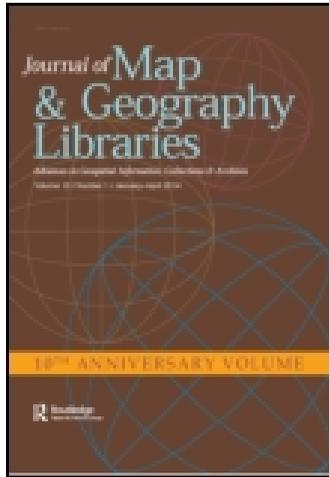


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Journal of Map & Geography Libraries: Advances in Geospatial Information, Collections & Archives

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/wmgl20>

Challenges Facing Chinese Map Libraries and Librarians: From Paper to Digital Worlds and Services

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Published online: 24 Nov 2014.

To cite this article: Juanle Wang, Hongsheng Li, Eryang Chen, Yifan Li, Mingyuan Duan, Peng Liu, Zhongqiang Bai & Jia Du (2014) Challenges Facing Chinese Map Libraries and Librarians: From Paper to Digital Worlds and Services, *Journal of Map & Geography Libraries: Advances in Geospatial Information, Collections & Archives*, 10:3, 266-287, DOI: [10.1080/15420353.2014.946211](https://doi.org/10.1080/15420353.2014.946211)

To link to this article: <http://dx.doi.org/10.1080/15420353.2014.946211>

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Articles

Challenges Facing Chinese Map Libraries and Librarians: From Paper to Digital Worlds and Services

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Although China has a long history of cartography and map collections, the condition of China's map collections and accessibility to geographic and digital data is still unknown to world counterparts. This paper discusses the paper and digital map collections situation in China from the perspective of multiple collections and from sharing services. Paper map collections are introduced through a survey and analysis of the National Library of China, Peking University Library, and Beijing Normal University Library. Dynamic map service Web sites and the related Web infrastructure are introduced as being representative of digital map collections in China. The Data Sharing Platform of Earth System Science (DSPESS) of the National Science and Technology Infrastructure of China, which has operated for more than ten years, is used as a case study to analyze digital map data sets sharing and services. Digital map data collection characteristics, the data sharing policy, user distribution, and the stewardship staff of DSPESS are analyzed. We also present challenges and potential demands facing China's map data collection and sharing services from the perspectives of a sharing mechanism, financial support, technical challenges, and allocation of professional staff resources.

KEYWORDS *map collections, data sharing, map library, digital infrastructure, China, DSPESS*

INTRODUCTION

China has one of the oldest traditions in the world for making maps. Following is a time line and account of the history of this tradition using milestone cartographic examples.

According to Chinese history, about 4,000 years ago Chinese sovereign Yu made "Jiu Ding," a bronze artifact, on which was engraved a map of ancient China. During the Spring and Autumn Period (770–476 BC), there also appeared the famous map, *Classic of Mountains and Seas*. In 1973, three silk color maps, which were made 2,100 years earlier, were unearthed in the tomb of Ma-Wang-Dui in Changsha. These three maps are the oldest maps in the world and are well preserved in China.

Pei Xiu, an ancient Chinese cartographer during the Western Jin Dynasty (AD 265–316) proposed six rules for cartography. He made eighteen Yugong

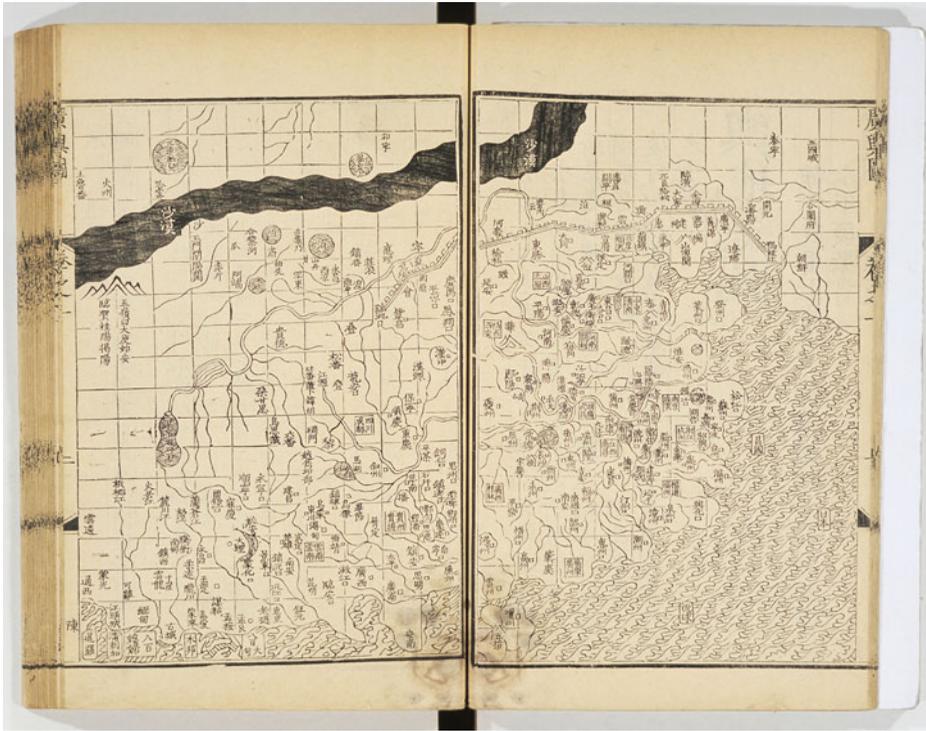


FIGURE 1 *Ancient Enlarged Terrestrial Atlas* made by Luo Hongxian in 1541, preserved in the National Library of China and Museum of Liaoning Province, China. The map shows seas in the eastern part; desert and the Great Wall in the northern part; and rivers, administration zoning and some counties' names in the central, western and southern parts of the map. The source of the Yellow River is shown by a cucurbit shape in the western part of the map.

geographical maps. In the Tang Dynasty (AD 618-907) the famous cartographer Jia Dan spent sixteen years compiling a *Map of China and Barbarian Countries* based on a specific map scale. The *Map of the Tracks of Yu of the Song Dynasty* (AD 960-1279), which is covered with 70 horizontal and 73 vertical grids and 5,110 squares, was one of the earliest maps made with grids found in China. Shen Kuo, during the Northern Song Dynasty, also compiled a *Counties' Map* at a uniform scale. The cartographer Zhu Sibei during the Yuan Dynasty (AD 1271-1368) used a method of counting meters and drawing squares to make the country's *Geographic Map*. The outstanding cartographer Luo Hongxian in the Ming Dynasty (AD 1541) used the cartography framing method to compile the first known *Enlarged Terrestrial Atlas* (see Figure 1) (Xu, Duan, and Ma, 2008). During the Qing Dynasty (AD 1616-1911), a massive nationwide surveying and mapping effort using geographic latitude and longitude on the map was carried out. Yang Shoujing spent fifteen years organizing the compilation of the *Atlas on Administrative Divisions and Important Places in Past Dynasties of China*, a summary published in thirty-six volumes.

In the mid-1930s, Ding Wenjiang, Wong WenHao, and Zeng Shiyong edited the *New Map of the Republic of China* and its abridged edition was published by the Shen-Hao Press. In the mid-1940s, Professor Huang Jiqing edited the first generation of Chinese small-scale geological maps; Ma Rongzhi and Zhu Lianqing edited *The Soil Map of China* at a scale of 1:10 million, and Zhu Kezhen compiled *The Climate Map of China*.

Since 1949 and the founding of the People's Republic of China, many new atlases have been published, such as the Natural Atlas of People's Republic of China, Geological Atlas, Atlas of Climate, Atlas of Hydrology, Atlas of the People's Republic of China and Atlas of China's Population (Cao, Zheng, Huang, and Niu, 1995, 1997a, 1997b; Liao, 2003). Most of the maps and atlases mentioned above are collected and archived in libraries freely accessible to the public.

China also has a long history of map collecting. According to the records of the *Rites of Zhou*, as early as the Spring And Autumn Period, China employed and trained specialized officers whose duties included preserving maps. According to the Chinese ancient geography book, *San Fu Huang Tu*, it is recorded that the Shi Qu Pavilion was the earliest and the largest map collection center of the Eastern Han Dynasty (AD 25–220).

Although China has a long history of mapping and map collecting, there are still many challenges facing those collections related to using the latest technologies for map cataloging, map acquisition and storage, and sharing cartographic services. To present a picture of map collections throughout the country, some important questions are, What is the current status of China's map collections, including print and digital types? About how many map archives or collections are there, and what about their users? What are the target audiences? What are the users' characteristics and where are they located? What is a typical map collection staff size and what educational structure exists for map data collection and services? All these questions need to be considered carefully when exchanging ideas with our international counterparts. To address these issues, we have organized this paper into five parts. The first section introduces the developmental history of Chinese maps and map collections. The next section describes the status of paper map and digital map collections in China. A third section uses a national scientific data-sharing platform as an example for analyzing map collection services and users and the structure of professional staff in collection settings. The next section discusses the challenges and potential demands of Chinese map collections and services by its users, and a final section serves as a brief conclusion.

STATUS OF MAP COLLECTIONS IN CHINA

Paper Map Collections and the Institutions that Manage Them

Paper maps in China are primarily collected and archived by university and research institutions' libraries, map publishing houses, and even some by

personal collectors. There are some major institutions that have sizable map collections; these include

- National Library of China (NLC)
- National Palace Museum
- Shanghai Library
- Peking University Library
- Beijing Normal University (BNU) Library
- Fudan University Library
- National Science Library of the Chinese Academy of Sciences (LAS)
- Library of the Institute of Geographical Sciences and Natural Resources Research (IGSNRR) of the Chinese Academy of Sciences (CAS)
- Sino Maps Press

Map Collections in Library Institutions

The National Library of China (NLC) has been collecting maps since 1909. According to its statistics for 2011, the NLC has on reserve nearly 8,000 different Chinese ancient and old maps including more than 3,000 ancient maps before 1911, nearly 5,000 old maps from 1911 to 1949, and more than 30,000 kinds of new maps, for a total of nearly 100,000 volumes (pieces) after 1949. In addition, it has maps published in more than twenty languages, including English, German, French, Japanese, and Russian; the total foreign language maps collection exceeds 50,000 pieces (Bai and Wu, 2012; NLC, 2011).

The Peking University Library can be traced back to the establishment of the Imperial University library building in 1898, which was one of the first modern libraries in China. In 1990 it had more than 4.1 million books. The collection also covers materials in more than twenty languages, including Chinese, English, German, Japanese, and Russian and volumes from many disciplines and professional fields in the humanities, social sciences, natural sciences, technical sciences, literature and arts, including maps.

The Beijing Normal University (BNU) Library traces its origin from the Imperial Normal School Library in 1902; the initial building was finished in 1922. It contains more than 3.57 million copies of Chinese and foreign books, periodicals, and dissertations and as well as ancient Chinese and foreign literature, maps, and rare periodicals.

The Library of IGSNRR was established on December 29, 1999. It is the largest professional library of the Chinese Academy of Sciences for the geography-related fields. Its map collection includes 24,000 topographic maps, 5,600 sets of professional atlases, and 500,000 aerial photographs. The *Yellow River Ancient Map* is a unique collection of this library, which has immense research value; it narrates the ecological environment of the Yellow River in the late Ming Dynasty (AD 1368–1644).



FIGURE 2 Photo of Pintuzhai showroom (Zhu Junxiang, Beijing, 2014).

Other Institutions with Map Collections

Sino Maps Press has collected more than 10,000 map products. In 2012 it constructed a cultural exhibition center of Chinese maps in Beijing, which covers an area of about 1,000 square meters and is open to the public. The exhibition center was arranged in five distinct sections: use of maps, history of cartography, study of maps, technique of making maps, and achievement and influence of maps.

Besides the above institutions, there are many private map collectors in China, including professional cartographers. The collections of Tan Zhaozhang and Yang Lang have more than 10,000 ancient Chinese maps (Xinhuanet 2004). As far as professional cartographers are concerned, Professor Chen ShuPeng, the father of China's geosciences remote sensing efforts, has an extensive collection of modern maps and atlases. All these map collections, and his own map manuscripts, are exhibited in a permanent gallery named Pintuzhai in the IGSNRR; it is open and can be visited by scholars (see Figure 2). Han Jiafu, a map collector of a new generation in IGSNRR, has collected more than 2,000 modern atlases.

The Service Capabilities of Paper Map Collections

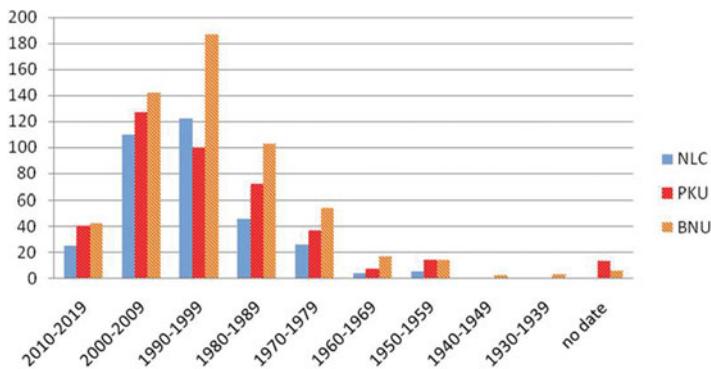
A map library has both an inherent interest in providing maps and also accompanying literature about maps in its collection. Of those libraries mentioned above, three have been selected for a description of their paper map collections and also their retrieval and service capabilities. Table 1 shows the

TABLE 1 Chinese and English Atlases Search Results

Library	Domain Name	Search Time	Chinese Atlas	English Atlas
NLC	www.nlc.gov.cn	2014/3/17	338	>1000
PKU	lib.pku.edu.cn	2014/3/17	411	381
BNU	lib.bnu.edu.cn	2014/3/17	570	521

retrieval results of Chinese and foreign atlases in the NLC and the libraries of PKU and BNU. When retrieving Chinese atlases, we used the Chinese characters “dituji” as the keyword. When retrieving English atlases, we used the English characters “atlas” as the keyword. Figures 3–6 show the spatial and temporal distribution of these retrieved atlases.

The results show that all three libraries have large-scale and thematic atlas collections. The NLC has a comprehensive collection of atlases, which includes a larger number of Chinese and, especially, foreign atlases. As far as the publication dates of these atlases are concerned, they range from the twentieth century to the early twenty-first century. The total circulation of these paper atlases initially increased and then showed a downward trend. Before the 1970s, the growth rate of the total circulation of paper atlases was low; it then grew significantly faster in the 1970s, then circulation peaked in the 1990s and declined in the early twenty-first century. As far as the areal coverage of these atlases is concerned, it appears that there are abundant atlases for Beijing, and Asia in general. In addition, there are still many American and European atlases in the collections. The geographic coverage of these atlases reflects those areas where the economy is developing fast and where there are relatively high demands for the atlases to satisfy various commercial, military, and diplomatic initiatives. For example, the rapid growth of atlases published in the 1990s reflects the need to understand economic development within the context of world multipolarization and economic globalization. Second, users mainly focused on atlases about

**FIGURE 3** Temporal distribution of retrieved Chinese atlases.

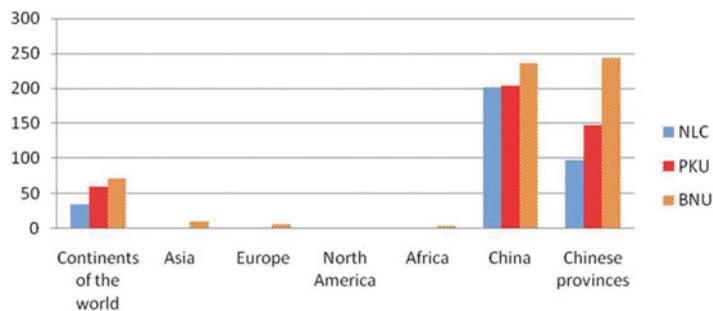


FIGURE 4 Spatial distribution of retrieved Chinese atlases.

their own area or adjacent areas because these atlases were more useful in understanding their own region's economic development and social stability. Finally, the number of paper atlases declined in the late twentieth century, perhaps because digital atlases have recently become a convenient alternative to the paper atlases in many people's lives.

DIGITAL MAP COLLECTIONS

Chinese Digital Map Collection Web Sites

Some government departments in China have their own internal thematic map-sharing and publishing Web sites. Several (not many) professional Web sites also provide open thematic map services, such as the National Mapping Geographic Information Bureau's National Dynamic Map Network (<http://www.webmap.cn/>), thematic atlas resource Web site of China (<http://www.zhuanlitu.com>), China Environmental Monitoring Station (<http://www.cnemc.cn/>), China Forestry Science Data Center (<http://www1.cfsdc.org/>), China Meteorological Data Sharing Service Network (<http://cdc.cma.gov.cn/>), Geological Sciences Data Sharing Network (<http://www.geoscience.cn/>), and China Data Sharing Platform of Earth System Science (<http://www.geodata.cn>). The digital maps published on these Web sites are very few and they are mainly visualized through geographic

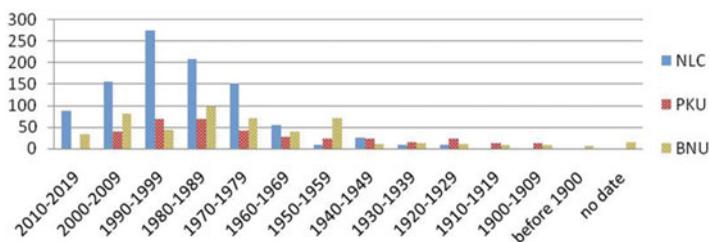


FIGURE 5 Temporal distribution of retrieved foreign atlases.

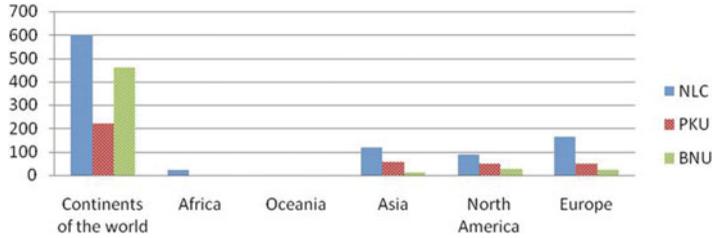


FIGURE 6 Spatial distribution of retrieved foreign atlases.

information systems (GIS) software. This not only leads to a slow map access speed, but also limits the users in special professional fields. Brief descriptions of representative Web sites are given below.

NATIONAL DYNAMIC MAP SITE

The National Dynamic Map Site is a nonprofit Web site that has been maintained by the National Administration of Surveying Mapping and Geoinformation since 2005 (Zhou, Liu, Jia, and Lu, 2009). The site is an online cartographic integrated system having a series of updated thematic maps. The map contents are connected with social, economic, tourism, living, natural, and other thematic topics and are linked to spatial distribution information. This system is updated continually. There are nearly 400 online thematic maps provided by this Web site for viewing, answering queries, simple cartography, and other customized services.

DITUHUI.COM

Dituhui is a company that is open for commercial enterprises and individual users to provide online cartography and publishing services (<http://www.dituhui.com>). It aims to make cartography easy for users without expert knowledge and programming experience. Since its beta version was published in September 2012, Dituhui has registered more than 100,000 users. It has accumulated tens of thousands of maps on different topics, including population, economics, society, resources and environment, energy, tourism, health, life, science and technology, education, culture, sports, leisure, entertainment, and other categories.

DATA-SHARING PLATFORM OF EARTH SYSTEM SCIENCE

The Data-Sharing Platform of Earth System Science is one of the national operational service infrastructures in China. It aims to archive and share science research data (including maps) from various scientific research activities. The platform has a dedicated map gallery that focuses on natural resource and

environmental topics (<http://159.226.111.21:33000/landuse/landuse/index.do>). The platform is discussed as a case study in the next section.

Chinese Map Collections and Map Editing Funded by Science and Technology Projects

Since 1999, the Ministry of Science and Technology has provided special funding to support programs for science and technology materials collecting and sharing, called the Science and Technology Basic Research Program. Map collection and editing projects can be carried out within this program. Usually a project period lasts three to five years. It stipulates that all map collections be archived in a national data center and open to the public when the project is finished. Several map collections and editing projects recently funded by this program are listed in Table 2.

There are many libraries, institutes, and universities hosting map collection and editing projects such as the LAS, Chinese Academy of Agricultural Sciences, Chinese Academy of Military Medical Sciences, Ministry of Land Resources, Institute of Scientific and Technical Information of China, Institute of Geology and Geophysics of the Chinese Academy of Sciences (CAS), IGSNRR, National Geomatics Center of China, and Xi'an Jiaotong University. These collections cover many research fields including soils, atmosphere, disasters, city environments, and human health. The implementation of these map collection and editing projects provide map data resources continually for map collecting and sharing within China.

CASE ANALYSIS OF A CHINESE DIGITAL MAP COLLECTION AND ITS SERVICES

Data-Sharing Platform of Earth System Science

The Data Sharing Platform of Earth System Science (DSPESS) is one of the operational platforms in the National Science & Technology Infrastructure. It is hosted by the IGSNRR of the CAS. It was launched as one of nine pilot projects of the China Scientific Data Sharing Program in 2003 (Xu, 2003), and it became a long-term national infrastructure project after being affirmed by the Ministry of Science and Technology and the Ministry of Finance of China in 2011. The major objectives of DSPESS are to (1) integrate Earth system science research data from research institutes, universities, data organizations, scientists, and independent research groups; (2) manage and archive research data using uniform data standards and specifications; (3) provide full and open data access, stewardship, and services for the scientific community and the public; (4) provide a data exchange portal for world data resources through cooperation with international data organizations;

TABLE 2 Science and Technology Basic Research Program Map Collection and Editing Projects List

Projects	Launch date	Hosting agency	Abstracts
Standards and Specification for Chinese Digital Library	2002	ISTIC, LAS, NLC	Formulating core standards system, construction and application mechanism, and key technology specifications of digital library
China's 1:50000 Soil Atlas Compilation and Database Construction ¹	2007	CAAS	Constructing 3,000 counties' high-precision digital soil database, editing 1: 50,000 large scale soil maps, covering half the regions of China
Integration of Ionosphere Historical Materials and Regional Electron Density Profile Mapping ²	2009	IGG	Archiving 60 years' ionospheric altimeter observing records, making ionosphere feature dataset and atlas under international standards
Geological Disasters Comprehensive Survey and Risk Mapping of Southwest Terrain ³	2011	MLR	Establishing the geological disasters information system and database, making geological hazard susceptibility and risk maps
China's Modern Map History Book ⁴	2012	IGSNRR	Integrating the maps and history documents of Ming and Qing Dynasty to form the complete records and summary of modern China's varieties on map data, mapping activities, cartography techniques and mapping events, etc.
The National Atlas of the People's Republic of China ⁵	2013	NGCC,IGSNRR	Compiling three volume atlases, including the <i>National General Atlas of People's Republic of China</i> , the <i>National Economic Atlas of People's Republic of China</i> and the <i>National Zoning Atlas of People's Republic of China</i>
Research and Compilation of Epidemiology Atlas of Natural Focus Diseases of China	2013	Chinese Academy of Military Medical Sciences	Compiling three-volume epidemiological atlas of natural focal diseases of China, including viral, bacterial, and parasitic diseases
Typical Urban Living Environment Quality Survey and Urban Climate Environmental Atlas Editing ⁶	2013	Xi'an Jiaotong University	Establishing a living environmental quality database, compiling an atlas reflecting the urban living environment conditions, and the characteristics of urban climate change

¹ http://www.most.gov.cn/jcs/jcsgzdt/200702/t20070224_53050.htm² http://www.most.gov.cn/kjbgz/200906/t20090601_70020.htm³ http://www.most.gov.cn/kjbgz/201112/t20111228_91621.htm⁴ http://www.igsnr.ac.cn/xwzx/zhxw/201207/t20120703_3608351.html⁵ <http://www.sbsm.gov.cn/article/chyw/201307/20130700128996.shtml>⁶ <http://www.sbsm.gov.cn/article/chyw/201307/20130700128996.shtml>

(5) discover effective mechanisms, architecture, and guidelines for research data sharing; and (6) facilitate data submissions from various projects in the resources and environment fields (Sun and Shi, 2003; Sun and Wang, 2009; Sun and Lin, 2009; Wang and Sun, 2009; Wang, Sun, Zhu, and Yang, 2013a).

DSPESS provides science data-sharing services to the public through its shared network system and stewardship teams. Full and open data-sharing policies are implemented by two approaches, through regular data services and special data services.

- Regular data services include online services and off-line services at no charge. Online services mainly refer to data browsing, data searching, data downloading, and data requirement consulting. Off-line services are provided mainly by e-mail, telephone, and CD-ROM.
- Special services include active data support, major project tracking data, data products customizing and processing, database system supporting services, data sharing, portal creating, and hosting services. The special services are mainly nonprofit. However, users pay compensational data processing fees according to the labor and professional costs involved in addition to necessary data replication and delivery costs.

Characteristics of Digital Map Data Resources

Through cooperation with more than forty alliance units, DSPESS has collected and archived more than 1,800 digital data sets, exceeding 40 terabytes (Wang, Sun, Zhu, and Yang, 2013a; Wang, Lin, Ran, Zhou, Song, and Du, 2014). There are thirty-four representative map data sets from the resources and environment gallery of DSPESS; they are listed in Table 3.

Through analysis undertaken on these map metadata, data documents, and data entities, we can list the following characteristics:

- Thirty-one (91%) of these data sets come from research institutes; only two (6%) come from universities. The institutions providing the most data sets are IGSNRR, the Institute of Soil and Water Conservation, and the Cold and Arid Regions Environmental and Engineering Research Institute. All belong to CAS.
- The areal or regional spatial scope of map data sets is different. There are twenty-three nationwide map data sets, accounting for 68% of the total, and there are eleven regional map data sets, accounting for 32%. There are no worldwide map data sets.
- The scales of map data sets differ. There are four data sets at a scale of 1:10 million or smaller, ten at a scale of 1:4 million to 1:10 million, fourteen at a scale of 1:1 million to 1:4 million, and six at a scale of 1:1 million or larger; they accounted for 12%, 29%, 41%, and 18%, respectively, of the total.

TABLE 3 Selected Map Data Resources from the DSPeSS Gallery

Metadata ID	Digital map data set name
100101-10241	Yellow River Delta & sub delta development since 1855
100101-10243	Coastline changes in the Yellow River Delta since 1855
100101-10261	Wetland changes in the Yellow River Delta since 1980s
100103-10002	1:1million traffic map of the Qinghai-Tibet Plateau
100103-10005	1:1 million vegetation map of the Qinghai-Tibet Plateau
100101-13	1:4 million Chinese soil map
100101-11	1:4 million Chinese soil organic carbon distribution map (1993–95)
100103-10127	1:4 million county boundary map of China
475000-2	Spatial database of the Yellow River main channel changes (1855–2005)
712100-10096	1:1 million soil erosion map sets of the Loess Plateau/Yellow River basin (1956)
712100-10091	1:1 million soil map sets of the Loess Plateau (1956)
100101-10820	1:500,000 vector data sets of the resources and environmental remote sensing series graphs in the Loess Plateau (1987–1990)
100101-10821	1:500,000 raster data sets of the resources and environmental remote-sensing series graphs of the Loess Plateau (1987–1990)
712100-10021	Cropland slope-grading map sets of the Loess Plateau
100101-42	1:1 million land-use zoning data sets of China (1996)
100101-10461	1:1 million forage grass spatial distribution map of China
100102-16	1:4 million cropland-quality data of China (1980s)
100102-15	1:4 million uncultivated land data suitable for agriculture of China (1980s)
100101-44	China meadow types and distribution data (1980s)
100101-51	China meadow resource database (by province, by county, 1980s)
100101-10801	China drought map for the past 500 years
100101-46	China township boundaries data sets
100101-24	1:1 million geomorphological map of China (1980s, 2000)
100101-65	1:1 million land resource data sets of China (1980s)
100101-48	1:1 million vegetation resource data sets of China (2000)
100101-31	1:1 million meadow resource data sets of China (1980s)
100101-22	1:4 million Geomorphological pattern map of China
100101-66	1:4 million multi indices basic geography data sets (1970s–1990s)
100101-2	1:4 million resource and environmental data sets of China (terrain)
100101-1	1:4 million resource and environmental data sets of China (swamp)
730000-10044	1:1 million desert data sets of China
730000-10140	1:100 000 glacier data sets of China
730000-10060	1:100 000 desert map of China (about 2000)
712100-10101	1:15 million soil erosion & water and soil conservation map of China

- The fields of mapped data are broad, relating to soils, glaciers, deserts, swamps, vegetation, meadows, cropland, wetlands, rivers, coastlines, topography, traffic, administrative divisions, and so forth.
- The average size of the map data is 115,302 KB. The largest map data set is 91410 KB, which is a *1:100 000 Map of Deserts in China in 2000*. The smallest is 38 KB.
- The map data format mainly includes ArcGIS Coverage, ArcGIS exchange format (E00), ArcGIS shapefile, ArcGIS Geodatabase, ArcGIS Grid, Excel, Roshal Archive, SQL (MDB), and Access mdb and txt. The number of ArcGIS formats is about 25; they account for 73% of all data sets. Roshal Archive and Excel formats account for 15% and 6%, respectively.

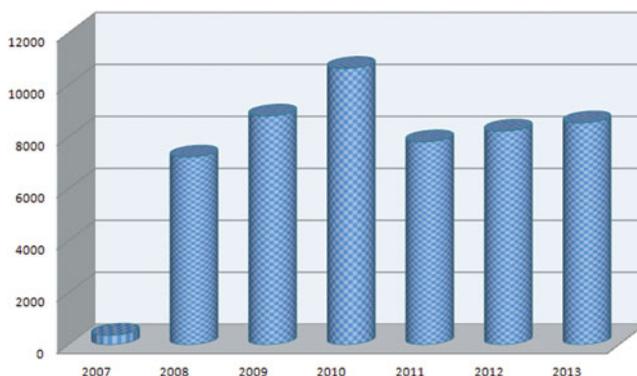


FIGURE 7 Map data sets download times from 2007 to 2013.

- The temporal scopes of the mapped data are also different. There are fifteen map data sets made before 1980 that account for 44% of the total; twelve sets from 1980 to 2000 (35%), and seven created after the year 2000 (21%).
- Most of the map data sets were published between 2007 and 2013. The first was *1:4 Million Multi Indices Basic Geography Datasets (1970s–1990s)*, published in 2007.
- The map service mode also includes online service and off-line service. Fifteen map data sets (44% of the total) can be accessed via the online service and nineteen (56%) can be accessed through the off-line service.

MAP DATA RESOURCES SERVICE

General Map Data Resources Services

The number of map data sets downloaded by users was 52,906 by the end of 2013. Figure 7 shows the download times from 2007 to 2013. The largest volume was 10,636 data sets downloaded in 2010, and the lowest was 364 in 2007; the average volume of downloaded data sets was 6,613. The records show that users' map data requirements are relatively stable, but also increasing.

The average number of downloaded map data sets was 1,556. The most popular data set was the aforementioned *1:4 Million Multi Indices Basic Geography Data Sets (1970s–1990s)*, which was downloaded 3,624 times. The least downloaded data set was *Spatial Database of The Yellow River Main Channel Changing (1855–2005)*. The data sets downloaded more than the average number of times were *1:500000 Raster Data Sets of the Resources and Environmental Remote Sensing Series Graphs in the Loess Plateau (1987–1990)*, *1:4 Million Resource and Environment Data Sets of China (Terrain)*, *1:4 Million Geomorphological Pattern Map of China*, *The 1:1 Million*

Land Use Zoning Data Sets of China (1996), and the *China Township Boundaries Data Sets*.

User Characteristics of Specific Map Data Resources

In order to gain some insights into user characteristics of digital maps in DSPESS, the most popular data set, *1:4 Million Multi Indices Basic Geography Data Sets (1970s–1990s)* was selected for detailed comment:

1. SPATIAL DISTRIBUTION OF USERS

A total of 2,061 users downloaded this data set; twenty-five international users came from eleven countries, including the United Kingdom, Germany, France, Italy, Belgium, Sweden, the Netherlands, Canada, Australia, the United States, and Japan. Chinese users of this data set numbered 2,036. They were located in almost all provinces in China. Since the map data set was collected mainly for scientific research in the field of resources and the environment, most users were located near universities or research institutes. Among these Chinese users, 705 came from Beijing, which included the most frequent users of this data set. Figure 8 shows that other large Chinese cities have large numbers of users, including Nanjing, Shanghai, Wuhan, and Guangzhou.

2. USER AFFILIATION STRUCTURE

The users who downloaded this map data set came from various agencies. Figure 9 shows user affiliations: 61% came from universities, 28% from research institutes, and only 5% (99) came from government agencies. The fewest users came from social enterprises. Thus the main users of the map data in DSNESS were from educational and research agencies.

3. USER EDUCATION BACKGROUND

Of the 2,061 users, those holding a PhD degree or who were PhD candidates were 688 in number, or 33% of the total. The number of users with master's degrees or MS candidates was 875 or 45% of the total, while only 19% of the users had a bachelor's degree or were BA candidates. Figure 10 shows the education background of the data set users. About 94% of these users had a higher education background. Users with different educational backgrounds have different map data requirements; those with or pursuing higher degrees had relatively strong science backgrounds.

Service Staff Structure

The service staff of the DSPESS comes from different institutes, including many institutes of the CAS, the China Polar Research Center of State Oceanic

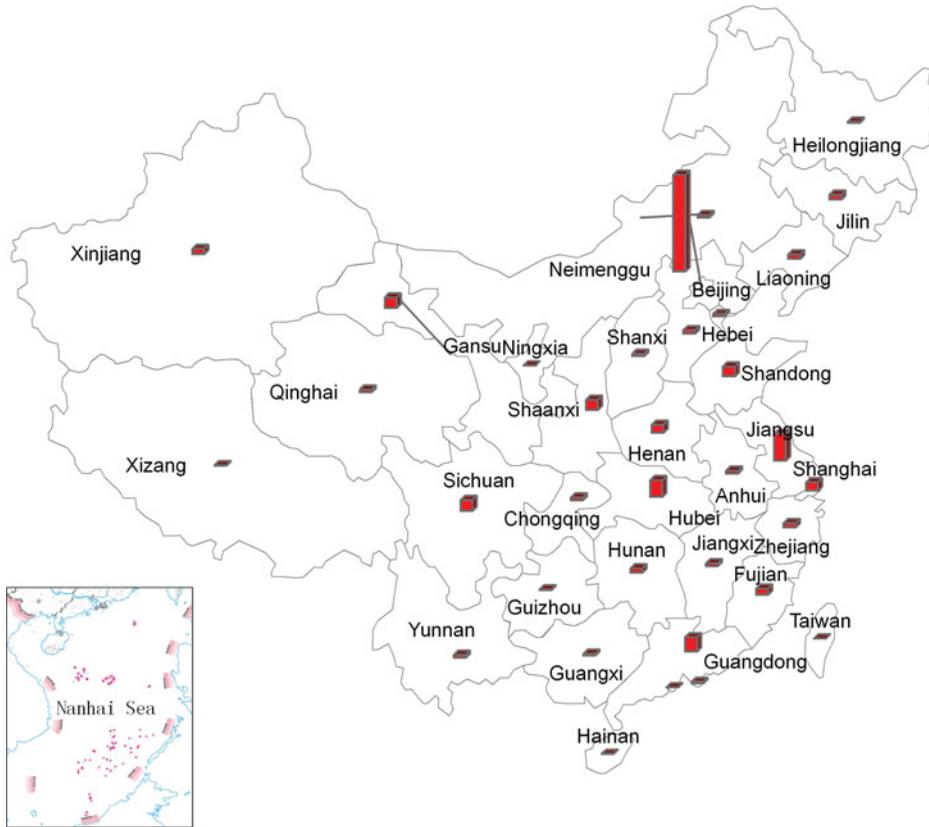


FIGURE 8 Chinese data set users' distribution.

Administration People's Republic of China, Nanjing University, Nanjing Normal University, and Henan University. There are forty-six daily, full-time staff members. Of these, thirty-six previously worked in the CAS and ten at various universities. Figure 11 shows the professional staff distribution in the DSPES.

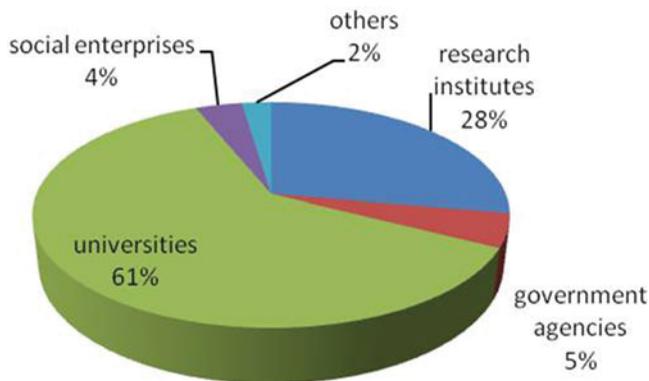


FIGURE 9 Chinese user affiliation structure.

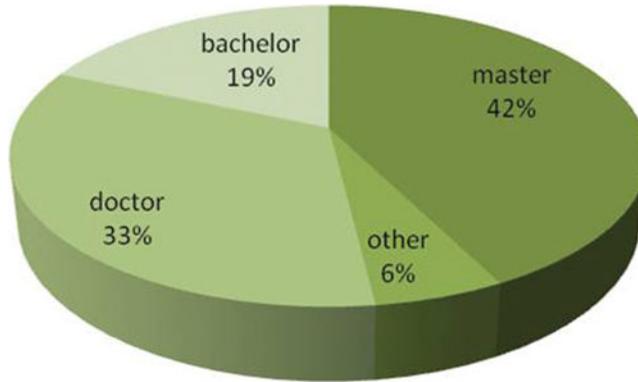


FIGURE 10 Users' education background structure.

Personnel with senior professional titles, intermediate titles, junior titles, and part-time students accounted for 22%, 58%, 13%, and 5% of the total, respectively. These figures illustrate that about 80% of the staff were full-time with a higher professional title; that is, staff specialization levels were high.

DISCUSSION

Mechanisms Related to Map Data Collecting and Sharing

Chinese cartography, as noted above, has a long history, and the number of map collections is large. However, the methods of acquiring, organizing, and sharing the data are considered professionally inadequate.

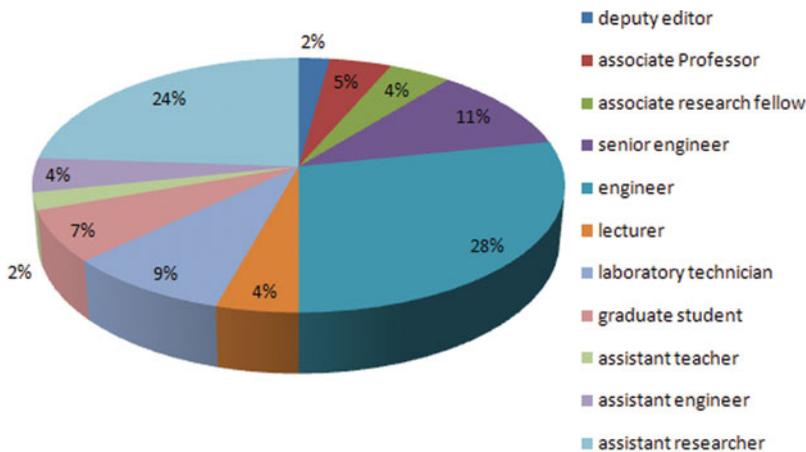


FIGURE 11 Professional service staff structure of the DSPSS.

To begin with, in China there are few nonprofit institutes such as specialized map libraries that are engaged in map collecting. Existing map collection institutions mainly provide universal paper or digital map archiving management in ways and methods that are similar to literature and books, which does not satisfy map data collection, management, and distribution services. Also, there is no universal data archiving mechanism to ensure that the map data sets produced by state-funded projects can be archived in time and shared with the public.

The third challenge is that an optimal or adequate data-sharing environment for personal map owners sharing their map data is missing; this exists because there is not a clear data-sharing policy statement among map producers, managers, and users (Wang, Zhu, Yang, Song, and Yue, 2013b).

What we learned from researching and producing this paper is that some Chinese map libraries or map data centers are run or managed outside China. For example, a Web site of Chinese map data sets exists at the University of Cambridge (<http://www.lib.cam.ac.uk/mulu/atlas.html>). This Web site lists many Chinese map data sets of broad topical areas that have been published within the last few years; it also provides detailed introductions about map data information, including map data names, publishing units, and the content and range of the map data. This site shows that maps of China are of interest to international users on the one hand but also reveals that what is lacking within China is a professional map collection mechanism for map-collecting institutions.

Funding Support for Map Data Collecting and Sharing

Although there have been some government funding programs for map data collecting and sharing, such as the science and technology basic research program of MOST, funding sources remain limited. The government needs to allocate increased funds to collect, archive, and share more historic, recent, and up-to-date map-data resources. According to library statistics, there have been 2,000 thematic atlases and nearly 200,000 maps published in China since 1949. And there have been various types of single thematic maps and series of thematic maps published as well. These map data resources could contribute to scientific research, technology innovation, education, and socioeconomic development if they were collected and made available for sharing in a timely fashion. Meanwhile, if these map data were to be published and made available to international users, it would require both training for and funding of language translation services. This is one of the obstacles facing China's collections, exchanges with other institutions, and colleagues around the world.

Technical Challenges of Map Collections and Services

The current technologies for Chinese map collecting and service fail to meet the demands of current map-data users. The existing map-data archiving management and search services are based mainly on a literature management and service model. The primary technology model is still based on metadata or data catalog management, and data contents are stored like literature management systems, totally lacking a GIS visualization environment. With the arrival of big data and cloud computing and with more and more resource and environmental maps being published, different topics and different academic perspectives should be brought together and visualized using state-of-the-art technologies. Meeting this objective will contribute to researchers in each branch of the geosciences obtaining new spatial knowledge of geographic environments and also being able to use the results for comparative purposes.

At present, it merits mention that some Chinese companies have already begun to provide distinctive map services. For example, the Story Maps Web site of Esri China Ltd. provides a professional, online cloud-mapping capability to Internet users (<http://storymaps.arcgis.com/en/>). It represents a step forward in digital map applications.

Stewardship of Map Collections and Services

The dedication of professionals toward their map collections and services is another key problem facing China's map collecting and sharing staff, including appropriate staff organization, professional expertise, training, and retention. For example, our case study of the service architecture of DSPSS showed that the professional level of staff was high, but Will it remain stable with new challenges? Crucial questions are how to mobilize the enthusiasm of service staff that is lacking the latest technologies and how to make the best use of staff. These are questions that need to be addressed in the near future.

Further Thinking about Library Services in China

Although more and more digital map data are being collected and shared in a national data-sharing platform and other Web sites, libraries are still the leading actors in China for paper and digital literature services, including map resources. Taking LAS as an example, some service mechanisms are listed and discussed below:

- Many big libraries in China have interlibrary loan (ILL) service with other libraries overseas and domestically. The LAS has an ILL link with

libraries in foreign countries such as Germany and the United Kingdom. It also has ILL services with more than ten libraries in China including the National Geological Library of China (<http://www.cgl.org.cn>), Science and Technology Library of GuangDong, China (<http://www.stlib.gd.cn>), Library of University of Science & Technology of China (<http://www.lib.ustc.edu.cn/lib/>), Library of Shanghai Information Center for Life Sciences, CAS (<http://www.slas.ac.cn>), Library of Beihang University (<http://www.buaalib.com>), Agricultural Information Institute of the Chinese Academy of Agricultural Sciences (<http://aai.caas.net.cn/>), NLC (<http://www.nlc.gov.cn>), Peking University Library (<http://lib.pku.edu.cn>), Tsinghua University Library (<http://lib.tsinghua.edu.cn>), and Shanghai Library (<http://ipac-en.library.sh.cn>). Each book or atlas will be charged six Chinese yuan (less than \$1) per transaction. The LAS repays the delivery fees for ILL users when the atlases or books are borrowed, but the users pay for delivery on returning the materials.

- LAS pays for mainly SCI journals and Chinese electronic journals according to common requirements of CAS, such as China National Knowledge Infrastructure led by the Tsinghua University and Tsinghua Tongfang Co., Ltd., and the CQVIP network of Chongqing VIP Information Co., Ltd. Special fields SCI journals are paid for by those institutes in special fields and LAS together. All the users in CAS can access these digital journals free of charge, including domestic and foreign scholars working or studying in the CAS. Foreign scholars seldom apply to borrow paper or digital materials from LAS overseas directly. By the way, the NLC has more international users under its huge ILL network; it charges a \$23 fee for each book loaned.
- A donating mechanism exists for books and atlases from scholars around the world in the LAS. The LAS provides a donation certificate to its donors. Most of the institutes in the CAS also have this mechanism. For example, the library of the IGSNRR has received many books and atlases in China from outside donors.

CONCLUSIONS

We have discussed the collecting and sharing of China's paper and digital maps from perspectives of map collecting and sharing services. DSPESS was used as a case study to illustrate the sharing and services of digital map data sets. It was analyzed using map data collection characteristics, data sharing policies, distribution of users and professional staff levels, and characteristics. We also outlined some of the challenges and potential demands facing China's map data collecting and sharing services, including providing the latest technological innovations, financial support issues, and allocation of and rewards for professional staff. Our goal is to provide an overview of

China's approaches on map collections and sharing services for our international counterparts and thereby to promote the development of China's global map collections and sharing abilities in the near future.

ACKNOWLEDGMENTS

Special thanks to Prof. Stanley D. Brunn from the Department of Geography, University of Kentucky, for his wise views, constructive comments, and English language editing for manuscript preparation.

We are grateful for the advice of Mrs. Chunfeng Liu, Mrs. Guangbing Fan, Prof. Liming Wang, Mr. Jiafu Han, and Mr. Bin Luo from IGSNRR, CAS, Dr. Xiuling Qing from LAS, and Prof. Shangyi Zhou from BNU. We appreciate the constructive discussions and the insightful comments of the Editorial Department of the *Journal of Map and Geography Libraries*.

FUNDING

This work was supported by the Science & Technology Basic Research Program of China (grants 2013FY114600, 2011FY110400, and 2013FY112800), the Specific Informational Infrastructure Program of the Chinese Academy of Sciences (Grant XXH12504-1-01), and the National Data Sharing Platform of Earth System Science in China (Grant 2005DKA32300).

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