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D12.1 – Disaster Risk Reduction Case study report

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Abbreviations and Acronyms

ADC	African Data Consensus
AIH	African Information Highway
AOSP	Africa Open Science Platform
API	Application Programming Interface
ASCII	American Standard Code for Information Interchange
AWS	Amazon Web Services
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station data
CODATA	Committee on Data of the International Science Council
CORDIS	Community Research and Development Information Service
CRED	Centre for Research on the Epidemiology of Disasters
CSV	Comma-Separated Values
DCAT	Data Catalog Vocabulary
DDI	Data Documentation Initiative
DEM	Digital Elevation Model
DKAN	Drupal-based Knowledge Management System
DOI	Digital Object Identifier
DRR	Disaster Risk Reduction
DRRKS	Disaster Risk Reduction Knowledge Service
EOSC	European Open Science Cloud
ESA	European Space Agency
ESRI	Environmental Systems Research Institute
FAIR	Findable, Accessible, Interoperable, Reusable
FEMA	Federal Emergency Management Agency

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FIP	FAIR Implementation Profile
FMS	Fiji Meteorological Service
GEBCO	General Bathymetric Chart of the Oceans
GFDRR	Global Facility for Disaster Reduction and Recovery
GIS	Geographic Information System
GPS	Global Positioning System
HEI	Higher Education Institution
HIP	Hazard Information Profile
IKCEST	International Knowledge Centre for Engineering Sciences and Technology
INSAR	Interferometric Synthetic Aperture Radar
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
LIDAR	Light Detection and Ranging
MODIS	Moderate Resolution Imaging Spectroradiometer
MOSAIKS	Monitoring System for Agricultural and Irrigation Knowledge System
MRD	Mineral Resources Department
NASA	National Aeronautics and Space Administration
NDMO	National Disaster Management Office
NEWRM	National Early Warning and Response Mechanism
NIWA	National Institute of Water and Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
NTWC	National Tsunami Warning Centre
OECD	Organisation for Economic Co-operation and Development
OSM	OpenStreetMap

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PDF	Portable Document Format
PDN	Pacific Disaster Net
RDA	Research Data Alliance
RDF	Resource Description Framework
RiX	UN Risk Information Exchange
RTK	Real-Time Kinematic
SDG	Sustainable Development Goals
SDGIO	Sustainable Development Goals Integrated Ontology
SDMX	Statistical Data and Metadata Exchange
SMA	Sudan Meteorological Authority
SOPAC	Pacific Islands Applied Geoscience Commission
SPC	South Pacific Commission Pacific Data Hub
SPREP	Secretariat of the Pacific Regional Environment Programme
SQL	Structured Query Language
SRS	Satellite Remote Sensing
SRTM	Shuttle Radar Topography Mission
SWEET	Semantic Web for Earth and Environmental Terminology
SYNOP	Synoptic Observation
TYPSS	Ten-Year Pacific Statistics Strategy
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNOSAT	United Nations Operational Satellite Applications Programme
UNSPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response

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URL	Uniform Resource Locator
USGS	United States Geological Survey
WACOP	Western and Central Pacific Ocean Portal
WAF	Water Authority Fiji
WIGOS	WMO Integrated Global Observing System
WMO	World Meteorological Organization
XML	Extensible Markup Language

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Executive Summary

This report describes the types of data used for disaster risk reduction (DRR) and provides two country case studies, for Fiji and Sudan, with an in-depth look at the DRR datasets and associated metadata used by each country. These datasets were assessed against 15 FAIR (Findable, Accessible, Interoperable, Reusable) data metrics to identify which elements of FAIR were met. The report also provides a broader context giving details on the national, regional, and global agencies providing or hosting DRR data as well as initiatives aiming to increase the FAIRness of DRR data.

Both of our case study countries are using remote sensing data which were assessed as having the richest metadata and met most of the FAIR metrics used in the assessment. Strategies for exploiting this data are discussed as they have great potential to provide up to date information during an emergency and to fill gaps in DRR data.

An essential task for any scientific discipline is the establishment of common standards and terminologies. Historically, standards have differed considerably with agencies creating standards and vocabularies based on their own use cases and priorities; consequently, there is currently no universal standard used by all DRR practitioners. We discuss the most widely used standard definitions and provide suggestions for harmonising standards. As both the United National Nations Office for Disaster Risk Reduction (UNDRR) and the World Meteorological Organisation (WMO) have been working toward improving the FAIRness and consistency of DRR data, we describe their efforts and outline their lessons learned and recommendations. Our next deliverable, which discusses metadata standards, controlled vocabularies, and ontologies, will add to this discussion.

While the current report focuses entirely on the DRR research area, DRR research is interdisciplinary by nature, encompassing researchers from earth sciences, climate change and environmental sciences, social studies, cultural information, and others. A key recommendation from the UNDRR is that there should be interdisciplinary collaboration when setting standards and definitions; therefore, increasing FAIRness in DRR has the potential to increase FAIRness across many related disciplines.

The study found that the data used by Fiji and Sudan for DRR is missing many key FAIR data elements. Hazard data tended to score highest for FAIRness, particularly hazard data originating from satellites. In contrast, vulnerability and exposure data were the least FAIR with little metadata and limited machine readability. However, there are some excellent regional and global initiatives aimed at increasing the level of FAIRness in DRR data. The UNDRR is currently reinventing its DRR database to provide a much more coherent and consistent view of the state of DRR both globally and nationally. We applaud this project and believe that significant effort should be made by the global and regional agencies to work together to provide standards, controlled vocabularies, data distribution platforms, resources and guidance for all people working to reduce the impact of disasters.

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1. Introduction

The United Nations Office for Disaster Risk Reduction (UNDRR) recently called for a data revolution and global partnerships to implement the Sendai Framework for Disaster Risk Reduction (UNDRR 2014). The Framework advocates for the substantial reduction of disaster risk and losses in lives, livelihoods, and health, and in the economic, physical, social, cultural, and environmental assets of persons, businesses, communities, and countries (UNDRR, 2014). Data that are valid, timely, useful, and most importantly interoperable, are a necessary requirement for the global effort in support of these ambitious targets.

The data used in DRR are highly heterogeneous, coming from multiple sources and delivered in multiple formats. Sources for this data include, but are not limited to, the World Bank, UNDRR, Relief Web, Earth Observation data, OpenStreetMaps, national statistics departments, ministries of infrastructure, and databases of past historical events. These heterogeneous data need to be combined to give a coherent assessment of the status of DRR at the local and global level. Critical data include population statistics, hazard information, and information on the vulnerability specific to a particular area and adaptive capacity. Many of the data required are dynamic and so must be monitored and updated on a regular basis, and therefore data provenance is essential information.

However, the data available are often incomplete, and/or inconsistent. DRR data can be incomplete through both space and time. Different databases have different definitions and different criteria for inclusion. Highly populated urban areas often have more data than sparsely populated rural areas. Data can be aggregated to different degrees or recorded at spatially different granularities. Inconsistencies over time can occur due to changes in the standards for collecting information on events. There have also been significant changes in the factors impacting vulnerability over time (Birkmann *et al*, 2017). The main changes have been to include socioeconomic factors such as poverty, inequality, and disability in vulnerability measurements. More recently environmental degradation has been identified as an important factor. This means for some aspects of DRR, historical data were never collected.

Multiple vocabularies have been created for DRR terms (Padgham,and Bosilj-Vuksic , 2018). These vocabularies are often bespoke and not aligned with standardised DRR vocabularies. Even when DRR vocabularies have consensus within the DRR scientific community, definitions may differ from those used within countries due to cultural differences and historical hazard consequences. National government information is often based on legacy databases or storage systems that were designed for internal use and the FAIR (Findable, Accessible, Interoperable, Reusable) principles were not embedded in the system. Consequently, much of the data currently used in DRR is not FAIR and this lack of FAIRness is having a direct impact on the effectiveness of DRR strategies.

Data interoperability is essential during and immediately after a disaster event when information is needed as fast as possible. The data used need to be in formats that can be used by individuals,

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government agencies, emergency responders and NGOs and must be compatible with different devices. DRR, climate change adaptation, and sustainable development strategies all benefit from the sharing of information across regions, governments, and research organisations.

The lack of interoperability also makes it difficult for DRR practitioners to leverage artificial intelligence (AI) techniques. These techniques can be extremely useful for DRR and have the potential to save lives. There has been a dramatic increase in the availability of satellite imagery and the power of geospatial services for DRR (Gou *et al,* 2019), yet significant challenges remain for the effective operationalisation of these data for practical purposes, policy making and disaster mitigation. AI-supported rapid damage mapping has the potential to significantly reduce the time required to identify areas most impacted by an event, increasing the effectiveness of emergency responders and aid agencies. Recent advances in AI provide methods for integrating heterogeneous data to provide enriched seamless datasets, but this can only be achieved if the different sources have rich metadata and are interoperable.

DRR research is interdisciplinary by nature, encompassing researchers from earth sciences, climate change and environmental sciences, social studies, cultural information, and others. The need for interdisciplinary research is vital given that climate change is predicted to increase the frequency and severity of disaster-inducing climatic events. FAIR data will enable more DRR research, help integrate DRR research with other scientific disciplines and potentially save lives.

2. Data Required for Disaster Risk Reduction

There are four main phases in disaster risk reduction: prevention/mitigation, preparedness, response, and recovery, with each phase having specific data requirements. Figure 1 shows the four phases and the priorities within each phase.

2.1. Prevention and mitigation

The prevention phase aims to minimise the impact of disasters on society and infrastructure. The first step of prevention is to build a comprehensive understanding of a country's disaster risk in terms of hazards, exposure, and vulnerability. The risk assessment should provide an evaluation of each hazard and its likely impact. This will identify key locations and hazards as well as the most effective prevention strategies. The other essential components of this stage are increasing resilience of the built environment and communities, and public education and awareness. Key data required include:

- Historical disaster event sets, including regional events
- Historical loss and damage information

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Figure 1: Four phases of Disaster Risk Reduction. Source: (Aslam 2019)

- Expected compounding or consequent disasters (i.e., probability of tsunami after earthquakes, probability of landslides occurring during heavy rain and flooding events)
- Climate indicators such as historical and current synoptic indicators
- Seismic information such as fault locations
- Topographic and geographic Information such as land elevation, land type, land use, topology, lithology, and soil types
- Location of geographic features (i.e. river locations)
- Locations and condition of critical infrastructure, lifelines, and roading networks
- Building information such as material type, roof type, number of stories, and location for public buildings such as schools, health services, and for commercial and residential buildings
- Mitigation measures and adaptive capacity
- Location, condition, and types of communication networks
- Population and demographic information including population density per geographic region
- Statistics on population vulnerability such as age, gender, income, health, disability, education, occupation, and access to communication.

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2.2. Preparedness

Preparedness includes all activities undertaken prior to an event that improves the response and recovery phases. These include national emergency and disaster response plans and operating procedures and early warning systems. Preparedness activities should be informed by risk assessments and knowledge of historical hazards and their locational impacts. Key data required include:

- Information on evacuation facilities
- Location and condition of aid supplies
- Number, type, and location of emergency facilities (e.g., fire engines and ambulances per region)
- Number, type, and location of emergency personnel
- Names, contact, and location of key people responsible for implementing disaster response
- Climate outlooks.

2.3. Response

The response phase begins with the first detection of a disaster and includes all activities taken just prior, during, and immediately after a disaster event. The main aim of the response phase is to save lives and mitigate damage. Key data required include:

- Early warning information including predicted location and impact of the event
- Actual location of event impact
- Information on any other current or expected subsequent disaster events
- Exposure and population at risk, based on predicted location of disaster
- Data from Prevention and Preparedness stages
- Damage estimates
- Location and demographics/vulnerability of people requiring evacuation or rescue
- Location and number of tourists or non-permanent residents
- Location of emergency relief centres/infrastructure.

2.4. Recovery

The recovery phase aims to restore critical infrastructure and the social and built environment back to the pre-disaster stage. This includes the reconstruction of damaged infrastructure and physical assets; resumption of production, service delivery and access to goods and services; restoration of governance and decision-making processes; reduction of risks (European Commission, United Nations Development Group, the World Bank, 2013). There is also an opportunity to 'Build Back Better' where, rather than restoring to prior standards, the aim is to

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improve resilience by incorporating higher standards into rebuilding designs. This requires information from all previous phases so that data-driven decisions can be made on what and where to build back. Key data required include:

- Data from all previous phases
- Disaster-induced damage to critical infrastructure, lifelines, and the built environment
- Disaster-induced damage to the human population
- Disaster impact on livelihoods and the economy
- Expected costs of rebuilding and resumption of activities.

3. Definitions

Most scientific disciplines develop standard definitions and vocabularies to enhance research, provide clarity for communication, and improve consistency and interoperability. This is also the case within the DRR discipline where it is generally acknowledged that agreement within the discipline will lead to a greater understanding of the impact and causes of a disaster and support effective implementation of DRR strategies. Gaillard and Mercer (2012) argue that there is often a disconnection between knowledge generated by researchers and practitioners, and the actions taken by decision-makers and communities. To address this, the authors suggest the development of a shared understanding of key concepts such as hazard, vulnerability, and risk. They highlight the need for interdisciplinary and collaborative approaches to disaster risk reduction, and the importance of involving communities and decision-makers in the process.

However, different agencies and organisations have developed standards or controlled vocabularies for defining DRR terms based on their own use cases and priorities and there is currently no universal standard used by all DRR practitioners. While most agencies agree on the fundamental definition of a hazard, definitions for vulnerability and exposure are more contentious. For instance, vulnerability can be defined as the functional relationship between hazard intensity and expected damage, or it can be defined by a list of attributes that make a person or location more vulnerable to a specific hazard.

There have been various initiatives aimed at promoting consistency and clarity in the definitions and controlled vocabularies for DRR. For instance, the UNIDRR developed the Sendai Framework for Disaster Risk Reduction, which includes a glossary of key terms related to disaster risk reduction. The Sendai Framework aims to standardise the definitions and terminology of hazard, vulnerability, and exposure to improve communication and coordination between different stakeholders (UNDDR, 2018). Similarly, the Intergovernmental Panel on Climate Change (IPCC) has developed guidelines for the use of consistent terminology in the assessment of climate change impacts, vulnerability, and adaptation. The guidelines provide standardised definitions and controlled vocabularies for key concepts related to climate change, including hazard, vulnerability, and exposure (IPCC, 2014). Most recently, the UNDRR published a Hazard Definition

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and Classification Review Technical Report which provides a common set of hazard definitions (UNDRR, 2020).

3.1. Risk

The UNDRR defines disaster risk as the "potential loss of lives, injuries, assets, and services that could occur to a system, society, or community within a specific timeframe" (UNIDRR, 2018). The agency emphasises that risk cannot be defined by hazard alone; rather, it is a combination of hazards, exposure (the presence of people and assets in the area impacted by a hazard), and vulnerability (the system or community's susceptibility and ability to withstand hazards).

Figure 2: Conceptual Diagram of DRR Risk. Source: Tonkin + Taylor adapted from IPCC.

UNDRR recognises that risk is dynamic and can change due to urbanisation, climate change, and socio-economic factors. The definition emphasises the need to address underlying risk factors and adopt a comprehensive approach that reduces vulnerabilities, enhances preparedness, and builds resilience to minimise the impacts of disasters and promote sustainable development.

3.2. Hazard

Hazard is commonly defined as a source of potential harm or adverse effect that can result from natural or human-induced phenomena. In the context of disaster risk reduction, hazard is historically classified into four types: geophysical, hydrological, meteorological, and climatological. Geophysical hazards include earthquakes, volcanic eruptions, and landslides. Hydrological hazards include floods, droughts, and tsunamis. Meteorological hazards include tropical cyclones, thunderstorms, and blizzards. Climatological hazards include heat waves, cold waves, and wildfires (UNIDRR, 2017). The UNDRR defines hazard as "a dangerous phenomenon, substance, human activity, or condition that may cause loss of life, injury, or other health impacts, property damage, social and economic disruption, or environmental degradation"

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(UNDRR, 2020). The U.S. Federal Emergency Management Agency (FEMA) defines hazard as "a natural or man-made source or cause of harm or difficulty" (FEMA, 2010).

Figure 3: Word cloud generated from all the different hazards. Source T+T.

Several agencies have published their own hazard definitions. The UNDRR uses a hazard classification system that includes six main categories of natural hazards: geological, meteorological, hydrological, climatological, biological, and technological. Within each category, there are specific hazard types, such as earthquakes, floods, droughts, and infectious diseases. In 2020 the UNDRR published its Hazard Information Profiles (HIPs). Each profile contains the name of the specific hazard, a reference number, a definition, selected annotations, key references and the name of the UN agency or organisation that issues guidance relating to the hazard. There is also a compilation of existing information that relates to the wider spectrum of hazards identified in the Sendai Framework and the other 2015 landmark United Nations agreements.

FEMA uses a hazard identification and risk assessment process that includes 18 hazards, including natural hazards such as earthquakes, hurricanes, and wildfires, and human-made hazards such as terrorism and cyber-attacks.

The EU uses a hazard classification system that includes 10 main categories, including geological, hydrological, meteorological, biological, and technological hazards, but also includes hazards related to conflicts and space weather. Future work to semantically map terms from each individual agency would ensure a common understanding of hazards.

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3.3. Vulnerability

Vulnerability describes the susceptibility of people, infrastructure, and other assets to the impacts of hazards. Vulnerability is influenced by physical, social, economic, and environmental factors or processes. Physical factors include the location of infrastructure and assets in hazard-prone areas. Social factors include demographic characteristics such as age, gender, ethnicity, and socioeconomic status. Economic factors include the level of development, income, and employment opportunities. Environmental factors include land use, ecosystem services, and climate change (Birkmann, 2013). Three definitions of vulnerability that reflect different priorities and perspectives are listed below.

UNDRR: "the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard" (UNDRR, 2020).

FEMA: "the susceptibility of a population to harm from exposure to a hazard" (FEMA, 2010).

EU: "the degree to which a system or component is likely to experience harm due to its exposure to hazards" (European Commission, 2010).

3.4. Exposure

If a hazard occurs in the absence of people, infrastructure, or other assets, it is unlikely to cause a disaster. Therefore, exposure is a key factor in determining disaster risk. Three definitions of exposure that reflect different priorities and perspectives are listed below.

The UNDRR: "the presence of people, assets, and activities in hazard-prone areas that are likely to be affected by a disaster" (UNDRR, 2020).

FEMA: "the identification of people, structures, systems, and other elements in an area that could be adversely affected if a hazard event occurs" (FEMA, 2010).

EU: "the condition of being present in or near a hazard area or event" (EC, 2010).

3.5. Controlled vocabularies

A FAIR vocabulary is designed to enhance the findability of terms and concepts by providing clear and consistent labels, definitions, and metadata. The vocabulary should be open access and available in standard formats. Interoperability requires vocabularies to have a coherent data model and valid ontology. Most importantly, it should be useful to the community of users. A successful DRR vocabulary needs to be accessible to a wide range of users and be able to incorporate or map to concepts from many disciplines.

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The main challenges with disaster risk reduction vocabularies in terms of FAIR standards include the lack of standardisation, limited adoption of FAIR practices, insufficient metadata and documentation, limited community engagement, and the need for ongoing maintenance and governance. Fragmentation and inconsistencies hinder interoperability, while the absence of comprehensive metadata and documentation limits findability, accessibility, and reusability. (UNDRR, 2020). These failings are well known within DRR agencies and there is currently an inter-agency and expert group working to advance a common statistical framework on disaster-related statistics to improve DRR statistics.

Below we provide a list of standard terms and controlled vocabularies currently in use:

- UNDRR: Hazard Information Profiles
- UNDRR: Sendai Framework Terminology on Disaster Risk Reduction
- UNISDR: Terminology on disaster risk reduction
- NOAA: Integrated Hazard Information Service
- WHO: International Statistical Classification of Diseases and Related Health Problems
- WMO: International meteorological vocabulary
- WMO: Meteoterm
- FEMA: Glossary of Terms
- EU: Glossary of Common Civil Protection Terms
- Common Alerting Protocol (CAP) Hazard List.

3.6. Disaster databases

Information about past disasters is extremely important when undertaking risk assessment and for building risk knowledge. According to the UNDRR, the open communication and dissemination of disaster data are the bases for disaster risk reduction (UNDRR 2014). These data tell us what happened during disaster occurrences in the past and form the basis of many modelled vulnerability curves and disaster scenarios. There are numerous disaster databases, some national or regional and several global databases including the UNDRR and Centre for Research on the Epidemiology of Disasters (CRED). The reinsurance companies SwissRe and MunichRe also provide an open dataset of insured losses due to disasters. However, these databases are often incomplete and have different criteria for inclusion. While metadata exists for each dataset, it is not rich enough to fully enable the FAIR data principles to meet FAIR data standards. UNDRR is currently working on how to improve and maintain its DesInventar Disaster Loss Database.

3.7. Community involvement

Community involvement in definition of standards is crucial, as it enables the integration of local knowledge and perspectives that may otherwise be overlooked by external experts. This inclusive

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approach ensures that the needs and perspectives of vulnerable populations are appropriately considered and addressed (Collins, and Vasilescu, 2016). By engaging with local communities, accuracy, relevance, and local perspectives and priorities can be better incorporated into definitions and standards. Such an approach fosters trust and collaboration between communities and external experts, ultimately leading to more effective and sustainable disaster risk reduction initiatives.

4. Case study 1: Fiji

4.1. Fiji institutions responsible for DRR

There are four main agencies involved in collecting and storing data required for DRR: the Fiji Meteorological Service (FMS), the National Disaster Management Office (NMDO), the Mineral Resources Department (MRD), and the national statistics office.

Fiji Meteorological Service: The FMS receives data on river and flood levels from a hydrological observation network across Fiji and is responsible for flood event prediction. FMS also provides early warnings for cyclones, rain and droughts, and is developing an early warning system for flash floods.

The FMS is connected to the WMO's Global Telecommunication System (GTS) to receive multi-hazard, multipurpose early warnings. These include all meteorological and related data; weather, water and climate analysis and forecasts; tsunami-related information and warnings; and seismic parametric data.

National Disaster Management Office: The National Disaster Management Office (NDMO) is responsible for flood warnings and is the lead agency of all aspects of tsunami response. During emergencies and disasters, the NDMO assumes its emergency coordination role as the National Emergency Operation Centre (NEOC) under the command of the Permanent Secretary of the responsible Ministry of Rural and Maritime Development.

Mineral Resources Department: The MRD operates the national seismological observatory 24/7 in Suva and monitors tidal gauges for possible tsunami threats through deep sea buoys. The MRD also monitors tidal gauges across Fiji to verify information on potential tsunami threats. The MRD is responsible for issuing tsunami threat messages to relevant agencies (Government of Fiji, 2017).

Fiji National Statistics Bureau: The Fiji National Statistics Bureau Office provides economic, social, tourism, and migration statistics as well as conducting a regular population and housing census.

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Data required for DRR are maintained in several databases managed by different authorities:

- The Hydrology Division of Water Authority Lautoka (WAF) maintains a database of observational past and present hazard data from the hydrometeorological stations network.
- The Australian Bureau of Meteorology maintains the CLiDE (Climate Data for the Environment) database[1]. CliDE is a free, open-source Climate Data Management System developed as part of the Pacific Climate Change Science Program, providing a central database for climate data.
- The Pacific Data Hub (SPC)[2] is a central data repository for the Pacific. The repository includes data on natural hazard damage and loss events from 1567 to 2014 as well as population statistics, fisheries science, climate change adaptation, disaster risk reduction and resilience, public health surveillance, conservation of plant genetic resources for food security, and human rights. There is an associated mapping portal, POPGIS3 FIJI: a data portal which maintains a range of geo-located census information.
- Fiji Disaster Risk Management maintains a geospatial data sharing platform for DRR and sustainable development. Data are provided by the National Disaster Management Office (NDMO). Data includes geospatial data of evacuation centres, fire stations, exposure data (infrastructure and building footprints), and Digital Elevation Model (DEM) data.

4.2. Methodology and datasets

For this study we looked at several datasets currently used by Fiji for DRR for Cyclone and Flood disasters. Appendix A provides descriptive tables for each dataset analysed and its corresponding metadata.

For each dataset we sourced the following data/characteristics:

- DRR Phase
- Instrument/Satellite Name
- Raw Data
- Derived Data
- Data Format
- Data Start and Stop
- Coverage Area / Observation area
- Spatial Resolution
- Temporal Resolution (Time cycle)
- Satellite Orbit type

[1] http://www.bom.gov.au/climate/pacific/about-clide.shtml
[2] https://pacificdata.org/

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- Band Numbers
- Metadata Format
- Metadata Content
- Licence
- Source.

We assessed the FAIRness of each dataset by scoring its associated metadata based on the 15 core metrics proposed by the FAIR Data Maturity Model Working Group (Devaraju *et al*, 2021).

4.3. Results

4.3.1. Data gaps

While Fiji-based DRR practitioners have a large amount of data at their disposal, this study identified some data gaps which, if filled, could lead to better risk information and improve the effectiveness of DRR strategies. The following data gaps were identified:

- High resolution land elevation, preferably Light Detection and Ranging (LIDAR) data
- High resolution Bathymetry Data
- Building and infrastructure data in low populated areas
- Building and infrastructure vulnerability characteristics (i.e., building material, roof type)
- Historical Loss and Damage Information
- Disaster footprints/maps
- Land use Data
- Rainfall and flow data – for areas not currently covered.

To fully understand and model local flood risk, including cyclone-induced storm surge, high resolution elevation data are needed, and currently the best data for this is LIDAR data. While LIDAR data are available for some areas, most of the country does not have this data available. Satellite-based Digital Elevation Models (DEM) have been used but these do not have the granularity needed. There are some promising results based on the fusion of LIDAR and DEM data where areas that have LIDAR data are used to calibrate available satellite DEMs and the calibrated DEMs can then be used for areas that do not have LIDAR data. Satellite data can also provide land use and building and infrastructure data with granularity of around 20 metres (Liu *et al,* 2019).

4.3.2. FAIR assessment

For each data set, we accessed the metadata and used the 15-core metrics to assess the level of FAIRness. The FAIR data assessment tool consists of a series of questions about the content of a dataset's metadata for each FAIR category. Figure 4 shows the percent of datasets that met each

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of the 15-core metrics. The majority or 80% of datasets had metadata that includes descriptive core elements, included in the Findable category. The interoperability category scored low, with just 50% of datasets having metadata that was represented using a formal knowledge representation language or using semantic resources, and just 30% of datasets having metadata that include links between the data and related entities. The lowest score was for the accessibility category with only 20% of metadata providing information about the access level and access conditions of the data.

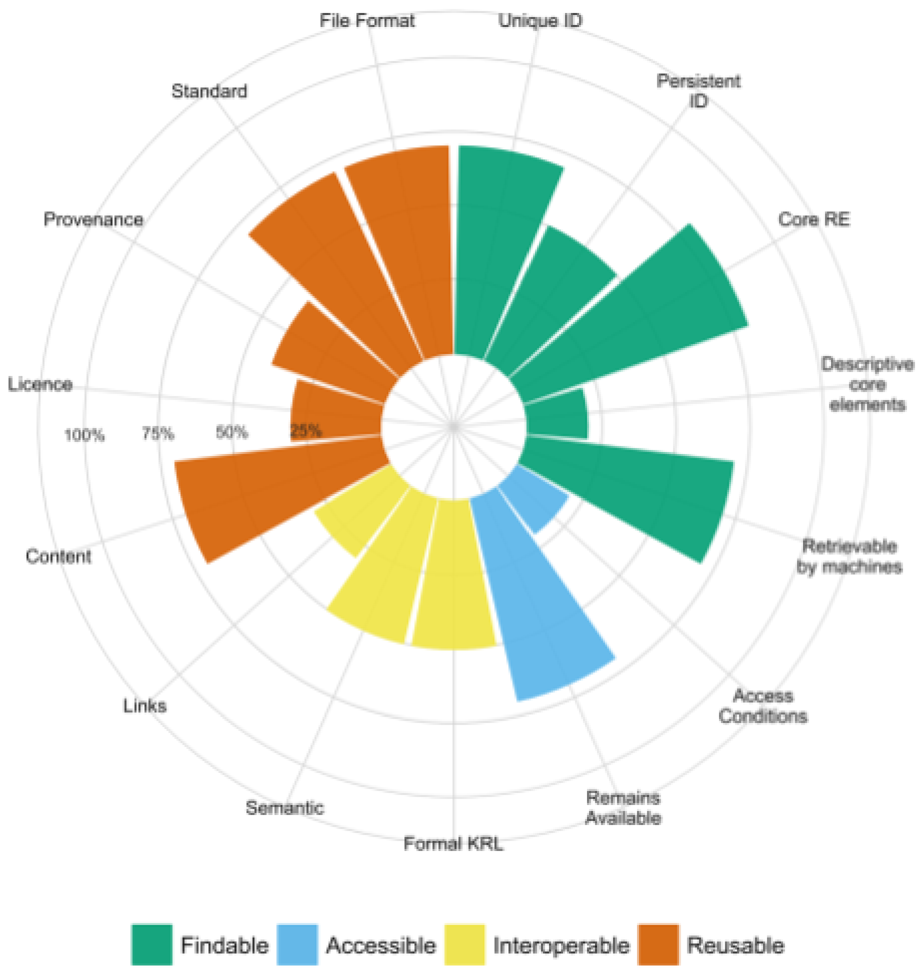

Figure 4: Fiji Metadata Percentage of datasets with each Item. Source: Tonkin + Taylor

Hazard datasets, particularly satellite-based hazard data, are quite FAIR, while vulnerability and exposure datasets are the least FAIR with little metadata available and limited machine readability. Vulnerability and exposure datasets are commonly provided by different agencies and often there is no common metadata standard; rather each agency has its own data

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management system. Table 1 shows the results of the FAIR data assessment. The score for each dataset is the number of recommended content items included in its metadata. Note that the number of questions differs for each FAIR category so scores in each category are not directly comparable. Full scoring tables for selected datasets are included in Appendix A.

Table 1: FAIR Assessment results for Fiji DRR datasets

Dataset	Source	FAIR Score (# Yes)			
		Findable (Max 5)	Accessible (Max 2)	Interoperable (Max 3)	Reusable (Max 5)
Rainfall Rate from IR satellite – Himawari 8	Japan Meteorological Agency/NOAA	4	1	2	3
Historic flood data – World bank climate change portal	World bank climate change knowledge portal	4	2	3	5
Lidar data	USGS	3	1	0	2
Household Data	Fiji Bureau of statics	3	1	1	1
Road network Building footprints Critical infrastructure	Open street maps/ Fiji Bureau of statics	3	0	1	4
historical cyclones from IBTrACS	National center for environmental information	5	1	3	4
Wave/Tide prediction data	Surf-forecasts data	0	0	0	0
Historic wave height	WACOP	0	0	0	0
Bathymetry data	GEBCO	5	2	2	5

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5. Case study 2: Sudan

5.1. Sudan institutions responsible for DRR

The main national agencies responsible for collecting, storing, and disseminating data required for DRR in Sudan are the Sudan Meteorological Authority (SMA), the National Early Warning and Response Mechanism (NEWRM), the National Disaster Management Council (NDMC), and the Sudan Central Bureau of Statistics.

Sudan Meteorological Authority: SMA has a mandate from the Government of the Republic of Sudan to monitor all the meteorological activities in Sudan. No agency or institution is entitled to carry out such activities without a proper liaison with SMA. The mandate of the Sudan Meteorological Authority is the provision of meteorological information and services for the safety of life, protection of property, and conservation of the natural environment to ensure growth of the economy, poverty alleviation, and eventually for the sustainable development of the nation.

The SMA provides weather forecasts and early warnings for natural disasters such as floods and droughts. It operates a network of weather stations throughout the country and provides regular updates on weather conditions and potential hazards.

National Early Warning and Response Mechanism (NEWRM): The NEWRM is a system that was established by the government of Sudan to provide early warnings and response to disasters such as floods, droughts, and epidemics. It is responsible for coordinating disaster risk reduction efforts at the national, state, and local levels, and for ensuring that early warning messages are disseminated to the public in a timely and effective manner.

National Disaster Management Council: The National Disaster Management Council includes the Civil Defence Department (CDD) and the Ministry of Irrigation and Water Resources (MOIWR). The Council coordinates disaster response activities and is responsible for national disaster management plans.

Sudan Central Bureau of Statistics: The Sudan Central Bureau of Statistics provides information on economic, health, and household statistics. Most data are provided in the form of reports in PDF format but there are some data available for downloading in CSV, Excel, JSON, and SDMX formats. However, there is no associated metadata provided along with the datasets. There are PDF files outlining different indices and methodology, but this information is not available in a machine-readable format.

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5.2. Methodology and Datasets

For this study we looked at several datasets currently used by Sudan for DRR for Drought and Flood disasters. Appendix A provides descriptive tables for each dataset analysed and its corresponding metadata.

For each dataset we sourced the following data/characteristics:

- DRR Phase
- Instrument/Satellite Name
- Raw Data
- Derived Data
- Data Format
- Data Start and Stop
- Coverage Area / Observation area
- Spatial Resolution
- Temporal Resolution (Time cycle)
- Satellite Orbit type
- Band Numbers
- Metadata Format
- Metadata Content
- Licence
- Source.

We assessed the FAIRness of each dataset by scoring its associated metadata based on the 15-core metrics proposed by the FAIR Data Maturity Model Working Group (Devaraju *et al,* 2021).

5.3. Results

5.3.1. Data gaps

Data gaps were similar to those found in the Fiji case study. As discussed above, high-resolution LIDAR data are essential for detailed flood risk assessment and this level of data is not available for Sudan. Information on historical loss and damage, rural area buildings and infrastructure, and rainfall and flow data in less populated areas are generally unavailable.

5.3.2. FAIR assessment

For each data set we accessed the metadata and used the FAIR data assessment tool to assess the level of FAIRness. Figure 5 shows the percent of datasets that met each of the 15-core metrics. The majority, or 88%, of datasets provided data in a file format recommended by the target research community (Accessible). Seventy-five percent of datasets were assigned a

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globally unique identifier (Findable). As with the Fiji data, very few datasets had metadata providing access level and access conditions for the data.

Overall, the scores for Sudan datasets tend to be lower than that for the datasets examined for Fiji. Satellite data should score very highly, however for Moderate Resolution Imaging Spectroradiometer (MODIS) and Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data (rainfall data), the metadata are supplied via a PDF document rather than being incorporated into the file and therefore are not in a machine-readable format. In addition, statistics and census data from the Central Bureau of Statistics are supplied in PDF report format and the actual data are not downloadable.

Figure 5: Sudan Metadata Percentage of datasets with each Item. Source: Tonkin + Taylor

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As found for Fiji, datasets for hazards in Sudan, particularly satellite-derived hazard data, scores relatively high for FAIR data metrics, whereas vulnerability and exposure datasets are less FAIR. There have been some concerted efforts by OpenStreetMap to provide highly detailed data on settlements and rural buildings, but this is limited to areas where conflicts and large-scale floods have occurred in recent years. Reporting for SDGs is occurring, but the data are not complete and generally very aggregated.

Table 2 shows the results of the FAIR data assessment for Sudan. Several data sets were the same as those used in Fiji and these are not included in Table 2. The score for each dataset is the number of recommended content items included in its metadata. Note that the number of questions differs for each FAIR category, so the categories with the most questions (Findable and Reusable) tend to have the highest scores. The full scoring table for each dataset is included as Appendix A.

Table 2: FAIR Assessment results for Sudan DRR datasets

Dataset	Source	FAIR Score (# Yes)			
		Findable (Max 5)	Accessible (Max 2)	Interoperable (Max 3)	Reusable (Max 5)
NOAA Climate Prediction Centre Rainfall Estimates	NOAA	4	1	3	4
Sudan Road Network Shape files	Humanitarian Data Exchange	4	1	3	4
Sentinel-1	ESA	0	0	0	1
SMOS	ESA	4	1	2	3
Cartostat-1	India Space Agency	3	2	1	2
CHIRPS	USGS	1	0	0	1
Socio Economic Database, 1960-2019	AFDB	0	0	0	0
World Bank historical flood data	World Bank	4	2	3	5

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6. Regional initiatives

There are some excellent regional initiatives to support Fiji and Sudan with environmental management, SDG reporting, and managing and distributing data sets. All these initiatives aim to improve data access and increase collaboration within each region.

6.1. Fiji organisations

Several organisations have launched projects which aim to improve FAIRness in data from all Pacific Island Nations. These are described below.

The Secretariat of the Pacific Regional Environment Programme (SPREP) is a regional organisation established by the Governments and Administrations of the Pacific charged with protecting and managing the environment and natural resources of the Pacific.

The South Pacific Commission (SPC) is the principal scientific and technical organisation of the Pacific region, established by treaty in 1947 with the signing of the Agreement establishing the South Pacific Commission (the Canberra Agreement). The SPC aims to fill data gaps in the Pacific and provide trusted and evidence-based information to decision makers.

Pacific Disaster Net (PDN) is a regional platform that provides access to various disaster risk reduction data in the Pacific Islands. The PDN platform uses a range of standardised metadata and data formats, including ISO 19115 and ISO 19139, ensuring interoperability with other regional and global databases.

Fiji South Pacific Applied Geoscience Commission (SOPAC) uses scientific and technical innovations to develop solutions that help overcome development challenges in the Pacific. Its goal is to ensure that earth sciences are fully exploited to improve the livelihoods of Pacific communities.

6.1.1. The Inform Project

The Inform Project is the unified response to the need for data-driven decision making in the Pacific thanks to the strategic partnership between Pacific Island Countries, SPREP and the United Nations Environment Programme (UNEP) to increase the availability of environmental data. The Inform project will work with the SPC to ensure all datasets on the hub include metadata outlined in Table 3.

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Table 3: Inform Project Metadata Standards

Title
Description
Resource Format
Author
Spatial/Geographical Coverage Area
Spatial/Geographical Coverage Location
Publishing Frequency
Data Standard
Temporal Coverage
Contact Name
Contact Email
Homepage URL
Data Standard
Language
Related Content
Language

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6.1.2. Ten Year Pacific Statistics Strategy

The Ten Year Pacific Statistics Strategy (TYPSS) encourages countries to share best practices and support each other to build statistical capacity for the national statistics offices. The TYPSS has a project to develop regional standard metadata and documentation and to increase capacity to retrieve metadata for later use (Cook and Paunga, 2010). There is a bi-annual conference on statistical data and metadata exchange which includes training sessions for national statistics personnel.

6.1.3. SOPAC Metadata Catalogue

In 1999 the Pacific Islands Applied Geoscience Commission (SOPAC) produced a report outlining the development of a metadata solution of the geographic data of the South Pacific (Serafim & SOPAC 1999). This project aims to develop a metadata catalogue of digital maps hosted on a SQL server. The system allows SOPAC employees to store their GIS data files in a safe location with mandatory metadata. The GIS data and associated metadata will be published online to improve access to Pacific GIS information. Data currently maintained and stored by SOPAC will be added to the system. Figure 6 shows the metadata that all users adding data to the GIS database will be required to supply.

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Category	Element	Comment	Size Max	Multi entries
Dataset	**Table Name**	The name of the file containing the GIS datas	8 char	
	Title	The ordinary name of the dataset.	160 char	
	Custodian	The organisation responsible for the dataset.	120 char	
	Jurisdiction	The state or country of the Custodian.	30 char	
Description	Abstract	A short description of the contents of the dataset.	2000 char	
	Search Word(s)	Words likely to be used by a non expert to look for the dataset.	60 char	YES
	Geographic Extent Name(s) OR	A picklist of pre defined geographic extents such as map sheets, local government areas, catchments, that reasonably indicate the spatial coverage of the dataset.	100 char	YES
	Geographic Extent Polygon(s)	An alternate way of describing geographic extent if no pre-defined area is satisfactory.	1000 char	YES
	Projection	In the MapInfo Format : Projection+Datum+Spheroid	200 char	
	Scale	Scale of the original data	100 char	
Data Currency	Beginning date	Earliest date of data in the dataset.	Date	
	Ending date	Last date of information in the dataset.	Date	
Dataset Status	Progress	The status of the process of creation of the dataset.	20 char	
	Maintenance and Update Frequency	Frequency of changes or additions made to the dataset.	20 char	
Access	Stored Data Format	The format or formats in which the dataset is stored by the custodian.	500 char	
	Available Format Type(s)	The formats in which the dataset is available, showing at least, whether the dataset is available in digital or nondigital form.	240 char	YES
	Access Constraint	Any restrictions or legal prerequisites applying to the use of the dataset, eg. Licence.	500 char	
Data Quality	Lineage	A brief history of the source and processing steps used to produce the dataset.	2000 char	
	Positional Accuracy	A brief assessment of the closeness of the location of spatial objects in the dataset in relation to their true position on the Earth.	2000 char	
	Attribute Accuracy	A brief assessment of the reliability assigned to features in the dataset in relation to their real world values.	2000 char	
	Logical Consistency	A brief assessment of the logical relationships between items in the dataset.	2000 char	
	Completeness	A brief assessment of the completeness of coverage, classification and verification.	2000 char	
Contact Information	Contact Organisation	Ordinary name of the organisation from which the dataset may be obtained.	120 char	YES
	Contact Position	The relevant position in the Contact Organisation.	40 char	YES
	Mail Address 1	Postal address of the Contact Position.	40 char	YES
	Mail Address 2	Optional extension of Mail Address 1.	40 char	YES
	Suburb or Place or Locality	Suburb of the Mail Address.	60 char	YES
	State or Locality 2	State of Mail Address.Optional extension for Locality.	40 char	YES
	Country	Country of the Mail Address.	40 char	YES
	Postcode	Aust:Postcode of the Mail Address.	10 char	YES
	Telephone	Telephone of the Contact Position.	25 char	YES
	Facsimile	Facsimile of the Contact Position.	25 char	YES
	Electronic Mail Address	Electronic Mail Address of the Contact Position.	80 char	YES
Metadata Date	Metadata Date	Date that the metadata record for the dataset was created.	Date	
Additional Metadata	Additional Metadata	Reference to other directories or systems containing further information about the dataset.	240 char	

Figure 6: Mandatory metadata for the SOPAC System. Source: SOPAC

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6.1.4. SPC statistical data and metadata exchange

The SPC have recently entered into a consultancy agreement to deliver a process for generating consolidated metadata reports for all datasets published. The SPC data hub metadata standards are based on the data catalogue (DCAT) vocabulary recommendations and implemented using DKAN. DCAT is an RDF vocabulary designed to facilitate interoperability between data catalogues published online. DKAN is a community-driven, free and open-source open data platform that was developed to reduce barriers for communities to publish open data on the web (DKAN, 2022). Table 4 outlines the recommended metadata for all datasets published on the hub.

Table 4: SPC recommended metadata

Title
Description
Indicators
Topic
Tags
PICTs covered
Source organisation
Licence
Link to the source
Data processing
Data update
Metadata update
Coverage

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Granularity
Period Covered (First and Last)
Geographical levels
Date collected
Comment on data collection
Data Revision policy
Dataset Content

6.2. Sudan

Regional initiatives in Africa have also aimed at increasing the FAIRness of data for DRR.

6.2.1. Africa Information Highway

The Africa Information Highway (AIH) was developed by the Statistics Department of African Development Bank as part of the Bank's statistical capacity building programme (SCB) in Africa. AIH is a mega network of live open data platforms (ODPs) electronically linking all African countries and 16 regional organisations. The overall objective is to significantly increase public access to official and other statistics across Africa, while at the same time supporting African countries to improve data quality, management, and dissemination.

This AIH provides all countries in Africa with their own open data platform that allows them to manage and disseminate data. There are several applications relating to disaster risk reduction such as an SDG data hub which can generate data and reports for the Sendai Framework Monitor (SFM), and census data. The individual country platforms can communicate automatically with data exchanged via Statistical Data Metadata exchange (SDMX). The system has been running since 2012 and a large part of the development and evolution of the system is geared towards solving challenges in sharing data between different government offices and statistical departments and building capacity so that national statistical offices can implement SDMX and other data standards.

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6.2.2. Africa Open Science Platform

Africa Open Science Platform (AOSP)[3] was launched in 2016 by the South African Department of Science and Innovation. The AOSP aims to increase access to scientific data and improve their quality, accessibility, and interoperability across Africa. The platform provides guidelines and resources to promote open science practices and data management in various domains, including DRR.

6.2.3. Africa Data Consensus

The Africa Data Consensus (ADC)[4] was developed by the African Union in 2019. The ADC aims to increase the availability and use of data in Africa by promoting data governance, data standards, and data innovation. The ADC recognizes the importance of data in DRR and emphasises the need for interoperability and collaboration among stakeholders to ensure that data are FAIR.

7. Global initiatives

This section is not exhaustive; rather, it describes a selection of global data initiatives that have the potential to transform the FAIRness of data used in DRR.

7.1. UNDRR

The UNDRR acknowledges that their Desenventar system data are often incomplete and do not meet FAIR standards. To improve this, in 2022 they produced a report entitled Data and Digital Maturity for Disaster Risk Reduction. The report will inform work to develop a new generation disaster loss accounting system aiming to improve on Desenventar, which has been in use since 1994. Head of UNDRR's Bonn Office, Dr Animesh Kumar, said: '*The initiative to develop a next generation hazardous event and disaster losses and damages tracking system will greatly improve the quality of information needed to benchmark successes, or failures, in managing disaster risk and adapting to a changing climate*'.

RiX is UNDRR's living repository of open-source global, regional, and national risk data and information to improve risk knowledge, risk literacy and risk analytics. Contributing to country-led efforts to strengthen their national risk data ecosystems, including for early warning and disaster risk reduction, RiX was launched as a beta in 2022 with new features added quarterly. As UNDRR's multi-purpose platform, RiX seeks to harmonise risk information to facilitate risk analysis by government, UN, private, and other actors for risk-informed decision making and resilience building.

[3] https://aosp.org.za/

[4] https://www.cgdev.org/sites/default/files/Africa-Data-Consensus.pdf

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UN-SPIDER Knowledge Portal is an online platform that provides access to a wide range of information related to the use of space-based technologies for DRR and emergency response. The portal aims to promote the sharing of knowledge and best practices among stakeholders, including government agencies, academia, and the private sector. This is achieved through a well-organised structure of the portal and using standardised metadata to describe the content.

7.2. Global Facility for Disaster Reduction and Recovery

The Global Facility for Disaster Risk Recovery (GFDRR) has developed OpenDRI. OpenDRI is a global programme that works to promote open data and improve data sharing for disaster risk reduction. It has implemented projects in various countries to support the collection, management, and sharing of data related to disaster risk. For example, OpenDRI supported the development of a geospatial platform for the Sudanese government to visualise flood-prone areas and improve early warning systems.

7.3. WMO HydroHub

The objective of WMO HydroHub is to support National Meteorological and Hydrological Services (NMHSs) with hydrological monitoring for the effective delivery of hydrological services aimed at DRR, social and economic development, and environmental protection.

The WMO Hydrological Observing System (WHOS) facilitates hydrological data sharing. It is a multi-scale (local, national, regional, and global) registry of hydrological data and information services catalogued using the standards and procedures developed by the Open Geospatial Consortium (OGC) and the WMO. The HydroHub has the potential to provide FAIR open meteorological data to all agencies involved in DRR.

7.4. International Knowledge Centre for Engineering Sciences and Technology

IKCEST is an international organisation that aims to promote knowledge sharing and capacity building in the field of engineering sciences and technology. IKCEST was established in 2014 as a joint initiative of UNESCO and the Chinese Academy of Engineering. One of the key areas of focus for IKCEST is DRR. Through its DRR knowledge service (DRRKS), IKCEST provides a platform for sharing knowledge and best practices related to disaster risk reduction. The DRRKS includes a wide range of resources including case studies, training materials, and research reports. IKCEST promotes the use of open data standards and metadata to ensure that data are interoperable and accessible across different systems and platforms. By using open data standards, IKCEST aims to promote transparency and accountability in the management of disaster risk reduction efforts, while also ensuring that all stakeholders have access to the same data and information. IKCEST has developed its own metadata profile, which includes specific elements that are relevant to the

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types of data and services that it provides. This profile is based on the ISO 19115 standard but includes additional elements and guidance for describing IKCEST resources.

8. Remote sensing data

With the recent progress in satellite remote sensing (SRS) technologies and data processing capacity, there is a great opportunity to fill in current data gaps for DRR. There are currently around 1,000 satellites specifically designed for Earth observation operated by government space agencies and private organisations, and there have been some excellent global initiatives aimed at improving public access to SRS data. Many of the government, non-military, satellites are freely available, and several private organisations provide free data in partnership with the European Space Agency's (ESA) Earth observation platform.

The utilisation of Interferometric Synthetic Aperture Radar (InSAR) (e.g. Sentinel-1) and optical imagery data (e.g. Sentinel-2) can provide an improved understanding of the built environment, including urbanisation and settlement trends, population changes, and changing infrastructure and transport needs. These data can provide information on the spatial location of buildings and infrastructure in urban and peri-urban areas, and the impact of heavy rainfall and sea-level rise and associated inland and coastal flooding and landslides on these assets.

The first dedicated Earth-observing satellite, MODIS, was launched in 1999 and continues to provide regular images of the entire globe. Therefore, SRS data allow comparisons over time and can provide effective, near real-time and large-scale monitoring systems. The regularity of satellite missions, with an image of every place on earth being collected at least once every five days, provides an excellent opportunity to monitor and detect both rapid and slow onset disasters. Potential impacts on food security can be detected through assessing the vulnerability of rural infrastructure assets and physical supply chain infrastructure, such as the road network, storage facilities and markets with INSAR data (ESA, 2019). As well as access to data, ESA[5], NASA[6], GEOSS[7], Google Earth[8], MOSAIKS[9], UNSPIDER[10] and others also provide online processing capabilities and open-source algorithms and processing tools. These allow end users to harness high performance virtual computers and pre-tested AI algorithms to process data.

There is a growing number of open-source AI techniques which can be used for all phases of DRR. For instance, the Sentinel-based Water Difference Index, DEMs, and ground-based precipitation observations can be combined to create a flood index that can be used for flood early warning systems. UNOSAT is using AI for post-disaster rapid damage detection. ESA's

[5] European Space Agency (esa.int)
[6] NASA
[7] GEOSS (earthobservations.org)
[8] Google Earth
[9] mosaiks.org
[10] Startpage | UN-SPIDER Knowledge Portal

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DataCube and MOSAIKS platforms allow socioeconomic and environmental conditions to be integrated with multiple satellite images to provide incredibly rich datasets. AI-enabled data fusion is allowing us to combine a vast number of remote sensors all with different temporal, spatial, and spectral characteristics to provide incredibly rich data with high spectral and spatial resolution. Using AI to integrate data from different formats, different vantage points, different spacecraft, and different times allows us to discover insights that are beyond the ability of human beings to see.

9. Lessons learned and best practices

Both the UNDRR and the WMO have acknowledged that there are gaps and issues with the data they collect and have produced reports outlining the lessons they have learned, and best practices adopted since they started collecting data (UNDRR, 2014; WMO, 2017). Both organisations emphasise that standardised data improves decision-making and that by using common data standards, decision-makers can more easily compare and analyse data from different sources, leading to more informed decisions. According to the WMO, standardised data and information systems can benefit society by improving our ability to monitor and respond to weather, climate, and water-related hazards. This can lead to reduced damage, injuries, and fatalities, and improved economic prosperity and environmental sustainability. Key findings from these reports are summarised below.

Collaborative development is key: Developing data standards is a collaborative process that involves many stakeholders. By including a wide range of stakeholders across all disciplines, the development process is more likely to ensure that definitions and standards are accurate, relevant, and reflect local perspectives and priorities. When compiling their Hazard Information Profiles (HIPs), the UNDRR gathered a team of international experts who all contributed to the definitions.

International cooperation is essential: Climate related hazards are inherently global in nature, and data standards should reflect this. The WMO has stressed the importance of international cooperation in data standardisation to ensure that data can be shared and used across different regions and countries.

Flexibility is important: While data standards provide a common framework for data collection and analysis, it is also important to recognize that different contexts may require different data standards. This calls for the development of methods that can map and translate standards. This will allow nations to report data in their preferred formats and may encourage more regular reporting.

Continuous improvement is necessary: Data standards are not static and should be continuously reviewed and updated to remain relevant and effective. Regular reviews and updates help ensure

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that data standards keep pace with changes in technology, scientific knowledge, and societal needs.

Data quality is crucial: Standardised data are only useful if they are accurate, complete, and reliable. The WMO has emphasised the importance of ensuring data quality through rigorous quality control procedures and metadata management.

Interoperability is critical: Data standards should be designed with interoperability in mind to ensure that data can be shared and used across different systems and platforms. UNDRR has emphasised the importance of developing data standards that are compatible with existing systems and technologies to maximise their usefulness.

10. Improving FAIRness

This study has shown that there is a wide range of FAIRness in the DRR data used by Fiji and Sudan, with datasets obtaining FAIR scores ranging from 0 to 14, out of a maximum score of 15. The least FAIR data are those collected and stored by national agencies and the most FAIR data are externally generated satellite and climate data, and data hosted by regional and global agencies. Interoperability measures had some of the lowest scores, which is expected given that this requires a formal knowledge representation and semantic links between datasets and concepts. The section below provides suggestions for increasing FAIRness at the national level and for DRR overall.

10.1. National-level FAIRness

All phases of DRR require information on modelled hazards, risk maps, historical climate indicators, climate change implications, vulnerability, and elements at risk. Currently different agencies collect, store, and maintain these data which are not always publicly available or easily accessible. Luckily, there are regional initiatives to increase metadata standards of all DRR datasets with the goal of meeting FAIR data principles. These initiatives also provide resources and assistance for national agencies to build capacity in data management. Given the excellent and ongoing work of the SPREP, the SPC, the AIH, and OpenDRI we would recommend that Fiji and Sudan use these platforms for all DRR datasets. That would require complying with the recommended metadata practices and, by doing so, improve the FAIRness of their data.

Rather than reconfiguring each agency's data management system, a solution would be to identify, for each dataset, which metadata are missing and how these gaps could be filled in by each agency, and then designing an API application which can refine and provide interoperability between the agencies. The API application will serve as a conduit to the different data sources and should allow remote and automatic sourcing of information.

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The national statistics offices in Fiji and Sudan currently supply some data in CSV format, but a large majority of the data are provided as PDF reports where data are presented in tables. The statistics office should investigate the possibility of distributing all statistical data in CSV or similar format, working with the administrators to ensure privacy and security policies conform with national privacy laws.

10.2. Overall DRR FAIRness

Many national space agencies have committed to providing open data easily accessible by the public. Therefore, satellite data has the potential to score maximum points for FAIRness with minor changes. The primary reasons for lower scores in the satellite data assessed for this study were that much of the metadata and information about the data are provided as user guides and documentation in PDF format rather than with the dataset itself. While these documents provide all the necessary information, they are not currently machine-readable.

NASA has developed and maintains a foundational ontology SWEET, but their SRS metadata does not always provide a link to that ontology. NASA currently has a project to increase the level of FAIRness in all data it produces and hosts. The project has established a set of requirements and recommendations for the sharing of research and data which aim to ensure that data are consistent with the FAIR Guiding Principles.

Adopting and enhancing metadata standards for all DRR agencies would improve overall DRR FAIRness. There are many organisations that have their own data standards and metadata guidelines, and these could be collated and integrated so that different but comparable rules can be consolidated or mapped together. However, this process does not address the lack of interoperability in DRR. To improve FAIRness in the DRR research area, we recommend creating an overarching DRR ontology that encompasses all phases of DRR. A fully realised ontology extends a formal, structured vocabulary by providing conceptual meaning to the described text labels that are included as entities. Entities are formally defined as classes and the relationships between classes are meaningful and represented in a formal logical language. Most importantly, the ontology will include logical constraints on classes and relationships to ensure validity. This is particularly important given the wide range of participants in the DRR discipline. UNEP gives an example of quantifying losses to forestry from disaster events. Some definitions of “forest” will include palm tree plantations, while others do not. When calculating total damage, different interpretations of “forest” will lead to different values of acreage. This becomes a wider issue when data are aggregated across countries and regions which may have varying conceptions of what qualifies as a forest (Buttigieg, 2016).

There are several DRR data models currently in use; however, many of them have been built for just one phase of DRR, particularly the ‘response’ phase. An overarching DRR ontology should incorporate these ontologies as much as possible and where necessary provide rules for mapping to similar entities. Making use of established models that are used within the scientific

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community should improve cross-discipline interoperability. The DOLCE[11], SWEET[12], and YAGO-SUMO[13] ontologies are widely used and could form the backbone of a DRR ontology. The well-established Friend of a Friend Ontology (FOAF)[14] is an ontology describing persons, their activities, and their relations to other people and objects. This could allow incorporation of citizen-based information such as social media posts. Citizen-based information can be extremely useful in a disaster event providing local context, rapid updates, and information on damage and injury.

Any DRR ontology should be compatible with the UNDRR hazard vocabulary and the Sustainable Development Goals Interface Ontology (SDGIO). SDGIO is an ongoing project which aims to clarify the nature of and interlinkages between the entities referenced by the SDGs, their targets, and indicators (GitHub, 2020). The ontology should be able to link with other data models and online open databases such as OpenStreetMap, Humanitarian Data Exchange, Global Risk Facility, NASA open data portal, Wikipedia, and others.

11. Conclusions

This study found that the data used by Fiji and Sudan for DRR are missing many key FAIR data elements. While internationally provided data such as satellite based early warnings and WMO weather observations have rich metadata incorporating all elements of FAIR, data from national institutions generally received low scores for FAIRness and some datasets had little or no associated metadata. There is also a lack of coordination between the national agencies in their data management practices and there is no common metadata standard for datasets.

Including local communities in the development process will ensure DRR definitions standards are more accurate, relevant, and reflective of local priorities. This can foster trust and collaboration between communities and outside experts, leading to more effective and sustainable disaster risk reduction efforts.

Both the UNDRR and the WMO have acknowledged that there are gaps and issues with the data they collect, and both have current projects hoping to transform data used and to improve FAIRness. Greater access and useability of DRR data will enhance our ability to make data driven decisions, which should lead to better outcomes during and after disaster events.

The level of FAIRness in DRR data in both Fiji and Sudan is already improving through the use of regional platforms and global initiatives. The UNDRR and WMO have promised to ensure every citizen on Earth is covered by early warning systems by 2025. This provides an excellent

[11] Laboratory for Applied Ontology - DOLCE (cnr.it)
[12] SWEET Ontology
[13] YAGO-SUMO (demelo.org)
[14] FOAF Vocabulary Specification (xmlns.com)

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opportunity to fill in missing data gaps and to provide capacity and information to further improve national DRR agencies metadata and data management practices.

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13. Appendix A

The tables below provide comprehensive summaries for several datasets assessed in this report.

Table A.1: Himawari 8

DRR Phase	Pre-Impact warning and real time
Satellite Name	Himawari-8
Derived Data	Rainfall Rate from IR satellite
Data Format	Himawari Standard Data , HRIT ,PNG , NETCDF
Data Start and Stop	27-01-2017 to Approx 2029
Coverage Area / Observation area	1. Full disk – Fixed observation area 2. Japan area – Fixed observation area 3. Target area – Flexible observation area 4. Landmark Area 1 – Flexible observation area 5. Landmark Area 2 – Flexible observation area
Spatial Resolution	Band 3 – 0.5 m Band 1,2,4 – 1m Band 5 to 16 – 2m
Temporal Resolution (Time cycle)	Temporal resolution depends on type of observation area Full disk – 10 mins time cycle Japan area and target are – 2.5 mins time cycle Landmark areas – 0.5 min
Satellite Orbit type	Geostationary orbit
Band Numbers	1-16 bands
Metadata Format	PDF
Meta Data Content	Metadata has 2 type of content 1. Global attribute: Title , Institution , Source, History (Acquisition time , data publication time , file format) ,Conventions 2. Variable attribute: Latitude , Longitude, TBB , start time ,End time
Licence	Creative Commons Attribution License 4.0
Source	Japan Meteorological Agency/ NOAA
Link to access documents and data	https://www.data.jma.go.jp/mscweb/en/himawari89/cloud_service/cloud_service.html

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Table A.2: Smart Rain Intensity Gauge

DRR Phase	Pre-Impact/ Warning and real time
Instrument	Smart Rain Intensity Gauge (NIWA)
Data	Rainfall
Data Format	
Data Start and Stop	2017 to not specified
"Coverage Area / Observation Area	Total 17 monitoring stations are placed across Fiji
Instrument Resolution	Drop resolution 0.03mm
Data Accuracy	+/-1% at 12mm/h
Temporal Resolution	Real time remote data access at every 30 mins
Meta Data Content	Acute precipitation measurements (wind & topography), Date &Time, reference intensity in mm/h, Average of intensity value in mm/h, Relative error of average intensity, Extremes of an interval, Relative error of extremes
Source	NIWA TelemtricTB3 Telemetered Weather stations
Link to access document or data	https://library.wmo.int/doc_num.php?explnum_id=3152

Table A.3: Historic Flood Data

DRR Phase	Pre-Impact Risk Assessment
Data	Historical Flood data
Data Format	CSV
Data Start and Stop	1901 - 2020
"Coverage Area / Observation Area	Ba River
Instrument Resolution	0.5° latitude by 0.5° longitude
Source	Climate Change knowledge portal

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Link to access document or data	https://climateknowledgeportal.worldbank.org/

Table A.4: Flood Data Using Aerial Photos/Videos

DRR Phase	Post-Impact Damage Assessment
Instrument	Unmanned aerial vehicle
Data	Flood data - Aerial Photos/videos
Data Format	jpeg
Source	World Bank Group, ACP-EU Natural, Disaster risk reduction programme

Table A.5: NIWA Pump Pro Water Level

DRR Phase	Pre-Impact/ Warning and real time
Instrument	ES&S Pump pro-6150
Data	NIWA Pump Pro Water Level
Data Format	Received in serial data interface at 1200 baud
Data Start and Stop	2018 - present
"Coverage Area / Observation Area	Both main islands cantered around main rivers, 11 Stations
Instrument Resolution	Analogue: 12 bits, Digital: 16 bits
Data Accuracy	Linearity: +/- 0.05% of FS Temperature: +/- 0.001% per Celsius Repeatability: +/- 0.01% of FS
Temporal Resolution	Real Time remote data access at every 30 seconds
Source	NIWA : ES&S Pump pro 6150 Manual
Link to access document or data	https://www.esands.com/Manuals/ENVIRO/ENV_6150_Manual_v1.23.PDF

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Table A.6: Bias Adjusted Radar precipitation data.

DRR Phase	Pre-Impact/ Warning and real time
Instrument	
Data	Flash Flood Guidance System: Bias Adjusted Radar precipitation data
Data Format	Displays Raster/Vector data on map via portal
Data Start and Stop	2018 - present
"Coverage Area / Observation Area	National (Fiji)
Spatial Resolution	
Data Accuracy	
Temporal Resolution	6 hours
Metadata Format	
Meta Data Content	Date, Country, Basin, Data format
Licence	
Source	WMO

Table A.7: Synoptic Automatic Weather Station

DRR Phase	Pre-Impact/ Warning and real time
Instrument	Synoptic Automatic Weather Station
Data	Rainfall Volume 5 min accumulation
Data Format	RDR, XML, JSON-LD, CSV
Data Start and Stop	11/1/2019 - Present
"Coverage Area / Observation Area	National but sparse
Instrument Resolution	Real Time
Data Accuracy	Precipitation: +/- 1% Precipitation Accuracy : +/- 1%

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Meta Data Content	Sensor type, manufacturer, model and serial number, principle of operation, method of measurement and observation, type of detection system, performance characteristics, unit of measurement and measuring range resolution, accuracy (uncertainty), time constant, time resolution and output averaging time, siting and exposure (location, shielding and height above or below ground), date of installation, data acquisition (sampling interval and averaging interval and type), correction procedures; calibration data and time of calibration, preventive and corrective maintenance (recommended and scheduled maintenance and calibration procedures, including frequency
Source	AWS Fiji NDMO and pulsonic
Link to access document or data	https://library.wmo.int/doc_num.php?explnum_id=5541

Table A.8: Manual Weather Station

DRR Phase	Pre-Impact/ Warning and real time
Instrument	Manual Weather stations
Data	Rainfall
Data Format	F20 Forms filled out manually and manually entered into database

Table A.9: Household Income

DRR Phase	
Data	Household Income
Data Format	PDF (from local database)
Data Start and Stop	2002 - 2014
"Coverage Area / Observation Area	fiji
Data Content	Incidence of Poverty by Division and Area, Estimates of Population Living in Poverty by Division and Area, Breakdown of Household Income Types, Decile Distribution of Household Income, Household Size of the Poor and Non Poor Population, Labour Force and Working Percentage of Poor and Non Poor, Educational Attainment of Poor and Non Poor, Age Breakdown and Dependency Ratios of the Poor and Non-Poor, Number of Rooms for Poor and Non-Poor Households
Licence	Fiji Bureau of Statistics
Source	Fiji Bureau of Statistics

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Table A.10: SRTM Shuttle Radar Topography Mission / Tandem X

DRR Phase	Pre-Impact Risk Assessment
Satellite Name	SRTM Shuttle Radar Topography Mission / TanDEM X
Raw Data	DEM (3D) / Historical Flood Series/ 90m Fiji DEM
Data Format	GeoTiff
Data Start and Stop	2000 - Unknown
Coverage Area / Observation area	Between 60° North and 56° South latitude (Fixed)
Spatial Resolution	1 arc-second for global coverage (~30 meters) 3 arc-seconds for global coverage (~90 meters)
Satellite Orbit type	polar satellite
Metadata Format	XML
Meta Data Content	Entity ID, Acquisition date, Publication date, Resolution, Data updated, NW,NE,SW,SE Corner Lat, NW,NE,SW,SE Corner Long, NW,NE,SW,SE Corner Lat dec, NW,NE,SW,SE Corner Long dec
Source	USGS Earth Explorer
Link to access documents and data	https://earthexplorer.usgs.gov/

Table A.11: RTK GPS ground survey -Lidar

DRR Phase	Pre-Impact Risk Assessment
Satellite Name	RTK GPS ground survey -Lidar
Raw Data	Lidar - Data
Derived Data	Point cloud data
Data Format	LAS or LAZ or ASCII
Data Start and Stop	2014-2014
Coverage Area / Observation area	Nandi Catchment
Spatial Resolution	1m Horizontal resolution with vertical accuracy of 73.3 mm

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Temporal Resolution (Time cycle)	In seconds
Meta Data Content	https://www.usgs.gov/ngp-standards-and-specifications/lidar-base-specification-deliverables#metadata
Source	USGS -Earth Explorer
Link to access documents and data	https://earthexplorer.usgs.gov/

Table A.12: NIWA 2D Flood Model

DRR Phase	Pre-Impact Risk Assessment
Model name	NIWA 2D Flood Model
Input Data Required	1. High resolution topography with accuracy +/- 0.15 m or better 2. under water topography 3. a geo-referenced map of surface roughness to allow calculation of water velocities over roads, fields, floodplains and through scrub, trees and buildings. 4. tides and storm surge data
Model accuracy / stability	https://niwa.co.nz/sites/niwa.co.nz/files/2016049CH-Flood-Frequency-Final-Report-Part1-NIWA.PDF
Coverage Total country vs main cities etc.	Nandi Catchment
additional information	captures large flood

Table A.13: Flood Damage Model: HEC-RAS 1D hydraulic

DRR Phase	Pre-Impact Risk Assessment
Model name	HEC-RAS 1D hydraulic
Input Data Required	1. Geometry data (shape file) : River reach, junctions, bridges, inline weir spillway, Area boundary, channel type 2. Raster data (tiff/ geo tiff): flood grid , water grid, land grid, terrain , stream , DEM , watershed , water TIN, land TIN 3. Cross section data: station, elevation, n – value, downstream reach length, manning's value, main channel bank stations, contraction coefficient, Expansion coefficient 4. Flow data: steady flow boundary condition / unsteady flow , known water surface , critical depth, normal depth, rating curve, Water Quality Data , Lateral distance from station in various direction

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	5. Input text parameters : input projection zone, datum units, output projection, zone datum units, spheroid parameters
Model accuracy / stability	theta varies from 0.5 to 1 where 0.5 has most accuracy and less numeric stability
Coverage Total country vs main cities etc.	Rewa Catchment
additional information	One dimensional model , considers single water surface across each cross section

Table A.14: Flood Exposure Data: Fiji Roads Street Map

DRR Phase	Flood exposure data
Data	Fiji Roads Street Map (OSM)
Data Format	PDF , XSLX & .shp
Data Start and Stop	2022-2022
"Coverage Area / Observation Area	National
Meta Data Content	Identification, Responsible, Information, Features, Contact point, Dataset Categories, Extent, Access (Licenses),Validation, References
Licence	Open Data Commons Open Database License - public
Source	OpenStreetMaps – OSM
Link to access document or data	https://risk.spc.int/layers/?limit=5&offset=0

Table A.15: Flood Exposure Data: Building Outlines

DRR Phase	Flood exposure data
Data	Building Outlines
Data Format	Shape Files containing Building ID, Type of building, Name
Data Start and Stop	2022-2022
"Coverage Area / Observation Area	National
Meta Data Content	Identification, Responsible, Information, Features, Contact point, Dataset Categories, Extent, Access (Licenses),Validation, References
Licence	Open Data Commons Open Database License - public
Source	Open Street Maps – OSM

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Link to access document or data	https://risk.spc.int/layers/?limit=5&offset=0

Table A.16: Infrastructure

DRR Phase	Flood exposure data
Data	Infrastructure (Bridge)
Data Format	Shape Files containing id, use group, main use, feat source, attrsource, shape length, shape area
Data Start and Stop	2022-2022
"Coverage Area / Observation Area	National
Meta Data Content	Identification, Responsible, Information, Features, Contact point, Dataset Categories, Extent , Access (Licenses), Validation, References,
Licence	Open Data Commons Open Database License - public
Source	OpenStreetMaps – OSM
Link to access document or data	https://risk.spc.int/layers/?limit=5&offset=0

Table A.17: Cyclone Hazard Data: IBTrACS

DRR Phase	Cyclone Hazard Data
Instrument	IBTrACS
Data	Cyclone data from IBTrACS
Data Format	CSV , NetCDF , Shapefile
Data Start and Stop	1841 to present
"Coverage Area / Observation Area	70° N to 70° S and 180° W to 180° E
Spatial Resolution	0.1° (~10 km)
Temporal Resolution	Interpolated to 3 hourly (most data reported at 6 hourly)
Metadata Format	
Meta Data Content	https://www.ncei.noaa.gov/sites/default/files/2021-07/IBTrACS_v04_column_documentation.PDF
Source	historical cyclones, extracted from the International Best Track Archive for Climate Stewardship (IBTrACS),

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Link to access document or data	https://www.ncei.noaa.gov/products/international-best-track-archive

Table A.18: Tide Data

DRR Phase	Cyclone Hazard Data
Instrument	
Data	tide data (Prediction data) or tide data
Data Format	XML, JSON , CSV
Data Start and Stop	1992 to present
"Coverage Area / Observation Area	Fiji
Temporal Resolution	hourly data
Licence	NOAA
Source	https://tidesandcurrents.noaa.gov/noaatidepredictions.html?id=1910000&legacy=1
Link to access document or data	

Table A.19: Building Footprints

DRR Phase	Cyclone Hazard Data
Data	Building footprint
Data Format	Geodatabase , shp ,EMF , XML
Data Start and Stop	24th September , 2021 - Present
"Coverage Area / Observation Area	Fiji
Meta Data Content	Updated , Expected Update Frequancy , Location , Visibility ,License , Methodology ,Comments, Tags, File format
Licence	Creative Commons Attribution for Intergovernmental Organisations
Source	POPGIS, Fiji Islands, Bureau of Statistics, Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI)

Table A.20: Bathymetry Data

DRR Phase	Cyclone Hazard Data

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Instrument	'base' version 2.4 of the SRTM15+ data set between latitudes of 50° South and 60° North
Data	GEBCO Gridded Bathymetry Data
Data Format	netCDF , GeoTIFF , ESRI ASCII Raster
Data Start and Stop	- To present
"Coverage Area / Observation Area	global coverage
Spatial Resolution	15 arc seconds
Metadata Format	XML
Meta Data Content	Global Attribute : Title, Summary , keywords, conventions, id , naming authority , history, Source , Comments, License, data created , Creator_name , creator_url, institution , Project,creator_type , geospatial_bounds (1,2,3,4,crs,vertical_crs) ,geospatial_lat(_min,_max,_units,_resolution) , geospatial_lon(_min,_max,_units,_resolution), geospatial_vertical(_min, _max ,_units, _resolution, _positive), identifier_product_doi, references, node_offset. Variable Attribute: lon ,lat ,elevation (standard_name, long_name, units, axis ,sdn_parameter_urn ,sdn_parameter_name ,sdn_uom_urn, sdn_uom_name), crs (grid_mapping_name, epsg_code inverse_flattering, semi_major-axis)
Licence	www.gebco.net
Source	https://www.gebco.net/data_and_products/gridded_bathymetry_data/
Link to access document or data	https://www.gebco.net/data_and_products/gridded_bathymetry_data/

The tables below show the FAIR data assessment results for several datasets assessed in this report.

Table A.21: Automated rainfall data, based on SYNOP data

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	No	Station Number but this may not be unique. Unique to WMO. Currently implementing WIGOS which should be unique.
	Data are assigned a persistent identifier.	No	
	Metadata includes descriptive core elements	Yes	Information incl in data file

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	Metadata includes the identifier of the data it describes.	No	
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	The individual msg is machine readable. How is it stored once msg is broadcast?
Accessible	Metadata contains access level and access conditions of the data.	No	
	Metadata remains available, even if the data are no longer available.	Yes	
Interoperable	Metadata are represented using a formal knowledge representation language.	Yes	
	Metadata uses semantic resources.	No	
	Metadata includes links between the data and its related entities.	No	
Reusable	Metadata specifies the content of the data.	Yes	Not totally machine readable
	Metadata includes license information under which data can be reused.	Yes	
	Metadata includes provenance information about data creation or generation.	No	Not sure how this data are stored?
	Metadata follows a standard recommended by the target research community of the data.	Yes	
	Data are available in a file format recommended by the target research community.	Yes	

Table A.22: World Bank historical flood data

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	

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	Data are assigned a persistent identifier.	Yes	
	Metadata includes descriptive core elements	Yes	
	Metadata includes the identifier of the data it describes.	No	Current metadata are referencing an old data set.
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	But DOI not registered in Google or DataCite
Accessible	Metadata contains access level and access conditions of the data.	Yes	Access information is not machine readable.
	Metadata remains available, even if the data are no longer available.	Yes	
Interoperable	Metadata are represented using a formal knowledge representation language.	Yes	JSON-LD and RDFa. No SPARQL endpoint.
	Metadata uses semantic resources.	Yes	Vocabulary namespace URIs can be identified in metadata.
	Metadata includes links between the data and its related entities.	Yes	
Reusable	Metadata specifies the content of the data.	Yes	Limited in JSON-LD but avail in the NetCDF file
	Metadata includes license information under which data can be reused.	Yes	
	Metadata includes provenance information about data creation or generation.	Yes	creation-related provenance information but not formal provenance metadata
	Metadata follows a standard recommended by the target research community of the data.	Yes	
	Data are available in a file format recommended by the target research community.	Yes	NetCDF file which is scientific research standard. Also avail in ASCII

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Table A.23: LIDAR data for Nandi Catchment

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	yes	Identifier is resolvable and follows unique identifier syntax
	Data are assigned a persistent identifier.	yes	Follows persistent identifier but could not identify a valid persistent identifier based on schema and resolution
	Metadata includes descriptive core elements	Yes	Not all core descriptive metadata exist
	Metadata includes the identifier of the data it describes.	No	Data identifier is missing
	Metadata are offered in such a way that it can be retrieved by machines.	No	Metadata can be but is not found through Data cite search or Data Cite registry
Accessible	Metadata contains access level and access conditions of the data.	No	No access information is available in metadata
	Metadata remains available, even if the data are no longer available.	Yes	
Interoperable	Metadata are represented using a formal knowledge representation language.	No	
	Metadata uses semantic resources.	No	No sematic vocabularies namespace could be identified in metadata
	Metadata includes links between the data and its related entities.	No	
Reusable	Metadata specifies the content of the data.	yes	Minimal information about available data content is given in metadata
	Metadata includes license information under which data can be reused.	No	License information unavailable in metadata

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	Metadata includes provenance information about data creation or generation.	No	
	Metadata follows a standard recommended by the target research community of the data.	yes	Multidisciplinary & metadata standard of repository is specified
	Data are available in a file format recommended by the target research community.	Yes	Data available in LAZ format

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Table A.24 : Road Networks and Building Footprints from OpenStreetMaps

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	No	
	Metadata includes descriptive core elements	Yes	Creator not machine readable
	Metadata includes the identifier of the data it describes.	No	
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	
Accessible	Metadata contains access level and access conditions of the data.	No	Licence available in the data source but not the metadata
	Metadata remains available, even if the data are no longer available.	No	Yes – all changes and change log available
Interoperable	Metadata are represented using a formal knowledge representation language.	No	There is a link to a wiki page for a description of the entity but this is not machine readable.
	Metadata uses semantic resources.	Yes	Vocabulary namespace URIs can be identified in metadata
	Metadata includes links between the data and its related entities.	No	
Reusable	Metadata specifies the content of the data.	Yes	Minimal
	Metadata includes license information under which data can be reused.	No	Is available in the data resource and on website
	Metadata includes provenance information about data creation or generation.	Yes	data creation-related provenance information
	Metadata follows a standard recommended by the target research community of the data.	Yes	

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	Data are available in a file format recommended by the target research community.	Yes	Can be exported as a GeoJSON file

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Table A.25 : Fiji Population census

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	No	No unique persistent identifier
	Metadata includes descriptive core elements	Yes	Not all metadata core elements exit
	Metadata includes the identifier of the data it describes.	No	
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	Metadata are not registered in major research registries
Accessible	Metadata contains access level and access conditions of the data.	No	
	Metadata remains available, even if the data are no longer available.	Yes	accessible through standardised communication protocol - HTTPs
Interoperable	Metadata are represented using a formal knowledge representation language.	No	
	Metadata uses semantic resources.	Yes	No vocabulary namespace is available
	Metadata includes links between the data and its related entities.	No	
Reusable	Metadata specifies the content of the data.	No	
	Metadata includes license information under which data can be reused.	No	
	Metadata includes provenance information about data creation or generation.	No	
	Metadata follows a standard recommended by the target research community of the data.	Yes	No metadata stand repository specified

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	Data are available in a file format recommended by the target research community.	Yes	As part of .xlsx file

Table A.26 : Historical Cyclone Track Data

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	Yes	
	Metadata includes descriptive core elements	Yes	Creator, title, data identifier, publisher, publication date
	Metadata includes the identifier of the data it describes.	Yes	
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	
Accessible	Metadata contains access level and access conditions of the data.	No	Data are open source and licence avail on website but not in metadata
	Metadata remains available, even if the data are no longer available.	Yes	Has a DOI so assuming this will remain.
Interoperable	Metadata are represented using a formal knowledge representation language.	Yes	
	Metadata uses semantic resources.	Yes	
	Metadata includes links between the data and its related entities.	Yes	
Reusable	Metadata specifies the content of the data.	Yes	Not formally represented in XML format but as keywords.

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	Metadata includes license information under which data can be reused.	No	This is available on the data website
	Metadata includes provenance information about data creation or generation.	Yes	
	Metadata follows a standard recommended by the target research community of the data.	Yes	
	Data are available in a file format recommended by the target research community.	Yes	

Table A.27 : Bathymetry Data GEBCO 2022

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	Yes	
	Metadata includes descriptive core elements	Yes	
	Metadata includes the identifier of the data it describes.	Yes	Is included in the NetCDF file metadata but not MR
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	
Accessible	Metadata contains access level and access conditions of the data.	Yes	Not MR
	Metadata remains available, even if the data are no longer available.	Yes	Based on DOI link
Interoperable	Metadata are represented using a formal knowledge representation language.	Yes	

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	Metadata uses semantic resources.	Yes	
	Metadata includes links between the data and its related entities.	No	Metadata has a link to the dataset documentation
Reusable	Metadata specifies the content of the data.	Yes	Not ML in NetCDF file
	Metadata includes license information under which data can be reused.	Yes	
	Metadata includes provenance information about data creation or generation.	Yes	
	Metadata follows a standard recommended by the target research community of the data.	Yes	
	Data are available in a file format recommended by the target research community.	Yes	As part of NetCDF file

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Table A.28 : Tide data

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	No	
	Metadata includes descriptive core elements	No	Insufficient metadata
	Metadata includes the identifier of the data it describes.	No	Content identifier is missing
	Metadata are offered in such a way that it can be retrieved by machines.	No	
Accessible	Metadata contains access level and access conditions of the data.	No	
	Metadata remains available, even if the data are no longer available.	No	
Interoperable	Metadata are represented using a formal knowledge representation language.	No	
	Metadata uses semantic resources.	No	
	Metadata includes links between the data and its related entities.	No	
Reusable	Metadata specifies the content of the data.	No	
	Metadata includes license information under which data can be reused.	No	
	Metadata includes provenance information about data creation or generation.	No	
	Metadata follows a standard recommended by the target research community of the data.	No	

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	Data are available in a file format recommended by the target research community.	No	

Table A.29 : Historic wave height

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	Yes	
	Metadata includes descriptive core elements	Yes	Not all core descriptive metadata information is available
	Metadata includes the identifier of the data it describes.	Yes	
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	
Accessible	Metadata contains access level and access conditions of the data.	Yes	Data are accessible to public but the information is not machine readable
	Metadata remains available, even if the data are no longer available.	Yes	
Interoperable	Metadata are represented using a formal knowledge representation language.	Yes	
	Metadata uses semantic resources.	Yes	Namespaces of known sematic resources cannot be identified in metadata
	Metadata includes links between the data and its related entities.	No	No related resources found in metadata

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Reusable	Metadata specifies the content of the data.	No	Measure variables given in metadata do not match data object
	Metadata includes license information under which data can be reused.	Yes	
	Metadata includes provenance information about data creation or generation.	Yes	Formal provenance metadata are unavailable
	Metadata follows a standard recommended by the target research community of the data.	No	No DOI available, No metadata standard of the repository specified
	Data are available in a file format recommended by the target research community.	Yes	

Table A.30 : Himawari 8 – Rainfall rate data

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	Yes	
	Metadata includes descriptive core elements	Yes	Not all core descriptive metadata information elements exit
	Metadata includes the identifier of the data it describes.	No	Data content identifier is missing
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	
Accessible	Metadata contains access level and access conditions of the data.	No	No access information provided

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	Metadata remains available, even if the data are no longer available.	Yes	
Interoperable	Metadata are represented using a formal knowledge representation language.	Yes	
	Metadata uses semantic resources.	No	Vocabulary namespace URIs can be identified
	Metadata includes links between the data and its related entities.	Yes	
Reusable	Metadata specifies the content of the data.	Yes	Minimal information
	Metadata includes license information under which data can be reused.	No	
	Metadata includes provenance information about data creation or generation.	No	Data creation related information can be identified
	Metadata follows a standard recommended by the target research community of the data.	Yes	
	Data are available in a file format recommended by the target research community.	Yes	Geo Tiff

Table A.31 : NOAA Climate Prediction Centre Rainfall Estimates

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	No	Syntax/option for this in the XML metadata file but PID not present

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	Metadata includes descriptive core elements	Yes	
	Metadata includes the identifier of the data it describes.	Yes	
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	Data are in XML format but it is not registered in major data registries and does not follow a standard schema from schema.org etc
Accessible	Metadata contains access level and access conditions of the data.	No	This is provided via NOAA site covering most datasets but not in the metadata file
	Metadata remains available, even if the data are no longer available.	Yes	
Interoperable	Metadata are represented using a formal knowledge representation language.	Yes	
	Metadata uses semantic resources.	Yes	Vocabulary namespace (s) or URIs specified but no match is found in LOD reference list (examples) -: ['https://data.noaa.gov/resources/iso19139/schema.xsd', 'http://www.opengis.net/gml/3.2', 'http://www.w3.org/1999/xlink']
	Metadata includes links between the data and its related entities.	Yes	Sources mentioned but no links
Reusable	Metadata specifies the content of the data.	Yes	
	Metadata includes license information under which data can be reused.	No	This is provided via NOAA site covering most datasets but not in the metadata file
	Metadata includes provenance information about data creation or generation.	Yes	
	Metadata follows a standard recommended by the target research community of the data.	Yes	

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	Data are available in a file format recommended by the target research community.	Yes	

Table A.32 : Sudan Road Network Shape files Humanitarian Data Exchange

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	No	
	Metadata includes descriptive core elements	Yes	Creator missing
	Metadata includes the identifier of the data it describes.	Yes	
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	
Accessible	Metadata contains access level and access conditions of the data.	No	Humanitarian Data Xchange has licence for all sets but not retrievable in the metadata
	Metadata remains available, even if the data are no longer available.	Yes	
Interoperable	Metadata are represented using a formal knowledge representation language.	Yes	JSON-LD and RDF
	Metadata uses semantic resources.	Yes	namespace": "http:\/\/www.w3.org\/ns\/dcat
	Metadata includes links between the data and its related entities.	Yes	
Reusable	Metadata specifies the content of the data.	No	Specifies that it is a shapefile but not the content

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	Metadata includes license information under which data can be reused.	Yes	
	Metadata includes provenance information about data creation or generation.	Yes	But not all provenance info avail
	Metadata follows a standard recommended by the target research community of the data.	Yes	
	Data are available in a file format recommended by the target research community.	Yes	

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Table A.33 : ESA Sentinel-1

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	Yes	
	Metadata includes descriptive core elements	Yes	Not all core descriptive metadata information elements exit
	Metadata includes the identifier of the data it describes.	No	Data content identifier is missing
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	
Accessible	Metadata contains access level and access conditions of the data.	No	No access information provided
	Metadata remains available, even if the data are no longer available.	Yes	
Interoperable	Metadata are represented using a formal knowledge representation language.	Yes	
	Metadata uses semantic resources.	No	Vocabulary namespace URIs can be identified
	Metadata includes links between the data and its related entities.	Yes	
Reusable	Metadata specifies the content of the data.	Yes	Minimal information
	Metadata includes license information under which data can be reused.	No	
	Metadata includes provenance information about data creation or generation.	No	Data creation related information can be identified

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	Metadata follows a standard recommended by the target research community of the data.	Yes	
	Data are available in a file format recommended by the target research community.	Yes	Geo Tiff

Table A.34 : ESA SMOS

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	Yes	
	Metadata includes descriptive core elements	Yes	Not all core descriptive metadata information elements exit
	Metadata includes the identifier of the data it describes.	No	Data content identifier is missing
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	
Accessible	Metadata contains access level and access conditions of the data.	No	No access information provided
	Metadata remains available, even if the data are no longer available.	Yes	
Interoperable	Metadata are represented using a formal knowledge representation language.	Yes	
	Metadata uses semantic resources.	No	Vocabulary namespace URIs can be identified
	Metadata includes links between the data and its related entities.	Yes	

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Reusable	Metadata specifies the content of the data.	Yes	Minimal information
	Metadata includes license information under which data can be reused.	No	
	Metadata includes provenance information about data creation or generation.	No	Data creation related information can be identified
	Metadata follows a standard recommended by the target research community of the data.	Yes	
	Data are available in a file format recommended by the target research community.	Yes	Geo Tiff

Table A.35 : India Space Agency Cartostat-1

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	No	
	Metadata includes descriptive core elements	Yes	
	Metadata includes the identifier of the data it describes.	No	
	Metadata are offered in such a way that it can be retrieved by machines.	Yes	
Accessible	Metadata contains access level and access conditions of the data.	Yes	
	Metadata remains available, even if the data are no longer available.	Yes	
Interoperable	Metadata are represented using a formal knowledge representation language.	No	

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	Metadata uses semantic resources.	No	
	Metadata includes links between the data and its related entities.	Yes	
Reusable	Metadata specifies the content of the data.	No	
	Metadata includes license information under which data can be reused.	No	
	Metadata includes provenance information about data creation or generation.	No	
	Metadata follows a standard recommended by the target research community of the data.	Yes	
	Data are available in a file format recommended by the target research community.	Yes	

Table A.36 : USGS CHiRPS Rainfall Data

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	Yes	
	Data are assigned a persistent identifier.	No	
	Metadata includes descriptive core elements	No	
	Metadata includes the identifier of the data it describes.	No	
	Metadata are offered in such a way that it can be retrieved by machines.	No	
Accessible	Metadata contains access level and access conditions of the data.	No	

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	Metadata remains available, even if the data are no longer available.	No	
Interoperable	Metadata are represented using a formal knowledge representation language.	No	
	Metadata uses semantic resources.	No	
	Metadata includes links between the data and its related entities.	No	
Reusable	Metadata specifies the content of the data.	No	
	Metadata includes license information under which data can be reused.	No	
	Metadata includes provenance information about data creation or generation.	No	
	Metadata follows a standard recommended by the target research community of the data.	No	
	Data are available in a file format recommended by the target research community.	Yes	

Table A.37 : AFDB Socio Economic Database, 1960-2019

FAIR Component	Question	Response	Comments
Findable	Data are assigned a globally unique identifier.	No	
	Data are assigned a persistent identifier.	No	
	Metadata includes descriptive core elements	No	
	Metadata includes the identifier of the data it describes.	No	

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	Metadata are offered in such a way that it can be retrieved by machines.	No	
Accessible	Metadata contains access level and access conditions of the data.	No	
	Metadata remains available, even if the data are no longer available.	No	
Interoperable	Metadata are represented using a formal knowledge representation language.	No	
	Metadata uses semantic resources.	No	
	Metadata includes links between the data and its related entities.	No	
Reusable	Metadata specifies the content of the data.	No	
	Metadata includes licence information under which data can be reused.	No	
	Metadata includes provenance information about data creation or generation.	No	
	Metadata follows a standard recommended by the target research community of the data.	No	
	Data are available in a file format recommended by the target research community.	No	

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