Water use and its impact zone in the lower reach of the Yellow River

Jianyao Chen[1,2], Yoshihiro Fukushima[2], Makoto Taniguchi[2]

[1]School of Geographical Science and Planning, Zhongshan (Sun Yat-sen) University, Guangzhou 510275, China

[2]Research Institute for Humanity and Nature, Kyoto 602-0878, Japan

Abstract

The lower reach of the Yellow River is defined as the zone from Huayuankou to Lijin with an administrative area of about $4.43x10^4$ km^2 and population of about $2.5x10^7$, including 15 cities and 83 counties The area irrigated by the diverted water from the Yellow River within this zone is about 1.93 $x10^4$ km^2. This area is not only related to the Yellow River, but also to Huahe and Haihe basins as the drained water from the irrigated area is the inflow of these two rivers, and could be regarded as the impact zone of the lower reach from the view of water diversion. Water shortage has affected this area since 1990s, and drying up has occurred several times in the main channel of the Yellow River due to over exploitation and climate change. The objective of the study is to identify the spatial and temporal change of water use in the lower reach over the last 50 years, and the causes of these changes.

Keywords: water use, impact zone, lower reach, Yellow River

1 Introduction

The lower reach of the Yellow River is defined as the zone from Huayuankou to Lijin with an administrative area of about $4.43x10^4$ km^2 and population of about $2.5x10^7$ (Ruan, 1997)(Fig.1). This is an important agricultural area with an irrigated area of about $1.93x10^4$ km^2 (in 1990) by using the water diverted from the Yellow River (CDCID, 2002; Xi, 1999), accounting for about one-third of total irrigation area of the whole basin. Since much of sediment precipitates in the lower reach, raising the riverbed, the Yellow River is higher than the riparian zone, i.e., the Yellow River is a suspended river in the lower reach. Therefore, water use in the lower reach is outside of the basin and related not only to the Yellow River but also to the Haihai River (within North China Plain) and Huihe River.

Water shortage is serious recently in the lower reach due to decreasing inflow at Huayuankou station and high demand for domestic, industrial and agricultural water use, especially in the North China Plain. In case of water crisis, the Yellow River was even diverted to supply water for Tianjin City. Drying up in the main channel of the Yellow River has thus occurred several times since 1972. Rational water allocation and use is a big issue in the management of the whole basin, and may affect environmental problems, such as flooding control, coastal sediment and erosion. The main objective of this study is to identify the spatial and temporal change of water use in the lower reach over the last 50 years, and the causes of these changes.

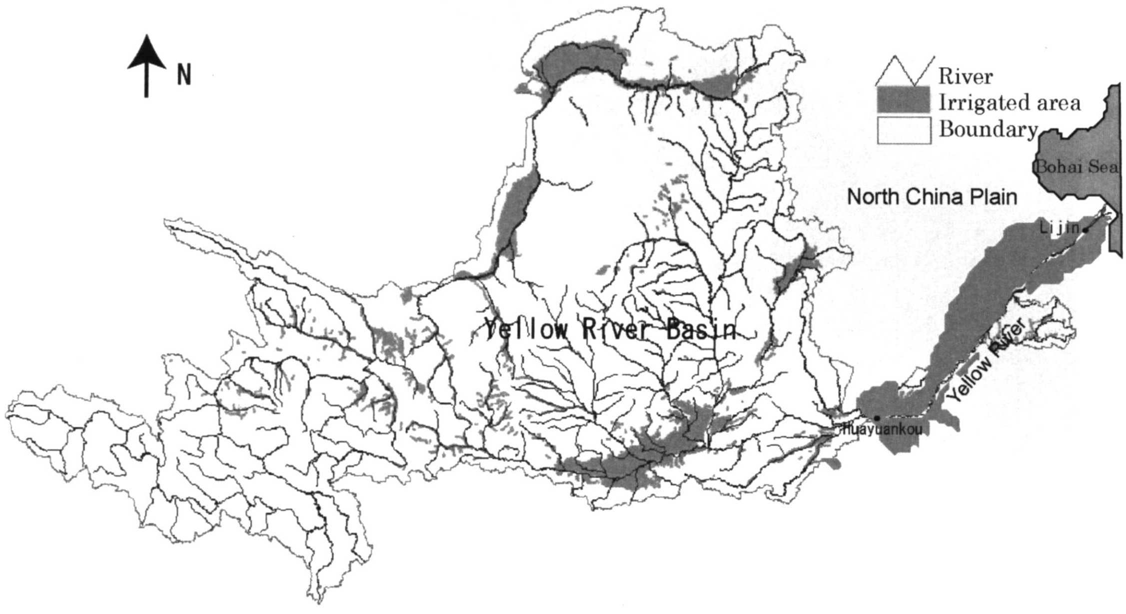

Fig.1 Schematic map of the Yellow River basin and irrigated area, and location of the lower reach. Map of irrigated area was modified after Xi (1999) and YRCC (2002).

2 Methodology

Water use (W_{use}) is estimated based on the difference of monthly discharge at Huayuankou and Lijin stations:

$$W_{use} = FL_H - FL_L$$

FL_H, FL_L are the discharge at Huayunakou and Lijin respectively. Annual water use is calculated by summarizing monthly data.

Though it is basically a suspended river in the lower reach and the flow decreases along the main channel, there are three tributaries flowing into the Yellow River, Tianran Wenyan Canal, Jindi River, and Dawen River. Annual average discharge for these three tributaries is about 2.1×10^9 m^3 (Liu and Chen, 2001). Flow is controlled by the gate in the tributaries and there is no inflow to the Yellow River in the dry season. There are four gauging stations between Huayuankou and Lijin (Fig.2), Gaocun, Sunkou, Aishan and Luokou, which are used to calculate the inflows in the lower reach. W_{use} is thus adjusted by adding the inflow:

$$W_{use}` = FL_H - FL_L + Inflow$$

Impact zone of the Yellow River in the lower reach is proposed by considering both water diversion and drainage from the irrigated area.

Impact zone in the lower reach of the Yellow River in terms of water diversion

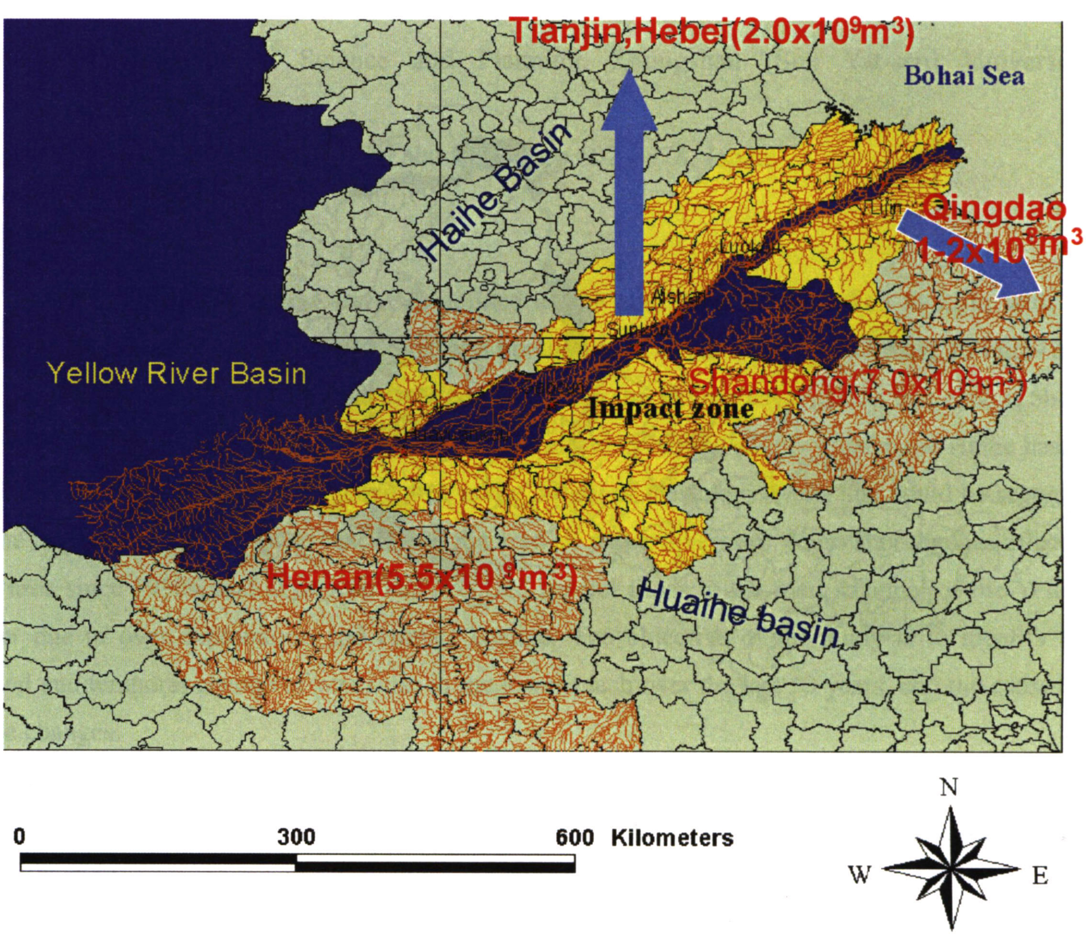

Fig.2 Location of gauging stations in the lower reach and impact zone from the view of water diversion. Data within the parenthesis is the allocation amount for each province or Qingdao City of Shandong Province, proposed by Ministry of Water Resources in 1987 (Xi, 1999).

3 Results

The result shows that annual average discharge at Huayuankou decreases from 4.51x10^{10} m^3 in the period of 1951-1980 to 3.29x10^{10} m^3 in the period of 1981-2000, while that at Lijin decreases from 4.21x10^{10} m^3 to 2.06x10^{10} m^3 respectively, i.e., water used in the lower reach increases about 9.2x10^9 m^3 in recent 20 years compared to the period of 1950-1980 (Fig 3&4). Too much water was diverted for irrigation during the period of 1959-1961 ("Great Leap"), and salinization occurred as drainage canal was not well constructed. As a result, newly developed irrigation area was abandoned except Renmin Shengli Canal with an irrigation area of 1.62x10^4 ha, and water use reduced sharply in 1962. Water was diverted again afterwards in the lower reach, and it increased obviously from 1971 to 1980 and then have kept a relatively stable level since the 1980s. Water amount allocated for Henan, Shandong, Hebei and Tianjin is about 1.45x10^{10} m^3. Since some area in Shandong and Henan Province is outside the reach between Huayuankou and Lijin, actual amount allocated for this reach is only 1.38 x10^{10} m^3 as indicated by the dash line. It shows clearly that water used in 1981, 1988, 1989 and 1999 is higher than the allocated amount.

Although discharge at Huayuankou decreases after 1960s, water diverted in the reach increases for the irrigation of newly developed land and water supply for Tianjin (Tab 1&2). Water diverted for Qingdao City started in 1989 with annual amount of about 2x10^8 m^3. Ratio of water diversion to the discharge at Huayuankou has increased continuously since 1960s, and more than half of water in the lower reach has been diverted in the 1990s, when the discharge is only about half of that in the 1950s and 1960s (Fig.5). This is considered to be the main reason for the world-known problem of drying up in the main channel.

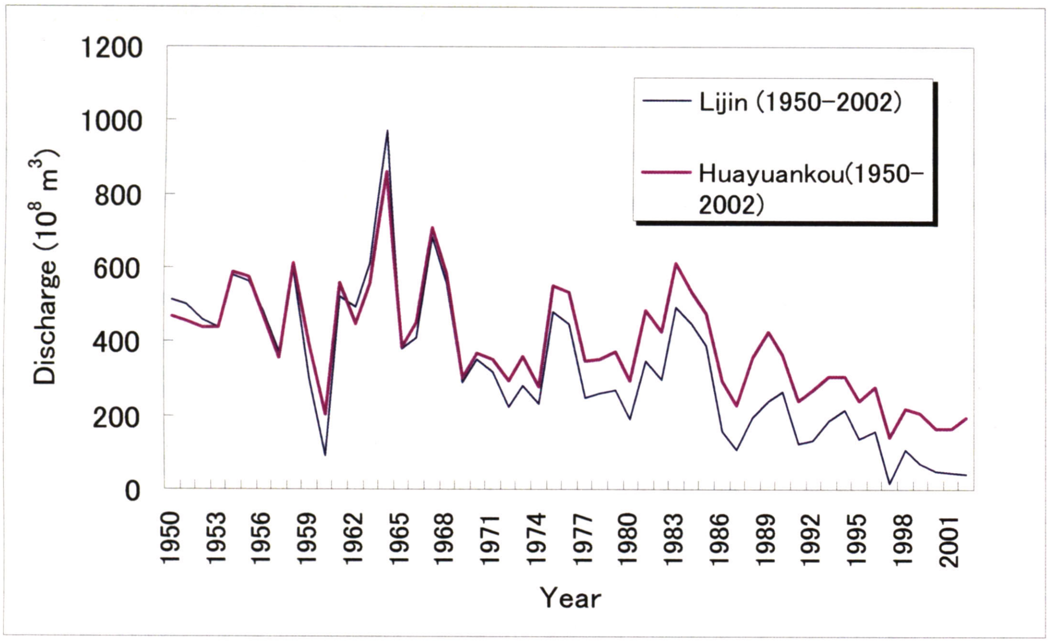

Fig. 3 Annual discharge at Huayuankou and Lijin during the period of 1950-2002

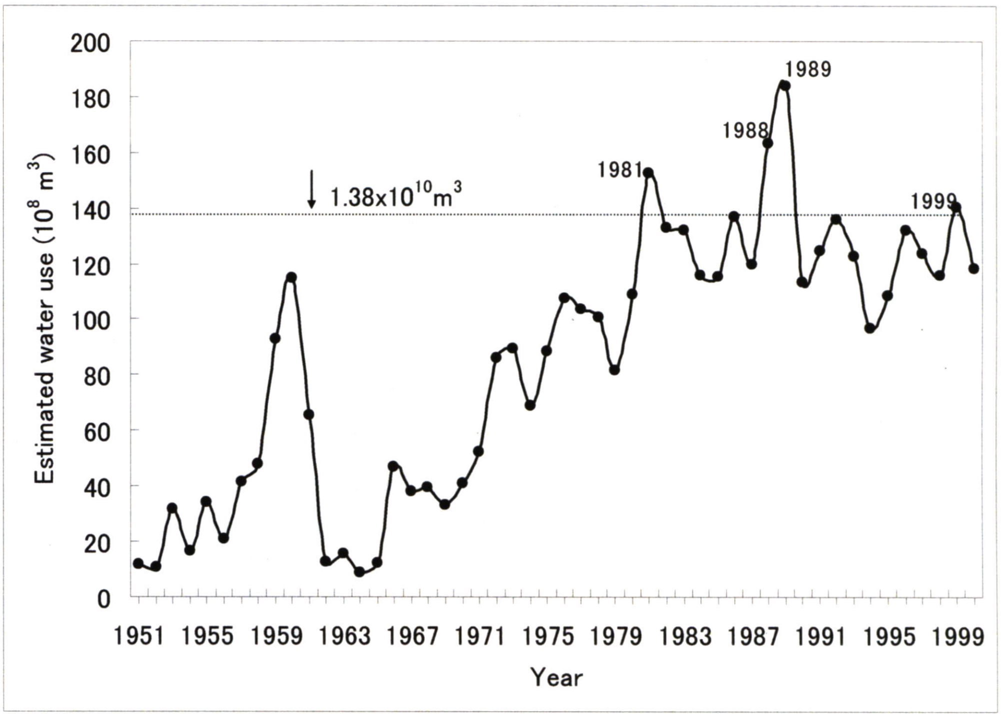

Fig 4 Calculated water use in the lower reach based on the discharge difference between Huayuankou and Lijin. 1.38x$10^{10}$$m^3$ is allocated water amount for the lower reach.

Tab 1 Water diversion from the Yellow River to Tianjin City when water crisis occurred (data was compiled based on information provided in the website: www.hwcc.com.cn)

	Period	Route	Amount collected in Tianjin (10^8 m^3)*
1	Nov.11/1972-Feb. 15/1973	Renmin Shengli Canal	1.62
2	May 13/1973-June 28/1973	Renmin Shengli Canal	1.08
3	Sept./1975-Feb.15/1976	Renmin Shengli Canal	4.0
4	Oct.15/1981-Jan.9/1982	Renmin Shengli Canal	4.472(10.023)
	Nov.27/1981-Jan.17/1982	Weishan Canal	
	Nov.27/1981-Jan.15/1982	Panzhuan Canal	
5	Nov.2/1982-Jan.5/1983	Weishan Canal	(2.76)
	Nov14/1982-Jan.5/1983	Panzhuang Canal	(2.35)
6	Oct.13/2000-Feb.2/2001	Weishan Canal	4.08(8.71)
7	Oct.31/2002-Jan.23/2003	Weishan Canal	2.47(6.03)
8	Sept.12/2003-Jan.6/2004	Weishan Canal	5.1(9.25)
9	Oct.9/2004-	Weishan Canal	4.3(9.8) planned

*data within parenthesis is the total amount of water diverted from the Yellow River.

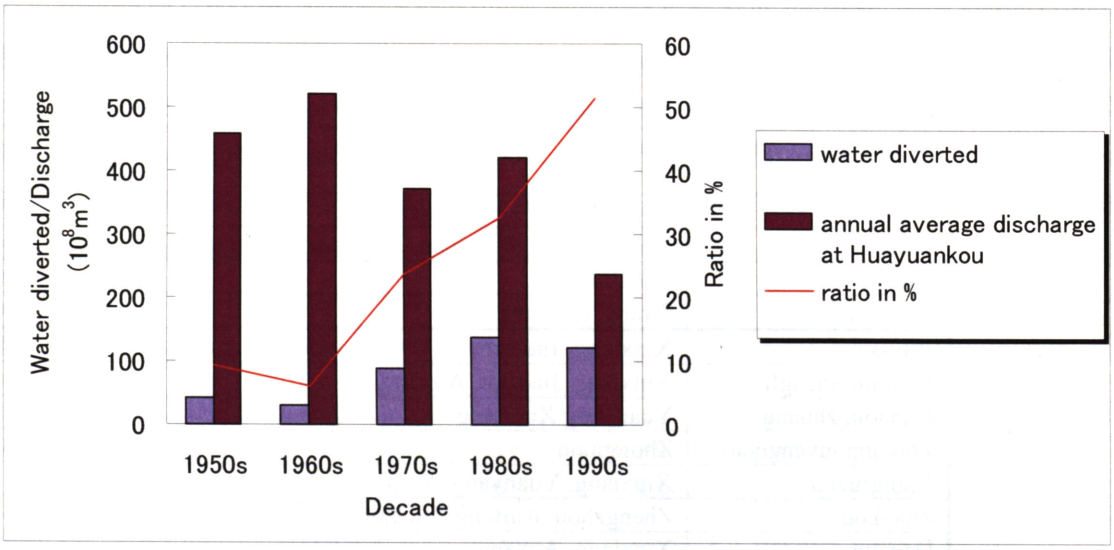

Fig 5 Decade average discharge at Huayuankou, water diverted in the lower reach and ratio of water diversion to the discharge at Huayuankou.

Average monthly discharge at Huayuankou and Lijin stations is given in Fig.6, and the difference between the two stations is equivalent to average monthly water diversion in the lower reach. As we know, the Yellow River basin is affected by monsoon, in which high flow occurs in the wet season (July-Oct) and low flow in the dry season (Nov-June). Water is generally diverted during the period of March to May, when winter wheat grows very fast and evapotranspiration is rather high.

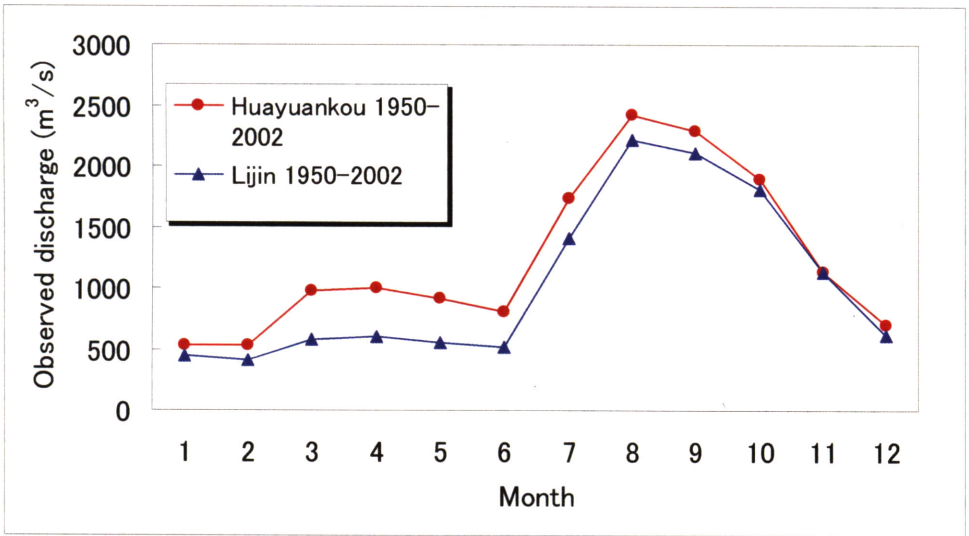

Fig. 6 Average monthly discharge at Huayuankou and Lijin Station during the period of 1950-2002.

Tab 2 Current large irrigation projects in Shandong and Henan Provinces in 2000. The projects inside the bold frame are located within the reach of Huayuankou and Lijin (modified after CDCID, 2002).

Province	Irrigation Project	Location	Current irrigation area (ha)
Henan	Zhaikou	Lingbao	9333.3
	Luhun	Luoyang, Pingdingshan, Zhengzhou, Songshan	34666.7
	Yinqin	Jiaozuo	20600.0
	Guangli	Jiyang, Qinyang etc	20666.7
	Wujia	Xinxiang, Jiaozuo	13333.3
	Renmin Shengli	Xinxiang, Jiaozuo, Anyang	56533.3
	Handongzhuang	Yuanyang Xinxiang	19400.0
	Zhongmouyangqiao	Zhongmou	22866.7
	Xiangfuzhu	Xinxiang, Yuanyang, Yanjin	21333.3
	Zhaokou	Zhengzhou, Kaifeng,Xuchang, Zhoukou etc	244333.3
	Dagong	Xinxiang, Anyang	94000.0
	Liuyuankou	Kaifeng,Qixian,Kaifeng	18266.7
	Sanyizhai	Kaifeng, Shangqiu	120666.7
	Shitouzhuang	Changyuan	20333.3
	Qicun	Puyang. Anyang	97133.3
	Nanxiaodi	Puyang,Qingfeng, Nanle	55333.3
	Penglou	Fanxian	18666.7
Shandong	Yantan	Heze,Dongming	66666.7
	Xiezhai	Heze, Dingtao	48000.0
	Liuzhuang	Heze	34933.3
	Susizhuang	Heze, Juancheng	30666.7
	Suge	Heze, Yuncheng	24666.7
	Yangji	Heze, Yuncheng	20266.7
	Chengai	Jining, Liangshan	28133.3
	Guonali	Jining, Liangshan	20666.7
	Penglou	Liaocheng, Shenxian, Guanxian	85800.0
	Taochengpu	Liaocheng, Shenxian, Yanggexian	49333.3
	Weishan	Liaocheng	338666.7
	Guokou	Liaocheng Donga	22000.0
	Panzhuang	Dezhou	220000.0
	Lijiaan	Dezhou	153333.3
	Tianshan	Jinan, Pingyang, Feicheng	16000.0
	Xingjiadu	Jinan, Jiyang, Shanghe	59533.3
	Chenmengquan	Jinan, Licheng District	16400.0
	Hujiaan	Jinan, Zhangqiu	23066.7
	Liuchunjia	Zibo, Gaoqing	20466.7
	Mazhazi	Zibo, Gaoqing	22000.0
	Hulou	Zouping	25333.3
	Bojili	Binzhou Huiming	51333.3
	Bailongwan	Binzhou Huiming	9666.7
	Xiaokaihe	Binzhou Huiming	44000.0
	Handun	Binzhou Huiming	26666.7
	Dayuzhang	Binzhou Boxing	25333.3
Total area within Huayuankou-Lijin			**2.32 million ha**

Annual average water diverted in the lower reach during the period of 1980-2000 is $1.28 \times 10^{10} m^3$. Based on the flow data at Huyuankou, Gaocun, Sunkou, Aishan, Luokou and Ljin, the amount of water diversion for each sub-reach is calculated by using the same method as mentioned. Tab.3 shows that more than half of the Yellow River water is diverted in two sub-reaches: Huayuankou-Gaocun, and Luokou-Ljin, while irrigate rate is the highest in the reach of Gaocun-Sunkou (Fig. 7).

Tab. 3 Basic information (Ruan, 1997) and water diverted in each reach between Huayuankou and Lijin

Reaches	Huayuankou-Gaocun	Gaocun-Sunkou	Sunkou-Aishan	Aishan-Luokou	Luokou-Lijin	Remarks
Area, km^2	11507.3	2565.2	6400.13	10430.5	13358.82	
Population, 10^4	681.3	232.66	454.11	598.03	535.98	In 1990
Agri. population, 10^4	487.75	205.43	409.11	514.24	458.11	In 1990
Arable land, 10^4 ha.	49.19	19.41	46.18	60.92	58.67	
Irrigation area, 10^4 ha.	40.81	15.71	38.37	49.31	48.39	In 1990
Annual average water diverted, $10^8 m^3$	36.6	17.8	17	27.0	29.6	1980-2000 total, 128

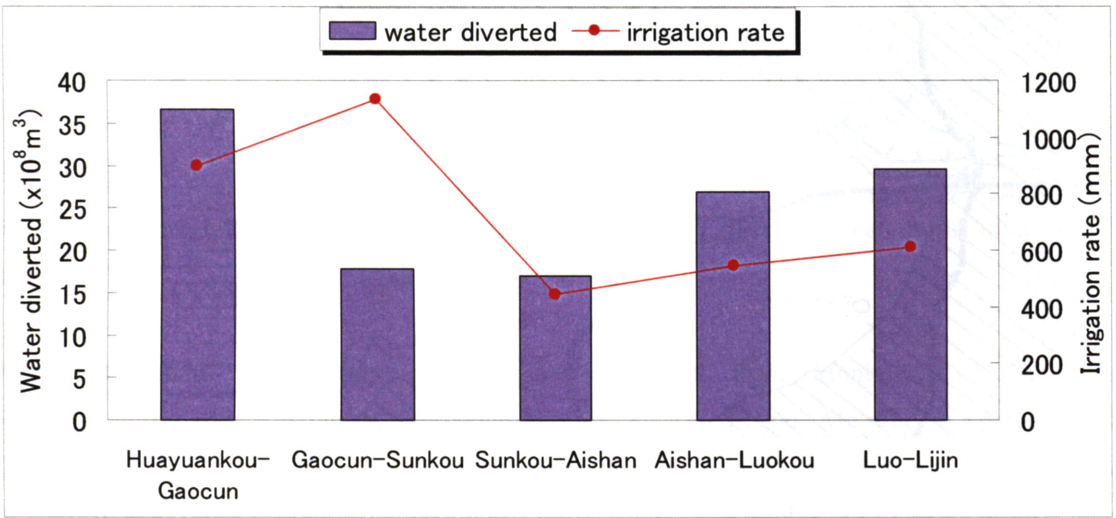

Fig.7 Annual average water diverted in the lower reaches of the Yellow River during the period of 1980-2000

4. Discussions

The impact zone given in Fig. 2 includes only the administrative area where the Yellow river is diverted and irrigated. Actually, a great number of canals were built in both sides of the Yellow River to drain the irrigated area after the failure of irrigation projects in the 1960s, connecting the Yellow River to the Haihe River in the northern side and the Huaihe River in the southern side. The drainage from the irrigated area is reused as input or inflow to Haihe and Huaihe basins.

The Yellow River has shifted many times in the lower reach and flows in the current channel only after 1855(Chen et al, 2004a). In the case of flooding event and breaching, the Yellow River may flow even to the north as far as to Tianjin, and to the south as far as to Hongze Lake and Gaoyou Lake (Fig.8). Therefore, the impact zone the Yellow River in the lower reach is regarded as equivalent to the flooding area defined by the historical flooding events. Since the discharge at Lijin decreases in the last 20 years, especially in the 1990s, the sediment reduces to an annual level of less than 5.0×10^8 tons (Saito and Yang, 1994), causing the coastal erosion in the estuary. Water use in the lower reach affects the sediment and erosion in Bohai Bay, and Bohai Bay should thus be included in the impact zone of the Yellow River from a comprehensive view.

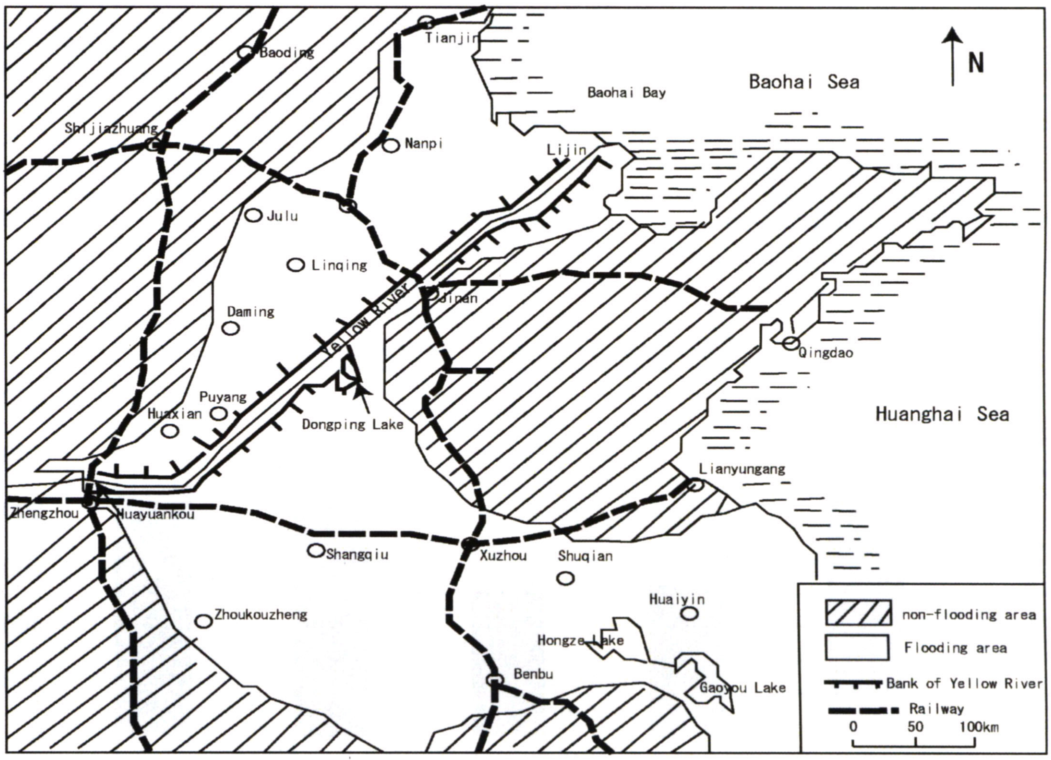

Fig. 8 Impact zone of the Yellow River in the lower reach from the comprehensive view of water use and flooding control, equivalent principally to the flooding area (modified from YRCC, 1984).

Precipitation at Jinan shows four years of heavy rainfall in 1961-1964 (Fig.9), related to the failure of irrigation projects in 1962 as mentioned. No decreasing trend was found for the period of 1980-2000, while on the other hand, pan evaporation decreases in this period. Thus, abrupt increase of water use during the period of 1971-1980 could be explained only by the expansion of irrigation area. Variation of precipitation and change of water use efficiency could contribute to the fluctuation of water use during the period of 1981-2000. Given water use efficiency β as the ratio of actual evapotranspiration (ETa) in the field scale to water diverted at the gate of the Yellow River, β is about 0.3-0.5 even though it does increase in the last 20 years due to the application of water saving technology. Annual average ETa at Yucheng experimental station is about 927 mm (Chen et al, 2004b), as annual average precipitation is 670 mm, water from the Yellow River for the deficit is estimated to be 257 mm. Annual average water diverted in the sub-reach of Aishan-Luokou (where Yucheng station is located) during the period of 1980-2000 is 547 mm, indicating a β of about 257/547=0.47.

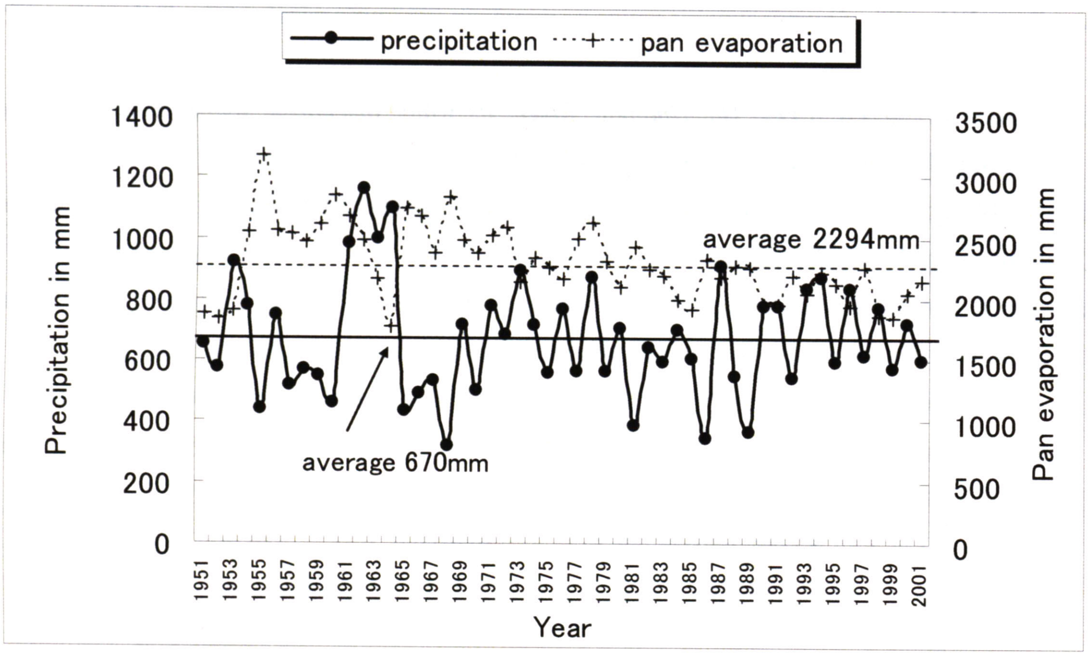

Fig.9 Annual precipitation and pan evaporation (pan diameter: 20 cm) at Jinan during the period of 1951-2001.

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