IRDR Working Paper Series

Integrated Research on Disaster Risk

Disaster Metadata Management System Based on pycsw and its Application

WANG Juanle
BU Kun
WANG Yujie

IRDR
Integrated Research on Disaster Risk

doi: 10.24948/2019.07

About the Series

This Working Paper Series is a new publication of Integrated Research on Disaster Risk (IRDR), following the decision of the IRDR Scientific Committee in April 2019 to act to 'Expand IRDR Network and Scientific Output' (No. 5 of the IRDR Action Plan 2018-2020).

IRDR is an international scientific programme under co-sponsorship of the International Science Council (ISC) and United Nations Office for Disaster Risk Reduction (UNISDR) and with support from China Association for Science and Technology (CAST) and Chinese Academy of Sciences (CAS). Started in 2010, the Programme has been pioneering in the promoting international and interdisciplinary studies on DRR and has made its contributions through scientific publication and policy papers as well as dialogue toward shaping international agenda in the understanding disaster risks, bridging science and policy gaps and promoting knowledge for actions, all required in the Sendai Framework for Disaster Risk Reduction 2015-2030 (SFDRR) and its top priorities. Over time, the scientific agenda of IRDR has attracted many international renowned expertise and institutions. IRDR community is now, institutionally speaking, characterized by its strong Scientific Committee and six thematic working groups, thirteen IRDR national committees (IRDR NCs) and one regional committee (IRDR RC), sixteen international centres of excellence (IRDR ICoEs), a group of some one hundred fifty Young Scientists (IRDR YS) and a broad partnership with national, regional and international institutions working for SFDRR.

This Working Paper Series is thus specially made to facilitate the dissemination of the work of IRDR NCs, ICoEs, YS and institutions and individual experts that IRDR considers relevant to its mission and research agenda, and of important values for much broader range of audience working in DRR domains. As one will notice, all working papers in this series has anchored their relevance and contributions of their work toward SFDRR, IRDR, SDGs and Paris Agreement on climate change. It is the hope of the authors of the working papers and IRDR that this working paper series will not only bring new knowledge, experience and information toward disaster risk reduction, but also helped build better coherence of DRR with the mainstream agenda of UN today toward inclusive, resilient and sustainable human societies.

Team of IRDR-IPO

Disaster Metadata Management System Based on pycsw and its Application

WANG Juanle[1,3*]
BU Kun[2,3]
WANG Yujie[1,3]

[1] State Key Laboratory of Resources and Environmental Information System, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China
[2] Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun, Jilin 130102, China
[3] International Knowledge Centre for Engineering Sciences and Technology under the Auspices of UNESCO, Beijing 100088, China

[*]Corresponding Author: wangjl@igsnrr.ac.cn

Published in 2019 by Integrated Research on Disaster Risk (IRDR), an interdisciplinary body of the International Science Council (ISC).

Cover photo:

http://blog.sina.com.cn/s/blog_dbfd52a80102v1ej.html#commonComment

Design: Fang LIAN

Edit: Qunli HAN, Lucy JONES

Printed by IRDR

Printed in Beijing, China

Citation of this publication: Wang, J., Bu, K., & Wang. Y. (2019). Disaster Metadata Management System Based on pycsw and Its Application. *IRDR Working Paper Series,* 14 pages. doi: 10.24948/2019.07

Content

Abstract of this Working Paper

Faced with frequent natural disasters and increasing losses, the international community has issued a number of measures to manage disaster risks. Among them, the *Sendai Framework for Disaster Risk Reduction 2015–2030* and the 2*030 Agenda for Sustainable Development* proposed urgent needs for knowledge and technology development and application of data, standards, information technology, data sharing, and other aspects of disaster risk reduction. The management and sharing of disaster information has become an important technical mechanism for international cooperation on disaster risk reduction and is an important guarantee for improving comprehensive disaster prevention, reduction, and relief capability. Based on open source pycsw software, this study establishes mapping of disaster core metadata standard, *Dublin core metadata standard*, and *ISO 19115 geographic information – metadata* based on an independently-designed disaster metadata standard. The disaster metadata management system is designed and analysed to realize the functions of online adding, editing, viewing, deleting, and data downloading of disaster metadata. The prototype system developed in this study is preliminarily applied to the Disaster Risk Reduction Knowledge Service System of the International Knowledge Center for Engineering Sciences and Technology (IKCEST) (http://drr.ikcest.org/).

Keywords

Disaster risk reduction, Metadata standard, Data management system, OSS (open source software)

Indications of contributions to IRDR Science Plan and UN Agendas

IRDR Sub-objectives	2.1
SFDRR targets	Target g
SDGs and/or Climate Goals	Target 11, 15
S/T Roadmap actions	Action 1.4

1. How does this study contribute to IRDR research objectives?

Metadata applications are designed to catalog, query, and exchange information on disaster datasets. These datasets can be used to assess disaster vulnerability. Furthermore, based on disaster prevention and reduction knowledge service system, the applications provide disaster-based data and metadata-based knowledge services to identify hazards leading to risks.

2. How does this study contribute to SFDRR targets?

Metadata system applications can enhance the reliability of early warning systems and provide key support for disaster information by publicizing and sharing dataset information. Establishing metadata standards can provide technical support for sharing disaster data, which is conducive to using this data effectively.

3. How does this study contribute to SDGs and the Climate Goal?

The available basic environmental disaster data in country or region acquired through metadata can assist in planning and designing disaster prevention and reduction into engineering construction, and strengthen the city's ability to withstand disaster risks. By providing data, standards, and technical support these applications can, to a certain extent, ensure sustainability and aid in coping with climate change and its impact and desertification, and make cities and human settlements inclusive, safe, resilient and sustainable.

4. How does this study contribute to Science & Technology Roadmap Actions?

Data are the basis for monitoring, reviewing, and evaluating disaster prevention and reduction and decision support. Establishing metadata applications is key to maintaining, updating, and exchanging dataset information

5. Main recommendations to DRR policy if not yet highlighted in the main texts

The open communication and dissemination of disaster data is the basis for disaster risk reduction. It is recommended that the policy makers integrate disaster data sharing into disaster risk reduction planning, establish policies related to disaster data sharing, promote real-time sharing and dissemination of disaster data, and reduce disaster risks.

Main Text

0. Introduction

The *Sendai Framework for Disaster Risk Reduction 2015-2030*[1] (Sendai Framework) has clearly defined 7 global targets, 13 guiding principles, and 4 priorities for action items. Separate from the two spatial scales of "national and local" and "global and regional", the framework has proposed knowledge and technology needs, i.e., the data, standards, information technology, and data sharing for disaster risk and reduction. The 17 sustainable development goals (SDGs index) proposed in the *2030 Agenda for Sustainable Development*[2] clearly stated the need to build cities with the ability to withstand disaster risks. These objectives urgently require support from authoritative data, unified standards, and advanced technology. To serve disaster risk and reduction, a number of disaster databases at the international, national, and regional levels have been established worldwide, providing different levels of data services. The international disaster database includes Emergency Events Database, EM-DAT, managed and maintained by the Centre for Research on the Epidemiology of Disasters, CRED, and the two other global sources are private: Sigma from Swiss Re and NatCat from Munich Re; the national disaster database includes British Geological Survey, BGS, United States Geological Survey Database, USGS Database and the China Earthquake Networks Center; the regional disaster databases include Network for social studies on disaster prevention in Latin America, La RED, Asian Disaster Reduction Center, ADRC. These disaster databases have made positive contributions to the international exchange and sharing of disaster information and the promotion of international disaster reduction[3]. However, these databases are incompletely collected for disaster information, and the classification criteria for disaster events are different[4], and these databases are mostly independent, less extensible, and less interoperable, which limits the sharing of disaster data resources. In addition, at present, the description, organization, management, integration, and sharing of disaster data resources have become the dominant concerns of data resource managers and users. Metadata is generally recognized as data suitable for describing data resources and aids in identifying and managing data [5]. At present, there is a certain research foundation for metadata standard in the disaster area. Even there are some metadata standards applicable to different disasters, but the metadata for most projects are maintained in the form of documents, lacking a unified metadata standard format, metadata management tools, and system. Based on the usefulness and characteristics of metadata, designing a disaster metadata management system and building a bridge for data exchange and sharing between data systems can effectively support scientific research in disaster prevention, reduction, and relief.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) has long attached great importance to global cooperation in disaster prevention and reduction, and has made it clear that it hopes to conduct in-depth cooperation with the International Knowledge Centre for Engineering Sciences and Technology under the Auspices of UNESCO (KCEST) in such areas as disaster metadata standards, education platform for disaster prevention and control, disaster risk and reduction training for developing countries, establishing methods, and promoting national/regional disaster databases. Driven by the mission of the IKCEST, and based on the open source metadata catalogue service tool pycsw, this study designs disaster metadata standards for disaster risk and reduction, implements mapping between disaster metadata standards and Dublin core metadata and ISO 19115[6] core metadata. Furthermore, a disaster metadata management prototype system is established and developed that supports publishing and editing of metadata, metadata browsing, and downloading of data entities to achieve the online management of disaster metadata.

1. Overview of disaster metadata standards

The core metadata for a disaster is designed with reference to core metadata, such as *Dublin core metadata standard (DC1.1)*, *Geographic Information—Metadata*, and *ISO 19115 geographic information - metadata*. The disaster core metadata is defined according to the needs of the disaster application. Disaster core metadata describes the minimum metadata set for basic information in the Disaster Risk Reduction Knowledge Service System platform. It provides 30 core metadata elements, including the dataset basic common information, such as the dataset title, dataset identifier ID, the character set of the dataset, data quality report, and data lineage; some disaster metadata describe disaster characteristics, such as disaster species and disaster process, as shown in Tab.1.

Tab. 1 Disaster core metadata

Name	Constraint/ Maximum occurrence	Name	Constraint/ Maximum occurrence
dataset title	M/1	data quality report	C/1
dataset identifier ID	C/1	data lineage	C/1
the character set of dataset	O/1	dataset access restrictions	O/N
dataset type	M/1	service restrictions	O/N
data format	M/1	dataset security restriction classification	M/1
dataset topic category	M/1	dataset thumbnail	O/N
dataset language	M/1	dataset key words	M/N
dataset summary	M/1	dataset contact information	M/N
dataset creation time	M/1	system unique identifier ID	M/1

dataset last update time	M/1	metadata language	C/1
space scope	M/1	metadata creation time	M/1
time scope	M/1	metadata last update time	M/1
online link	O/1	metadata standard name	M/1
disaster process	O/1	metadata standard version	M/1
disaster species	M/N	metadata contact information	M/1

Note: "M" / "O" / "C" respectively indicates the element is Mandatory/ Optional/Conditional, and the "1" indicates the element appears single time, the "N" indicates the element may appear repeating times.

2. Technological foundation

(1) Python

The Python language is an object-oriented literal translation computer programming language [7], which is characterized by unique and concise syntax that allows the user to work quickly and effectively integrate systems. It can easily perform complex programming with extension modules. As a scripting language, Python is very flexible and generally does not require a programmer to explicitly compile a script; it can compile itself as needed. Python 3.5 is used in the development of this project.

(2) pycsw

pycsw is an open source implementation of OGC CSW metadata catalog services written in Python, which was released in 2010. pycsw allows for the publishing and discovery of geospatial metadata via numerous APIs (CSW-2/CSW-3, OpenSearch, OAI-PMH, SRU), providing a standards-based metadata and catalogue component for spatial data infrastructures. pycsw is Open Source, released under an MIT license, and runs on all major platforms (Windows, Linux, Mac OS X). As a network metadata directory service tool, it has the following features: (1) lightweight application platform; (2) the only implementation of OGC CSW service application written in Python that makes it easier to exchange information with other Python directory libraries, which provides a more effective way to implement near-real-time OGC directory services [8]; (3) easy to deploy and configure, and supports multiple metadata models; (4) tools are available for automatically generating metadata[9]. The version of pycsw used in this project is 2.2.0.

(3) PostgreSQL

PostgreSQL is a powerful, free object-relational database server (database management system) and an open source database that uses and extends the SQL language combined with many features that safely store and scale the most complicated data workloads. PostgreSQL has earned a strong reputation for its proven architecture, reliability, data integrity, robust feature set, extensibility, and the dedication of an open source community behind the software to consistently deliver performance and innovative solutions. The version of PostgreSQL used in deployment is 9.5.

3. Architecture of the disaster metadata management system

The disaster metadata management system is deployed according to the Web Service framework, and the overall structural framework of the system is shown in Fig.1. The core components of the disaster metadata management system are the pycsw metadata server and disaster metadata server. First, a disaster metadata database is built and offline disaster metadata information is entered into the database. This database is used as the local disaster database for the disaster metadata management in response to user demand for publishing, editing, browsing, and data downloading. Second, a pycsw cloud database is configured to store metadata in the disaster database into the pycsw cloud database using two mechanisms, active publishing and being harvested by pycsw, thereby establishing communication between the pycsw metadata server and disaster metadata server. The pycsw metadata server, as the catalog services tool for the disaster metadata management system, is responsible for gathering and harvesting metadata information for other sub- centers in its metadata directory service framework and providing disaster metadata catalog services.

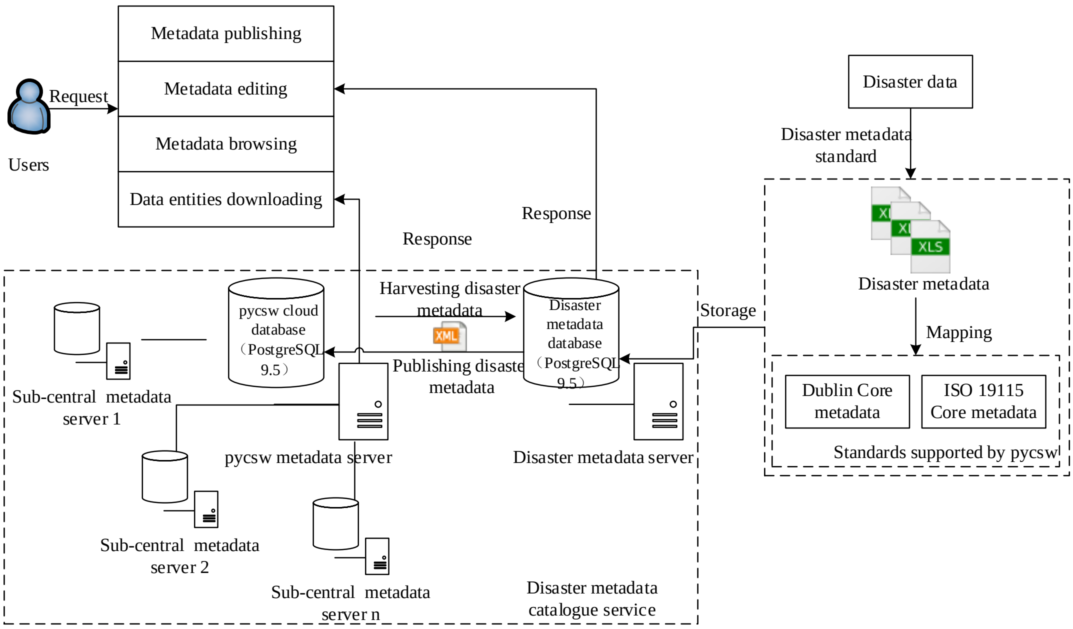

Fig. 1 Architecture for the disaster metadata management system

4. Implementation process

4.1 pycsw configureation

Because pycsw uses many open source geospatial libraries, it is easier to install under the Linux operating system. It is deployed on Debian Linux and installed using Python's pip tool, which is a modern, universal Python package management tool that provides the ability to find, download, install, and uninstall Python packages. Unlike other CSW servers, pycsw can implement a distributed search on its own. When pycsw is enabled, it searches all specified directories and returns a uniform set of search results to the client. pycsw deployment has three configurations (CSW-1, CSW-2, CSW-3) and three endpoints. Each endpoint is based on an opaque metadata repository (based on subject/location/discipline, etc.). The goal is to perform a one-to-one search of all endpoints. pycsw has the ability to perform server-side repository or database filtering to override all CSW requests to query a specific subset of the metadata repository and return specific query results.

4.2 pycsw metadata server configuration and transformation

The main function of pycsw metadata server is to register metadata records and establish metadata databases based on metadata standards. The pycsw metadata server needs to be configured independently to communicate with the disaster metadata server through open interconnection standards, which conforms to the Web Service architecture.

The system and database of the disaster metadata server and pycsw metadata server are independent. Establishing communication between the disaster metadata server and pycsw metadata server is a prerequisite for the system to publish metadata in the disaster metadata database. Currently pycsw supports two open communication data formats, XML and JSON. To simplify development, JSON is used as the de facto standard for data exchange. There are two ways to communicate between servers. First, the disaster metadata database actively pushes metadata information to the pycsw metadata server. Second, the pycsw metadata server harvests metadata information in the disaster metadata database. The deployment mode is automatic on-duty operation, which is guaranteed to be updated at least once a day. The cooperation between the two schemes ensures the real-time release of disaster metadata data while avoiding possible problems in the information release.

In the specific operation, the technical problem that needs to be considered is primarily the mapping of the disaster metadata database and the metadata items in pycsw. It is necessary to map the disaster metadata to the pycsw metadata database first. The specific method is to retrieve records from the disaster metadata database, obtain the relevant fields, and store them in dictionary variables. The information is then added or updated based on the ID in the pycsw metadata database.

4.3 Disaster metadata converging and harvesting

The pycsw disaster metadata directory service architecture consists of one pycsw central node (pycsw metadata server) and multiple sub-central nodes (such as the Disaster metadata server, Node 1, Node 2, ……, Node n). As the sub-central node of pycsw, the disaster metadata server exchanges metadata information with other sub-central nodes through the pycsw interface. Fig. 2 describes the location of each node of the disaster metadata server in the architecture. The pycsw metadata server can harvest metadata information of each node by active harvest and passive push, and store it in the pycsw database. While pushing disaster metadata information to pycsw, the disaster metadata server can use the CSW protocol to harvest metadata information in the pycsw central library.

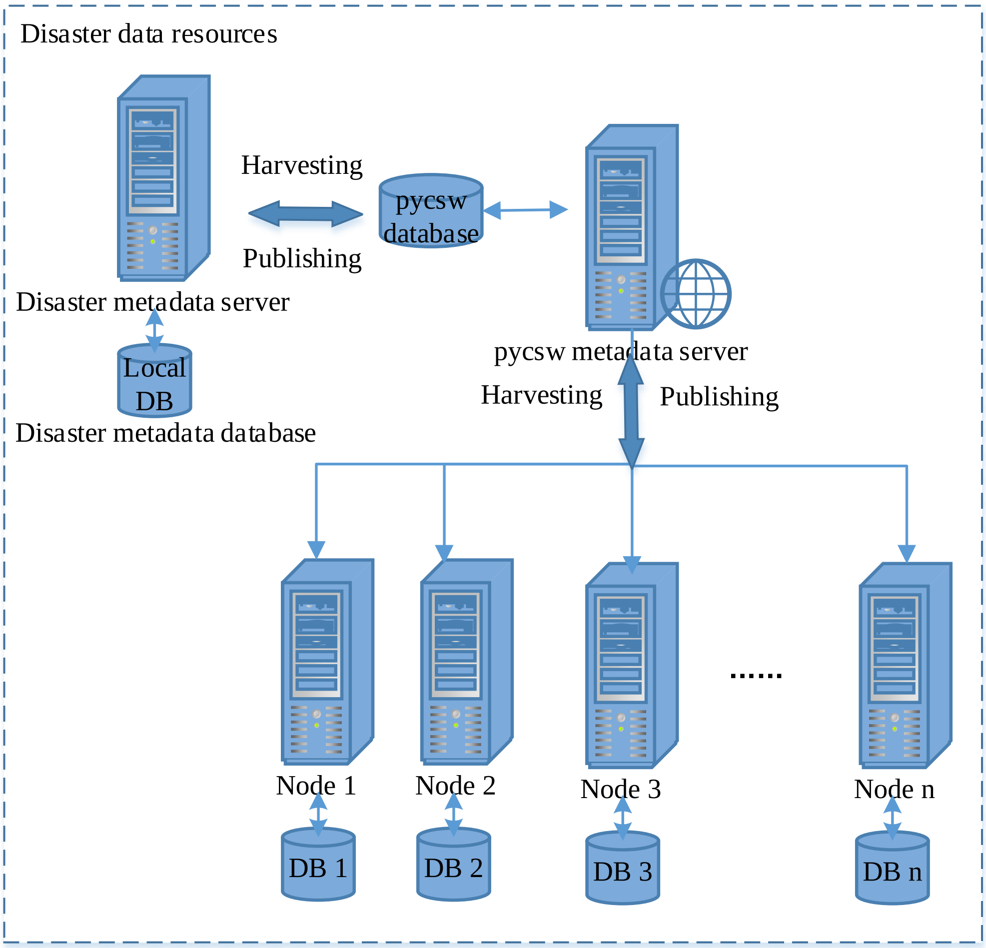

Fig. 2 Converging and harvesting disaster metadata

4.4 Release of disaster metadata

Two methods are used for disaster metadata publishing in this work: (1) directly publishing disaster metadata standards to the public (2) analyzing the difference between the disaster metadata standard and standards supported by pycsw, and publishings the disaster standards after transforming into the standard format that are supported by pycsw.

(1) Direct publish of disaster metadata

The implementation of metadata interoperation and data exchange in a computer system must be based on certain description systems, such as XML and JSON. The XML description language is universal and was developed early, JSON was developed later, but it has an advantage in data exchange processing [10]. pycsw supports both of these systems, and the default output is in XML code format; therefore, XML is preferred in this work.

a) Create a metadata database field table

The disaster core metadata standard in Tab. 1 is expressed in tabular form to establish the disaster core metadata database field table (30 of the core metadata fields for disasters in Tab. 2, which are not all shown here), which contains all the fields for the 30 core metadata elements of the disaster. In this table, the First class and Second class together constitute unique identifiers in the metadata database system. The system reads the number after t by default, and then the first and second class numbers together form a four-digit system unique identifier. The unique identifier that identifies disaster metadata is 3121, the Field name is the field name in the metadata database, and the Title is the client name displayed for each field in the metadata database system.

Tab. 2 Disaster core metadata

First class	Second class	Field name	Title	UUID, Universal Unique Identifier	DtId, identifier	mdChar, characterSet
t31	t21	specdb_datasets	Science Datasets	1	1	1

b) Build the disaster metadata database

The Python program is used to parse the information of the metadata fields in Tab. 2, then create the classification, and store field information (such as the Universal Unique Identifier, identifier, characterSet, etc.) of the disaster metadata in the disaster metadata database. The metadata database is built on PostgreSQL. The database can provide users with local disaster information storage, query, and other functions. The user performs operations, such as Add, Delete, Edit, and View in the disaster metadata list page, and these operations are synchronously updated in the disaster data core metadata database in PostgreSQL.

c) Read and publish metadata information

As a central node for metadata publishing, pycsw can perform Harvest operations to update local repositories. Users can remotely update the local repository via CSW-T.pycsw and insert a service object into the pycsw server registry, store the acquired metadata information into the pycsw server, and publish the formal metadata information for the disaster CSW service. The user can find the metadata information based on the URI of the metadata.

(2) Publish the converted disaster metadata

pycsw has now publicly declared several types of metadata standards it supports, including *Dublin core metadata standard*, *ISO 19139 Geographic information - Metadata - XML schema implementation, ISO 19115 geographic information - metadata*, *Federal Geographic Data Committee,* which can receive and publish metadata information published in one of the described standard formats. The disaster metadata standard refers to a number of domestic and foreign metadata standards in the early stage of design. The conversion to these two metadata standards is convenient and feasible. Furthermore, there use can avoid the loss of necessary disaster metadata information, and fully guarantee the integrity of the converted metadata information.

During the mapping process, Python reads the disaster metadata database, encapsulates the metadata items into dictionaries, and then uses the XML/JSON extension package to transform and publish the data. Because the conversion principle is the same, the mapping principle and method are illustrated taking the mapping of disaster metadata and *Dublin core metadata* as an example.

The *Dublin core metadata* consists of 15 metadata items; 18 metadata in the disaster core metadata can be accurately matched with Dublin core metadata to ensure more than 60% of valid information output. The remaining metadata items that are not precisely matched, for example, disaster species and disaster process, can be summarized in the resource description of the *Dublin core metadata*. The thumbnail and data quality report formats are image and .doc format respectively, which cannot be matched successfully. After information matching, the Dublin core disaster metadata retains at least 90% of the disaster metadata. The specific matching scenario is shown in Tab. 3. The Dublin core metadata and disaster core metadata in each row that correspond are shown as matches, with unmatched information left as blanks in the table.

Tab. 3 Mapped to Dublin Core metadata

Dublin Core metadata	Disaster core metadata
Title	Dataset title
Subject	Dataset topic type
Description	Dataset summary
Source	Data lineage
Language	Dataset language, metadata language
Relation	
Coverage	Space scope, time scope
Creator	
Publisher	Dataset contact information
Contributor	Metadata contact information
Rights	Access restrictions, service restrictions, security restriction classification
Date	Dataset creation time, dataset last update time, metadata creation time
Type	Dataset type
Format	Data format
Identifier	Dataset identifier ID

Through the same operation mentioned above, the results for the *ISO 19115 geographic information -- metadata* core metadata and disaster metadata conversion are as follows: 21 metadata in the disaster metadata standard can be accurately matched with ISO 19115 disaster metadata, which can guarantee more than 70% of effective information output from the ISO 19115. After information matching, the ISO 19115 core disaster metadata also retains at least 90% of the disaster metadata.

5. Disaster Metadata Management Prototype System

Under the support of the International Knowledge Center for Engineering Sciences and Technology (IKCEST) – Disaster Risk Reduction Knowledge Service System (http://drr.ikcest.org/), the main functions were realized by the disaster metadata management prototype system are: ①metadata publishing, ②metadata editing, ③ metadata browsing, and ④ data entities downloading. The user performs CRUD (Create, Retrieve, Update, Delete) through the metadata management page, all of which are updated in the background scientific data metadata database synchronously.

5.1 Metadata publishing

Users who have disaster metadata editing authority can add disaster science data metadata information in the Disaster Risk Reduction Knowledge Service System after logging into the system user account. Clicking on the Publishing Science Datasets Data control authorizes the addition of Title, Category, Category Name and other information. Clicking on Submit at the bottom of the page then submits this metadata information. For example, if you add the metadata for "The flood disaster database of Songliao basin in the northeast of China", Category: 31_Science Datasets, Category Name: Basic Geography can be selected. Once all the metadata information has been submitted, clicking Submit saves this data. (see Fig.3 (a)).

5.2 Metadata editing

To facilitate managing metadata, the metadata management prototype system provides a function for reediting metadata information. The metadata editing page is shown in Fig. 3(b). Clicking on the Edit button in the metadata page opens the metadata reediting page. Similar to the metadata addition operation, the modified metadata information is submitted after completing the editing. At this time, the metadata information saved in the disaster metadata database is replaced with the modified information. Metadata deletion can be achieved by directly clicking the Delete button. All metadata management process logs will be recorded. Under the Review section, a manager can check whether the metadata management operation is appropriate. Through the system's secondary check, the error rate can be reduced and metadata management quality can be improved.

5.3 Metadata browsing

The metadata information stored in the disaster database can be used to reflect the basic information in the disaster scientific data set. All metadata information provided by the Disaster Risk Reduction Knowledge Service System is reflected in the system page in the form of a list. Users select metadata for the disaster data they are interested in and can view the corresponding metadata information, as shown in Fig. 3 (c) for “The flood disaster database of Songliao basin in the northeast of China.”

5.4 Data entities downloading

The system provides an online download function for the data entity. When users browse the disaster metadata information, the data entity corresponding to the metadata can be downloaded through the Download module in the metadata detail page (see Fig. 3 (d)). Any registered user of the system can download the data entity after logging in.

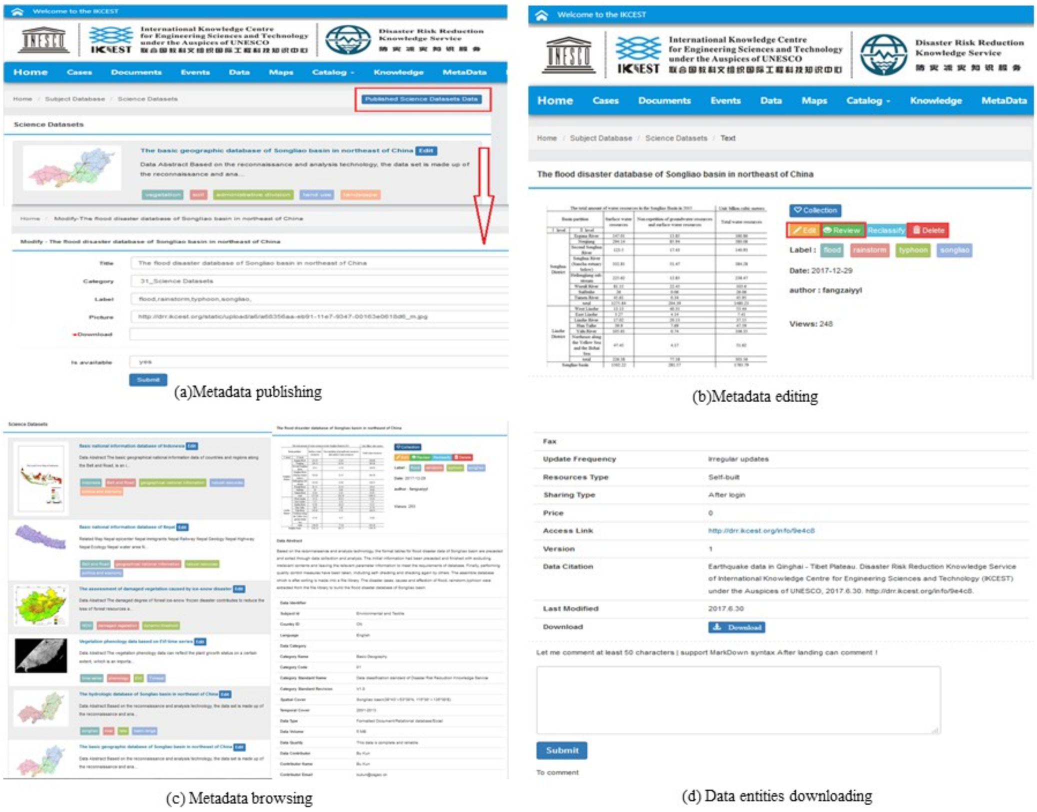

Fig. 3 Demonstration of specific operation functions of the disaster metadata management prototype

6. Conclusion

This work is aimed at the knowledge and technology needs of the Sendai Framework for data, standards, information technology, data sharing, and other aspects, and studies the management of disaster metadata issues. Using open source software pycsw, this study achieved mapping of an independently-built disaster metadata standard and Dublin core metadata and ISO19115 core metadata supported by pycsw to publish disaster metadata in various forms. This method and formatting accomplishes the sharing and interoperability of disaster data, and serves the disaster data collection, analysis, management, information sharing and use. At present, the disaster metadata management prototype system has been designed and the online management of disaster metadata has been realized. The preliminary results have been integrated into the Disaster Risk Reduction Knowledge Service System platform (http://drr.ikcest.org/) as a metadata service.

7. References

[1] United Nations. Sendai Framework for Disaster Risk Reduction 2015-2030. United Nations Office for Disaster Risk Reduction (UNISDR), 2015.

[2] Sachs, J., Schmidt-Traub, G., Kroll, C., Durand-Delacre, D. and Teksoz, K. (2017): SDG Index and Dashboards Report 2017.

[3] Yan L J. Disaster Information Integration of Natural Disasters: Theoretical and Empirical Research. 2016. (in Chinese)

[4] Liu Y L, Xu S Y, Wang J, et al. A Study on the Present Status of Disaster Data and Information Sharing at Home and Abroad. Journal of Catastrophology, 2008, 23(3):109-113. (in Chinese)

[5] Li K R. Study on Geographic Internet Protocol of Spatial Geography Data Subdivision. Chengdu University of Technology, 2011. (in Chinese)

[6] ISO 19115-1: Geographic information -- Metadata -- Part 1: Fundamentals[S]. Switzerland: International Organization for Standardization, 2003.

[7] Zhao Z S, Zhang X, Ma T. Research and implementation of Java and Python integration scheme. Network Security Technology & Application, 2015, (1):146-148. (in Chinese)

[8] Song J, Di L. Near-Real-Time OGC Catalogue Service for Geoscience Big Data. International Journal of Geo-Information, 2017, 6(11):337.

[9] Sharma V K, Amminedu E, Rao G S, et al. Assessing the potential of open-source libraries for managing satellite data products: A case study on disaster management. Geographic Information Sciences, 2016, 23(1): 55-65.

[10] Liu B L. Research and comparison of Python text parsing. Computer Programming Skills & Maintenance, 2015, (09): 14-15. (in Chinese)