

Ministry of Education and Science of Ukraine
V. N. Karazin Kharkiv National University
School of Mathematics and Computer Science
Department of Theoretical and Applied Informatics

Qualification work

Master

On the topic: Big Data Approaches for Sustainable Development on the example of drinking water problems in specific regions

Done by: 2-th year student, group MCS64
specialty - Computer Sciences and
Information Technologies,
educational program: "Informatics"
REN PENG
Supervisor: Natalya Kizilova
Reviewer: Volodymyr Khalturin

Kharkiv, 2024

Contents

List of Figures	1
List of Tables.....	1
1. Introduction	1
2. Literature Review	5
3. Research Design.....	9
3.1 Research Model	10
4. Overview of Chengdu and its Water Resource.....	11
4.1 Socio-economic of Chengdu	13
4.2 Agriculture of Chengdu	13
4.3 Industry of Chengdu.....	14
4.4 Water Resources of Chengdu	15
4.5 Surface Water Resource	15
4.6 Groundwater Resources of Chengdu.....	17
4.7 Total Amount of Water Resources	17
4.8 Water availability	18
4.9 Current Condition of Water Resources Development and Utilization in Chengdu	20
4.10 Water Usage Analyzing of Chengdu.....	20
4.11 Analysis of Drinking Water Consumption and Trends in Chengdu.....	23
5. Analysis of Changes in Drinking Water Consumption.....	25
6. Discussion.....	27
7. Conclusion.....	30
References.....	34

List of Figures

Figure 1. The research model of the thesis

Figure 2. Administrative divisions and Water Resource Map of Chengdu

Figure 3. Rainfall Contour Plot 2022, Chengdu

Figure 4. Contour Plot of Annual Precipitation from the Average, 2022, Chengdu

List of Tables

Table 1. The total amount of water resources in Chengdu, 2022

Table 2. Surface Water, Groundwater and Other Water Sources in Chengdu, 2022

Table 3. The composition of surface water supply in Chengdu, 2022

Table 4. Water supply of Chengdu Administrative District, 2022 (Unit: million m³)

Table 5. Water Consumption of Chengdu Administrative Districts, 2022 (Unit: million m³)

Table 6. Chengdu's population growth from 2000 to 2022 (Million)

1. Introduction

Water is essential for human survival and is a key element in the sustainable growth of the national economy, playing an indispensable role in both daily living and production. Water resources are finite, with about 0.26% of the total freshwater available for human utilization, rendering water scarcity a global issue (Mishra, 2023). At the inaugural United Nations Conference on Environment and Development in 1972, it was forecasted that the subsequent issue following the oil crisis would be the water problem. In 1988, the World Commission on Environment and Development (WCED) asserted that water is supplanting oil as the primary issue precipitating global crises (Grubb et al., 2019). The International Symposium on Water in 2000 highlighted that water is not solely an environmental concern, but also a social and political one, in light of international disputes over this resource. The World Water Development Report published by the Fourth Water Forum in 2006 indicated that global water supply increased sixfold in the 20th century, outpacing population growth by a factor of two. Additionally, 1.1 billion individuals lacked access to sufficient water, while 2.6 billion were unable to secure water sanitation, exacerbating the water crisis (Connor, 2015).

Despite China's ample total water resources, per capita availability is limited. In 2012, China's per capita water resources were merely 2,100 m³, constituting 28% of the global per capita average, so designating it as one of the most water-scarce nations acknowledged by the United Nations (Koncagül, 2015). The spatial and temporal distribution of China's water resources is markedly uneven, exhibiting significant annual variations and substantial disparities between the southern and northern regions. Moreover, China faces significant issues of water contamination, inadequate water delivery infrastructure, and substantial waste of water resources. Statistics indicate that the yearly industrial loss in metropolitan areas, attributed to water supply shortages, totals 120 billion yuan, with pollution-related losses representing 6 percent of the state's fiscal revenue for that year (Chen, 2020). The efficient and swift advancement of urban water supply directly influences the sustainable growth of China's national economy.

The National Comprehensive Water Resources Plan identifies 470 cities facing diverse water supply issues, comprising 111 cities with excessive shallow groundwater extraction, 61

cities with unsustainable deep groundwater, 193 cities experiencing ecological water use displacement, and 402 cities with inadequate water supply (中华人民共和国国家发展和改革委员会, 2020). In numerous regions of China, water resources have emerged as a critical determinant in the magnitude and functional allocation of urban development. Simultaneously, China's urbanization will progressively intensify; the sixth national census conducted in 2010 indicates that the urban population in China is 665.57 million, or 49.68% of the total population. Conversely, by 2030, the configuration of China's three primary industries will undergo additional modification, and the anticipated rise in China's demand for freshwater resources would predominantly manifest in industrial and domestic water, namely in urban water supply (中华人民共和国国家发展和改革委员会, 2020). The issue of urban water pollution is increasingly severe, imposing significant pressure on the safety of inhabitants' drinking water. In the 21st century, the correlation between social and economic development and water utilization will intensify, making the optimization of urban water use a critical issue in urban development.

Chengdu, the capital of Sichuan Province in China, is situated in the western region of the Sichuan Basin and serves as a prominent economic, cultural, technological, and financial hub of western China. Chengdu is a city characterized by a profound historical and cultural legacy, plentiful natural resources, and a dynamic contemporary economy. As of 2023, Chengdu has a resident population of approximately 20 million, positioning it among the cities with the greatest populations in China (Zuo et al., 2024). Chengdu is the largest and most appealing city in Sichuan Province, experiencing a significant annual migration of migrants. Chengdu holds a significant economic position in western China. Chengdu's economic output ranks among the highest in the western area, with its GDP in 2023 nearing 2 trillion yuan (Hu, 2024). The economy is primarily bolstered by contemporary manufacturing, electronic information, automobile production, aerospace, food and beverage, and financial services, while also enhancing the development of high-tech industries and fostering an ecosystem of innovation and entrepreneurship in recent years. Chengdu possesses ample water resources; yet, urbanization has led to a yearly increase in residential water usage. The Chengdu Municipal Water Bureau reports a gradual increase in water consumption among people in Chengdu in recent years. In 2023, home water consumption in Chengdu will represent around one-third of the city's overall water usage (Jia et al., 2023). The domestic water in Chengdu can be classified

into the following categories: Domestic water include drinking water, bathing, cooking, cleaning, and other daily activities. The daily water consumption of inhabitants constitutes the primary factor of water usage. Utilization of water in industrial applications: Despite Chengdu's substantial industrial water supply, the ratio of residential to industrial water remains generally balanced. Agricultural water utilization is primarily concentrated in suburban and adjacent rural regions. As urbanization accelerates, the percentage of water utilized for agriculture is steadily declining.

The utilization of water and its variations significantly influence urbanization over the long run. This paper primarily examines the relationship characteristics between various stages of the urbanization process and water use in the urban development process of Chengdu. It identifies the interaction and law between them, provides quantitative results, and subsequently establishes a model of the appropriate scale of urban development based on the analysis results. The model is based on the use of big data to promote the sustainable development of residents' water consumption. The optimal scale of urban expansion, considering the coordinated advancement of urban areas and water utilization, has been determined. This holds substantial theoretical and practical importance for harmonizing the interplay between social and economic development and water resources, hence achieving sustainable urban development. Simultaneously, it offers a rational and efficient foundation for decision-making within the management department, thereby mitigating potential water issues that may arise during urban development and facilitating the sustainable utilization of urban water resources.

1.1 Big Data Definition

In many fields, scientists often encounter limitations and obstacles in analytical processing due to the excessive size of data sets; These areas include meteorology, genomics, neural network omics, complex physical simulations, and biological and environmental studies. Such limitations also have implications for web search, finance, and economic informatics. As big data is increasingly mentioned, some exclaim that the era of big data has arrived, as a 2012 New York Times column wrote that the era of "big data" has arrived, and decisions in business, economics, and other fields will increasingly be based on data and analysis, rather than on

experience and intuition. But not everyone is interested in big data, and some even think that it is a buzzword used by business schools or consulting firms to sensationalize, which seems novel, but it is just a repackaging of tradition, and it has been supported by massive data in academic research or policy decision-making, and big data is not a new thing. Big data is made up of huge data sets that are often larger than humans can collect, use, manage, and process in an acceptable amount of time. The size of big data changes frequently, and as of 2012, the size of a single data set ranged from terabytes (TB) to terabytes (petabytes). In a 2001 research and related presentation, Doug Laney, an analyst at the META Group (now Gartner), pointed out that there are three directions to the challenges and opportunities of data long: volume, velocity and variety, collectively referred to as "3Vs" or "3Vs". Gartner, along with most companies in the big data industry, continues to use the 3 Vs to describe big data. Gartner revised its definition of big data in 2012: "Big data is a high-volume, high-speed, and/or dynamic information asset that requires new ways of processing to enable greater decision-making, insight, and optimization." In addition, there are institutions that define the fourth V: Veracity as the fourth characteristic in addition to the 3Vs. Big data must be statistical, compared, and analyzed by computers to obtain objective results. The United States began to work on big data in 2012, and Obama invested \$200 million in the development of big data in the same year, emphasizing that big data will be the future oil in the future. Big data analysis is generally analyzed from three aspects: data capacity, data rate, and data format, and there are many big data analysis methods, and selecting the appropriate data analysis method according to the specific data analysis type plays an important role in improving the efficiency of data analysis (Liu, 2019). Data mining is about how to parse big data. Big data requires special technologies to efficiently process large amounts of data that tolerate elapsed time. Technologies for big data, including massively parallel processing (MPP) databases, data mining, distributed file systems, distributed databases, cloud computing platforms, the Internet, and scalable storage systems.

Examples of big data applications include big science, RFID, sensing device networks, astronomy, atmospheric, transportation, genomics, biology, big social data analysis, Internet document processing, Internet search engine indexing, communication record details, military reconnaissance, financial big data, medical big data, social networking, commuting time prediction, medical records, photo images and image storage, large-scale e-commerce, etc.

The advent of big data has increased the demand for information management specialists, with Software AG, Oracle, IBM, Microsoft, SAP, EMC Analytics, Hewlett-Packard and Dell already spending more than \$15 billion on data management analytics specialists. In 2010, the data management and analytics industry was worth more than \$100 billion and is growing at a rate of nearly 10% per year, twice the growth rate of the entire software industry (Wang et al., 2013)

2. Literature Review

The relationship between urbanization and water use has been assessed qualitatively. Kassouri (2021) analyzed water usage in various regions of Europe and identified that urbanization-related water demand is characterized by distinct phases. During the initial phase of urbanization, rapid economic growth leads to an increased demand for water in urban areas. The deceleration of urban development results in a decline in water demand within cities; however, a gradual upward trend persists. In advanced stages of urbanization, the demand for water resources in cities typically declines and ultimately stabilizes at a specific equilibrium point. Rashid et al. (2018) posits that population factors directly or indirectly influence water consumption and the health of natural ecosystems. Population growth, urbanization, and migration significantly influence water sustainability. Water resources significantly influence populations. Inadequate water quality and sanitation issues resulting from water scarcity elevate disease incidence and mortality rates. Numerous migrations result from floods, droughts, or environmental degradation.

Bao et al. (2020) examined the pressures on the water resource system in the Yangtze River region of China, attributed to environmental degradation, increasing food demand, and industrialization, by analyzing the region's historical development and comparing the water carrying capacity of the Yangtze River basin with its economic and social conditions. Xinchun et al. (2017) employed the water resources ecological footprint methodology to develop a model for analyzing the water resource utilization within the Changzhutan urban agglomeration in the Xiangjiang River Basin. Jia et al. (2018) integrated the concept of metabolism from biology into the analysis of regional water resource carrying capacity, positing that the socio-economic system generates products, services, and pollution through water consumption, thereby innovatively proposing the theory of regional water resource metabolism. Kaaviya and Devadas (2021) investigated the correlation between urbanization

and water vulnerability in Chennai, India, employing a coupled human-environment system model, and contended that governments must create innovative urban management and planning institutions to mitigate water scarcity. Al-Addous et al. (2023) examined the impact of urbanization in the Tafila basin of South Jordan on drought, pollution, and water quality degradation, identifying the climatic traits of arid and semi-arid regions, elevated population growth rates, and the absence of sewage systems as contributors to pollution. Rashid (2018) examines the struggle among industries for water resources throughout urbanization, focusing on technological, economic, political, and social transformations, as well as the feasibility of satisfying the water demands of urban expansion. Aleksandrova (2015) asserts that freshwater shortage is a critical determinant in the advancement of Central Asia, attributing 70% of developmental issues to insufficient freshwater availability, with the primary objective being the regulation of runoff and the alleviation of water stress. Zhao (2015) initially examined the correlation between urbanization, water quality, and land use changes in Shanghai, concluding that the swift advancement of urbanization is associated with a rapid decline in water quality, and that the degradation of urban land use and water quality is positively correlated.

Qualitative research in China about the correlation between urbanization and water usage primarily emphasizes the examination of water consumption levels and structures, the interplay between urbanization and water utilization, and the assessment of water resource carrying capacity. Lian et al. (2019) employed GIS technology to methodically examine the historical development of Beijing's water supply system and forecasted that the implementation of the South-to-North Water Diversion Project will further alter Beijing's water supply dynamics, resulting in reduced pressure on surface water and groundwater resources. Jin examined the urbanization levels of cities in the North China Plain, the correlation between urbanization development patterns and water resource utilization, and concluded that the structure of urban water usage is transitioning towards a production-centric model. The disparity between urban water availability and demand is significant, and groundwater overexploitation is severe in many regions. Shang et al. (2023) examined the evolution of water usage structure in the Guanzhong region over the past two decades, employing the information entropy method to investigate the developmental trends of this structure. They concluded that the water resource development framework in the Guanzhong region is progressing towards a more balanced and stable model with enhanced functionality.

Cai (2018) examined the panel data on urbanization and water usage in China's provincial regions from 2004 to 2013 to investigate the existence of a Kuznets curve link between urbanization and the structure of water use. A comparable curve link among agricultural, industrial, and home water use was constructed by iterative comparison and selection. The findings indicate that the reduction in agricultural water usage is insufficient to alleviate the water use pressure resulting from the rise in industrial and home water consumption. In accordance with the research findings, the author provided relevant recommendations. Lin et al.(2019) examined the differentiation patterns of urbanization systems and water resource environments in Northwest China, providing a comprehensive analysis using the Gansu segment of the Lanzhou-Xinjiang Economic Belt as a case study. The extent of coupling between the urbanization system and the water resources environment is influenced by the city's development and external influences, including regional interconnections and disparities. Hou et al. (2023) utilized urbanization and water usage statistics from cities in the Tarim River Basin over the past 25 years to formulate a mathematical correlation between the two variables. The findings indicate that water resources exert a considerable limiting influence on the urbanization process. Cui al. (2019) developed an indicator system for the complete water resource environment index and the comprehensive urbanization index, employing the coupling coordination model to examine the interaction coupling between urbanization and water resources in Nanchang from 2000 to 2010. The results indicated that the level of coupling coordination between the two exhibited a variable growth pattern. Jia et al.(2019) utilized the Shiyang River Basin, an arid interior river in Northwest China, to develop a computation model for a water resources-urbanization complex system. The findings indicated that the water resources system and urbanization system of Jinchang City and Wuwei City within the basin were in a preliminary association state. Yang et al.(2019) proposed a comprehensive model for evaluating the carrying capacity of regional water resources and employed a fuzzy comprehensive evaluation model to assess the stage of water resources development and utilization in the Pingba area of the Hanzhong Basin. Wu et al. (2021) employed a comprehensive decomposition model to statistically assess the impact of urbanization on economic growth and alterations in water usage across China and its 31 provinces, municipalities, and autonomous areas. The findings indicated that urbanization accounted for approximately 30% of China's economic growth; the economic expansion resulting from

urbanization resulted in heightened water consumption. However, due to the optimization of industrial structure and enhancements in water use efficiency, the water conservation benefits of urbanization surpassed its water consumption effects. Consequently, urbanization has resulted in a decrease in water use nationwide and in most provinces and cities. Simultaneously, government agencies must develop water diversion initiatives and implement compensation systems to prevent water crises in urbanized and densely inhabited regions. Yang et al. (2021) examined the effects of urbanization on the regional socio-economic landscape, ecological environment, and hydrological cycle, and developed a water resource carrying capacity model for urbanized regions employing target comprehensive analysis and multi-level grey correlation evaluation methods, conducting a case study in Tongzhou District, Beijing. Koop and Leeuwen (2017) proposed a novel definition of water resource carrying capacity, positing that it represents the maximum population a country or region can sustain in the foreseeable future, contingent upon existing technology and population quality, utilizing locally available water resources, while ensuring human biological water needs, promoting ecologically sustainable development, and maintaining living standards that align with social and cultural norms. Hong (2022) discovered that despite Beijing's population significantly above its purported water resource carrying capacity, residents do not perceive the strain of water resource overutilization in their daily activities and livelihoods. The ultimate result is that the calculated carrying capacity of water resources varies based on different parameters. The existing population is sustained at the cost of compromising the ecological environment and exploiting the carrying capacity of neighboring regions. Consequently, it is essential to refine the water utilization framework and enhance water usage efficiency.

The current study on urbanization and sustainable urban water resources, as well as their interrelationship, exhibits several deficiencies. Numerous distinct research exist about urbanization processes and the sustainable management of urban water resources. The two are insufficiently examined as two organically related systems. Numerous evaluative descriptions exist on the relationship between urbanization and water usage; nevertheless, there are limited forecasts for target year planning. Furthermore, there is an absence of extensive study regarding the correlation between urbanization and water consumption. The primary objective of the research on the correlation between urbanization and water

utilization is to establish a foundation for water resource planning and serve as a reference for urban growth. Various cities exhibit distinct trajectories of development, necessitating the establishment of a plausible urban development timeframe for predictions, grounded in historical data and trend analysis. Certain models, however, prioritize idealized outcomes based on specific urban characteristics, leading to discrepancies between calculated results and actual development.

3. Research Design

The primary focus of this work encompasses the following aspects. Examination of trends in home and industrial water consumption in Chengdu. An analysis of Chengdu's natural geographical conditions was conducted, focusing on geographical location, geological landforms, climatic characteristics, hydrology and water resources, and river systems. Additionally, the current characteristics of Chengdu's social and economic development were described in relation to population, economy, and social development levels. This document outlines the overall status of water resources and their development and utilization in Chengdu. The water consumption statistics of Chengdu, as presented in the Sichuan Water Conservancy Yearbook, was analyzed using trend analysis methods to examine the water consumption patterns across various industries in the region during the past 30 years. Examination of urban water consumption patterns in Chengdu. The urbanization process of Chengdu, as delineated by statistical data including population figures from the Chengdu Statistical Yearbook, is categorized into three phases: the early and medium stages of urbanization, the middle and late stages of urbanization, and the late stage of urbanization. This study examines the features of water consumption, the structure of water usage, and the efficiency of water utilization in the city during the early, middle, and late phases of urbanization.

Big data analytics examines the water requirements associated with urbanization. Beginning with the interplay and stress dynamics between the urbanization process and water utilization, a scheduling model was developed, and a system evaluation index framework was established. Comprehensive evaluation metrics for both the urbanization system and the water utilization system were derived through big data analysis. The coupling coordination degree between urbanization and water utilization was computed based on these comprehensive evaluation metrics, providing quantitative assessments of the coupling

relationship across various years and delineating the coupling coordination level of the two systems.

An analysis of the optimal size of urban areas in relation to water limitations. The primary objective is urban economic and social development, constrained by water supplies, utilizing big data methodologies to create a suitable scale model of urban development within these limitations. The future urban water demand was forecasted, and the urbanization trajectory equation for Chengdu was established. The quantitative outcomes of the suitable urban development size for Chengdu have been derived by big data analysis. Based on the analysis results, recommendations for future urban growth and sustainable water resource management in Chengdu are provided.

3.1 Research Model

The research model of this thesis is shown in Figure 1, which mainly covers the research background, literature review and analysis, and analyzes the basic situation of Chengdu from three levels: demographic information, social economy and water resources. Regarding the current water resource utilization in Chengdu, this paper mainly analyzes domestic water, industrial water, agricultural water and total water consumption. On the basis of this analysis, this paper collects the basic data of big data by visiting the official website data website and analyzes it in multiple dimensions. In the chapter of data collection, collection and analysis, the data of urban and rural population changes in Chengdu from 2000 to 2022 and the water flow of Chengdu from 2000 to 2022 are mainly collected. With the support of the above data, the trend analysis of the future population and water use situation of Chengdu was carried out to verify the data analysis. Finally, this paper discusses and analyzes the above data results, and draws some conclusions and suggestions. In the conclusion part, the advantages and disadvantages are discussed and analyzed, and the prospects and suggestions for future research are put forward.

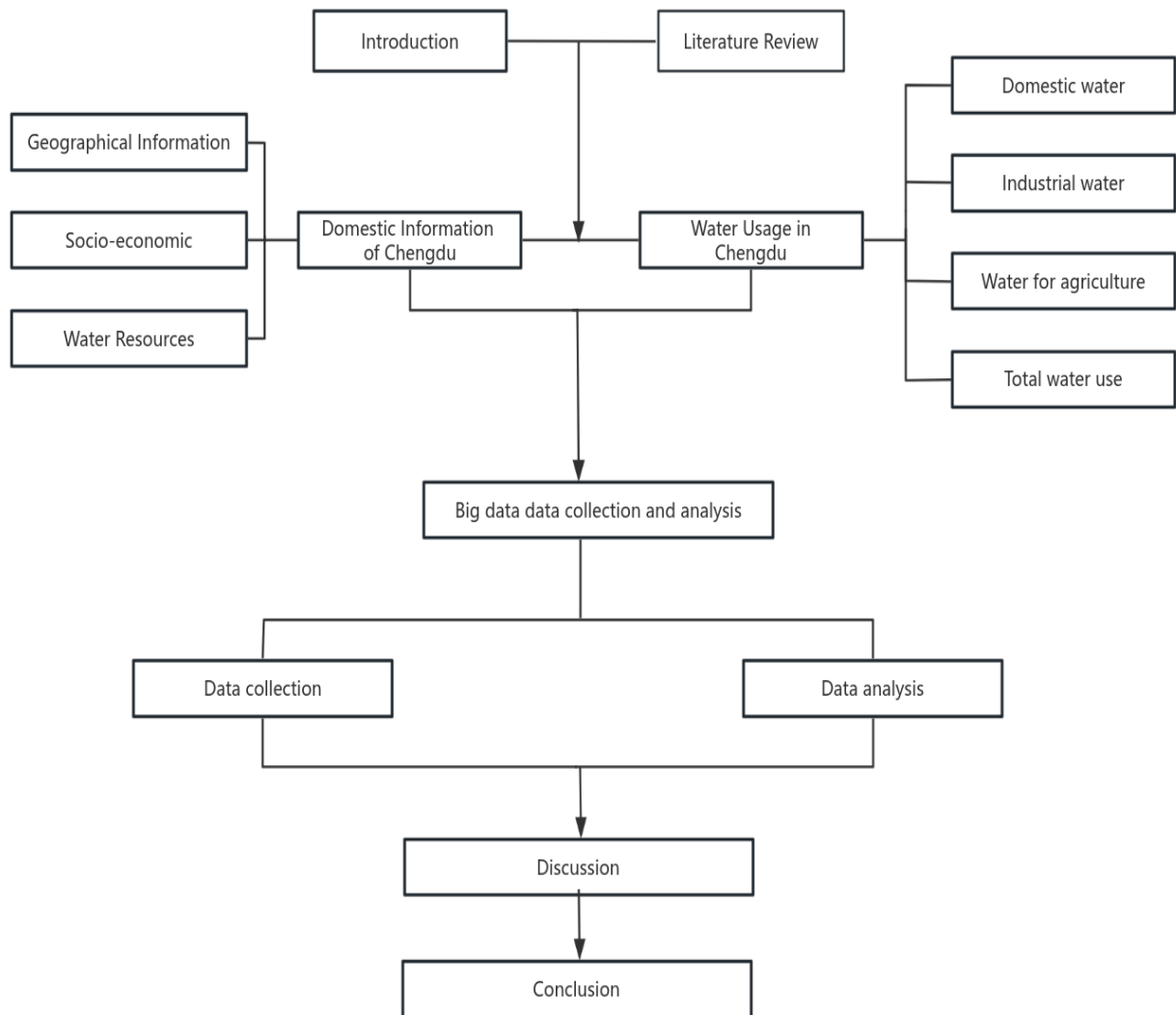


Figure 1. The research model of the thesis

4. Overview of Chengdu and its Water Resource

Chengdu is the capital of China's Sichuan Province, located in the western part of the Sichuan Basin, between 103° and 104° east longitude and 30° and 31° north latitude (Fig.2). Located on the western edge of the Sichuan Basin, it is surrounded by mountains. The Sichuan Basin is an inland sedimentary basin located in southwestern China and has relatively flat terrain. As the central city of the Sichuan Basin, Chengdu benefits from the basin's warm climate and abundant water resources. Chengdu is surrounded by mountains on all sides, with the Longmen Mountains to the east, the edge of the Tibetan Plateau to the west, Daba

Mountain to the north, and Qionglai Mountain to the south. Thanks to the barriers of these mountains, Chengdu's climate is relatively mild and protected from external interference, resulting in a unique natural environment. The main river flowing through Chengdu is the Min River, which is one of the important water sources in Chengdu and Sichuan Province. The Minjiang River system provides abundant water resources for Chengdu and is one of the important sources of water supply in the city. Chengdu also diverts water from nearby Dujiangyan to ensure the city's drinking water supply. Dujiangyan is one of the world's famous ancient water conservancy projects and one of Chengdu's historical and cultural heritages. In terms of climate, Chengdu is located in the subtropical humid climate zone, with a mild and humid climate with four distinct seasons and an average annual temperature of about 16 °C (成都计,2020). Affected by the geographical location of the Sichuan Basin, Chengdu has warm and humid summers, relatively mild winters, and abundant precipitation, with annual precipitation of more than 1000 mm. Due to the barrier effect of the mountains around the urban area of Chengdu, the air humidity is high in summer, and haze often occurs, especially in winter and spring.

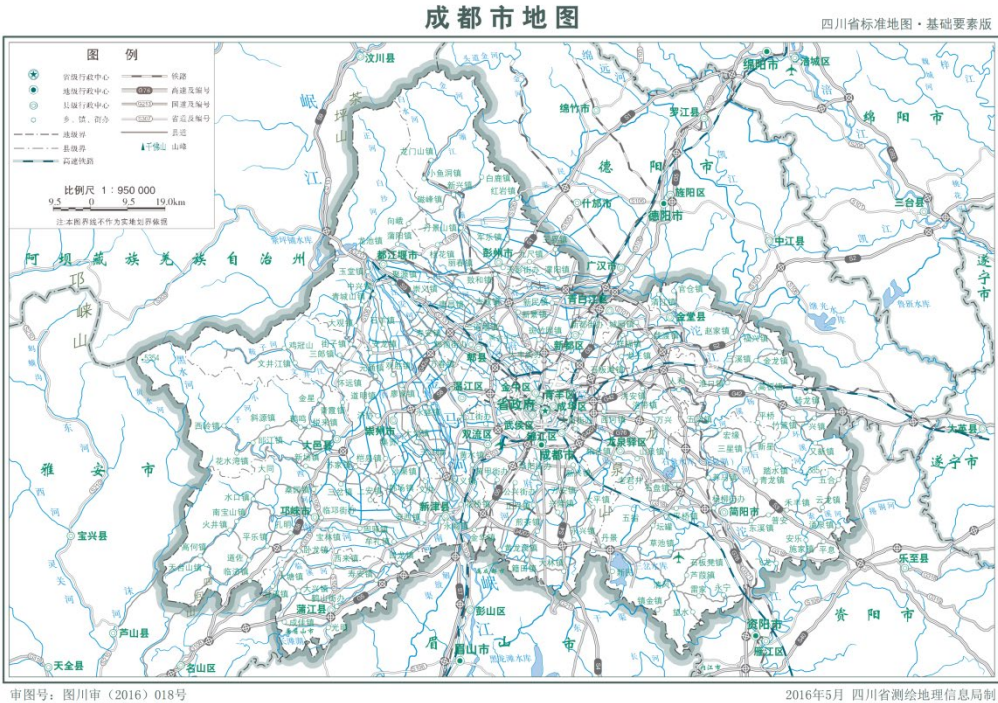


Figure 2. Administrative divisions and Water Resource Map of Chengdu

4.1 Socio-economic of Chengdu

Chengdu is the capital of Sichuan Province and one of the 15 sub-provincial cities in China. After the founding of the People's Republic of China, the administrative jurisdiction of Chengdu was gradually expanded after several adjustments: in 1976, Shuangliu County and Jintang County in Wenjiang Region were included in the jurisdiction of Chengdu City; In 1983, the system of city-led counties was implemented, Wenjiang District was abolished, and its 10 counties were merged into Chengdu (成都市统计局,2020). In 1990, the urban division of Chengdu was adjusted, and the original 5 districts were divided into 7 districts. In May 2016, with the approval of the State Council, Jianyang City, a county-level city managed by Ziyang City, was changed to Chengdu City. In 2022, Chengdu has jurisdiction over 12 districts of Jinjiang, Qingyang, Jinniu, Wuhou, Chenghua, Longquanyi, Qingbaijiang, Xindu, Wenjiang, Shuangliu, Pidu and Xinjin, 5 county-level cities of Jianyang, Dujiangyan, Pengzhou, Qionglai and Chongzhou, and 3 counties of Jintang, Dayi and Pujiang. At the end of 2023, the permanent resident population will be 21.403 million, of which 17.229 million will be urban and 4.174 million will be rural. The land area is 14,340 square kilometers, and the permanent population density is 1,484 people per square kilometer (成都市统计局,2020).

4.2 Agriculture of Chengdu

Chengdu is located in the southwest, the climate is pleasant, the terrain is flat, the soil is fertile, the irrigation water mainly comes from the irrigation water of the Dujiangyan Water Conservancy Project, and the water resources are relatively rich. In 2020, the city's gross domestic product (GDP) will be 745.639 billion yuan, an increase of 2.3% over the previous year at comparable prices, of which the added value of the primary industry will be 378.791 billion yuan, an increase of 2.7%, the added value of the secondary industry will be 371.921 billion yuan, an increase of 4.0%, and the added value of the tertiary industry will be 118.912 billion yuan, an increase of 2.1% (成都市统计局,2020). The total output value of agriculture, forestry, animal husbandry and fishery in the city will be 548.569 billion yuan. According to this calculation, the output value of Chengdu's primary and secondary industries in 2020 increased by 4.4% and 2.5% respectively over the previous year, and the city's total output value of agriculture, forestry, animal husbandry and fishery in 2020 ranked second among all cities in

Sichuan(成都市统计局,2020). The foundation and advantage of Chengdu's agricultural development is that it is rich in land resources and agricultural products. Chengdu has a cultivated land area of 12,400 hm², and the per capita cultivated land area is 0.34 hm², which is 1/2 of the national average. Among them, the area of permanent basic farmland is 81.29 million hm², accounting for 80.7% of the cultivated area. In recent years, Chengdu has vigorously developed modern agriculture and promoted the integrated development of primary, secondary and tertiary industries in rural areas, and the status of agriculture in the economy has been continuously improved(成都市统计局,2020). In 2019, the total output value of agriculture, forestry, animal husbandry and fishery in Chengdu was 538.125 billion yuan, an increase of 10.4% over 2018. Among them, the total output value of agriculture was 411.534 billion yuan, an increase of 8.2 percent, the total output value of animal husbandry was 375.519 billion yuan, an increase of 6.4 percent, and the total output value of fishery was 10.645 billion yuan, an increase of 9.3 percent(成都市统计局,2020).

4.3 Industry of Chengdu

As the capital of Sichuan Province, Chengdu is an important economic, industrial and technological center in southwest China. In recent years, the industrialization process of Chengdu has been accelerating, and an industrial system has been formed with high-tech industries as the leading and traditional industries and modern industries at the same time. Chengdu's industry not only supports the local economy, but also occupies a certain position in the national economy, making it one of the most dynamic industrial cities in western China. From the 50s to the 70s of the 20th century, Chengdu relied on its abundant resources and strategic position to establish an industrial base dominated by heavy industry. With the reform and opening up, Chengdu's industrial structure has undergone profound changes, and it has gradually transformed to high-tech, modernization and service-oriented, especially in the fields of electronic information, new energy, aerospace, machinery manufacturing and other fields (Zhang et al., 2021). From January to October 2024, Chengdu's total industrial output value was 842.59 billion yuan, a year-on-year increase of 4.4%. From January to October, the added value of Chengdu's industrial enterprises above designated size increased by 4.4% year-on-year, an increase of 0.3 percentage points from January to September. In terms of industries, 25 of the city's 37 industrial categories achieved positive growth in added value, and 10

industries maintained double-digit growth. The top 10 industries in terms of volume drove the growth of the city's above-scale industries by 3.0 percentage points (Zhao, W., & Zhou, 2022).

4.4 Water Resources of Chengdu

In 2022, Chengdu's total surface water resources was 6.939 billion cubic meters, groundwater resources will be 2.99 billion cubic meters, and total water resources will be 7.035 billion cubic meters (after deducting double counting of surface water and groundwater) (Pan et al., 2021). Chengdu is located in the Yangtze River tributaries of the Minjiang River and Tuojiang River Basin, the main stream of the Minjiang River and the Tuojiang River pass through the city, the main stream of the Minjiang River is 96 kilometers long, the main stream of the Tuojiang River is 146 kilometers long, and the area of the Minjiang River and Tuojiang River basin accounts for 55% and 45% respectively. , a decrease of 22.4% from 2021 and below the average since 2000; The city's total water supply and total water consumption are 5.396 billion m³, of which the water supply from surface water sources accounts for 97.3%, and the water supply for agriculture, domestic water, industry and ecology accounts for 56.2%, 34.2%, 6.5% and 3.2% of the total water consumption, and the per capita annual water consumption of the permanent population is 254 m³. A total of 264 domestic sewage treatment plants of various types in urban (rural) towns are in operation in the city, with a total treatment capacity of 1.662 billion tons, an increase of 4.29% over 2021, and the water use efficiency has been further improved (Qiao et al., 2021). From the perspective of administrative division, the total water resources of Pengzhou City, Dujiangyan City and Dayi County occupy the top three in the city, and the total water supply of Xindu District, Pengzhou City and Shuangliu District ranks among the top three in the city.

4.5 Surface Water Resource

In 2022, the total surface water resources of Chengdu were 6.939 billion cubic meters. This data reflects the abundance of surface water resources in Chengdu (Fig.3), which is of great significance for the city's water resources management and utilization (Xia et al., 2021). Chengdu is located in the Minjiang and Tuojiang River basins, tributaries of the Yangtze River, the main streams of the Minjiang River and Tuojiang River pass through the city, the main stream of the Minjiang River is 96 kilometers long, the main stream of the Tuojiang River is 146

kilometers long, and the area of the Minjiang River and Tuojiang River basins accounts for 55% and 45% respectively (Qiao et al., 2021). The transit water volume of Chengdu is dominated by the transit water of the Minjiang River, which is not only rich in water, but also has excellent water quality, and the terrain is condescending, which is convenient for artesian quotation, and is the main water supply source of Chengdu (Fig.4). However, in the summer of 2022, it was the most severe high temperature and drought disastrous weather in Chengdu since meteorological records began, the first red warning for high temperature was issued for 14 consecutive days since meteorological records began, and the highest temperature reached 43.4°C since meteorological records began(Xia et al., 2021). In 2022, Chengdu received the least rainfall in ten years during the main flood season, and the drought caused by high temperatures was also directly reflected in the amount of precipitation. According to the communiqué, the average precipitation in the city in 2022 was 906mm, and the total precipitation was about 12.988 billion m³, a decrease of 18.6% compared with the precipitation in 2021 and a decrease of 20.4% compared with the average precipitation for many years (成都市水务局, 2024).

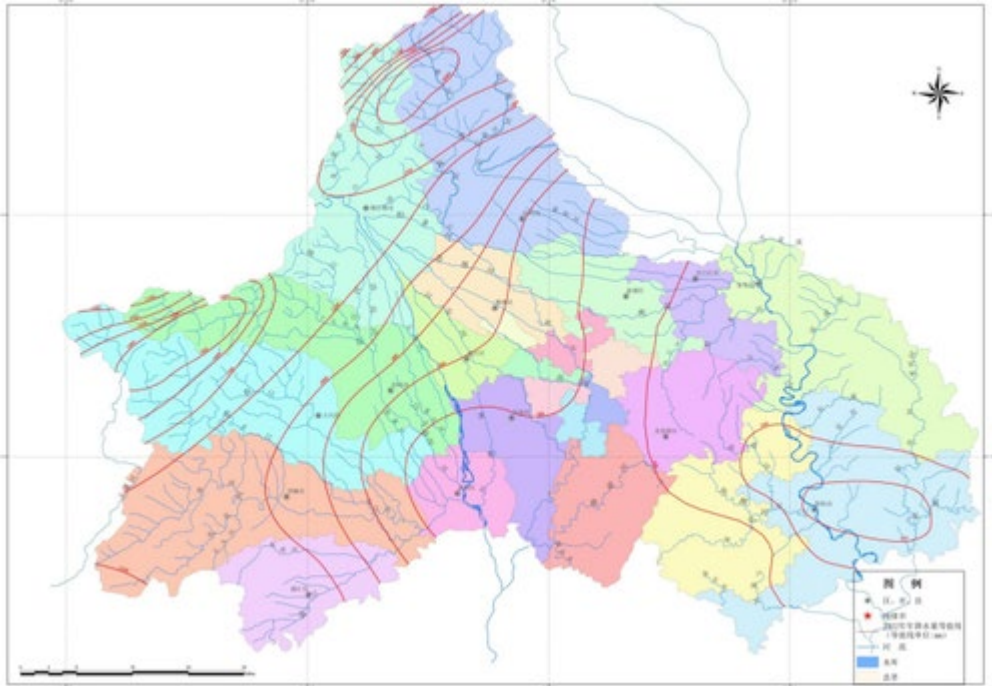


Figure 3. Rainfall Contour Plot 2022, Chengdu

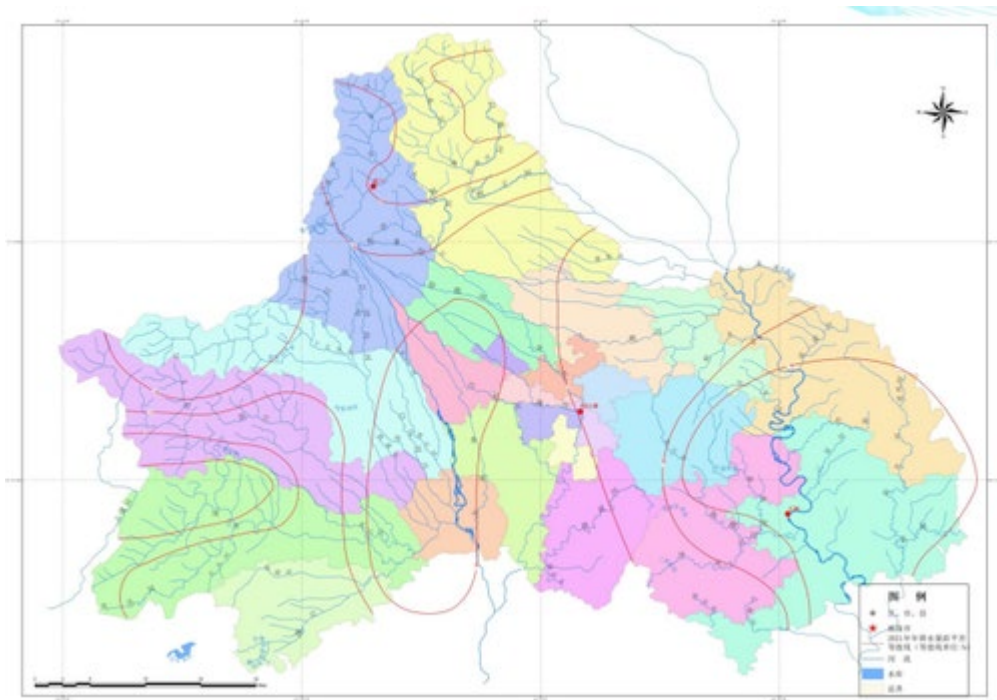


Figure 4. Contour Plot of Annual Precipitation from the Average, 2022, Chengdu

4.6 Groundwater Resources of Chengdu

In 2022, the total groundwater resources in Chengdu were 2.99 billion cubic meters, which are mainly distributed in the covered red bed (J-K) sandstone fissure water area in the Taiwan area and the red bed (J-K) fissure water area in the low hilly area of Longquan Mountain. The area of covered red beds (J-K) sandstone and mudstone fissure water area in Taiwan area is 337 square kilometers, with natural groundwater reserves of 56.55 million cubic meters and recoverable resources of 18.94 million cubic meters. The red bed (J-K) fissure water area in the low hilly area of Longquan Mountain covers an area of 218 square kilometers, with 4.69 million cubic meters of natural groundwater reserves and 2.42 million cubic meters of exploitable resources (成都市水务局, 2024).

4.7 Total Amount of Water Resources

Water resources primarily denote freshwater resources pertinent to human societal production and consumption, which may be sustainably replenished. The total water resources

encompass both surface water and groundwater. Surface water primarily consists of river and lake water, which are replenished by atmospheric precipitation, alpine glacier melt, and groundwater recharge. Groundwater refers to the water stored in underground aquifers, recharged by precipitation and surface water infiltration. Calculating total water resources allows for the analysis of the maximum potential of available water under current natural conditions, thereby providing a reference for the rational development and utilization of these resources.

The city's total water resources plummeted to 7.035 billion m³ (Table 1), a decrease of 22.4% from 2021 and below the average since 2000 (8.523 billion m³). Among them, the surface water resources had the greatest impact, which was 6.939 billion m³, equivalent to a runoff depth of 484 mm, a decrease of 22.8% compared with 2021. The volume of groundwater resources was 2.99 billion m³, an increase of 4.4% over 2021. Calculated according to the registered population, the per capita water resources are 448 m³; In terms of permanent population, the per capita water resources are 331 m³. From the perspective of the administrative division of total water resources, Pengzhou City, Dujiangyan City and Dayi County ranked the top three in the total water resources of the city, with 1.396 billion m³, 1.096 billion m³ and 940 million m³ respectively, accounting for 48.78% of the city's total (成都市水务局, 2024).

Table 1. The total amount of water resources in Chengdu, 2022

	Annual precipitation (million m ³)	Surface water (million m ³)	Groundwater (million m ³)	Surface water and groundwater are not double-counted (million m ³)	Total amount of water resources (million m ³)	Water resources per capita (m ³)
Chengdu	12.902	6.939	2.99	0.096	7.035	331(448)

4.8 Water availability

Water availability constitutes a component of a region's overall water resources and, from a resource standpoint, pertains to the volume of water that can be utilized. The annual availability of surface water at various levels in Xi'an, the recoverable quantity of shallow water

in the basin plain region, and the accessible volume of groundwater in the hilly area are aggregated, from which the volume of reused water exchanged between surface water and groundwater is subtracted to determine the net amount of reused water. The extent of reuse between surface water and groundwater primarily encompasses the following. When the development and consumption of water resources are extensive, the river base flow will be prioritized for use, thus being included into the available river base flow, which results in duplication with the accessible surface water amount. The seepage from the canal system and the volume of irrigation infiltration that recharges shallow groundwater in flat regions and intermountain basins constitute the residual water following surface water irrigation usage. The replenishment of shallow groundwater in flat regions and intermountain basins involves the reutilization of groundwater.

In 2022, Chengdu's total water supply and total water consumption were both 5.396 billion m³ (成都市水务局, 2024). Among them, the water supply from surface water sources was 5.251 billion m³, accounting for 97.3%; the water supply from groundwater sources was 82 million m³, accounting for 1.5% (Fig.5). The water supply from other sources was 63 million m³, accounting for 1.2%. agricultural water use was 3.030 billion m³, accounting for 56.2%; industrial water used 349 million m³, accounting for 6.5%; domestic water consumption was 1.847 billion m³, accounting for 34.2%; Ecological water use is 170 million m³, accounting for 3.2%. According to the registered population, the per capita annual water consumption is 343 m³; According to the permanent population, the per capita annual water consumption is 254 m³, the water consumption per 10,000 yuan GDP (current price) is 25.9 m³, the water consumption per 10,000 yuan of industrial added value (current price) is 6.5 m³, and the effective utilization coefficient of farmland irrigation reaches 0.564 (成都市水务局, 2024).

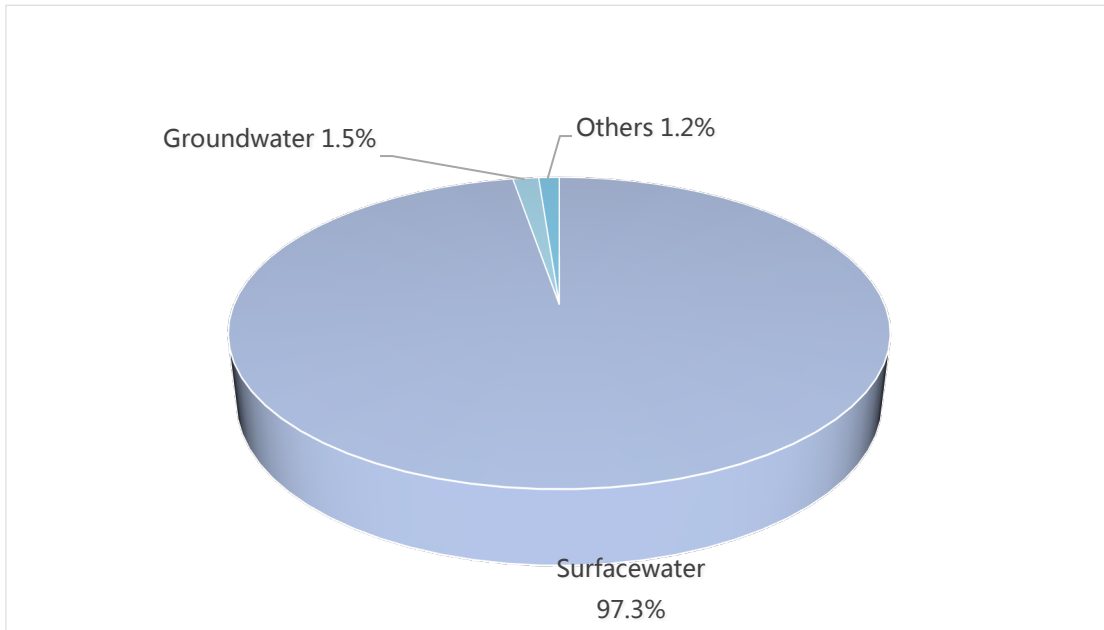


Figure 5. Surface Water, Groundwater and Other Water Sources in Chengdu, 2022

4.9 Current Condition of Water Resources Development and Utilization in Chengdu

Chengdu as a water-scarce city, not only the total amount of water resources is small, and the distribution of time and space, within the year, between years is uneven, which makes the development and utilization of water resources more difficult, after the reform and opening up, the development and utilization of water resources in Chengdu has a certain scale, but still has the potential for further development and utilization. In recent years, the water storage projects, water diversion projects, and water lifting projects that have been completed and put into use in Chengdu can reflect the development and utilization of surface water resources to a certain extent.

4.10 Water Usage Analyzing of Chengdu

Chengdu's total annual water consumption has continued to increase in recent years, especially during the peak summer water consumption period, and the city's water supply pressure is greater. According to public data, the total annual water consumption of Chengdu is about 5 billion cubic meters, and it is on the rise, mainly driven by factors such as urban

population, industrial development, and agricultural irrigation(成都统计局, 2020). In 2022, Chengdu's total water supply and consumption both amounted to 5.396 billion m³ . Of the total water supply, 5.251 billion m³ originated from surface water sources, representing 97.3%; 82 million m³ came from groundwater sources, constituting 1.5%; and 63 million m³ was sourced from other means, accounting for 1.2% (Fig.6). Agricultural water usage was 3.030 billion m³ , representing 56.2%; industrial water consumption was 349 million m³ , constituting 6.5%; domestic water use totaled 1.847 billion m³ , accounting for 34.2%; ecological water utilization was 170 million m³ , comprising 3.2% (成都市水务局, 2024). The per capita yearly water use, based on the registered population, is 343 m³ . The per capita annual water consumption is 254 m³ , water consumption per 10,000 yuan GDP (current price) is 25.9 m³ , water consumption per 10,000 yuan of industrial added value (current price) is 6.5 m³ , and the effective utilization coefficient of farmland irrigation is 0.564 (成都市统计局, 2020). Among them, in the surface water supply, the water diversion project is the absolute main force, with a water supply of 4.832 billion m³ and a surface water supply of 92.02%; The water supply capacity of the water storage project is 205 million m³ , and the water supply of surface water is 3.90%; The water supply capacity of the water lifting project is 214 million m³ , covering 4.08% of the surface water supply (成都市水务局, 2024).

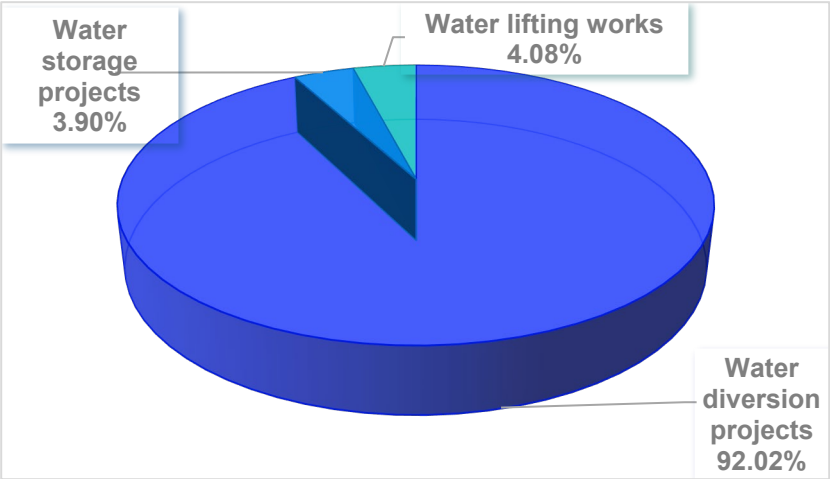


Figure 6. The composition of surface water supply in Chengdu, 2022

From the perspective of administrative division, the five urban districts and high-tech zones, Wenjiang districts, Pidun districts and Chongzhou cities all rely on drinking water projects

for water supply in terms of surface water utilization (Table 2, Table 3). Xindu District, Pengzhou City, and Shuangliu District are the top three in terms of total water supply in the city, with 392 million m³, 390 million m³, and 380 million m³ respectively (成都市统计局, 2020). In terms of specific water use categories, Pengzhou City, Chongzhou City, and Qionglai City occupy the top three for agricultural water consumption, and Shuangliu District, Pengzhou City, and Qingbaijiang District rank among the top three for industrial water use, which can also give a glimpse of the regional industrial development trend; As a megacity with a population of 21 million, in terms of domestic water use, in addition to the five urban districts and high-tech zones, Shuangliu District, Longquanyi District, Tianfu New District, Xindu District and other places use more than 100 million m³, which is closely related to the rapid growth of population in these areas in recent years (成都市水务局, 2024).

Table 2. Water supply of Chengdu Administrative District, 2022 (Unit: million m³), Sourced from 2022 Chengdu Water Resources Bulletin

District	Surface Water				Underground Water	Other	Total
	Diversions Projects	Storage Project	Pumping Project	Total			
Tinafu	231.29	13.80	5.50	250.59	0.14	1.09	251.82
East New District	151.94	0	18.41	170.35	0.50	3.10	173.95
Five Main District and Gaoxin	822.44	0	0	822.44	3.12	17.02	842.58
Longquan	200.90	8.40	0.90	210.20	0.41	4.16	214.77
Qingbaijiang	206.26	12.50	4	222.76	0.60	5	228.36
Xindu	387.88	2.45	1.50	391.83	0.17	0.15	392.16
Wenjiang	199.78	0	0	199.78	1.03	3.20	204.01
Shuangliu	313.96	14.13	48.26	376.34	3.48	0.25	380.08
Pidu	261.28	0	0	261.28	1.95	0	263.23
XInjiang	183.63	1.99	52.40	238.01	1.07	8.08	247.17
Jianyang	133.37	29.85	2.44	165.66	0.38	3.93	169.97
Dujiangyan	270.95	0.95	1.88	273.79	8.22	0.90	282.91
Pengzhou	377.19	4.35	0	381.55	8.85	0	390.40
Qionglai	297.74	10.87	12.01	320.61	9.49	1.27	331.36
Chongzhou	321.90	0	0	321.90	22.62	3.92	348.44
Jintang	118.30	71.94	60.58	250.83	4.69	4.27	259.79

Dayi	255.16	0.38	0.87	256.41	13.72	5.16	275.29
Pujiang	97.86	33.56	5.01	136.43	1.20	1.68	139.30
Total	4831.83	205.16	213.76	5250.74	81.64	63.20	5395.58

Table 3. Water Consumption of Chengdu Administrative Districts, 2022 (Unit: million m³),
Sourced from 2022 Chengdu Water Resources Bulletin

District	Agriculture	Industry	Domestic Supply	Ecology	Total
Tinafu	131.08	105.00	116.38	331.00	251.82
East New District	158.60	526.00	7.34	275.00	173.95
Five Main District and Gaoxin	10.40	4755.00	729.95	5468.00	842.58
Longquan	71.62	2185.00	117.48	382.00	214.77
Qingbaijiang	137.26	3460.00	41.88	1463.00	228.36
Xindu	260.03	1702.00	111.49	361.00	392.16
Wenjiang	96.51	2386.00	73.30	1035.00	204.01
Shuangliu	140.51	4636.00	169.29	2393.00	380.08
Pidu	135.08	1000.00	115.14	300.00	263.23
XInjiang	186.26	1872.00	30.49	1170.00	247.17
Jiayang	120.93	482.00	33.62	1060.00	169.97
Dujiangyan	214.63	418.00	56.30	782.00	282.91
Pengzhou	288.57	3783.00	62.32	168.00	390.40
Qionglai	277.62	1306.00	36.74	394.00	331.36
Chongzhou	285.56	2022.00	42.15	50.00	348.44
Jintang	188.00	2801.00	36.96	682.00	259.79
Dayi	211.90	993.00	47.15	632.00	275.29
Pujiang	115.20	451.00	18.88	70.00	139.30
Total	3029.75	34882.00	1846.85	17016.00	5395.58

4.11 Analysis of Drinking Water Consumption and Trends in Chengdu

The population problem is related to the sustainable development of society, and to a large extent restricts the effective use of various resources, especially on water resources, which has a strong binding force, so it is of great significance to analyze the changing trend of population and explore the prominent contradictions and problems it is facing, which is of great significance for the rational use of water resources (Fig.7). The analysis data of this

population survey are mainly based on the Chengdu Statistical Yearbook, and the population of Chengdu is counted according to the "Technical Requirements for National Comprehensive Water Resources Planning" and "Technical Requirements for Comprehensive Water Resources Planning of Sichuan Province" according to different calibers, so the changes in Chengdu's total population, urban population and non-agricultural population from 2000 to 2022 are analyzed according to different statistical channels (成都市水务局， 2024).

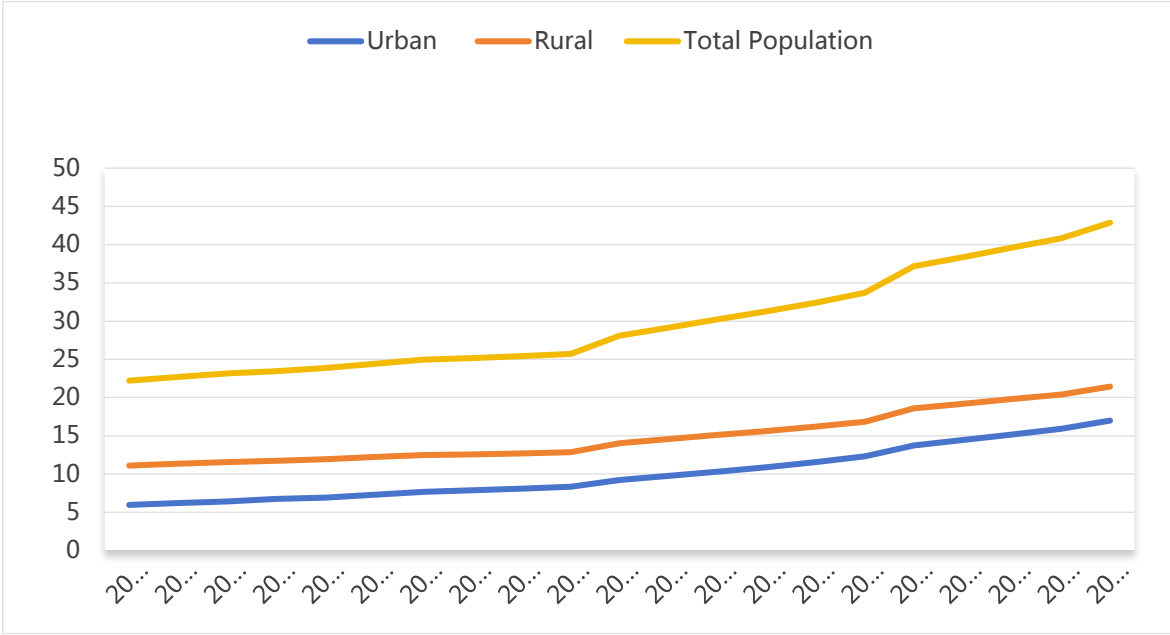


Figure 7. Chengdu's population growth from 2000 to 2022 (Million)

China holds the title of the most populous country globally and has faced significant population challenges that directly impact its development. Since 1978, the country has implemented family planning measures that have effectively alleviated the pressure of population growth on the ecosystem, ecological environment, and natural resources. However, despite these efforts, the population continues to grow in the current period. The population of Chengdu has experienced consistent growth, increasing from 11.108 million in 2000 to 20.947 million in 2020 (成都市统计局， 2020). Concurrently, the urban population has surged from 5.141 million in 2000 to 16.991 million in 2020(成都市统计局， 2020). The overall trend indicates that the demographic situation remains quite critical. The ongoing increase in population and scale, coupled with the swift advancement of the economy and the rising standards of living and consumption, inevitably exerts additional pressure on the ecological

environment and natural resources. If not managed promptly and effectively, this situation could significantly jeopardize the stable survival and development of urban areas. The connection between the current situation and long-term objectives establishes a robust basis for tackling upcoming challenges.

5. Analysis of Changes in Drinking Water Consumption

Total drinking water consumption encompasses the water usage of both urban and rural populations, closely linked to population increase. Currently, the residential water consumption of urban people is steadily rising due to ongoing urban development. The residential water usage among rural inhabitants has increased gradually. Over the previous two decades, residential drinking water consumption has risen. Between 2000 and 2020, residential water use shown a gradual increase. From 2000 to 2009, water consumption had a sudden and significant surge, attaining its zenith. It reverted to normal levels in 2010 and subsequently saw gradual growth (Jian et al., 2022). The pattern of residential water usage among urban people closely mirrors that of overall water consumption. Overall, the water consumption of rural inhabitants has increased gradually and has even exhibited a declining tendency in recent years. From 2002 to 2007, rural residents had a marginal rise in water consumption; however, over the period of 2008-2009, despite an overall increase in total water consumption, rural residents' water usage declined (Yu et al., 2022).

From 2000 to 2020, the domestic water consumption of cities and towns has increased significantly, from 400 million m³ to 1.6 billion m³, because the urban water system is very complex, and the factors that can have an impact on the urban domestic water consumption are diverse, the changes in the domestic water consumption are not only subject to the economic development level of the city, but also the urban residents are the main consumers of water resources, but also because of the fluctuation of the population to produce changes, population increase (Gao et al., 2023). The improvement of residents' living standards, the construction of urban ecological environment and the development of service industries will increase the domestic water consumption of cities and towns. For a long time to come, the proportion of domestic water consumption in total water consumption will continue to show a slow growth trend. Compared with the rapid increase in urban water consumption, the

change of water consumption in rural areas has been relatively flat, from 250 million m³ in 2000 to 1 billion m³ in 2020 (成都市统计局, 2022).

Chengdu, being the economic, technical, cultural, and educational hub of Southwest China, has urban water demand influenced by various factors, including population size, industrial composition, water resources, and policy direction. The seventh national census report indicates that Chengdu's population rose from 14.05 million in 2010 to 21.26 million in 2021, reflecting an increase of 7.21 million over a decade (成都市水务局, 2024). By 2035, Chengdu's population is projected to rise between 28 million and 30 million. The swift increase in population is directly elevating the demand for water. The seventh national census report indicates that Chengdu's population rose from 14.05 million in 2010 to 21.26 million in 2021, reflecting an increase of 7.21 million over a decade. By 2035, Chengdu's population is projected to rise between 28 million and 30 million (成都市统计局, 2024). The swift increase in population is directly escalating the demand for water. As a prominent agricultural metropolis in the southwestern region, agricultural water has consistently constituted a significant portion of water demand. The efficiency of agricultural water use is low, resulting in significant water waste. Enhancing agricultural water use efficiency can conserve significant water resources. As a prominent agricultural metropolis in the southwestern region, agricultural water has consistently constituted a significant portion of water demand. Nevertheless, the efficiency of agricultural water usage is suboptimal, resulting in significant water wastage. Enhancing agricultural water use efficiency can result in significant water conservation. The total water resources in Chengdu are rather scarce, with unequal spatial and temporal distribution. In 2022, Chengdu's total water resources amounted to 7.035 billion cubic meters, reflecting a 22.4% decline from 2021 (成都市水务局, 2022). The water issue has restricted Chengdu's water demand. The present state of water resource utilization in Chengdu is marked by substantial agricultural water consumption, a year-on-year increase in industrial water usage, and a consistent rise in domestic water consumption. Nonetheless, with the rapid urbanization and ongoing population growth, the demand for water resources in Chengdu would escalate, exacerbating the issue of water scarcity. Simultaneously, seasonal water scarcity and groundwater overexploitation provide obstacles to the management of water resources in Chengdu.

In conclusion, Chengdu possesses ample water resources that are unevenly distributed, and while the overall water quality is satisfactory, localized pollution issues persist. Chengdu has achieved significant advancements in enhancing water use efficiency and management; nonetheless, it continues to encounter numerous obstacles. Chengdu should enhance the protection and management of water resources, advocate for the establishment of a water-conserving society, and guarantee the sustainable utilization of water resources in the future.

6. Discussion

In summary, Chengdu is situated in the Sichuan Basin, characterized by relatively ample water resources, mostly dependent on the Minjiang and Tuojiang Rivers, as well as precipitation, to augment the city's water supply. Chengdu is confronting the combined problems of enhancing water resource consumption efficiency and addressing the supply-demand imbalance due to rapid economic development, population increase, and accelerated urbanization. Chengdu possesses enormous water resources; nevertheless, their distribution and sustainability are challenged by various circumstances. The entire yearly water resources of Chengdu approximate 5 billion cubic meters. The Minjiang River serves as the primary water supply, constituting the majority of Chengdu's water supplies. Despite the relative abundance of total water resources, climate change, irregular precipitation, and regional water pollution exert significant pressure on the availability of these resources. Due to rapid urbanization, population growth, and heightened industrial and agricultural water consumption, Chengdu's water resources are experiencing a supply-demand imbalance, particularly during dry seasons or water pollution events, where the issue of water scarcity becomes more pronounced. Consequently, this research, grounded in big data analysis, recommends the following enhancement strategies for the sustainable development of drinking water in Chengdu.

Establish a cohesive data platform that consolidates the water affairs department's data resources, encompassing water resources, river and lake management, water supply and drainage, construction and security, water conservancy and protection, flood control, and other operational data, to create a unified data platform. Data governance facilitates the realization of data exchange and sharing, the building of data catalogs, the regulation of data quality, and the monitoring of data resources. Establish a centralized smart water business platform to enable a cohesive application framework for the entire city, offering fundamental

services such as video AI recognition, intelligent report summary, and data visualization through charts. Implement cohesive user management, centralized login access, and standardized interface presentation across all application systems of the Water Affairs Bureau to enhance operational efficiency.

Develop a water demand forecasting model utilizing numerous socio-economic factors from Chengdu during the last year, and conduct rolling predictions along with a rationality analysis of the monthly water demand within the water usage sector. This facilitates the proactive planning of water allocations and mitigates seasonal water constraint. Develop an intelligent scheduling system for water resources and create an optimal allocation model for a multi-gate dam system, along with a real-time scheduling model for the environmental capacity of multiple sluice and dam systems. The water distribution plan is dynamically modified by clever algorithms based on real-time water, rainfall, and flood conditions to optimize the utilization of water resources. Utilize big data technology to assess water consumption across diverse businesses and locations, identifying areas with significant water conservation potential. Enhance water utilization efficiency by advocating for water-conserving technologies, devices, and appliances. Formulate rational water quota requirements based on the outcomes of big data analysis. Implement early warnings and penalties for excessive water consumption, and instruct water users on conservation practices. Consolidate the IoT sensing apparatus from ecological, public security, hydrological, meteorological, and other sectors to establish a water quality monitoring network. Immediate surveillance of water quality fluctuations to identify and address water contamination events promptly. Utilize big data technology to analyze water quality monitoring data to identify the source and cause of pollution. Devise specific interventions to enhance the quality of the aquatic environment. Establish a public engagement segment inside the smart water system to promptly gather and analyze public opinions and recommendations regarding the ecological conditions of rivers and lakes within the jurisdiction. Establish a robust framework for extensive engagement, collaborative development, and dissemination, while enhancing public understanding of water conservation and protection. By analyzing big data, we can ascertain public awareness and demand for water conservation, enabling the development of tailored PR and educational initiatives. Utilize several channels and methods to implement water

conservation awareness and educational initiatives, fostering a positive environment for collective societal engagement in water preservation.

Wuhou area in Chengdu has established a smart water command and dispatch center utilizing Internet of Things and big data technology, enabling intelligent monitoring and management of critical river sections in the area. The command and dispatch center features a large LCD screen that presents a dynamic image of the Jiang'an River together with real-time water quality monitoring data from each monitoring post along the river. The Wuhou smart water platform facilitates real-time monitoring of the Jiang'an River, Qingshui River, Jigongyan, Jinhuyan, and other river basins, establishing an intelligent water management and control system within the Wuhou District basin. The Wuhou smart water management and control platform has established a regional water environment big data center, facilitating real-time, precise, and intelligent management of regional flood prevention and disaster mitigation, water environment monitoring and protection, as well as water ecological restoration and reconstruction. The intelligent water system can monitor real-time dynamic data of the river and address received issues promptly. The system has established 19 water quality monitoring stations at critical locations, including the river's source, inflow, and outflow, primarily assessing total phosphorus, total nitrogen, ammonia nitrogen, permanganate index, and other water quality indicators in real time. Upon exceeding the monitoring indicators, the system will generate an alarm and promptly initiate the disposal procedure. Alarm information will be promptly dispatched to the pertinent accountable individual via app notifications, text messages, and other means for tracking and processing. The system has established three rainfall monitoring stations and seventeen flow monitoring stations in the pertinent river basins to observe the rainfall and river flow. The implementation of early rainfall storage level monitoring points, river water level video surveillance, and operational management and dispatch centers offers comprehensive data, models, and decision-making support for intelligent water management, thereby enhancing the precision of big data collection and analysis related to water resources, water environment, and water security in the basin.

In conclusion, addressing the urban water issue in Chengdu through big data methodologies requires a multifaceted approach, including the establishment of a smart water system, optimization of water resource allocation, enhancement of water quality monitoring

and early warning systems, promotion of water-saving technologies, encouragement of public participation, and reinforcement of collaborative water governance. The utilization of big data technology and the investigation of creative management models can enhance the high-quality development of Chengdu's water affairs sector, while ensuring robust urban water security.

Based on the requirements of water safety management and application, a hybrid approach of manual and procedural methods, along with internal analysis and field surveys, is employed to create a comprehensive map of Chengdu's water system, with extensive geographic coverage and complete attribute data. Execute data sorting and aggregation pertaining to water security, gather business data including water resources, river and lake management, water supply and drainage, construction and security, water conservancy and protection, and flood control. Implement data governance, facilitate exchange and sharing, and establish data catalog construction, data quality control, and monitoring of data resources. Develop a comprehensive business application support platform for the entire city, offering fundamental services such as video AI recognition, intelligent report summarization, and chart visualization in a cohesive manner, while achieving unified user management, centralized login access, and standardized interface presentation for all application systems of the Water Affairs Bureau. Consolidate IoT sensing devices from ecological, public security, hydrological, meteorological, and other sectors to provide a comprehensive water quality monitoring network. Continuous surveillance of water quality fluctuations to guarantee the safety of potable water sources. Big data technology is employed to analyze water quality monitoring data, identify anomalies promptly, and offer early alerts to facilitate timely interventions.

7. Conclusion

With the acceleration of urbanization and the continuous growth of population, urban water management is facing unprecedented challenges. Problems such as water shortage, water pollution, and frequent floods are becoming increasingly prominent, posing a serious threat to the sustainable development of cities. In this context, the use of big data to solve the problem of sustainable urban water use has become an important research direction. This paper uses big data to analyze the urban population change and water resources data of Chengdu from 2000 to 2020, and puts forward suggestions for urban water use in Chengdu from a multi-dimensional level. For example, by integrating the data resources of the water

department, a unified data platform is built to achieve data governance, exchange and sharing. Big data technology is used to process and analyze water data in real time to provide a scientific basis for water resources management and decision-making. Big data technology is used to analyze water quality monitoring data, find water quality abnormalities in time and issue early warnings. Through the construction of a water quality early warning system, the water quality safety of drinking water sources can be effectively guaranteed. Big data technology is used to analyze water quality monitoring data, find water quality abnormalities in time and issue early warnings. Through the construction of a water quality early warning system, the water quality safety of drinking water sources can be effectively guaranteed. Big data is used to accurately dispatch and optimize the allocation of water resources to ensure the rational allocation and efficient use of water resources.

However, although big data has significant advantages in the sustainable development of urban water use, there are still some challenges. For example, data sharing and security issues, technology maturity issues, capital investment, and O&M costs. In response to these challenges, this article provides some suggestions for future researchers. For example, establish a cross-departmental data sharing mechanism, formulate unified data standards and specifications, and ensure the secure transmission and storage of data. Establish a cross-departmental data sharing mechanism, formulate unified data standards and specifications, and ensure the secure transmission and storage of data. Therefore, this paper argues that big data provides strong support for solving the problem of sustainable development of urban water use. By building a smart water system, optimizing the allocation of water resources, strengthening water quality monitoring and early warning, and promoting water-saving technologies, we can effectively improve the efficiency of water resource management, ensure water security, and promote the construction of a water-saving society. In the future, with the continuous progress of technology and the deepening of application, big data will play a more important role in the sustainable development of urban water use.

This study also expects the following study could do a deep integration of artificial intelligence and big data: With the rapid development of artificial intelligence technology, urban water management will pay more attention to the deep integration of big data and artificial intelligence in the future. Through machine learning, deep learning and other

algorithms, a higher level of analysis and prediction of massive water data is carried out to realize intelligent and automated water resource management. Build a comprehensive perception of the intelligent water Internet of Things: With the help of the Internet of Things technology, cities will build a more complete intelligent water Internet of Things system in the future. Through sensors and monitoring equipment throughout the city, multi-dimensional data such as water quality, water quantity, and water pressure are collected in real time to provide richer and more accurate information support for water resource management. Promote cross-regional collaborative management of water resources: With the acceleration of urbanization, cross-regional water resources management will become an important direction for the sustainable development of urban water use in the future. The information sharing and collaborative management of cross-regional water resources through big data will help improve the efficiency of water resources utilization and reduce water waste and pollution. Strengthen data governance and standardization: In order to give full play to the role of big data in the sustainable development of urban water use, data governance and standardization should be strengthened. Develop unified data standards and specifications to ensure the accuracy, completeness, and reliability of data. At the same time, strengthen data security management to ensure data security and privacy. The application of big data in the sustainable development of urban water requires professional technical support and talent guarantee. Therefore, it is necessary to strengthen the training and team building of relevant talents, and improve the professional quality and innovation ability of technical personnel. At the same time, interdisciplinary cooperation and exchanges are encouraged to promote the deep integration of big data technology and water management.

This study also suggests that the government should increase policy guidance and financial support for the application of big data in the sustainable development of urban water use. Formulate relevant policies to encourage enterprises and social capital to participate in the construction and operation of smart water systems, and promote technological innovation and industrial upgrading. At the same time, special funds should be set up to support the construction of relevant scientific research projects and demonstration projects, and promote the wide application of big data in the sustainable development of urban water use. In order to raise public awareness and awareness of water conservation and water conservation, public

publicity and education should be strengthened. Use big data to analyze the needs and preferences of the public, and develop targeted publicity strategies and education plans. Through a combination of online and offline methods, we have carried out extensive publicity and education activities on water conservation to improve the public's awareness of water conservation and water resource protection.

In summary, big data provides strong support for solving the problem of sustainable development of urban water use. By building a smart water system, optimizing the allocation of water resources, strengthening water quality monitoring and early warning, and promoting water-saving technologies, we can effectively improve the efficiency of water resource management, ensure water security, and promote the construction of a water-saving society. In the future, with the continuous progress of technology and the deepening of application, big data will play a more important role in the sustainable development of urban water use. Therefore, we should strengthen the construction of data governance and standardization, cultivate professionals and team building, strengthen policy guidance and financial support, and strengthen public publicity and education, so as to promote the wide application and in-depth development of big data in the sustainable development of urban water use.

References

- Al-Addous, M., Bdour, M., Alnaief, M., Rabaiah, S., & Schweimanns, N. (2023). Water resources in Jordan: a review of current challenges and future opportunities. *Water*, *15*(21), 3729.
- Aleksandrova, M. (2015). Water scarcity under climate change: Impacts, vulnerability and risk reduction in the agricultural regions of Central Asia.
- Bao, H., Wang, C., Han, L., Wu, S., Lou, L., Xu, B., & Liu, Y. (2020). Resources and environmental pressure, carrying capacity, and governance: A case study of Yangtze river economic belt. *Sustainability*, *12*(4), 1576.
- Cai, J., Yin, H., & Varis, O. (2018). Impacts of urbanization on water use and energy-related CO2 emissions of residential consumption in China: A spatio-temporal analysis during 2003–2012. *Journal of cleaner production*, *194*, 23-33.
- Chen, X. (2020). China and the Mekong: Domestic hydro politics. In *Opportunities and Challenges for the Greater Mekong Subregion* (pp. 142-175). Routledge.
- Connor, R. (2015). *The United Nations world water development report 2015: water for a sustainable world* (Vol. 1). UNESCO publishing.
- Cui, X., Fang, C., Liu, H., & Liu, X. (2019). Assessing sustainability of urbanization by a coordinated development index for an Urbanization-Resources-Environment complex system: A case study of Jing-Jin-Ji region, China. *Ecological Indicators*, *96*, 383-391.
- Grubb, M., Koch, M., Thomson, K., Sullivan, F., & Munson, A. (2019). *The Earth Summit'Agreements: A Guide and Assessment: An Analysis of the Rio'92 UN Conference on Environment and Development* (Vol. 9). Routledge.
- Gao, C., Bracken, G., & Herdt, T. (2023). Balancing water rights in metropolitan water conservation areas: the case of Chengdu, China. *Local Environment*, *28*(10), 1211-1230.
- Hou, Y., Chen, Y., Li, Z., & Wang, Y. (2023). Changes in Land Use Pattern and Structure under the Rapid Urbanization of the Tarim River Basin. *Land*, *12*(3), 693.
- Hongzhou, Z. (2022). *Cross-border Resource Governance in China and the Role of the Provincial Governments: A Three-part Case Study*. National University of Singapore (Singapore).
- Hu, R. (2024). *Megaregional China*. Taylor & Francis.

- Jia, J. J., Lu, T., Jiang, M., & Wu, H. (2023). How to make effective household water demand-side management policy in China? Evidence from survey data in 50 cities. *Cities*, *140*, 104383.
- Jia, W., Xu, X., Yuan, R., Ma, X., Zhu, G., & Li, Z. (2019). Variation characteristics of stable isotopes in precipitation and the environmental factors that influence them in the Shiyang River Basin of China. *Environmental Earth Sciences*, *78*, 1-14.
- Jia, Z., Cai, Y., Chen, Y., & Zeng, W. (2018). Regionalization of water environmental carrying capacity for supporting the sustainable water resources management and development in China. *Resources, Conservation and Recycling*, *134*, 282-293.
- Jian, Y., Yunting, X., Xianghong, T., Rong, Z., & Zhanqiang, B. (2022). Endocrine disrupting compounds (EDCs) in source water, finished water, and tap water from drinking water treatment plants and its human risk assessment in Chengdu Plain, China. *Human and Ecological Risk Assessment: An International Journal*, *28*(8), 862-877.
- Kaaviya, R., & Devadas, V. (2021). Water resilience mapping of Chennai, India using analytical hierarchy process. *Ecological Processes*, *10*, 1-22.
- Kassouri, Y. (2021). Monitoring the spatial spillover effects of urbanization on water, built-up land and ecological footprints in sub-Saharan Africa. *Journal of Environmental Management*, *300*, 113690.
- Koncagül, E. (2015). *Facing the challenges: case studies and indicators: UNESCO's contributions to the United Nations world water development report 2015* (Vol. 2). UNESCO Publishing.
- Koop, S. H., & van Leeuwen, C. J. (2017). The challenges of water, waste and climate change in cities. *Environment, development and sustainability*, *19*(2), 385-418.
- Lin, J., Lei, J., Yang, Z., & Li, J. (2019). Differentiation of rural development driven by natural environment and urbanization: A case study of kashgar region, Northwest China. *Sustainability*, *11*(23), 6859.
- Mishra, R. K. (2023). Fresh water availability and its global challenge. *British Journal of Multidisciplinary and Advanced Studies*, *4*(3), 1-78.
- Lian, Q., Yao, L., Uddin Ahmad, Z., Lei, X., Islam, F., Zappi, M. E., & Gang, D. D. (2019). Nonpoint source pollution. *Water Environment Research*, *91*(10), 1114-1128.

- Pan, Y., Ma, L., Tang, H., Wu, Y., & Yang, Z. (2021). Land use transitions under rapid urbanization in Chengdu-Chongqing Region: A perspective of coupling water and land resources. *Land*, *10*(8), 812.
- Qiao, X., Schmidt, A. H., Xu, Y., Zhang, H., Chen, X., Xiang, R., ... & Wang, W. (2021). Surface water quality in the upstream-most megacity of the Yangtze River Basin (Chengdu): 2000–2019 trends, the COVID-19 lockdown effects, and water governance implications. *Environmental and Sustainability Indicators*, *10*, 100118.
- Rashid, H., Manzoor, M. M., & Mukhtar, S. (2018). Urbanization and its effects on water resources: An exploratory analysis. *Asian Journal of Water, Environment and Pollution*, *15*(1), 67-74.
- Rashid, H., Manzoor, M. M., & Mukhtar, S. (2018). Urbanization and its effects on water resources: An exploratory analysis. *Asian Journal of Water, Environment and Pollution*, *15*(1), 67-74.
- Shang, J., Dong, L., Ali, R., Shen, X., & Rehman, R. (2023). The influence mechanism of new-type urbanization on the eco-environment in western china-guanzhong using improved entropy weight method. *International Journal of Environmental Science and Technology*, *20*(6), 6395-6418.
- Wu, Q., Zuo, Q., Ma, J., Zhang, Z., & Jiang, L. (2021). Evolution analysis of water consumption and economic growth based on Decomposition-Decoupling Two-stage Method: A case study of Xinjiang Uygur Autonomous Region, China. *Sustainable Cities and Society*, *75*, 103337.
- Xinchun, C., Mengyang, W., Xiangping, G., Yalian, Z., Yan, G., Nan, W., & Weiguang, W. (2017). Assessing water scarcity in agricultural production system based on the generalized water resources and water footprint framework. *Science of the Total Environment*, *609*, 587-597.
- Xia, C., Liu, G., Meng, Y., Wang, Z., & Zhang, X. (2020). Impact of human activities on urban river system and its implication for water-environment risks: an isotope-based investigation in Chengdu, China. *Human and Ecological Risk Assessment: An International Journal*, *27*(5), 1416-1439.
- Yang, D., Yang, Y., & Xia, J. (2021). Hydrological cycle and water resources in a changing world: A review. *Geography and Sustainability*, *2*(2), 115-122.

- Yang, Z., Song, J., Cheng, D., Xia, J., Li, Q., & Ahamad, M. I. (2019). Comprehensive evaluation and scenario simulation for the water resources carrying capacity in Xi'an city, China. *Journal of environmental management*, 230, 221-233.
- Yu, Y., Zhou, T., Zhao, R., Li, Z., & Shen, C. (2022). A scenario analysis-based optimal management of water resources supply and demand balance: A case study of Chengdu, China. *Plos one*, 17(5), e0267920.
- Zhao, W., & Zhou, B. (2022). Out of the Dilemma: Industrial Heritage Value Evaluation and Renewal Suitability Research in Chengdu, China. *Journal of Urban Planning and Development*, 148(2), 04022004.
- Zhao, J., Lin, L., Yang, K., Liu, Q., & Qian, G. (2015). Influences of land use on water quality in a reticular river network area: A case study in Shanghai, China. *Landscape and Urban Planning*, 137, 20-29.
- Zuo, J., Fan, J., Huang, X., Li, C., & Luo, J. (2024). Classification and Spatial Differentiation of Subdistrict Units for Sustainable Urban Renewal in Megacities: A Case Study of Chengdu. *Land*, 13(2), 164.
- 成都统计局. (2020). 《成都统计年鉴》.
- 成都市水务局. (2024). 《2022 成都市水资源公报》.
- 刘政宇(2019).大数据分析挖掘技术及其决策应用研究[J].科学技术创新,2019(23):84-85.
- 王元卓,靳小龙,程学旗(2013).网络大数据:现状与展望[J].计算机学报,2013,36(06):1125-1138.
- 中华人民共和国国家发展和改革委员会.全国水资源规划 (2010-2030) [R].2010.
- 中华人民共和国统计局.第七次全国人口普查[R], 2020.