The Application of Geographic Information System (GIS) to the Study of Chinese History

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Abstract: Historical geographic information system construction echoes the call of academic development in the information era and demonstrates the in-depth advancement of history studies. In recent years, an increasing number of data platforms have been built to facilitate historical information storage, display, management and analysis. In such a context, the geographic information system (GIS) begins to contribute to the study of Chinese history. Its contribution is highlighted in nine areas: historical climate, fluvial landforms, town economies, rural settlements, hydraulic societies, environmental changes, ancient cities, ancient maps and HGIS-enabled research methods. The application of GIS to the study of Chinese history initiates a reform in research methods and at the same time upgrades the philosophy of history studies, facilitating the utilization of a diversity of historical data (documents, ancient maps, remote-sensing images, archaeological information, etc.) for dynamic tracing and multi-factor comprehensive research. At present, restricted by traditional disciplinary boundaries, the construction of HGIS platforms remains slow and insufficient, making it difficult to extensively apply GIS to the study of Chinese history.

Keywords: historical geographic information system (HGIS); study of Chinese history; research and application

The rapid development of information technology (computer, electronics, the Internet, etc.) is influencing human production and life in an all-round way. These new technologies are applied to natural sciences and engineering management and at the same time are also being integrated with humanities and social sciences, and will have a huge impact on traditional research philosophies and methods.

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Computer and information technologies are used by people to enable problem analysis and method renewal and form computer language and thinking model. Such technologies are now indispensable for the R&D work in various areas. According to many scholars, computer technology is transforming the existing academic ecology in an all-round way; in particular, a variety of database technologies have been developed, theorized and applied to production, making relevant research approaches and methods more and more comprehensive, diversified and interdisciplinary. The extensive application of computer integration, relational databases, cloud computing, etc. to academic research today has brought about what is known as an "era of pan-data research." This era has unveiled numerous research topics beyond imagination and realized research objectives seemingly impossible to complete. Multi-disciplinary participation has become possible, and such an attempt has been made in history studies and is forming a trend or an approach.

Early in the 1980s, some scholars attempted to apply database technology to history studies. Their databases roughly fell into three categories, namely bibliographic, ① quantitative② and spatial ③databases, which are independent from but closely related to each other. As the scope of information management continues to expand and new technology emerges, compatibility is an inevitable trend among the three categories. Spatial databases are now mainly supported by geographic information system (GIS), which has become a primary means of spatial data management, analysis and trouble-shooting. Here come the following questions. What is geographic information system (GIS)? Which types of data can be managed by GIS? How can GIS help history studies? How can China give play to GIS advantage in the exploration of new research methods for the study of Chinese history?

1. GIS Development Process and Subject Characteristics

Geographical information system, or geographical information science (GIS), is a computer technology-enabled system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data and products (e.g. digital map). Based on the theories of systems engineering and information science, this integrated computer information system has emerged with the development of computer technology in the information era.

The concept of GIS was originally proposed by Roger Tomlinson, an English geographer who first used this term in 1963 and initiated the Canadian Geographic Information System, the first computerized GIS in the world to manage and plan national natural resources in 1971. Following this, the Land Use and Natural Resource Inventory (LUNR) was officially launched. It was among the earliest system platforms applying GIS to the management of national land and natural resources. Due to technical and cost restrictions, early GIS

① Bibliographic database: a database of bibliographic records, an organized digital collection of references to published literature. Bibliographic database allows sorted and processed bibliographic information to be input into the computer, where it is edited, typeset and outputted. Bibliographic database primarily serves for bibliographic information retrieval purposes.

② Quantitative database: a database system that mainly covers population, education, assets, revenue, tax revenue, social strata and society and is characterized by mass data summarization and analysis. Quantitative database is particularly supportive of quantitative and trend analyses. Some representative scholars of quantitative database–enabled history studies have emerged over the past years, among whom are Li Zhongqing and Chen Zhiwu.

③ Spatial database: a database that is optimized to store and query data that represents objects defined in a geometric space. Spatial database targets geography and related objects and concerns earth surface, geology, atmosphere, etc. Its data capacity is large enough to describe such information and its spatial data model is relatively complicated. Spatial database does not merely store a single type of data, but covers almost all types of geography–related data, which can be categorized into attribute data, graph & image data and spatial data.

versions were only accessed by large-enterprise users for computer management and computer-aided design (CAD). Its application scope did not yet cover spatial analysis or geoscientific research. In the 1980s-1990s, as computers were popularized, computer functions were continuously improved, GIS upgrading was accelerated, digital spatial data were substantially increased and overall GIS technology was rapidly advanced. In such a context, scientists and scientific workers began to extensively apply GIS to spatial analysis and model structuring and to examine a range of geographic issues from a scientific perspective. Thus, the GIS application scope was extended from pure spatial data management to scientific research and its concept was transformed form "geographical information system" to "geographical information science." ① From then on, GIS has been widely accepted as a subject, which allows scientific workers to propose a series of research questions to be analyzed, studied and innovated while utilizing computer technology to store, manage, retrieve and analyze geographical information.

So far, GIS has mainly been combined or integrated with other technologies to develop more comprehensive technology systems. GIS advancement has primarily relied on the development of computer technology and the expansion of its application scope. Almost every previous IT breakthrough brought about a GIS upgrade (spatial data management, WebGIS, 3DGIS, etc.). Today, the enhancement of big data, cloud computing and other information-based means enables constant improvement of GIS services, which are now offered to support social activities, as well as spatial technology and analysis. The abbreviation GIS has thus gained one more alternative interpretation: geographical information service.

The existing GIS application scope covers public utilities, telecommunications, traffic, urban emergency management, land administration, city planning, military affairs, library management, healthcare, political domains, landscape reservations, land cover & land use monitoring in urban and regional planning, national & global agriculture, environmental monitoring and assessment, etc. In areas such as eco-landscape planning, computer science, paleoanthropology and forest management, GIS has grown from a loosely organized single-function system into a comprehensive information system with multiple functions for sharing. Such a system can use an expert knowledge system to make comprehensive analyses, predictions and decisions and go intelligent.

With outstanding performance in management and data analysis, GIS is being more and more extensively applied in the areas of humanities and social sciences. Moreover, it has made significant contributions to economics, criminology, public health, public policy & planning, etc. Subsequently, more importance has been attached by governments of all countries to the building of GIS platforms for their humanities and social sciences-related studies. In the USA, UC Santa Barbara (UCSB) launched the Center for Spatially Integrated Social Sciences (CSISS) sponsored by the National Science Foundation (NSF), ② in a bid to give play to GIS technology in various social science studies. In the UK, the Center for Advanced Spatial Analysis (CASA) at University College London (UCL)③ gathers scientists and experts from diverse areas ranging from GIS, geography, economics, physics, to computer science, etc. CASA aims to summarize objective laws of

① M.F.Goodchild, 2018, February 25, Geographic information systems and science: today and tomorrow. Annals of GIS 15 (1) pp., 3–9. http: // www.geog.ucsb.edu/~good/papers /483. pdf [2018–02–25].
② Retrieved from: http: //www.csiss.org/[2018–02–23]
③ Retrieved from: http: //www.bartlett.ucl.ac.uk/casa/[2018–02–24]

socioeconomic systems during spatio-temporal evolution and formulate corresponding policies and plans. In the 21st Century, GIS has been widely applied in all walks of life and common households, becoming an indispensable tool or helper in people's production, work, study and life.

2. Building of Large HGIS Platforms both in China and Abroad

Around the 1980s, historians began to apply GIS to history studies, which concerns event development processes, regional economic development, settlement growth & change, region-specific crowd characteristics, spatial evolution of disasters or epidemics, etc. These areas require a comprehensive understanding of a particular region and rely primarily on a precise orientation in time and space. Capable of giving full play to its advantage in these areas, GIS was used. From a perspective of geography, of all human information, some 80% concerns geographic location and spatial distribution. Such information can affect human decision-making both in history and at present, which lays the theoretic basis for GIS application to history studies. This move requires relevant scholars to master GIS software. In the 1980s-1990s, however, then limited IT and GIS popularity posed high costs on related technical research and development. That is why basic GIS work in the early period was mainly initiated by research institutions with substantial R&D strength. By virtue of favorable R&D conditions, advanced computer equipment and adequate funds, these institutions attempted to develop some HGIS platforms. These pioneers not only developed HGIS platforms but also applied them to historical analysis in practice and truly promoted HGIS applications. Most HGIS researches in the early days came from the abovementioned research institutions.

Today, there are a number of well-known major international HGIS platforms, including the Great Britain Historical Geographical Information System (GBHGIS), which is funded by the UK government and hosted by the University of Portsmouth, ① the National Historical Geographic Information System, which is funded by the US government and developed by the Minnesota Population Center (MPC), ② the Belgian Historical GIS project, which is operated by Ghent University, Belgium. ③ As of 2018, HGIS platforms have been launched in countries worldwide. ④ Moreover, there is no shortage of internationally well-known theme HGIS platforms, among which are the Worldmap, ⑤ which is being developed by the Center for Geographic Analysis at Harvard University; the "Animated Atlas of African History 1879-2002" program, which is an online year-by-year map of selected themes in the history of Africa developed by Brown University; ⑥ the Batanes Islands Cultural Atlas, which is part of the Electronic Cultural Atlas Initiative (ECAI) launched by UC Berkeley; ⑦ the New York City Historical GIS Project, which is developed by the New York Public Library; ⑧ Wikipedia's Historical Geographic Information System; ⑨ Mapping the Jewish Communities of the Byzantine Empire, which has been developed using JavaScript in collaboration with Humla, Umea

① Retrieved from: http: //www.port.ac.uk/research/gbhgis/[2018–02–24]
② Retrieved from: https: //www.nhgis.org/[2018–02–24]
③ Retrieved from: http: //www.hisgis.be/[2018–02–24]
④ Wang, Daxue, 2016.
⑤ Retrieved from: https: //worldmap.harvard.edu/[2018–02–23]
⑥ Retrieved from: http: // www.brown.edu/Research/AAAH/map.htm[2018–02–24]
⑦ Retrieved from: http: //ecai.org/batanesatlas /[2018–02–24]
⑧ Retrieved from: https: //www.nypl.org/blog/2012/06/13/nyc–historical–gis–project[2018–02–24]
⑨ Retrieved from: https: //en.wikipedia.org/wiki/Historical_geographic_information_system[2018–02–24]

University, Sweden;[①] the "Countryside Transformed: The Railroad and the Eastern Shore of Virginia" program, 1870-1935, which is a collaborative effort of the Eastern Shore Public Library and the Virginia Center for Digital History of the University of Virginia, [②] etc. There are altogether over 100 such programs, all featuring power databases, platform development systems, themed databases with specified targets, multiple data sources, large information systems with vivid pictures and illustrations, as well as abundant map resources. In addition, HGIS programs strive to unveil the spatio-temporal laws behind major historical events and integrate their natural background (climate, soil, forest, etc.) into the system in a bid to carry out comprehensive analyses and spatial simulations. Many large international comprehensive HGIS programs cover Chinese historical geographic information. For example, Harvard University's Worldmap has a system called Chinamap. [③]

Of all China-related HGIS platforms, the following platforms are arguably the most influential: China Historical GIS (CHGIS), a collaborative effort of Harvard University and Fudan University; [④] the Chinese Civilization in Time and Space (CCTS), a system developed by Academia Sinica (Taiwan, China); [⑤] A Historical GIS Dataset of Urban Cultures in Republican Beijing, a database developed by the Institute of Space and Earth Information Science, the Chinese University of Hong Kong. [⑥]

The Chinese HGIS (CHGIS), mainly targeting administrative divisions in Chinese history, aims to build a basic geographic information database to provide researchers with basic R&D data, time statistics, search tools and models. The system covers the entire span of imperial China, from the establishment of the Qin Dynasty in 221 BC to the fall of the Qing Dynasty in 1911 AD, attempting to represent the progressive year-by-year changes in administrative divisions in Chinese history. [⑦] At present, this database is still under construction and only part of the administrative division data are concluded and offered for downloading. In recent years, based on the CHGIS, Hou Yangfang developed the "Chinese Population GIS" (CPGIS) and the "Qing Dynasty GIS" (QDGIS), both of which have already been launched online.

Chinese Civilization in Time and Space (CCTS), a system developed by Academia Sinica (Taiwan, China), has already taken shape. CCTS is based on the "Historical Atlas of China," an 8-volume work edited by Tan Qixiang in combination with V.K. Ting Atlas edited by Ding Wenjiang in 1930. Exhibiting all historical maps of China from the Pre-Qin period (21st Century BC-221 BC) to the Qing Dynasty (1636 -1912 AD), CCTS forms a primary geographical base map of all dynasties during the 2000-year history of imperial China. Moreover, CCTS also adopts ArcChina (a 1:1,000,000-scale digital map of China in the 1990s) as the modern geographical base map and incorporates Scripta Sinica (Academia Sinica), the Qing Dynasty Grain Prices Database (Institute of Modern History, Academia Sinica) and the Union Catalogue Database of China Local Gazetteer. It creates an applied environment of Sinology which features precise space orientations, combines time with space and offers convenient searches and retrievals.

① Retrieved from: http: //www.humlab.umu.se/en/research-development/completed-projects/mapping-the-jewish-communities-of-the-byzantine-empire/ [2018-02-24]
② Retrieved from: http: //eshore.iath.virginia.edu/node/33[2018-02-24]
③ Retrieved from: https: //worldmap.harvard.edu/chinamap/[2018-02-23]
④ Retrieved from: http: //yugong.fudan.edu.cn/views/chgis_index.php?list=Y&tpid=700[2018-02-12]
⑤ Retrieved from: http: //ccts.ascc.net/index.php?lang=zh-tw[2018-02-24]
⑥ Retrieved from: http: //www.iseis.cuhk.edu.hk/history/beijing/intro.htm[2018-02-24]
⑦ Retrieved from: http: //www.fas.harvard.edu/~chgis/[2018-02-23]

Silk Road Historical Geography Information Platform

A Historical GIS Dataset of Urban Cultures in Republican Beijing is a database developed by the Institute of Space and Earth Information Science, at the Chinese University of Hong Kong. It attempts to examine a modern city's spatial model of cultural change in the context of cultural diversity with an HGIS approach. It is based on the city of Beijing from the establishment of the Republic of China to the full-scale War of Resistance against Japanese Aggression (1912-1937). This HGIS database showcases Beijing during that period in an all-round way, covering its urban patterns, population, markets, education, public medicare, legal system, religious culture, etc. Relying on credible large-scale maps, this database utilizes GIS to present relevant datasets in spatial forms and changes and offers online browsing of the available maps.

In addition, the Silk Road Historical Geography Information Platform, a joint effort of the Center for Historical Geography Studies and Capital Normal University, was officially launched in June 2017. ① This platform integrates database technology and model analysis into an organic whole, and has developed into a sound and complete HGI database covering a range of essential aspects along the 2000 years-long history of the Silk Road (eco-environments, ancient sites & relics, ethnic religions, transportation & commerce, cultural communications, etc.) and aims to reflect the on-going changes of natural and cultural environments along the Silk Road. To boost data use, the platform has also adopted a whole set of GIS modeling, including geographic profile analysis, nuclear density analysis, buffer analysis, temporal property analysis, regional river network extractions & analysis, etc. to further enable relevant scholars to carry out individual studies with data from the platform.

As of now, substantial achievements have been made in the design and development of CHGIS. Yet, compared with international peers, China still has room for improvements in terms of data integration, analysis, online releases and sharing. Major programs in this regard tend to be released in Web-GIS form, which allows users to view historical administrative regions, place names and maps via a browser. Given this, they fall into the category of basic HGIS platforms, whose role in historical analysis and research remains very much limited.

3. GIS Contribution to the Study of Chinese History

In the 1990s, US scholars Anne Kelly Knowles and Ian N. Gregory, based on their research experience

① Retrieved from: http: //www.srhgis.com/homePage[2018–02–25]

and methods, determined the advantages of GIS in history studies. According to Kelly and Gregory, GIS is a visualized publishing platform, as well as a research tool for historical data integration; GIS can help include complicated spatial techniques in historical analyses in a bid to outline the future application of GIS to history studies. During the 1990s, a series of large HGIS platforms were successively built, providing basic support for scholars to utilize spatial and environmental data. Consequently, some scholars pioneered in applying GIS to historical analysis. Most of these pioneers were scientific research personnel at institutions which were the earliest builders of HGIS platforms. They actively developed solutions to existing problems and promoted HGIS technology, forming an important driving force of HGIS construction and GIS-aided history studies. China has abundant stock of historical documents, a long time-span of regional research and historical geographic analyses, and unique approaches to the study of spatial processes, all of which are particularly conducive to GIS applications. Several such attempts have been made over the past years, making substantial progress in studies of environmental evolution, fluvial landforms, climate change, hydraulic societies, rural settlements, urban morphology, traditional maps, epidemic transmissions, etc., and resolving many tough chronic problems by GIS means. Because of this, GIS application has been increasingly valued by scholars.

3.1 The study of historical climate

The study of historical climate is mostly preferred by scholars of historical geography. Climate change is closely related to economies, people's livelihoods and, above all, disasters. In the past, due to a lack of measurement and observation tools, it was difficult to reproduce the climate processes behind drastic weather changes and major natural disasters, for which quantitative analysis is needed to capture changes in temperature and humidity. In 2000, Man Zhimin published his essay "Climatic Background of the Severe Drought in 1877," [①] attempting to deduce the climate features behind some major natural disasters depicted in historical records using a GIS-based spatial approach. In his essay, Man Zhimin did a case study of a severe drought in northern China in the third year of the reign of Emperor Guangxu of the Qing Dynasty (1877 AD). He examined relevant statistical reports submitted by affected counties in Shanxi province and Zhili province (current Hebei province). The reports respectively concerned local disaster-stricken villages, counties & prefectures enjoying tax exemptions the next year, and local official's drought surveys & investigations. Man calculated the number of affected villages using the Kriging method, made up for the deficiency of spatial data with the isopycnic spatial interpolation method, and drew a thematic map to represent the spatial differences of drought between Shanxi province and Zhili province that year. Based on the reconstructed drought-level map, Man Zhimin determined the position of three drought centers and the drought's duration and used the spatial difference in disaster indexes to infer the then rain belt's advancement in northern China and subsequently concluded the time of the summer monsoon that year. In this way, he proved that this severe drought was influenced by the global ENSO circulation, which significantly weakened the monsoon in Asia and varied the advancement route of the monsoon rain belt and rainfall process. This is a good example of how to apply data regarding disasters to the study of monsoon belt advancement in a given historical period. More importantly, Man's research also initiated a new approach to the study of historical climate. In recent years, many scholars, represented by Pan Wei and Man Zhimin, have further deepened this research by applying GIS to the creation of relevant databases, and studied the frequency of disaster occurrence (droughts & floods), changes in river

① Man, 2000.

runoff, as well as the relationships between such earth surface changes and summer monsoon patterns. Breakthroughs have been made in research methods. ①

3.2 The study of fluvial landforms

For historical physical geography, the study of fluvial landforms is a primary direction, and the representation of waterway shifting is particularly important. By the end of the 20th Century, the historical shifting of waterways had become clearer. Judging from the results, however, the representation remained at the stage of "drawing waterways by connecting multiple dots" and no detailed historical geomorphological map was produced to cover the entire span of a waterway. In 2007, Man Zhimin published the essay "A Study of the Old Jingdong Watercourse of the Northern Song Dynasty", in which he proposed to apply multi-source data to the representation of historical geomorphology. Based on the Global Digital Elevation Model (DEM) acquired by the National Aeronautics and Space Administration (NASA) in November 2000, Man Zhimin identified the relics of the Yellow River course through history based on the remote-sensing images. By consulting historical documents and corresponding ancient place names with contemporary names, he managed to reconstruct the Yellow River course from Henglong via current Shandong to the sea during the period from the Eastern Han Dynasty (25 - 220 AD) to the first year of Jingyou of the Northern Song Dynasty (1034 AD). That segment is exactly the "Old Jingdong Watercourse." The essay located the "Old Jingdong Watercourse," presented an accurate watercourse route, and effectively positioned the previous places that the ancient Yellow River ran through, becoming a significant breakthrough in the study of historical river geomorphology in the "new era" (1978-). According to Man Zhimin, modern remote-sensing data plays a unique role in the study of historical river geomorphology. In fact, apart from the Old Jingdong Watercourse of the Northern Song Dynasty, most watercourses (Henglong, Shanghu, Beiliu, etc.) could also be traced using remote-sensing data, which provides substantial help in creating accurate descriptions of critical changes in the Yellow River channel. In the era of information, new data sources are combined with new research approaches, and fast and easy access to literature and documents is enabled. Thanks to this, academic programs with traditional themes can also boost the study of historical geography to a new height. ②

3.3 The study of town economies

Cities and towns in Jiangnan (regions around the Yangtze River Delta) during the Ming and Qing Dynasties have been much talked about by scholars focusing on the economic history of the two dynasties. Back in the 1920s-1930s, Japanese scholars had been dedicated to this academic area. In the 1950s-1960s, scholars in China's Mainland worked even harder on exploring why the seeds of capitalism in Jiangnan failed to sprout and thrive by analyzing the collected data of local counties back in the two dynasties. Since the 1980s, their research scope has been extended, with most scholars in this regard connecting urban growth to urban development. ③ For more than half a century, this study was on multiple diversions and experienced several paradigm shifts. Yet, the approach to data processing remained basically unchanged, making it difficult to generate new research ideas. After 2000, Fan I-chun, a scholar in Taiwan, China, published a series of essays in this regard, such as the "*Market Towns and Regional Development to the East of Lake Tai*

① Pan, Zhuang & Li, 2011; Pan, Man, Zhuang & Ye, 2012; Pan, Xiao & Yan, 2013; Liu & Pan, 2014; Pan, Man, Liu & Yan, 2014.
② Man, 2006.
③ Fan, 1998; Ren, 2001.

during the mid–Ming Dynasty" and [①] the "*Nature of the Expansion of the Jiangnan Market Towns during the Ming–Qing Dynasty*." [②] These essays were later included in the monograph *Traditional Market and Regional Development: A Case Study of the Regions to the East of Lake Tai in the Ming and Qing Dynasties 1551–1861*, which was published by Linking Publishing Co., Ltd. in 2005. Fan marked all market towns in different historical periods on a large-scale map of the Lake Tai region and studied the links between market-town vicissitudes and regional development. In this way, he discovered that in Jiangnan during the Ming and Qing Dynasties, only some large market towns maintained a sustained growth momentum, while the rest majority witnessed ups and downs in regional development. When it comes to the increases in market towns, the nature of the increases varies from case to case. And the regional development issue behind the increase in market towns in Jiangnan over a period of 600 years (i.e. the Ming and Qing Dynasties) is truly worth discussion and research. In fact, such an increase did not have much to do with regional urbanization. This claim is in stark contrast with the overall conclusions of previous studies on Jiangnan market towns. Fan I-chun combined the geographic information technology of geolocation with zone modeling to conduct his research. Relevant data derived through this research has been included in Chinese Civilization in Time and Space (CCTS), a system developed by Academia Sinica (Taiwan, China).

3.4 The study of rural settlements in history

In 2008 Fan I-chun published his essay, "Local Society in Late Qing Hebei as Seen in Village Maps from Two Counties," in which, through digitalization, all villages on two rare village maps (i.e. "Map of Villages in Qing County" and "Map of Villages in Shenzhou") were represented on one large-scale map. The author developed an element layer through GIS-enabled space intussusception and consulted basic documents and historical materials to study the two counties' villages & settlements layout, population characteristics, local education, temples & religions, local gentry, land distribution and bazaar structures. The author attempted to apply GIS to comprehensively analyze region-specific multi-elements and challenge the conventional view on the model of village distribution in north China in the late Qing Dynasty. Fan I-chun also studied markets and bazaars by linking them with villages and settlements and overlapping population density maps. In doing so, his essay unveiled the links between different market categories and "corresponding villages, settlements and populations," thoroughly analyzed the inherent connections among local markets, settlements and population sizes, and rectified the traditional view concluded by G. William Skinne through his related study. This proved to be an effective attempt of applying GIS to the comprehensive analysis of settlements, villages and other factors. [③]

3.5 The study of hydraulic societies in history

Hydraulic societies have become a focus of regional social history in recent years. Traditional Chinese society is agriculture based. For agriculture, water conservancy is of vital importance and is closely related to a country, local government and the public. It also directly reflects the interaction between the central and local governments. [④] In his essay, "*From Inside to Outside: the Historical Transition of the Dispute of Water Conservancy in the Irrigated Area of Hòu Cun Zùn* (1763-1945)," Li Chin-yi, a scholar in Taiwan, China, analyzed the evolution of water conservancy disputes in the Irrigated Area of Hòu Cun Zùn in the plain between the Tamsui River and Dahan River in the

① Fan, 2004.
② Fan, 2002.
③ Fan, 2008.
④ Zhang, 2012.

west of the Taipei Basin from the 28th year under the reign of Emperor Qianlong of the Qing Dynasty (1763) until 1945. The purpose of this case study was to explore the qualitative change in water conservancy disputes from a traditional society to a modern one. The author geo-located the irrigated areas and irrigation canals of the period, specified the correlations between canal head and canal segments, and completed a map of the irrigation authority's primary residences, a map of their ancestral homes and a map of all water intakes and pump stations in the hydrological system in the drainage basin, which were all marked on Google Earth. In this way, the essay explicitly exhibited the correlations between traditional and modern approaches to water conservancy development and their transitions, and analyzed the position relations among relevant factors and their correlations with the areas in water conservancy disputes to represent the spatial links between the targeted areas and relevant arguments. According to Li Chin-yi, in the era of traditional water conservancy, given that Hòu Cun Zùn was located at the end of the waterhead, it acquired the smallest volume of water intake among all the water canals in the drainage basin. That explains why the fiercest contention for water diversion took place during the dry season. And such a contention was mainly between villages/settlements and had a lot to do with the water intake model and water flow direction. In modern times (1840-1949), more large water conservancy facilities were launched. This move was mainly led by government authorities, whose protection of the irrigated areas became a focus of the dispute over water conservancy. Since then, the dispute shifted from one between/among villages to one between the common people and the government.[①] Li Chin-yi's essay explained relevant geographic concepts in a vivid and detailed way, based on solid facts, and clearly explained the water conservancy disputes with the then water environment, hydrotechnics, regional groups, etc., for which the conclusion was convincing.

3.6 The study of environmental change

The shift of focus from natural landscapes to cultural landscapes is a primary direction for future economic development and environmental improvement. In the mid-20th Century, Hou Renzhi began to study the land desertification in north China and approached it through sites of ancient cities. Thanks to his efforts, historical eremology became one of the most important areas of historical geography. In the new era, the introduction of 3S technology indicates a clearer direction for eremology research. Deng Hui, along with other scholars, conducted spatial simulation of the process of desertification in the Mu Us Desert during the Ming and Qing Dynasties, and accurately presented the cultivation and land-use patterns during that period on maps, described the use ratio of "station farms" in Yunlin Town and changes in the desert's southern border, and corresponded historical documents with photographic maps. Based on that, Deng concluded that the reclamation of wasteland by the Ming army did not result in the southward expansion of the Mu Us Desert and that its then boundary was generally the same as today's. This research is a reminder that station farms in Yunlin Town were directive, with most of them around the central and west fortresses and a few around the east fortress. The relationship between the military Wei-Suo system and the station farms was key in this regard. Besides, the land-use models also mattered. In the Qing Dynasty, the border region of Shaanxi adopted a land-use model featuring "grain planting in the south and grass planting in the north," which did help some in protecting the local ecology. These conclusions are of great significance to a better understanding of the process of environmental change in Mu Us Desert.[②] The environmental change in "water towns" of southern

① Li, 2012.
② Deng, Shu, Song & Xing, 2007; Wu, Deng & Shu, 2014; Shu, Deng & Wu, 2016.

China has become a new research direction in recent years. Substantial historical facts all indicate that the transformation of river networks in Jiangnan, along with low-lying paddy fields (surrounded with dykes) and urban development, directly resulted in local environmental change. In this regard, scholars such as Man Zhimin and Pan Wei have done a great deal of work. For example, with the help of large-scale historical maps, they represented the sediment conditions of Nanzhi Shuidao (southern part of the Yangtze Estuary) from 1861 to 1953 and the changing process of the river network density in Qingpu District, Shanghai from 1915 to 1978. They extracted map data with the analytical method of "Grids," analyzed the sandbank displacement, river network expansion/contraction and environmental changes in different periods by comparing equal-area sandbanks and river network densities, and eventually evaluated the environmental changes and corresponding mechanisms of action in "water towns" of southern China.[①] Such studies, involving expressions and simulations of changing trends, visualized the "route" of environmental changes.

3.7 The study of urban history & urban historical geography

Previous studies of urban history and urban historical geography focused on the restoration of urban looks based on historical records, attaching great importance to aspects such as position of city gates, thickness of city walls and urban size. Limited research methods and tools made it difficult for researchers in this field to further explore the historical changes in urban morphology. [②] The development of remote sensing and information technology has made it possible and easier to carry out morphological studies. In the 1990s, Li Xiaocong and Wu Honglin began to combine color-infrared photographs with historical documents to analyze the relocation process of three cities along the Yangtze River (Jiujiang, Anqing, Wuhu) since the Ming Dynasty. Following the spatio-temporal sequence of the evolution of geomorphic conditions and urban morphology, they explored the links between the gradual urban expansions and the changes in the Yangtze River channels since the Ming and Qing Dynasties.[③] Based on large-scale maps of Shanghai made in the period during1855-1900, Zhang Xiaohong made a contrastive analysis and combined it with historical documents to examine the evolutionary process of the socio-cultural space of Shanghai and thus to represent the process of urban space formation and urban management system building there.[④] Similarly, Deng Hui also made an analysis of the cultural connotations of Tongwan City, the capital of the Xia Kingdom.[⑤] Man Zhimin, based on his years-long practice of HGIS application, held that an urban area should be understood as an area covered by roads and public utilities, and that GIS technology should be extensively applied to the analysis and presentation of mass data processing and the deduction of urban expansion. Wu Junfan, a PhD candidate under Man Zhimin's supervision, did a case study of "filling rivers to build roads" in previous Shanghai. With the help of GIS technology and copies of old title deed, Wu represented the evolution process of the Shanghai transport network, from the traditional farmland landscape and riverside road system to urban road networks and thereby analyzed the process of urban expansion in Shanghai's early development period and the driving factors behind it.[⑥] Chen Li used the copies of the title deed to study the process of land-use rights

① Pan, 2009; Pan, Sun & Man, 2010.
② Cheng, 2010.
③ Li et al., 1992.
④ Zhang, 2013.
⑤ Deng, Xia & Wang, 2003.
⑥ Wu, 2008.

transfers, and analyzed and positioned the urban landscape changes prior to and at the beginning of the British Concession in Shanghai.[①] Mu Zhenyu used the same method to represent the dynamic transformation of Shanghai's French Concession area from low-lying paddy fields to urban areas.[②] These studies visualized the dynamic process of urban landscape evolution. Moreover, in recent years some scholars have also attempted to use collected urban maps of the late Qing Dynasty and the Republic of China era (1840-1949) to analyze the spatial-temporal characteristics of urban social space, class polarization and crime commitment, further exploring the internal structural changes of the cities during this time.[③]

3.8 The study and digitalization of ancient maps

As a country with a long history, China has a long-term development of topology and enjoys abundant map resources. In tradition-related research, however, the application of maps as historical resources remains limited. Making full use of maps to provide clearer spatial information for historical research is of great significance to the abovementioned researches. In this regard, GIS technology has an exceptional advantage. In 2004, Lay Jinn-guey, along with other scholars in Taiwan, China attempted to develop a "Territorial Map of Taiwan" and studied it from a perspective of spatial cognition. Compiled in the late Qing Dynasty (1878), the "Territorial Map of Taiwan" is a grid map system composed of latitude and longitude lines. It was made in the context of the Qing imperial government's implementation of its "Kai Shan Fu Fan" policy (development of remote mountainous regions & pacification of ethnic tribes) and tightening of its administrative control of Taiwan. Prior to that, or rather during the era from Emperor Kangxi to Emperor Qianlong, the Qing imperial government had completed latitude and longitude measurements of over 600 locations across China, of which seven were in Taiwan (Penghu Islands, Taiwan Prefecture, Fengshan County, Shama Jitou, Zhuluo County, Tamsui Town and Jilong). Yet, only a limited number of spots were measured. Besides, the spatial relationships among those spots were identified based on accumulated experience and accepted knowledge, for which the compiled map was significantly different from the contemporary version. Lay Jinn-guey and his fellow researchers had this map scanned, positioned and digitalized, and converted its coordinate system. Subsequently, they placed it over a contemporary map of Taiwan to de-construct its value of space utilization from a perspective of spatial cognition. According to Lay, previous researches failed to "translate" the ancient map into a historical map in a contemporary map-drafting norm. The introduction of GIS technology enables the normalization of geographic information maps in different standards and makes it possible to make quantitative analyses of some ancient maps. This can help decipher the scientific components of ancient maps, analyze the then people's spatial recognition processes and degree, extract useful information, enrich history studies, and extend the scope of research.[④] This research direction has become a highlight of history studies in the new era, with territorial maps, urban maps and cadastral maps all included in scholars research scope.[⑤] Furthermore, the approaches to the digitalization of actual measurement-based maps and large-scale maps are constantly improving. Scholars in this field have developed rules regarding the digitalization of the actual

① Chen, 2010.
② Mu, 2012.
③ Wang & Zhu, 1999; Wei, Yan & Liu, 2008; Zhang & Sun, 2011; Yang, 2015.
④ Lay, Huang & Shih, 2004, pp. 253–271; Lay, Huang & Yap, 2005, pp. 47–67.
⑤ Wang, Song & Zhou, 2000; Gong, Qi & Xia, 2014; Han, 2015; Han, 2016; Wang, 2011; Jiang, 2013.

measurement-based maps and the 1:50,000-scale and 1:100,000-scale digital maps and thus created a new method for the application of historical maps to the analysis of historical materials.[①]

3.9 Approaches to the digitalization of historical geographic information

In terms of research groups, HGIS is no longer exclusive to scholars of historical geographers and it now also benefits increasing research in regional history, urban history and archaeology. Still, from a perspective of disciplinary development, historical geographers remain the primary subject of this study. Historical geography is essentially a branch of geography. In recent years, GIS has become an indispensable technological means in information acquisition, analysis & processing, achievement exhibition, etc. The development of this academic subject requires relevant practitioners to improve the accuracy of the study of historical geography, integrate data of historical nature with that of humanity, and advance the "virtual expression" of historical geographical environment-related information. Compiling digitalized historical maps and building CHGIS has brought the study of Chinese historical geography to a new height.[②] The digitalization of historical geography-related information concerns an extensive scope ranging from administrative division, population, economics, land use, nationality and religion, to culture. Such historical geography-related information is mainly retrieved from available ancient Chinese historical records, which were limited, unsystematic and descriptive. Whether such historical records can be transformed to useful geographical information is primarily determined by the adoption of a proper approach. Regarding this issue, scholars in this area have made a series of attempts over the years and provided many available approaches.[③] The "Grids" for small area studies, which was proposed by Man Zhimin, is especially recommendable. The "Grids" is now a major approach to the standardized processing of spatial data in the geographical world. This system divides a geographic interface into different sized grids to acquire the level and density of elements with an equal area, expose density differences among elements with an equal area, and thus evaluate the land-use degree and level in different regions. Man Zhimin took Shanghai as an example to clarify his point. According to Man, the analysis of the historical process of land use in the area of Shanghai requires a comparison of three types of thematic data, i.e. drainage characteristics, settlement changes and urban evolution. The three different special topics correspond with three carriers, namely, network of rivers, settlements and urban built-up areas/streets, which respectively fall into the categories of point, line and plane in GIS spatial data. This is followed by summarization and comparison in the same spatial scale. This involves a unified basis of comparison, which in nature is a matter of standardized data processing. According to Man Zhimin, the "Grids" has the advantageous capacity of holding multi-source data and standardizing and transforming historical data to same-level space. This brings a huge convenience for researchers to unveil the spatial form covered by the earth's surface and is also a most feasible approach to the description of the spatial process of the man-land relationship in a small area.[④] Previous regional researches were seldom down-to-earth and accurate calculations were almost impossible. This is exactly the challenge that the "Grids" approach can help to tackle. The application of the approach enables spatial quantification of the methods and process of resource utilization and improves the spatial and

① Lu, Han, Zhu & Qian, 2011.; Pan, Sun & Man, 2010; Jiang, 2015.
② Ge, 2002.
③ Wang & Chen, 2001; Man, 2002; Wang, Chen & Yuwen, 2003; Wang, Wang & He, 2007; Lin, Zheng & He, 2008.
④ Man, 2008.

regional accuracy of research on the man-land relationships in different historical periods.

GIS is also extensively applied to other history-related studies, such as archaeological site orientation,[①] Dunhuang documents and geographical space, [②] study on historical populations, [③] study on epidemic diseases [④] and disasters in history[⑤], study on religions,[⑥] and study on land use and cadastral management.[⑦] GIS has now become an important tool to the study of Chinese history, extensively applied and promoted by researchers in archaeology, historical geography and regional social history.

4. GIS Value to the Study of Chinese History & Its Development Bottlenecks

GIS is a combination of computer technology with spatial data and facilitates the improvement of history study models and the reform of historical ecology. In this sense, it initiates a disruptive change to history study. Most of the above cases were innovative attempts in research methods and interpretation tools, which nevertheless prove that GIS application has helped to tackle many problems which would have been impossible with traditional research methods. GIS has arguably changed the study of Chinese history in an all-round way and therefore its contribution shall not be ignored. Then here come two questions. How is it valued as a brand-new technology and how should relevant scholars cope with such a reform?

4.1 Four significant changes brought about by the application of GIS to the study of Chinese history

The first change lies in research methods. GIS is a research method, as well as a technological tool. As a computer-based technology, it inevitably requires standardized language which can be recognized and analyzed by computer. China, known for being a country with a long history, has a tremendous amount of historical records and materials, which, however, mostly consist of narratives and lack supporting statistical figures. Consequently, the study of traditional history in China is primarily qualitative research-based; and quantitative analysis has seldom been a preferred choice partly due to its inconvenient practice. As mentioned above, the application of GIS to the study of Chinese history first requires data quantification. More specifically, traditional Chinese records and materials should be transformed to a whole set of standardized data to identify their spatial properties, form graphic data and attribute data, and create spatial databases. The application of GIS to the study of Chinese history, which involves analyses and comparisons of various materials and data digitalization, is only the first step. After that, more methodological issues, which were previously unimaginable, come one after another (how to determine the standard of historical period measurement; how to properly conduct spatial orientation; how to determine the principles of "point, line, surface" representation; etc.). The CHGIS was jointly developed by the Center for Historical Geographical Studies of Fudan University and Harvard University. Its major contribution lies in the introduction and application of 'place names' "life cycles," which is

① Nishimura & Kitamoto, 2016.
② Rong, 2016.
③ Lu, 2012; Lu, 2014; Lu, 2015; Jiang, 2015.
④ Gong, 1993; Gong, Wang & Zhang, 2014.
⑤ Kong, Li & Chen, 2017.
⑥ Chen, 2010.
⑦ Zhao, 2005.

now extensively accepted among scholars in this field.[①] With the continuation of the HGIS platform development, such new attempts and standardized research models will keep emerging.

The second change lies in the diversification of research materials. The application of GIS to the study of Chinese history requires spatial orientation of historical materials. Research materials incorporate digitalized ancient maps, large-scale maps, remote-sensing images, gazetteers, positionable archaeological sites and even photos plates, which are combined to significantly enrich data sources for history study and form a historical data diversity-enabled research approach. Judging from the abovementioned essays and works, none of the research findings, which were derived from GIS application to the study of Chinese history, is solely based on document materials. In fact, basic historical documents only form part of their resources and some previously overlooked or excluded materials (remote-sensing images, large-scale maps, gazetteers, old photos plates, etc.) have become indispensable in support of this study. Moreover, these recently valued materials give rise to new research directions such as the digitalization of historical maps and image history.[②] The creation of historical place name databases has also been placed on the agenda and historical toponymy is valued. These new research areas keep enriching the study of Chinese history, creating an unparalleled academic diversity and bringing about an unprecedented academic impact.

The third change lies in analysis methods. The analysis method changes are mainly reflected by two aspects. One is the dynamic tracking of historical events. History study attaches great importance to timelines. It tends to target a particular event during a certain period of history, analyze its occurrence, contributing factors and the intrinsic mechanism of social reform, and explore its origin and transition. Dynamic space tracking can hardly be done. The longer the space-time span is, the more difficult this tracking becomes, for which this is almost a mission impossible at the local level. Although GIS technology was not originally developed to assist the study of Chinese history, it enjoys an absolute edge in facilitating the dynamic tracking of historical processes. The first step of this application is to identify the start-time and end-time of an event. For example, relevant researchers may need to determine a traffic route's construction time and diversion time, an administrative seat move's start-time and end-time, as well as how urban morphology has been shaped so far. Those dynamic processes can all be presented in the form of timelines supported by the HGIS platform to enable long-term historical tracking.

Analysis method change is also reflected in the comprehensive analysis of multiple factors. The process of a historical event is determined by multiple factors, such as land reclamation, population migration and settlement development, all of which take place in a particular natural or social environment. That is why comprehensive analysis of multiple factors is emphasized in the study of history and serves as an effective means of explaining complicated historical processes. Previous studies seldom truly integrated a variety of humanistic elements with the natural environment, for it was difficult to do so. Now GIS application allows scholars to transform historical data in accordance with space-time coordinates and map orientations, analyze

① Throughout the Chinese history, the administrative division has witnessed numerous changes by means of creation, revocation, rank promotion, administrative seat move, border adjustment, etc. Each of those changes was reflected both by time and space, developing a process and results of continuous changes in a particular administrative division within a certain period of time. The concept of "life cycle" in CHGIS refers to the extraction of a state of being's start–time and end–time to describe all the changes in administrative division happening in that particular time–space dimension on the premise that "administrative division change" is already defined.

② Zhang, 2014; Wu, 2014.

multiple factors through map-layer overlapping, discover spatial relationships difficult to be identified with traditional methods of historical data analysis, and develop new research perspectives and views. Furthermore, researchers can conduct spatial statistical analysis based on available quantifiable historical data and thus push the limits of the traditional study of quantitative history. Such research can truly represent the process of history at a local level and shift the focus of Chinese history study from space to specific regions. No longer restricted by insufficient historical records on region-dependent segmentations, relevant researchers use basic economic areas in different historical periods as research units and make comparative studies of core areas and peripheral areas.

The fourth change lies in the upgrade of research philosophy. So far, GIS development has experienced three stages, i.e. geographical information system, geographical information science and geographical information service. When it comes to GIS application to the study of Chinese history, the whole journey so far has undergone computer-aided drafting (CAD) to model analysis, and then to today's upgraded research philosophy. This process is under the influence of increasingly advanced computer software and hardware and accords with the technological requirements of GIS as a research method. The application of GIS to the study of Chinese history brings about changes in its research method, analysis method and historical data use, which are combined to deliver an impact on relevant scholars' ways of thinking, forcing them to review such a transformation through a brand new perspective. In such a context, data extraction becomes more delicate; element expression becomes more accurate; historical data is truly integrated with geographical environment and landscape features facilitating a virtual expression of earth in history analysis and transforming previous descriptions of spatial indications and basic tendencies of historical maps. While setting higher standards for academic research in this area, this brand-new perspective is introduced to subvert previous research findings, draw fresh conclusions and develop an incentive for academic progress.

4.2 The development bottlenecks facing the application of GIS to the study of Chinese history

GIS technology is of great significance to the study of Chinese history. Yet its application to this area remains limited, which is beyond any doubt. There are many constraints which can be roughly placed into two categories.

The first category is the existence of a disciplinary boundary. The application of GIS to the study of Chinese history can only be done by highly competent scholars. First, researchers must have a profound knowledge of history study, acquire proper research approaches to Chinese history, and have a thorough understanding of Chinese historical documents. They must be good at extracting valuable data from a sea of historical materials to serve their research purposes, well aware of the core issues in the study of Chinese history, and have a definite object in view. At present, researchers in this regard are mainly scholars of history, geography and historical geography, with different academic focuses and academic backgrounds. Accordingly, their approaches to historical data vary. Whatever approach they take, the accuracy of their extracted data matters most, for it directly concerns the reliability of their conclusions and thus influences the academic quality of their research findings. Judging from the existing academic achievements so far, many research conclusions fail to convince scholars of Chinese history mainly due to the careless processing of historical data.

Second, researchers must also acquire GIS technology. Of course, they can also choose to cooperate with relevant technicians, and this can be just as effective. Even so, learning about GIS technology and

acquiring the basics is still essential. In China's Mainland, GIS application is not that extensive in the study of Chinese history, with few related courses offered by departments of history in colleges and universities. This reality, along with limited interdisciplinary attempts, restricts scholars of history from applying this technology. This is in contrast with the situation in Taiwan, China, where GIS-related courses are already offered by the departments of history in local colleges, universities and research institutions. Those without this course regularly host related workshops to popularize GIS among students of history. For example, workshops aiming to apply GIS to the study of humanities have been successively hosted by Academia Sinica, National Taiwan University, National Changhua University of Education, National Dong Hwa University and Soochow University (SCU). And GIS-related courses are offered by following Taiwan-based institutions and universities: Graduate Institute of History, National Chuanghua University of Education; Digital Archives and Application, National Chung Hsing University; Department of History, Soochow University; Department of History of NTPU; Department of Taiwan and Regional Studies, NDHU; Department of History and Geography, University of Taipei; Department of Culture and Natural Resources, National University of Tainan (NUTN). According to Li Chung-hsin and Ku Ya-wen's statistics, there are more than 200 GIS-enabled essays on Taiwan regional history published over the past two decades. These essays were mainly about three major topics, namely, ethnic groups and land ownership, water conservancy research and religious activities. They have significantly boosted the development and study of Taiwan's regional HGIS and played an exemplary role in terms of methodology. The departments of history in Chinese colleges and universities should offer related elective courses to enable future scholars of history to truly understand and apply this technology. This is also an important approach to GIS development.

The second category is a lack of a basic GIS platform for the study of Chinese history. As is known, the study of space and regions cannot be performed without a historical map. This same is also true of HGIS applications, to which a basic platform of historical geographical information is crucial. Yet, such platforms are in dire need in China's Mainland. The CHGIS, jointly developed by the Center for Historical Geographical Studies of Fudan University and Harvard University, primarily aims to grow into an open platform of maps and data that shares historical data, archives, statistics and images with academic circles. [①] So far, however, only part of the database concerning administrative divisions has been completed. There is still a long way to go before the original vision can be realized. Domestic achievements and efforts in this regard are as follows: "2010 Beijing HGIS program" chaired by Tang Xiaofeng (College of Urban and Environmental Sciences, Peking University); "2012 Atlas of the Qing Dynasty History", a major program funded by the National Social Sciences Fund and chaired by Hua Linfu (Renmin University of China); the Atlas of Epidemic Disasters in Chinese History program chaired by Gong Shengsheng (College of Urban & Environmental Sciences, CUES). These programs all enjoy corresponding special geographical information databases. And, There are also the "2013 Atlas of Chinese Agricultural History," a major program funded by the National Social Sciences Fund and chaired by Han Maoli (College of Urban and Environmental Sciences, Peking University), with its corresponding geographical information database still under construction; the "2014 Silk Road-themed Historical Geographic Information System Construction", a major program funded by the National Social

① Ge, 2002.

Sciences Fund and chaired by Zhang Ping (School of History, Capital Normal University); and the "2015 Basic Information Platform for Modern and Contemporary Administrative Divisions of China 1912-2013", a major program funded by the National Social Sciences Fund and chaired by Zhou Zhenhe (Center for Historical Geographical Studies of Fudan University and Harvard University). Most of these are on-going programs and are yet to have their data released.

It has been some 30 years since the initial application of GIS to the study of Chinese history. As an analysis tool and research means, GIS is beginning to deliver results which is universally recognized. At this stage, joint wisdom and efforts are needed to make it more useful to historians and scholars of history. A tough and lasting task as this may be, it is worth a try because of GIS' advantages in settling complicated historical issues. Many scholars who are closely following the latest academic developments have consciously or unconsciously applied GIS to the development of data resources and creation of HGIS databases, with increasing support from the Central Government. The author believes that the scope of GIS applications will be constantly expanded and that its prospects will be even more promising. The completion of creating geographically-dispersed databases shall of course not be deemed mission accomplished. Relevant scholars then should think about more upcoming issues (how to centralize those GI databases, how to further introduce standardized processing of relevant data, how to build an online platform to share such data with most researchers, how to promote the digitalization of history study, etc.) There is still a long way to go and further exploration is needed. Judging from present conditions, the existing promotional means are far from efficient and the popularization of GIS applications was not quick enough. These problems need to be further analyzed and addressed.

REFERENCES

Chen Chiu-kun. (2010). Landlord, religious organization and dispersion of lower Danshui tribe in Wandan region of Pingtung Plains (1720-1900). *Taiwan History Research*, (3).

Chen Li. (2010). *Urban and Rural Landscape Changes in Modern Shanghai (1843--1863)--Based on the data processing and analysis of Shanghai title-deed archives*. (PhD dissertation). Fudan University, China.

Cheng Yinong. (2010). A review of studies on urban morphology in ancient China. *Journal of Chinese Historical Studies*, (1).

Deng Hui, Shu Shiguang, Song Yuqin & Xing Fulai. (2007). The changes in the south boundary of quicksand distribution in Mu Us Desert. *Chinese Science Bulletin*, (21).

Deng Hui, Xia Zhengkai & Wang Bengyu. (2003). The application of color-infrared photographs to the further study of Tongwan city. *Chinese Archaeology*, (1).

Fan I-chun. (1998). The study of Ming-Ch'ing market towns in the lower Yangtze delta: A review. *New History*, 9(3).

Fan I-chun. (2002). The nature of the expansion of the Jiangnan market towns in the Ming-Qing Dynasty. *Bulletin of the Institute of History and Philology Academia Sinica*, 73(3).

Fan I-chun. (2004). Market towns and regional development to the east of Lake Tai during the mid-Ming Dynasty. *Bulletin of the Institute of History and Philology Academia Sinica*, 75(1).

Fan I-chun. (2008). Local society in late Qing Hebei as seen in village maps from two counties. *New History*, (1).

Ge Jianxiong. (2002). Map of Chinese history: from tradition to digitalization. *Historical geography, 18*. Shanghai: Shanghai People's Publishing House.

Gong Shengsheng. (1993). A preliminary study on variations of the distribution of Zhang-disease for the past 2000 years in China, *Acta Geograhica Sinica*, (4).

Gong Shengsheng, Wang Xiaowei & Zhang Tao. (2014). A geographic study of epidemic disasters of Jiangnan area in the Ming Dynasty (1638-1644). *Geographical Research*, (8).

Gong Zeyi, Qi Qingwen & Xia Xiaolin. (2014). Research on evolution of Chinese modern urban system. *Science of Surveying and Mapping*, (8).

Goodchild M. F. (February 25, 2018). Geographic information systems and science: today and tomorrow. *Annals of GIS*, 15(1).

Han Zhaoqing. (2015). Huangyu Quanlantu of the Kangxi-reign and its impact on Western recognition of the territory of the Qing China. *Journal of Tsinghua University (Philosophy and Social Sciences Edition)*, (6).

Han Zhaoqing. (2016). The digitization of Kangxi complete atlas of imperial territories and its significance for the study of environmental change and historical geography. *The Qing History Journal*, (4).

Jiang Weitao. (2013). The cadastration in the period of Nanjing national government and its evaluation--A discussion of different kinds of land data in the Republic of China. *Journal of Chinese Historical Geograph*, 2.

Jiang Weitao. (2015). Research on urban population of Jiangnan in the Republic of China: Base on GIS and the data of topographic maps. *Researches in Chinese Economic History*, (4).

Kong Dongyan, Li Gang & Chen Hai. (2017). Spatial-temporal characteristics and environmental background of locust plague in Beijing-Tianjin-Hebei region during the Ming and Qing Dynasties. *Journal of Palaeogeography*, (2).

Lay Jinn-guey, Huang Ching-Chi & Shih Ya-Hsuan. (2004). Quantitative analysis of 1878 Taiwan Qian-Hou-Shan Map. *Essay collection of the first symposium on geographical names (Taiwan, China)*.

Lay Jinn-guey, Huang Ching-chi & Yap Ko-hua. (2005). Exploring the spatial cognition in early maps: A case study of the "Territorial Map of Taiwan" 1878. *Journal of Geographical Sciences*, (42).

Li Chin-yi. (2012). From inside to outside: the historical transition of the dispute of water conservancy in the irrigated area of Hòu Cun Zùn (1763-1945). *Baisha Journal of GeoHistory*, (2).

Li Xiaocong, et al. (July 1992). The application of color-infrared photographs to the study of urban historical geography--A case study of the links between cultural landscape evolution and river-channel change in the cities of Jiujiang, Wuhu and Anqing along the Yangtze River. *Journal of Peking University (Special Issue of Historical Geography)*.

Lin Shanshan, Zheng Jingyun & He Fanneng. (2008). The approach for gridding data derived from historical cropland records of the traditional cultivated region in China. *Acta Geograhica Sinica*, (1).

Liu Huan & Pan Wei. (2014). The initial time of the rainy season on the Loess Plateau during 1766-1950 and its response to the summer monsoon. *Journal of Earth Environment*, (6).

Lu Junwei, Han Zhaoqing, Zhu Xuanlin & Qian Hao. (2011). A statistical analysis on the projection type applied in Huang Yu Quan Lan Tu. *Science of Surveying and Mapping*, (6).

Lu Weidong. (2012). The distribution of Hui people's settlements in Shaanxi-Gansu areas and the related database construction before the Tongzhi reign of the Qing Dynasty. *Northwestern Journal of Ethnology*, (4).

Lu Weidong. (2014). A research on the small probability events with tiny population base under GIS--Case study on scale and spatial distribution of Chin-shihs from Hui ethnic group in Qing Dynasty. *Journal of Hui Muslim Minority Studies*, (2).

Lu Weidong. (2015). Spatial distribution of Hui Muslim Chin-shihs and population during the Ming and Qing Dynasties. *Journal of Beifang University of Nationalities*, (2).

Man Zhimin. (2006). A study of the Old Jingdong Watercourse of the Northern Song Dynasty. *Historical Geography, 21*. Shanghai: Shanghai People's Publishing House.

Man Zhimin. (2000). Climatic background of the severe drought in 1877. *Fudan Journal (Social Sciences Edition)*. (6).

Man Zhimin. (2002). Digitalization: Some concepts and methods of Chinese HGIS. *Historical Geography*, 18.

Man Zhimin. (2008). Spacial and temporal data structure for local study. *Journal of Chinese Historical Geography*, 4.

Mu Zhenyu. (2012). *From a landscape of weeds and fisherman's songs to oriental Paris: A study on the spatial process of urbanization in Shanghai's French Concession in modern times*. Shanghai: Shanghai Bookstore Publishing House.

Nishimura Yoko & Kitamoto Asanobu. (2016). Re-identify ancient ruins on the Silk Road and establish ruins database. *Journal of Shaanxi Normal University (Philosophy and Social Sciences Edition)*, (2).

Pan Wei. (2009). Reconstruction of erosion-deposition in Yangtze River Estuary south branch and related problem study, 1861-1953. *Journal of Chinese Historical Geography*, 1.

Pan Wei; Man, Zhimin; Liu, Dawei & Yan, Tingxia. (2014). The changing of Chinese coastal typhoon frequency based on historical documents, 1644-1911 AD, *Geographical Research*, (11).

Pan, Wei, Man Zhimin, Zhuang Hongzhong & Ye Sheng. (2012). Onset of flood season in the middle reach of Yellow River, Qinhe River and Yongding River and summer monsoon strength in the Qing dynasty. *Advances in Water Science*. (5).

Pan Wei; Sun Tao & Man Zhimin. (2010). The grid methods of drainage density data reconstruction in big river delta--Based on the case of Qingpu, Shanghai, 1918-1978 A.D. *Journal of Chinese Historical Geography*, 2.

Pan Wei, Xiao Lingbo & Yan Fangfang. (2013). The study of the relationship between PDO and the streamflow of Yongdinghe River (Lugouqiao) since 1766 AD. *Journal of Chinese Historical Geography*, 1.

Pan Wei, Zhuang Hongzhong & Li Zhuolun. (2011). Reconstruction of the precipitation (May-Oct) in the upper and middle reaches of the Yellow River (1766-1911). *Journal of Earth Environment,* (1).

Ren Fang. (2001). A 20th century study of the market town economy in the Ming and Qing Dynasties. *Historical Research*, (5).

Rong Xinjiang. (2016). A view of the historical-geographic information of the ancient Gaochang in terms of the unearthed documents in Turpan. *Journal of Shaanxi Normal University (Philosophy and Social Sciences Edition)*, (1).

Shu Shiguang, Deng Hui & Wu Chengzhong. (2016). The temporal and spatial distribution of settlements in the area along the Great Wall in Yansui Town during the late Ming Dynasty. *Geographical Research*, (4).

Wang Daxue. (2016). The construction and application of national GIS in international academic circles: reality and inspirations. *Journal of Jiangsu Normal University (Philosophy and Social Sciences Edition)*, (3).

Wang Jun & Chen Xiangdong. (2001). The construction of population database of the Han Dynasties and its GIS application. *Science of Surveying and Mapping*, (3).

Wang Jun & Zhu Gongwu. (1999). A preliminary study of the social geography of Beijing during the late Qing and the early Republican Period. *Acta Geographica Sinica*, (1).

Wang Jun, Chen Xiangdong & Yuwen Zhong. (2003). GIS data processing of historical records--The case of the Qing Dynasty in Shaanxi. *Geo-information Science*, (1).

Wang Jun, Song Donghu & Zhou Rong. (2000). The research and application to some old maps of Beijing in the end of Qing Dynasty and Republic of China. *Progress in Geography*, (1).

Wang Jun, Wang Hong & He Fanneng. (2007). Design and application of the historical county level administrative GIS database--a case of Shaanxi in Qing dynasty. *Science of Surveying and Mapping*, (4).

Wang Yifan. (2011). *Geographic Surveying and Mapping in the Late Qing Dynasty: A study of Kangxi complete atlas of the Qing empire (PhD dissertation)*. Center for Historical Geographical Studies of Fudan University, China.

Wei Lihua, Yan Xiaopei & Liu Yuting. (2008). The socio-spatial structure of Guangzhou in the Qing Dynasty. *Acta Geographica Sinica*, (6).

Wu Chengzhong, Deng Hui & Shu Shiguang. (2014). The study on the land development process in the border area between Shaanxi and Inner Mongolia. *Geographical Research*, (8).

Wu Junfan. (2008). *From Region of Rivers and Lakes to Metropolis: The urban road system evolution and environment of modern Shanghai (1843-1949)*. (PhD dissertation). Fudan University, China.

Wu Xuebin. (September 12, 2014). The emergence of image history fever. *Chinese Social Sciences Today*.

Yang Xiaoguang. (2015). *A study of the time-space of crime commitment in the city of Shanghai in the late Qing Dynasty (1864—1905)* (1864—1905)). (PhD dissertation). Fudan University, China.

Zhang Gong. (September 12, 2014). Image history: Discovering history from images. *Chinese Social Sciences Today*.

Zhang Junfeng. (2012). The study of the social history of water conservancy in China: From a theoretic perspective. *Historiography Quarterly*, (2).

Zhang Xiaohong & Sun Tao. (2011). Urban space production: Urbanization of Wujiaochang Area in Jiangwan Town of Shanghai in 1900-1949. *Scientia Geographica Sinica*, (10).

Zhang Xiaohong. (2013). Urban maps in modern China and its application to the urban spatial study of the earliest British Concession in Shanghai. *Historical Geography, 28*. Shanghai: Shanghai People's Publishing House.

Zhao Yun. (2005). *Land Use and Its Incentive Mechanism in Jiangsu and Anhui (1500—1937)*. (PhD dissertation). Fudan University, China.

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