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Article

Outline of the Yellow River basin, China

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Abstract: The paper aims to summarize the features of the Yellow River basin from viewpoints of physiographic conditions, climate, hydrography, economic development and water resources demand. The Yellow River basin is higher in the west and lower in the east, descending in three huge topographic steps. Most of the area belongs to the arid and semiarid continental monsoon climate zones and relatively dry. The main stream of the basin is 5,464 km long, and divided into upper, middle and lower reaches. The catchment area for upper reach is 38.6×10^4 km^2, and that for middle reach is the same, but lower reach very small (2.24×10^4 km^2). Both the upper and middle reaches are sections of rich water resources, but the middle reaches are also the main source for silt load. Economic development is presently unbalanced between upper-middle and middle-lower reaches. Based on these datasets, water demand for 2010 and 2020 is predicted.

Keywords: Yellow Rriver, physiography, climate, hydrography, economic development, water resource, water demand

1. Physiogeographic conditions

The Yellow River originates from the Yuegouzonglie Basin on the north foot of the Bayan Har Mountains of the Qinghai Plateau, winding eastward and crossing the Loess Plateau and the Huang-Huai-Hai Plain into the Bohai Sea. The length of the mainstream is 5,464 km, with a drop of 4,480 m and total drainage area of 79.5×10^4 km^2 (including the endorheic area of 4.2×10^4 km^2).

1.1 Topography and geomorphology

The Yellow River basin is higher in the west and lower in the east, descending in three huge topographic steps (Fig. 1).

The highest step is Tibet-Qinghai Plateau formed by a series of NW-SE-trending mountains, e.g., the Qilian Mountains, Jishi Mountains and Bayan Har Mountains. Its eastern margin is bounded by the Qilian Mountains in the north, and the Minshan Mountains in the south. The mountains on both sides of the river valley within this step are 5,500-6,000 m above sea level with relative elevation of 1,500-2,000 m. The Amnyemaqen Mountains with the main peak towering 6,282 m, the highest point of the Yellow River basin, stand out in the center. Snow accumulates on the summit all year round. The Yueguzonglie Basin at the north foot of the Bayan Har Mountains is the source of the Yellow River, and there are broad valleys and numerous lakes in the source areas up Madoi.

The second step is roughly bounded by the Taihang Mountains, having an average elevation of 1,000-2,000 m including some large geomorphologic units such as the Hetao Plain, Ordos Plateau, Loess Plateau, and Feng-Wei Basin. It is also the main region subject to drought and waterlogging. The Ordos Plateau is bounded by the Yellow River on the west, north, and east. The south is bounded by the Great Wall showing near square-shaped platform of arid denuded plateau. Eolian landform is well developed, and the sand dunes are mostly fixed or semi-fixed. The Loess Plateau is bordered by the Great Wall in the north, and the Qinling Mountains in the South. The thick loess, loose soil, uncovered surface and intensive erosion have resulted in the broken landform, resulting in the main source for the silt load of the river. The Hetao Plain and the Feng-Wei Basin are featured by fertile soil and abundant products, and are important grain-producing areas.

The third step begins from the Taihang Mountains via the east of Mangshan Mountain to the Bohai Sea, with the elevation generally below 100 m. It is formed by the lower alluvial plain of the Yellow River and the Luzhong (Central Shandong) Hills (elevation may reach 1,000 m), and the estuarine delta. When the river flows

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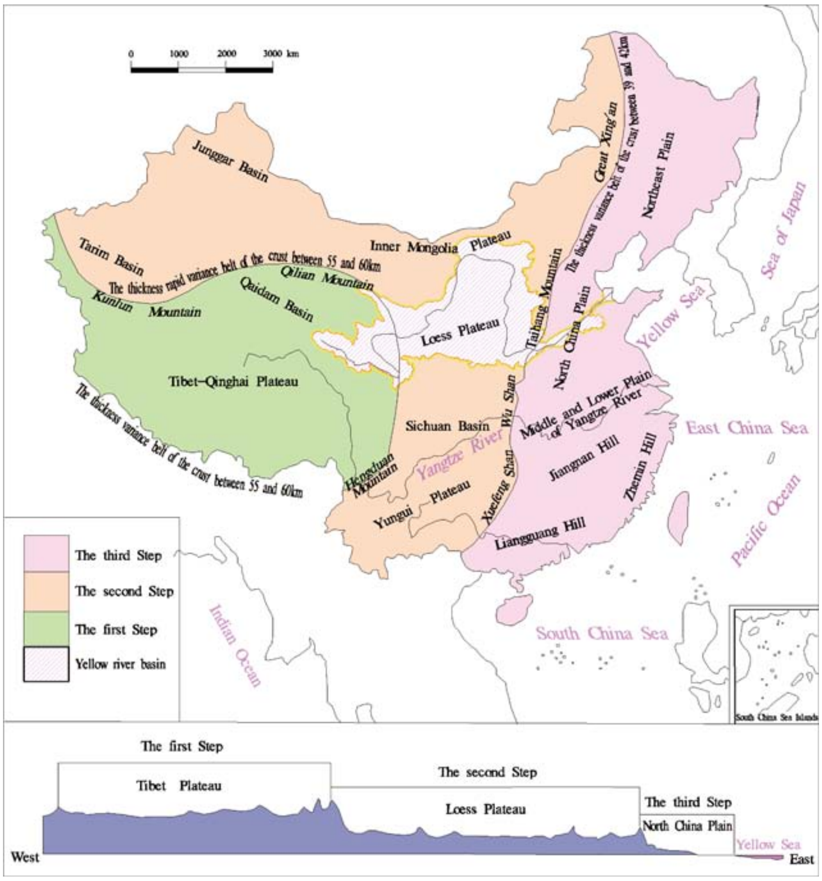

Fig. 1 Sketch map of the three steps of Chinese topography (modified from the *Atlas of Geography of China*, 2000)

into the alluvial plain, the channel becomes broader and smooth, mud and sand silted along the river, so that the riverbed is 3-5 m, or even 10 m higher than the ground on both banks, resulting in the well-known “river above ground”.

1.2 Climate

The Yellow River basin lies between the arid region in the northwest and the humid region in the southeast with great differences in local areas. Most of the area, however, belongs to the arid and semiarid continental monsoon climate zones and relatively dry (Fig. 2).

1.2.1 Temperature

The Yellow River basin consists of a vast area with complex topography. The elevation differs remarkably between the upper and the lower reaches, and so the temperature shows great variations. The lowest temperature of the year occurs in January and the highest mostly in July. Besides, the annual variation of temperature is large owing to influences of the landform and the monsoons. In winter, it is mostly below 0°C affected by the dry and cold airflow from the Siberia. The extremely low temperature may reach -25°C to -40°C in the upper, and -15°C to -20°C in the middle, and lower reaches, so that the river is frozen at many sections in winter.

1.2.2 Precipitation

The Yellow River basin has an average annual precipitation of 479 mm, but it is uneven either in space or in time. The general trend of its distribution in the region is that precipitation being larger in south and east than in north and west, decreasing gradually from southeast to northwest (Fig. 3). The precipitation for most areas ranges 200-650 mm, and exceeds 650 mm for the southern parts of the middle-upper and the lower reaches. It may reach 700-1,000 mm on the north foot of the Qinling Mountains affected by the landform, forming the high-precipitation zone of the basin, whereas it is below 150 mm in Ningxia and some areas of Inner Mongolia, making them the lowest-precipitation zones. As to the temporal distribution, it is dry in winter and spring while rains are concentrated in summer and autumn owing to influences of monsoons. The precipitation in the four months from June to September may account for 58-77 % of the annual amount.

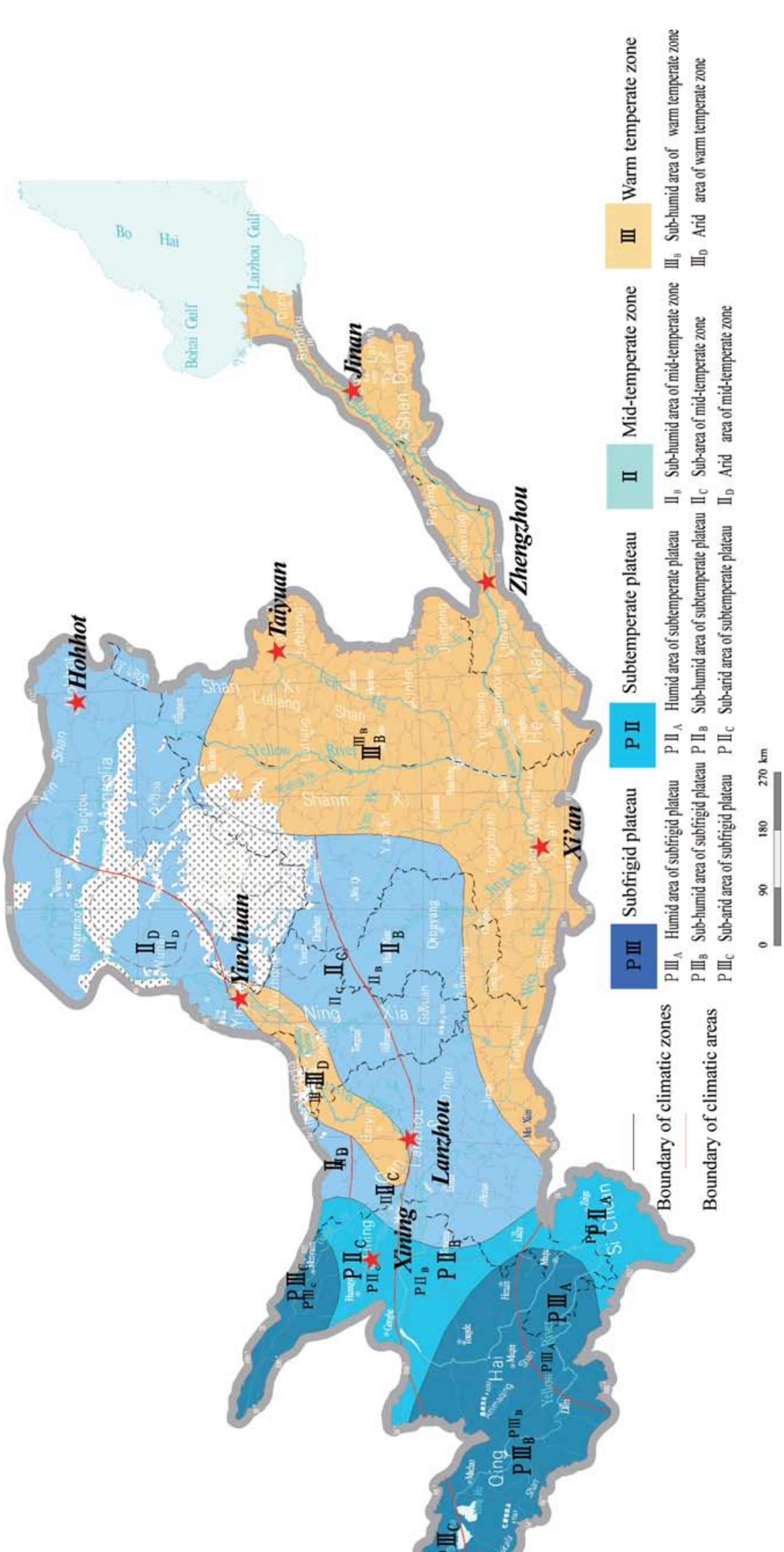

Fig. 2 Climate division in the Yellow River basin
(Modified from Liu, M., 2000)

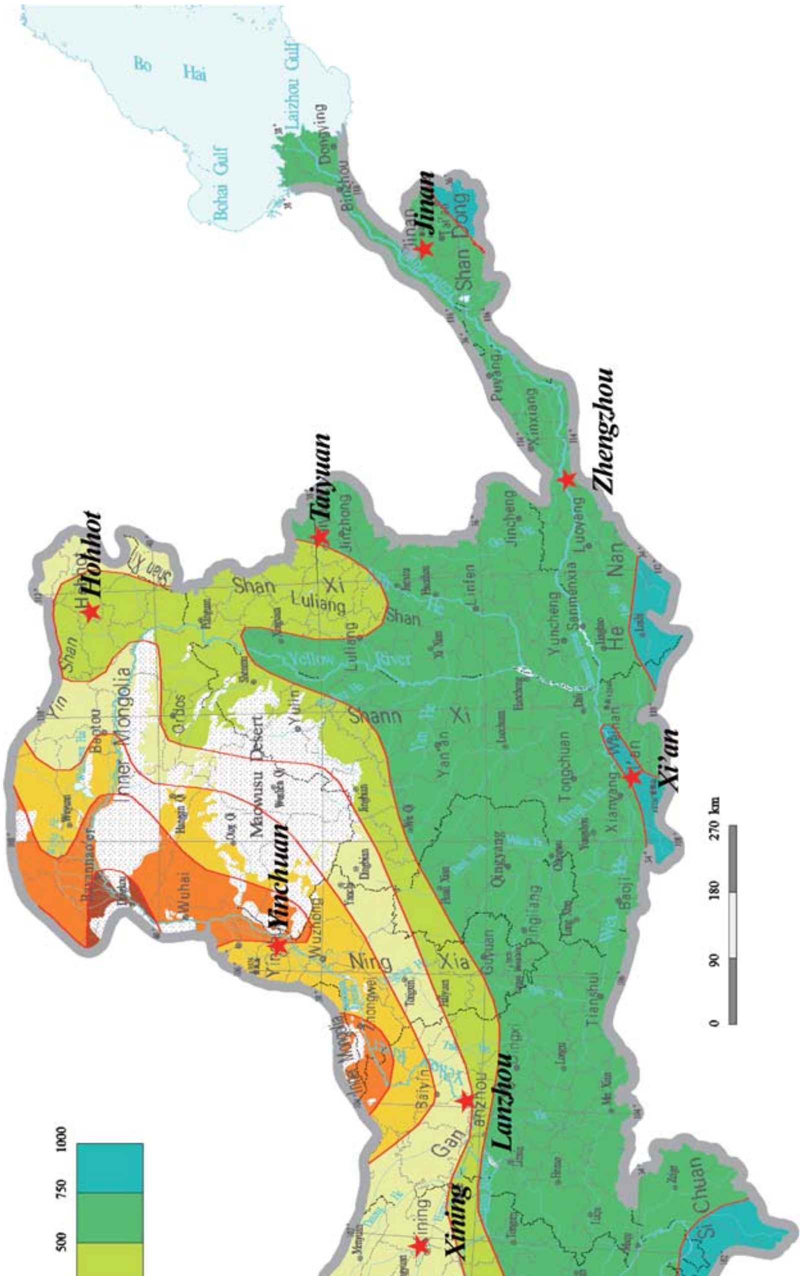

Fig. 3 Precipitaion in the Yellow River basin
(Modified from Liu, M., 2000)

1.2.3 Evaporation

Amount of evaporation can be divided into the one from the water surface and the other from the ground surface. The former, also called the evaporation power, is generally measured by an evaporation pan, and mainly depends on climatic factors such as temperature and humidity; the latter means the actual evaporation discharge from the ground surface, which cannot be measured directly and usually obtained by indirect methods such as integrated observations and remote sensing.

The water surface evaporation in the basin is distributed roughly as follows: in the rocky mountains and forest areas of the Qinghai-Tibet Plateau, temperature is low, and the average water surface evaporation discharge is 800 mm/a; down from Lanzhou, it increases gradually from southeast to northwest; Gansu, Ningxia and the central-western areas of Inner Mongolia are zones of the highest evaporation discharge in China, and the maximum annual evaporation may exceed 2,500 mm; in the lower plain of the Yellow River, it is relatively humid, and the water surface evaporation ranges from 1,200 to 1,700 mm.

The ground surface evaporation is affected by factors such as water supply conditions, evaporation capacity and the unsaturated zone. When the annual precipitation is less than 300 mm per year, the ground surface evaporation decreases with decreasing precipitation, with a ratio of about 0.97; when the annual precipitation for a year is 300-400 mm, the ground surface evaporation increases with increasing precipitation, and the ratio is about 0.95. Thus, the variation rule of ground surface evaporation is similar to that of precipitation, i.e., decreasing gradually from southeast to northwest. However, in the Qinling Mountains area, the ground surface evaporation (only 400 m) does not increase with increasing precipitation (~800 mm), because precipitation is greater than evaporation.

1.3 Hydrography

The main stream of the Yellow River is 5,464 km long in total. The upper reaches starts from the source to Togtoh County, with a length of 3,471.6 km, a drop of 3,846 m and a catchment area of 38.6×10^4 km^2, accounting for 48.5 % of the total area of the basin; the middle reaches begins from Hekou Town to Taohuayu of Zhengzhou, with length of 1,224.3 km, drops of 895 m and catchment area of 38.6×10^4 km^2 same as the upper reaches, comprising 48.5 % of the total. Both the upper and middle reaches are sections of rich water resources, but the middle reaches are also the main source for silt load. Down from Taohuayu is the lower reach, with length of 767.7 km, a drop of 895 m and its catchment area of 2.24×10^4 km^2, comprising 3 % of the total.

1.3.1 Discharge

The Yellow River has an average natural runoff of 574×10^8 m^3/a, accounting for 2.2 % of the total runoff volume of all rivers in China, but this cannot be said to be abundant in terms of water volume. According to historical data, a hydrographic cycle takes 40-60 years, and it is somewhat similar in the upper and lower reaches.

The runoff volume is uneven during the year: July, August and September are flood months, with the water volume accounting for 60 % of the whole year, while the minimum occurs in February, which comprises only 2 %. Because of water consumption by industry and agriculture, drying up of the lower Yellow River occurred in 21 years among the 27 years from 1972 to 1998. In 1997, there were 226 dry-up days at the Lijin Hydrologic Station in the lower reaches of the river. The dry-up section went upstream to somewhere near Kaifeng, Henan, with a length of 704 km. The last dry-up occurred on August 11, 1999. Since 1999 measures have been taken for centralized control of the water volume. Dry-up has been controlled for 7 years in succession, and the once deteriorated ecological conditions of the Yellow River basin are being improved.

1.3.2 Silt

The Yellow River contains the greatest silt load in the world. In the lower reaches of the river, the average annual load amounts to 16×10^8 tons with the silt content of 35 kg/m^3.

The water and silt of the basin have different sources. The upper reaches (Togtoh, Inner Mongolia) has an area of 38.6×10^4 km^2 comprising 48.5 % of the whole basin, but the silt load accounts for only 9 % while the water volume is 53 % of the total. Between Togtoh to Tongguan, the section has an exorheic area of 34.4×10^4 km^2 and endorheic area of 4.2×10^4 km^2, comprising 48.5 % of the whole basin, but the silt load accounts for 90 % of the total, reaching 14.4×10^8 tons whereas the water volume makes up only 37 %. The section downstream from the Sanmen Gorge comprises 3.0 % of the whole basin, with its silt load and water volume making up 1-2 % and 10 %, respectively, of the whole basin. This demonstrates that the river silt is derived from the Loess Plateau. Besides, water and silt in the upper, middle and lower reaches are dynamically consistent, i.e., the year of plentiful water corresponds with the silt-rich year, and the low-water year coincides with the low-silt year. The silt content of the river is uneven in the year: 85 % of silt comes from the flood season, and is often concentrated in a few rainstorms.

When the lower Yellow River enters the plain area, the gradient ratio abruptly becomes small, and the flow rate decreases, resulting in deposition of the silt carried from the upper and middle reaches in large volume, reaching 2-4×10^8 tons per year. According to the grain size analysis of suspended matter, silt with diameters larger than 0.05 mm makes up 84-94 % of the total.

1.3.3 Tributaries and lakes

The Yellow River has numerous tributaries. There are 76 tributaries with the drainage area larger than 1,000 km^2 (among which 14 tributaries are with drainage area over 5,000 km^2), with water volume larger than 10×10^8 m^3/a and silt load larger than 1×10^8 t/a. The tributaries in the upper reach, e.g., Baihe River, Heihe River, Taohe River and Huangshui River, are characterized by large water volume and small silt content, whereas most tributaries in the Loess Plateau show smaller water volume but larger silt content, e.g., Zuli River, Qingshui River, Kuye River, Wuding River etc. In other tributaries such as Fenhe River and Weihe River both the water volume and the silt content are large. The tributaries near the lower Yellow River have large water volume but small silt load, e.g., Yiluo River, Qinhe River and Dawen River.

There are numerous lakes in the Yellow River basin, most of them located in the source region. Among them Zhaling Lake and Eling Lake are the largest fresh water lakes in the basin, having areas of 526.1 km^2 and 610.7 km^2, respectively. Ulansuhai Nur and Dongping Lake are the relatively large lakes in the upper and lower reaches.

2. Outline of economic development and demand on water resources

2.1 Economic development

The Yellow River basin has a total population of about 100 million, comprising 7.6 % of total of China. There are 8 provincial capitals and 36 cities above the prefecture level (Fig. 4), with a cultivated area of 179 million *mu* (1mu ≒ 666.7m^2), about 12.5 % of the whole country. It is rich in land, water, oil and gas, coal and mineral resources, occupying an important position in the country.

The Yellow River basin has long been an important agricultural region of China, where there are 179 million *mu* of cultivated area, 153 million *mu* of forest land and 419 million *mu* of grassland. Besides, there are about 30 million *mu* of waste land which can be reclaimed. The Yinchuan, Zhongwei and Hetao plains in the upper, the Fen-Wei Basin in the middle, and the Yellow River-diverting irrigation area in the lower reaches are the major agricultural regions and grain-producing bases. The basin boasts rich mineral resources, 114 of which have proved reserves including oil and gas as well as coal resources abundant in the middle and lower reaches. At present, its output of raw coal exceeds 50 % of the whole, and that of oil about 1/4 of the total of China. For example, the Ordos Basin located in the middle reaches of the river, whose reserves of oil, gas and coal rank among the first in China, is an important strategic base for energy and chemical industry. The Shengli Oilfield in the lower reach is the second largest of China. In recent years, along with the rapid development of China's economy, a number of energy bases, industrial bases and newly emerging cities have been set up in the basin. Energy industry, nonferrous metallic industry and rare earth industry are well developed in the basin, which lay a foundation for further development of regional economy.

However, the economic development is presently unbalanced in the region. The upper-middle reaches are economically not well developed, whereas the middle-lower reaches are densely-populated areas where economic development ranks among the first in the country. Therefore, it is of key importance to speed up the balanced economic development of the whole basin to reduce the geographical difference in China's economic development, by developing western China, and building a well-off society in an all-round way.

2.2 Demand on water resources

According to the "*Bulletin on Water Resources of the Yellow River Basin in 2005*", the total water supply amounted to 465×10^8 m^3 for the Yellow River basin in 2005, among which that for agriculture was 326.36×10^8 m^3, accounting for 70 %; that for industry 65.43×10^8 m^3, making up 14 %; and that for domestic uses 27.91×10^8 m^3, comprising 6 %. The remaining 10 % was consumed for forestry, animal husbandry and fishery, as well as urban township public and ecological environment uses. Agriculture is the main consumer in the basin. The largest water-consuming section is from Lanzhou to Toudaoguai, and the largest water-consuming regions are Inner Mongolia and Ningxia, with the amounts reaching 98×10^8 m^3 and 80.31×10^8 m^3, respectively. Next are Shandong, Henan and Shaanxi provinces, with the figures being 67.48×10^8 m^3, 60.24×10^8 m^3 and 57.56×10^8 m^3, respectively.

Lin Xueyu *et al.* (2006), based on four indexes of population growth rate, urbanization rate, and industrial and agricultural growth rates, with references to the national economy development plans and water conservancy development plans compiled by the provinces, made prediction on water demand for agriculture, industry, and domestic uses in the basin for 2010 and 2020, respectively (Table 1).

In comparison with the average annual water consumption of 475.37×10^8 m^3 for 1998-2005, if 50 % of precipitation is assumed, the present water supply volume in the basin can meet the demand in the future; if 75 % is assumed, the water volumes by 2010 and 2020 would be deficient by 50.25×10^8 m^3 and 78.53×10^8 m^3, respectively; if 95% is assumed, the water volumes

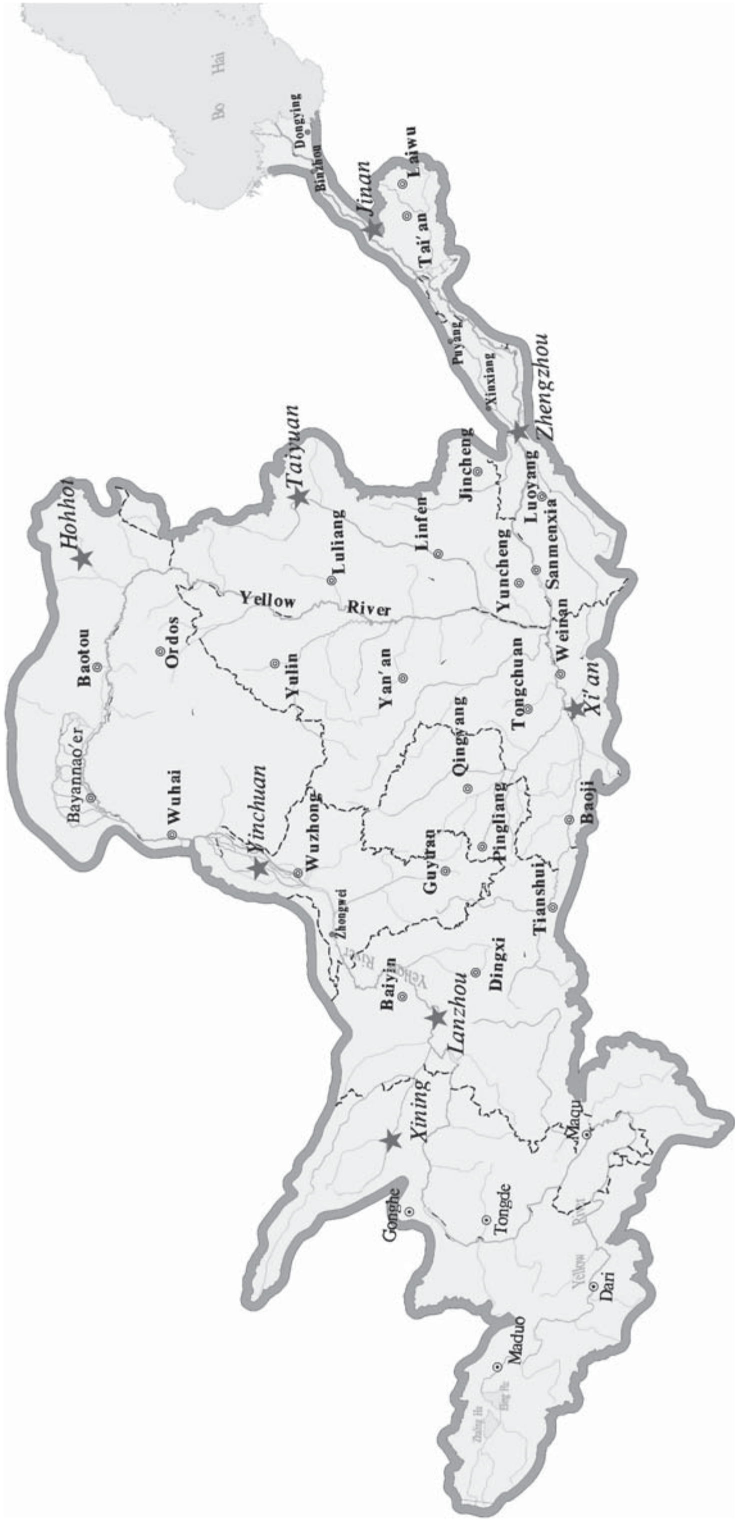

Fig. 4 Location of major cities in the Yellow River basin

would be deficient by $90.4\times10^8\,m^3$ and $111.53\times10^8\,m^3$, respectively, in 2010 and 2020 (Fig. 5).

According to the research by Lin Xueyu *et al*. (2006) in the region, the proportion of water consumption by agriculture would decrease in the future, while that by industry would increase. However, agriculture would still be a large consumer of water in the future. By 2010, water resources in Qinghai Province, Gansu Province, Ningxia Hui Autonomous Region etc. would be relatively rich, while that in Inner Mongolia Autonomous Region, Shaanxi Province, Shandong Province etc. would be lower, among which Shandong would have the largest shortage for water because of its rapid economic development. By 2020,

Table 1 Prediction on the water demand under different assumed rate of precipitation in the Yellow River basin by 2010 and 2020

Year	Water demand under different assumed rates of precipitation ($10^8 m^3$)		
	50 %	75 %	95 %
2010	435.67	525.62	565.77
2020	465.85	553.9	586.90

(Lin X. *et al*., 2006)

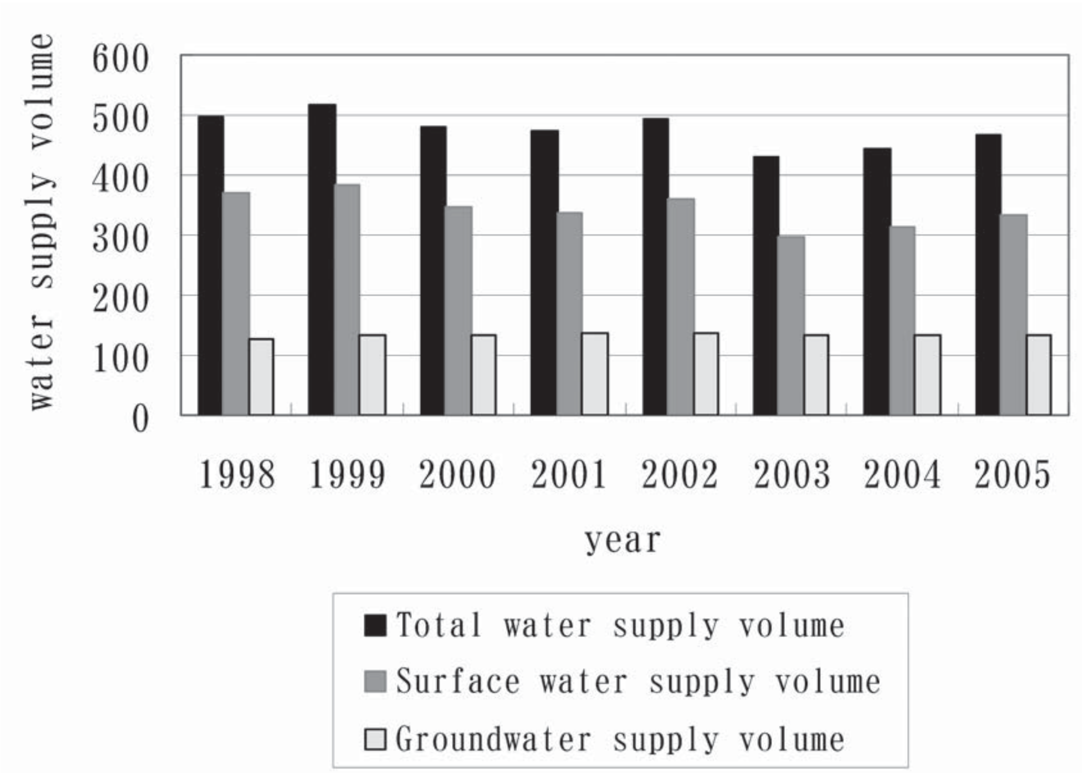

Fig. 5 Histogram of total water supply volumes in the Yellow River basin from 1998-2005 (Ministry of Water Resources, 2005)

the situation would remain unchanged, except that Henan Province would be included into the provinces with relatively high surplus water resources. Besides, there would be cases that water resources are enough in some provinces on the whole, but some local areas are short of water. Generally speaking, the situation for water demand and supply in the basin would still be grave in the future.

In recent years, because of climate changes and irrational development and utilization of water resources in the Yellow River basin, a series of problems on ecological environment and geology have arisen, e.g., glacial retreat in the source region, melting of frozen soil, degradation of grassland and reduction in the capacity of water conservation in the source. A number of man-made water pollution accidents in the main stream and tributaries once threatened the safety of drinking water in major cities along the river. Problems such as ground subsidence and cracking as well as groundwater shortage induced by irrational development and utilization of groundwater resources have seriously hindered the sustainable development of regional economy in the basin. Therefore, carrying out research on groundwater resources in the basin, and on the environmental problems is of important realistic significance in safeguarding sustainable utilization of water resources and sustainable development of regional economy in the basin.

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中国，黄河流域の概要

ウェンドンガン・チャンファワン・チャンアルヨン・ガオスンロン・ハンチャンタオ

要　旨

本報告は，黄河流域の特徴を地形学的状況，気候，水路測量学，経済発展，水資源の需要の観点から，取り纏めている．黄河流域は地形的に西から東に向かって低下するが，大きな二つの段差によって上中下の三面に大別できる．ほとんどの地域は乾燥ないし半乾燥の大陸性モンスーン気候区に属し，相対的に乾燥している．黄河の本流は長さ5,464 kmで，上流，中流，下流に区分される．流域面積は，上流と中流でいずれも $38.6 \times 10^4 km^2$ であるが，下流は $2.24 \times 10^4 km^2$ と相対的に非常に狭い．また，上流と中流は水資源が豊富であるが，中流域は泥の供給源ともなっている．経済発展は上—中流域と中—下流域で大きな格差がある．これらのデータに基づいて，2010年と2020年の水需要量を予測した．