

Supplementary Figure A | National Hazards Events (NHE) Database dashboard view.

Supplementary Table A | South African Natural Disaster Deaths (1997–2016).

REFERENCES

AgriSA. (2016). *A Raindrop in the Drought. Report to the Multistakeholder Task Team on the Drought—Agri SA's Status Report on the Current Drought Crisis*. February 2012, Centurion, South Africa.

Asian Disaster Reduction Center (2004). *Global Disaster Identifier Number (GLIDE).* Available online at: https://glidenumber.net/glide/public/search/search.jsp (accessed July 30, 2020).

Coronese, M., Lamperti, F., Keller, K., Chiaromonte, F., and Roventini, A. (2019). Evidence for sharp increase in the economic damages of extreme natural disasters. *Proc. Natl Acad. Sci. U.S.A.* 116, 21450–21455. doi: 10.1073/pnas.1907826116

CRED (Centre for Research on the Epidemiology of Disasters). (2020). *EM-DAT: The International Disaster Database Explanatory Notes*. Brussels: CRED. Available online at: https://public.emdat.be/about (accessed July 30, 2020).

Department of Environment Forestry and Fisheries (2020). *National Climate Change Information System*. Available online at: https://ccis.environment.gov.za (accessed July 30, 2020).

Department of Environmental Affairs (2014). *Climate Information and Early Warning Systems to Support Disaster Risk Reduction and Management under Future Climate Conditions in South Africa. Long Term Adaptation Scenarios*. Pretoria, South Africa.

Department of Science and Innovation (2020). *South African Risk and Vulnerability Atlas*. Available online at: https://sarva.saeon.ac.za (accessed July 30, 2020).

Engelbrecht, F. A., Thambiran, T., and Davis, C. L. (2018). *Chapter 3: Climate Change over South Africa: From Trends and Projected Changes to Vulnerability Assessments and the Status Quo of National Adaptation Strategies.* Department of Environmental Affairs, South Africa's 3rd National Communication to UNFCCC.

Field, C. B., Barros, V., Stocker, T. F. and Dahe, Q. (eds.). (2012). *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.

Forsyth, G., Le Maitre, D., van den Dool, R., Walls, R., Pharoah, R., and Fortune, G. (2019). *The Knysna Fires of 2017: Learning From This Disaster*. CSIR, Stellenbosch University and Santam. Cape Town, South Africa.

Green, H. K., Lysaght, O., Saulnier, D. D., Blanchard, K., Humphrey, A., Fakhruddin, B., and Murray, V. (2019). Challenges with disaster mortality data and measuring progress towards the implementation of the Sendai framework. *Int. J. Disast. Risk Sci.* 10, 449–461. doi: 10.1007/s13753-019-00237-x

Haagsma, J. A., Graetz, N., Bolliger, I., Naghavi, M., Higashi, H., Mullany, E. C., et al. (2016). The global burden of injury: Incidence, mortality, disability-adjusted life year estimates and time trends from the Global Burden of Disease Study 2013. *Injury Prevent.* 22, 3–18. doi: 10.1136/injuryprev-2015-041616

Integrated Research on Disaster Risk (2014). Peril Classification and Hazard Glossary (IRDR DATA Publication No. 1). Beijing: Integrated Research on Disaster Risk. Available online at: http://www.irdrinternational.org/wp-content/uploads/2014/04/IRDR_DATA-Project-Report-No.-1.pdf (accessed July 30, 2020).

Kar-Purkayastha, I., Clarke, M., and Murray, V. (2011). Dealing with disaster databases–what can we learn from health and systematic reviews?: Application in practice. *PLoS Curr.* 3:RRN1272. doi: 10.1371/currents.RRN1272

Li, G., Jing, Z., Virginia, M., Carol, S., and Lianchong, Z. (2019). Gap analysis on open data interconnectivity for disaster risk research. *Geo-Spatial Inf. Sci.* 22, 45–58. doi: 10.1080/10095020.2018.1560056

McPhillips, L. E., Chang, H., Chester, M. V., Depietri, Y., Friedman, E., Grimm, N. B., et al. (2018). Defining extreme events: a cross-disciplinary review. *Earth's Future* 6, 441–455. doi: 10.1002/2017EF000686

Migliorini, M., Hagen, J. S., Mihaljević, J., Mysiak, J., Rossi, J. L., Siegmund, A., et al. (2019). Data interoperability for disaster risk reduction in Europe. *Disaster Prev. Manag.* 28, 804–816. doi: 10.1108/DPM-09-2019-0291

National Disaster Management Centre (2018). *Disaster Atlas App*. Available online at: https://gis-portal.ndmc.gov.za/portal/apps/webappviewer/index.html?id=700928590ea84665b234b038eb96c210 (accessed July 30, 2020).

Osuteye, E., Johnson, C., and Brown, D. (2017). The data gap: an analysis of data availability on disaster losses in sub-Saharan African cities. *Int. J. Disaster Risk Reduct*. 26, 24–33. doi: 10.1016/j.ijdrr.2017.09.026

Republic of South Africa (2002). *Disaster Management Act No. 57 of 2002*. Pretoria, Government Printers.

Republic of South Africa (2005). *National Disaster Management Policy Framework*. Pretoria, Government Printers.

Reyers, B., Nel, J. L., O'Farrell, P. J., Sitas, N., and Nel, D. C. (2015). Navigating complexity through knowledge coproduction: mainstreaming ecosystem services into disaster risk reduction. *Proc. Natl. Acad. Sci.* 112, 7362–7368. doi: 10.1073/pnas.1414374112

Sapir, D. G., Hargitt, D., and Hoyois, P. (2004). *Thirty Years of Natural Disasters 1974-2003: The Numbers*. Centre for Research on the Epidemiology of Disasters, Universities the Lovain Press, Belgium, pp. 38–56.

Sitas, N., Nel, J., and Reyers, B. (2019). "Lessons for mainstreaming ecosystem services into policy and practice from South Africa," in *Mainstreaming Natural Capital and Ecosystem Services into Development Policy,* ed P. Kumar (London: Routledge), 40–59. doi: 10.4324/9781315531212-3

Smith, H. M. (2005). The relationship between settlement density and informal settlement fires: case study of Imizamo Yethu, Hout Bay and Joe Slovo, Cape Town Metropolis. *Geo-Inf. Disaster Manag.* 1333–1355. doi: 10.1007/3-540-27468-5_92

StatsSA (2007). *Community Survey 2007*. Statistics South Africa, Pretoria.

StatsSA (2019). *Sustainable Development Goals: Country Report 2019*. Statistics South Africa, Pretoria.

StatsSA (2020a). *P0302—Mid-Year Population Estimates, 2020*. Available online at: http://www.statssa.gov.za/?page_id=1854andPPN=P0302 (accessed July 30, 2020).

StatsSA (2020b). *P9115—Non-Financial Census of Municipalities*. Available online at: http://www.statssa.gov.za/?page_id=1854andPPN=P9115 (accessed July 30, 2020).

StatsSA (2020c). *P0211—Quarterly Labour Force Survey (QLFS).* Available online at: http://www.statssa.gov.za/publications/P0211/P02111stQuarter2020.pdf (accessed July 30, 2020).

StatsSA (2020d). *P3041.2—Manufacturing: Production and Sales*. Available online at: http://www.statssa.gov.za/?page_id=1854andPPN=P3041.2 (accessed July 30, 2020).

StatsSA (2020e). *P0211—Quarterly Labour Force Survey (QLFS).*Available online at: http://www.statssa.gov.za/?page_id=1854&PPN=P0211 (accessed July 30, 2020).

StatsSA (2020f). *P0277—Quarterly Employment Statistics (QES), 1st Quarter 2020*. Available online at: http://www.statssa.gov.za/?page_id=1854andPPN=P0277 (accessed July 30, 2020).

Stewart, J. (2008). *Space and survival: the aftermath of a fire disaster in a Cape Town informal settlement* (Unpublished (Ph.D. thesis). University of Stellenbosch, Cape Town. Available online at: http://etd.sun.ac.za/handle/10019/906 (accessed April 14, 2010).

Storiea, J. M. (2017). "Mapping disaster risk reduction and climate change adaptation: progress in South Africa," in *Proceedings of ICA* (Aachen). doi: 10.5194/ica-proc-1-105-2018

Swiss, R. E. (2020). Sigma. Available online at: https://www.sigma-explorer.com (accessed July 30, 2020).

Thornton, P. K., Ericksen, P. J., Herrero, M., and Challinor, A. J. (2014). Climate variability and vulnerability to climate change: a review. *Glob. Change Biol.* 20, 3313–3328. doi: 10.1111/gcb.12581

Tschoegl, L., Below, R., and Guha-Sapir, D. (2006). *An Analytical Review of Selected Data Sets on Natural Disasters and Impacts*. Louvain: Centre for Research on the Epidemiology of Disasters.

UNISDR (2017). *Technical Guidance for Monitoring and Reporting on Progress in Achieving the Global Targets of the Sendai Framework for Disaster Risk Reduction*. United Nations, Geneva.

UNISDR (2019). *Measuring Implementation of the Sendai framework—Global Targets Reporting Years 2015–2018*. United Nations, Geneva.

United Nations Disaster Risk Reduction (2020). *Desinventar Sendai.* Available online at: https://www.desinventar.net/index.html (accessed July 30, 2020).

United Nations Environmental Program (2013). *Global Risk Data Platform*. Available online at: https://preview.grid.unep.ch (accessed July 30, 2020).

Valachamy, M., Sahibuddin, S., Ahmad, N. A., and Bakar, N. A. A. (2020). "February. geospatial data sharing: preliminary studies on issues and challenges in natural disaster management," in *Proceedings of the 2020 9th International Conference on Software and Computer Applications,* 51–56. doi: 10.1145/3384544.3384596

Van Huyssteen, E., Van Niekerk, W., and Le Roux, A. (2013). Analysing risk and vulnerability of South African settlements: attempts, explorations and reflections. *JÀMBÁ* 5, 1–8. doi: 10.4102/jamba.v5i2.80

Van Niekerk, D. (2014). A Critical analysis of the south african disaster management act and policy framework. *Disasters* 38, 858–877. doi: 10.1111/disa.12081

Vermaak, J., and Van Niekerk, D. (2004). Disaster risk reduction initiatives in South Africa. *Dev. Southern Afr.* 21, 555–574. doi: 10.1080/0376835042000265487

Wallemacq, P. (2018). *Economic Losses, Poverty and Disasters: 1998-2017*. Brussels: Centre for Research on the Epidemiology of Disasters (CRED).

Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., et al. (2016). The FAIR Guiding Principles for scientific data management and stewardship. *Sci. Data* 3, 1–9. doi: 10.1038/sdata.2016.18

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.