Chapter 3

Operation of the Zhanghe Irrigation System

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Abstract

This paper explores the water management of the Zhanghe Irrigation System (ZIS) tracing key decision points for water allocation and distribution. We outline the kinds of arrangements made at key points from the reservoir to farmers' fields, then consider the mechanism and the flow of money from farmers' fields to reservoir operators for the payment of services. We feel that delivery practices of canal water are very important to facilitate on-farm water-saving irrigation (WSI) practices. It is important to understand how water deliveries and payments are made in a large, complex irrigation system, so that lessons can be derived and applied elsewhere.

The ZIS, situated in the Hubei Province in central China, north of the Changjiang (Yangtze) river irrigates an area of about 160,000 hectares and is one of the most important bases of commodity grain in the Hubei Province. The main water supply is the Zhanghe reservoir. Apart from this reservoir there are tens of thousands of medium- and small-size reservoirs, small basins and pump stations in the Zhanghe Irrigation District (ZID) partly incorporated into the irrigation system but sometimes operating independently.

At the beginning of the irrigation season (end March, begin April) the Zhanghe Irrigation Administration Bureau makes a long-term forecast allocation plan for ZIS based on irrigated area, weather forecast and the condition of water sources (mainly storage in the main reservoir). The result is an overall scheme for water allocation and distribution. The water allocation to each main canal is based both on experience and on the requests coming from the water users in the command area. However, during the flooding season, the Hubei Provincial Government has the power to decide on the amount of water to be allocated to hydropower and flood-control release. As much water as possible is stored to meet the water demand for all sectors, but irrigation has first priority. In general, the Zhanghe reservoir has enough water to fulfill all requirements. About 42 percent of the total water release is allocated to agriculture and about 45 percent to hydropower while the rest is for industry and municipalities.

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The timing of the water releases from the reservoir depends on the weather situation. There are usually around three to five releases a year to any given branch canal. However in general, the third main canal receives water only twice a year, which is considerably less than what the fourth main canal receives. This difference is explained by the better local water sources (reservoirs and ponds) in the third main canal command area and light soils in some parts of the command area of the fourth main canal. The periods of water releases are almost the same every year.

While farmers do order water, many of the decisions about when to release water comes from higher levels in the canal-operations hierarchy. Thus it appears that the management of canal water has not only an element of farmer demand but also a strong element of a supply approach where reservoir operators make decisions based on available storage, rainfall and on an overall view of when crops need water. The ponds and small reservoirs located within the irrigated area allow farmers to get a much more flexible supply of water on demand. So the entire system functions as an on-demand system because of its in-built flexibility to store water close to the water users, which is a prerequisite for adopting WSI techniques like the AWD irrigation.

The Provincial Finance and Pricing Control Bureau determines the price per unit of water per sector. The price for agricultural use has more than doubled over the last decade. The Zhanghe Irrigation Administration Bureau charges the water fee on a volumetric basis. The water user groups and villages pay the water fee on a volumetric basis to the section office of the ZIS main canal. However, at the end of the season, the group and village heads convert this volumetric water fee into a water fee for the farmers based on area. The total volumetric fee paid to ZIS is divided by the total area of the group or village. Besides this water fee, which is related to the volume used by the group or village, farmers pay another type of flat water fee based on area, to be paid to the local government. People have to pay this water fee even if they do not use water.

Even though farmers pay a water fee per area they are quite aware of the link between the volume of water used and the price they have to pay for the water at the end of the season. For this reason, farmers minimize the amount of the Zhanghe irrigation water and catch rainfall to the maximum extent on their fields, use water from local sources that have no direct connection to ZIS and reuse drainage water, since this is for free.

Introduction

This paper explores the water management of ZIS, tracing key decision points for water allocation and distribution. We outline the kinds of arrangements made at key points from the reservoir to farmers' fields, then consider the mechanism and the flow of money from the farmers' fields to reservoir operators for the payment of services. We feel that the delivery practices of the canal water are very important to facilitate on-farm WSI practices. It is important to understand how water deliveries and payments are made in a large, complex irrigation system, so that lessons can be derived and applied elsewhere.

First, a short description of ZIS is presented after which we explore the water management of ZIS described as the water flows: from the reservoir down to the farmers, first considering farmer requirements. We also trace the flow of payments for water services, which is described as the money flows: from farmers up to the Zhanghe Irrigation Administration Bureau.

Zhanghe Irrigation District

The ZID is situated in the Hubei Province in central China, north of the Changjiang (Yangtze) river. The area of the Zhanghe basin is 7,740 km^2 including a catchment area of 2,200 km^2. The ZIS accounts for most of the irrigated area within the ZID. See text box 1 for features of ZID.

Text box 1. Features of ZID.

Crops. The main grain crops are rice and winter wheat. The upland crops are beans, sesame oil and sweet potatoes. Rice cultivation accounts for about 80 percent of the total area of which about 85 percent is planted by the middle-season rice (May to September).

Climate. The average annual air temperature is 16 °C, varying from a minimum temperature of –19 °C in January to a maximum near 41 °C in July. On average, there are 246–270 annual frost-free days.

Rainfall. The ZID is located in the subtropical zone and is affected by monsoonal rains. The average annual rainfall is 970 mm but it is unevenly distributed between years (the extreme values are 610 mm in 1966 and 1,330 mm in 1980) and over the year. On average, 82 percent of the annual rainfall occurs during the rice- and maize-growing season (April to October). The average rainfall decreases from south to north in ZIS.

Topography. The ZID slopes from an elevation of 120 m above sea level in the northwest to an elevation of 26 m in the southeast. About 80 percent of the irrigated area lies in the hilly region.

Soil. The soil textures of the irrigated area are mostly clay (57%) and loam (43%).

Zhanghe Reservoir

The Zhanghe reservoir was built between 1958 and 1966 on the Zhanghe river, a tributary of the Juzhanghe river, which flows into the Yangtze river. The reservoir was designed for multipurpose uses of irrigation, flood control, domestic water supply, industrial use, aquatic culture and power generation. The primary purpose is still irrigation. The reservoir consists of three main reservoirs connected by open channels. The main hydraulic structures are located along the southeast bank and include four main dams and one auxiliary dam (the highest about 67 m), three spillways and six diversion gates. See table 1 for reservoir features.

Table 1. Salient features of the Zhanghe reservoir.

Zhanghe reservoir		
Descriptor		Capacity (in billion m^3)
Catchment area	2,212 km^2	
Area covered by water	104 km^2	
Total storage capacity		2.035
Normal water level	123.50 m	1.783
Dead water levels	113.00 m	0.862
Average annual water yield		0.773

Zhanghe Irrigation System

The ZIS is one of the most important bases of commodity grain in the Hubei Province. It is one of the typical large-size irrigation systems in China and its total area is 5,540 km^2 of which about 160,000 hectares comprise the irrigated area. The ZIS incorporates nine classes of canals constituting one general main canal, five main canals and more than 13,000 branch canals with a total length of more than 7,000 kilometers and over 15,000 structures. Besides these, there are tens of thousands of medium- or small-size reservoirs, small basins and pump stations in the area partly incorporated into the system but sometimes operating independently. The Zhanghe reservoir supplies most of the ZIS irrigation water. The drainage system consists of natural streams and ditches.

Since the 1980s, a rehabilitation program has been carried out to improve the performance of ZIS. The strategies included popularization of WSI techniques like AWD irrigation, canal lining, volumetric charging of water, drainage water reuse and other management innovations. It is hypothesized that the popularization of the AWD technique, one of the strategies in the rehabilitation program, has enabled the reservoir to transfer water to other higher-valued uses without significant loss in crop production.

Water Resources of ZIS

Water resources of ZIS include reservoir water, precipitation, groundwater and river water (see text box 2 and table 2).

Table 2. Water sources of ZIS.

	Total water released for agriculture (%)		
	Zhanghe reservoir	Small reservoirs	Other sources
1966–1978	71	18	11
1979–1988	47	32	21
1989–1998	52	29	20

Text box 2. Water sources of the ZIS.

Reservoir water. The average annual water supply from the Zhanghe reservoir is about 0.500 billion m^3. There are about 86,000 small ponds and tanks. Besides these, more than 300 medium- and small-size reservoirs have been constructed with a total beneficial storage capacity of 0.819 billion m^3.

Precipitation. The average annual precipitation is 970 mm and the total average annual rainfall is 5.199 billion m^3. The observed average annual runoff is 2.15 billion m^3.

Groundwater. The groundwater resources are rich, distributed in a large area and are easy to exploit. No data are available about groundwater extraction.

River water. Along the Yangtze river, the Hanjiang river and the Changhu lake there are more than 430 pump stations with a total capacity 0.2 million kW. The annual water withdrawal from rivers is about 0.112 billion m^3.

Most of the data about the operation and payments for water services in ZIS were collected with the help of interviews with farmers and system operators at different levels. We also collected substantial data on long-term flow records of the Zhanghe reservoir and some main canals.

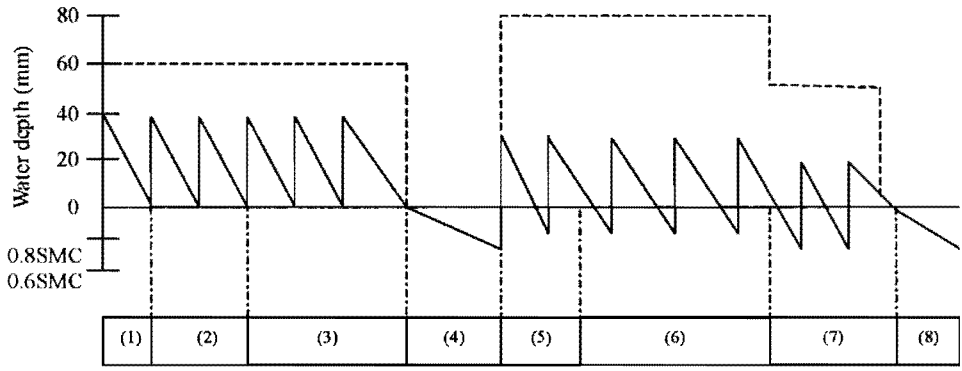
Operation

In this section we explore the management of ZIS, tracing key decision points for water distributions and the kind of arrangements made at these points. This is described as the water flows: from the reservoir down to the farmers, first considering farmer requirements.

The Target—Meeting the AWD Demands

On-farm water-saving practices have been scientifically developed over time to reduce irrigation application requirements and to improve the growing conditions, thereby increasing yield. The practice calls for frequent light irrigation applications until late tillering. During this initial period, water levels on the field can drop until the soil is saturated (the soil is exposed) and then another irrigation application is required. During late tillering, a mid-season drainage is required. After late tillering, a series of wet and dry cycles is repeated until the milk ripening stage after which the soil can further dry to levels below saturation (see figure 1).

Figure 1. Graphical description of AWD irrigation regime.



(1) Transplanting, (2) Revival of green, (3) Early and middle stages of tillering, (4) Late state of tillering, (5) Elongating and booting, (6) Heading and flowering, (7) Milk ripening, (8) Yellow ripening (SMC = Saturated Moisture Content).

Given the variability in evaporative demand and rainfall, meeting such a schedule requires care and precision even under controlled conditions. In a large canal irrigation system the target is particularly difficult. A very flexible system in rate, duration and frequency is required to meet the irrigation requirements. An on-demand system, where water is delivered shortly after it is ordered would be ideal to meet such requirements. Farmers could predict when water is needed and order the volume required. If it rains they could delay the order. A rotation system would not work so well because farmers would not be easily able to turn off the water (they could divert it away from their fields, but this would counter benefits gained from reduced applications). Providing the required flexibility seems a daunting task in a large canal system serving thousands of smallholder farmers with variable demands.

Two questions arise: i) To what extent do farmers at Zhanghe practice WSI (i.e., what are the on-farm practices)? and ii) What are canal-management and water-management practices, and how do they influence on-farm practices?

Farmer Practices

The first step is to understand actual farmer practices. Detailed measurements were taken on six farmer's fields in TL and WJX (described in chapter 6 of this publication). Additionally, water levels were measured in 12 fields in the mezzo sites. Figure 2 represents farmer practices in a typical field. The remainder of the results is presented in the annex to this paper.

Immediately apparent is that farmers do not practice an ideal system as presented in figure 1, and as expected there is high variability in practices. But certain key elements of WSI practices exist, and certain patterns emerge. Farmers do not require standing water all the time. They let water levels drop to the field surface but do not allow it to remain at this level for periods longer than a few days except during the period of mid-season drainage.

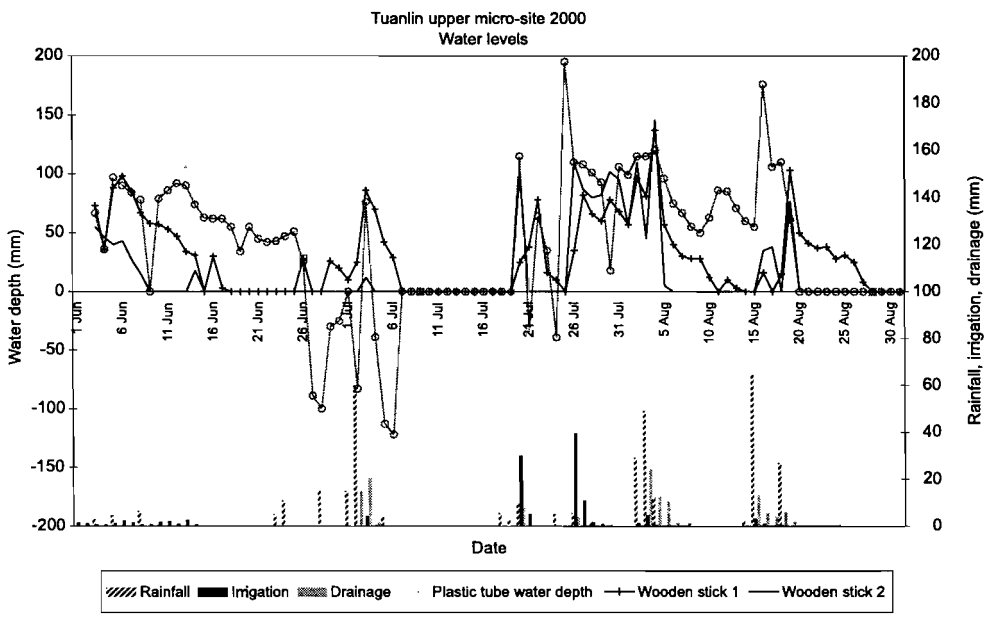
From the water level measurements in 2000, it becomes clear that most farmers practice mid-season drainage. If there is rain during the mid-season drainage period, it looks as if some farmers opt to store the rainwater in their fields instead of letting it drain off. One explanation is that they perceive more benefits from keeping the water and thus not having to pay for additional supplies, rather than draining it and having to obtain supplies later. Farmers do not actually drain their fields for the mid-season drainage, but let them dry out for a period. In 1999, the mid-season drainage was not so obvious as in 2000, which can be attributed to less-accurate measurements and rainfall in the period.

The TL farmers come closer to meeting the ideal AWD practice than WJX farmers. We frequently heard that this was due to the flat topography and the ease of access to water sources in TL, as opposed to the hilly terrain, more difficult access to water and light soils in WJX.

Farmers capture all rainfall possible and only drain it if the rainfall is very high. The irrigation schedule is very well adjusted to this capturing of rainfall and farmers rarely irrigate directly after rainfall.

How is the canal managed? Do operations facilitate on-farm requirements? The next section focuses on allocation and distribution from the reservoir to the farmer's fields.

Figure 2. Water levels on the upper micro-site in TL in 2000.



Decision Making on Allocation of Water among Sectors at the Zhanghe Reservoir

At the beginning of the irrigation season (end March, begin April) the Zhanghe Irrigation Administration Bureau makes a long-term forecast allocation plan based on irrigated area, weather forecast and the condition of water sources (mainly storage in the main reservoir). The result is an overall scheme for water allocation and distribution.

In the beginning of the irrigation season, the Zhanghe Administration Bureau sends water application forms to the main canal sections that pass them on to the stakeholders in their command area (townships and villages), which subsequently pass them on to the water users. Farmers can fill in their demand for the coming irrigation season. The forms are returned and a calculation is made of the total demand and the amount to be allocated to the different main canals. In a normal year, farmers are allocated the amount they request.

After this, a more detailed allocation and distribution plan is made in meetings (30 to 40 people attending) with the heads of both the main-canal section and canal, and others.

In general, the Zhanghe Irrigation Administration Bureau decides on the amount of water allocated to each sector, with one exception: during the flooding season, the Hubei Provincial Government has the power to decide on the amount of water to be allocated to hydropower and flood-control release. The water for hydropower is recycled for irrigation and municipal use outside of ZID. This water flows into the Juzhang river from a different outlet from the reservoir than the irrigation water.

The objective of water supply is not only subordinate to flood control but also a prerequisite for reservoir safety. As much water as possible is stored to meet water demand for all users, but irrigation has first priority and all other sectors (hydropower, industries and municipalities) receive water after the irrigation requirements are met. However, in general, the Zhanghe reservoir has enough water to fulfill all requirements.

In a normal year, about half of the total water releases of the Zhanghe reservoir are allocated to irrigation (table 3 and figure 3).

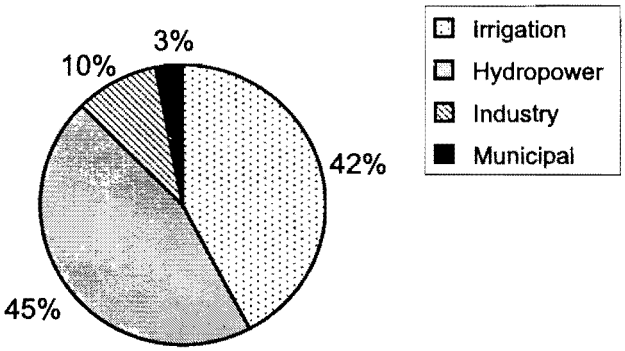
Table 3. Annual Zhanghe reservoir inflow and releases (average in 1989–1998).

Sector	Amount (mcm)
Irrigation	211
Hydropower	225*
Industry	48*
Municipal	15*
Inflow	927**

* No data available from 1998.

** No data available from 1997 and1998.

Figure 3. Sector water allocation, Zhanghe reservoir (average values for 1989–1998).



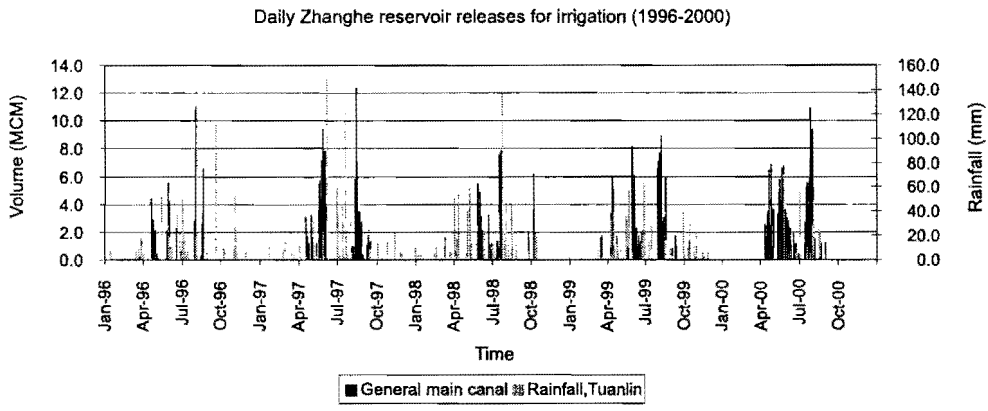
Timing and Amount of Water Releases from the Zhanghe Reservoir

There is an annual meeting held in April at the main-canal level to discuss the ZIS plan for water releases, financial matters, and issues related to O&M. In the third main canal, the water users are represented at these meetings by representatives from the Irrigation Associations. It is not clear how the water users in the fourth main canal are represented at this meeting. Township Water Resources Bureaus are also represented.

As stated earlier, the timing of the water releases from the reservoir depends on the weather situation. There are usually around three to five releases a year to any given branch canal. While farmers do order water, many of the decisions on when to release water comes from higher levels in the canal-operations hierarchy. Thus it appears that the management of canal water has not only an element of farmer demand but also a strong element of a supply approach where reservoir operators make decisions based on available storage, rainfall, and on an overall view of when crops need water. The ponds and small reservoirs located within the irrigated area allow farmers to get a much more flexible supply of water on-demand. However, if users request to stop the water releases from the reservoir, because of ample supply by rainfall, ZIS will close the gates. The water already flowing in the canals has to be paid for by the users. So the entire system functions as an on-demand system because of its in-built flexibility to store water close to the water users, which is a prerequisite for adopting WSI techniques like AWD irrigation. If we look at figure 4 we see that, in general, there are three to five releases from the reservoir to the general main canal.

After correlating the monthly rainfall with the monthly reservoir release to irrigation over the season, in a scatter diagram it becomes clear that there is a trend that in months with high rainfall the reservoir releases are lower. This is strongest in the period May to August, which is the main period for irrigation.

Figure 4. Daily Zhanghe reservoir releases for irrigation, 1999–2000.



ZIS Operation

Part of ZIS is not directly operated by the Zhanghe Irrigation Administration Bureau itself. The third main canal is managed by the Jingmen City Water Resources Bureau. The second main canal delivers water to Jingmen city, Dang Yang county and Jingzhou city. The third main canal delivers water only to Jingmen city. The fourth main canal delivers water only to the Jingmen prefecture (city, district, county).

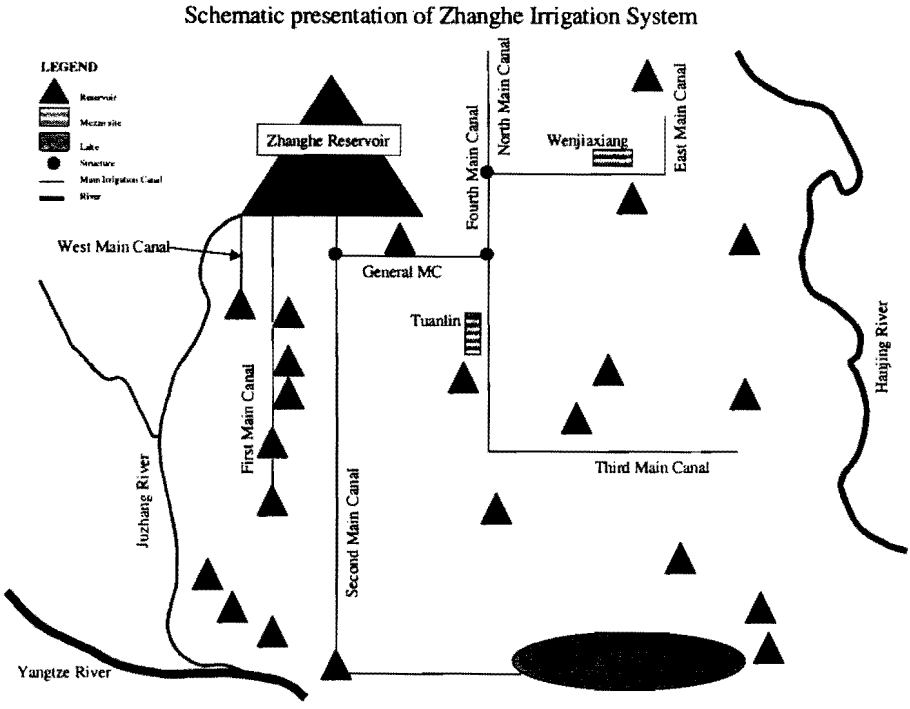
See table 4 for water releases per main canal and figure 5 for details about the distribution network of ZIS.

Table 4. Water releases for irrigation per main canal (average 1989–1998).

Canal	Water release for irrigation (mcm)
General main canal	179*
West main canal	1.8*
First main canal	6.8*
Second main canal	53
Third main canal	101
Fourth main canal	25

*Average values over 1996–2000.

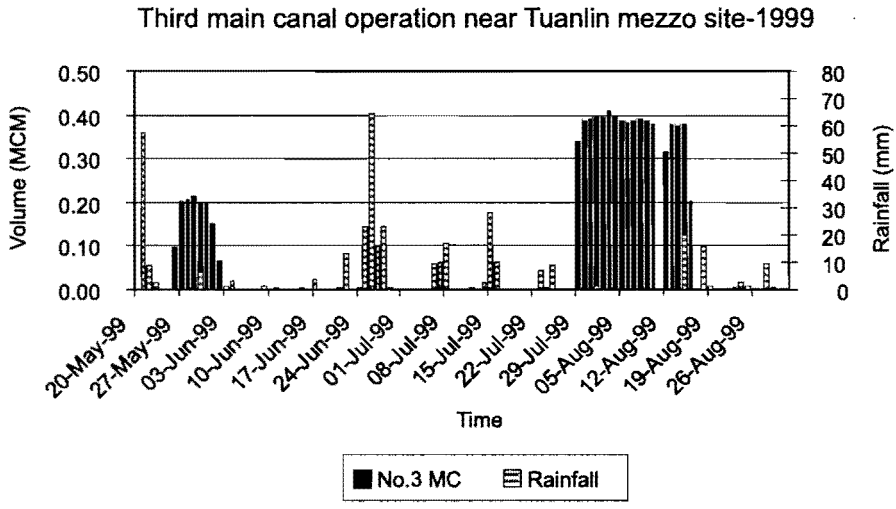
Figure 5. Schematic presentation of the ZIS.



Third Main Canal

The third main canal is not managed by ZIS but by the Jingmen City Water Resources Bureau because most of the command area is within the Jingmen city prefecture limits. In general, the third main canal receives water twice a year for about 20 days in a row. This is considerably less than what the fourth main canal receives, which is explained by the better local water sources (reservoirs and ponds) in the third main canal command area (see also figure 7). In dry years when the demand is higher the number of turns remains the same, but the flow period in the canal is extended. Figure 6 illustrates the daily releases of the third main canal for 1999 and 2000 from which it becomes clear that the releases occur in the same time period in both years.

Figure 6. Daily operation of the third main canal near the TL mezzo site, 1999 and 2000.



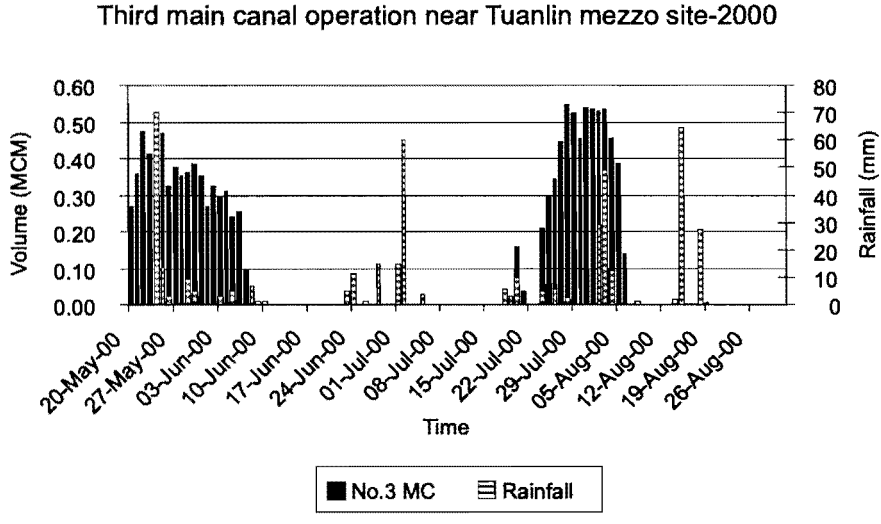


Figure 7. Third main canal water sources.

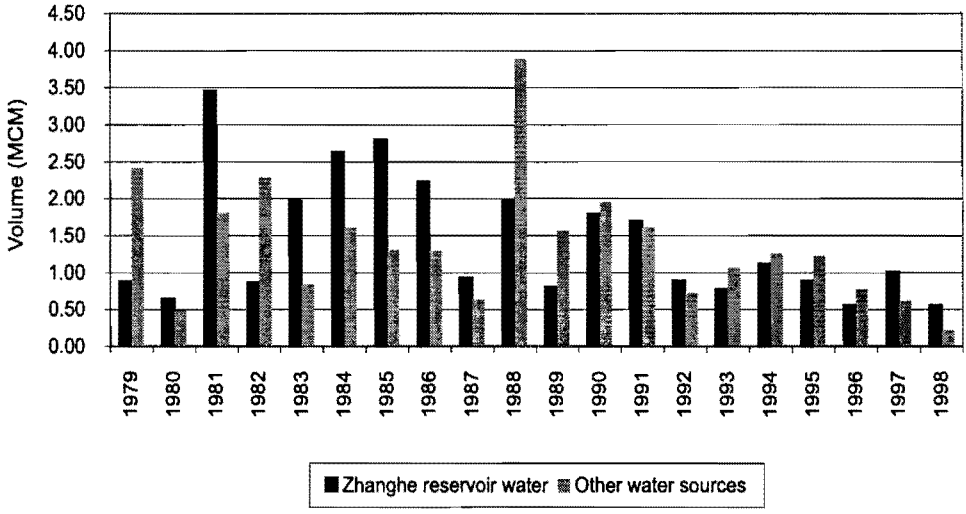


Figure 7 shows the contribution of local water sources to the command area of the third main canal. Note that not all irrigation with local water sources is necessarily on the same area as the Zhanghe reservoir water is also used. There are reports that the third and fourth main canal command areas are partly irrigated by the third and fourth main canal, respectively, and that the other parts of the command area are irrigated with water from local sources.

Fourth Main Canal

The fourth main canal bifurcates into the east main canal (direction of WJX) and the north main canal. It is possible to operate a sort of rotational schedule between the east and the north main canal. However this is rarely done. In the fourth main canal, the priority for allocation is as follows: domestic, industry, agriculture and hydropower. This is different from the priority setting at reservoir level where agriculture gets first priority.

Water requests are handled according to the irrigation-management regulations. Before the irrigation season starts the management divisions of the fourth main canal, townships and counties have a meeting about the provincial government regulations. After this meeting, the management division of the fourth main canal has a one-day meeting from 10 to 15 April with all the users. Three topics are discussed: how much water from ZIS is to be allocated, water use plan for all sectors and how much water is to be allocated to each sector. In general, all demands can be met and it remains unclear how the decision-making process is working during periods of water shortage.

During the irrigation season the water users request water from the sections of the fourth main canal. The section collects all information on demands (volume and timing). The fourth main canal office receives all water requests from all the sections in the fourth main canal and cumulates these after which a request is made to the Zhanghe reservoir to release water. The sections should apply to the fourth main canal office at least 3 days in advance. The fourth

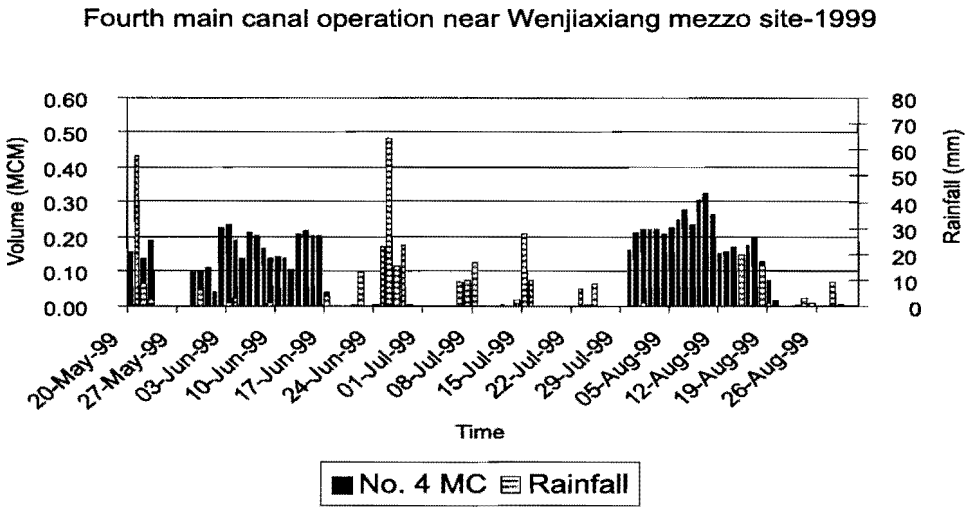
main canal office should apply to the Zhanghe Irrigation Administration Bureau at least 2 days in advance. The final decision about water releases from the reservoir remains with the Zhanghe Irrigation Administration Bureau. The periods of water release are almost the same every year. In general, the fourth main canal receives water four times a year (see table 5), because of a longer canal, complex topography and light soils in some parts of the command area: the first time for seedbed preparation, the second time for transplanting and the third and fourth times during the middle rice-growing season. The water in the main canals and branches flows for about 20 days and there is rotation of water among laterals.

Table 5. General timing of water releases to the fourth main canal.

Fourth main canal operation	
Period	Number of days
10–12 April	3
20 May–5 June	10
End of June–early July	10 to 15
10–20 August	10 to 15

Figure 8 shows that the year 1999 has especially deviated from the general schedule of releases as stated by ZIS (table 5). There were two main releases after the middle of May, the first lasting 29 days from 20 May to the middle of June (including 4 days without releases) and the second from the end of July to 20 of August. In 2000, the schedule was much closer to the general proposed schedule, except for an extra release in mid-June, which postponed the planned release by end of June by 3 weeks.

Figure 8. Daily operation of the fourth main canal near the WJX mezzo site in 1999 and 2000.



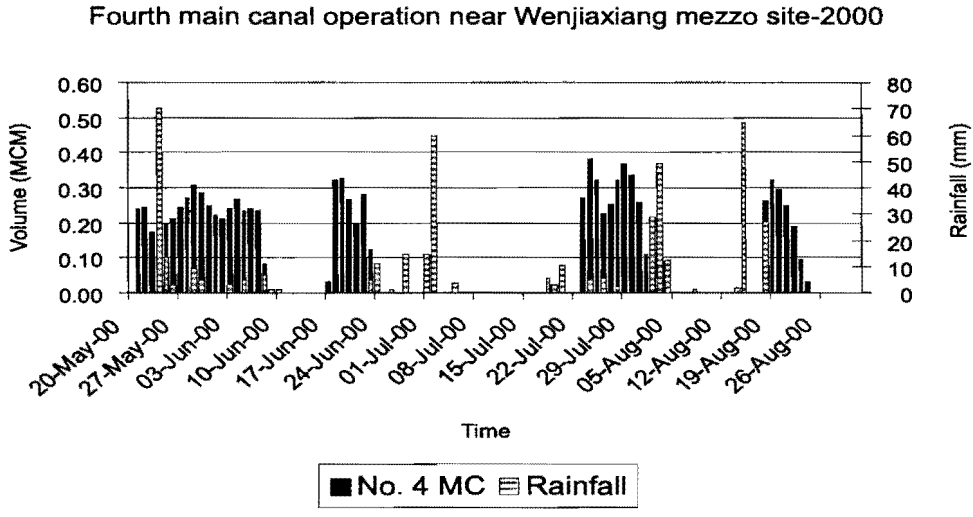
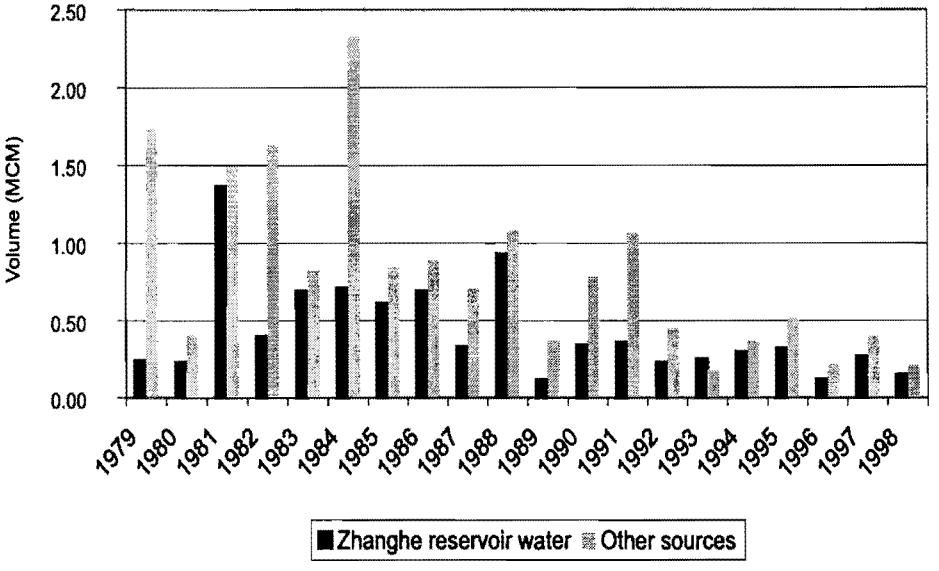


Figure 9 shows the contribution of local water sources to the command area of the fourth main canal. This contribution is lower than in the third main canal but it is still considerable and, in most years, more than that from the Zhanghe reservoir. Note that not all irrigation with local water sources is necessarily on the same area as the Zhanghe reservoir water is also used.

Figure 9. Fourth main canal water sources.



The average volume of "city water" released to the fourth main canal is about is 6 mcm per year. "City water" includes municipal and industrial water. It is taken from the same intake in the fourth main canal. Although it is impossible to differentiate between the two the total volume is known.

Main Canal Section, Township, Village, Group, Farmer

At the level of the main canal there are regular meetings with water users to discuss the water delivery schedule. The Chinese local administration is organized along the line of townships, villages, groups and finally of individuals. Many villages and groups and most of the townships have a contract with the main canal section that specifies the command area, volume of water to be delivered, price and terms of payment. The advantage of having a contract is that it simplifies the application procedure. However, even without a specified contract between water users and ZIS it is possible to receive water.

Tuanlin Mezzo Site

The village has a good relationship with the section. Although they have no contract they just pay and, at the end of the season, they never owe money to the section.

In general, farmers request water either directly from their village head or from their group head who will cumulate the request of the group members and inform the village head. Another path of request is that the group head directly contacts the section office of the main canal. Then the request goes up through the ZIS administrative layers (section, branch, main canal and the Zhanghe reservoir).

The reason for this different path of request is explained by a village head in TL who stated that if some groups within a village are not in good terms with one another it is better that the village head keeps an eye on the requests. On the other hand, it is clear that it is easier for all parties involved that the group head goes directly to the section, because it is easier to manage, especially when the village is big. However, it requires a good organized group. In our mezzo site in WJX, most group heads go directly to the main canal section.

When it rains farmers can request the closure of gates, but they have to pay for the water in the canals (up to 3 days of lag-time). After heavy rains the authorities of the main canal section can close some gates but they have to inform the higher administrative unit directly. Generally, there is a rotational water supply to groups below the village level.

Decision on Allocation of Water for Irrigation in Years of Shortage

During years of extreme water shortage (or flooding) the Flood Control and Anti-Draught (FC&AD) organization, headed by the Vice President of P.R. China, represented in ZIS by the Mayor of Jingmen city, takes over the water management from the Zhanghe Irrigation Administration Bureau and local governments. De facto, there is little difference between this organization and the local government; however, according to some people, it is better that the FC&AD organization gives an order in these times, since they carry more authority. The FC&AD organization gives orders to the second, third and fourth main canal. Local governments and ZIS are represented in the organization. In years with less water shortage, the Zhanghe Irrigation Administration Bureau solves the problems independently by rationing the various canals and branch canals proportionally. On main-canal level the townships are rationed proportionally.

Water Management Service Fee

In this section we explore the flow path of payments for water management services, which is described as the money flows: from the water users up to the Zhanghe Irrigation Administration Bureau. The following different levels are distinguished: the farmers, groups, village and township, the ZIS main-canal section and the Zhanghe Irrigation Administration Bureau.

Farmers

There are two ways farmers pay for water. The first is a flat rate based on area to be paid to the local government. This "water tax" or "basic water fee" is included in the overall tax bill everyone gets from the village. The "flow path" of the basic water fee is from the farmers, to group, to village, to township after which it most likely goes to the county. People have to pay the basic water fee even if they do not use water. There are different reports on the amount of this basic water fee expressed either in yuan per unit area (varying from yuan 2 to 10/mu) or in kilograms of rice per unit area. The second way is a water fee related to the amount of

water used and has to be paid to the Zhanghe Irrigation Administration Bureau via different administrative layers. In the following sections the main focus will be on this latter water fee. Almost all the farmers in ZIS pay their water fee on a per area basis. There are reports that farmers pay per volume of water; however this is confined to certain areas. In general, farmers either pay their water fee to their group head or to the village head.

Groups, Village and Township

Groups, village and township pay the water fee on a volumetric basis to the section office of the the ZIS main canal. However, they convert this volumetric fee into an area-based fee for the farmers. Different group heads and village heads, both in the TL and WJX areas, state that, at the end of the season, they calculate the total amount paid to the section office of the ZIS main canal and divide this amount by the total area. After this, the water fee per area is known and is charged to the farmers. There is no money that remains somewhere at this level. Salaries of pump operators or village "water people" are not included in the per-area-based water fee but are paid from other taxes.

There is a big difference between water fees for pumped water and gravity irrigation. In general, the price of pumped water is expressed as an amount of money per hour charged to the farmers. When water is pumped from a ZIS canal, the additional volumetric water fee has to be paid to the section office of the ZIS main canal.

In the TL mezzo site the water fee to the groups is also expressed as a volumetric fee. However, the volume is derived from the recorded time the gate was open and the specific diameter of the pipe. The group head and the irrigator (from the village) go together to the gate and the irrigator opens the gate. Both of them record the time of opening and closure. After harvest, the group head pays to the village according to the calculated volume and the village passes this on to the section office of the ZIS main canal. The group head calculates the total fee paid and divides it by the total area. The farmers pay their water fee on a per-area basis.

There are several statements that the use of water from both small ponds that have no direct connection to ZIS and drainage water is for free. The volumetric water fee from other reservoirs (although they may not be connected to ZIS) is the same as the ZIS volumetric water fee.

There is no visible clear trend over time of the per-area fee since the price depends on the amount of water used by the group or village and this depends on the weather conditions of a particular year.

ZIS Main Canal Section

The ZIS main canal section acts mainly as an intermediary between the group, village and township and the Zhanghe Irrigation Administration Bureau. However, as stated above, many villages and groups and most of the townships have a contract with the main canal section that specifies the command area, volume of water to be delivered, the price and terms of payment. However, even without a specified contract between water users and ZIS it is possible to receive water.

Zhanghe Irrigation Administration Bureau

The Zhanghe Irrigation Administration Bureau is financially independent from the Hubei Provincial Government and is the final recipient of the water fees paid by the water users. However, the Provincial Finance and Pricing Control Bureau determines the price per unit of water per sector. Of late, the price per unit of water has been linked to the price of rice. This is to protect the farmers, since the price of rice has dropped dramatically and the water fee has more than doubled over the last decade (see table 6). Before 1984, the provincial government subsidized the water price, which was a fraction of the current price. After 1984, the reservoirs had to be financially self-sufficient and prices went up according to the regulations of the provincial government. Table 7 shows the water fees per sector in 2000. The price for municipal water is almost double that for irrigation water and the price for industrial water is almost three times that for irrigation water. The revenue from hydropower seems rather low.

Table 6. Agricultural water fee development over time.

	Agricultural water fee
Year	Yuan/m^3
Before 1984	0.007*
1991	0.01610
1992	0.01933
1993	0.02002
1994	0.03126
1995	0.03850
1996	0.04158
1997	0.04235
1998	0.04235
1999	0.04235 (0.0385**)
2000	0.0371**

Source: Fourth main canal office, the Jingmen city.
**Source:* Tongqianshan reservoir.
***Source:* Zhanghe Irrigation Administration Bureau.

Table 7. Water fees in per sector in 2000.

Sector	Water fee (Yuan/m^3)*
Irrigation	0.0371
Municipal	0.068
Industry	0.105
Hydro–old plant	0.017**
Hydro–new plant	0.044

* Exchange rate 2000: US$1.00 = Yuan 8.27.
**Based on 9 m^3 of water to produce 1kWh.
Source: Zhanghe Irrigation Administration Bureau.

According to the fourth main canal office, it is sometimes very difficult to distinguish between water allocated to the municipal and industrial sectors, because the water is taken from the same outlet in the main canal. The fourth main canal calls this water "city water." For the calculation of the water fee a certain percentage is used to differentiate between the two sectors. In 2000, 23.3 percent of the total volume of city water was allocated to industry. The percentage comes from "the statistics." It is not clear if the percentage has changed over time. However, it is clear that the use of city water has increased over time.

Discussion and Conclusion

In general, we do have a broad idea of how ZIS is managed on different levels, how the water flows are managed and how the water fees are calculated, collected and passed on to different levels in the ZIS management organization. The closer the water gets to the farm, the more the variability in the operating procedures making it difficult to understand the process.

During the study it was apparent that very few people could explain the entire functioning of this complex system. But it is also apparent that it is not necessary for any individual in the system to know all this. The system has been divided into several layers—reservoir operators, canal operators, townships, villages, farmer groups and farmers. The least a person has to know to be effective are the requirements to get water and make payment to the layer above, and the procedures for passing the water and collecting money from the layer below. Looking as an outsider into this maze, it is amazing that it all works!

The ZIS operates independently from the Hubei Province and has to be financially self-sustainable. However, ZIS has to operate within regulations set by the Hubei Province. These regulations concern mainly the minimum water releases for downstream use and fixed water fees.

On average, in the last decade, the Zhanghe reservoir has allocated about 42 percent of the released water to irrigation, 45 percent to hydropower and the rest to industrial and municipal uses. The reservoir operation is subject to flood control and is a prerequisite for reservoir safety.

On-farm water-saving practices to reduce irrigation application requirements and to improve the growing conditions, thereby increasing yield, call for frequent light irrigation applications until late tillering. During late tillering, a mid-season drainage is required. After late tillering, a series of wet and dry cycles is repeated until the milk ripening stage after which the soil can further dry to levels below saturation.

Given the variability in evaporative demand and rainfall, meeting such a schedule requires care under controlled conditions. In a canal irrigation system though, the target is particularly difficult. A very flexible system in rate, duration and frequency is required to meet the irrigation requirements. An on-demand system, where water is delivered shortly after it is ordered would be ideal to meet such requirements. Providing the required flexibility seems a daunting task in a large canal system serving thousands of smallholder farmers with variable demands.

The timing of the water releases from the Zhanghe reservoir depends on the weather situation. There are usually around three to five releases a year to any given branch canal. While farmers do order water, many of the decisions on when to release water come from higher levels in the canal operations hierarchy. Thus it appears that management of canal water has

not only an element of farmer demand but also a strong element of a supply approach where reservoir operators make decisions based on available storage, rainfall, and on an overall view of when crops need water. The ponds and small reservoirs located within the irrigated area allow farmers to get a much more flexible supply of water on-demand. However, if users request to stop the water releases from the reservoir because of ample supply by rainfall, ZIS will close the gates. The water already flowing in the canals has to be paid for by the users. So the entire system functions as an on-demand system because of its in-built flexibility to store water close to the water users, which is a prerequisite for adopting WSI techniques like AWD irrigation.

The contribution of local water sources to irrigation is high. For the fourth main canal it is, in most years, more than the contribution from the Zhanghe reservoir. However, not all irrigation with local water sources is necessarily on the same area as the Zhanghe reservoir water is also used. There are reports that the third and fourth main canal command areas are just partly irrigated by the third and fourth main canals, respectively, and that the other parts of the command area are irrigated with water from local sources. The small ponds located close to the farmers' fields are not accounted for in official statistics, but from our observations, their contribution to irrigation is quite high.

Actual farmer practices show that they are not able to follow the theoretical AWD techniques and, as expected, there is high variability in practices. But certain key elements of AWD practices exist and certain patterns emerge. Farmers do not require standing water all the time. They let the water level drop to the field surface but do not allow the level to remain for periods longer than a few days except during the period of mid-season drainage.

From the water-level measurements at the field it becomes clear that most farmers practice mid-season drainage. If there is rain during the mid-season drainage period, it seems that some farmers opt to store the rainwater in their fields instead of letting it drain off. One explanation is that they perceive more benefits from keeping the water, and thus not having to pay for additional supplies; rather than draining it and having to obtain supplies later. In 1999, the mid-season drainage was not so obvious as in 2000, which can be attributed to less-accurate measurements and rainfall in the period.

The TL farmers come closer to meeting the ideal AWD practice than the WJX farmers. We frequently heard that this was due to the flat topography and the ease of access to water sources in TL against the hilly terrain, more difficult access to water and light soils in WJX.

Farmers capture all rainfall possible and only drain it only if the rainfall is very high. The irrigation schedule is very well adjusted to this capturing of rainfall and farmers rarely irrigate directly after rainfall.

There are two ways farmers pay for water. The first is a flat rate based on area to be paid to the local government. This "water tax" or "basic water fee" is included in the overall tax bill everyone gets from the village. People have to pay the basic water fee even if they do not use water. The second way is a water fee related to the amount of water used, which has to be paid to the Zhanghe Irrigation Administration Bureau via different administrative layers. In general, farmers either pay their water fee to their group head or to the village head.

Groups, village and township pay the water fee on a volumetric basis to the section office of the ZIS main canal. However, they convert this volumetric fee into an area-based fee for the farmers, by calculating the total amount paid to ZIS and dividing this amount by the total area.

The section office of the ZIS main canal acts mainly as an intermediary between groups, village and township and the Zhanghe Irrigation Administration Bureau. However, many villages and groups and most of the townships have a contract with the section office of the main canal that specifies the command area, volume of water to be delivered, the price and terms of payment. Even without a specified contract between water users and ZIS it is possible to receive water.

The Provincial Finance and Pricing Control Bureau determines the price per unit of water per sector. Of late, the price per unit of water has been linked to the price of rice to stabilize the water fees. The water fee has more than doubled over the last decade. Before 1984, the provincial government subsidized the water price, which was a fraction of the current price. After 1984, the reservoirs had to be financially self-sufficient and prices went up according to the provincial regulations. There is no visible, clear trend over time of the per-area fee, since the price depends on the amount of water used by the groups or village and this depends on the weather conditions of a particular year.

The use of water from both small ponds that have no direct connection to ZIS and drainage water is for free. The volumetric water fee from other reservoirs, which may not be connected to the ZIS, is the same as the ZIS volumetric water fee, since the price is set for the whole Hubei Province by the Provincial Finance and Pricing Control Bureau.

Some of the very strong points of the design and operation of this system are:

1. The division of the task of delivering water into several layers. It is not necessary for the main canal operators to deliver water to farmers. More decentralized decisions are made to better meet farmer needs.

2. Clear rules or understanding has developed at each point of water transfer and money transfer.

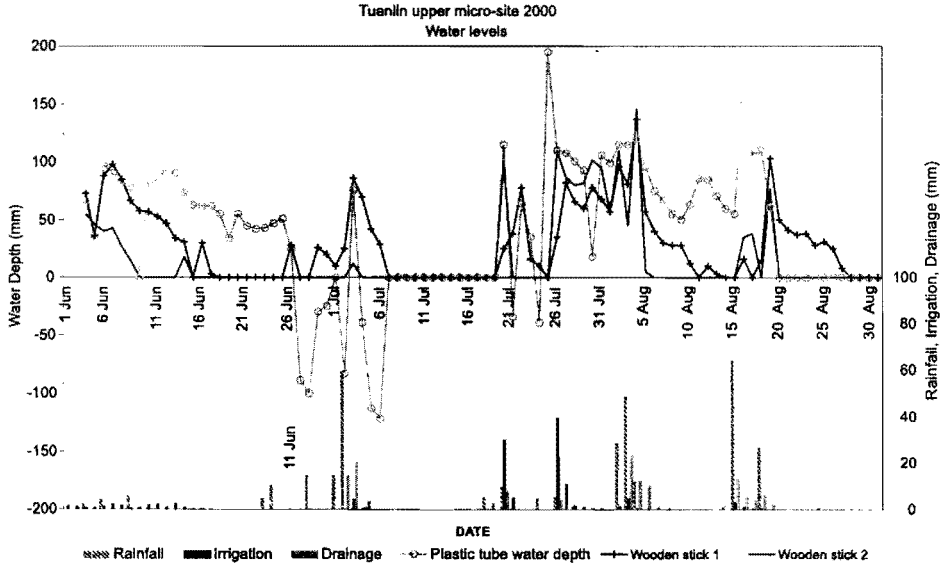
3. The strategy of making a few deliveries from the main reservoir at somewhat predictable intervals.

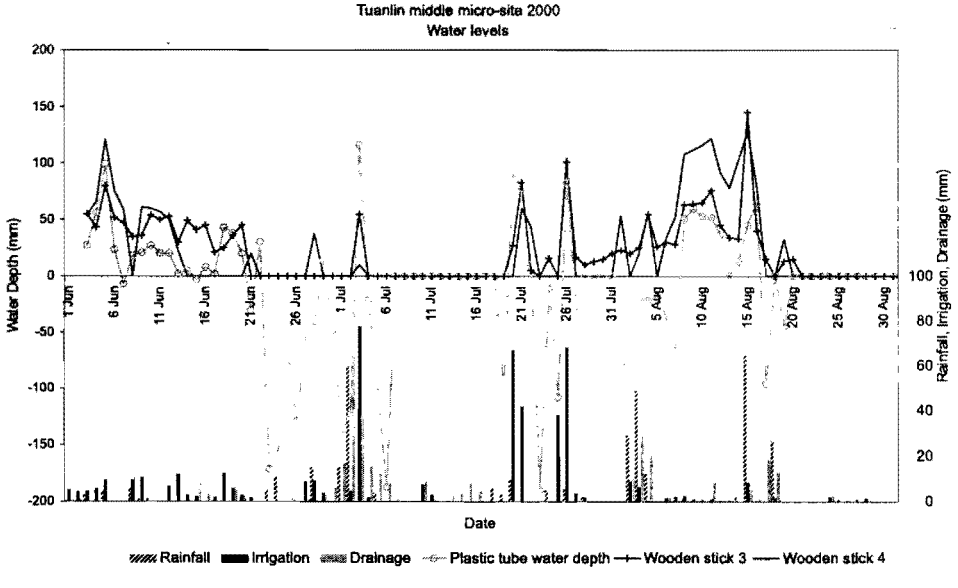
4. The reliance on local sources for flexibility.

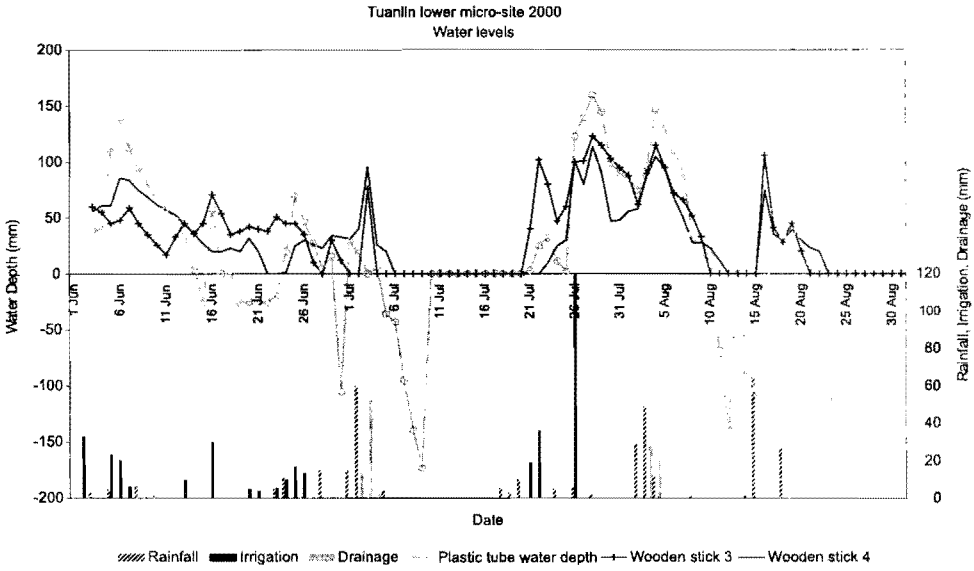
In our discussion with farmers, we found that an area that requires improvement is the communication to farmers when water is released. Several farmers were unsure of the timing of canal releases.

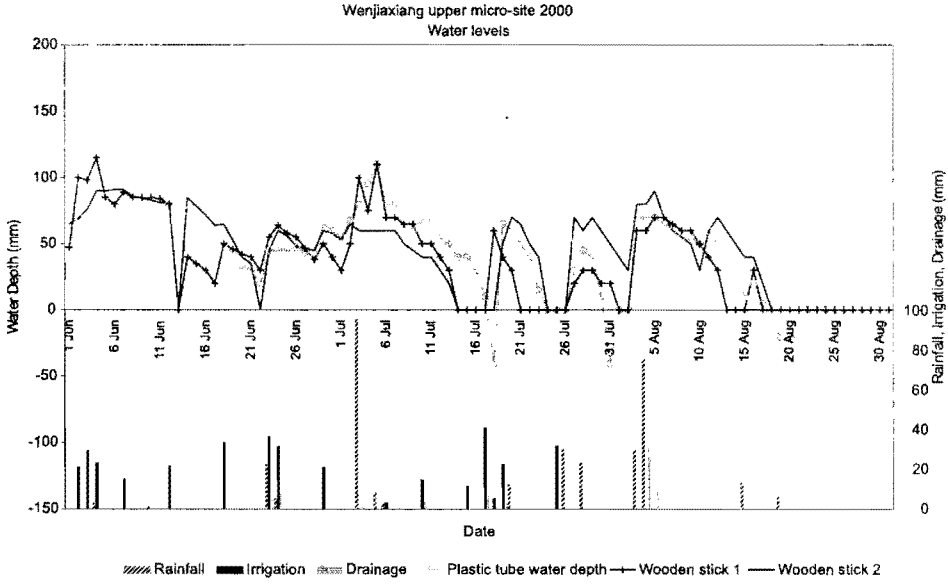
Annex

Water level graphs of selected micro-sites in 1999 and 2000.






Tuanlin lower micro-site 2000
Water levels
Water Depth (mm)
Rainfall, Irrigation, Drainage (mm)
Date
Rainfall
Irrigation
Drainage
Plastic tube water depth
Wooden stick 3
Wooden stick 4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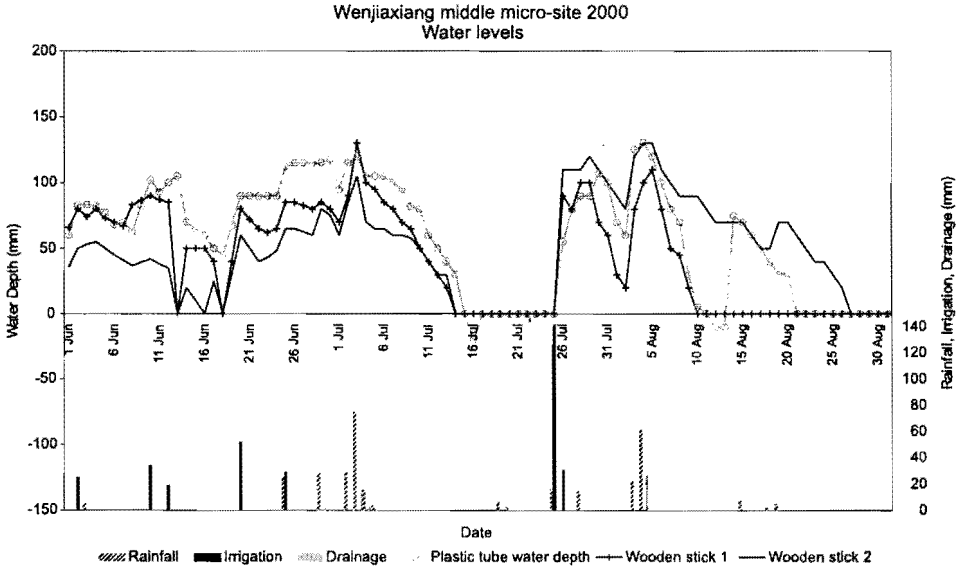
Water levels
Water Depth (mm)
Rainfall, Irrigation, Drainage (mm)
Date
Rainfall
Irrigation
Drainage
Plastic tube water depth
Wooden stick 1
Wooden stick 2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Water levels
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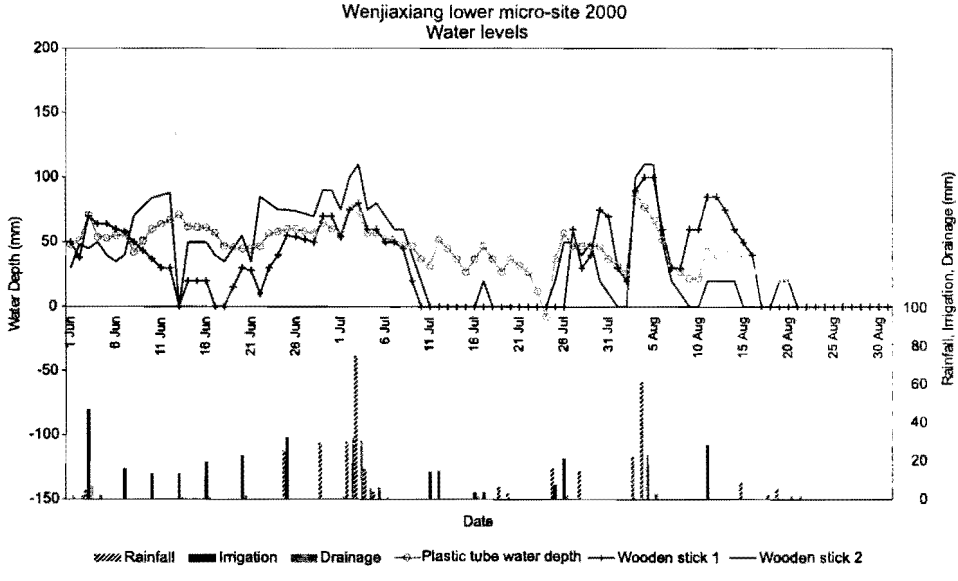
Date
Rainfall
Irrigation
Drainage
Plastic tube water depth
Wooden stick 1
Wooden stick 2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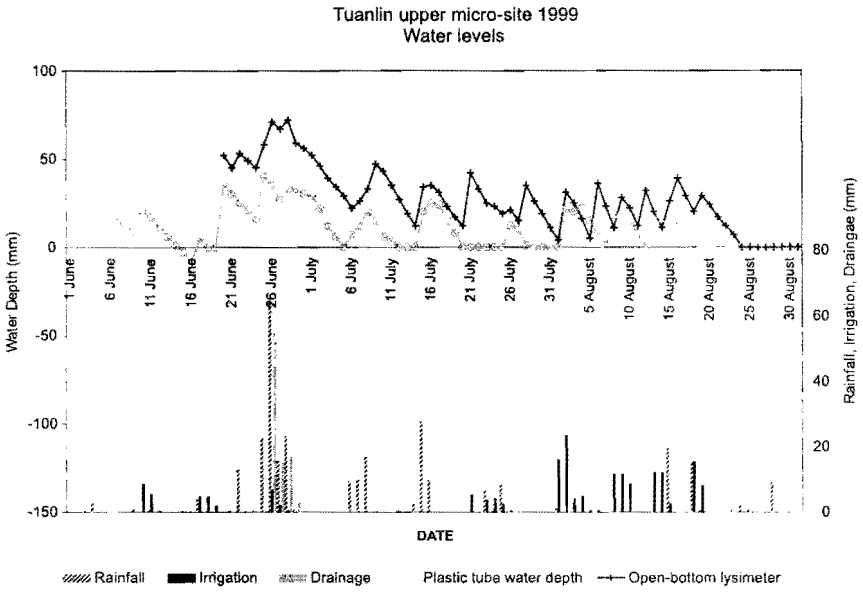
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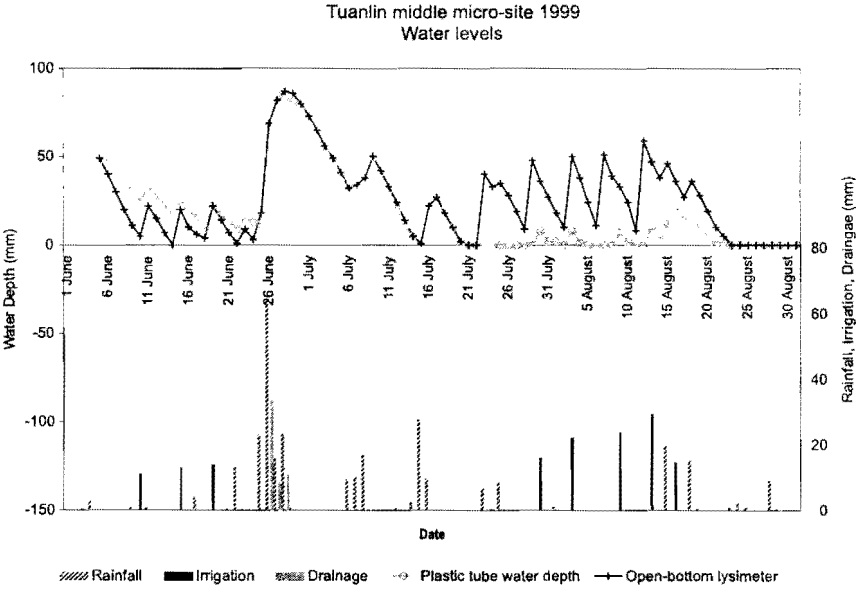
Irrigation
Drainage
Plastic tube water depth
Open-bottom lysimeter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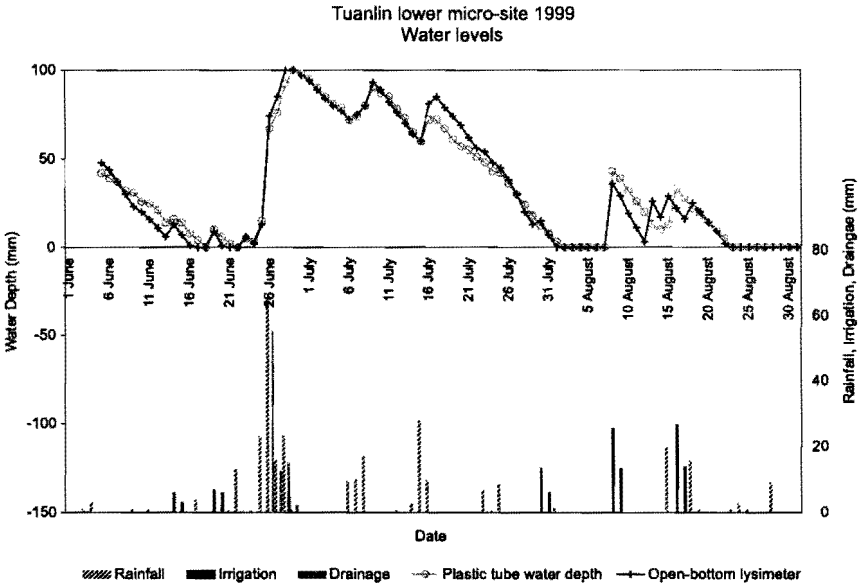
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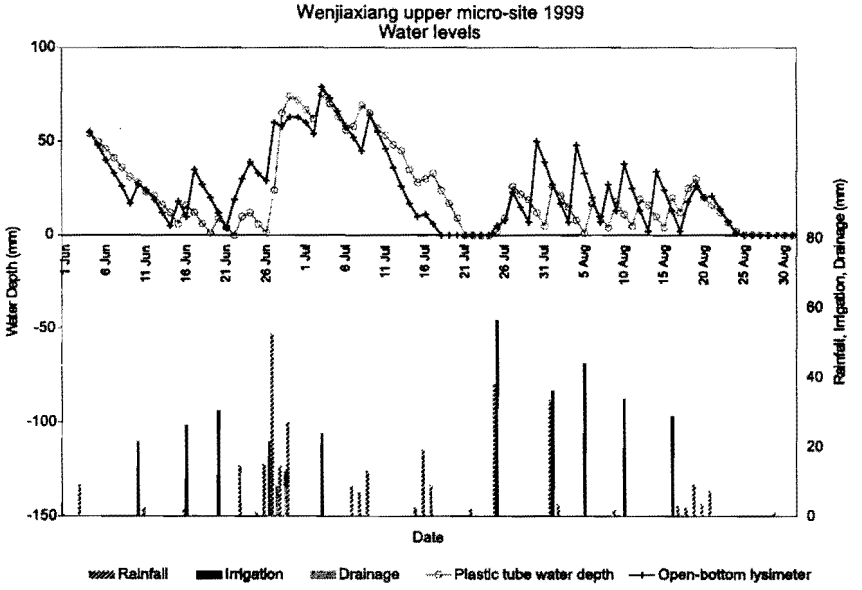
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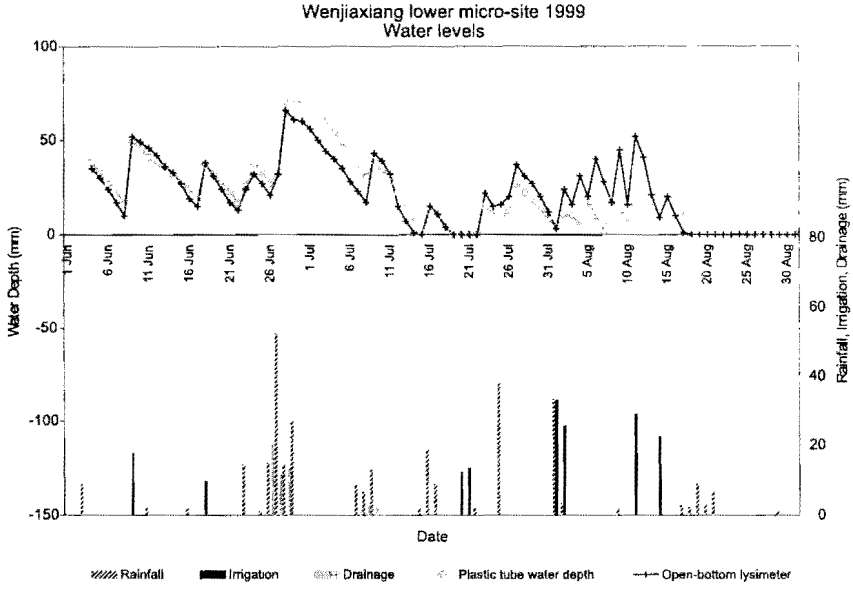
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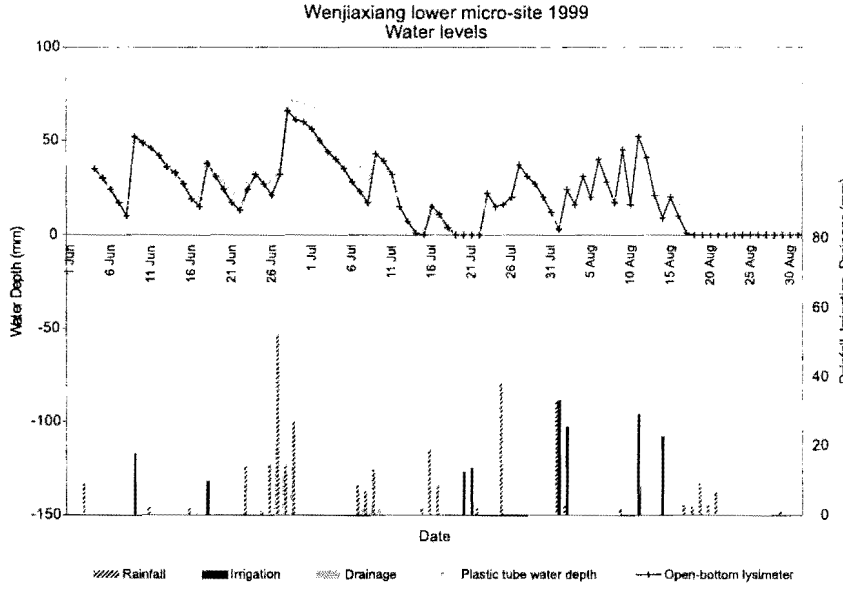
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