Terrestrial Environmental Sciences

TianXiang Yue · Erik Nixdorf
Chengzi Zhou · Bing Xu · Na Zhao
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Olaf Kolditz *Editors*

Chinese Water Systems

Volume 3: Poyang Lake Basin

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Preface

Situated in the rugged beauty of rural Jiangxi Province, China's largest freshwater lake, Poyang Lake, is not only famous for being the scene of historic dynastic struggles like the Battle of Lake Poyang in 1363 AD but also for its highly diverse subtropical flora and fauna, including remarkable assemblages of endemic species such as the freshwater finless porpoise. From October to March each year, vast areas of marsh and small water areas appear in the alluvial plain of Poyang Lake are a habitat of international importance for hundreds of thousands of migratory birds from Siberia and Northern China. In addition, Poyang Lake provides a vital source of resources to millions of people in Jiangxi Province living either at its shoreline or in the hinterland of the basin.

Although having a relatively higher water quality compared to other Chinese lakes, the water resources of Poyang Lake are threatened due to land reclamation, sand dredging, overexploitation, and the exposure of the aquatic system to pesticides from agricultural sources. Moreover, existing and proposed dam projects and changing climatic conditions already adversely impact the seasonal water balance of Poyang Lake. Since the 1990s, the Chinese government has made substantial efforts to address the problem of polluting freshwater resources. More recently, in April 2015, the Action Plan for Prevention and Control of Water Pollution was launched which requires that by 2020, the implementation of adequate protection measures will have improved the water quality of 70% of the water areas of the seven key basins including Yangtze River Basin, which contains Poyang Lake, to be "excellent" or "good" according to the Chinese standard.

In his speech at the 19th National Congress of the Communist Party of China last October, President Xi Jinping demanded the adoption of a holistic approach to conserving natural resources and protecting the environment. Considering that a sustainable management of aquatic resources must be built upon a thorough assessment of status and dynamics of the water resource in relation to human impacts, a research-oriented, multi-disciplinary approach is required. Transferring this approach to Poyang Lake, a research symposium called "sustainable water management and ecosystem restoration in the Poyang Lake Basin," held in Nanchang in November 2014, allowed bringing together German and Chinese

scientists from different disciplines such as hydrology, ecology, climate research, and information science as well as involving authorities and stakeholders from the Poyang Lake Basin. Consequently, the Poyang Cooperation group was formed in 2015 to build a joint Sino-German network to encourage synergy between the research groups and to facilitate research on environmental aspects of the Poyang Lake Basin.

This book compiles scientific results achieved by members of the aforementioned joint research group. In addition, experts from renowned research facilities such as Jiangxi Normal University, the Leibniz-Institute of Freshwater Ecology and Inland Fisheries, and Tomsk Polytechnic University made valuable contributions to this book volume. Although far from covering all current environmental research on Poyang Lake and its basin, the present book provides a comprehensive overview in English about current environmental research topics at Poyang Lake. This is of particular interest for those readers who are not able to access the great volumes on the hydrology of Poyang Lake written in Chinese by Shengrui Wang (Chinese Research Academy of Environmental Science) or the combined work of Wenbin Zhou and Jinbao Wan (Nanchang University) together with Jiahu Jiang (Nanjing Institute of Geography and Limnology).

Summarizing, we hope that the positive outcomes and experiences of the joint research recorded here can also prove to be useful for both scientists and funders aiming to design and implement water resource protection projects in other areas and practitioners looking for a modern methodological framework to assess, document and present the state of an aquatic system. Furthermore, this book is the third volume in the Springer series *Chinese Water Systems* that presents the application of state-of-the-art approaches in environmental research to Chinese water systems of national and international importance, namely:

- Song, Yonghui, et al. (eds.). *Chinese Water Systems: Volume 1: Liaohe and Songhuajiang River Basins*. Springer, 2018.
- Sachse, Agnes et al. (eds.). *Chinese Water Systems: Volume 2: Managing Water Resources for Urban Catchments*. Springer, 2018.

Few books are without errors, and this book is likely no exception. Should you discover errors that should be corrected, we would be grateful if you let us know to help improve this book.

Leipzig, Germany Erik Nixdorf
June 2018

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Part I
Introduction

Chapter 1
Background Information about Poyang Lake Basin

Erik Nixdorf and Chengzi Zhou

1.1 Administration

The by maximum annual extension biggest Chinese freshwater lake—Poyang Lake is located in the southeastern part of China (Fig. 1.1) [1]. The total area of Poyang Lake Basin is about 162 000 km^2. 96.7% of the basin is located within the provincial borders of Jiangxi Province and 1.8% belongs to Huangshan prefecture in Anhui Province. Furthermore, a smaller proportion of 0.7% of the catchment area is located in Fujian Province within the prefectures Nanping and Longyan. Additionally, 0.5% of the basin belongs to Chengzhou in Hunan Province and 0.3% to Xuzhou prefecture in Zhejiang Province. In other terms, 94.2% of Jiangxi Province is located within Poyang Lake Basin, which means that data provided for Jiangxi Province is suitable to represent the characteristics of the Poyang Lake Basin.

Jiangxi Province is with an area of 166 919 km^2 the 13th largest province of China. Jiangxi is bordered by Anhui Province to the north, Zhejiang Province to the northeast, Fujian Province to the east, Guangdong Province to the south, Hunan Province to the west and Hubei Province to the northeast. The mountain ridges of the watershed define most of the provincial border. However, parts of the northern border to Hubei and Anhui Province are formed by the water course of Yangtze River.

Jiangxi Province is divided into 11 prefectures, which are further delineated into 100 counties. Except of a large part of Pingxiang District in the west of Jiangxi Province, the southern parts of Ganzhou Prefecture and the northern parts of Jiujiang Prefecture, which drain directly to Yangtze, all prefectures are located within the Poyang Lake Basin. Nanchang is the capital of Jiangxi, which is, in dependence on the lake's water level, between 50 and 60 km away from the shoreline of Poyang Lake. Most large cities in Jiangxi Province (indicated as red dots in Fig. 1.1) are located near the major rivers.

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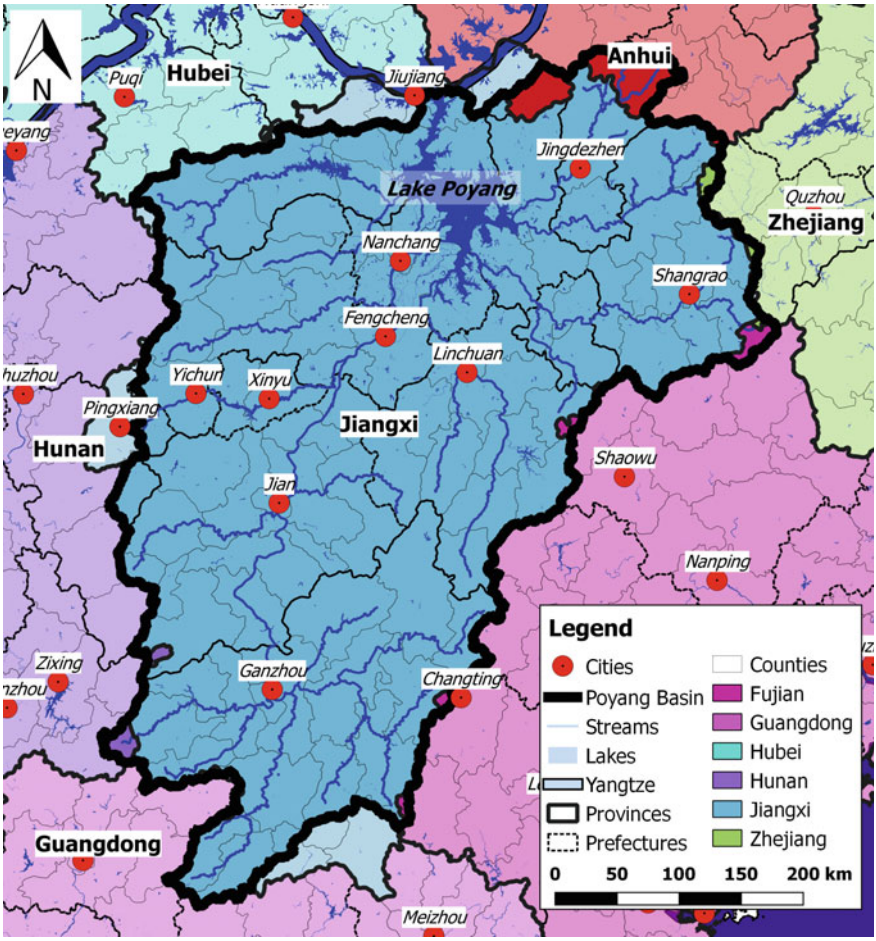

Fig. 1.1 Administrative division of the Poyang Lake Basin

1.2 Physical Topography

Jiangxi has beautiful landscapes with green mountains and clear waters. The main mountain ranges are distributed along three sides of the province border of Jiangxi (Fig. 1.2): The Mufu Mountains, Jiuling Mountains and Luoxiao Mountains on the west; Huaiyu Mountains and Wuyi Mountains on the east; and Jiulian Mountains and Dayu Mountains in the south. Huanggang Mountain at the border to Fujian province is the highest peak with a height of 2158 m above sea level. However, in total, mountainous areas higher than 1000 m are associated to less than 2% of the basin area. Aside of the mountain ranges, the main topographical patterns of Jiangxi Province vary from hilly landscapes with intercepting valleys in the south to flat

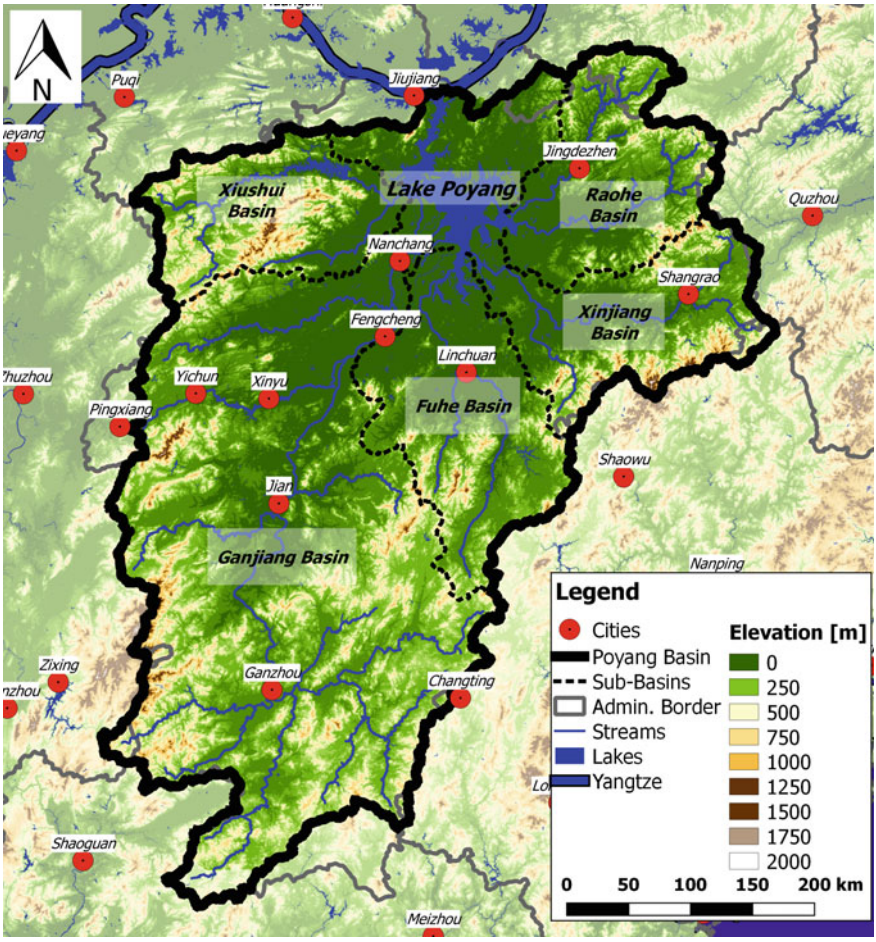

Fig. 1.2 Physical topography of Jiangxi Province. The elevation data is derived from the STS–99 Shuttle Radar Topography Mission [3], which provides data in a spatial grid resolution of about 90 m

alluvial plains in the lower reaches of the primary watercourses in the northern part of the province, where also Poyang Lake is located [2]. The mean altitude of Poyang Basin is 245 m above sea level. More than 70% of areas have an altitude of less than 400 m, which shows the lack of larger plateaus in the catchment.

Forest is the dominant land cover type within Poyang Basin, comprising 49.6% of the total area in 2009. The total standing forest stock is 445 mio. m^3 [4]. The large forest areas are mainly concentrated on elevated areas in the mountain ranges of the catchment (Fig. 1.3).

Another main landcover type is farmland constituting approximately about 29.7% of the area in the Poyang Lake Basin. Mainly the wide valleys formed by the main rivers and the Poyang Lake plain in the central-northern part of the catchment are

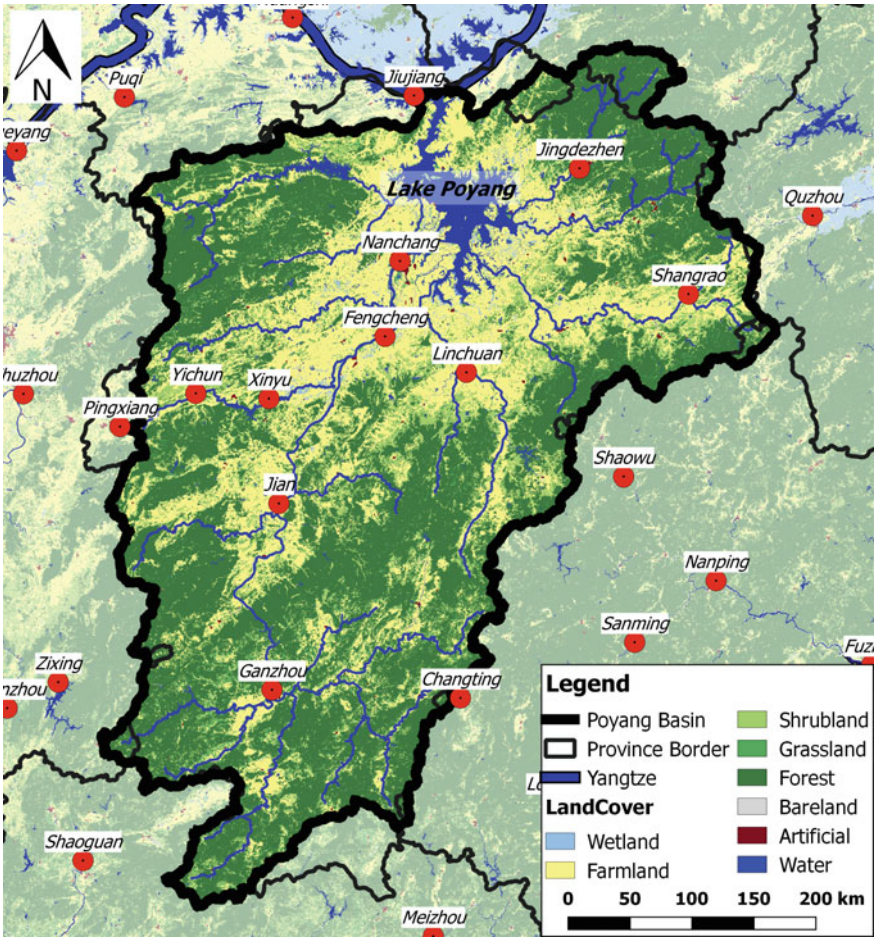

Fig. 1.3 Land cover in Jiangxi Province in 2009 derived from the GlobCover 2009 dataset [5]

extensively cultivated by agricultural activities making Jiangxi Province to one of China's main grain production bases south of the Yangtze River. Shrubland and grassland cover 11.5 and 5.6% of the land area mostly in areas with medium altitude. Although 2.5% of the area is covered by water bodies and 0.6% by wetland according to the input dataset, these shares are subject to seasonal changes due to the water level dynamics of Poyang Lake. During the past twentieth century, many levees were constructed to protect existing farmland from being flooded and to convert wetland areas into farmland used for grain production. However, wetland reclamation was banned in 1986 and laws have been subsequently introduced to promote wetland restoration. Only small areas of the catchment are delineated as bareland (0.4%) which comprises of sand dunes around Poyang Lake but may include other areas e.g. land being prepared for construction activities. Although artificial structures cover

only about 0.1% of land in Poyang Lake Basin, cities and towns continue to grow which will in turn require larger shares of available land in the future.

1.3 Climate

Poyang Lake Basin has a humid subtropical climate with short but relatively cool winters and hot and humid summers. Average annual temperature in the capital Nanchang is 17.7 °C. Temperatures can be close to freezing point during winter. Snowfall is very rare in the plain area of Poyang Lake but, more likely, a snow layer can be formed in the mountainous areas of the basin. In spring, temperatures rise fast and reach high average summer temperatures of more than 30 °C in low altitude areas like Nanchang.

Annual precipitation shows a wet and a dry season with a short transition period in between. In Nanchang, annual average precipitation is about 1500 mm per month. Precipitation increases quickly from January to June. June is with 300 mm precipitation the most precipitous month of the year. Average monthly rainfall decreases sharply in July to values of about 150 mm per month. However, Jiangxi province can be impacted by tropical cyclones bringing days of heavy thunderstorms and rainfall in late summer. The dry season begins in September and lasts through December. December is the month with the lowest rainfall of the year with an average rainfall of less than 50 mm in Nanchang (Fig. 1.4).

The distribution of annual average precipitation in Poyang Lake Basin depends mostly on the altitude. Rainfall in mountains areas is much higher than in the hilly and plain area of the basin (Fig. 1.5). Rainfall rates are highest in the northeast part of Jiangxi and decrease further west due to the Wuyi Mountains acting as a protective barrier against the inflow of cold air from the northwest and retain warm moist air originating from the sea. In 2.6% of the basin, annual precipitation can reach more than 2000 mm with maximum values of 2225 mm in the Wuyi Mountains. In contrast, about 87% of the basin receives annual rainfall between 1450 and 1850 mm per year. In some of the river valleys in the southwest part of the basin and in the northern region precipitation descend to 1415 mm.

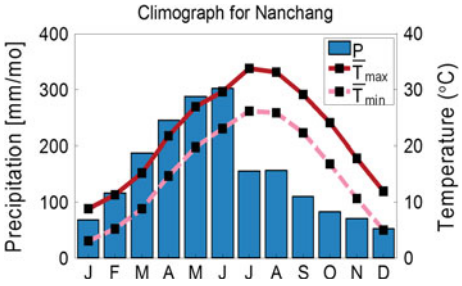

Fig. 1.4 Climograph of monthly temperature and precipitation in Nanchang

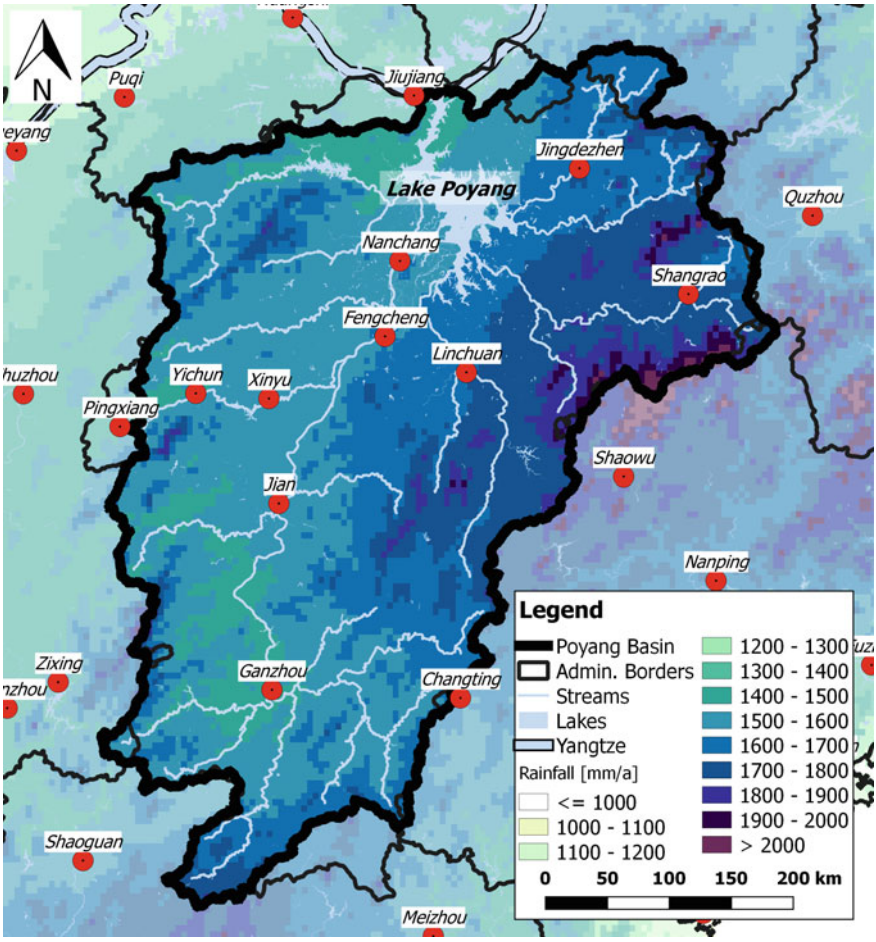

Fig. 1.5 Spatial distribution of average annual precipitation in Poyang Lake Basin

1.4 Cultural Geography

In 2015, Jiangxi Province is home to more than 45 mio. people (Table 1.1). The share between urban and rural population is 52% and 48%, respectively, which means, that more people live in cities than in the countryside. In 1987, when Jiangxi had a population of more than 31 mio. people, only 16.75% of population lived in urban whereas 83.25% lived in rural areas. 99% of the population is Han Chinese due to receiving successive waves of migration from Northern China through the ages.

The population distribution in the Poyang Lake Basin is very uneven (Fig. 1.6).[1] Although the overall population density is about 270 P/km^2, the maximum

[1] http://sedac.ciesin.columbia.edu/data/collection/gpw-v4/citations.

Table 1.1 Population and water supply in the prefecture-level cities of Jiangxi [4]

Prefecture city	Population (1000 P)	Pop. density (P/km^2)	GDP (RMB/P)	Water supply (100 bn. m^3)
Nanchang	5272	737	75879	3.06
Jingdezhen	1635	312	47216	0.83
Pingxiang	1895	496	48133	0.75
Jiujiang	4816	253	39505	2.35
Xinyu	1163	369	81354	0.78
Yingtan	1150	324	55568	0.74
Ganzhou	8527	217	23148	3.24
Ji'an	4890	194	27168	3.00
Yichun	5502	296	29457	4.27
Fuzhou	3984	212	27735	2.35
Shangrao	6701	295	24633	3.19
Average	4139	336	43617	2.23

population density is more than 60 000 P/km^2 in downtown Nanchang. Many factors such as climate, landform, land cover, resources, economy and transportation influence the population distribution. In the mountainous regions of Jiangxi, the population density is typically less than 100 P/km^2 due to less farmland and inconvenient transportation opportunities. Outside of the mountain areas, population density often exceeds 500 P/km^2.

The capital Nanchang is with more than 5 mio. Inhabitants the largest city in Jiangxi and the Poyang Lake Basin. It is the center of economy, transport and culture of Jiangxi Province. Since decades, Nanchang Metropolitan Area is experiencing a strong population growth, which lead to an expansion of the city into former wetland areas of Poyang Lake.

1.5 Economy and Water Management

Jiangxi was one of the nation's most affluent regions before trade patterns changed by opening of treaty ports to the Western Powers in the mid-19th century.[2] In 2015, Jiangxi's GDP was about 1 672 bn. RMB. The total value of foreign exports and imports of goods was about 33 bn. USD and 9 bn. USD, respectively.

The GDP of agriculture goods was 177.3 bn. RMB in 2015. Although the GDP from agriculture lags behind industry and services, Jiangxi is one of the three largest rice-producing provinces in China. Rice growing areas account for more than 60% of the overall cultivated area in Jiangxi. Paddy fields cover 85 to 90% of the area

[2] https://www.britannica.com/place/Jiangxi#toc71324.

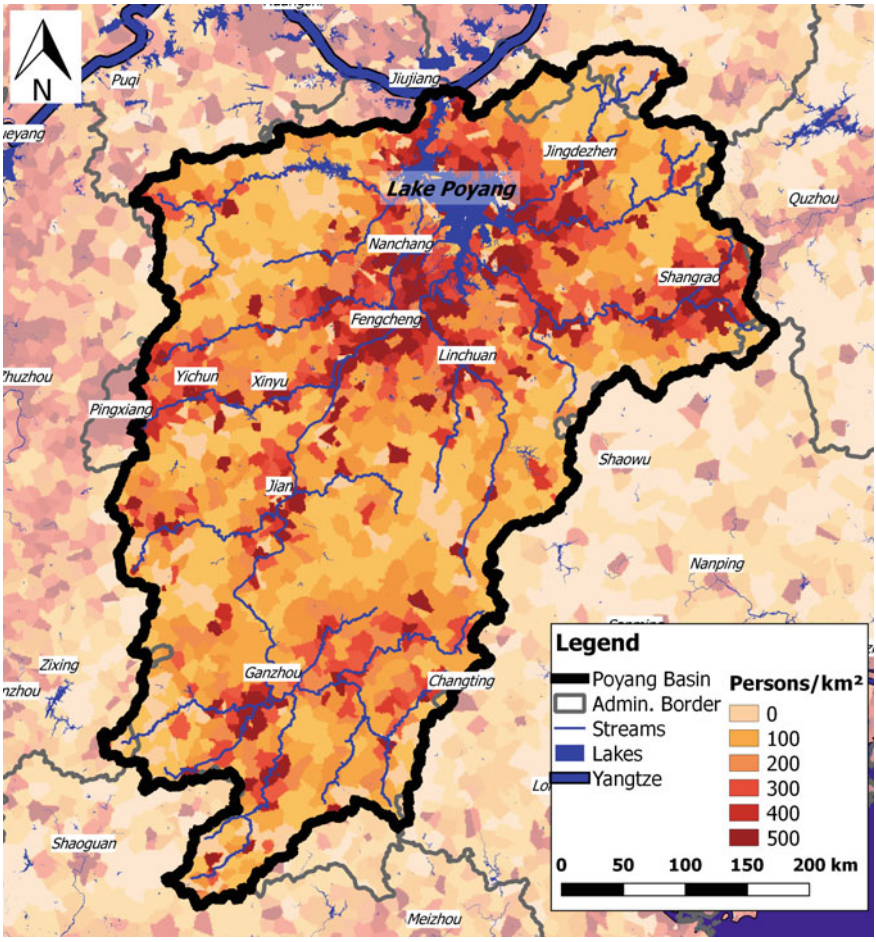

Fig. 1.6 Population density in Jiangxi Province in 2015

planted with grains.[3] Other food crops produced in Jiangxi include cotton, sugar cane, fruits and oil-bearing crops. In 2015, 21.48 mio. tons grain, 1.1 mio. tons cotton and 50 356 tons tea were produced. The total cultivated freshwater area of the whole province is 43.32 thousand hectares with more than 150 different species of fish being raised. The GDP of the industry in Jiangxi was 841 bn. RMB in 2015. Jiangxi's core industries include chemical industry, steel industry, cement industry and pharmaceutical industry. By the end of 2015, the GDP of the service sector was about 654 bn. RMB. Banking, insurance and real estate are the key service industries in Jiangxi [4]. In addition, some areas such as the northern part of Wuyi Mountains are famous scenic tourist areas [1].

[3] http://europe.chinadaily.com.cn/epaper/2015-07/17/content_21307209.htm.

Jiangxi Province has rich deposits of minerals, making it is one of the provinces with highest matching degree of mineral resources in China. Copper, Tungsten, Uranium, Tantalum, Rare Earths, Gold and Silver are called "the seven gold flowers of Jiangxi". Among others, Jiangxi is the largest producer of copper in China with most production coming from the Dexing mining district in the east of Jiangxi Province.

The province's total water supply was about 24.42 bn. m^3, accounting for 12.3% of the total annual water resources (Table 1.1). The vast majority of 23.6 bn. m^3 is supplied by surface waters followed by groundwater supply of in total 824 mio. m^3. Compared with 2014, the province's total water supply decreased by 1.349 bn. m^3 in 2015. In 2015, the total water use in Jiangxi was equal to the supply with about 24 bn. m^3. About 14 bn. m^3 of water were used for agriculture, which was about 59% of the totally used water volume. Annual agricultural water demand highly depends on the precipitation. For instance, the demand decreased by 1.3 bn. m^3 in comparison to 2014, because of unusual high rainfall during the growing season. The second largest water user was the industry with 6 bn. m^3, which was 25% of the total water use. Residential use demanded about 2.8 bn. m^3 of supplied water [6].

1.6 River Network

There are more than 2 400 rivers of various size in Jiangxi province, which have a combined total length of about 18 400 km. Most of them enter Poyang Lake, which in turn empties into Yangtze River. The five major rivers are Gan River, Fu River, Xin River, Xiu River, and Rao River [4]. Gan River with a length of 751 km is the longest river in Jiangxi and the second largest tributary of Yangtze River in terms of water volume. Coming from the west part of Wuyi Mountains Gan River flows through the entire length of the province from south to north, passing cities from Ganzhou to Hukou before pouring into the Yangtze River. Thirteen major tributaries flow into Gan River, which is navigable on more than 500 km of its watercourse.[4]

The Chinese Standard for Surface Water Quality divides the surface waters of China into 6 classes according to their chemical and physical water properties with class I being the best and class >5 being the worst [8]. The water quality of 80 rivers in the province with a total river length of 6 241 km is evaluated annually by governmental organisations of Jiangxi province [6] based on data from 307 monitoring sections. In 2015, 2.9% of all investigated river sections could achieve the highest surface water quality whereas rivers with poor quality had a share of 7.1% (Fig. 1.8). The majority of rivers showed a water quality associated with class II of the standard. The polluted river sections are mainly distributed in the Gan River (e.g. Qingshan section), Fu River (e.g. Luoxi section and Yunshan section), Rao River (e.g. Le'an and Hanjia crossing section) and Xiu River (North Liao River and Jing'an section) with

[4] http://ziliaoku.jxwmw.cn/system/2008/11/12/010079359.shtml.

Fig. 1.7 Surface water quality in Yangtze River Basin [7]

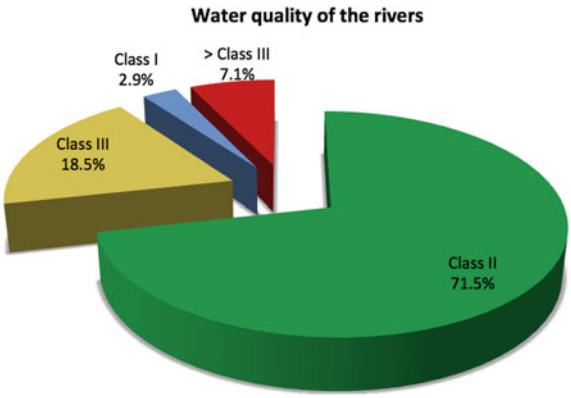

Fig. 1.8 Surface water quality of the rivers in Poyang Basin [6]

main pollutants being ammonia and phosphorus [6]. However, focusing on the entire Yangtze River Basin, the rivers of the Poyang Lake Basin have an above average water quality (Fig. 1.7).

1.7 Reservoirs and Floodplain Lakes

Due to humid subtropical climate, the precipitation pattern in Poyang Lake differs between rainy season and dry season. Therefore, many reservoirs were constructed in the last century to supply drinking water, to prevent water damages, to generate electrical energy and to manage the rivers effectively. Jiangxi Province has 29 large reservoirs and 251 medium-sized reservoir with a total storage volume of 13.165 bn. m^3. Among them, the large reservoirs have a total storage capacity of 10.121 bn. m^3 [6]. The main reservoirs are Hongmen, Shangyoujiang, Zhelin, Jiangmen and Tuolin Reservoir. Zhelin Reservoir, which is located at Xiu River in the northeast part of Poyang Lake Basin is the largest in Jiangxi Province with a storage capacity of 7.9 bn. m^3. The second largest reservoir is Hongmen reservoir in Rao River basin with a capacity of about 2 bn. m^3. Its lake with a surface of about 40 km^2 is a renowned tourist site and a natural reserve for birds.

The water quality of 53 reservoirs of large and medium-sized reservoirs in the province is evaluated on a regular base, including 14 large-scale reservoirs and 39 medium-sized reservoirs. In 2015, all reservoirs achieved class III water standard or better during the whole year, including flood season and non-flood season. Additionally, the eutrophication level is less than in reservoirs and lakes in other regions of China (Fig. 1.9) [1]. However, all major reservoirs are threatened of being continuously filled by incoming sediment loads due to high soil erosion in many upstream areas [9].

Poyang Lake is located in the middle and lower reaches of Yangtze River and has a shoreline of about 1200 km. The lake receives water mainly from five rivers: Xiu

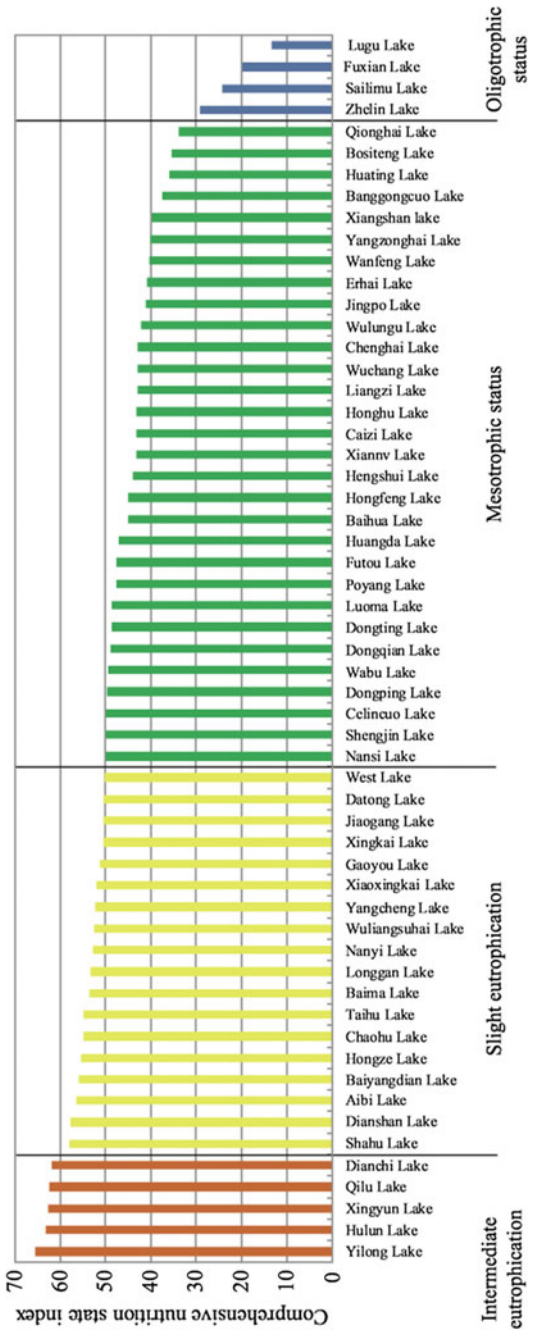

Fig. 1.9 Categorisation of Chinese water bodies by their trophic status in 2016 [1]

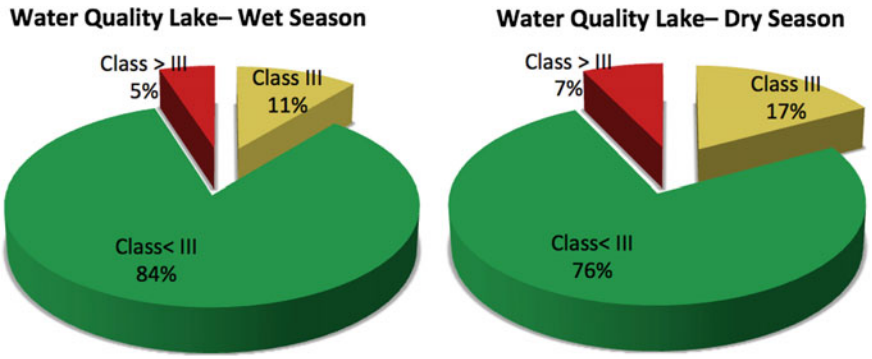

Fig. 1.10 Water quality of Poyang Lake during wet season and dry season

River, Gan River, Fu River, Xin River, and Rao River and discharges into the Yangtze River through a channel in its north part (Fig. 1.2). In response to the annual cycle of precipitation, Poyang Lake can expand to a large water surface of 3 800 km^2 and a volume of 32 bn. m^3 in the wet season, but shrinks to little more than a river during the dry season and thereby exposes extensive floodplains and wetland areas [10].

The modern Poyang lake was formed less than 3000 years ago after the Yangtze River switched to a more southern water course causing the Gan River to back up and form Poyang Lake. Poyang Lake reached its largest size during the Tang Dynasty, when its surface area was about 6 000 km^2. Until the late Ming and early Qing Dynasty it was ultimately gradually evolved into the shape of today's lake [11].

The hydrologic processes of Poyang Lake are complex. Its hydrologic regime is mainly driven by both the five main tributaries and the Yangtze River to which the Poyang Lake drains about 150 bn. m^3 per year [12]. Additionally, the hydrologic system is increasingly disturbed by hydraulic construction measures. The opening of the Three-Gorges-Dam (TGD) in 2003 significantly influenced the hydrological regime in Poyang Lake by reducing length and occurrence of reverse flow conditions [13]. The opening is considered of being one factor of generally decreasing water levels in Poyang Lake during the last decade [14]. If water levels in Poyang Lake continue to decline, the reducing groundwater stores could become a serious concern for the wetland ecosystem, too. This lead to the proposed construction of a new dam at the outflow of Poyang Lake in order to compensate the side effects of the TGD and to rise the lake water level during dry season.

The water quality of Poyang Lake varies with its water volume. Most of Poyang Lake achieves a water quality standard of class III or better (Fig. 1.10). However, water quality deteriorates during dry season with about one fourth of the water body being classified as having class III water quality or worse. In recent years, water quality is continuously deteriorating as the rivers draining to Poyang Lake face several pollution pressures such as an continuous inflow of nutrients and fertilizer residuals from its extensively cultivated shorelines [15] as well as acidity and heavy metals from mining areas [16] and industrial sites [17].

Fig. 1.11 Inside the large wetland areas of Poyang Lake

1.8 Wildlife

Jiangxi Province is characterized by its wide coverage of vegetation and diversity of wildlife. In Jiangxi Province live more than over 600 kinds of vertebrates, including over 170 species of fish, 40 species of amphibians, 70 species of reptiles and 270 species of birds, which all account for more than 20% of the national total of these animal classes.[5] One of the most biodiversity rich areas in Jiangxi Province is the Poyang Lake-wetland system. The large wetlands of Poyang Lake are Asia's largest winter destination for migratory birds [18]. About 95% of the world's Siberian white cranes, 50% of its white-naped cranes and 60% of its swan geese spend winter here every year (Fig. 1.11).[6]

Jiangxi government transformed parts of the wetlands into natural reserves to improve the protection of habitats. One example is the Poyang Lake National Nature Reserve, which is located in the northern part of Poyang Lake covering an area of about 224 km^2. It is one of the first six important wetlands, which joined the Ramsar Convention in China in 1983. It forms a multi-functional complex wetland ecosystem of unique topography and geomorphology, which provides a good habitat for wild animals, especially birds. In this natural reserve alone live 45 species of mammals, 310 species of birds, 48 species of reptiles, 136 species of fish, 227 species of insects, 40 species of shellfishes, 46 species of zooplankton, 50 species of phytoplankton and 476 species of higher plants.[7]

[5] http://www.china.org.cn/english/features/55638.htm.

[6] http://www.china.org.cn/environment/2012-10/17/content_26815948.htm.

[7] http://www.globalnature.org/33539/Nature-Reserve/02_vorlage.asp.

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