Performance Impacts of Transfer

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Water control is the lifeblood of agriculture--Mao Zedong

1. Introduction

AS ONE OF the oldest societies in the world, irrigation in China has a very long history 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 size irrigation districts (between 667-20,000 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 tubewells 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, a major push was made initially to rehabilitate existing irrigation systems in order to reestablish the system of food production that had been disturbed during the long civil war. From the 1950s to 1970s a number of 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, tubewell technology was 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 the 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 and irrigation district officials to achieve financial independence from the Central and Provincial Governments. Measures advocated include (Turner and Nickum 1994):

1. increasing irrigation fees and collection rates;

2. stimulating investment from private sources;

3. creating joint stock cooperatives;

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4. borrowing from domestic and international banks;

5. soliciting aid from international organizations; and

6. establishing and managing sideline economic enterprises to earn additional income.

In order to study the irrigation performance impacts of the recent economic and policy reforms, the International Irrigation Management Institute (IIMI) and the Shijiazhuang Institute of Agricultural Modernization (SIAM) have been carrying out a collaborative research project in the Hebei Province. The overall objectives of the study are: (1) to identify and document management policy changes before and after the economic reforms; (2) to document the process by which transfer of management responsibility has occurred; and (3) to assess the impacts of these changes on systems performance and financial sustainablility. The purpose of this paper is to present some preliminary findings related to the impacts of these changes on performance.

2. Sample Irrigation Districts[3]

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 Country, both of which are near 38^0 N latitude. The location of these counties within Hebei Province can be seen in Figure 1.

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. Average annual rainfall is 544 mm, with the majority of this 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. Primary canals are 16 km long and the secondary canals extend 104.4 km. 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.

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 Gangnan Reservoir. This transbasin conveyance project ensures irrigation water for Bayi ID. Water purchased annually is 20-30 million m^3.

In addition to surface water, the groundwater table is about 17 m below the surface. As a result there are 1,074 tubewells within the command area. 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. The pumping rate is 120 million m^3 while the annual recharge is 100 million m^3. In order to address this problem, since 1989 the district has received about 20 million m^3 each year from the Yehe River to attempt to stabilize groundwater levels within the county. In 1989, the district paid yuan 0.7 100 m^3 and in 1991, 1992, and 1993 they paid yuan 1.1 per 100 m^3 for this water.[4]

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 income in Bayi ID was 670 yuan in 1991, while the average in Shijiazhuang Prefecture was 650 yuan. The literacy rate within the district is estimated at 80 percent.

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[3]This material is primarily taken from Chapter 2 Physical and Agricultural Context of Nanyao and Bayi Irrigation Districts, of the draft final report for the collaborative study between SIAM and IIMI, **Changing Patterns of Irrigation Management in North China: Case Studies from Hebei Province.**

[4]Exchange rates for the Chinese yuan for the last six years have been one US dollar equals: 1989, 4.72 yuan; 1990, 5.22 yuan; 1991, 5.34 yuan; 1992, 5.78 yuan; 1993, 8.8 yuan; and 1994, 8.6 yuan.

Nanyao ID was designed in 1957 and in 1958 construction was started. 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 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 Bayi ID. Average annual rainfall is 535 mm, with the majority 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.

Designed 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 sub-branch 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 the total water discharge varies from 10.4 million 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.

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

3. Agricultural Production

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 main two 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 Nanyao ID. Table 1 contains the detailed area of the different crops as well as the percentages of the total.

As the climate in the area is hot and wet in the summer and dry and cold in the winter, rainfall during 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, the 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. In order to ensure that maize has sufficient moisture, farmers often relay plant the maize in the wheat and then germinate the maize seeds using moisture from the last irrigation on the wheat. In this case, the last irrigation for wheat has a dual purpose. However, during dry years maize will often require one or two irrigations to obtain high yields (note: Tables 2 and 3 were developed by using the UNFAO CROPWAT program, as part of the collaborative SIAM-IIMI case studies).

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 in 1992 for Bayi ID and from 5,250 kg in 1972 to 8.500 kg in 1992 in Nanyao ID. At present, the net income for the two seasons of wheat and maize is 4,200 yuan/ha for Bayi ID and 3,300 yuan/ha for Nanyao ID.

4. Irrigation Management Changes due to Rural Reforms

Prior to the economic reforms, irrigation management was bureaucratic. Management was coordinated at the county level by the Water Conservancy Bureau of the Ministry of Water Resources. Below the county level, management was by a small number of professional irrigation technicians assisted by labor allocated by the commune. Under this system, the emphasis in water resources was not on efficient or economical water use, but rather on expanding available irrigation water supplies through capital construction. Between 1952 and 1978, about two-thirds of State spending on water was for capital construction and only one-third for operating expenses. Much of the capital construction was carried out using farmers drafted to work during the winter agricultural slack season (Gitomer 1985).

People's Communes were the basic collective institution in the rural areas. Below the commune were production brigades and below these were production teams. During the initial stage of the rural reforms, from 1979 to 1982, two sets of policies were important in the countryside:

* The first, which is really a package of several reforms, was the *agricultural production responsibility system.* This package included distribution of communal production land and decentralization of production decision making from the production team to families, as well as a general 50 percent increase in the grain procurement price.

* The second was a general retrenchment of investment. Government investment in the countryside, particularly in capital construction, dropped dramatically. It halved between 1979 and 1981.

Very quickly, it became obvious that there was a basic conflict between the incentives of family farms and the communes. With the improvement of markets for agricultural inputs and outputs, the communes began to obstruct input and output flows rather than facilitate them. This led to a second stage of reforms; that of dismantling the communes, which was effectively accomplished by the end of 1983 (Gitomer 1994).

The reforms of the 1980s initially led to confusion within the irrigation sector. Farmers wished to work their fields rather than volunteer labor to maintain irrigation infrastructure. There was confusion within the villages and the agencies about roles and responsibilities. As government personnel no longer had the authority to force farmers to volunteer their labor for irrigation related work, irrigation systems fell into disrepair. In addition, theft and stealing of water occurred as there was no effective enforcement system. The strict budgetary constraints on capital investment made it impossible to use capital to address the problem, therefore, management improvement was seen as the only other alternative. Farmers were interested in increased output, which required higher quality irrigation service. This, in turn, meant more management input into the operation and maintenance of the irrigation districts.

In the large and medium government owned systems, management improvement took the form of the *work post responsibility system (WPRS),* which was seen as a counterpart to the agricultural production responsibility system. For collective-owned systems, a revolutionary reform system was implemented, the *economic contract responsibility system (ECRS).* Although originally limited to small irrigation systems, in many cases, elements of the ECRS have also been implemented within larger government irrigation systems and, in fact, it is expected that eventually ECRS will become the dominant system.

The WPRS is an attempt to introduce positive incentives into bureaucratic organizations. It is applied to organizations that have some responsibility to the government (central, provincial or county), but which are positioned at the interface between administrative and economic management (such as an irrigation bureaucracy that is between the roles and regulations of the government related to control over water resources and farmers involved in private economic enterprise). Under the WPRS, organizations retain a traditional bureaucratic structure and workers receive a fixed wage, though with the prospect of performance bonuses. Several forms of the WPRS are in operation, but they all are based on the principle of linking a portion of the remuneration with a measure of project output. WPRS, as well as ECRS for operation of lift irrigation and wells, is in place in both Bayi and Nanyao IDs.

A second important element of the reform program was institutional reform. Here attention was focused on three areas. The first related to irrigation fee charging systems and the second to more effective use of irrigation system resources and capital equipment, while the third directly addressed the enhanced role of the village-level farmer groups in irrigation management. In the past, irrigation fees had been paid by the commune and placed into the general government revenue accounts, thus providing little incentive for collection and inadequate funding for O&M. Under the reforms, irrigation fees collected are now placed in irrigation districts' accounts and laws relating to water fees now have provisions that forbid diversion of funds collected as irrigation service fees for other uses.

In the second area, comprehensive management has been introduced to provide fuller use of systems resources and to supplement irrigation fee revenue. This approach emphasizes supplemental market-oriented enterprise development. It was introduced at the same time as the WPRS in 1985 and received Central Government sanction. This system encouraged irrigation units to shift management style from that of a service provision unit to that of an enterprise unit. This aspect was driven by the need to compensate for the loss of subsidies from the communes and the Ministry of Water Resources. Loss of subsidies, in turn, forced irrigation districts to develop into multiproduct firms, so that sideline enterprises could subsidize[5] irrigation services (Gitomer 1985).[6]

[5]These irrigation districts are allowed to use their income from other activities to maintain a lower cost for a necessary commodity (irrigation water). In return for providing this service at an artificially low price, irrigation districts are allowed entry into markets for other goods or services where they can make positive profits (Gitomer 1994).

The third area was a significant change in the role of the Village Irrigation Management Groups. A detailed description of this process for the two sample irrigation districts is presented in the paper by Vermillion, Wang, Zhang and Mao (1994) and will not be repeated here.

5. Performance Impacts of the Rural 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.

5.1 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 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 4. Recently, however, farmers have shifted to growing more cash crops such as watermelon, vegetables and fruit trees in order to maximize their income.

Prior to development of 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 4, irrigated grain production increased significantly. As a result, the farmers sold 1/6th of their winter wheat and 1/10th of their maize production in Nanyao ID and 1/3rd of their winter wheat and 1/10th of their maize production in Bayi ID 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 grain to sell on the local market.

Currently in 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. For maize about 10 percent of the total production is sold to the government, about 65 percent is sold on the free market and the remainder is used for animal feed. In 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. For maize, about 0.75 T/ha 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 4 compares the yields, input levels and net incomes for 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, resulted in impressive improvements in net income in the two districts. Bayi ID, due to its higher yields, has been able to sustain its growth in net income, while Nanyao ID has seen a drop off of net income as annual per ha production of wheat and maize has stagnated during the 1990s.

5.2 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 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 levels as well as collection rates. These approaches have been successful as water fee collection increased from 436 million yuan in 1984 to 1,830 hundred million yuan in 1991 and in 1992 they doubled to 3,570 million yuan (all in current yuan). In addition to increased fee levels, collection rates

[6]Xuren Chen and Renbao Ji (1994) have a good discussion of this phenomenon in their overview paper.

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 operation and maintenance (O&M) expenses also served as catalysts to improved fee collection in many areas.

The situation has been the same in Nanayao and Bayi irrigation districts. Fee levels and collection rates have increased since the institution of the rural reforms. For example, in 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 wasn't until 1993 that the collection rate rose above 90 percent (95 percent). The case of 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 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 Nanyao ID the rates are 1.5 yuan/100 m^3 and 112.5 yuan/ha, while Bayi ID presently charges 7.19 yuan/100 m^3 and 15 yuan/ha. In Nanyao, volumetric charges are only charged at the main canals as they do not have measuring devices at the sub-branch level. Therefore, at the Village Irrigation Management Group (VIMG) level farmers are charged a flat rate of yuan 225 per ha for irrigation water.

Figure 5 illustrates the historical trend of 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 225 yuan 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.

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 6 the steadily increasing water costs have encouraged conservation in water use, thus per ha water use has declined significantly since the early 1980s.

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 a supplemental market-oriented enterprise. To date, Nanyao ID has not developed any such enterprise, but Bayi ID has been extraordinarily successful in this area. At present Bayi ID has 9 enterprises, of which 8 are making a profit. These include:

1. Building materials (producing limestone, cement and bricks),
2. Food and services (two restaurants and a barber shop),
3. Engineering services (design, feasibility studies, and technical consulting),
4. Machinery repairs (farm equipment and pumps),
5. Well installation (well digging and pump installation), and
6. 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 profit-sharing among the enterprise employees. In 1992, the irrigation district received 103,000 yuan in enterprise profits. This, combined with the 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 375,000 yuan to purchase water from the Gangnan Reservoir. Thus, Bayi ID has been able to use profits from sideline enterprises to maintain financial stability. In the past, 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.

5.3 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 (Figure 7). Water supply has shown considerable variability over this period (Figure 8), 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 9 shows that for most of the past 20 years, Nanyao has had a supply of about 1,000 millimeters 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 60 MCM (Figure 8). Because area irrigated held steady during this period, the result is reflected in Figure 8 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 principally a result of increasing upstream abstractions.

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 7). Figure 7 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 8 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 9) show more variability than do those for Nanyao, but have declined somewhat from peak years.

Even though both systems have shown declining duties over their lifetimes as they come to use water more efficiently, duties in Nanyao are still about double those in Bayi, even though rainfall and cropping patterns are similar. Scarcity is obviously unevenly distributed and though both systems buy and sell water, markets in water are clearly not yet completely efficient.

Another interesting comparison is that illustrated in Figures 10. This figure compares the number of irrigations per year for the two systems. This provides an interesting comparison as Nanyao has clearly much more water than Bayi, yet output per irrigation in water-rich Nanyao is only about one-third that in Bayi as Bayi produces about 3 kg/m^3 of water, while Nanyao manages only around 1 kg/m^3.

Although the levels of other input use must be considered in making a valid comparison of this type, these results are suggestive of greater production efficiency in Bayi. It should be remembered that Bayi is producing almost 12 tons of grain/hectare with this water, while the annual output in Nanyao is only about 8.5 tons/hectare. A challenge which must be faced in this region is the development of institutions and pricing and marketing systems which will move water from less efficient systems to more efficient ones.

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Table 1. Crop Patterns in Nanyao and Bayi I.Ds (Average in 1990s)

Crop	Bayi I.D		Nanyao I.D	
	Area (ha)	Percentage (%)	Area (ha)	Percentage (%)
Winter - Wheat Maize	7738.9	74.3	2473.3	74.2
Cotton	1385.3	13.3	333.3	10.0
Vegetables	364.6	3.5	93.3	2.8
Rice	-	-	66.7	2.0
Water Melon	250.0	2.4	36.7	1.1
Fruit Orchard	177.1	1.7	10	0.3
Sweet Potato	166.2	1.5	180.0	5.4
Spiked Millet	93.7	0.9	50.0	1.5
Drug Plants	-	-	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	0.3
TOTAL	**10415.8**	**100**	**3333.3**	**100**

Table 2. Patterns of Water Requirements by Winter Wheat

	Developing Stage	Before Over-wintering	Over Wintering	Turning Green to Jointing	Jointing to Heading	Heading to Maturing	Total
	Duration	1/10-30/11 61 days	1/12-28/2 90 days	1/3-31/3 31 days	1/4-30/4 30 days	1/5-10/6 41 days	263 days
Bayi I.D	ETp[4]mm	55.4	44.1	55.2	118.8	213.8	484.9
	Average Rainfall*** (mm)	47.0	13.1	10.2	20.5	56.6	147.4
	Difference	8.4	31.0	45.0	96.1	157.2	337.7
Nanyao I.D	ETp[4]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	17.4	30.6	45.7	93.9	166.4	351.4

Table 3. Patterns of Water Requirements by Maize

	Developing Stage	Early Growing Period	Jointing Period	Heading Period	Milky Period	Total
	Duration	10/6-30/6 20 days	1/7-30/7 30 days	1/8-20/8 20 days	21/8-20/9 31 days	102 days
Bayi I.D	ETp[4]mm	44	118.7	85.6	116.6	384.9
	38.8age Rainfall** (mm)	38.82	142.2	110.1	87.89	378.9
	Difference	5.2	-23.5	-24.5	28.8	-14.0
Nanyao I.D	ETp[4]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	8.5	-28.4	-18.0	27.5	-10.4

Table 4 Inputs and Outputs from Farming Bayi and Nanyao IDs

Item	Bayi ID					Nanyao ID				
	1950s	1960s	1970s	1980s	1990s	1950s	1960s	1970s	1980s	1990s
Chem. Fert (yuan/ha)		8	187.5	740	1535		8	187.5	645	1260
Pesticide (yuan/ha)			7.5	105	135			7.5	150	150
Manure/1 (yuan/ha)	30	30	45	55	55	30	30	45	75	75
Seed (yuan/ha)	150	180	200	210	390	150	180	200	210	390
Labor/2 (yuan/ha)	270	270	300	310	270	270	270	300	350	380
Machinery (yuan/ha)			10	157.5	322.5			10	150	202.5
Water Fee (yuan/ha)		6	8	50	240				52.5	225
Total Input (yuan/ha)	450	494	758	1628	2948	450	488	750	1633	2683
Avg 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 (yuan/ha)	0.66	0.87	0.67	0.58	0.69	0.66	0.87	0.67	0.58	0.69
Total Output (yuan/ha)	693	1392	2412	5104	7590	594	1218	2479	4408	5244
Net Income (yuan/ha)	243	898	1654	3477	4643	144	730	1729	2776	2562

/1 manure price = 1 yuan/m3 for 50s, 60s amd 70s, 2 yuan/m3 for 80s and 90s
/2 market price using 0.4 x wheat price + 0.6 x cotton price
/3 labor = 0.3 yuan/day in 50s and 60s, 0.5 yuan/day in 70s and 1 yuan/day in 80s and 90s.

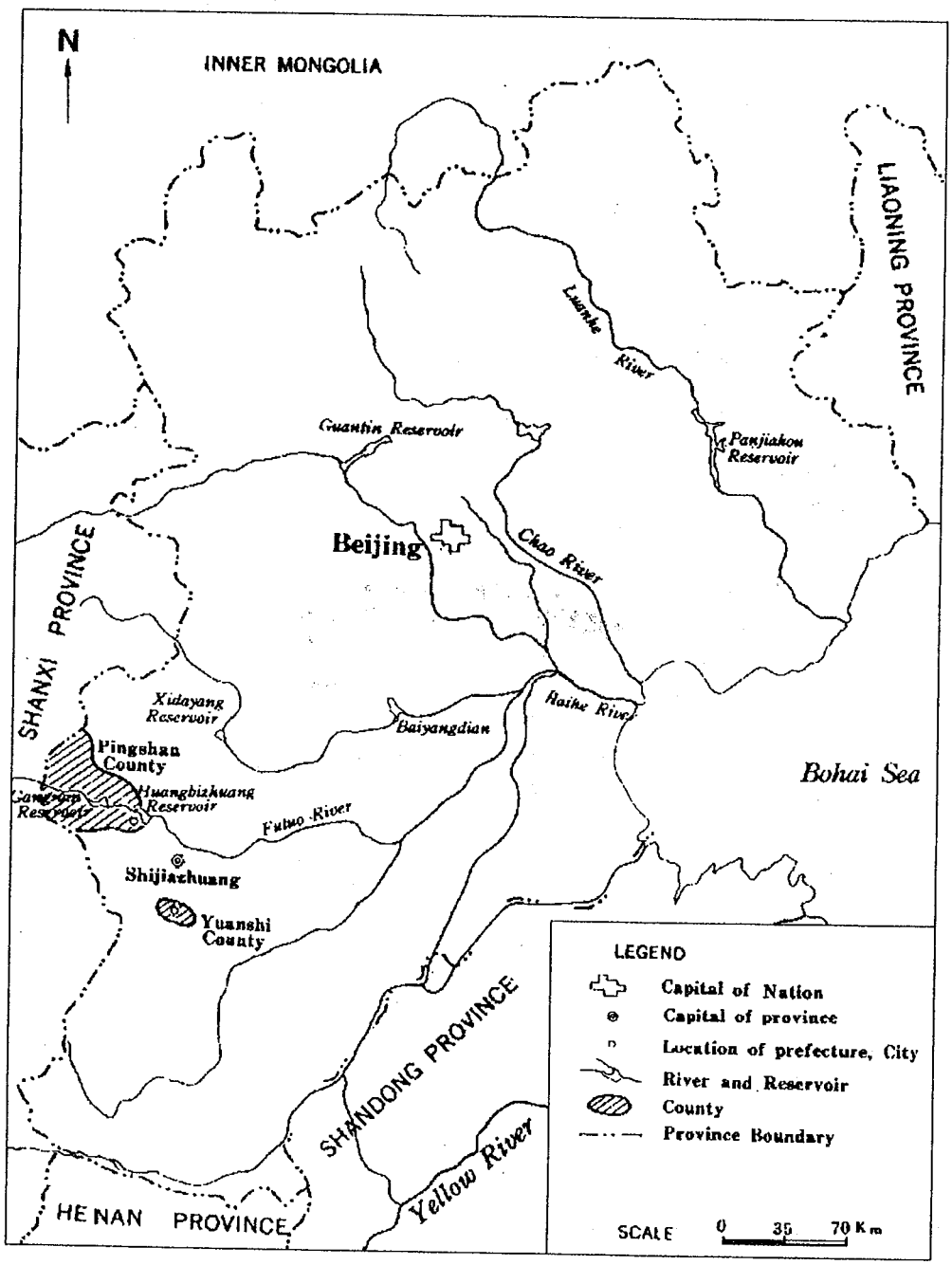


Figure 1 Hebei Province Showing Location of Pingshan and Yuanshi Counties

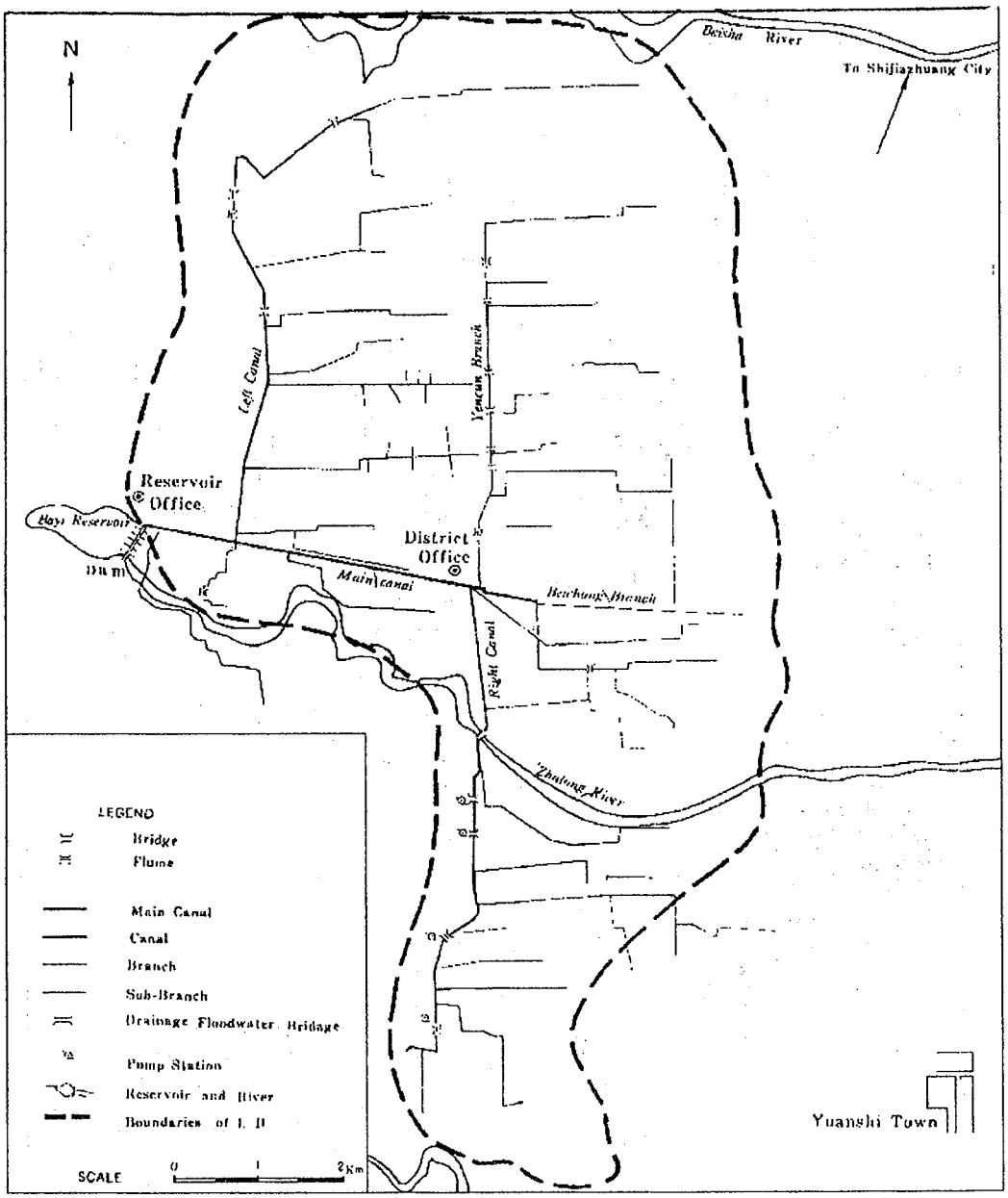


Figure 2 Canal Schematic Layout for Bayi Irrigation District

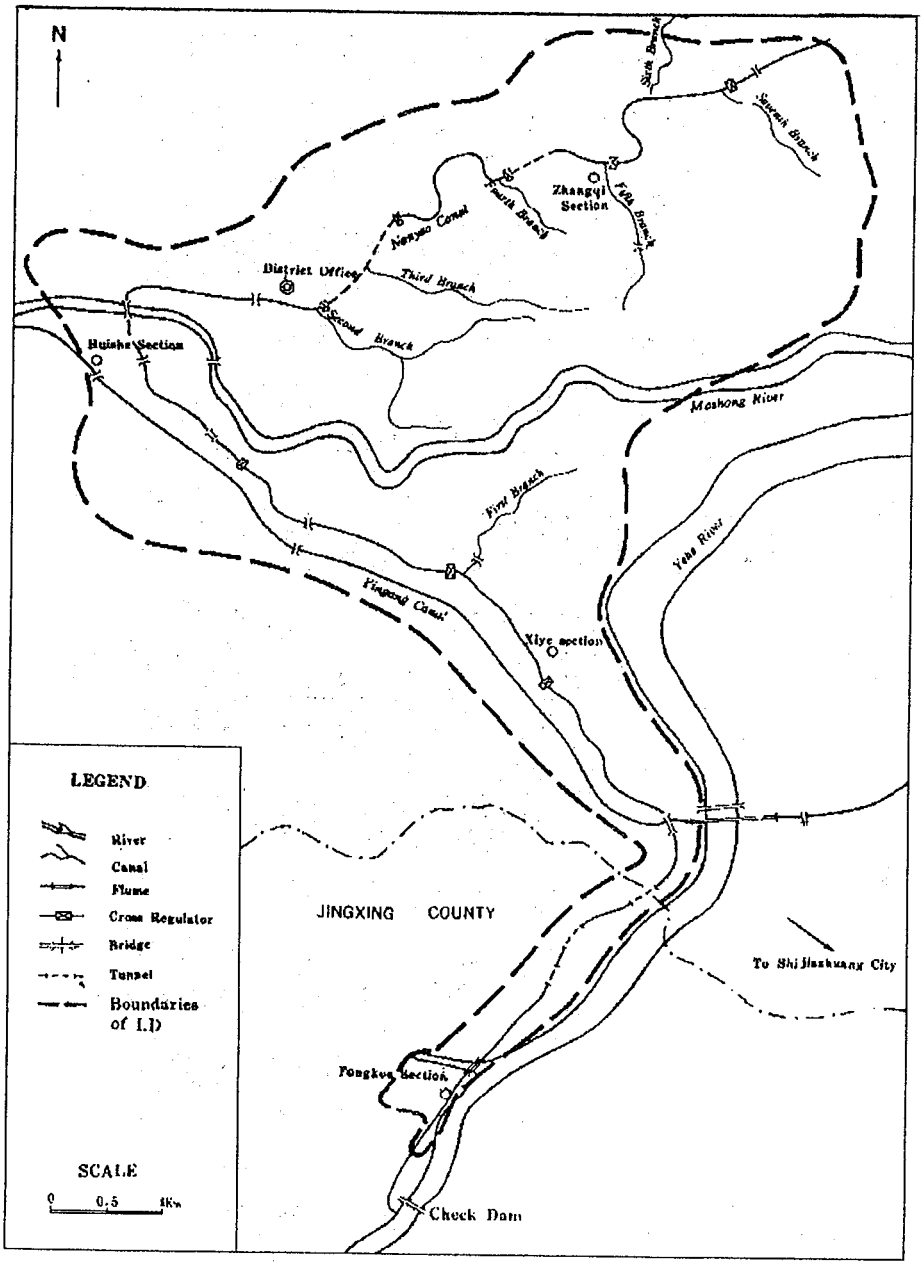
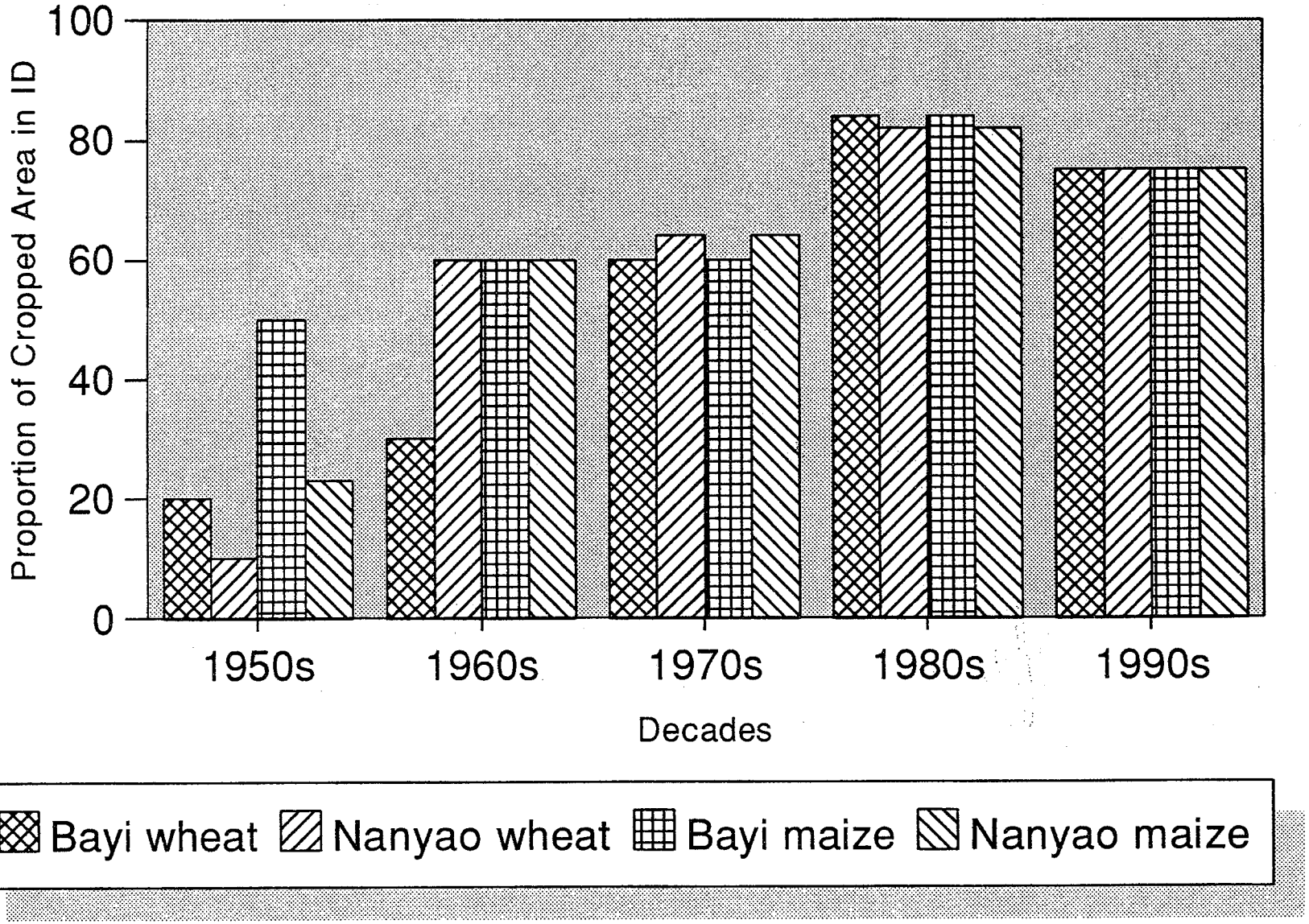


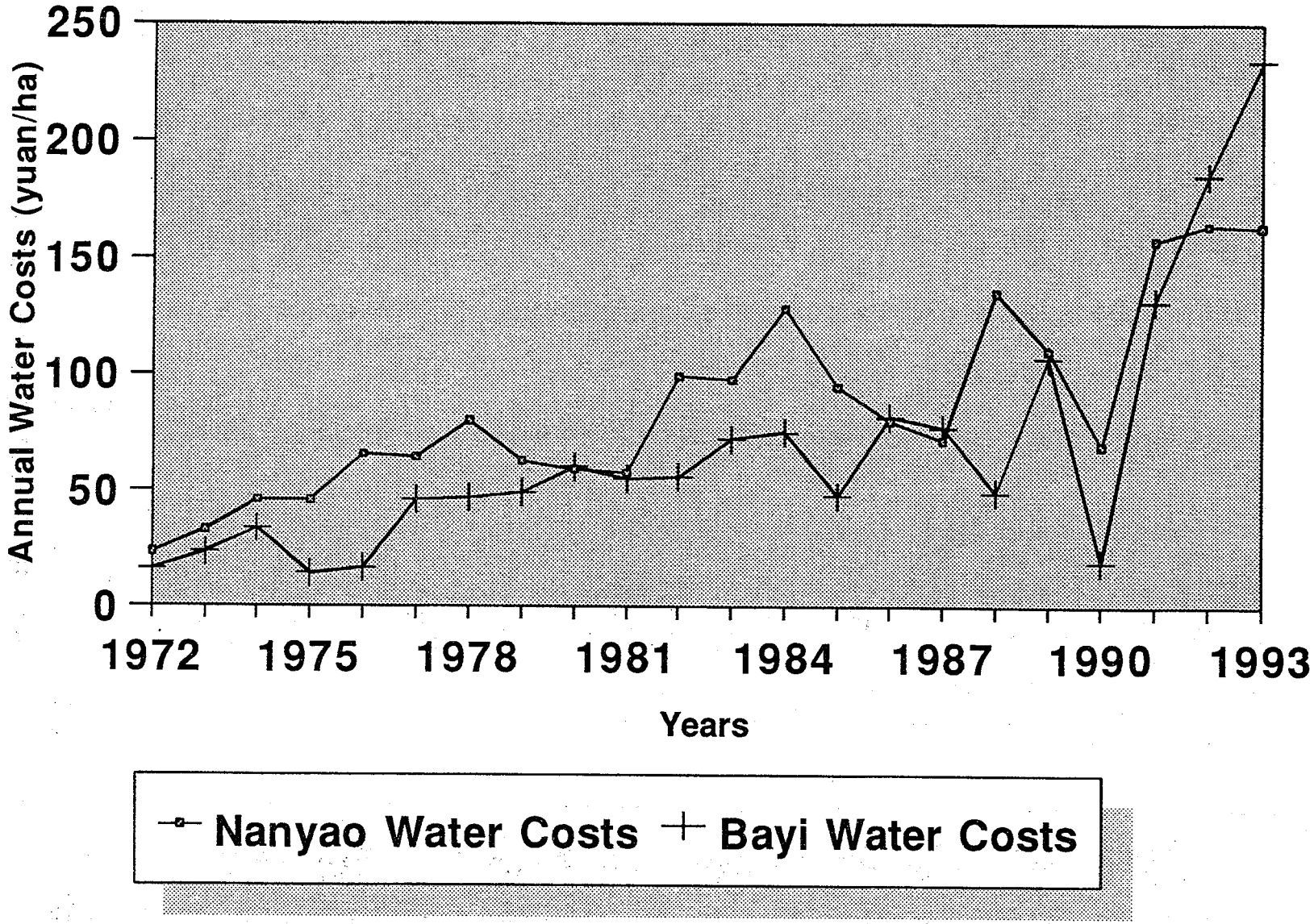
Figure 3 Schematic Canal Layout for Nanyao ID

Figure 4 Proportion of Land in Irrigated Grain Crops Bayi and Nanyao IDS -- By Decades 50s-90s



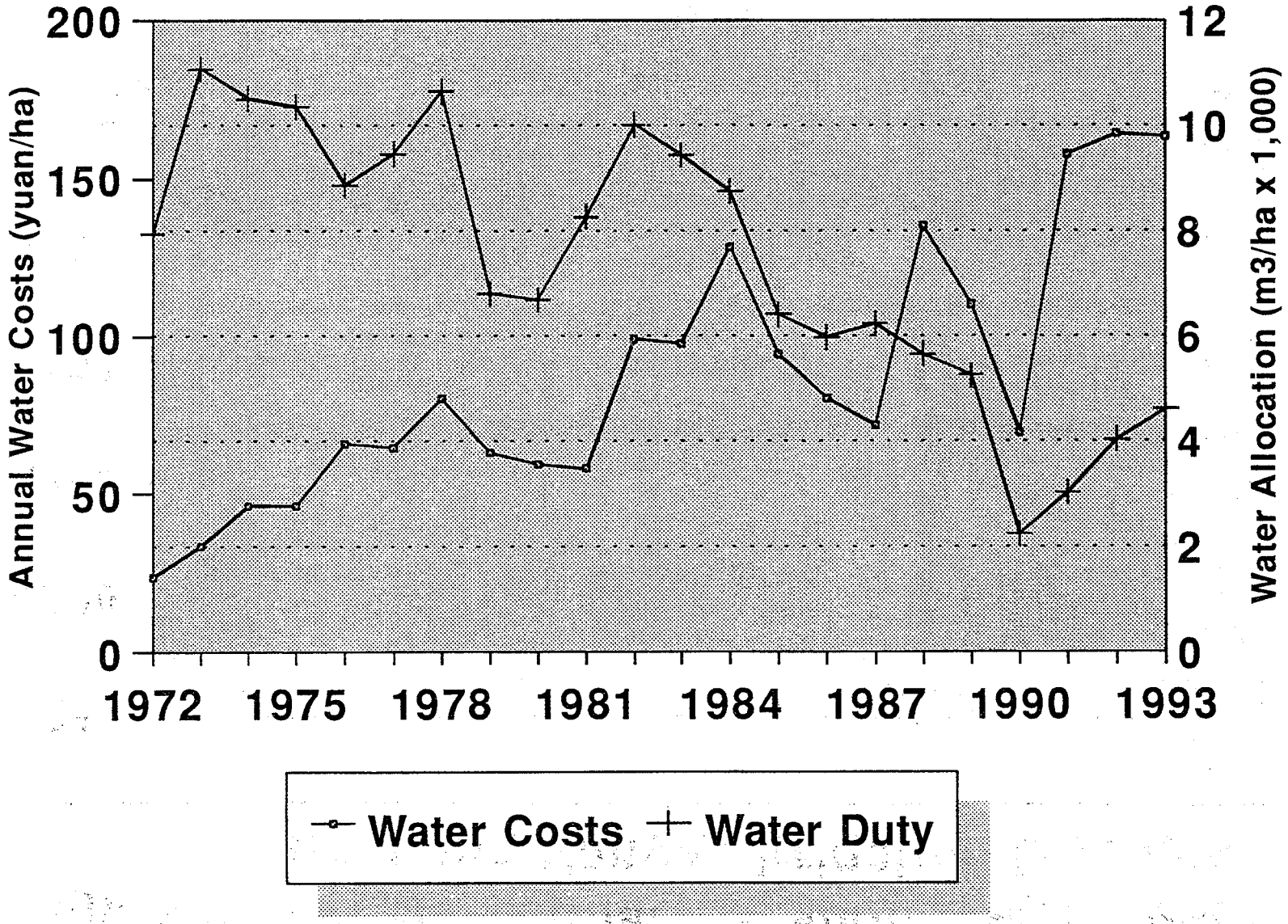
data from IIMI-SIAM collborative study, 1993-94

Figure 5 Per Ha Annual Irrigation Water Costs Bayi and Nanyao Irrigation Districts



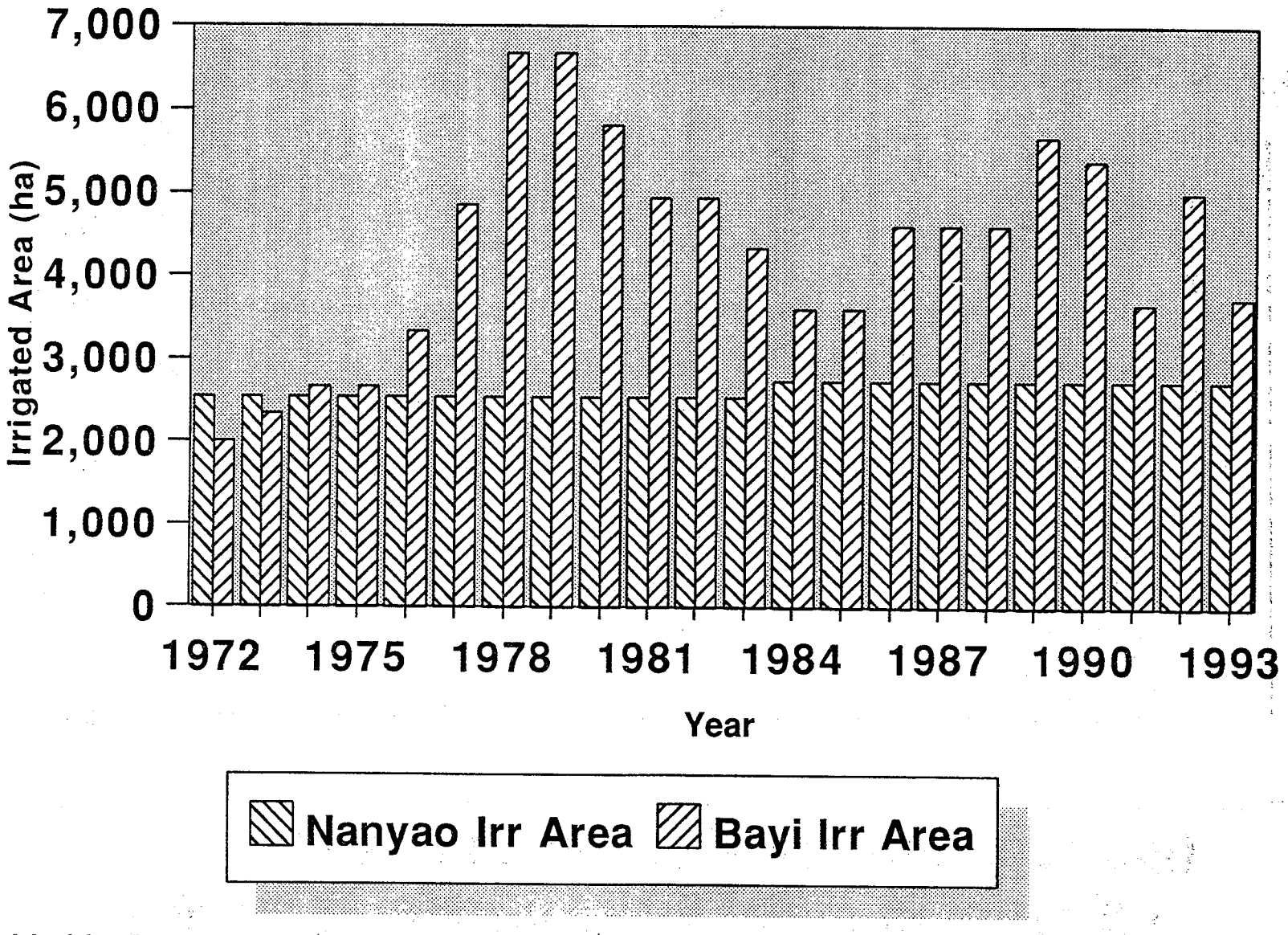
Converted to 1991 Chinese Yuan

Figure 6 Compare Annual Water Costs and Duty Per Ha Values for Nanyao ID 1972-93



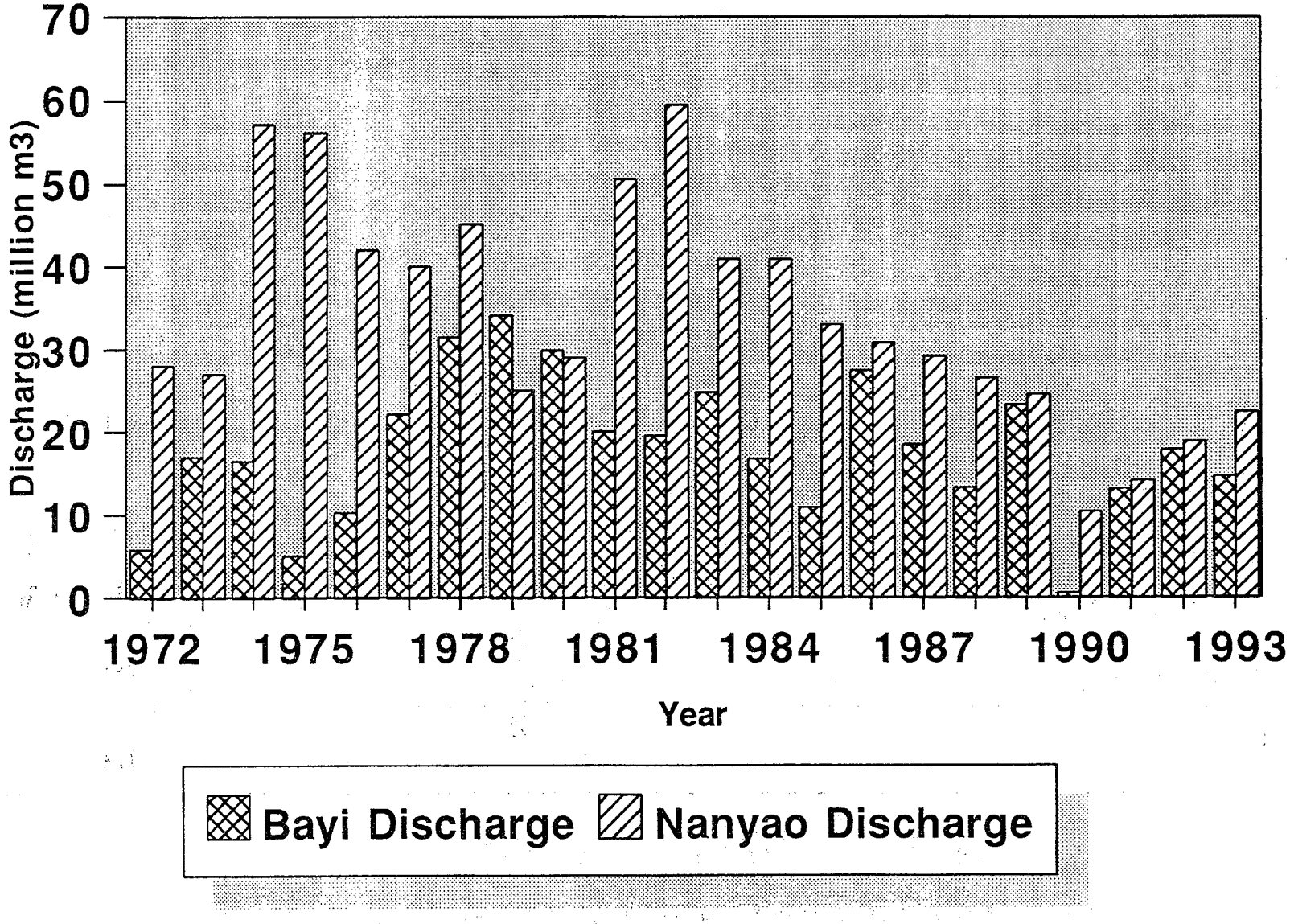
Costs converted to 1991 Chinese yuan

Figure 7 Annual Irrigated Area (ha) In Bayi and Nanyao IDs



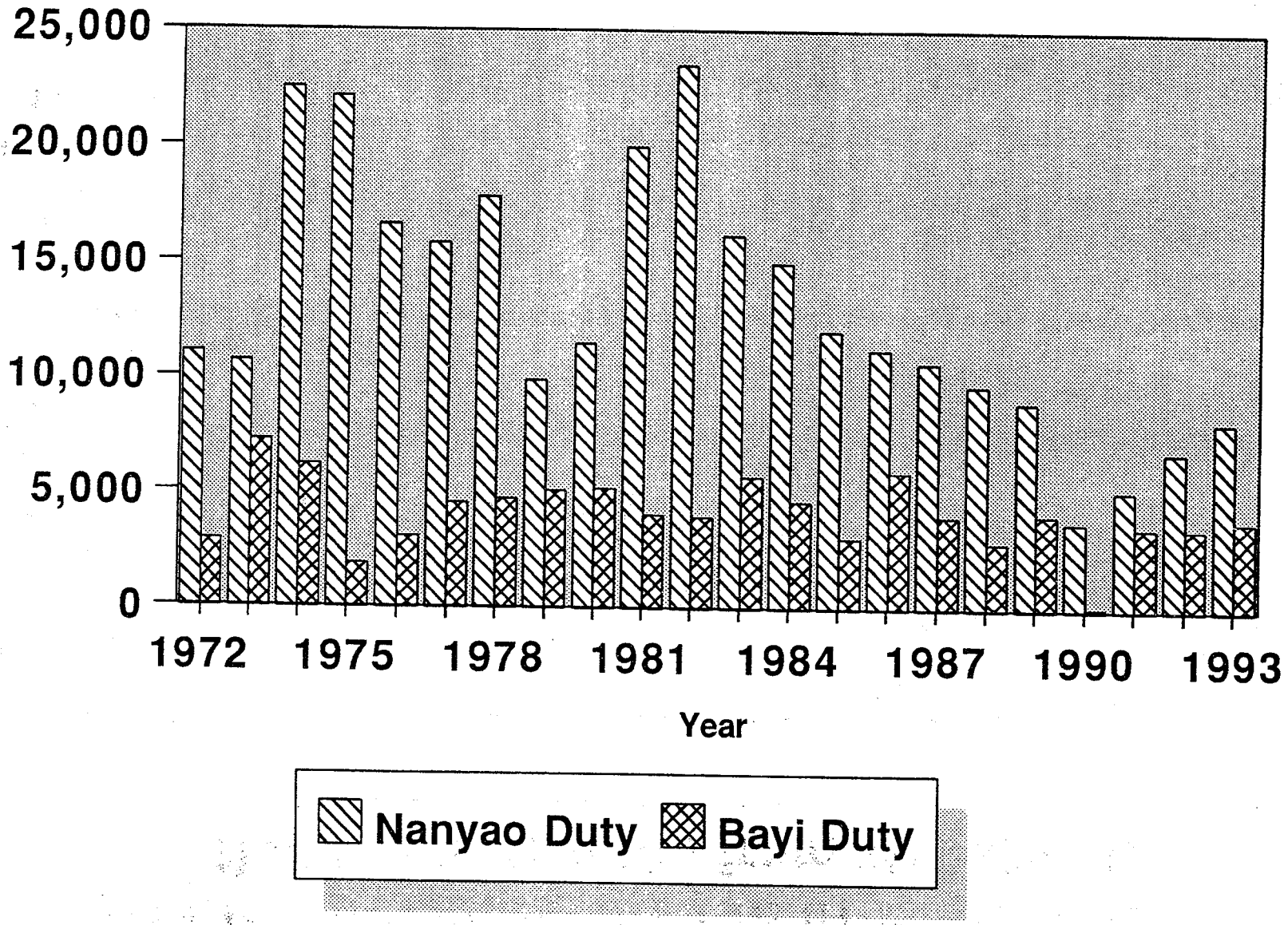
data provided by Bayi and Nanyao IDs

Figure 8 Annual Main Canal Discharge Nanyao and Bayi IDs (million m3)



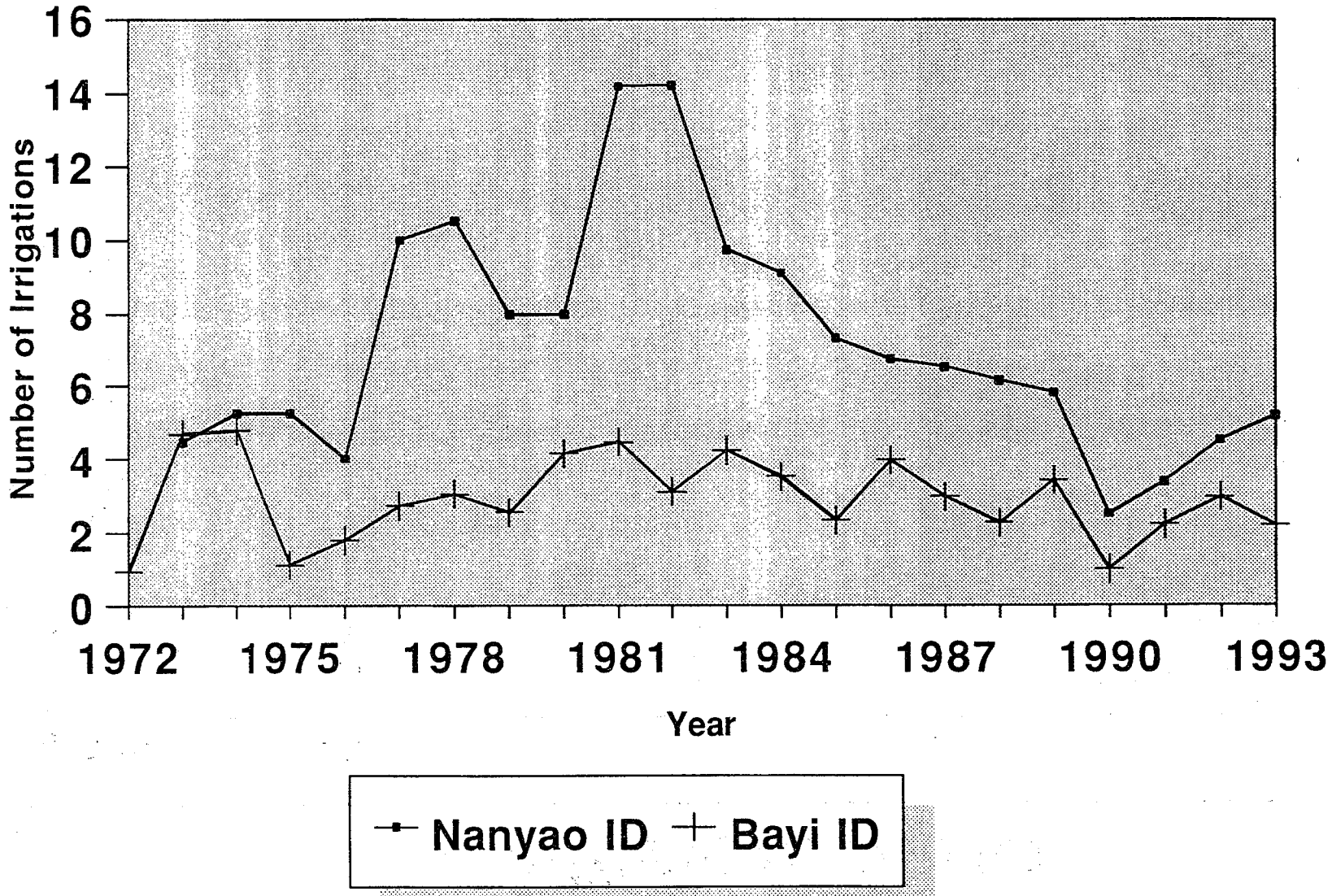
data provided by Nanyao and Bayi ID

Figure 9 Annual Irrigation Duty In Bayi and Nanyao IDs



Based on diversion into main canal

Figure 10 Annual Number of Irrigations Nanyao & Bayi IDs from 1972-1993



Data provided by Nanyao and Bayi IDs