

Review of the existing geospatial metadata standards and the metadata frameworks in geospatial applications

Acknowledgement

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Abbreviations

ANZLIC	The Australia and New Zealand Land Information Commission
APIC	Indonesia Smart Initiative Association
APSDI	Asia Pacific Spatial Data Infrastructure
BDTC	Big Data Technical Community
BIG	Badan Informasi Geospasial
BMKG	Indonesia Agency for Meteorology, Climatology and Geophysics
BNPB	National Agency for Disaster Countermeasure
CDD	Consecutive Dry Days
CDI	Combined Drought Index
CIESIN	Center for International Earth Science Information Network
CMR	Common Metadata Repository
CSDGM	Content Standards for Digital Geospatial Metadata
DIAS	Data Integration and Analysis System
DIF	Directory Interchange Format
DoL	Thai Department of Lands
EDO	European Drought Observatory
EGNSS	European Global Navigation Satellite Systems
FGDC	Federal Geographic Data Committee
GeoJSON	Geographic Javascript Object Notation
GISTDA	Geo--Information and Space Technology Development Agency
GPCC	Global Precipitation Climatology Centre
GSCF	Garuda Smart City Framework
GSDI	Global Spatial Data Infrastructure
HTC	Hydrothermal Coefficient
ICT	Integrating information communication technology
IDN	International Directory Network
IMG	ERDAS Imagine
INSPIRE	Infrastructure for Spatial Information in the European Community
IoT	Internet of Things
IPB	Bogor Agricultural University
ISO/TC 211	International Organization for Standardization Technical Committee
ITB	Institute of Technology Bandung
IVCI	Integral Index of Vegetation Conditions
LAPAN	National Institute of Aeronautics and Space
LISAT	LAPAN-IPB Satellite
NCASM	National Coordinating Agency for Surveys and Mapping of Indonesia
NDDI	Normalized Difference Drought Index
NDVI	Normalized Difference Vegetation Index
NICO	National Information Standards Organization
NSDI	National Spatial Data Infrastructure

PDSI	Palmer Drought Severity Index
RDCYIS	Regional Drought and Crop Yield Information System
RTSD	Royal Thai Survey Department
SCCIC	Smart City Community and Innovation Center
SDGs	Sustainable Development Goals
SIMBA	Information System for Disaster Mitigation
SMDI	Soil Moisture Deficit Index
SPI	Standardized Precipitation Index
SWI	Standardized Water Level Index
TISI/TC904	Thai Industrial Standards Institute/Technical Committee 904: Geographic Information
TRMM	Tropical Rainfall Meteorological Missions
UNOOSA	United Nations Office for Outer Space Affairs
URI	Uniform Resource Identifier
VCi	Vegetation Condition Index
VHI	Vegetation Health Index
VSWI	Vegetation Supply Water Index
WMO	World Meteorological Organisation
WTL	Water Table Level

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Chapter 1: Introduction

Geospatial information is data with location labels, including satellite images, land cover data, and GPS location data. It reflects human activities, natural changes, and social developments in the physical world and is widely used in the areas of disaster risk reduction, natural resources management, and urban planning in the past decades. Since geospatial information and its applications play an increasingly influential role in the afore-mentioned areas and newly-emerged fields including smart transport and smart city, it is considered as a type of national resource by some countries. As reported by a study conducted by the United Nations Office for Outer Space Affairs (UNOOSA) in 2018, European Global Navigation Satellite Systems (EGNSS) and Copernicus applications can directly use such information to assist in monitoring or implementing the outcomes of 65 out of 169 SDGs targets ^[1]. Many governments, organizations, and other stakeholders attempt to benefit from the applications of geospatial information to achieve the Sustainable Development Goals (SDGs).

In the process of utilizing geospatial data, government organizations always face various challenges. Take disaster risk reduction as an example, these organizations can leverage space applications to detect disaster-affected areas. However, it is a complex task to figure out how many people/households are affected by the disaster since it is hard to integrate demographic data with geospatial data. Also, cross-sectoral collaboration of data sharing is another unsolved challenge. The geospatial data and statistical data at the city/region levels held by various sectors/divisions are not connected each other for data sharing. Government agencies lack internal agreements for data sharing and data integration. These problems slow down the emergency response for disasters and bring challenges to other areas such as natural resource management and urban planning.

To address these challenges, the United Nations and the World Bank developed the Integrated Geospatial Information Framework as a guideline for their member states, especially for the lower to middle income countries to strengthen their capabilities in developing geospatial information applications ^[2]. The framework identified eight goals, one of which is to develop integrated geospatial information systems and services. To achieve this goal, a more integrated common data format involving geospatial data and statistical data should be adopted to deepen the collaboration of sectors and break through the gaps between geospatial and statistical data. A common data format can provide straightforward means for governments and other stakeholders to manage, access, analyze, and share the integrated geospatial data. As the first step of examining the feasibility of the common data format, the existing metadata frameworks should be reviewed and the metadata as an indispensable component of the construction of common data format should be specified.

In this report, we will review the existing metadata framework of geospatial data files, identify the existing gaps and trends of metadata, and analyze the current status and developing trends of metadata in geospatial applications, especially in the areas of smart city and drought monitoring.

Chapter 2: Metadata in Geospatial Data

With the development of GIS technologies and network communication technology, an increasing number of countries, departments, and private sectors have built geospatial data sharing portals for the public. The difficulty of managing and accessing large data sets efficiently is becoming a prominent problem for geospatial data sharing platforms. Data producers need more effective means to manage and maintain geospatial data and provide timely, accurate, easily-accessible, and manageable data for users, while data users need faster, more comprehensive, and effective ways to query, access, acquire, and explore geospatial data. Metadata, an important means to improve the readability and accessibility of data and achieve efficient management of data resources, can be leveraged to alleviate this problem.

Metadata types and functions

Metadata is data describing data files and is highly structured data provided by the data producer. Specifically, geospatial metadata is the data describing name, creation time, quality, condition, location and other basic information of geospatial data files. According to the article of National Information Standards Organization (NISO), the information stored in metadata can be classified into four categories of information ^[3]. The first is descriptive metadata, the information about the content of resources for searching or understanding it, such as title, author, genre. The second is administrative metadata, referring to the information related to its creation or needed for managing a resource, including technical metadata, preservation metadata, and rights metadata. The technical metadata is the information necessary for decoding or rendering files, such as file type, file size, and creation time. Preservation metadata supports the long-time management and the digital file migrations or emulation in the future, e.g., hash and checksum, and rights metadata provide the details about intellectual property rights of the files, such as license terms and rights holders. Structural metadata, distinct from the former two, refers to the inner relationships of parts of data to one another, including the sequence place in a hierarchy. This type of metadata aims to improve data navigation. The final category is markup languages, used with other types of metadata to mark the notable features.

The functions of metadata mainly focus on the areas of digital resource management and preservation, resource discovery and display, navigation, interoperability, and digital identification ^[3]. In the area of digital resource management and preservation, metadata provides the information needed for rendering contents appropriately and delivers the matched version for users to support digital resource management. Metadata is key to preserve the easily-altered data resources and ensure that data be survived and continue to be accessible in the future. Metadata records data lineage which describes the information about data origin and data variation over time. Preservation is achieved by conducting the integrity verification of the contents after transfer or other actions. For resource discovery and display, metadata allows users to search for resources by relevant criteria and helps to distinguish

dissimilar data resources and find similar data resources. Some properties of metadata are helpful to display to users for better understanding or identification of resources. In the area of navigation, the structural metadata supports navigation within parts of resources, for example, switching from one item to the next, or among different versions of objects. Metadata use schemes and shared transfer protocols to support more seamlessly cross-system data exchange and facilitate interoperability. Actually, each data resource has its corresponding metadata and digital identification. The digital identification in metadata differentiates one resource from others for validation purposes. Metadata is the bridge of interaction between data producers and data users. Data producers can effectively organize, manage, and maintain data resources through metadata, while data users can understand, query, and access geographic data through metadata. *Table 1* shows the four categories of metadata and their usage.

Table 1. Metadata types and uses

Metadata Type	Sub-type	Description	Example Properties	Uses
Descriptive metadata	-	Information for discovering and understand a file	<ul style="list-style-type: none"> · Title · Author · Genre 	<ul style="list-style-type: none"> · Resource discovery and display · Interoperability · Digital identification
Administrative metadata	Technical metadata	Information for decoding and rendering files	<ul style="list-style-type: none"> · File type · File size · Creation date 	<ul style="list-style-type: none"> · Interoperability · Digital resource management and preservation
Administrative metadata	Preservation metadata	Information for supporting long-time data management	<ul style="list-style-type: none"> · Checksum · Hash 	<ul style="list-style-type: none"> · Digital resource management and preservation · Interoperability
Administrative metadata	Rights metadata	Details about intellectual property rights of files	<ul style="list-style-type: none"> · Copyright · License terms · Rights holder 	<ul style="list-style-type: none"> · Interoperability · Digital resource management
Structural metadata	-	Relationships of parts of files to one another	<ul style="list-style-type: none"> · Sequence Place in hierarchy 	<ul style="list-style-type: none"> · Navigation
Markup languages	-	Marks for notable features	<ul style="list-style-type: none"> · Heading · List · Name 	<ul style="list-style-type: none"> · Navigation · Interoperability

Geospatial Metadata Standard

Uniform metadata standard helps software/systems to read and understand the information stored in metadata files more easily and effectively. Besides, it is a critical component of geospatial data standardization and an easier way to establish data exchange between different data management software. Currently, many organizations and institutions in the world have been working on the research of metadata standards (*Table 2*). Among these geospatial metadata standard formats, Content Standards for Digital Geospatial Metadata (CSDGM) and ISO Geographic Information/Geomatics are the most mature and widely-accepted, while Directory Interchange Format (DIF) is developed by NASA that is often used for raster data at the collection level. This section mainly focuses on the introduction of these three standards and compares their advantages and disadvantages.

Table 2. Geospatial information metadata standards

Number	Metadata	Organization
1	Content Standards for Digital Geospatial Metadata (CSDGM)	Federal Geographic Data Committee (FGDC)
2	Geographic Information-Data Description-Metadata	CEN/TC 287
3	Core Metadata Elements	The Australia and New Zealand Land Information Commission (ANZLIC)
4	Directory Interchange Format (DIF)	NASA
5	ISO Geospatial Metadata Standards	ISO/TC211
6	CIESIN metadata standard	Center for International Earth Science Information Network (CIESIN)

Content Standards for Digital Geospatial Metadata (CSDGM)

CSDGM was established and published by the Federal Geographic Data Committee (FGDC) in 1994, which emphasizes the role of metadata in data accessibility, fitness, access, and transformation. This standard is organized in the hierarchy of sections, compound elements and data elements ^[4]. The top level is section 0 (“metadata”) that consists of many compound elements. A section, a special kind of compound elements, has its name, its definition and its production rules which defines data elements and compound elements. A compound element, a set of data elements and other compound elements, is a higher-level term than data elements. Data element is the most basic metadata unit, which is used to describe a certain aspect of geospatial data and has a certain value range. The “metadata” content aggregates seven main sections which are composed of specific compound elements (*Table 3*). CSDGM

also has another three assistant sections, i.e., citation information, time period information, and contact information, which are always used by other sections.

Table 3. The metadata content of CSDGM

Level-0	Level-1(Main section)	Level-2 (Compound elements)
Metadata	Identification information	Citation, description, time period of content, status, spatial domain, keywords, access constraints, use constraints, point of contact, browse graphic, data set credit, security information, native data set environment, and cross reference
	Data quality information	Attribute accuracy, logical consistency report, completeness report, positional accuracy, lineage, and cloud cover
	Spatial data organization information	Indirect spatial reference, direct spatial reference method, point and vector object information, and raster object information
	Spatial reference information	Horizontal coordinate system definition, vertical coordinate system definition
	Entity and attribute information	Detailed description, overview description
	Distribution information	Distributor, resource description, distribution liability, standard order process, custom order process, technical prerequisites, and available time period.
	Metadata reference information	Metadata date, metadata review date, metadata future review date, metadata contact, metadata standard name, metadata standard version, metadata access constraints, metadata use constraints, metadata security information, and metadata extensions

ISO Geospatial Metadata Standards

ISO Geographic Information/Geomatics is developed by the International Organization for Standardization Technical Committee 211(ISO/TC 211) which focuses on the standards of digital geographic information and geomatics. ISO/TC 211 aims to establish a series of standards for objects or phenomena related to the location of the earth, including the acquisition, processing, analysis, access, representation, and transformation of digital geographic information methods, tools, and services ^[5]. Based on the CSDGM standard, ISO/TC211 established the international standard for geographic metadata, namely ISO 19115, which can be applied to data set cataloging, data interchange networks, and detailed

description of data sets. The development of ISO 19115 Geographic Metadata Standard began in 1994 and two generations have been published until now. ISO 19115-1:2014 is the second standard version defining metadata elements and schema about geospatial resources. This standard contains more than 400 elements and divides them into three types: mandatory, optional, and mandatory under certain conditions. There are 20 core level metadata elements in this standard, which can be classified into the element group describing metadata and the element group describing geospatial dataset/resource. *Table 4* lists the core level metadata elements named “Discovery metadata for geographic resources” in ISO 19115-1:2014. The high-level structure of this metadata standard has 12 classes which describe different aspects of the geospatial metadata in detail (*Table 4*). Besides, according to the latest edition, ISO 19115 provides the metadata standard for geospatial data acquisition and processing, namely ISO 19115-2:2019 and the XML schema implementation standard of ISO 19115-1 and ISO 19115-2, namely ISO 19115-3:2016, while the encoding rules of XML schema implementation are identified in the ISO 19139-2:2019 standard.

Table 4. The high-level structure of ISO 19115-1:2014

Class_0	Class_1	Description
MD_Metadata: Including information about metadata	MD_SpatialRepresentation	Identifying whether it is vector data or grid data
	MD_MaintenanceInformation	Information about data maintenance
	MD_Reference system	Information about spatial, temporal reference system
	LI_Lineage	Information about data lineage
	DQ_Data quality	Information about data quality
	MD_Distribution	Information about data distributor
	MD_Identification	Information about unique identification of data
	MD_ContentInformation	Information about data content, such as feature catalogue
	MD_PortrayalCatalogueReference	Information rendered for human visualization
	MD_Constraints	Security and legal constraints
	MD_ApplicationSchemaInformation	Information about application schema of data
	Metadata extension information	Metadata about extensions specified by users

Directory Interchange Format (DIF)

The DIF standard was first proposed in NASA in 1987 and latest updated in 2019. DIF is a kind of metadata developed and approved by NASA, which describes a set of attributes for earth science data at the data collection level and is recommended using in NASA Earth Science Data Systems ^[6]. DIF is also the recommended standard for exchange of collection level metadata, metadata records exchange within IDN (International Directory Network) and metadata submission to CMR (Common Metadata Repository). There are three categories of fields in this metadata standard listed in *Table 5* including required fields, highly recommended fields and recommended fields.

Table 5. The description of DIF fields

Type	Fields
Required	Entry ID, entry title, science keywords, ISO topic category, organization, summary, related URL, platform/instrument, temporal coverage, spatial coverage, project, and metadata dates
Highly recommended	Dataset citation, personnel, location, data resolution, quality, access constraints, distribution information, dataset progress, and dataset language
Recommended	Originating center, multimedia sample, metadata association, IDN node, DIF revision history, version description, additional attributes, product level ID, collection data type, extended metadata, ancillary keyword, publication/reference, and privacy status

Comparison of three kinds of metadata standard

These three kinds of metadata standard widely used in its applicable fields by many governmental divisions and private sectors. Each of them has its strengths, weaknesses, and limitations. *Table 6* lists the comparisons of three kinds of metadata standard ^[4,5,6,7].

Table 6. Comparisons of three kinds of metadata standard

	Content Standards for Digital Geospatial Metadata (CSDGM)	ISO Geospatial Metadata Standards	Directory Interchange Format (DIF)
Strength	<ul style="list-style-type: none"> ● Establish the names, definitions and value domain of data elements and compound elements included in metadata ● Available and useable for all level of governments and private sectors ● Suitable for different purpose and different data organizing 	<ul style="list-style-type: none"> ● Support a wide variety of geospatial resources, including data, sensors, applications, collection, services, models and so on ● Use Spatial Reference System identifiers to simplify the identification of geographic coordinate systems ● Nations and organizations can extend the classes and attributes for their varied needs and purposes ● A foundation for regional, national and global geospatial data interoperability 	<ul style="list-style-type: none"> ● Mature specification ● Actively used and maintained by varieties of organizations for data management and a means to interact with GCMD ● Compatible with ISO 19115 standard and CSDGM ● An already NASA-endorsed standard ● Easy and lightweight ● Benefit from contrary to ISO
Weakness	<ul style="list-style-type: none"> ● Not for an implementation design. ● No specification for how to organize metadata in computer systems and how to transmit, communicate, present to users 	<ul style="list-style-type: none"> ● Too complicated for some lightweight data documentation 	<ul style="list-style-type: none"> ● Many metadata providers think it should be superseded by ISO 19115

Applicability	<ul style="list-style-type: none"> ● Support the processing and collection of geospatial metadata ● Geospatial data documentation standard for GIS vector and raster data. 	<ul style="list-style-type: none"> ● Applicable for GIS vector, imagery, and gridded data, and geospatial data services/applications including web mapping, data catalogs 	<ul style="list-style-type: none"> ● Primarily for metadata interchange with other external organizations, including export or import metadata
Limitations	<ul style="list-style-type: none"> ● Superseded by ISO 19115. In 2010, the FGDC encouraged to transition to ISO standard 	<ul style="list-style-type: none"> ● Some existing metadata cannot be converted to the ISO 19115 metadata because of technical or fiscal limitations 	<ul style="list-style-type: none"> ● Not directly for inventory level data ● Not totally compatible with ISO

ISO 19115 as an international metadata standard, which can support multi-languages and multi-nations geospatial resource environments and highly-accepted by international organizations and countries, e.g., WMO (World Meteorological Organisation), Australian Ocean Data Centre, INSPIRE (Infrastructure for Spatial Information in the European Community), and so on. Also, many metadata standards have been revised and appended with some additional attributes to be compatible with ISO 19115 and some metadata transformation services/tools have been developed to convert metadata to the ISO 19115 metadata. In addition, ISO/TC 211 is in the process of improving and revising ISO 19115 to feed up the needs of applicability for novel geospatial technologies and applications. In a word, ISO 19115 is the mainstream in geospatial metadata standards for now and future. When developing metadata for new geospatial data format, the developers are suggested to reference this international metadata standard and build their own profiles based on ISO 19115.

Metadata in Geospatial data

Geospatial data

The GIS data formats could be divided into two categories: vector data format and raster/grid data format. Vector data use geometry to represent the geospatial features. Geometry is composed of one or more vertices ^[8]. A vertex is a location with X, Y, optional Z value and presents a point feature. The geometry consisting of two or more vertices where the first and the last vertex are not in the same location is a line feature. The geometry consisting of three or more vertices where the first and the last vertex are in the same location is a polygon feature. Vector features have text or numerical attributions describing the features.

Raster data are composed of a matrix of pixels and each pixel has a value of attribution in this pixel area ^[9]. Each pixel area represents a geographical region in the real world. Among

vector data formats as *Figure 1.a*, ESRI Shapefile is the most common geospatial file and nearly all commercial and open geospatial data platforms accept shapefile, which has three required files: SHP, SHX, and DBF, and other files are optional: PRJ, XML, SBN, and SBX. XML is the metadata file. Geographic Javascript Object Notation (GeoJSON) is widely used for web-based mapping. OSM is OpenStreetMap's XML-based file format, while KML/KMZ is XML-based and is mainly used for Google Earth. ArcInfo Coverages contains a series of folders including points, arcs, polygons or annotation. Raster GIS data format includes 7 classes and as *Figure 1.b*. Among them, GeoTIFF is an industry image standard file for GIS and satellite remote sensing applications; ERDAS Imagine (IMG) files are commonly used for raster data to store single and multiple bands of satellite data; ASCII uses a set of numbers (including floats) between 0 and 255 for information storage and processing.

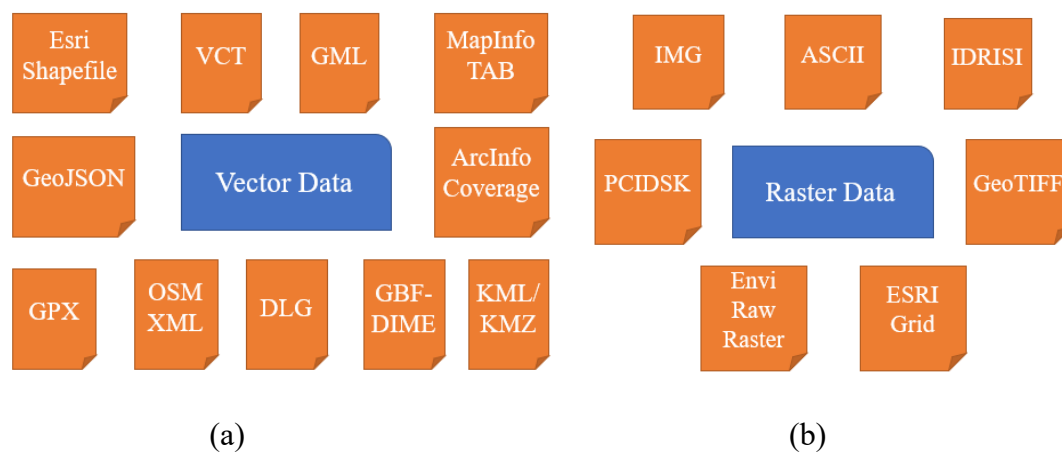


Figure 1. The classification of geospatial data

Geospatial metadata

The section of geospatial metadata standard reviewed the existing widely-accepted metadata standards for geospatial data which identify the needed descriptive information included in metadata, while this section mainly introduces how metadata is stored in geospatial data. In vector geospatial data, geospatial metadata is always stored as an ancillary and not directly stored within the geospatial features^[10]. For example, XML files in shapefile format are used to store geospatial metadata. And XML metadata files are not mandatory/required for shapefiles, which means that shapefiles can normally be read and written by GIS software without XML metadata files. When users download geospatial data such as GeoJSON, KML files from the data sharing portals, metadata is always excluded from the exported geospatial data. Even for shapefiles, data managers may only provide shapefiles without XML metadata files for users to download. This measure may be conducted to protect security-sensitive data from leaking out. But it also indicates that the lack of metadata will not affect the normal usage of vector geospatial data. Hence, data producers always ignore the edit of metadata and fail to keep the structure of metadata, which will sometimes cause the mess of data storage. This is really a challenge for geospatial metadata management, especially in the situations

that metadata is becoming more essential for data management in web geospatial services and cloud services.

In raster data, geospatial metadata is encoded in the interior of raster data (such as Geokey in GeoTIFF) or in an ancillary document (such as header files with the file extension .hdr in ENVI-format images and metadata with the file extension .xml in RapidEye satellite images)^[11]. XML is being the most widely used format to describe structured metadata content aligning with the ISO geospatial metadata standards. Compared with vector data, metadata for raster images has more special properties that are not needed in the vector, such as pixel size, spatial resolution, multiband images and special quality indicators, etc. In remotely sensed images, metadata is essential for the automatic processing and rendering of images. Metadata provides spatial reference and pixel-related parameters available for the image rendering and automatic geometric correction. Image acquisition date/time, sun azimuth and sun elevation are used to retrieve solar illumination and radiative energy information in the process of radiometric correction. Besides, radiance gain, reflectance gain and bias values are used to calculate the atmosphere reflectance. The wavelength information is essential for pan sharpening and the application of spectral analysis. Many satellite missions provide well-structured metadata files and their detailed product specifications for users and many image processing software and GIS can support the automatic read of metadata and the metadata applications in RS images.

Metadata framework in online portal

With the emergence of Web GIS services and high-speed network communication technology, increasing countries, departments and private sectors have built geospatial data online data sharing portals available for the public. Online portals allow users easily query, access and download geospatial data. Metadata framework available for online cloud-based portal is distinct from metadata in geospatial data. For metadata in geospatial data, it is stored in the ancillary file or in the internal of geospatial data. If users need to read the metadata information, they need to utilize software/ support packages to read the file and then read the metadata contained in it. This means is low-efficient and unwise, especially for searching from large amounts of metadata. For the metadata framework available for online cloud-based portal, metadata should be stored in the metadata repository. Metadata repository is a database storing metadata to support the maintenance, operations of the data warehouse. For every data file in the data warehouse, metadata repository has a corresponding metadata record.

Well-organized metadata repository allows the integrations of data in different formats from different datasets and increases the discoverability of data. At present, many open data portals (e.g. DATA.GOV) harvest different agencies' data listings following a given metadata schema into the central catalog. The portals do not host these amounts of data directly but aggregates the open data sources' metadata in a centralized site ^[12]. The data agency is only responsible for its own data. Metadata is the road map to datasets and acts as the directory to

locate the contents of the data warehouse. According to DATA.GOV (U.S. government open data website, <https://catalog.data.gov/dataset>), the searching results of Federal geospatial datasets rely heavily on the quality of geospatial metadata.

According to the report “Metadata for Open Data Portals” published by Development Initiatives in 2016, only 55 portals listed their data management platforms in the survey of global open data portals and 330 remaining portals did not provide this kind of information, and CKAN, Junar and Socrata are the most widely-used open source platforms among these online portal ^[13]. The core metadata standards (the detailed description available in *Table 7*) supported by open data platform are listed in *Table 8*.

Table 7. The core metadata standards

Core Metadata Standard	Description
RDF	<ul style="list-style-type: none"> • Resource Description Framework, a metadata standard model for web data interchange, allows to effectively integrate data from multiple sources • In RDF, every resource has its URI (Uniform Resource Identifier) • Mature, robust, widely-tested, flexible, interoperable and richly interlinked
Dublin Core	<ul style="list-style-type: none"> • One of the most widely used and best-known metadata standards • It is the basic framework for almost metadata standards today • Easily understood and implemented
DCAT	<ul style="list-style-type: none"> • Most commonly used • Flexible and in elegant design • High interoperability in multiple data catalogues
Geospatial Metadata Standard	Description
ISO 19115	<ul style="list-style-type: none"> • See Section of Geospatial Metadata Standard
ISO 19139 Metadata Implementation Specification	<ul style="list-style-type: none"> • Geographic information metadata XML schema implementation • Complied with ISO 19115

INSPIRE Metadata Schema	<ul style="list-style-type: none"> • Infrastructure for Spatial Information in Europe • The profile developed by European Commission based on ISO 19139: 2007 standard.
FGDC CSDGM	<ul style="list-style-type: none"> • See Section of Geospatial Metadata Standard
North American Profile of ISO 19115:2003	<ul style="list-style-type: none"> • The profile developed by Canadian General Standards Board based on ISO 19115: 2003 standard. • Originally designed for North American organizations

Table 8. The common open data platforms and their supporting metadata standards

Open data platform	Portal user	Support Metadata Standard
CKAN	DATA.GOV, EUROPEAN DATA PORTAL, HDX (Humanitarian Data Exchange), opendata.swiss, BERLIN OPEN DATA, Australian Government, Government of Canada, NSW GOVERNMENT, DATA61, and datos.gob.mx.	RDF, DCAT, Dublin Core, and INSPIRE
Junar	Oefa, TIGRE MUNICIPIO, Regional Transportation Authority Mapping and Statistics in Chicago, Junar in Chile, and Chilean Open Data Initiative.	RDF, Dublin Core, and DCAT
Socrata	The World Bank, The United Nations, The European Commission, The National Governors Association, and public sectors in US, Canada, UK, Australia, Italy, such as US Census Bureau, and US Department of Commerce.	RDF
DKAN	CivicActions, NDI, ANGRY CACTUS, and ANNAI	Dublin Core, DCAT, INSPIRE, and FGDC CSDGM.
ArcGIS Open Data	HALIFAX Open Data, Maryland's GIS Data Catalog, and Johns Creek DataHub	FGDC CSDGM, INSPIRE, North America Profile, and ISO 19139 metadata content

Open data platforms can be built on the existing standard or their own standards. Their self-developed standards are rooted in the existing standards including RDF and Dublin Core. However, for the geospatial data, their metadata is documented with geospatial metadata standards and stored in geospatial metadata catalog. These kinds of geospatial metadata allow platforms displaying geospatial data properly and utilizing spatial functionality. Open data portals will develop the mapping of elements between general metadata schemas and geospatial metadata standards. This crosswalk enables online portals to more efficiently and concurrently meet both general and geospatial metadata requirements.

More cases indicate that online portals did not inform the specific metadata standard information and the platform they used. It is hard to know the internal metadata frameworks and metadata storage model. Besides, until now there exists the lack of interoperability of metadata in the open data portal and it is not easy to link data to map across multiple standards. Hence, open data platforms force a widely-accepted, unified and basic standards or develop a machine-readable mapping between standards. While it is certain that since ISO geospatial metadata framework is becoming the mainstream for geospatial data, online portals and open data platforms will align with ISO metadata standards to keep metadata consistency and strengthen geospatial data interoperability.

Chapter 3: Metadata in geospatial applications

Traditional geospatial data resources include satellite remote sensing, photogrammetry, LiDAR, and land survey. Remote sensing data has significant advantages in terms of spatial coverage, accessibility, and accuracy and it is an essential geospatial information source being widely used in drought monitoring, disaster risk reduction, natural resources management, and sustainable city development. With the widely civil use of the Global Navigation Satellite System and the emergence of Internet services, increasing academic institutions, organizations, and private sectors can generate location-based data including GPS traces, trajectories, and geotagged social media messages. Compared with traditional data resources, these novel geospatial data sources are with high position accuracy and nearly real-time advantages, catalyzing many new geospatial information applications. Increasing web mapping services based on location-based data have emerged, including route direction service, turn-by-turn navigation, public transit information, etc. Location-based data (e.g., mobile phone traces, detailed vehicle locations, and smart cards data) updating spatial location in real time, can be utilized with data mining technologies for smart living and smart transportation. In this chapter, we will focus on the metadata in geospatial applications, taking Smart City, a new developing area and drought monitoring, a developed geospatial application as examples.

Metadata in Smart City

For defining smart city, one comprehensive definition is that smart city utilizes Integrating information communication technology (ICT), Internet of Things (IoT) and other related technologies to strengthen the efficiency of city operations including transportation, urban planning, enhance the quality of life and ensure the resource availability for present and future from social, economic, and environmental perspectives. Based on the conventional internet network, the Internet of Things (IoT) connects various intelligent devices and sensors to achieve the interconnection and data sharing of people, machines, and things in a city level. Leveraging information communication technology (ICT) into city operations has promoted the construction of digital cities. The six main concepts of smart city are as follows:

- (1) Smart Governance: Governments should lead to execute and operate smart city projects and provide open data to citizens through e-government and ICT integration.
- (2) Smart People: Cities should improve the quality of education, emphasize the development of manpower, value creativity and create an inclusive society.
- (3) Smart Economy: Cities should encourage innovation, entrepreneurship, productivity, efficiency and local and global business interaction, such as developing smart agriculture, smart manufacturing, and smart tourism.

- (4) Smart Living: Cities should be safe and vibrant, enhance the quality of life and the happiness of residents, such as promoting smart health care, smart security, and smart education.
- (5) Smart Environment: Cities should protect the environment and be sustainable with the use of green energy and making optimal urban plans with smart air quality monitoring and smart waste management.
- (6) Smart Mobility: Cities should improve commercial and public transport and provide mixed-modal access through ICT, such as smart parking, smart public transport, and smart traffic light.

Increasing countries (such as the United States, Britain, Spain, Germany, China) have developed plenty of projects related to the construction of smart cities (<https://www.nominet.uk/list-smart-city-projects/>). EU establishes a website dedicated to smart city projects (<https://smartcities-infosystem.eu/>). To achieve the goals of Smart City, various Smart City architectures are proposed with the integration of advanced technologies and multiple data sources by many organizations and technological corporations. A comprehensive Smart City architecture example is shown in *Figure 2* ^[14]. In order to enable entities, infrastructure, city become smart, a Smart City architecture acts as an intelligent data management and analysis framework, which collects multiple data sources from sensor devices, leverages cloud service, big data, machine learning, AI, decision-making technologies to store, manage, analyze data, and then feeds data/knowledge/intelligent solutions back to governments, citizens, and private sectors.

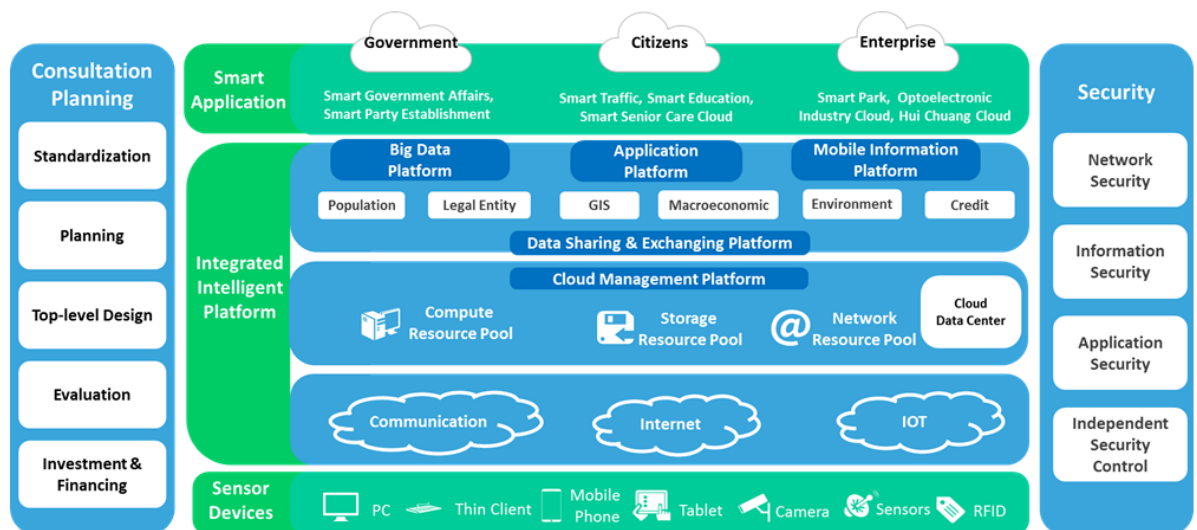


Figure 2. Smart City architecture example from FiberHome
<http://www.fiberhome.com/en/industry/solution/149/245.aspx>

IoT, an essential technology implemented in the development of Smart City, enables large quantities of mobile devices to collect location-based data in different formats such as text,

image, and markup language and send collected data back to the controller or store in database. This novel type of geospatial data possesses the strengths that previous data sources lack: high spatial accuracy, real-time, and easy to implement. Located-based data offer brand-new data insights for sustainable city management and development. *Table 9* illustrates how traditional and novel geospatial data can be utilized in the construction of the six concepts of Smart City.

Table 9. Geospatial information application in smart city

Concepts of Smart City	Geospatial data/Service	Applications
Smart governance	Satellite images, web mapping service	The City Planning Department: Long-time urban area monitoring to evaluate the process of urban development through satellite images ^[15] E-government: Web mapping is a visualization platform for displaying data, such as government division locations
Smart people	Geospatial data from different governmental divisions and organizations and web mapping service	Open data portal: enable geospatial data freely available to citizens to enhance government transparency and accountability
Smart economy	Satellite images, located-based data, web mapping service, and optimal path algorithm	Smart agriculture: satellite images and located-based data collected by temperature sensors, humidity sensors help to monitor the crop growth, drought to promote “smart” in agriculture Smart tourism: provide route direction service and attraction recommendation service through ICT technologies
Smart living	Located-based data, GIS, and web mapping service	Smart health care, smart security: provide nearest health care, police station services through ICT technologies
Smart environment	Satellite images, located-based data, and GIS	Monitoring air quality; evaluating the pollution influence on residential area; evaluating accessibility of open space
Smart mobility	Located-based data, GIS, and road data	Smart traffic: collecting sensor data, CCTV data to monitor traffic flow and use GIS and big data technologies to improve traffic flow and reduce traffic congestion

Until now, Smart City is still in the initial evolutionary stage for a large number of cities and countries. There is no widely-accepted or common solution in the smart city domain. Since

the Smart City framework needs big cloud servers and advanced technologies including AI, machine learning, and Big Data, and technology enterprises can stably and credibly provide these services and propose a nearly-inclusive solution to build Smart City, major cities cooperate with technology corporations and these corporations will build a Smart City platform for the cities. Major corporations involved in the smart city domain are NOKIA, Intel, Microsoft, HUAWEI, HITACHI [16]. The Smart City platforms are always customized according to the city's specific needs and local standardization policies. The technical details in Smart City platforms will not be published by cities or their cooperative partners. Hence, it is hard to know the internal metadata structure in platforms.

Many countries and international organizations have launched their Smart City standards and guides of Smart City framework. *Figure 3* shows an overview of the major standards in the smart city domain [17]. U.S., UK, European Union, Australia and New Zealand have conducted research on standards in the smart city domain and released the related achievements. While in the Asia-Pacific region, many governments are trying to leverage the standards already established by ISO, ITU, IEEE, and other international standards organizations. Some countries have built their own frameworks, such as Thailand, India. However, these framework documents did not specify the metadata schema or metadata standards.

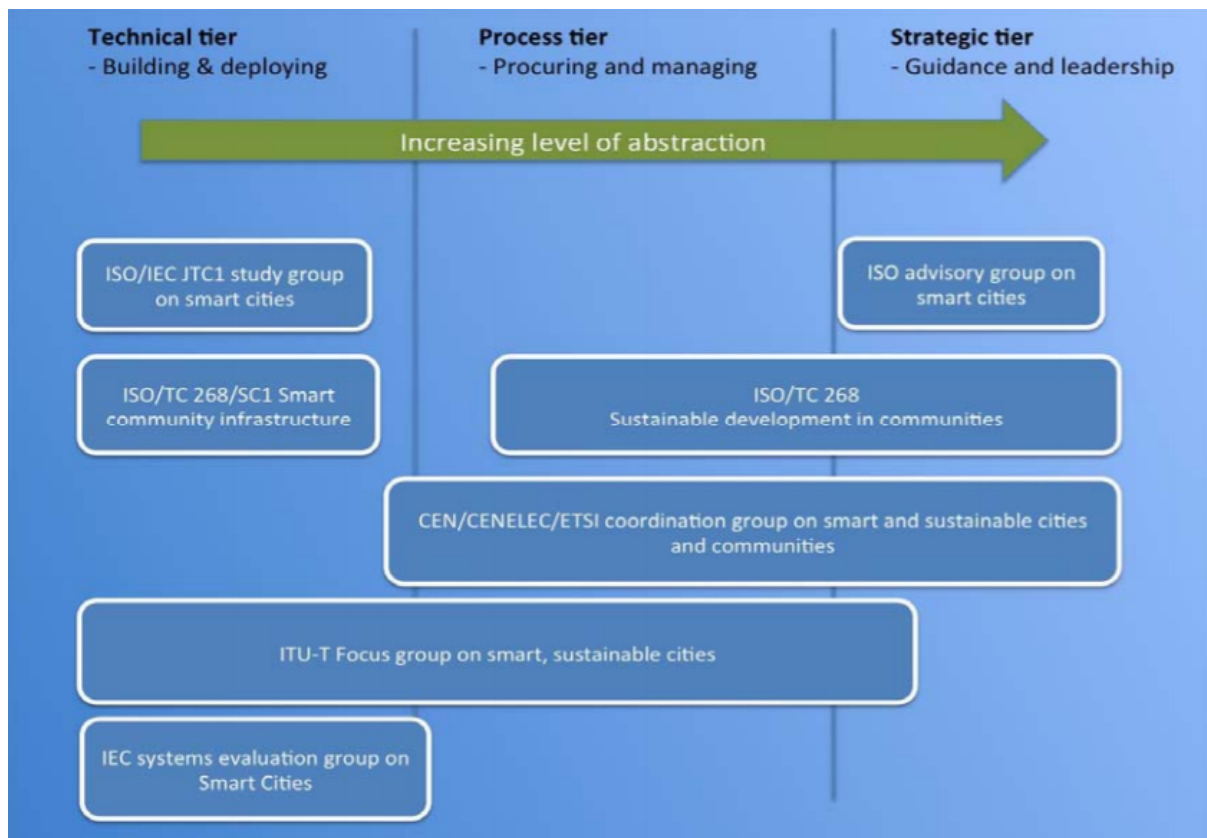


Figure 3. An overview of the major standards in the smart city domain (Source: Smart Cities: An Overview of the Technology Trends Driving Smart Cities)

James and Ajith (2019) indicate that even though there are growing publications in Smart City, there are few enforceable standards, and most of the publications are guidance and specifications ^[18]. This is due to the challenges in developing holistic standards and the different understandings of Smart City. In Smart City, there are great variations in the software, coding methods, hardware and nomenclatures used among the data sources. Given the varieties of data formats, locations, structures and access standards, data aggregation and interoperability are extremely difficult and complex. IEEE Big Data Technical Community (BDTC) is attempting to develop metadata standards to describe the information of big data so that the searching and the processing of big data would be easier and more effective. Before specific metadata standards in Smart City data management are released officially, metadata generations depend on the existing core metadata standards or the Smart City platforms conducted by different technology corporations. While for geospatial data (specifically raster data and vector data), their metadata is documented with geospatial metadata standards. As mentioned in previous section, since there is the lack of metadata interoperability between geospatial metadata standards and general metadata schemas, data management platforms would develop the crosswalk between two categories of standards. The location-based data, most of which are collected from IoT networks, are documented in distinct formats from vector and raster geospatial data. The location information is stored as a property and the location-based data is always stored in the tables in the database. Hence, Location-based data usually adopt the general core metadata standards (e.g. Dublin Core) or specific metadata standards for IoT data rather than geospatial metadata standards.

Metadata in drought monitoring

Drought is defined as an extreme and persistent lack of precipitation in a region over a certain period, which includes meteorological drought, agricultural drought, hydrological drought, and drought with socio-economic consequences ^[19]. Insufficient precipitation leads to meteorological drought, which in turn affects the agricultural drought caused by distinct soil moisture reduction. And then agricultural drought causes low recharge from soil to water flow (such as streams and lakes), leading to the delayed hydrological drought. Prolonged and severe drought adversely affects the economy of one state or region and leads to a series of negative social consequences, namely the drought with socio-economic consequences. Humans may suffer famine, water shortage and large economic losses because of grain and water reduction caused by drought. The drought in the United States in 1988 caused nearly 40 billion dollars of damages. The most serious drought in Iberian Peninsula occurred in 2005, which reduced approximately ten percent EU cereal yields. India experiences a drought almost every three years. Even worse, extreme and long-duration drought may lead to social unrest. Hence, many countries take drought monitoring as a kind of national level task and implement many initiatives in drought early warning and drought risk reduction.

Generally, the initiative information contains meteorological and hydrological data and space-observed satellite images. The meteorological and hydrological data that widely

distributed for ground-based drought investigation includes precipitation, air temperature, air humidity, surface runoff, groundwater and reservoirs levels, soil moisture, snowpack and glacier, etc. Based on these kinds of data, indices or parameters (e.g. Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI)) that used to describe aridity events can be achieved with respective calculation formulas. With the rapid development of geospatial technologies and remote sensing applications, satellite imagery and geographical information systems have leveraged as effective digital solutions to drought monitoring and other climate issues. Space technologies provide a stable, long-term, remotely-sensed, widely-covered, near real-time means to monitor drought. Drought signs can be observed from space, for instance, drought affected areas, drought severity and vegetation growth can be observed from satellite imagery. The common drought indicators based on satellite images includes Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), which can be computed out of multiple bands of satellite data, mostly of which are in low and medium spatial resolution captured by NOAA-AVHRR, SPOT-IV and MODIS etc. *Table 10* shows the data sources and formats used in drought monitoring.

Table 10. Data sources and formats used in drought monitoring

Data category	Data	Data formats
Meteorological data	Precipitation	NetCDF, GRIB, and HDF
Hydrological data	streamflow, water lost, groundwater levels	ASCII Fixed Width format files (.dat files)
Space-observed satellite images	Near-infrared and red light images	GeoTIFF, HDF
Drought products	Map, reports, charts and tables	JPG, IMG, GIS data formats and pdf
Others	Regional boundary	Shapefile, KML

Due to the climatic and geographical characteristics dramatically varying within countries and regions, it is hard to fix a single, universally-accepted definition of the moisture deficiency situation, and for the same reason, building a single monitoring system or product that fits in all drought circumstances can be tough. Facing different droughts, the selection of data, indices and parameterization methods are the heart of building an effective monitoring model. There are many drought monitoring platforms which integrate remote sensing technologies and meteorological and hydrological data for the vast non-professional users to acquire handy drought monitoring information. Drought monitoring products in different periodicity (e.g. daily, weekly, monthly), different scale (e.g. Global, national, regional) are available in the drought monitoring platforms, online portals. The Republic of Kazakhstan

European Drought Observatory(EDO) provides drought monitoring mapping viewer, drought reports, drought in media and associated time series analysis and drought data download services (<https://edo.jrc.ec.europa.eu/edov2/php/index.php?id=1000#>). To move to HTTPS protocol, EDO stops access to the Drought Metadata Catalogue which was based on XML files [20]. One XML file matches one metadata record. These metadata XML files indicate that even though metadata of these drought data sources are based on different geospatial metadata standards (e.g. FGDC CSDGM, ISO 19115:2003), they are encoded in GML schema aligning with the ISO 19139 standard. The encoding specification is in the INSPIRE Metadata Implementing Rules: Technical Guidelines based on EN ISO 19115 and EN ISO 19119 (available in https://inspire.ec.europa.eu/reports/ImplementingRules/metadata/MD_IR_and_ISO_20081219.pdf) [21]. The uniform encoding rules can keep metadata consistency and interoperability and be helpful to manage/search multiple data sources and datasets.

```
<?xml version="1.0" encoding="UTF-8"?>
<gmd:MD_Metadata xmlns:gco="http://www.isotc211.org/2005/gco"
  xmlns:gmd="http://www.isotc211.org/2005/gmd"
  xmlns:gml="http://www.opengis.net/gml"
  xmlns:xlink="http://www.w3.org/1999/xlink"
  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.isotc211.org/2005/gmd http://schemas.opengis.net/iso/19139/20060504/gmd/gmd.xsd">
  <gmd:fileIdentifier>
    <gco:CharacterString>Moldova_Atlas</gco:CharacterString>
  </gmd:fileIdentifier>
  <gmd:language>
    <gmd:LanguageCode
      codeList="http://www.loc.gov/standards/iso639-2/" codeListValue="eng">eng</gmd:LanguageCode>
    </gmd:language>
  <gmd:characterSet>
    <gmd:MD_CharacterSetCode
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      codeListValue="MD_CharacterSetCode_utf8" codeSpace="ISO19115">MD_CharacterSetCode_utf8</gmd:MD_CharacterSetCode>
    </gmd:characterSet>
  <gmd:hierarchyLevel>
    <gmd:MD_ScopeCode
      codeList="http://standards.iso.org/ittf/PubliclyAvailableStandards/ISO_19139_Schemas/resources/CodeList/ML_gmxCodeLists.xml#MD_ScopeCode" codeListValue="dataset">dataset</gmd:MD_ScopeCode>
    </gmd:hierarchyLevel>
  <gmd:contact>
    <gmd:CI_ResponsibleParty>
      <gmd:organisationName>
        <gco:CharacterString>Institute of Ecology and Geography Academy of Sciences, Moldova</gco:CharacterString>
      </gmd:organisationName>
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  </gmd:contact>
  <gmd:role>
```

Figure 5. Part of an example of metadata XML file

Some systems have two metadata catalogues, one for geospatial data and one for non-geospatial data (e.g. maps in JPG formats, tables, reports). For more drought monitoring platforms, they only provide outline metadata of non-geospatial data such as data name, organization, publish date, data format, and data temporal coverage. While for some systems, they have built a stretchable metadata framework for all data sources. For instance, DIAS(Data Integration and Analysis System, available in <http://search.diasjp.net/en>) provides natural, climatic, meteorological datasets and multiple data sources. The metadata information available on the website shows in *Table 11* and *Figure 6* and the classifications and elements in metadata are selectable and customized according to data source needs.

Table11. Metadata information available in DIAS

Number	Classification	Elements
1	Identification information	Name, edition and metadata identifier
2	Contact information	Organization, address and email
3	Dataset overview	Abstract, topic category, temporal extent, geographic extent, grid information, keywords, online resource, data environment information and distribution information
4	Document author	
5	Document creator	
6	Date of document	
7	Data of dataset	
8	Data processing	
9	Data remarks	
10	Use constraints	
11	Acknowledgement	
12	Reference	

IDENTIFICATION INFORMATION

Name	APHRODITE Middle East precipitation dataset
Edition	V1101
Abbreviation	APHRO_ME
Metadata Identifier	APHRO_ME20191219143455-DIAS20180903143952-en

CONTACT

CONTACT on DATASET

Name	APHRODITE Team
Organization	Hiroaki University
Address	Japan
E-mail	yasutomi@chikyu.ac.jp, aphrodite.precinfo@gmail.com

CONTACT on PROJECT

Data Integration and Analysis System

Name	DIAS Office
Organization	Remote Sensing Technology Center of Japan
Address	TOKYU REIT Toranomon Building 2F 3-17-1 Toranomon, Minato-ku, Tokyo, 105-0001, Japan
E-mail	dias-office@diasjp.net

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DATASET CREATOR

Name	Yatagai Akiyo
Organization	Research Institute for Humanity and Nature

DATE OF THIS DOCUMENT

2019-12-19

DATE OF DATASET

- creation : 2010-06-01

DATASET OVERVIEW

Abstract

Asian Precipitation - Highly-Resolved Observational Data Integration Towards Evaluation (APHRODITE's) of Water Resources project develops state-of-the-art daily precipitation and temperature datasets with high-resolution grids for Asia. The datasets are created primarily with data obtained from a rain-gauge-observation network.
Product APHRO_ME offers gridded daily precipitation of the Middle East for 1951-2007.

Topic Category(ISO19139)

- climatologyMeteorologyAtmosphere

Temporal Extent

Begin Date	1951-01-01
End Date	2007-12-31
Temporal Characteristics	Daily

Geographic Bounding Box

North bound latitude	45
West bound longitude	20
Eastbound longitude	65
South bound latitude	15

Grid

Dimension Name	Dimension Size (slice number of the dimension)	Resolution Unit
row	180	15 (minute)
column	120	15 (minute)

Keywords

Keywords on Dataset

Keyword Type	Keyword	Keyword thesaurus Name
theme	APHRODITE, daily precipitation, Middle East	No_Dictionary

Figure 6. Screenshot of metadata available in DIAS

In the area of drought monitoring, geospatial data is an essential data source for drought detecting and geographical information tools have become effective, mature digital solutions to drought monitoring. With the more and more frequent occurrence of drought, increasing

countries, regions, organizations attempt to launch online drought monitoring systems to release drought news and warnings timely. Due to distinct standardization policies and limited budget, these platforms vary in drought products, services, system performance, data and metadata standards. While international organizations or cross-countries cooperation organizations usually align with widely-accepted metadata schemas such as ISO 19115 and FGDC CSDGM, since standard consistency is the technical foundation of data integrations/sharing in countries/regions. With the emergence of cloud services and innovative data analysis technologies, drought monitoring systems will likely transfer to the cloud-based system and automatic online portals, and metadata become more essential in cloud-based data management. ISO 19115 is the mainstream in geospatial metadata standards for now and future and drought monitoring systems should keep metadata in alignment with this metadata standard as far as possible.

Chapter 4: Conclusion

Metadata, which are the structured data describing the detailed information about data sources, are becoming more essential than ever before. With the development of ICT, cloud services and big data, metadata plays an indispensable role in data management to discover, locate, maintain data resources. And geospatial metadata management has been essential to cross-division data sharing and data integration. Even though many international organizations have announced that member countries and stakeholders should enhance the cross-sectoral integration of geospatial data and build the integrated geospatial frameworks and published research reports, there are few materials about the significance of metadata and the construction of metadata framework. The US, European Union and many developed countries possess a mature geospatial metadata framework and have more than 10-year experience in the operation and maintenance of metadata catalogue. While a large number of developing countries lack sufficient awareness about geospatial metadata frameworks and how to start the construction of geospatial metadata frameworks. This report attempts to enhance awareness of metadata and give an overview of geospatial metadata and its developing trends. And we hope that this review can deliver useful experiences and suggestions for more governments to build their national/regional geospatial metadata frameworks.

There are many metadata frameworks/standards developed by international metadata organizations and countries. The current situations indicate that many metadata standards have been revised and appended with some additional attributes to be compatible with ISO 19115 and some metadata transformation services/tools have been developed to convert metadata to the ISO 19115 metadata. ISO geospatial metadata standards is the trend of geospatial data. Big data management must first address the challenge of the complexities of processing multiple data formats, which are tightly coupled to the data sources and the user community that applies data for applications and services. Besides, many applications such as Smart City increase their dependence on knowledge about the source of data. Metadata is the digital solution for these challenges. Hence, ISO/TC is exploring the further development of ISO geospatial metadata to adapt to Web services and novel geospatial applications. Although there is no optimal metadata framework for cloud-based data and online portals until now, the developers are suggested to apply metadata aligning with the existing experiences in metadata applications. The advantages of widely-accepted international geospatial metadata standards includes that even though users have to convert it to the future metadata standards, the conversion tools and technical documents would be sufficient for users. In the short term, the cost of building and maintaining a geospatial metadata framework is high-priced, while in the long term, geospatial metadata framework will cost-effective, which can promote the data sharing and data interoperability and be easier and lower-cost to adapt to brand-new geospatial applications.

Annex of metadata development in pilot countries

Thailand

Existing metadata standards in geospatial information

In Thailand, more than 100 agencies work on GIS, and the major national geospatial data organizations are as follows: the first one is The Geo-Information and Space Technology Development Agency (GISTDA, website is <https://www.gistda.or.th/>), which is responsible for coordinating all activities, applications and developments of geo-information and space technologies among all Thai organizations. The second is the Thai Industrial Standards Institute/Technical Committee 904: Geographic Information (TISI/TC904), which focuses on geospatial information standards in Thailand. Besides, the Royal Thai Survey Department (RTSD) aims to provide topographic maps for Thailand and the Department of Lands (DoL) is responsible for land related activities (e.g. land registration, land valuation, and statutory actions).

There are many data-related challenges that exist in Thailand, such as duplication on data production, limited cooperation and collaboration, and poor data sharing, etc. To address these problems, National Spatial Data Infrastructure (NSDI) has been proposed and adopted ISO 19115:2003 as the national metadata standards to strengthen interoperability and data sharing ability ^[22]. Besides, Thailand also is trying to leverage online GIS services to further enhance data sharing. For example, ThaiSDI provides an online portal to collect and store data and produce standardized maps and custom maps by using geo-processing analysis tools.

Smart City in Thailand

Thailand is located at the central part of the Central South Peninsula, with a land area of 513,120 square kilometers and a population of 69 million. The GDP in 2018 is 504.993 billion US dollars. In 2016, Thailand government proposed an economic model called “Thailand 4.0”. “Thailand 4.0” aims to unlock the country from several economic challenges resulting from past economic development models including “a middle-income trap”, “an inequality trap”, and “an imbalanced trap”, and to drive Thailand into a smart and high-income country. In 2017, Thailand government announced that it aimed to develop 100 smart cities within two decades in the future as the essential part of Thailand 4.0 initiative. To facilitate and promote Smart City development schema, the National Smart City Committee has been set up by Thailand government, and more than ten ministries will collaborate with this committee. Thailand aims to develop 10 smart cities in 7 provinces in the first stage (2018-2019), namely Bangkok, Rayong, Chiang Mai, Phuket, Khon Kaen, Chachoengsao, and Chonburi. In the second stage (2019-2020) and next three years (2020-2022), Thailand hopes to develop 100 smart cities in 76 provinces and Bangkok. Thailand collaborating with HUAWEI and other public and private sectors have developed a comprehensive Smart City

framework in the pilot city, Phuket and published Smart City services for Phuket White Paper^[23]. This white paper hopes to provide guidance to support the service prioritization and recommendations of Smart City for multi-stakeholders in Thailand. *Figure 7* shows the details about the Smart City Framework suggested in the white paper.

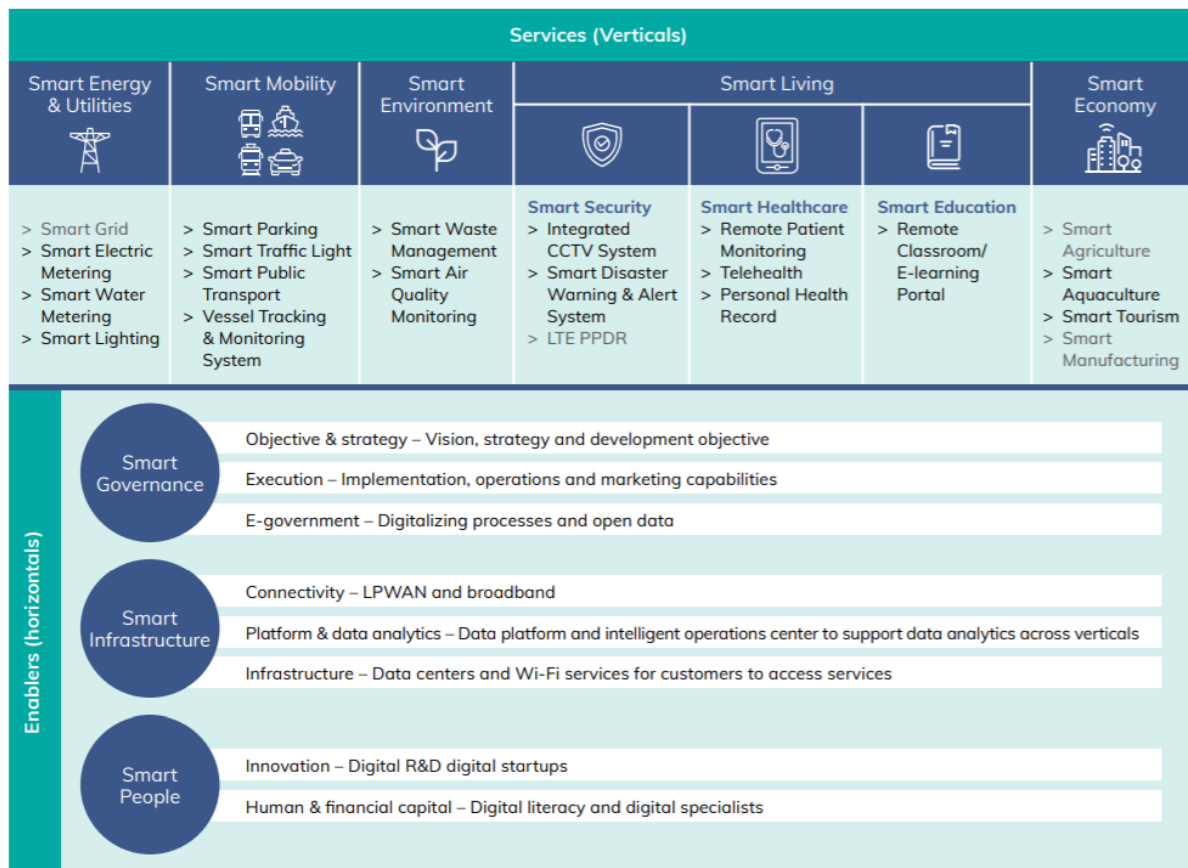


Figure 7. The suggested Smart City Framework in Thailand (source: SMART CITY FRAMEWORK AND GUIDANCE FOR THAILAND)

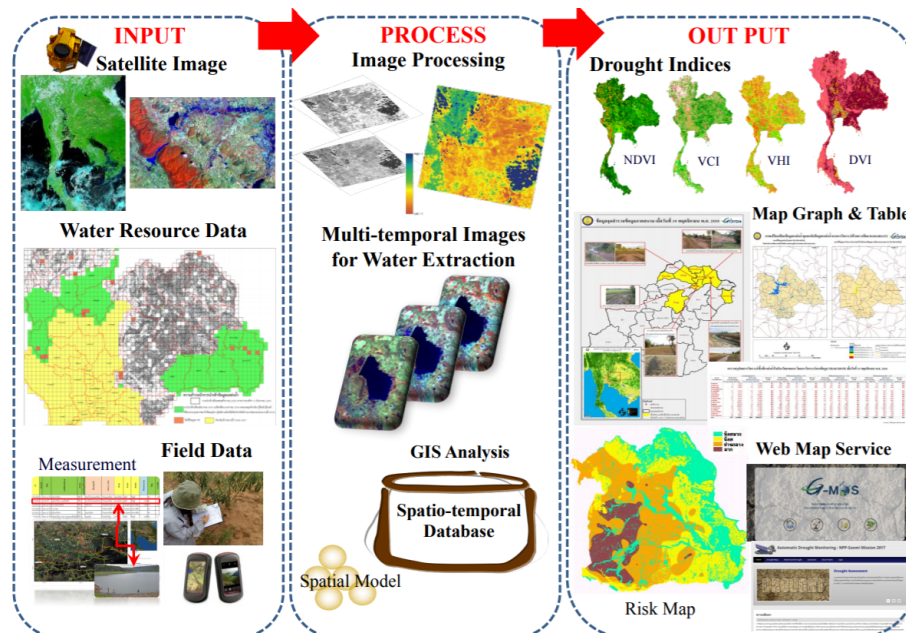
Bangkok is concerned as the foremost smart city in Thailand. The main smart city goals of Bangkok include green energy, smart living, and smart mobility. According to the estimate of the World Bank, approximately 60% of the population will live in urban areas in Thailand by 2050, most of them are in and around Bangkok. As the capital of Thailand, Bangkok already has relatively complete urban infrastructures, but it is experiencing rapid population growth and urbanization which bring many city problems such as air pollution, traffic congestion. These problems can be addressed by Smart City and cities can benefit from IoT and geospatial information to improve efficiency and create additional values. Take Smart mobility as an example, Smart Traffic Light in smart mobility aims to reduce traffic congestion through IoT solutions. Combining knowledge of logistics and transportation in GIS and the intelligent algorithms (e.g.AI), Smart Traffic Light can collect CCTV, sensor data, simulate traffic flows and formulate the optimal solution of traffic light time to improve traffic flows. In addition, the real-time traffic flows can be applied in a real-time schedule of public transport and rational path planning for private car drivers, which would alleviate the

traffic pressure in Bangkok. These solutions can effectively reduce traffic emission and air pollution and decrease large numbers of economic losses caused by traffic congestion.

Smart City white paper in Thailand has proposed a city data platform and data analytics projects but it did not provide technical details about the platform construction and the information about metadata. And until now, there are no more details about the process of the city data platform published by Thailand government.

Drought monitoring in Thailand

Annual drought has caused negative influences on both regional and national socio-economic development in Thailand. Nearly 72 provinces suffered enormous economic damages caused by drought during 1989-2013, and the greatest damage was nearly USD 220 million in 2005. Thailand has launched its earth observation mission, THEOS, which provides satellite images to support drought monitoring, flood risk management and other geospatial applications. GISTDA takes charge of the THEOS' data management and processing. In addition, GISTDA has developed Thailand Drought Monitoring System based on multiple earth observation data sources and water resources monitoring system which can support drought management ^[24]. *Figure 8* shows the process of drought monitoring and the water resources monitoring system structure in Thailand.



(a)

Thailand has already possessed abundant scientific technologies and tools to conduct drought monitoring tasks. GISTDA also collaborated with ESCAP, Myanmar, Cambodia and other organizations and countries and held many training workshops for trainees from Myanmar, Cambodia to strengthen their ability in drought monitoring ^[25].

Indonesia

Existing metadata standards in geospatial information

Indonesia National Coordinating Agency for Surveys and Mapping of Indonesia (NCASM) proposed the Indonesian Geospatial Data Clearinghouse to deliver the geospatial data that all Indonesia geospatial data producers produce to the geospatial data users ^[26]. The National Geospatial Data Clearinghouse is a distributed database system that connects data producers, managers and users and enables geospatial data accessible through the internet. The geospatial metadata in the clearinghouse consists of inventory metadata, collection metadata and organization metadata. Inventory metadata is detailed information about all collected data. Collection metadata is metadata about a collection of data. While organization metadata is information about the data producer organization. The geospatial metadata standard is Content Standard for Digital Geospatial Metadata (CSDGM) launched by the Federal Geographic Data Committee. All geospatial data producers in Indonesia will use this standard when editing their geospatial metadata. Indonesia has developed a metadata generating tool called MDSN available on the web.

The National Geospatial Data Clearinghouse consists of large quantities of metadata servers which are network nodes developed and maintained by data producing organizations and these metadata servers interconnect to form a network. Within the network, an additional metadata gateway server contains the registry of all nodes belonging to the clearinghouse and it provides applications to search and retrieve metadata stored in metadata node servers. Moreover, the metadata gateway server allows system to connect to other networks. Data users can access metadata through the metadata gateway server on the internet. The National Geospatial Data Clearinghouse would be an integrated node linked to Asia Pacific Spatial Data Infrastructure (APSDI) and to the global network called the Global Spatial Data Infrastructure (GSDI).

Smart City in Indonesia

Indonesia, located in southeast Asia, is the world's largest archipelago country. With a population of 262 million in 2019, Indonesia ranks the fourth in the world. Indonesia estimates that nearly 70% of people will live in cities by 2050. While the increase of urban population will lead to more serious traffic congestion, increasing energy consumption, water shortage, etc. The city governors need to innovate in how they manage and improve urban infrastructures to reduce these city problems. The notion of smart city offers a new approach to address these problems and improve the efficiency of city operations. In 2017, many

Indonesia public sectors including the Communications and Information Ministry, National Development Planning Board and some private sectors collaboratively proposed the “Movement Toward 100 Smart Cities” initiative. In 2017, Smart City Community and Innovation Center (SCCIC) of the Institute of Technology Bandung (ITB) in Indonesia launched the Garuda Smart City Framework version 2.0 (GSCF 2.0) based on GSCF 1.0. And GSCF 2.0 has been adopted by the Indonesia Smart Initiative Association (APIC) to develop Smart City in Indonesia [27].

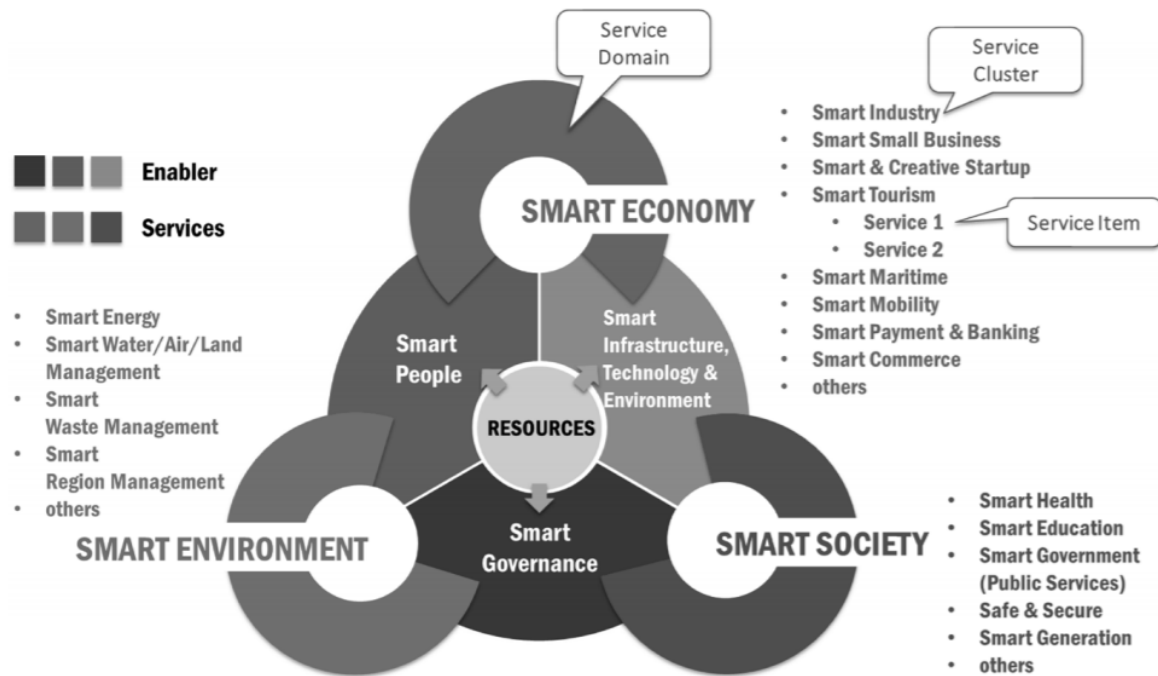


Figure 10. The Garuda Smart City model²⁶

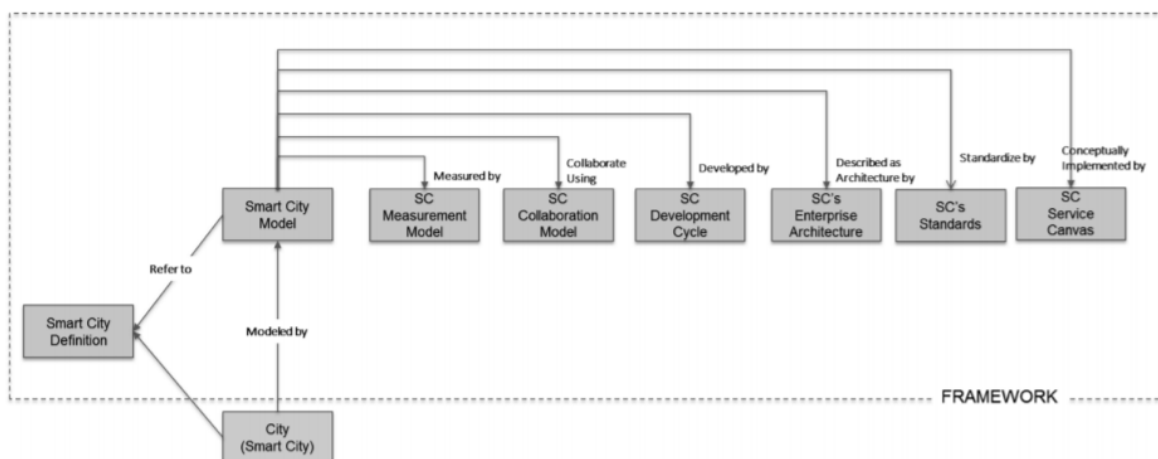


Figure 11. The components of GSCF 2.0²⁶

In the Garuda Smart City model 2.0 (*Figure 10*), there are hierarchical levels: resources, enablers, services. The components of GSCF 2.0 (*Figure 11*) consist of Smart City Model, Smart City Measurement Model, Smart City Collaboration Model, Smart City Deployment Model, Smart City Enterprise Architecture, Smart City Standards, and Smart City Service Canvas. While until now, there are no more details about the process of the construction of the smart city standards.

Jakarta, the capital of Indonesia has one of the highest rates of urbanization in the world and possesses the highest incomes per capita in Indonesia. But it also faces many city challenges. With the rapid urbanization, Jakarta needs to address traffic congestion problems, improve city infrastructure, reduce air pollution and enhance the quality of citizens' life ^[28]. The Jakarta Smart City program, launched in 2014, aims to effectively and securely promote and implement smart city initiatives through ICT and the IoT to manage public resources and assets, such as waste management, law enforcement and transportation systems. Other cities in Indonesia also are looking forward to smart city initiatives. Bandung in West Java is interested in a smart integrated surveillance and monitoring system, as well as smart lighting system. Surabaya in East Java has implemented e-government and Makassar in South Sulawesi focuses on Smart Card and Smart Traffic. In 2019, Indonesia government sought corporations with foreign companies and other countries. French companies agreed to collaborate with local governments such as Jakpro, Bandung and Surabaya to develop local sustainable city programs.

Drought monitoring in Indonesia

Indonesia has two seasons namely dry season and rainy season. In the dry season, Indonesia often suffers drought and El Nino concurrently. According to the National Agency for Disaster Countermeasure's (BNPB) record, Indonesia suffered drought from 1811 until 2011. Indonesia needs to pay attention to drought monitoring and forecasting. The Indonesia Agency for Meteorology, Climatology and Geophysics (BMKG) is responsible for the updates of meteorological drought information. The products issued by BMKG contain monthly and quarterly Standardized Precipitation Index (SPI) and monthly soil moisture content percentage ^[29]. BMKG also launched the Climate Early Warning System which includes meteorological drought warning and precipitation prediction services. The meteorological drought warning service offers the maps of monthly and quarterly Standardized Precipitation Index (SPI) in Sumatera, Jawa, Bali & Nusa Tenggara, Kalimantan, Sulawesi, Maluku & Papua and the whole Indonesia, the tables of the drought level details of different cities and regions and the maps of consecutive dry days (CDD) which are updated every 10 days ^[30].

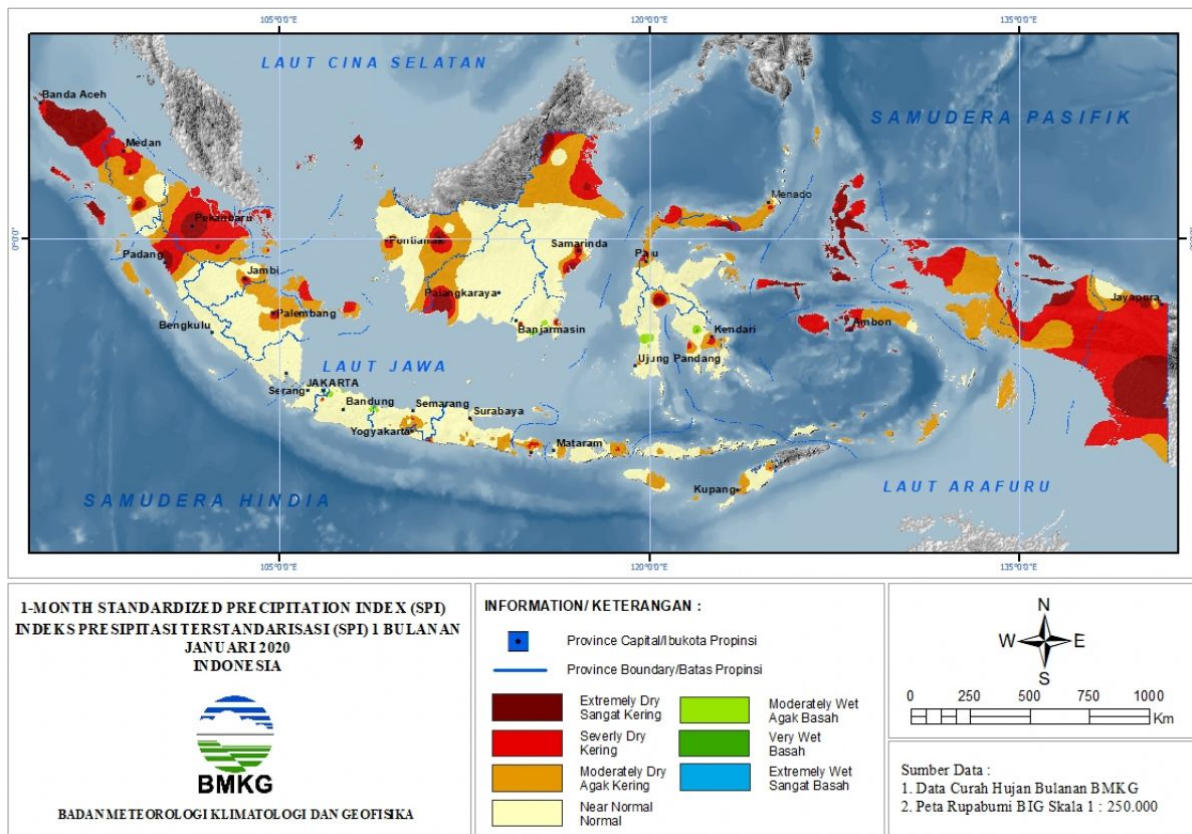



Figure 12. The 1-month Standardized Precipitation Index in Indonesia in November, 2019
(Source: Indonesia Climate Early Warning System, available in https://cews.bmkg.go.id/Peta/Indeks_Presipitasi_Terstandarisasi.bmkg)

In addition, BMKG provides an online database with daily meteorological data from ground monitoring station and earthquake data. Users can download data and metadata from the online portal. The available metadata is rough, and a metadata example displayed in *Figure 13* only consists of station name, ID, location and data information. The metadata in the database is available in the EXCEL table format.



ID WMO

Station Name

Latitude

Longitude

Elevation

: 96039

: Stasiun Geofisika Tapaktuan Aceh Selatan

: 3.17333

: 97.28637

: 2

Date	RH_avg
No data available in table	

Notes :

8888: Unmeasured Data

9999: No Data

RH_avg: Average humidity (%)

Figure 13. An example of metadata of a ground monitoring station from BMKG online database

In 2010, National Institute of Aeronautics and Space (LAPAN) collaborated with Bogor Agricultural University (IPB) and the National Institute of Aeronautics and launched a satellite namely LAPAN-IPB Satellite (LISAT) which can support the drought monitoring, disaster risk reduction and other natural and society issues in Indonesia. LAPAN as Regional Support Office of UN-SPIDER has evolved in many drought monitoring projects such as monitoring the drought condition over Southeast Asia ^[31]. The drought products encompass Vegetation Health Index (VHI), Vegetation Greenness condition and Vegetation Condition Index (VCI) based on NOAA data, Standardized Precipitation Index (SPI) based on TRMM data. LAPAN has developed the Information System for Disaster Mitigation (SIMBA) to offer disaster warning services and emergency response based on remote sensing data for national or regional stakeholders such as the Ministry of Environment and Forestry, National Agency for Disaster Management, local governments ^[32]. The drought warning service in this system provides monthly SPI maps for users. But there are no detailed geospatial metadata delivering to users.

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