# Chapter 2

## Analysis of Changes in Water Allocations and Crop Production in the Zhanghe Irrigation System and District, 1966–1998

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## Introduction

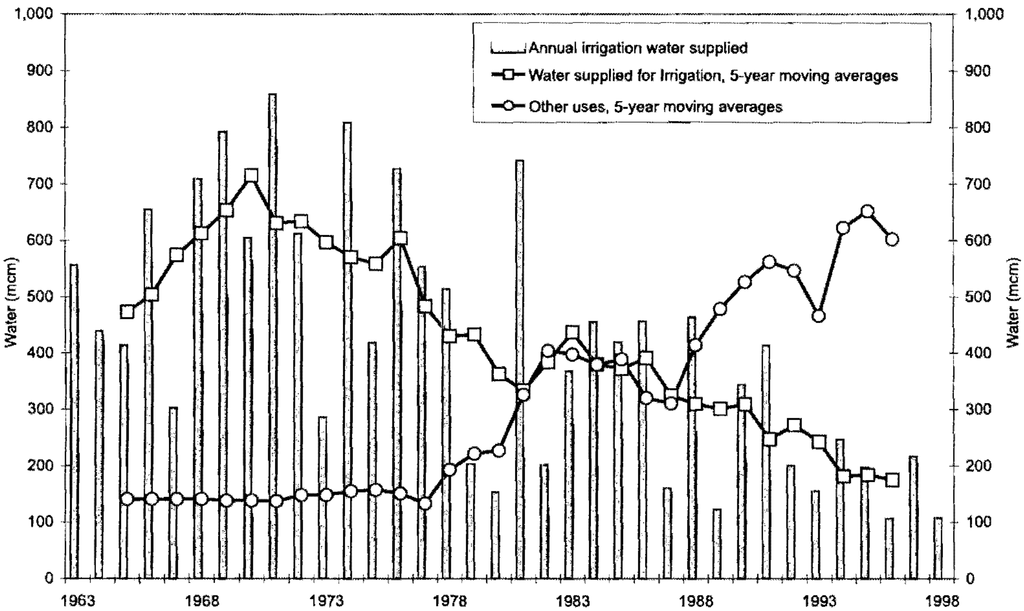
The Zhanghe Irrigation District (ZID) is situated in the middle part of China north of the Changjiang (Yangtze) river.[1] The area of the Zhanghe basin is 7,740 km$^2$ including a catchment area of 2,200 km$^2$. The Zhanghe Irrigation System (ZIS) accounts for most of the irrigated area within ZID. It is one of the typical large-size irrigation systems in China. Its designed irrigation area is about 160,000 hectares. The Zhanghe reservoir, built between 1958 and 1966 on a tributary of the Changjiang river, supplies most of the irrigation water to ZIS. The reservoir was designed for multipurpose uses of irrigation, flood control, domestic water supply, industrial use and power generation.

This paper describes and analyzes the changes in water allocation and crop production in ZIS and ZID over the 33-year period 1966–1998. From the late 1970s to the late 1990s, water allocated to irrigation from the Zhanghe reservoir dropped from 600 million cubic meters (mcm) to about 200 mcm (figure 1). The water allocated for other uses (municipal, industry and hydropower) has increased steadily. By the end of the 1990s, irrigated area and production had declined considerably but by much less than the decline in deliveries of irrigation water. In analyzing these changes, we identify those factors that seem to have contributed to the increase in water productivity.

This paper is divided into seven sections. The first section discusses the sources of data and the rationale for dividing and averaging the data across three separate time periods. The second section describes available water resources in the main reservoir and the change over time in water allocation among alternative uses. The third section describes trend over time in water releases from the main reservoir and from other ZIS sources. The next two sections describe the changes in area irrigated and crop production over time. The sixth section discusses the factors that may have contributed to increases in crop production and water productivity over time and identifies the most probable sources of growth in water productivity. The final section presents the conclusions.

[1] ZID is an administrative unit consisting of all or parts of several county and city jurisdictions. The water used by ZID comes principally from the main reservoir although smaller reservoirs and other sources such as groundwater also supplement this water.

*Figure 1. Annual water allocations for irrigation and other uses, ZIS, 1965–1998.*




## Analysis of Data by Trend and Time Period

The time series on which this report is based was compiled by ZIS for the period 1966 to 1998. The full data are presented in a series of four tables in the annex to this paper. The figures in the text show the trends over time. In the text tables, however, mean values are shown for three separate time periods, 1966–78, 1979–88 and 1989–98. This division was made to reflect the very sharp changes that occurred at the end of the first and second time periods.

Following the end of the Cultural Revolution in the late 1970s, significant reforms took place that affected both irrigation and agricultural production. Volumetric pricing was introduced. New pumping stations were built. Medium- and small-size reservoirs were restored or expanded. Introduction of improved varieties and increased use of chemical fertilizers led to a sharp increase in rice yields.

The end of the 1980s saw further changes. The installation of two new hydropower plants greatly increased the hydropower capacity. Industrial and domestic demand also rose, resulting in a further decline in water available for irrigation. The pressure to save water led to an expansion of the alternate wetting and drying (AWD) irrigation techniques at the farm level and to other water-saving practices such as canal lining. The introduction of hybrid rice gave a further boost to rice yields.

## Regulation and Allocation of Water among Alternative Uses in the Zhanghe Reservoir

In ZIS, most of the irrigation water comes from the Zhanghe reservoir but with substantial supplies from medium- and small-size reservoirs (table 1) and supplemented by a pumping station. Thus, a large irrigation network including storing, diverting and withdrawing water has been established.

*Table 1. Water supplied for irrigation in ZIS, by source.*

| | Million mcm x 100 | | | |
|---|---|---|---|---|
| Period | Main reservoir | Small reservoirs | Other sources | Total |
| 1966–78 | 6.03 | 1.50 | 0.96 | 8.50 |
| 1979–88 | 3.63 | 2.47 | 1.65 | 7.74 |
| 1989–98 | 2.11 | 1.17 | 0.81 | 4.10 |

The water available for irrigation includes rainfall, water from the main and small reservoirs, river water and groundwater. The annual rainfall is 960 mm with a standard deviation of approximately 20 percent. Also, in more recent years, there have been significant releases of water for flood control. The flood year 1996 provides a clear example. The rainfall (1,354 mm) and inflow ($16.4 \times 10^8 m^3$) were abnormally high. Water released for flood control ($8.2 \times 10^8 m^3$) was the highest on record. When water released for flood control is adjusted, the available supply of water from the Zhanghe reservoir does not appear to have changed significantly over time.

Why water releases for flood control have increased over time is not clear. However, if in earlier years surplus water was released into the irrigation system this would help explain why water productivity was so low in the first period. There are large year-to-year fluctuations in rainfall, which affect the annual releases for irrigation (figure 1). When rainfall is low and the irrigation system needs more water for irrigation, the water yield from the catchment is small. When the irrigation system needs less water, the water yield from the catchment is usually large. Varying water storage across years deals with this problem.

Zhanghe is a multipurpose reservoir. While the primary purpose is irrigation, other uses include flood control, hydropower, municipal and industrial water supply, navigation and aquatic culture. The tasks of regulation are based on planning, design and experience. The objectives of water supply are subordinate to flood control and the prerequisite of reservoir safety. As much water as possible is stored to meet water demand for all users, but irrigation has first priority. In years of extreme shortage, such as in 2000, industrial and municipal demands had first priority followed by agriculture. Thus, water for hydropower is reduced.

In the 1966–78 period, the main water use was irrigation but water was not managed well. The standard of flood control was low. There was excess water at the upper end of the canal but, often, farmers at the lower end did not receive water. In the period 1979–88, there were substantial improvements in regulation and management, and volumetric pricing of water was initiated. In the most recent period, 1989–98, new management tools and information technologies were tested and implemented. These included multi-objective optimization modeling, real-time information feedback for forecasting weather and inflow into the reservoir, and remote sensing. Reservoir regulation and flood control were successfully linked with weather forecasting. In summary, improvements in regulation and management have improved the capacity of the Zhanghe reservoir in flood control and in satisfying demands for water among alternative users.

Over the past three decades, with the increase in population and industry, the water demand from city, industry and power generation has increased (figure 1). Jingmen city, a few kilometers from the Zhanghe main reservoir, is a new industrial city with a population of about one million. Jingmen has developed quickly in recent years. The central, provincial, and prefectural governments have established a number of factories in the city. Major industries include oil, chemicals, textiles and leather. In addition to Jingmen city, other smaller cities and towns have developed rapidly, placing a growing demand on water for industrial and municipal uses. The Zhanghe main reservoir supplies water to Jingmen city, while groundwater or medium and small reservoirs supply domestic water for smaller cities and towns.

However, the largest increase in water allocation has been for hydropower, followed by industrial and municipal uses (table 2). The Zhanghe main reservoir was designed with one hydropower plant of 2 x 800 kW capacity utilizing, on average, a water supply of 0.84 x $10^8$ $m^3$. In contrast to most irrigation systems, the water flowing through the generators cannot be diverted back to irrigation. In 1989 and 1995, two new hydropower sets of 1 x 800 kW and 2 x 1,600 kW were installed. The water allocated to hydropower in the 1989–98 period exceeded the water allocated to irrigation—2.5 v 2.1 $10^8$ $m^3$ per annum (table 2). As a result of the growth in demand by hydropower and other sectors, the amount of water from the Zhanghe main reservoir allocated to irrigation in the past decade has declined to one third of its 1966–78 level (6.0 to 2.1 x $10^8$ $m^3$).

*Table 2. Water inflow and releases from the Zhanghe reservoir.*

| Period | Average Water Uses (mcm X 100) | | | | | | | Rainfall (mm) |
|---|---|---|---|---|---|---|---|---|
| | Irrigation | Industrial | Municipal | Hydroelectric | Flood control | Evaporation | Inflow | |
| 1966–78 | 6.03 | 0.17 | - | 0.25 | 0.15 | 1.24 | 69,387 | 952 |
| 1979–88 | 3.62 | 0.37 | - | 0.53 | 2.27 | 1.19 | 75,275 | 967 |
| 1989–98 | 2.12 | 0.48 | 0.15 | 2.51 | 2.83 | 1.23 | 90,273 | 967 |

1975–78 Average for industrial water use.
1973–78 Average for hydroelectric water use.

## Changes in Irrigation Water Supplies in ZIS

Figure 2 compares the trend in sources of irrigation water supply over time for ZIS. In the 1960s and 70s, the main reservoir supplied three quarters of the water for irrigation, but now it supplies only half. The water supply for irrigation by ZIS has dropped sharply since the mid-1980s.

*Figure 2. Water use for irrigation by ZIS from different sources, 1966–1998.*

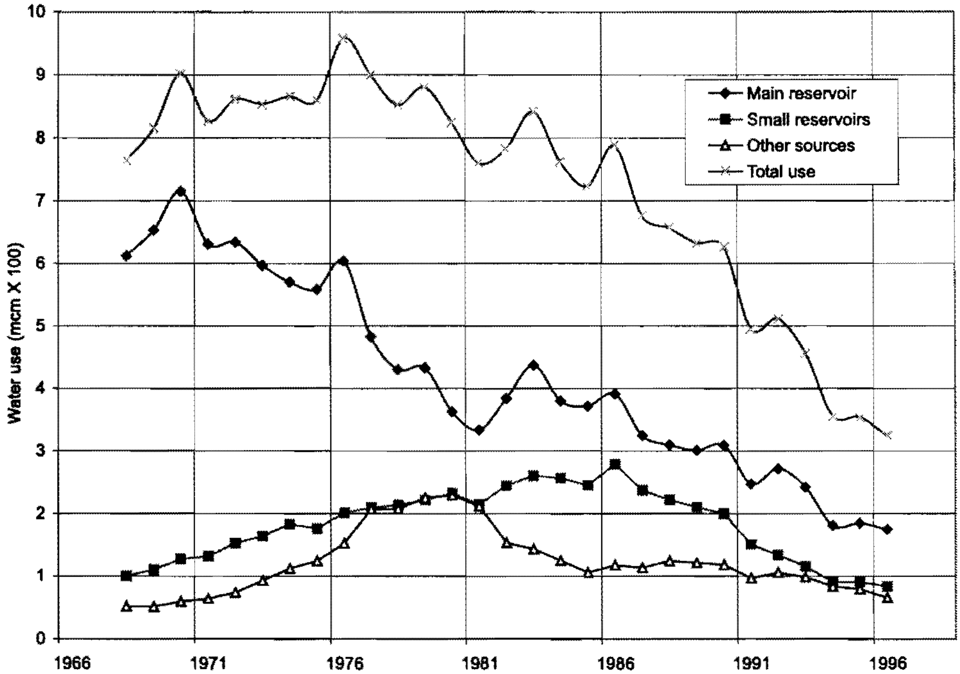



Table 1 shows the water supplied for irrigation in ZIS over three time periods. Despite the sharp drop in the water supply from the reservoir in the 1979–88 period, the total water supply for ZIS declined less than half. This is because in the 1980s a number of medium-size reservoirs and ponds were restored or constructed to increase the water-storing capacity. This evened out farm-level water availability from year to year and provided greater water control during the cropping season, facilitating water saving through AWD management of water in rice fields. In the 1990s, however, the ZIS irrigation water supply from other sources declined. This seems to be because many of the medium- and small-size reservoirs were required to support themselves and were technically no longer a part of ZIS.

## Changes in Crop Area Irrigated in ZID and by ZIS

Table 3 shows the crop area irrigated in ZID and by ZIS for three time periods. Most of the irrigation is for rice. Figure 3 compares the trend in rice area irrigated by ZIS and rice area under irrigation in ZID. In the 1966–78 period, the area irrigated in ZID and by ZIS approximated the command area. However, by the end of the 1990s, rice area irrigated had declined substantially compared to the end of the previous decade. In the 1995–98 period, rice irrigated area declined by 36 percent in ZIS and by 25 percent in ZID over the 1985–88 period. While this decline is relatively large, it is much less than the 61 percent decline in irrigation water supplied by ZIS over the same period.

*Table 3. Command area and area irrigated by ZID and in ZIS (1,000-ha units).*

| Period | Command area | | Area irrigated in ZID | | Area irrigated by ZIS | | Uplands |
|---|---|---|---|---|---|---|---|
| | Total | Rice | Total | Rice | Total | Rice | |
| 1966–78 | 150 | 138 | 143 | 138 | 134 | 130 | 19 |
| 1979–88 | 156 | 142 | 140 | 134 | 103 | 100 | 35 |
| 1989–98 | 147 | 131 | 133 | 118 | 82 | 77 | 63 |

The smaller decline in irrigated area in ZID as compared to ZIS appears to be due to the development of new sources of water that are not under ZIS management. For example, tanks not under ZIS management capture the drainage water from ZIS. As the downward trend in irrigated area in both ZIS and ZID continued in the late 1990s farmers have increased the area planted to upland crops (table 3).

## Change in Rice Crop Production and Land and Water Productivity in ZID

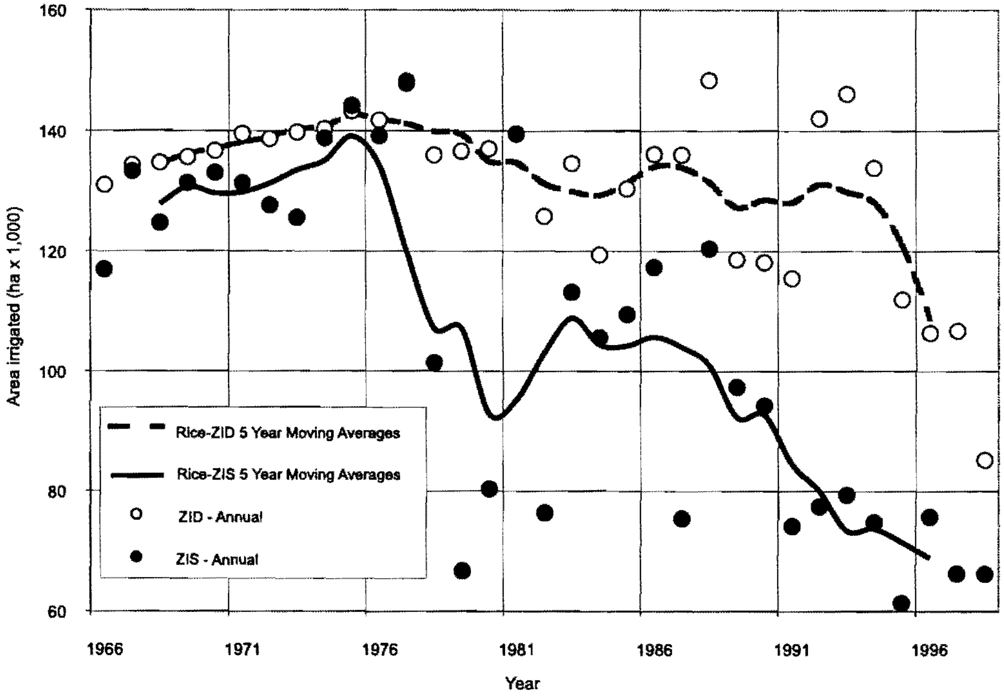
What impact does the reduced allocation of water for irrigation have on crop production, and on land and water productivity? The reported rice-grain production, planted area, and rice yield per hectare for ZID are shown in table 4. Rice production rose sharply in the period 1979–88 compared to the previous period despite a decline of 13 percent in planted area. This is because rice yields rose sharply due to the spread of modern varieties and increased use of chemical fertilizers following the change in agricultural policies at the end of the Cultural Revolution. Over the three time periods the yield per hectare of rice doubled. When rice irrigated area began to decline substantially by the second half of the 1990s, rice production followed suit as yield growth had slowed to almost nothing. Comparing 1995–98 with 1985–88, rice area planted declined 27 percent while average yields rose by just 4 percent. The net effect was a 24 percent fall in rice production. To some extent, this was compensated for by increased production of upland crops.

*Table 4. Changes in rice irrigated area, planted area, production and yield in ZID.*

| | Irrigated area ha x 1,000 | Planted area ha x 1,000 | Rice production MT x 1,000 | Rice yield t/ha | Water supplied Million mcm x 100 | Yield* kg/m$^3$ (irrigation) |
|---|---|---|---|---|---|---|
| 1966–78 | 138 | 173 | 698 | 4.04 | 8.50 | 0.82 |
| 1979–88 | 134 | 151 | 1,015 | 6.72 | 7.74 | 1.31 |
| 1989–98 | 118 | 122 | 952 | 7.80 | 4.10 | 2.32 |

*Note:* MT=Metric tons.
* Upper limit, see text for discussion.

*Figure 3. Rice area irrigated by ZIS and ZID, 1966–1998.*



There are no data of ZID water supply for irrigation. However, if we assume that the main supply of water to areas in ZID not served by ZIS is the ZIS drainage water, then we can estimate the change in water productivity. This assumption seems reasonable since in the period 1966–78 the area irrigated by ZIS and ZID was almost identical. However, to the degree that this assumption does not hold, the water productivity values shown in table 4 represent an overestimate. For example, if it were assumed, as stated earlier, that the reservoirs formerly under ZIS control were still supplying water to ZID, then the water productivity in the third period would be approximately the same as in the second.

## Factors Contributing to the Increase in Crop Production and Water Productivity

Long-term trends in water allocation across sectors and in yield per hectare and per cubic meter of irrigation water supplied show that there have been water savings and a considerable increase in water productivity over time. Despite the decline in water for irrigation from the reservoir (figure 1) and in the area irrigated in ZID, crop production has been sustained.

Several factors may have contributed to sustained rice production including: i) economic and institutional reforms initiated in 1978, ii) a shift in cropping pattern from two to one crop of rice, iii) on-farm and system WSI practices (e.g., AWD irrigation of rice fields), iv) volumetric pricing of water, which may have encouraged AWD irrigation, v) development of alternate sources of water such as small reservoirs and groundwater, and vi) recapture and reuse of return flows through the network of reservoirs. Of course, the various changes that occurred are not independent of each other but we are attempting to identify more precisely the contribution of each of these factors.

Table 5 shows that the trends in yield per hectare of rice for ZID, Hubei Province, and all China are remarkably similar. It seems reasonable to assume that the increase in yield per hectare in ZID explains more than half of the increase in water productivity. But a substantial amount of the gain in water productivity remains to be explained by other factors.

*Table 5. Annual percentage increase in rice yields for China, Hubei and ZID.*

| Period | China | Hubei | ZID |
|---|---|---|---|
| 1966–78 to 1979–88 | 3.9 | 4.2 | 5.2 |
| 1979–88 to 1989–98 | 2.0 | 2.6 | 1.7 |
| 1966–78 to 1989–98 | 3.0 | 3.5 | 3.5 |

AWD irrigation may be one of the reasons behind the increase in water productivity in ZIS over time. Chapter 5 of this publication shows that many farmers have adopted some form of AWD irrigation while chapters 4 and 5 show that adoption of AWD irrigation has no effect on yields. Coupled with the reduced water use in AWD irrigation, this leads to an increase in water productivity, at least at the farm scale. However, it has proved difficult to quantify the system-level effects of increased water productivity at the farm scale.

In the future, we would like to see whether water-saving technologies used successfully in China can be utilized in other rice-growing areas of the world. We feel that WSI practices such as AWD irrigation and recapture of return flows are suitable for monsoonal areas where there is considerable outflow that could be saved and put to productive use. In the more arid regions, especially those where water resources are already committed to various uses, the scope for water saving by AWD irrigation and related techniques may be more limited.

## Conclusions

ZIS was originally designed as a multipurpose reservoir but water was supplied initially only for irrigation. Gradually, the supply and management of water for other purposes have grown in importance. These include flood control, hydropower, and municipal and industrial water needs. The reservoir also serves environmental needs, tourism, aquatic culture and navigation.

In this paper, we have examined the trends in water allocation among sectors, in area irrigated, and in crop production and productivity. As water demand has grown for purposes other than irrigation, the water supplied to irrigation has fallen sharply. To maintain crop production, several water-saving practices have been adopted. While yield per hectare has doubled from the 1960s to the 1990s, yield per cubic meter of water supplied appears to have tripled.

There are a number of factors that may have contributed to the increase in water productivity, including AWD irrigation, improved system management, volumetric pricing, development of new water sources that reduce uncertainty surrounding water availability during key crop-growth stages and improved reuse of drainage water. A major objective of future research will be to identify those practices that could be successfully extended to other regions, both inside and outside China.

*Annex table 1 contains data for the Zhanghe reservoir for the period 1966–1998.*

Zhanghe Irrigation Reservoir

Annual inflow, water releases for alternative uses and other losses
Cubic meters x 10,000

| Year | Water uses: Irrigation | Industrial | Domestic | Hydro-electric | Flood Releases | Evaporation | Inflow | Rainfall (mm) |
|---|---|---|---|---|---|---|---|---|
| 1966–78 | 60,325 | 1,667 | | 2,459 | 1,473 | 12,434 | 69,387 | 952 |
| 1979–88 | 36,245 | 3,659 | 931 | 5,277 | 22,716 | 11,943 | 75,275 | 967 |
| 1989–98 | 21,165 | 4,826 | 1,487 | 25,128 | 28,340 | 12,280 | 90,273 | 967 |
| | | | | | | | | |
| 1966 | 65,441 | | | | 1,473 | 12,448 | 44,462 | 772 |
| 1967 | 30,198 | | | | | 10,991 | 94,389 | 1,192 |
| 1968 | 70,916 | | | | | 15,444 | 109,060 | 1,138 |
| 1969 | 79,281 | | | | | 15,907 | 77,388 | 1,014 |
| 1970 | 60,455 | | | | | 14,401 | 62,256 | 949 |
| 1971 | 85,928 | | | | | 12,391 | 91,919 | 1,064 |
| 1972 | 61,207 | | | | | 11,195 | 29,302 | 646 |
| 1973 | 28,666 | | | 4,720 | | 10,146 | 123,632 | 1,214 |
| 1974 | 80,859 | | | 6,508 | | 14,766 | 44,053 | 819 |
| 1975 | 41,854 | 1,375 | | 779 | | 12,242 | 99,250 | 1,173 |
| 1976 | 72,726 | 2,218 | | 710 | | 12,796 | 31,110 | 724 |
| 1977 | 55,314 | 1,559 | | 120 | | 10,746 | 59,939 | 865 |
| 1978 | 51,378 | 1,517 | | 1,915 | | 8,165 | 35,275 | 801 |
| 1979 | 20,371 | 2,672 | | 982 | | 8,704 | 92,729 | 1,156 |
| 1980 | 15,364 | 2,832 | | 2,969 | 24,576 | 14,093 | 126,234 | 1,181 |
| 1981 | 74,159 | 2,783 | | 1,250 | 10,275 | 15,791 | 39,577 | 740 |
| 1982 | 20,164 | 3,690 | | 818 | | 10,522 | 87,674 | 982 |
| 1983 | 36,764 | 2,763 | | 2,826 | 43,632 | 12,017 | 118,802 | 1,223 |
| 1984 | 45,546 | 3,316 | | 7,699 | 27,368 | 12,787 | 76,517 | 1,005 |
| 1985 | 41,966 | 4,155 | | 17,457 | 7,727 | 12,058 | 57,964 | 931 |
| 1986 | 45,656 | 4,511 | | 5,247 | | 11,117 | 28,932 | 772 |
| 1987 | 16,067 | 5,070 | | 4,227 | | 10,504 | 81,319 | 994 |
| 1988 | 46,391 | 4,797 | 931 | 9,298 | | 11,837 | 43,003 | 687 |
| 1989 | 12,297 | 4,126 | 1,236 | 19,546 | 11,905 | 9,592 | 121,400 | 1,239 |
| 1990 | 34,420 | 5,112 | 1,291 | 23,349 | 51,453 | 12,033 | 94,558 | 1,049 |
| 1991 | 41,362 | 5,138 | 1,474 | 19,315 | 14,191 | 12,842 | 90,122 | 936 |
| 1992 | 20,022 | 4,947 | 1,279 | 19,243 | 2,793 | 13,383 | 65,286 | 878 |
| 1993 | 15,489 | 4,553 | 1,441 | 21,857 | | 11,870 | 81,417 | 811 |
| 1994 | 24,656 | 4,137 | 1,482 | 15,838 | | 12,324 | 48,573 | 763 |
| 1995 | 19,768 | 4,566 | 1,681 | 28,219 | | 12,621 | 74,878 | 871 |
| 1996 | 10,663 | 5,027 | 1,623 | 25,934 | 81,525 | 12,610 | 164,171 | 1,354 |
| 1997 | 21,646 | 5,556 | 1,677 | 29,685 | 16,685 | 13,364 | 63,526 | 783 |
| 1998 | 11,329 | 5,095 | 1,689 | 48,293 | 19,830 | 12,163 | 98,799 | 988 |

*Note:* Data are reported on the annual releases of water for alternative uses (irrigation, industry, domestic, hydropower). There are also data on inflow, loss due to evaporation, releases for flood control and on annual rainfall.

*Annex table 2 shows the amount of water released for irrigation in ZIS for the period 1966–1998.*

Zhanghe Irrigation District

| | Annual water sources for irrigation in ZIS Million cubic meters x 100 | | | |
|---|---|---|---|---|
| | Water uses | | | |
| Year | Main reservoir | Small reservoirs | Other sources | Total sources |
| 1966–78 | 6.03 | 1.50 | 0.96 | 8.50 |
| 1979–88 | 3.63 | 2.47 | 1.65 | 7.74 |
| 1989–98 | 2.11 | 1.17 | 0.81 | 4.10 |
| 1966 | 6.54 | 0.79 | 0.60 | 7.93 |
| 1967 | 3.02 | 0.97 | 0.52 | 4.51 |
| 1968 | 7.09 | 1.13 | 0.57 | 8.79 |
| 1969 | 7.92 | 1.04 | 0.46 | 9.42 |
| 1970 | 6.04 | 1.08 | 0.45 | 7.57 |
| 1971 | 8.59 | 1.29 | 0.57 | 10.45 |
| 1972 | 6.12 | 1.82 | 0.92 | 8.86 |
| 1973 | 2.87 | 1.36 | 0.80 | 5.03 |
| 1974 | 8.08 | 2.09 | 0.97 | 11.14 |
| 1975 | 4.18 | 1.65 | 1.39 | 7.22 |
| 1976 | 7.27 | 2.23 | 1.53 | 11.03 |
| 1977 | 5.53 | 1.47 | 1.54 | 8.54 |
| 1978 | 5.14 | 2.63 | 2.21 | 9.98 |
| 1979 | 2.04 | 2.51 | 3.69 | 8.24 |
| 1980 | 1.54 | 1.86 | 1.42 | 4.82 |
| 1981 | 7.41 | 2.61 | 2.41 | 12.43 |
| 1982 | 2.02 | 2.03 | 1.73 | 5.78 |
| 1983 | 3.68 | 1.72 | 1.34 | 6.74 |
| 1984 | 4.55 | 4.03 | 0.77 | 9.35 |
| 1985 | 4.20 | 2.64 | 0.93 | 7.77 |
| 1986 | 4.56 | 2.41 | 1.48 | 8.45 |
| 1987 | 1.61 | 1.46 | 0.78 | 3.85 |
| 1988 | 4.64 | 3.40 | 1.93 | 9.97 |
| 1989 | 1.23 | 1.96 | 0.56 | 3.75 |
| 1990 | 3.44 | 1.87 | 1.48 | 6.79 |
| 1991 | 4.14 | 1.83 | 1.31 | 7.28 |
| 1992 | 2.00 | 0.92 | 0.63 | 3.55 |
| 1993 | 1.55 | 0.95 | 0.87 | 3.37 |
| 1994 | 2.46 | 1.12 | 1.01 | 4.59 |
| 1995 | 1.98 | 0.97 | 1.11 | 4.06 |
| 1996 | 1.07 | 0.60 | 0.57 | 2.24 |
| 1997 | 2.16 | 0.88 | 0.41 | 3.45 |
| 1998 | 1.07 | 0.61 | 0.19 | 1.87 |

*Note:* The release includes the water from the main reservoir, from smaller reservoirs and from other sources such as groundwater.

*Annex table 3 shows the command area, the area irrigated in ZID (i.e., the irrigation district) and the area irrigated by ZIS (i.e., the irrigation system) for all crops including rice for the period 1966–1998.*

Zhanghe Irrigation District

| | Command area and area irrigated in ZID and by ZIS 1966–1998. ha X 1,000 | | | | | |
|---|---|---|---|---|---|---|
| | Command area | | Area irrigated in ZID | | Area irrigated in ZIS | |
| Year | Total | Rice | Total | Rice | Total | Rice |
| 1966–78 | 150 | 138 | 143 | 138 | 134 | 130 |
| 1979–88 | 156 | 142 | 140 | 134 | 103 | 100 |
| 1989–98 | 147 | 131 | 133 | 118 | 82 | 77 |
| 1966 | 141 | 130 | 136 | 131 | 121 | 117 |
| 1967 | 139 | 134 | 139 | 134 | 138 | 133 |
| 1968 | 146 | 135 | 139 | 135 | 127 | 125 |
| 1969 | 149 | 136 | 140 | 136 | 134 | 131 |
| 1970 | 143 | 137 | 141 | 137 | 135 | 133 |
| 1971 | 153 | 140 | 145 | 140 | 134 | 131 |
| 1972 | 154 | 141 | 145 | 139 | 132 | 128 |
| 1973 | 153 | 140 | 144 | 140 | 135 | 126 |
| 1974 | 152 | 139 | 143 | 140 | 140 | 139 |
| 1975 | 154 | 141 | 147 | 143 | 146 | 144 |
| 1976 | 154 | 140 | 145 | 142 | 141 | 139 |
| 1977 | 155 | 141 | 149 | 148 | 149 | 148 |
| 1978 | 155 | 141 | 145 | 136 | 104 | 101 |
| 1979 | 154 | 140 | 141 | 137 | 70 | 67 |
| 1980 | 156 | 142 | 141 | 137 | 82 | 80 |
| 1981 | 155 | 142 | 144 | 139 | 144 | 139 |
| 1982 | 155 | 141 | 131 | 126 | 78 | 76 |
| 1983 | 151 | 140 | 137 | 135 | 121 | 113 |
| 1984 | 153 | 140 | 127 | 119 | 103 | 106 |
| 1985 | 162 | 142 | 142 | 130 | 117 | 110 |
| 1986 | 163 | 146 | 146 | 136 | 120 | 117 |
| 1987 | 161 | 143 | 136 | 136 | 75 | 75 |
| 1988 | 149 | 145 | 150 | 148 | 121 | 120 |
| 1989 | 148 | 142 | 119 | 119 | 99 | 97 |
| 1990 | 149 | 136 | 139 | 118 | 105 | 94 |
| 1991 | 165 | 133 | 153 | 115 | 90 | 74 |
| 1992 | 151 | 128 | 162 | 142 | 82 | 77 |
| 1993 | 142 | 133 | 148 | 146 | 80 | 79 |
| 1994 | 140 | 123 | 147 | 134 | 80 | 75 |
| 1995 | 149 | 134 | 136 | 112 | 77 | 61 |
| 1996 | 149 | 134 | 123 | 106 | 68 | 76 |
| 1997 | 149 | 134 | 112 | 107 | 76 | 66 |
| 1998 | 131 | 109 | 91 | 85 | 68 | 66 |

Conversion factor: 1mu = 0.0667 ha.

*Note:* Data for the ZID are obtained by ZIS from the counties and cities, a portion or all of which fall within the ZID.

*Annex table 4 shows the ZID production, planted area, and yield per hectare for rice only. All of the rice is irrigated and most farmers grow only a single crop. Other grain crops are normally not irrigated.*

Zhanghe Irrigation District

Area, production and unit yield of rice in ZID, 1966–1998

| Year | Rice area planted ha X 1,000 | Rice production Mt X 1,000 | Unit yield kg/ha |
|---|---|---|---|
| 1966–78 | 173 | 698 | 4,037 |
| 1979–88 | 149 | 1,001 | 6,719 |
| 1989–98 | 123 | 950 | 7,802 |
| 1966 | 154 | 637 | 4,125 |
| 1967 | 161 | 594 | 3,683 |
| 1968 | 166 | 638 | 3,840 |
| 1969 | 165 | 631 | 3,825 |
| 1970 | 170 | 677 | 3,990 |
| 1971 | 184 | 569 | 3,098 |
| 1972 | 168 | 491 | 2,918 |
| 1973 | 181 | 706 | 3,908 |
| 1974 | 184 | 719 | 3,900 |
| 1975 | 177 | 795 | 4,500 |
| 1976 | 180 | 887 | 4,920 |
| 1977 | 185 | 864 | 4,680 |
| 1978 | 169 | 863 | 5,100 |
| 1979 | 152 | 872 | 5,753 |
| 1980 | 150 | 806 | 5,355 |
| 1981 | 152 | 899 | 5,925 |
| 1982 | 150 | 913 | 6,068 |
| 1983 | 153 | 969 | 6,353 |
| 1984 | 152 | 1,046 | 6,885 |
| 1985 | 152 | 1,127 | 7,403 |
| 1986 | 139 | 1,112 | 8,025 |
| 1987 | 150 | 1,117 | 7,440 |
| 1988 | 144 | 1,147 | 7,988 |
| 1989 | 159 | 1,219 | 7,650 |
| 1990 | 167 | 1,237 | 7,395 |
| 1991 | 143 | 1,011 | 7,065 |
| 1992 | 122 | 1,029 | 8,445 |
| 1993 | 106 | 798 | 7,493 |
| 1994 | 101 | 797 | 7,905 |
| 1995 | 120 | 843 | 7,035 |
| 1996 | 103 | 819 | 7,988 |
| 1997 | 110 | 1,001 | 9,120 |
| 1998 | 94 | 746 | 7,920 |

*Note:* The information on production, area, and yield per hectare is obtained from various administrative offices in ZID and compiled by ZIS.