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MANAGEMENT REFORM AND PERFORMANCE CHANGES IN TWO IRRIGATION DISTRICTS IN THE NORTH CHINA PLAIN

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Purpose of the Series

The *Short Report Series on Locally Managed Irrigation* is designed to disseminate concise information on the role of local management in irrigation and irrigation management transfer or turnover experiences and policies. The *Series* is distributed worldwide to a broad range of peoplepolicymakers, planners, researchers, donors and officials in both public and nongovernmental organizationswho are concerned with the irrigated agriculture sector. IIMI's goal is not to promote policies such as irrigation management transfer, but to enhance the knowledge base available to decision makers and advisors as they face questions of policy adoption and strategies for implementation.

Locally managed irrigation can be of many types, such as traditional farmerconstructed diversion or tank schemes, indigenous and often new lift irrigation, governmentconstructed but farmermanaged irrigation systems and systems where management is or has been transferred from an outside agency to a local user organization.

By "irrigation management transfer" we mean some degree of transfer of responsibility and authority for irrigation management from the government to farmer groups or other nongovernmental entities. This generally involves contraction of the role of the state and expansion of the role of the private sector and water users in irrigation management. In other words, there is a shifting upstream of the point where management responsibility and control of the water supply are transferred from the irrigation authority to local management. This may involve changes in policies, procedures, practices and the performance of irrigated agriculture. It may or may not involve "privatization" of ownership of the assets of the irrigation system. The *Short Report Series* addresses questions such as the following:

What are the necessary conditions which support viable locally managed irrigation?

What sociotechnical conditions, institutional arrangements and change processes lead to sustainable locally managed irrigation?

What is the range of different models that are being applied worldwide for turnover or transfer of responsibility for local management for recently developed irrigation?

What are the effects of management transfer on the productivity, profitability, financial viability, equity, efficiency and sustainability of irrigated agriculture?

What are the perspectives of farmers, managers, policymakers, urban consumers and other stakeholders in irrigated agriculture about irrigation management transfer?

What adjustments in government may be needed as a result of turnover to provide support to locally managed irrigation systems and to improve productivity in the public sector?

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Editors' Note

This paper examines the conditions and policy changes which prompted basic reforms in the management of two medium-sized irrigation districts in the north China plain. The study describes how the policy reforms were implemented at the operational level—introducing financial autonomy, the concept of service for payment, internal performance assessment, new mechanisms for accountability and increased participation of farmers and village governments in management. The paper analyzes the effects of the reforms on management performance and agricultural and economic productivity. The study finds a relatively high level of performance which is apparently based in part on an elaborate set of checks and balances and incentives for managers, village representatives and farmers.

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INTRODUCTION

China, with one of the oldest societies in the world, has a very long history of irrigation with documented development of large-scale irrigation schemes as far back as 605 B.C. By 1949, China had approximately 16 million hectares (ha) of irrigated land. However, after the founding of the People's Republic of China irrigated area expanded rapidly to almost 48 million ha by 1992. This includes 144 large irrigation districts of over 20,000 ha of effective irrigation area each covering 7.9 million ha in total. There are 5,198 medium irrigation districts (between 627 and 20,000 ha) covering 13.3 million ha. Large and medium systems serve about 47 percent of the total irrigated area in the country. Small reservoirs, ponds, and pumping schemes with an area less than 667 ha are managed by local organizations. This accounts for 27 percent of the irrigated area in China, while other smaller irrigation systems including tube wells are managed by farmers. The command area of irrigated land directly managed by farmers is 26 percent of the total area (Ministry of Water Resources 1991).

With a population exceeding 1.2 billion, China is extremely concerned about ensuring that it can feed its population. In this regard, irrigated land is critically important as 65 percent of the food grains, 75 percent of the cash crops and 90 percent of the vegetables are produced on irrigated land. In addition, irrigation districts supply 70-80 percent of the drinking water for people and livestock in rural areas (Xueren Chen and Renbao Ji 1994).

After the founding of the People's Republic of China, initially a major push was made to rehabilitate existing irrigation systems to reestablish the system of food production that had been disturbed during the long civil war. From the 1950s to the 1970s several new irrigation systems were developed. The majority of the existing medium and large systems were developed during this period. With its increased manufacturing and industrial capacity, China constructed a number of pump-based irrigation systems, primarily large systems lifting water from rivers and other surface water sources. From the 1970s, tube well technology has been developed and widely distributed to exploit the vast underground water resources that existed in the country (Liu et al. 1994).

By the late 1970s, the negative impacts of such a massive irrigation development program were beginning to manifest themselves. A combination of substandard irrigation construction and ineffective management was combined with poor national and local economic conditions. This resulted in a situation where unsuitable management, structural deterioration and inadequate maintenance all held irrigation performance far below actual potential.

Beginning in 1978, Deng Xiaoping introduced a new era of economic reform and opened the Chinese economy to the outside world. At the beginning of the economic reforms,

irrigation management agencies found it difficult to fit their existing management structure within the requirements of the reforms. As a result, irrigated area in China declined. After ten years of effort, the declining trend in irrigated area was reversed and irrigation management has now been strengthened and consolidated (Xueren Chen and Renbao Ji 1994).

Under the reform program, a central aspect of improved water resource management has been the issue of financing. Significant efforts have been made to encourage lower-level water conservancy bureau (WCB) and irrigation district officials to achieve financial independence from the Central and Provincial Governments. Measures advocated include (Turner and Nickum 1994):

* increasing irrigation fees and collection rates
* stimulating investment from private sources
* creating joint stock cooperatives
* borrowing from domestic and international banks
* soliciting aid from international organizations
* establishing and managing sideline economic enterprises to earn additional income

Institutional Reform in the Irrigation Subsector

Before the Peoples' Communes were dismantled in 1983 (Shue 1984), they were at the top of a three-level arrangement for organizing agricultural production and distribution and irrigation development and management. Communes were generally the size of townships and consisted of 10 to 15 production brigades. A brigade generally consisted of several production teams which were the basic units for organizing agricultural production. Teams consisted of 10 to 20 households. Payments to farmers in cash and goods were made on the basis of the amount of work points farmers earned through their farm labor and attendance at communal works activities, including irrigation construction and maintenance.

Irrigation development and management were directed by county level water resources (or "conservancy") bureaus, under the Ministry of Water Resources. At the irrigation system level, bureau staff coordinated irrigation management with the aid of labor assignments made by the commune. During the 1950s, 1960s, and 1970s about two-thirds of government funds allocated to the water sector were for construction and one-third for operations (Gitomer, forthcoming). Subsidies from both central and provincial funds and from the communes supported the management of irrigation systems. General labor on irrigation systems was paid by communes in work points. Irrigation managers were salaried officials of the county water resources bureau. The costs of irrigation O&M not paid by commune revenues were generally funded by the Ministry of Water Resources.

Change at the National Level

As a result of considerable inefficiencies and declining central government revenues available for investment in rural development, the production responsibility system (PRS) replaced the

Peoples' Communes in the early 1980s. Under the PRS households were allocated long-term leases on farm land and were free to organize their own production and marketing and retain profits. With the advent of the PRS government subsidies for irrigation construction declined by over 60 percent from 3.49 billion yuan in 1979 to 1.3 billion yuan in 1981 (ibid.). Between 1979 and 1985 government irrigation construction investment declined from 0.87 percent to 0.21 percent of gross domestic product. This precipitous decline in government subsidies to the local level, combined with a disruption of the communal organization of irrigation maintenance, led to a 2 percent net decline in the total irrigated area in China from 1979 to 1985 from 45 to 44.04 million ha, respectively. During the early 1980s there were widespread reports of chaos, water conflicts and rapid deterioration of irrigation infrastructure.

Alarmed at these trends, in the early 1980s the government began introducing a series of reforms, starting with relatively modest measures and moving to progressively more fundamental changes. The first reform was the *work post responsibility system* introduced in the early 1980s. This was an attempt to introduce a system of incentives to water resources bureau officials to improve their work productivity. Monetary bonuses and penalties were introduced in annual work performance evaluations amounting to 20 percent or more of base salaries. Nickum (1985) notes, however, that this modest reform tended to amount to only, "a threat to withhold a small amount of nominally discretionary wages for poor attendance." The county water resources bureaus remained intact with the demise of the communes. After decollectivization the Ministry of Water Resources added a lower tier below the county level, the *water resources stations* which were created to replace production brigade functions at the township level. *Village irrigation management groups* (VIMG) were created at the village level following the demise of the multifunctional production teams. These were to be under the jurisdiction of village governments but were managed and financed independently from the village government.

Two more far-reaching reforms were introduced through national regulations, both of which were decreed in 1985. These were: 1) the national *Regulation on Water Fees* and 2) the State Council *Regulation on Diversified Sideline Enterprises*. The regulation on water fees stated the principle that revenues for O&M of irrigation districts should come mainly from fees collected from water users. The precise level of fees should be determined at the system level according to the local cost of O&M. However, central and provincial governments continue to place ceilings on the maximum level of fees which can be charged to farmers. Even assuming 100 percent collection rates, fees generally did not provide for the full cost of O&M, let alone for rehabilitation and capital replacement costs. The water fee regulation supported development of a widespread tri-partite system of resource mobilization. This included a fixed area fee (based on the area irrigated by a farmer), a volumetric fee (based on an estimate of the amount of water diverted into a farmer's field), and an annual labor contribution for system maintenance. The latter is not a minor input. Chen and Ji (1994) estimate that contributed farmer labor constitutes more than one-third of the total value of resources invested in existing irrigation districts. While the introduction of volumetric fee assessment is spreading, it is not universal since measurement is frequently difficult and costly. Irrigation fees cannot be legally used for purposes other than O&M for the system from which they are collected.

Irrigation districts often had underutilized assets and resources which had potential economic value. There was generally a gap between the level of resources which could be raised by the irrigation fees (because of political reluctance to require farmers to pay for the full cost of irrigation service) and the actual costs of O&M. By 1988, it was official policy that no central or provincial government funds could be used for regular O&M in irrigation districts. By the 1980s, salaries of irrigation district officials were dropping in real terms below alternative employment opportunities in rural China. Many skilled staff were leaving the

service due to low salaries and poor working and housing facilities in irrigation districts. To bridge the gap between the limited revenue which could be raised from fees and the amount needed for O&M and to boost salaries and facilities for irrigation workers, the government introduced the concept of diversified sideline enterprises into the irrigation sector. Irrigation districts were encouraged to develop sideline enterprises to raise additional revenue from the profits of businesses to cross-subsidize the costs of irrigation management. Such enterprises developed gradually during the late 1980s and early 1990s, beginning first with underutilized existing assets such as reservoirs (for sale of water outside the district, fisheries, recreation, tourism) and reservoir bunds and reserved lands (for tea, orange and tree plantations). Later, sideline enterprises spread to all sorts of businesses, from bottling and food processing to restaurants, construction contracting, bicycle repair shops, petrol stations, production of shirt collars, and so on. Although income from sideline enterprises is growing, generally it provides only a small percentage of the total resources invested in irrigation.

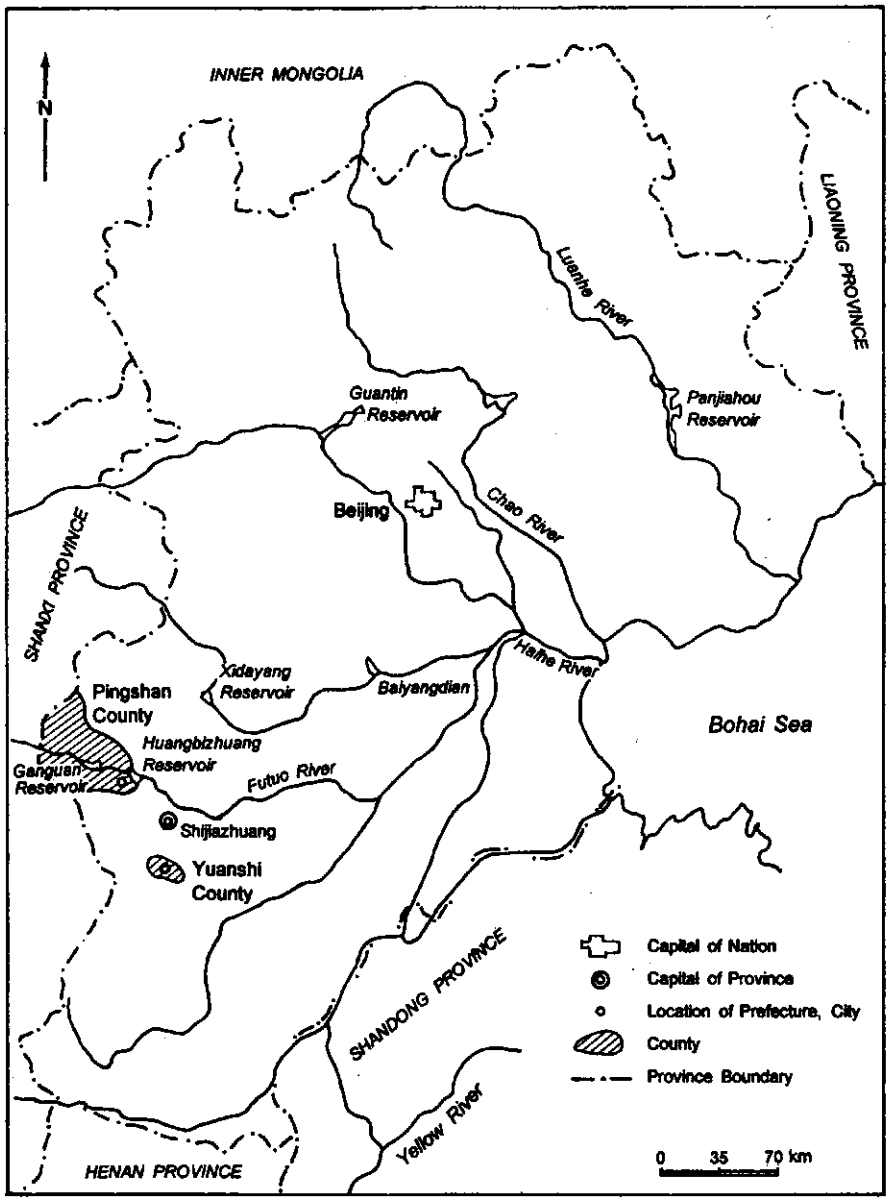
The Water Law enacted in 1988 introduced a water extraction permit system, new authority to apply sanctions against water use violations at local levels, and procedures for mediating water disputes. The Law establishes measurable water rights and facilitates the allocation of water between sectors through buying and selling. However, implementation of the new Law has been slow. By 1993, only 11 provinces or autonomous regions had passed implementing regulations for the Law.

They have resulted in a variety of organizational arrangements throughout China at the level of irrigation districts. What the reforms have in common is an evolution toward local financial and managerial autonomy (both vertical and horizontal). The tripartite irrigation fee (area and volumetric fee plus an annual labor duty), diversified local financing, and village irrigation management groups have resulted in irrigation districts which are increasingly multifunctional and multi-organizational entities with extensive inter-organizational linkages for cross-subsidies and joint accountability. Irrigation districts are also increasingly managed by small, locally contracted "irrigation management firms" which receive multiyear contracts from villages or irrigation districts, depending on the level of management involved (Svendsen and Vermillion 1992).

Bayi and Nanyao Irrigation Districts, Hebei Province

The two irrigation districts selected for the research study are located in Shijiazhuang Prefecture of Hebei Province. Bayi Irrigation District (Bayi ID) is located in Yuanshi County while Nanyao Irrigation District (Nanyao ID) is located in Pingshan County, both of which are near lat. 38^0 N. The location of these counties within Hebei Province can be seen in figure 1.

Figure 1. Hebei Province showing location of Pingshan and Yuanshi counties.



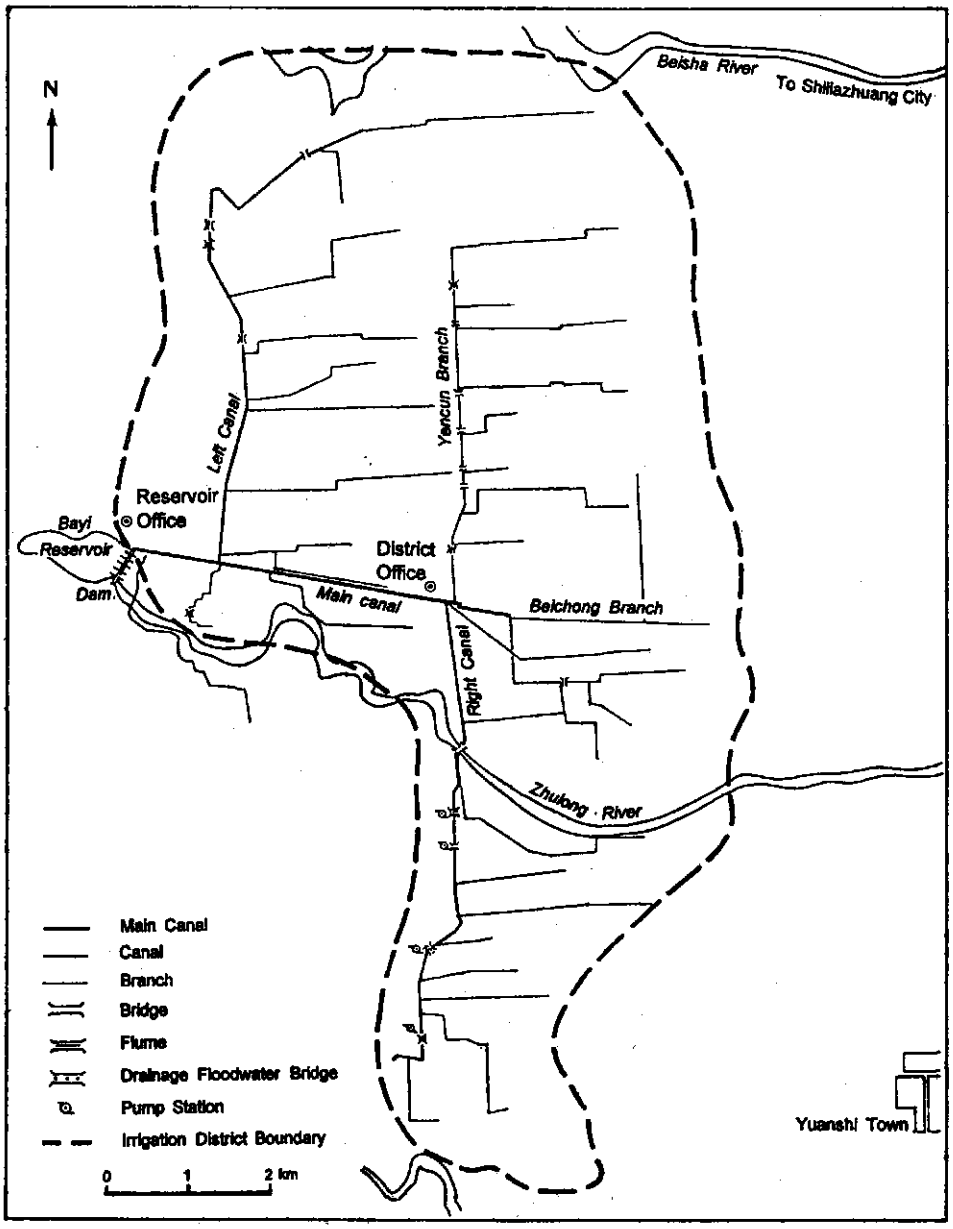
The Bayi ID

The arable land area of Bayi ID is 10,415 ha. Within the district most of the soil is loamy with a medium level of soil fertility. The average annual rainfall is 544 mm, with most of the rainfall concentrated from June until September. However, the annual amount varies widely, from as low as 250 mm to over 1,200 mm.

The source of water for the district is the Bayi reservoir with an overall capacity of 73.87 million m^3. The development of Bayi ID was started in 1959 with the construction of the Bayi reservoir. Originally, the design area was 13,000-20,000 ha. Starting in 1961, a small area was

irrigated, until by 1967 the construction of the reservoir was completed and the irrigated area eventually adjusted to 5,333 ha. Within the irrigation district the main canal is 5.4 km long with two main branch canals of 13.5 km in total length. The lengths of the primary and secondary canals are 16 km and 104.4 km, respectively. Within the system there are over 1,400 structures. There has been no rehabilitation since 1976 when a limited amount of canal lining was done on the main canal and some of the branches. Figure 2 illustrates the canal layout of the irrigation district.

Figure 2. Canal schematic layout for the Bayi irrigation district.



However, the Bayi reservoir was not able to provide all the irrigation water required for Bayi ID. Consequently, a canal from the Gangnan reservoir—a large reservoir on the Mountain Taihang—was started in 1970 and completed in 1976. Since the completion of the Yingang canal, Bayi ID has been able to purchase water from the Gangnan reservoir. This transbasin conveyance project ensures irrigation water for Bayi ID. The annual water purchased is 20-30 million m^3.

In addition to surface water, there are 383 tube wells within the command area, of which 363 are in operation annually. About 4,000 ha can be conjunctively irrigated with both canal and well water. However, due to overpumping, the water table in the county fell dramatically during the 1980s. In 1979, the average depth to the water table was 11.9 meters, while in 1993 the depth to the water table was 25.5 meters. In some areas, it declined at the rate of 1.1 m/year while in other areas it declined in excess of 1.5 m/year. In the entire county, the pumping rate is 120 million m^3 while the annual recharge is 100 million m^3. To address this problem, since 1989 the county has received about 20 million m^3 of water each year from the Yehe River to attempt to stabilize groundwater levels within the county. In 1989, the district paid yuan[1] [Y] 0.7 100 m^3 and in 1991, 1992, and 1993 it paid Y 1.1 per 100 m^3 for this water. As a result of their efforts, the groundwater table is at present around 17 m from the surface. On average, around 8 million m^3 of water are pumped annually in Bayi ID.

The population in Bayi ID is approximately 90,200 which includes 18,531 male laborers and 13,808 female laborers. There are off-farm employment opportunities as well as agricultural income, and therefore the average income in Bayi ID was Y 670 in 1991, while the average in Shijiazhuang Prefecture was Y 650. The literacy rate within the district is estimated at 80 percent.

The Nanyao ID

The Nanyao ID was designed in 1957 and construction was started the following year. Funds for purchasing materials were provided by the townships and volunteer labor was provided by the involved villages. Therefore, the degree of government subsidy in the system was very small. There was a significant amount of rehabilitation in 1977-80, with almost all the labor coming from the farmers. The County contributed 200,000 yuan for materials only.

Within the Nanyao ID the total arable land area is 3,333 ha. The soils in Nanyao are a sandy loam with lower levels of fertility than those in the Bayi ID. The average annual rainfall is 535 mm, with most of the moisture concentrated in the period from June until September. However, the annual amount varies widely, from as low as 200 mm to over 950 mm. The water source for Nanyao is the Yehe River that originates on the Shanxi Plateau and passes through Pingshan County before joining the Hutuo River. The average discharge of the river is 100 m^3/s, although during the flood season discharge increases to 500 m^3/s and during the dry season decreases to 20–50 m^3/s.

Design discharge at the head of the main channel is 15 m^3/s. Within the irrigated area of 2,473 ha, the total length of the main canal, branch canals and subbranch canals is 111.5 km, of which 39.6 km are lined. The main canal is 30.3 km with 18.6 km lined. There are 339 structures within the system and total water discharge varies from 10.4 to 59.4 million m^3/year. System-level water use efficiency is 53 percent. Figure 3 presents the canal layout of the irrigation district.

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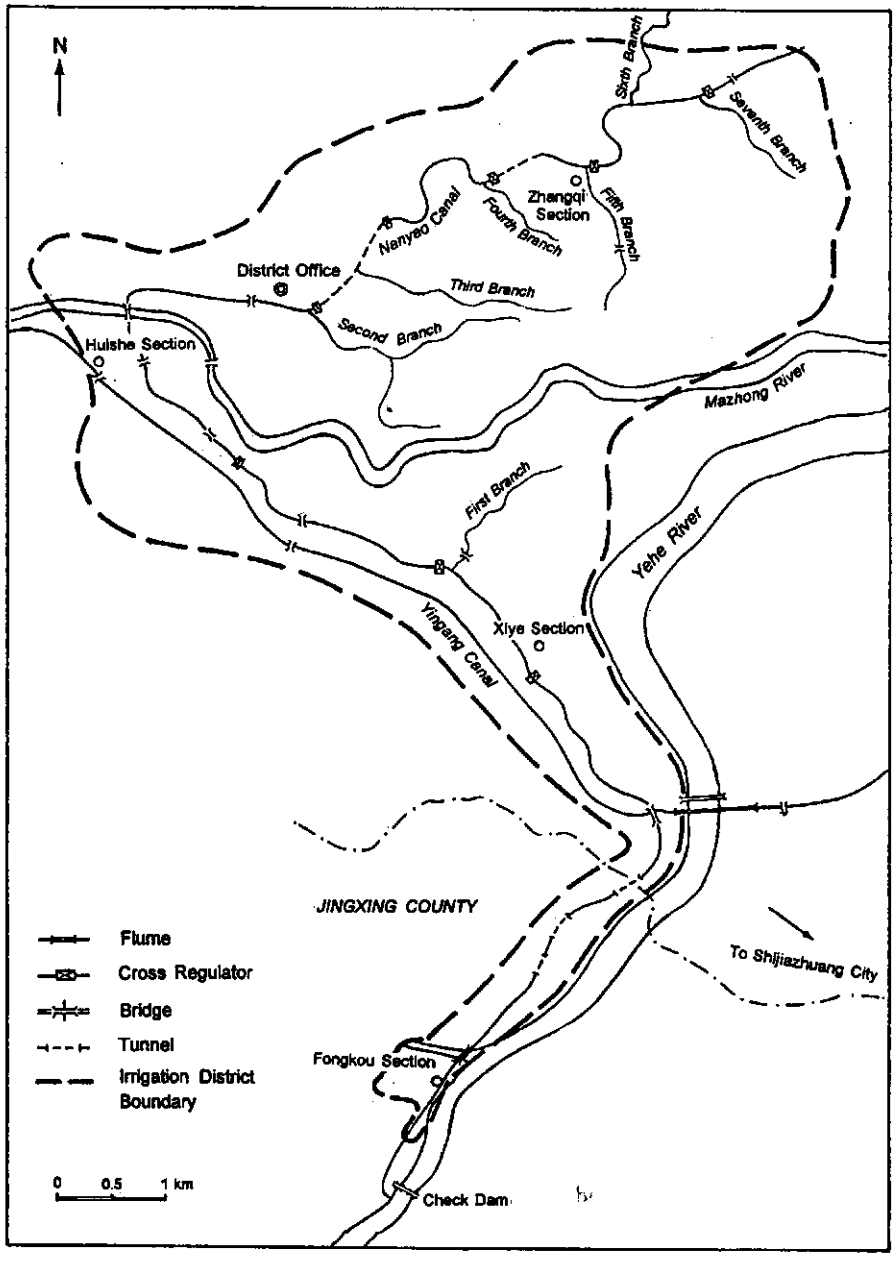
1 Exchage rates for one US dollar from 1989 to 1994 were as follows: 1989:Y4.72; 1990:Y5.22; 1991: Y5.34; 1992: Y5.78; 1993: Y8.8; and 1994: Y8.6.

Figure 3. Schematic canal layout of the Nanyao irrigation district.



The population in the Nanyao ID is 35,545 with 7,112 male laborers and 5,405 female laborers. Income is almost exclusively from agriculture and was Y 414/capita in 1991. The literacy rate was approximately 77 percent.

Once irrigation water was available, agriculture production in the two districts shifted from rain-fed to irrigated crops. In Bayi and Nanyao, winter wheat and summer maize are the two main crops, with cotton, vegetables, water melon and fruit orchards making up the other

major crops. In addition, a small area is planted in rice in the Nanyao ID. Table 1 contains the detailed area of the different crops as well as the percentages of the total.

Table 1. Crop areas in the Bayi and Nanyao irrigation districts [average in the 1990s].

Crop	Bayi Irrigation District		Nanyao Irrigation District	
	Area (ha)	Percentage	Area (ha)	Percentage
Winter - wheat maize	7,738.9	74.3	2,473.3	74.2
Cotton	1,385.3	13.3	333.3	10.0
Vegetables	364.6	3.5	93.3	2.8
Rice	0	0	66.7	2.0
Water melon	250.0	2.4	36.7	1.1
Fruit orchard	177.1	1.7	10.0	0.3
Sweet potato	166.2	1.5	180.0	5.4
Spiked millet	93.7	0.9	50.0	1.5
Dru plants	0	0	16.7	0.5
Beans	83.3	0.8	40.0	1.2
Sorghum	62.5	0.6	23.3	0.7
Others	104.2	1.0	10.0	0.3
Total	10,425.8	100	3,333.3	100

As the climate in the area is hot and wet in the summer and dry and cold in the winter, rainfall from June to September is about 80 percent of the total annual rainfall. From October to May, the growing season for the winter wheat, only about 150 mm of rainfall is available. As this is far below the requirements for wheat, irrigation is required to produce a wheat crop. In contrast, in general, rainfall during the summer is sufficient for a maize crop and therefore no irrigation is required during normal and above-normal rainfall years. Table 2 presents the winter moisture regime for the two irrigation districts. As can be seen in the table, a wheat crop requires at least 350 mm of supplemental moisture.

The water requirements for maize are in stark contrast to the water requirements for wheat. As can be seen in table 3, during the average year moisture from rainfall is such that it actually exceeds the evapotranspiration requirements. Thus, in many years maize does not require irrigation. To ensure the maize has sufficient moisture, farmers often relay-plant the maize in the wheat and then germinate the maize seeds using moisture from the previous irrigation on the wheat. In this case, the previous irrigation for wheat has a dual purpose. However, during dry years maize will often require one or two irrigations to obtain high yields.[2]

In addition to the increased use of chemical fertilizers and pesticides, new seed varieties along with the availability of irrigation have resulted in significant yield increases. The annual combined per ha production of wheat and maize (for the two seasons) has increased from 1,125 kg in 1960 to 11, 905 kg for the Bayi ID in 1992 and from 5,250 kg in 1972 to 8.500 kg in the Nanyao ID in 1992. At present, the net income for the two seasons of wheat and maize is Y4,200/ha for the Bayi ID and Y3,300/ha for the Nanyao ID.

2 Tables 2 and 3 were developed using the UNFAO CROPWAT program, as part of the collaborative SIAM-IIMI case studies.

Table 2. Water requirements of winter wheat, the Bayi and Nanyao irrigation districts.

	Developing stage	Before over-wintering	Over-wintering	Turning green to jointing	Jointing to heading	Heading to maturing	Total
	Duration						
	Dates	1/10-30/11	1/12-28/2	1/3-31/3	1/4-30/4	1/5-10/6	
	Days	61	90	31	30	41	253
Bayi	Potential evapotranspiration (mm)	55.4	44.1	55.2	118.8	213.8	484.9
Irrigation District	Average Rainfall (mm)	47.0	13.1	10.2	20.5	56.6	147.4
	Difference (mm)	8.4	31.0	45.0	96.1	157.2	337.7
Nanyao Irrigation District	ETP (mm)	50.7	44.1	57.9	118.5	219.6	498.9
	Average rainfall (mm)	43.3	13.5	12.2	22.7	54.2	147.5
	Difference (mm)	17.4	30.6	45.7	93.9	166.4	351.4

Table 3. Water requirements of maize, the Bayi and Nanyao Irrigation Districts.

	Developing stage	Early growing period	Jointing period	Heading period	Milky period	Total
	Duration					
	Dates	10/6-30/6	1/7-30/7	1/8-20/8	21/8-20/9	
	Days	20	30	20	31	101 days
Bayi	Potential evapotranspiration (mm)	44	118.7	85.6	116.6	384.9
Irrigation District	Average rainfall (mm)	38.8	142.2	110.1	87.89	378.9
	Difference (mm)	5.2	–23.5	–24.5	28.8	–14.0
Nanyao Irrigation District	ETP (mm)	43.2	118.7	81.3	116.3	359.5
	Average rainfall (mm)	34.7	147.1	99.3	88.8	369.9
	Difference (mm)	8.5	–28.4	–18.0	27.5	–10.4

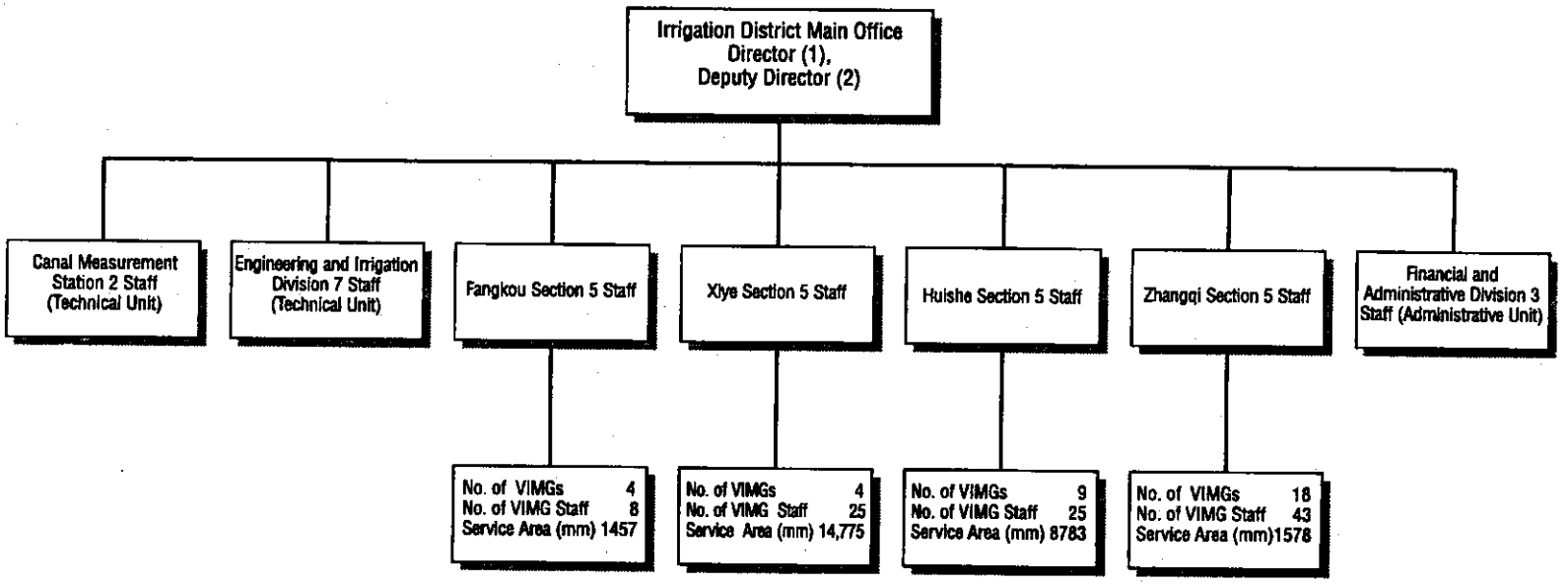
Organizational and Managerial Change in the Two Districts

Under the commune system, O&M of the districts were handled first by *water conservancy groups,* created in 1964. These were soon absorbed financially and managerially by the collectives and later, villages. Irrigation staff interviewed in this study reported that under the commune system responsibility was often confused and coordination was difficult because irrigation matters were handled by busy multifunctional production brigades and later, by village committees. Irrigation district staff had little authority relative to the communes. When the production responsibility system replaced the collectives, water resource stations and village committees replaced brigades and production teams, respectively. Water conflicts and system deterioration increased dramatically in the Bayi and Nanyao IDs during the transition period after the collapse of communes but before the new reforms of village irrigation management groups (VIMG), the new system of irrigation fees, and sideline enterprises began to be adopted locally. These were phased in during the mid-1980s in the Bayi ID and during the late 1980s and early 1990s in the Nanyao ID.

At present, in the Nanyao ID in the Pingshan County, the two top levels of canals are managed by the irrigation district and the third and lower-level canals are managed by VIMGs. The Nanyao ID has five levels of canals (as do most districts in both counties). The district office has two tiers, the main office and four sections which are subdivisions of the system (figure 4). The Nanyao ID has 30 staff members plus 5 temporary workers. All receive their total salaries from the water charge. There are four geographic sections and three managerial sections supervised by the district office, canal measurement, engineering and irrigation, and financial and administrative. Nanyao ID has 40 village irrigation management groups (VIMGs). The Nanyao ID has not yet developed any sideline enterprises under a "Diversified Management Division."

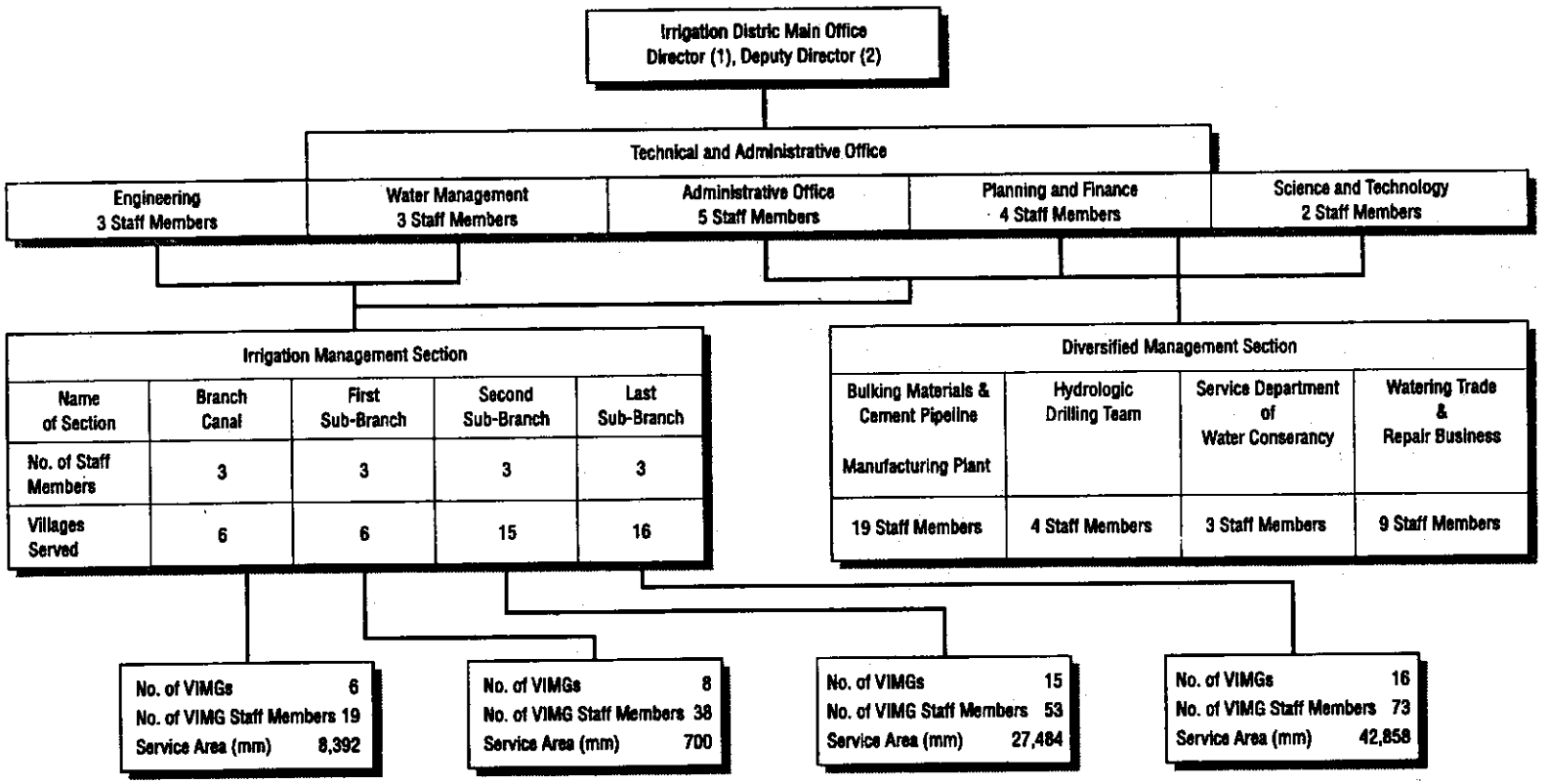
The Bayi ID office has three tiers, the main office, which oversees the entire system and operates the reservoir, two technical units, one administrative unit, and below them, four sections, which manage the main and branch canals and liaise with VIMGs (figure 5). The Bayi ID (including the reservoir) has a total of 67 staff members, 20 positions of which have a temporary status. Thirty-two staff members are performing water management functions (12 engineers) and 35 are in the "Diversified Management Division," producing revenues from sideline enterprises. All 32 staff members in the Irrigation Management Division (IMD) are ID employees and receive all of their salaries and pensions from the Bayi ID, not from the county WCB. None of the staff members are civil servants under the WCB. Hence, the irrigation district is an independent public utility, not part of the government bureaucracy. The Bayi ID has four levels (including VIMG) in contrast to Nanyao's three levels. The Bayi ID has five technical and administrative offices which in turn supervise the Irrigation Management and Diversified Management Divisions. It incorporates 45 VIMGs.

Figure 4. Organizational chart for the Nanyao irrigation district, Pingshan County, Hebei Province.



Permanent Staff 30
Temporary Staff 5

Figure 5. Organizational chart for the Bayi irrigation district, Yuanshi County, Hebei Province.



As part of the reforms begun in the early 1980s, VIMGs were organized in Pingshan and Yuanshi counties to take over direct responsibility for managing irrigation. A VIMG generally has about three to five members, selected by the farmers in a village. VIMGs normally have a head, a deputy (who inspects canals for problems or damages), a treasurer, a head of water fee collection and a head of maintenance. Their duties are to clean canal sections which pass through the village (normally branch canals and below), distribute water among village farmers, collect water charges ("under the supervision of the ID"), ensure proper passage of water through the canals, maintain and organize schedules among farmers for water delivery, and protect field-level irrigation facilities of the WCB. Often, the VIMG head is also an official on the village committee. Each VIMG staff member has responsibility for coordinating water distribution among roughly 200 households farms.

Irrigation fees

Both Bayi and Nanyao IDs are attempting to implement the new system of water fees. Each irrigation district in the two counties has a different water fee level, according to availability of revenue sources, variable O&M costs and the number of irrigation turns delivered in a year. While the Nanyao ID calculates water charges according to its estimate of water volume delivered, the VIMGs translate an otherwise volumetric water fee into an area-based charge levied against individual farmers. The Hebei Province official water charge rate is Y 3 per 100 m^3 (maximum allowed). The Nanyao ID is charging less than the allowed amount because the farmers refuse to pay more than the current rate. The fixed area fee is Y 7.5 per mu and the volumetric fee is Y 2.5 per 100 m^3. The amount of the fee is estimated by the district based on village area irrigated. Both components are combined into a single fee, treated as a fixed area fee, at the rate of Y 15 per mu. This assumes five irrigations per year.

In Nanyao, if the VIMG collects 100 percent of the fee by the end of March, it retains 5 percent of it. If it collects 10 percent by the end of April, it retains only 3 percent. If it collects less than 100 percent by May then it must pay a fine of an additional 3 percent of the remaining amount uncollected. The entire fee for the year is collected once a year, in February, 10 days before the first irrigation. Fee collection rates for 1993 were 97 percent, 90 percent and 95 percent for each of the three sections.

In Bayi the volumetric water fee is Y 7.11 per 100 m^3. The area fee is Y 1.5 per mu. Before 1984 the water fee was only a fixed-area fee so the use of water was very inefficient. The volumetric water fee was introduced in the mid-1980s, after 1984, as part of the reforms. The Hebei Province standard rate for the volumetric fee was Y 3.3 per 100 m^3, but since the Bayi ID purchases water from the Bayi reservoir and sometimes from another county (Pingshan) and has more than 100 km of canal to supply this water to the district, it has a higher fee based on the actual higher costs for water. The Bayi reservoir and the ID propose a fee level which is approved by the county government, based on the provincial standard modified to take into account actual local costs. So there is some slippage between central or provincial standards and what irrigation districts actually charge for water fees. The fee standards seem to be considered more as guidelines than as rules.

Diversified Sideline Enterprises

The Nanyao ID which is in a poorer area than Bayi began implementing the reforms later. It has still not developed any sideline enterprises. Its officials have the desire to establish them but report difficulty in raising initial capital and getting organized. The Bayi ID's Diversified Management Division was created in 1984. By 1994, it has become highly diversified. It has

11 kinds of sideline businesses: 1) survey and design of small-scale irrigation projects, 2) fitting of water pipes and taps, 3) repair of farm machinery and irrigation and drainage equipment, 4) well boring and pump installation, 5) building construction, 6) a small restaurant, 6) a bicycle repair shop, 7) an agricultural products store, and the production of 8) cobblestones, 9) cement tiles, 10) cement pipes, and 11) talcum powder. Since 1984, the Bayi ID has received many prizes and awards from the county, prefecture and province for its successful Diversified Management Division (Wu 1994). Profits from sideline enterprises provide approximately 7 percent of the total revenues of the district. The businesses also provide employment for family members of district staff (as well as others) and thereby enhance the standard of living of staff families.

At the level of the Hebei Province, in 1992 a total of Y 450 million (US$52.3 million) gross income was raised province-wide by the WCB from diversified sideline enterprises. Y 66 million (US$7.7 million) of it was invested in construction and rehabilitation of water projects. These enterprises also provided employment for 13,155 people.

Post-Reform Management Practices in Bayi and Nanyao Districts

Performance Standards

Under the work post responsibility system, yearly personnel evaluations of district and WCB staff members are required. For irrigation district staff members these include an assessment of water fee collection rates, the quality of maintenance work and water distribution. Both Bayi and Nanyao make annual assessments of the performance of staff and district management according to the same basic set of eight "economic norms" (or performance standards) promoted by the work post responsibility system. They vary in how points, bonuses or fines are calculated. Assessment is done at the level of individual staff members, section offices, divisions and at the district office level. The eight criteria used are: irrigation efficiency, proportion of structures which are functional, balance of income and expenditures, total water use, irrigated area, water use efficiency, irrigation schedule targets and crop yields obtained.

Table 4 shows the system of performance measures used by the Nanyao ID itself in 1993. The rating was 96.5 percent of potential. In comparison with problems of advancing siltation and deterioration, this rating lends some support to Nickum's argument (1985) that the water fee assessment system in China is only used in a modest way to remind staff not to shirk duties too much. Performance standards are set for each of these criteria and percentage figures are used to measure levels of achievement relative to that standard. If a staff member gets a rating below 60 percent, no annual salary bonus is given and salary is reduced by one grade for that year. This has never happened yet. As a gesture to increase work incentives, the Nanyao ID recently decided that from 1994 onwards, if a staff member is ranked below 79 percent he gets no bonus and the salary will be reduced by one grade. For scores above 79 percent, the higher the score the higher the bonus. Scores tend to be stable in most years. The overall annual performance rating for the Nanyao ID increased from 81 points in 1987 to 96.5 points in 1993. This was likely a combination of some "rating inflation" and real improvements.

Staff grades generally increase according to seniority, promotion and performance ratings in accordance with the guidelines of the National Personnel Ministry. Grade levels determine salary. The Labor Ministry designates base salary levels for all kinds of positions, even in financially independent irrigation districts.

*Table 4. Annual performance assessment for the Nanyao irrigation district, 1993.**

Item	Planned	Actual	Potential Points	Points Awarded
1. Water Delivery				
Total discharge (m^3)	45 million	56 million	4	4
Irrigation water (m^3)	20 million	21.5 million	5	5
Delivery to Yingang canal (m^3)	15 million	34.5 million	3	3
Water delivery days	300	307	3	3
Total points			15	15
2. Irrigated Area				
Net irrigated area (ha)	2,733	2,733	5	5
Irrigated area x 4 irrigations (ha)	12,000	12,000	5	5
Total points			10	10
3. Water Use Efficiency [WUE]				
WUE of main canals	0.715	0.715	4	4
WUE of branches	0.82	0.82	4	4
WUE of subbranches	0.91	0.91	4	4
WUE of whole canal system	0.534	0.534	4	4
Total points			16	16
4. Irrigation Duty & Effieiency				
Irrigation duty at the head of main canal (m^3/ha)	1,522.5	1,519.5	3	3
Irrigation duty at the outlet of sub-subbranches (m^3/ha)	892.5	892.5	2	2
Irrigation duty in field (m^3/ha)	813	811.5	2	2
Annual gross irrigation water per ha	6,870	7,875	3	3
Irrigation efficiency at the head of main canal (ha/m^3/s)	56.7	56.8	3	3
Irrigation efficiency at the outlet of sub-subbranches (ha/m^3/s)	96.9	97.1	2	2
Total points			15	15
5. Rate of Functional Structures				
Number of structures	447	447	4	4
Canals and branches (km/number)	48	48	3	3
Total points			7	7
6. Maintenance				
Lined canals (km)	10	10	6	4
Silt clearance (km/number)	271/62	271/62	4.5	4.5
Structures maintained (number)	35	35	4.5	4.5
Total points			15	13

(Continued)

Item	Planned	Actual	Potential Points	Points Awarded
7. Income and Expenditure				
Total income (US$)	31,395.3	38,372.1	5	5
Total expenditure (US$)	26,744.2	36,627.9	5	5
Operating and managing costs (US$)	20,930.2	6,046.5	3	3
Annual maintenance costs (US$)	5,813.95	12,558.0	3	3
Total points			16	16
8. Crop Yield Assessment				
Grain (kg/ha)	3,262.5	3,045	2	1
Wheat (kg/ha)	4,425	4,605	2.5	2.5
Cotton (kg/ha)	6,000	5,850	1.5	1
Total points			6	4.5
Grand total of potential points	= 100	Grand total of points awarded = 96.5		

*This is the irrigation district's own performance evaluation and is not derived from this research.

Financial Management

Under the collectives or village committees, general commune or village revenues subsidized routine irrigation costs. Central and provincial level funds are now available only for construction and rehabilitation, on a cost-sharing basis with villages or farmer groups. Financing routine O&M has always been the responsibility of the irrigation districts and farmers. Officials report that neither the Nanyao ID nor the Bayi ID has ever received *central* government funds for routine O&M.

While no funds are provided by the government for O&M, between 1988 and 1992 the county WCB provided Y 519,000 (approximately US$85,000) to the Bayi ID for canal lining and extension. This amount was one-third of the total expended. According to the requirement for matching investments, the same amount was invested by both the Bayi ID and member villages (mainly in the form of labor).

In 1992, the Nanyao ID's total budget was approximately Y 365,000 (about US$63,000), Y 350,000 of which was from the collection of current and back accounts for water fees. Expenditures totaled Y 341,500, including a Y 36,500 repayment of its 1991 budget deficit. Nanyao ID spent Y 36,500 to purchase supplemental water from the Yie He River. Therefore, Nanyao had a budget surplus of approximately Y 13,500.

Between 1984 and 1992 Bayi's Diversified Management Division produced Y 400,000 (approximately US$60,000) in profits. Of this, Y 260,000 (65%) was submitted to the ID office to finance water management. The other Y 140,000 (35%) went to salaries and bonuses for staff of the Diversified Management Division, many of whom are spouses of the ID staff. In 1992, total revenues from irrigation fees in the Bayi ID amounted to Y 906,000, while total revenues (i.e., profits) from sideline enterprises amounted to Y 70,000. This total income of Y 976,000 (approximately US$168,000) produced a surplus of Y 258,000 (US$45,000) over total expenditures of Y 718,000 (US$124,000). Purchase of water amounted to Y 360,000 (US$64,000) or 52 percent of total expenditures.

In about two-thirds of the villages in the Nanyao ID, the VIMG collects water fees from individual farmers; in the other third the villages produce enough off-farm collective income

so that the village committee pays all of the water fees charged to the village and often also pays for other agricultural taxes, educational fees and village fees. For example, the Dong Hui She village has successful collective enterprises, including a brick factory, a fertilizer bag production plant and a fruit orchard. Eighty percent of the factory workers are also farmers from the village. Workers are paid on a piecemeal basis. The Dong Hui She village paid 100 percent of its water fee by March 5 in 1992 and 1993 and thereby received a 5 percent rebate.

The Bayi ID collects the water fee from farmers, through the VIMGs, three to five days before the village's scheduled water turn. The VIMG broadcasts with megaphones announcements of pending water delivery three to five days in advance, reminding farmers to pay their water fee before delivery. Two members of the VIMG wait at a designated location for farmers to come and pay. At least two VIMG staff members must together receive water fees. A receipt is issued to farmers upon payment. Normally, 90 percent of the farmers pay the fee in advance of the water delivery. Others still get water but must pay afterwards or they will not be allowed the next water turn until they pay up—but this is reportedly "very rare."

Compensation for VIMG staff members is sometimes from the village committee funds and sometimes from a village-levied surcharge on the water fee. This compensation ranges from Y 400 to 1,000 between different villages, varying by the size of village irrigated area, amount of work required and differences in wealth between villages. Most villages in the Bayi ID have a surcharge on the water fee of about 2 to 5 percent to pay for the cost of compensation for VIMG staff members.

Water Management

The Nanyao ID normally obtains its full water supply from the Yie He River according to a withdrawal permit. Occasionally, as in 1992, supplemental water is purchased. The Bayi ID obtains water from the Bayi reservoir. Before 1976, the amount of water in the Bayi reservoir was 3 to 5 million m^3. By purchasing water from other counties by feeder canals, the amount of water in the reservoir has expanded to 35 million m^3 today. Purchased water constitutes 95 percent of the water in the reservoir today. All imported water directly or indirectly comes from the Yie He ID. Seventeen to 25 million m^3 of water per year are imported into the Bayi reservoir. Seventeen million m^3 of water were purchased by the Bayi ID in 1992. The Bayi ID pays between Y 100,000 and 200,000 per year to purchase water. The amount varies according to rainfall and how much the Bayi ID requests, which can depend on the number of turns requested from Bayi and the VIMGs. In both Bayi and Nanyao IDs wheat and corn are the main crops. Farms normally receive five irrigations per year. Water is distributed by the ID to the respective VIMGs according to a preannounced schedule.

All VIMGs are responsible for scheduling, managing and recording water deliveries within the village area. Deliveries are arranged to irrigate one farm at a time along a given canal, starting from the farm nearest the top end and working downstream. The duration of each turn depends on how long it takes the water to reach the entire field. This varies between 10 minutes to one-half an hour per mu for furrow-irrigated wheat. A member of the VIMG opens and closes canal offtakes for each water turn and records the time of start and finish and assesses the individual volumetric fee on the basis of the actual duration of the turn. If a farmer has not paid the water fee before his scheduled irrigation delivery, the VIMG pays his fee to the district (so that the village-level payment is complete before its scheduled irrigation) and his turn is delayed until he pays. Sometimes, water delivery to a village is delayed if the VIMG is late in paying the fee to the ID. Information on volume of water delivery scheduled, schedule dates and times and target fee level assessed to the village are all posted publicly in the village. After the irrigation the information is completed with comparative information on

actual schedule and volume of delivery implemented. Actual assessable fee is recorded for comparison with target fee assessment. Adjustments to payments on the basis of actual recorded deliveries, for either adding or reimbursing, are normally made at a meeting of VIMG representatives with irrigation district staff at the end of the cultivation year, usually in December.

In the Bayi ID actual discharges are monitored by superiors and compared with targets. Bonuses are given or refused on the basis of the evaluations. The Director of the Bayi ID fines staff members who do not deliver the right amount of water to the branch canals, on time and for the right duration. A district staff member and a VIMG staff member jointly measure actual discharges at the head of each sub-subbranch canal once a day for the duration of the village's water delivery period. In Bayi and Nanyao, staff members use gauges, current meters, v-notch and cipoletti weirs and flumes to measure water deliveries from the main canal to branch offtake levels. In Bayi, water is also measured down to the level of "sub-subbranch" outlets..

The Bayi ID purchases a considerable amount of water each year to improve water use efficiency. To encourage greater efficiency, the Bayi ID gives a small cash bonus to VIMGs for using less water than planned (+Y 10–20). These bonuses are paid from money collected from fines levid by the ID from some villages that waste water. (Sometimes a village does not prepare all its land or repair or clean channels properly so it needs and requests more water than planned.)

The irrigation districts generally settle irrigation disputes which are not settled by the VIMGs or which are between villages. A common sanction for breaking rules, such as taking water out of turn is to levy a fine (the most common method). Farmers who damage structures are required to repair the structures and pay a fine. Irrigation districts also have the legal right to cut off water delivery to farmers, but this is rarely used.

In the Bayi ID farmers caught illegally opening field offtake gates must pay twice the area and volumetric water fee assessed for that irrigation. The last time this happened was in 1985. For repeated offenses they would pay an extra Y 200 to Y 500. For closing cross regulators, farmers would pay double the water fee for the estimated amount of illegal extra water taken, plus an additional Y 100 to Y 200. If the farmer refuses to pay, he is sent to the police station. Sometimes this happened before 1985, but rarely thereafter, except in 1987 which was a drought year. The district never fines farmers for absence at the time of scheduled delivery; they just move his or her turn to the end of the schedule for the village. For damaging structures, farmers must pay for the repairs and the police levies a fine. The last time this happened in Bayi was in the winter of 1990.

Maintenance

In Nanyao the average annual unpaid maintenance labor contribution from farmers is about 11 days, 10 days for subbranch canals, plus normally one day on main or branch canals. The actual number of unpaid maintenance labor requirements for farmers varies between villages according to the amount of land served and the length of channels used in the village. In Bayi maintenance labor requirements for farmers varies between villages but is in the order of 15 to 20 work days per year. Most of this labor is for maintenance and repair of channels below the main and branch canal levels. Farmers are permitted to pay cash for a day of maintenance labor not worked, paid at the rate of a standard day's labor cost.

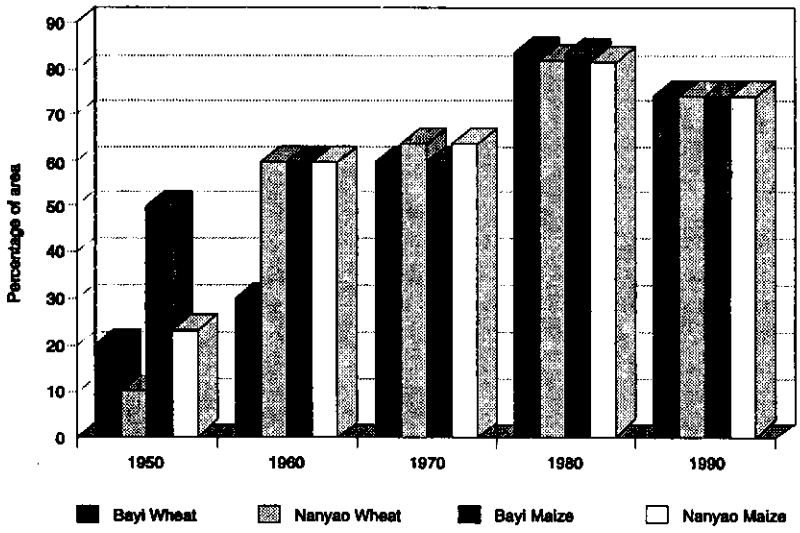
Performance Impacts of the Reforms

Although there is no question that the rural reforms have resulted in significant changes in the way water resources and, in particular, irrigation are managed in China, the critical question is whether these changes have resulted in improvements in performance. In this section, performance impacts of rural reforms are examined in terms of three aspects: agronomic changes, financial sustainability, and hydrologic efficiency.

Agronomic Changes

As indicated earlier, access to irrigation water significantly changed the cropping patterns in the two districts. Before construction of the irrigation districts in Bayi and Nanyao, the main crops grown were maize and other spring sown crops such as spiked millet, sweet potatoes, buckwheat, and beans, which are all drought-tolerant crops. Very little winter wheat was grown. During the 1980s, after the irrigation systems had been established and were working well, the percentage of irrigated winter wheat and maize in the cropping system reached its highest levels. This is illustrated in figure 6. Recently, however, farmers have shifted to growing more cash crops such as watermelon, vegetables and fruit trees to maximize their income.

Figure 6. Percentage of area in irrigated grain crops, Bayi and Nanyao - by decades, 1950s–1990s.



Data from IIMI-SIAM collaborative study, 1993–1994.

Prior to development of the Bayi and Nanyao irrigation districts, farmers living in the two regions consumed all their grain production within the household. In fact, in dry years the government was forced to provide grain to the rural families in the area at below-market prices. After the irrigation systems were constructed, as illustrated in figure 6, irrigated grain production increased significantly. As a result, the farmers in the Nanyao ID sold 1/6th of their winter wheat and 1/10th of their maize production and those in the Bayi ID sold 1/3rd of their winter wheat and 1/10th of their maize production to the government. With the development of the agricultural production responsibility system there has been sufficient

grain after providing their quota to the government for farmers to have grain for consumption and still have enough grain to sell on the local market.

Currently, in the Bayi ID about 1.5 t/ha of wheat is sold to the government, about 1.5 t/ha is left for farm family consumption and 1.0 t/ha is sold on the free market. About 10 percent of the total maize production is sold to the government, about 65 percent is sold on the free market and the remainder is used for animal feed. In the Nanyao ID, about 0.75 t/ha winter wheat is sold to the government, the remainder is left for family consumption and only a small percentage is sold on the open market. About 0.75 t/ha of maize is sold to the government, half of the remainder is sold on the open market and the remaining stock is used for animal feed.

As a result of increased yields, facilitated by access to irrigation water, chemical fertilizers and pesticides, and new high-yielding seed varieties, net returns per hectare have increased significantly. Table 5 compares the yields, input levels and net incomes for the Bayi and Nanyao IDs for the 1950s, 1960s, 1970s, and 1980s. As can be seen, development of the irrigation systems, combined with implementation of the rural reforms, has resulted in impressive improvements in net income in the two districts. The Bayi ID, due to its higher yields, has been able to sustain its growth in net income, while the Nanyao ID has seen a drop off of net income as annual per ha production of wheat and maize has stagnated during the 1990s.

Financial Sustainability

Central to the transfer of irrigation management, development and reform has been the issue of financing. In this process it has been critical so that farmers and irrigation officials alike recognize that irrigation water is not a free good, but a valuable production resource. Since the implementation of the rural reforms, education and propaganda schemes have been used to educate users and suppliers of agricultural water on the importance of financial stability to ensure long-term security of irrigation supplies.

Prior to the reforms, water fees were paid by the communes and thus "collection rates" were always 100 percent. However, as the reforms were instituted, collection rates dropped drastically as there was confusion within the irrigation systems about management responsibility. Improved management services and extensive education programs have been used as a mechanism to increase water fee level as well as collection rates. These approaches have been successful as water fee collection increased from Y 4.36 hundred million in 1984 to Y 18.3 hundred million in 1991 and in 1992 they doubled to Y 35.7 hundred million (all in current yuan). In addition to increased fee levels, collection rates increased from 30 percent in 1984 to 70 percent in 1991 (Turner and Nickum 1994). The reduction in subsidies and the obvious necessity to increase local funding to support O&M expenses also served as catalysts to improved fee collection in many areas.

The situation has been the same in Bayi and Nanyao irrigation districts. Fee levels and collection rates have increased since the institution of the rural reforms. For example, in the Nanyao ID the water fee collection rate was 100 percent until 1984 while it was paid by the commune. After, 1984, when the rural reforms were first introduced, due to the confusion and an actual reduction in irrigation service, combined with an increase in the volumetric water fee, the collection rate fell to 85 percent. It fell even further from 1988 to 1991 as the district struggled with instituting a revised management system, including the WPRS. It was not until 1993 that the collection rate rose above 90 percent (95 percent). The case of the Bayi ID is even more striking. Again the collection rate for irrigation water fees was 100 percent while paid by the commune. When the rural reforms were first introduced in 1983, the water fee

Table 5. Cost of inputs, yields and returns, 1950–1990.

Item	Bayi Irrigation District					Nanyao Irrigation District				
	1950s	1960s	1970s	1980s	1990s	1950s	1960s	1970s	1980s	1990s
Chem. Fert (Y/ha)		8	187.5	740	1535		8	187.5	645	1260
Pesticide (Y/ha)			7.5	105	135			7.5	150	150
Manure[1] (Y/ha)	30	30	45	55	55	30	30	45	75	75
Seed (Y/ha)	150	180	200	210	390	150	180	200	210	390
Labor (Y/ha)[2]	270	270	300	310	270	270	270	300	350	380
Machinery (Y/ha)			10	157.5	322.5			10	150	202.5
Water fee (Y/ha)		6	8	50	240				52.5	225
Total input (Y/ha)	450	494	758	1628	2948	450	488	750	1633	2683
Average yield (t/ha)	1.05	1.6	3.6	8.8	11	0.9	1.4	3.7	7.6	7.6
Market price[3] (Y/ha)	0.66	0.87	0.67	0.58	0.69	0.66	0.87	0.67	0.58	0.69
Total output (Y/ha)	693	1392	2412	5104	7590	594	1218	2479	4408	5244
Net income (Y/ha)	243	898	1654	3477	4643	144	730	1729	2776	2562

[Converted to 1991 Chinese yuan]

[1]Manure price = Y 1/m^3 for the 50s, 60s and 70s; Y 2/m^3 for the 80s and 90s.

[2]Labor = Y 0.3/day in the 50s and 60s; Y 0.5/day in the 70s and Y 1/day in the 80s and the 90s.

[3]Market price using 0.4 x wheat price + 0.6 x cotton price.

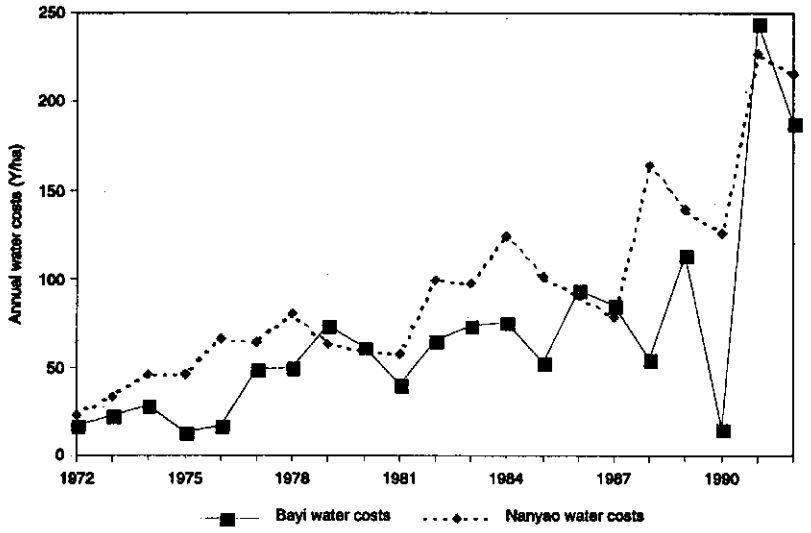
collection rate fell to 5 percent. It rose to 80 percent the following year and has been fairly close to 100 percent since then.

Water rates and, therefore, actual water costs to the farmers have gone up significantly since the mid-1980s when the reforms were implemented. This is based on the principle, *he who benefits must take responsibility for management and make investments.* In both sample districts, irrigation water fees are a combination of a fixed fee based on irrigated area, and a volumetric fee based on water used. For the Nanyao ID the rates are Y 1.5/100 m^3 and Y 112.5/ha, while the Bayi ID presently charges Y 7.19/100 m^3 and Y 15/ha. In addition, in the Bayi ID irrigation from groundwater costs about Y 150/ha. In Nanyao, volumetric charges are only levied at the main canals as they do not have measuring devices at the subbranch level. Therefore, at the Village Irrigation Management Group (VIMG) level, farmers are charged a flat rate of Y 225 per ha for irrigation water.

Figure 7 illustrates the historical trend of surface water fees for the two districts. These data are in constant 1991 Chinese yuan so the significant increases are real, not just reflections of inflation in the Chinese yuan. As can be seen, in Nanyao the rate based on volumetric flow is less than the Y 225 per ha. The additional funds collected are used to pay lower-level irrigation staff and provide incentives to the VIMGs to ensure they collect 100 percent of the water fees. Figure 8 includes the cost of groundwater irrigation for Bayi. It is readily apparent what impact this makes on water costs in the irrigation district. Yet, as the net returns in Bayi are about Y 2,000/ha more than in Nanyao, the farmers can afford the additional costs.

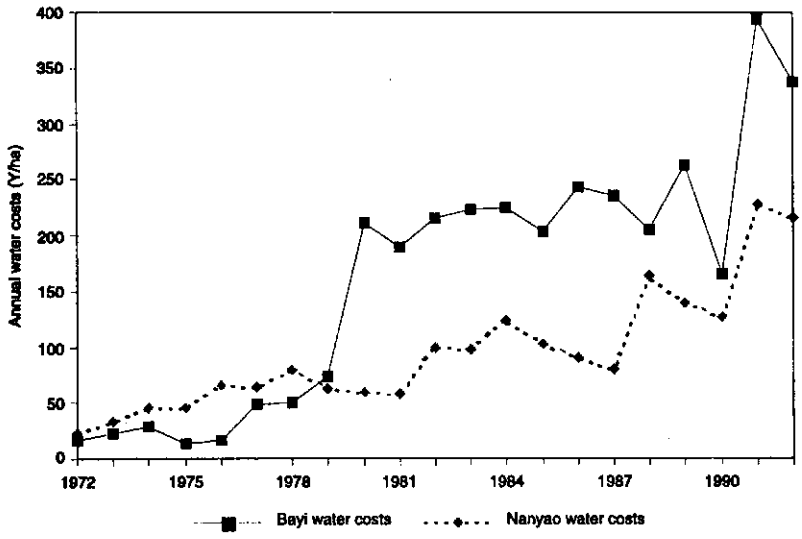
Even though Nanyao is known as a water surplus area and both buys and sells water, the increases in O&M costs as the rural economic reforms and the WPRS have been implemented have forced the actual per ha water costs to increase. As can be seen in figure 9 the steadily increasing water costs have encouraged conservation in water use, thus per ha water use has declined significantly since the early 1980s.

Figure 7. Per ha water costs in the Bayi and Nanyao districts.



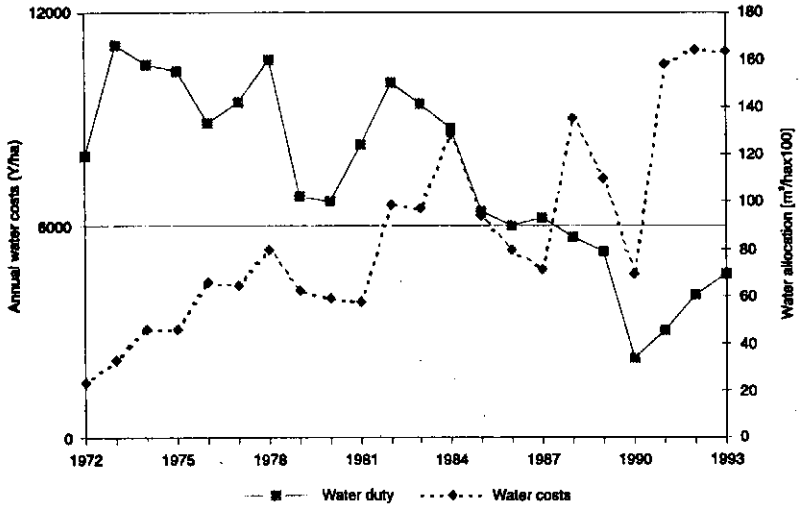
[Converted to 1991 Chinese yuan. Water charges for surface water only.]

Figure 8. Per ha water costs in the Bayi and Nanyao districts.



[Converted to 1991 Chinese yuan. Including costs of groundwater in Bayi district.]

Figure 9. Annual water costs and duty per ha, the Nanyao district, 1972-1993.



[Costs converted to 1991 Chinese yuan]

Expenditures and revenues have both increased since the implementation of the economic reforms. As indicated earlier, one of the mechanisms encouraged to address the need for additional revenue is the development of supplemental market-oriented enterprises. To date, the Nanyao ID has not developed any such enterprises, but the Bayi ID has been extraordinarily successful in this area. At present the Bayi ID has 9 enterprises, of which 8 are making a profit. These include:

* building materials (producing limestone, cement and bricks)
* food and services (two restaurants and a barber shop)
* engineering services (design, feasibility studies, and technical consulting)
* machinery repairs (farm equipment and pumps)
* well installation (well digging and pump installation)
* construction (building and renting apartments and small houses)

Within the district, the ratio of gross income from water fees to gross income from enterprises is 5:3. In terms of net income, the ratio is 2:1. Of the 67 employees in the irrigation district, 30 work in water management while 37 are involved in enterprise management. For diversified enterprise management, targets are established based on anticipated net profit. These are normally negotiated between the irrigation district and the enterprise managers. Up to the level of the target, all profits go to the irrigation district. Profits above the target are retained by the enterprise and are usually distributed as profitsharing among the enterprise employees. In 1992, the irrigation district received Y 103,000 in enterprise profits. This combined with the Y 873,000 in water fees paid by farmers and a small amount of maintenance funds from the county allowed Bayi to cover all of its expenditures, including paying Y 375,000 to purchase water from the Gangnan reservoir. Thus, the Bayi ID has been able to use profits from sideline enterprises to maintain financial stability. In the past, the Nanyao ID has been able to remain financially stable without requiring other income. However, with constantly increasing expenditure levels, the district is actively exploring alternative revenue possibilities.

Hydrologic Performance

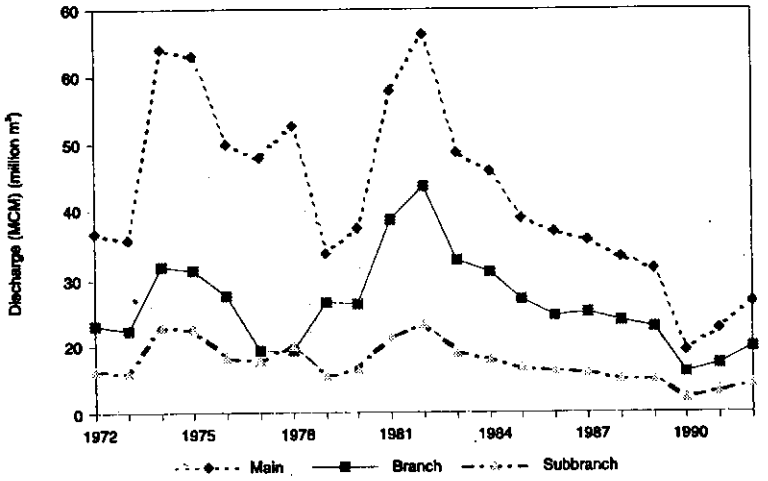
One of the most important hydrologic relationships in irrigation management is that between available water and land. In this context, one of the primary tasks facing irrigation system managers is to match area to be irrigated with the current water supply. Other things being equal, good managers will try to maximize the area served while producing acceptable yields on all of the area. Viewed another way, the manager's task is to make each available unit of gross water supply go as far as possible.

In Nanyao, irrigated area has remained almost constant for the last 20 years, suggesting that this is the maximum service area of the system. Water supply has shown considerable variability over this period (figure 10), and these two facts taken together indicate that water supply is not constraining in Nanyao. Combining area and discharge information results in a set of figures portraying the duty of water supplied, which is the amount of water supplied per unit area irrigated. Figure 11 shows that for the period 1972 to 1988, Nanyao had an overall

supply in excess of 10,000 m^3/ha per year available to it. Following the canal lining program during the 1977–80 period, it can be seen that water deliveries increased sharply before beginning a steady decline from the 1982 peak of almost 25,000 m^3/ha. Because area irrigated held steady during this period, the result is reflected in figure 11 as a steady and dramatic decline in the duty of water supplied in Nanyao. Water use per unit area today is just one-third of the amount supplied in the early 1980s. This is said to be a result of increasing upstream abstractions, as well as the impact of increasing water costs.

In Bayi, which is located in flatter terrain, only a fraction of the potential command is irrigated, and area irrigated has fluctuated considerably from year to year. Figure 12 shows clearly the result of the completion of the Yingang supply channel from the Gangnan reservoir in 1976, as irrigated area increases dramatically in the following two years, peaking at around 6,600 hectares. In subsequent years, area stabilizes at around 4,500 hectares. Figure 13 shows the main canal discharge, which also increased substantially after 1976, but then shows a continuing downward trend from 1979 to the present. Duty figures (figure 14) show more variability than do those for Nanyao, but have also declined somewhat from peak years.

Figure 10. Annual discharge into the Nanyao district main, branch and subbranch levels.



Even though both systems have shown declining duties over their lifetimes as they come to use water more efficiently, duties in Bayi and Nanyao vary widely, though rainfall and cropping patterns are similar. What is also quite striking is that although the main system duty in Nanyao is far greater than that for Bayi, as can be seen in figure 15, the number of surface irrigations for the systems are remarkably similar. The explanation for this can be drawn from figure 16. As can be seen, in Nanyao on average about 23 percent of the discharge at the main canal actually reaches the subbranches while in Bayi on average 68 percent of the discharge at the main canal is available in the subbranches for irrigation. Figures 11 and 14 illustrate this same relationship as the duty at the subbranch level in Nanyao is less than the duty at the subbranch level in Bayi even though the duty at the main canal is much greater for Nanyao. Access to groundwater in Bayi and the high distribution losses in Nanyao result in a situation where water in the main canal is much greater in Nanyao than in Bayi, yet the water actually available for irrigation is more in Bayi than in Nanyao. This can be seen in figure 17 where the water available at the subbranch level is around 4–5,000 m^3/ha while in Nanyao on average the water available for irrigation is less than 3,000 m^3/ha.

Figure 11. Surface irrigation duty in the Nanyao district main, branch and subbranch levels.

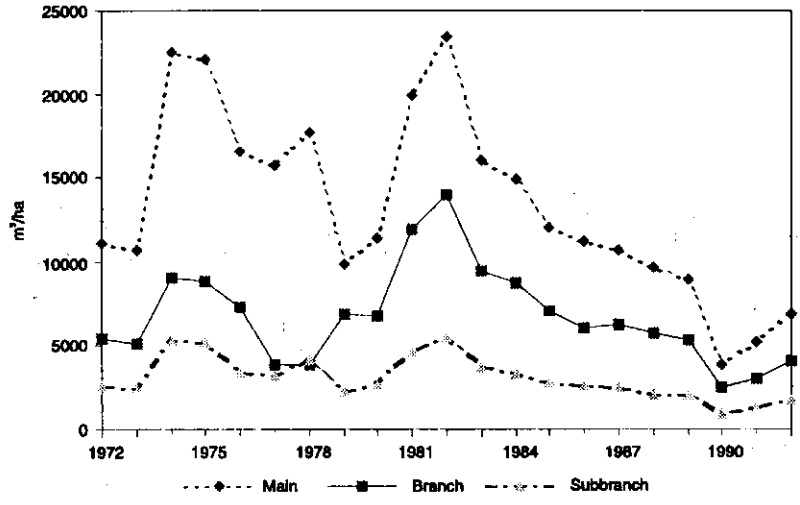


Figure 12. Irrigated area in Bayi and Nanyao districts.

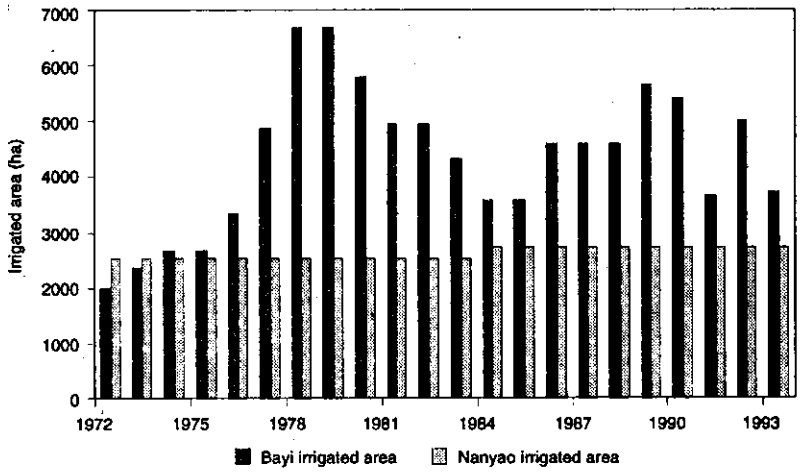


Figure 13. Annual discharge into Bayi district main, branch and subbranch levels.

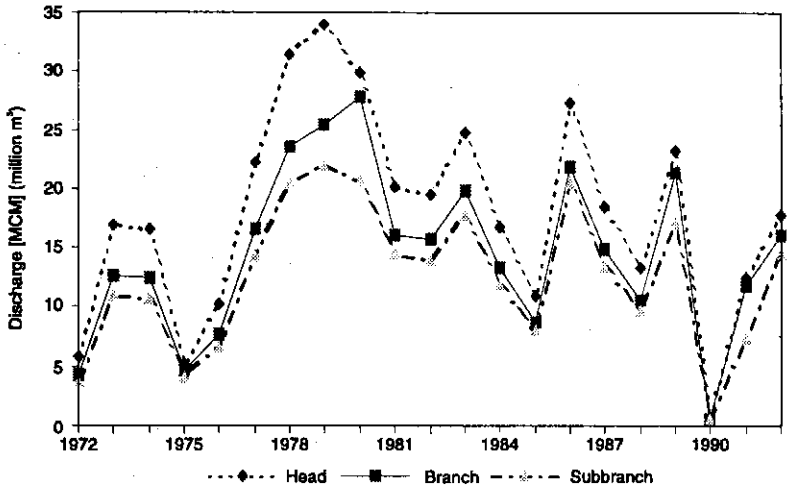


Figure 14. Surface irrigation duty in Bayi District main, branch and subbranch levels.

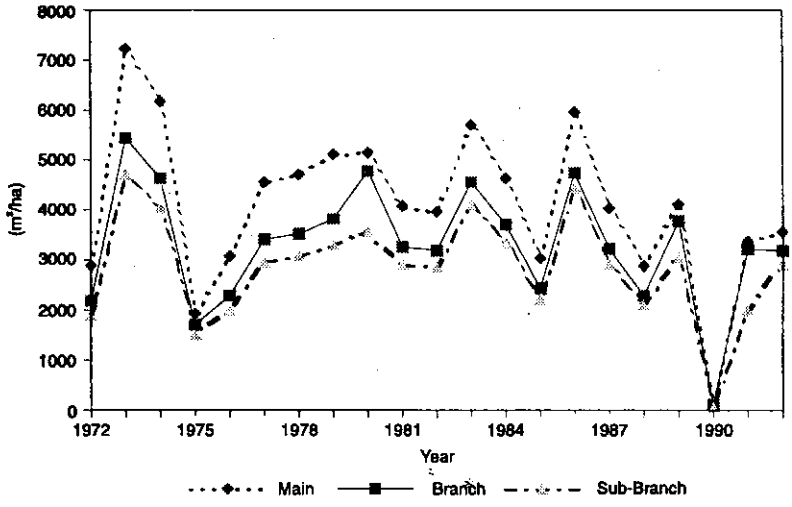


Figure 15. Annual number of surface irrigations: subbranch-level discharge, Bayi and Nanyao.

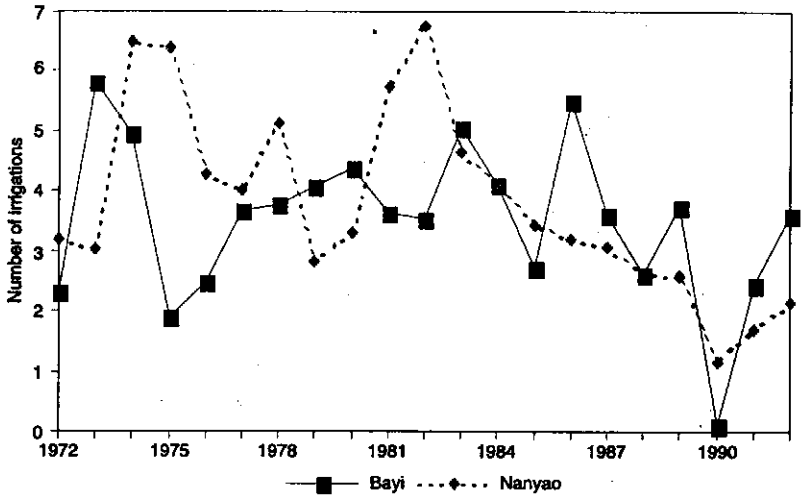
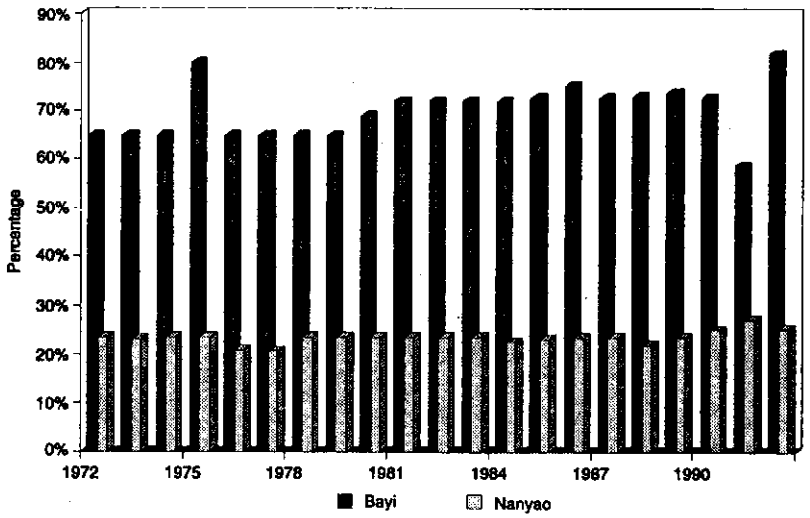


Figure 16. Percentage of discharge reaching subbranches, Bayi and Nanyao.



An interesting comparison is presented in figure 18. This figure shows the annual grain output in Bayi and Nanyao. Since 1984 the growth in per hectare annual grain output in Bayi has significantly exceeded that of Nanyao. However, when surface water and groundwater supplies are combined, the output per unit water in both systems is remarkably similar. As can be seen in figure 19, for 1992, Bayi produced about 1.5 kg of grain per cubic meter of water while Nanyao produced about 1.3 kg of grain per cubic meter of water.

Figure 17. Surface + groundwater irrigation: subbranch-level for Bayi and Nanyao.

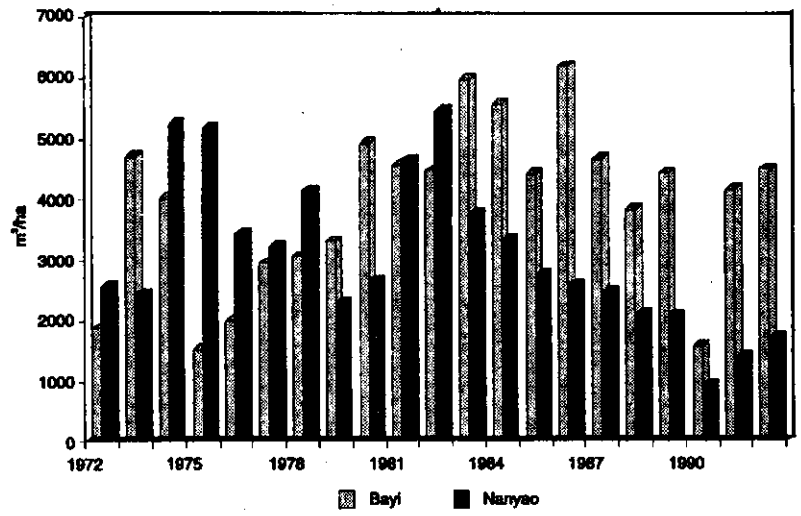
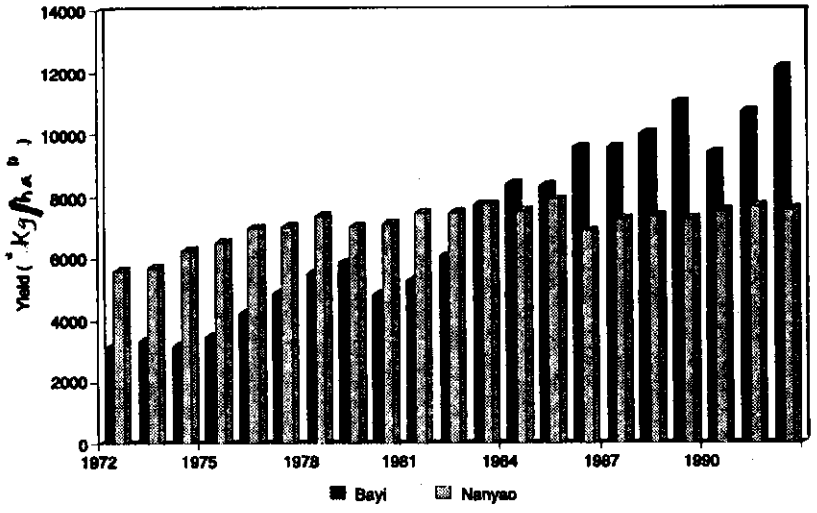


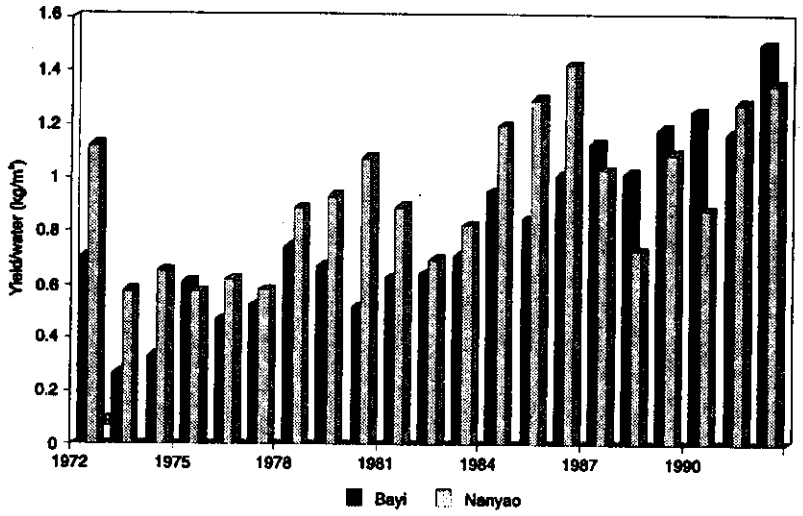
Figure 18. Annual wheat and maize yields for two seasons, the Bayi and Nanyao districts.



Although the levels of other input use must be considered in making a comparison of overall production, it can be seen that Bayi is producing almost 12 tons of grain/hectare per year while the annual output in Nanyao is only about 8.5 tons/hectare. It is unlikely if Nanyao can increase its grain output without additional irrigation water supplies at the field level. Therefore, the challenge facing Nanyao is to reduce the internal distribution losses. This will

require the development of more effective irrigation institutions as well as additional funding for O&M. This, in turn, will require additional funding. Unless the farmers want to pay a significantly higher water tariff, these funds will need to come from sideline enterprises. Thus, it is probably necessary for Nanyao to follow the path taken by Bayi and concentrate on the expansion of sideline enterprises.

Figure 19. Annual grain yield per unit of water, the Bayi and Nanyao districts.



Conclusion

National level policy reforms promoting local financial and managerial self-reliance are being adopted, although in a somewhat variable manner, at the level of the Bayi and Nanyao irrigation districts. The Nanyao ID is a smaller system in a less-productive area, relative to Bayi. The Nanyao ID has been slower in introducing the volumetric water fees and creating village irrigation management groups. It has still not yet developed sideline enterprises. The Bayi ID started its first sideline enterprises in 1982. The Nanyao ID has a relatively abundant, river-based supply of water and has often been in water surplus. The Bayi ID on the other hand is in a water-deficit situation and must purchase large amounts of water each year. This dependence on water purchasing, together with the apparent greater ability of farmers to pay (due to higher productivity), may be the driving influences for development of sideline enterprises in Bayi and more concern about improving water use efficiency. Both Bayi and Nanyao IDs have implemented numerous rules and practices which create various financial incentives and accountability mechanisms aimed at enhancing water use efficiency and the transparency of financial accounting and water delivery.

It is apparent that the reforms are producing more viable local management of irrigation. They provide reasonably clear delineation of responsibilities, water rights and linkage between rights to water and paying for it. Where sideline enterprises have developed they are helping

to stem the flow of skilled staff out of the irrigation sector by improving facilities and standards of living for families of irrigation district staff and water resources officials.

Farmers must pay the water fee in advance in order to receive water. If they do not in fact receive water their fee is refunded. Within limits, farmers may pay a higher level of fee to receive more water. In the Bayi ID, this appears to be a powerful mechanism which achieves an impressive level of performance of water and financial management. The village acts as a mediating guarantor to see that these rules apply to the individual farmer. This appears to be resulting in gradual enhancement of self-reliance of irrigation districts. However, as indicated in the Nanyao ID, it is apparent that some irrigation districts in less-favorably endowed areas may be in need of external technical and financial support services to implement volumetric water delivery, fee assessment and diversified sideline enterprises.

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