Bakel Small Irrigated Perimeters Project. Water Management Synthesis Report 9, Agricultural and Irrigation Engineering, Utah State University Logan, Utah 84322 USA.
Miller R.P. 1985. Peasant Autonomy and Irrigation: Innovation in the Senegal River Basin, Cornell Studies in Irrigation, No. 4. Cornell University, Ithaca, New York, USA.
Ni van Nguyen. 1982. Irrigation Scheduling and Organization for Corn, Bakel Project Small Irrigated Perimeters (unpublished report).

From: Irrigation and drainage systems, vol. 4, no. 3. p. 195-214 (1990)

Innovations in irrigation management and development in Hunan province

Financial autonomy, water wholesaling, turnover to farmers, mass movement labor

MARK SVENDSEN[1] & LIU CHANGMING[2]
[1]*International Food Policy Research Institute, 1776 Massachusetts Avenue, Washington, DC 20036, USA;* [2]*Institute of Geography, Chinese Academy of Sciences, P.O. Box 771, Beijing 100012, Republic of China*

Received 3 August 1989; accepted 1 June 1990

Key words: irrigation financing, irrigation management, resource mobilization, water management

Abstract. Mass movement labor was an important contributor to irrigation system construction in China during the seventies, making up a third or more of system costs. Total per-ha system costs are roughly consistent with those in other Asian countries when contributed labor is valued at estimated farm wage rates, but less than average if zero labor opportunity cost is assumed.

Innovative practices are being employed in managing and supporting irrigation system operations in Western Hunan Province. Many are ones which have been advocated repeatedly elsewhere but infrequently applied. These include the volumetric wholesaling of water to distribution organizations, farmer water charges with both fixed and volumetric components, financially autonomous irrigation management agencies, and delegation of water distribution and fee-collection responsibility to village-based organizations. Heavy emphasis currently rests on financial self-reliance of schemes as denoted by the slogan, 'let water support water.' This has led to a proliferation of secondary income-generating enterprises associated with irrigation system management, as well as strenuous efforts to collect irrigation fees. Often the secondary enterprises generate a larger share of total income than does the irrigation service itself.

Fee levels for rice generally fall into the $12 to $20 ha/yr range, intermediate to those prevailing in Pakistan at $8.50/ha for two crops of rice and the Philippines at $45/ha for double cropped rice. Collection of fees is typically handled by the village. Charges are usually levied on an area basis but one large system employed a more complicated system which had both fixed and variable components. Water allocation at lower system levels is also delegated to the village in many cases, with the state serving as a wholesale provider of water.

Abbreviations and units: ha-m – hectare-meter, jin – unit of weight equal to 0.5 kg, kw – kilowatt, mu – unit of land area equal to 1/15 ha, Rmb – Renminbi (Yuan) equal to US$ 0.27 officially in September 1988 and about half of that unofficially, RMD – Reservoir Management Division, WCB – Water Conservancy Bureau, WMD – Water Management Department

Introduction

This case study grows from a trip made by the authors to western Hunan province in September 1988. During visits to several small, medium, and large irrigation systems in the area, we were impressed by the diversity of practices being employed in managing and supporting system operations. Moreover, a number of the approaches were ones which have been suggested, and advocated, repeatedly by observers of Asian irrigation in recent years, but, with several notable exceptions, infrequently applied. These include the volumetric wholesaling of water by reservoir agencies to separate distribution organizations, farmer water charges with both fixed and volumetrically-based components, financially autonomous irrigation management agencies, and formal delegation of water distribution and fee-collection responsibility to village-based organizations.

The paper attempts to describe some of these practices and the overall context in which they occur. It is based on visual inspections and interviews with irrigation officials at various levels in three medium irrigation systems and one large one. These interviews were probing and usually lasted for 2 to 4 hours. In them numeric data were solicited and cross-checked with other data for consistency, which was not always found. Still, patterns did regularly emerge. Most unfortunately, because of the nature of our schedule, there was little opportunity for similar interactions with farmers served by the systems, which was a distinct limitation to our approach. However, the overview gained of the policies and practices employed by the Water Conservancy and Hydropower Bureau in this region comprises a valuable introduction to the issues, and provides a useful base for further exploration.

Background

Hunan province is located in South China between 25 and 30 degrees north latitude. Civil administration is centered in the provincial capital, Changsha. Governmental structure then descends in hierarchic fashion to the prefecture, the county, the township, and the village. As seen in Table 1, the ratios of the provincial population to that of a prefecture and the prefecture to the county are around 20:1 and 8:1, respectively. The units of the commune (roughly equivalent to the current township) and the brigade (corresponding to the village) which were important elements of organizational structure during the 1970s are no longer used. However, the production team retains a functional identity at the sub-village level, though it is no longer the fundamental accounting unit for agricultural activities. The village, sometimes termed a 'natural village', remains an important local-level administrative entity.

The primary government irrigation development and management agency in the province is the Water Conservancy and Hydropower Bureau, which is headquartered in Changsha with branches at the prefecture, and county levels. Its mandate emphasizes construction and reservoir management, though it also

Table 1. Descriptive statistics for selected regions in Hunan province.

	Hunan province	Xiangxi prefecture	Fenghuang county	Yongshun county	Dayong county
Population* (million)	56.957	2.885	0.304	0.400	0.365
Cult. area* (thousand ha)	3300	193	23.51	29.58	28.00
Agric. pop. (thousand)	49496	2570	277	365	322
Farmland p.c. (ha)	0.067	0.075	0.085	0.081	0.087
Income p.c.* (Rmb)	471	409	442	370	588
Rice yields (tons/ha)	NA	4.87	4.59	5.06	4.95
Water p.c. (km^3)	3.7	5.4	4.3	NA	NA
Cities/counties	7/97	2/8	–	–	–
Limestone area (%)	NA	49.2	71.8	NA	NA
Irr. area* (thousand ha)	2772	111.5	13.9	17.3	19.9
Farmland irrigated (%)	84.0	57.8	59.1	58.5	71.1
Fert/ha (kg of product)	570	300	195	285	330

Source: Hunan Provincial Statistics Bureau, *Hunan Statistical Yearbook, 1987*. (Changsha: China Statistical Press, 1987).

Note: Items marked with an asterisk report 1986 values and are from the source indicated. Other data refer to 1985 levels and are from miscellaneous State Statistical Bureau publications or are 'current' values from briefings by provincial and county officials.

includes the operation of larger canals. There are separate organizations at county and township levels for managing water below this point.

Irrigation systems visited were located in the Wulin Mountains, all but one in Xiangxi Prefecture in the far western part of the province. This is an area officially classed as poor by the provincial government and as a special 'autonomous prefecture', being inhabited predominately by two minority groups – the Earth Family and the Miao People, the latter belonging to the same ethnic group living in Northern Thailand and Laos where the usual spelling is 'Meo.' Together these two groups make up about two-thirds of the prefecture's 2.89 million population.

The prefecture covers about 21000 km^2 and its elevation ranges from 300 to 800 m. Other statistics describing the province, the prefecture, and the three counties visited are shown in Table 1 and Fig. 1. One item to be noted is the very small amount of farm land available in the prefecture per capita, (0.075 ha) and the fact that this is slightly larger than the average for the province as a whole (0.067 ha). As a point of reference, this area is somewhat smaller than the average rice paddy in a typical Southeast Asian floodplain region. Also to be noted is the fact that rice yields in this poor region run between 4.5 and 5 tons/ha, which would be model yields in many parts of South and Southeast Asia, but are low average values here. In two of the counties, around 60% of the agricultural land is irrigated and in the third, around 70%, while the average for the province as a whole is about 80%.

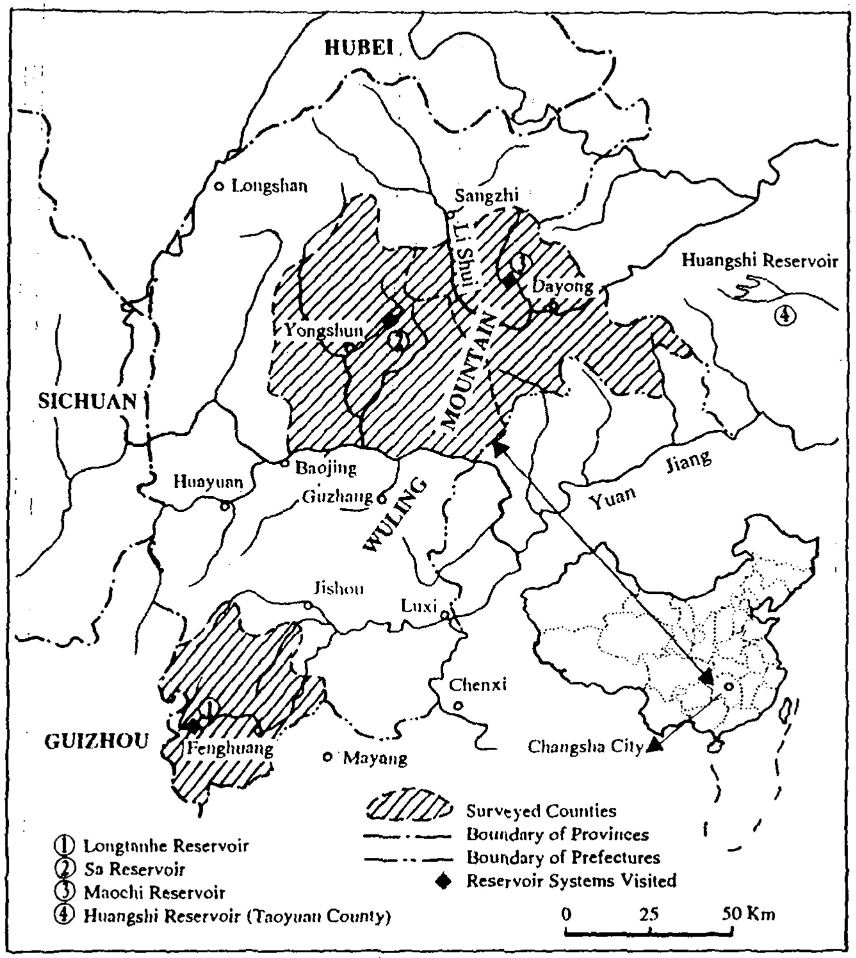

Fig. 1. A plan of Xiangxi Prefecture.

Rainfall in the area averages 1482 mm/yr with values descending from 1800 mm in the far northern part of the prefecture to around 1300 mm in the south. The Wulin Mountains are limestone, and limestone underlies about half of the prefecture. The area is drained by more than 500 rivers and is extensively eroded into a classic Karst landscape. Internal drainage is excellent, as witnessed by the numerous rice fields to be found at the bottom of sinkholes with no surface drainage whatsoever. As a result, rivers often appear and disappear from the surface and the building of roads, dams and lengthy canal networks proves difficult and costly. However river flow is relatively stable, with the ratio of maximum to minimum flows said to be generally less than 2:1.

Precipitation and temperature data for the three sample counties are found in Table 2. More than 70% of annual rainfall is concentrated in spring and

Table 2. Meteorologic data for selected countries.

	J	F	M	A	M	J	J	A	S	O	N	D	Total/or average
Fenghuang													
(1) Precip (mm)	37.7	52.2	79.1	164.0	221.1	182.3	138.3	140.0	75.5	111.2	75.5	36.2	1313.1
(2) ET (mm)	38.6	39.0	60.7	93.6	115.8	137.7	216.2	204.9	139.5	92.9	53.1	41.8	1233.8
(3) (1)-(2) (mm)	-0.9	13.2	18.4	70.4	105.3	44.6	77.9	-64.9	-64.0	18.3	22.4	-5.6	79.3
(4) Temp (deg C)	4.5	5.7	10.4	15.9	20.2	24.0	27.0	26.4	22.4	16.8	11.4	6.7	16.0
Max	8.7	9.9	15.1	21.0	24.8	28.7	32.2	32.1	27.9	22.0	16.0	11.1	20.8
Min	1.2	2.5	6.9	12.1	16.7	20.5	22.8	22.4	18.5	13.2	8.1	3.5	12.4
Yongshun													
(1) Precip (mm)	25.7	37.2	72.4	145.2	206.0	229.2	200.8	151.3	108.8	107.3	64.8	31.4	1380.1
(2) ET (mm)	42.0	45.4	69.9	102.0	129.5	151.9	223.2	230.2	149.3	96.3	53.2	43.5	1336.4
(3) (1)-(2) (mm)	-16.3	-8.2	2.5	43.2	76.5	77.3	-22.4	-78.9	-40.5	11.0	11.6	-12.1	43.8
(4) Temp (deg C)	4.8	6.3	11.1	16.5	20.5	24.3	27.3	26.8	22.7	17.3	111.8	7.0	16.4
Max	9.4	10.8	16.0	21.9	25.5	29.5	32.7	32.8	28.3	22.6	16.6	11.6	21.5
Min	7.6	7.7	8.4	9.2	8.5	8.9	9.4	10.0	9.3	8.7	7.8	7.5	8.6
Dayong													
(1) Precip (mm)	31.3	44.5	81.9	157.0	212.0	236.2	183.0	145.0	94.8	99.6	61.6	35.3	1382.2
(2) ET (mm)	48.1	51.4	75.6	111.2	144.5	170.0	222.4	249.9	168.9	118.1	65.0	50.0	1475.1
(3) (1)-(2) (mm)	-16.8	-6.9	6.3	45.8	67.5	66.2	-39.4	-104.9	-74.1	-18.5	-3.4	-14.7	-92.9
(4) Temp (deg C)	5.1	6.4	11.2	16.7	20.9	24.8	28.0	27.5	23.1	17.8	12.2	7.4	16.8
Max	9.4	10.7	16.0	21.8	25.7	29.8	33.2	32.9	28.3	23.0	16.9	11.7	21.6
Min	2.0	3.2	7.8	13.1	17.5	21.2	24.1	23.6	19.5	14.2	9.1	4.4	13.3

Source: Data from the files of the Institute of Geography.

Note: Values shown are averages of 20 or more years of record.

Table 3. Characteristics of selected irrigation systems.

	Maochi	Sa	Changhong
Res. capacity (million m³)	55	16	2.4
Command area			
Planned (ha)	3867	2600	NA
Actual (ha)	2933	1133	200
Catchment (km²)	308	44	6.4
Villages	60[a]	21	5
Irr. season	May-Sept.	May-Sept.	NA
Crop	two crop rice	long season rice	long season rice
Investment (million Rmb)	Rmb 11.6[b]	Rmb 8	NA
Began operation	1980[c]	1975[c]	NA
Labor investment (million person days)	8	NA	NA

[a] One station serves 12 villages and 587 ha. Figure shown is extrapolated from this on basis of total command area.
[b] Not including hydropower facility at Rmb 3.7 million.
[c] On part of area.

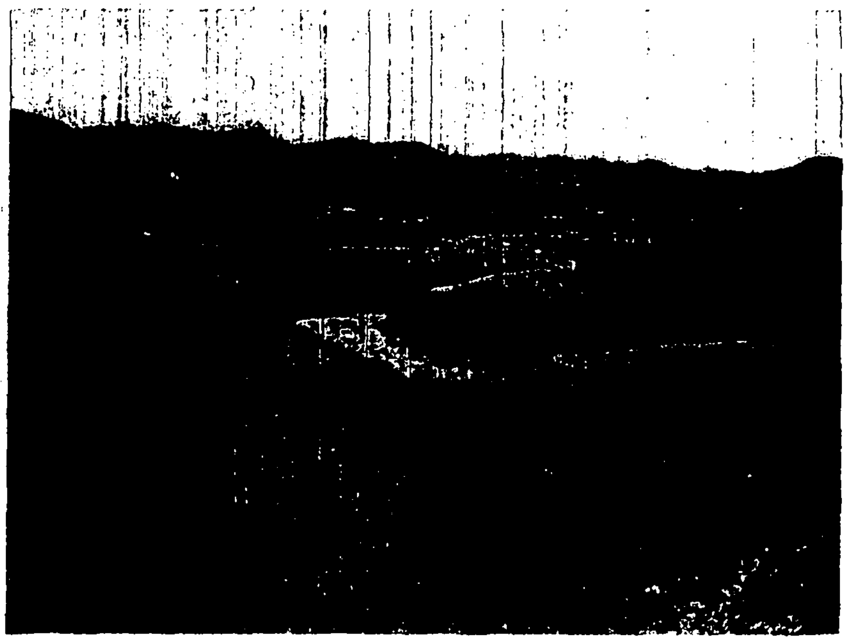

Fig. 2. Terraced rice fields typical of the Wulin region.

summer. This rainfall pattern coincides with warm temperatures (11°C to 28°C) to be quite suitable for paddy growing. In comparison with most other regions in China, spring rainfall in this region prevails and can exceed evapotranspiration. Although summer rainfall accounts for the highest proportion of the annual total, a rainfall deficit typically appears in July and August which must be made up by irrigation (see Table 2). Such deficits usually last through mid-autumn.

Most of the following discussion will focus on three medium irrigation systems, one in each of the three principal counties visited, and one large system located in an adjacent prefecture. Basic descriptive statistics on the three counties are found in Table 3.

Irrigation organization and management

System classification

Reservoir-based surface irrigation systems in Hunan province are classified by reservoir capacity according to the following criteria.

Large-scale	> 100 Mm³ (10,000 ha-m)
Medium-scale	< 100 Mm³ and > 10 Mm³ (1000 ha-m)
Small-scale #1	< 10 Mm³ and > 1 Mm³ (100 ha-m)
Small-scale #2	< 1 Mm³
Ponds and small dams	very small, built without outside assistance

Other irrigation categories include electrical surface pumps, diesel surface pumps and wells. The latter category is relatively unimportant because of the abundance of surface water. The surface pump category is important, and irrigation by individually-owned pumpsets in the 3 to 5 horsepower range, mostly diesel, is said to be the fastest growing category is irrigated area in the prefecture. The extent to which private pumpsets are included in government statistics is unclear, but it is very likely that many of the privately-owned pumps are not included. In addition, there is a significant but unknown number of small farmer-constructed surface diversion schemes without storage that do not appear in provincial statistics. These systems appear to be similar to schemes based on temporary weirs found in mountainous regions of Nepal, Indonesia, northern India and the Philippines.

For Dayong County, Table 4 gives an idea of the distribution of irrigated area among these different system types. It indicates that only 13% of the irrigated area is served by pumps and that nearly three-quarters of the area is irrigated by government built or assisted reservoir-based systems, dominated by those in the 100 to 1000 ha-m capacity range. These numbers must be treated

Table 4. Irrigation capacity in Dayong county, Hunan province.

	No.	Total storage (Mm³)	Eff. storage (Mm³)	% of total (%)	Irr. area (ha)	% of total (%)
Med. Res.	3	77.43	59.68	54.6	3307	18.3
SS #1	17	40.07	32.54	29.8	5887	32.5
SS #2	73	22.95	17.03	15.6	3927	21.7
Ponds					2513	13.9
Small dams					213	1.2
Diesel pumps					667	3.7
Elec. pumps					733	4.0
Water powered pumps					867	4.8
		140.45	109.25	100.0	18114	100.0

with some caution, however, because of the nature of the statistical collection process employed and because the totals do not include locally-constructed diversion irrigation systems and may not include completely the area served by privately-owned pumpsets.

It may also be noted that the larger, medium-scale reservoirs have about three times the storage capacity per irrigated hectare that the smaller ones do. This can be explained by the fact that the medium systems are also locally-important producers of electricity and because several of the medium systems do not yet have fully developed distribution systems, as discussed subsequently.

Resource mobilization

Pre-season meeting

In medium systems, a pre-season meeting is held each April to discuss the coming irrigation season. The meeting is conducted by the Water Management Department (WMD) of the Water Conservancy Bureau (WCB) and is attended by representatives of the Department and the Bureau, village leaders, and township officials. Water Conservancy Bureau personnel notify each village leader in advance of the date of the meeting, which is usually held at the WCB office and normally lasts all day. At the Maochi system meeting this April, about 50 people were in attendance, about 80% of them farmers. The agenda typically consists of four items.

a) Previous year's irrigation season, including water delivery, fee receipts, and expenditures
b) Maintenance work performed the previous winter

c) Improvement of fee collection
d) Fee collection schedules

The morning is devoted to reports by the Water Management Department and the afternoon to responses by farmers and discussion. After discussion, the water fee for the coming season is determined.

Irrigation fee levels

Guidance issued by the province suggests that irrigation fee levels for medium systems be set between 3 and 5 Renmimbi (Rmb) per mu (0.067 ha) per year or about $12 to $20/ha. Two of the three medium systems in Dayong county have rates of 3 Rmb per mu ($12.10/ha) while one charges 'approximately' 2 Rmb per mu ($8.07/ha). No distinction is made for type of crop or number of crops taken in a year, since the systems typically run for only about 6 months and irrigate rice almost exclusively – either one crop of long season rice (150 days) or two crops of short season rice (105 days). Total water requirements thus do not differ a great deal.

In Yongshun County, the rate for the Sa Reservoir system is denominated in jin (0.5 kg) of rice. Last year, the rate for the 1988 season was raised from 8 jin per mu (60 kg/ha) to 15 jin/mu or 112.5 kg/ha – about 2% of a typical yield. When valued at the official procurement price of 0.20 Rmb/jin this converts to 3 Rmb/mu, the lower limit of the provincial guidelines. Farmers have the option of paying either in rice or in cash. However those paying in cash are charged a rate of 5 Rmb/mu. The fact that roughly 10% of farmers opt to pay this nominally higher rate in cash relates to the fact that the free-market price of rice is often considerably higher than the official procurement price and that these farmers can apparently profit by selling the rice themselves and paying the higher cash rate. To make this arrangement profitable, farmers need to sell the paddy for more than 0.33 Rmb/jin, or 65% over the national government procurement price.

The fact that not all farmers take advantage of this apparent opportunity suggests that many farmers may have little or no paddy left over to sell after subsistence needs are taken care of and perhaps that a certain quantum of surplus is necessary before the costs and trouble of moving the rice to market become worthwhile.

From the collector's point of view, the valuation and payment in paddy is also advantageous. In Hunan province the WCB can sell the rice to the provincial government at a rate of 0.24 Rmb/jin and so actually gain a 20% premium over the nominal cash rate of 3 Rmb/mu. Still both logic and experience from the Philippines (Svendsen, Adriano & Martin 1990) suggest that an agency not specifically set up to handle grain collection and marketing can incur significant costs in doing so. In the Philippines, this cost is as much as 45% of the

Table 5. Typical irrigation fee computations, Huangshi Reservoir.

Depth appl. (mm)	Volume appl. (m^3/mu)	Fixed	Variable (Rmb/mu)	Total (Rmb/mu)	Total ($/ha)
			Gravity		
200	133	1.5	1.33	2.83	11.41
300	200	1.5	2.00	3.50	14.11
450	300	1.5	3.00	4.50	18.01
750	500	1.5	5.00	6.50	26.21
			Pump[a]		
200	133	0.8	0.67	1.47	5.93
300	200	0.8	1.00	1.80	7.26
450	300	0.8	1.50	2.30	9.27
750	500	0.8	2.50	3.30	13.31

Note: 1 mu equals 1/15 ha.

[a] *Figures from pump systems exclude power changes.*

value of the grain collected by the National Irrigation Administration as irrigation fees.

Farmers in the Maochi system in Dayong may also opt to pay either in cash or kind but with the conversion made directly at the official 0.20 Rmb/jin rate. Thus the farmer can pay either 15 jin/mu (112.5 kg/ha) or 3 Rmb/mu ($12.10/ha). Almost all farmers there opt to pay cash.

The large Huangshi Reservoir system, located in Taoyuan County in a neighboring prefecture, presents a more complicated and extremely interesting fee structure in which water charges are a combination of two – or in the case of pump-supplied areas, three – components. The first is an area-based flat rate levied on each farmer in the system regardless of the amount of water taken, which presumably represents the cost of maintaining the capacity of delivery to the farm. This 'connection charge' is set at 1.5 Rmb/mu ($6.05/ha) for gravity irrigated land and 0.8 Rmb/mu ($3.23/ha) for pump irrigated land. Gravity-supplied farmers must pay an additional 0.01 Rmb/m^3 for water actually delivered while pump-supplied farmers are charged at half that rate. Rates for pump-supplied farmers are said to be lower because these farmers must also pay a third charge to the county water management station for the power used to lift the water.

Sample computations of fees resulting from this schedule are shown in Table 5. In this table, a 200 mm application depth represents the design duty for cotton or a very economical use of irrigation water for growing a short-duration rice crop during a year. The 750 mm application depth represents a lavish use of water for growing long-season rice. A 450 mm application is considered a typical delivery level for rice. Thus irrigation water charges might be expected to vary in the range of $11 to $26/ha for gravity supplies and $6 to $13/ha plus power charges for pump-supplied water. At moderate use levels, these rates are consistent with those found in the medium systems visited, though extravagant users would pay considerably more than they would in the fixed-rate systems.

Some small-scale reservoir systems levy and collect fees from their members and some do not. The 200 ha Changhong system collects 3 Rmb/mu ($12.10/ha), however fees for such small systems are said more typically to run about 1 Rmb/mu ($4.03/ha).

Fee collection procedures

In the Huangshi Reservoir system, township water management stations, which are separate entities from the WCB management organs, collect the fees. Receipts are turned over to the county financial departments and then distributed to other appropriate departments, including payments to the WCB for wholesale deliveries of water to the county stations.

Typically in medium systems, farmers undertake the actual collection of irrigation fees. This is done at the village level by the village leadership following the end of the last harvest of the irrigation season. Each village has a bookkeeper who keeps a list of names of the farmer responsible for production on each parcel of village land, the extent of each person's area, and the fee due from each. In Sa Reservoir system, where 90% of the collection is in the form of paddy, the village leaders collect, weigh, store, and record the paddy brought in by each farmer. Officials of the WMD then arrange to accept receipt of and transport the paddy on an appointed day – usually using tractors and carts hired in the village. This represents a change from the practice prevailing prior to 1988 where WMD personnel tried to visit each farmer to make the collection directly. Department officials claim that they refuse to accept paddy that is not well dried and that grain handling is not a major problem. They also indicate that there was only a 5% shortfall in collection for the 1987 irrigation season. However the 80000 jin of paddy they report having collected would represent only about 59% of the fees due on the 17000 mu service area of the system, valued at last year's rate of 8 jin/mu.

In Maochi, where most of the fee collections are in cash, the process is somewhat simpler. Village leaders collect the cash and record payment, turning over the proceeds to the WMD station accountant either upon his visit to the village or at the station. The station accountant also maintains duplicate copies of the collection records at the station. These are then aggregated alternatively by canal reach, village, and station. Personnel in the Guangping station of Maochi indicated that their collection rate was 100% in 1987 while that of the other station in the system was around 80%. Here, the amount due from 44000 mu of land currently under irrigation command would be 132000 Rmb. However system personnel indicate that only 40000 Rmb in system revenue is derived from irrigation fees. This is just 30% of the nominal total due and tends to contradict the claim of a 100% collection level.

One possible explanation for this discrepancy is that it represents a shortfall of area actually irrigated relative to nominal 'effective irrigated area', which typically describes area provided with irrigation facilities. It seems unlikely, though, that this explains the entire gap, especially in Maochi, and system-wide collection performance may not be as effective as reported.

Collection incentives are provided both to WMD personnel and to villages. In Maochi, staff of the station with the best performance rating, a measure which emphasizes fee collection performance, receive a bonus which averages 300 Rmb/employee and the village is allowed to keep 10% of collections. In the Sa Reservoir system, there is a similar competition among stations with the best one receiving an award of 4 months additional salary (about 100 Rmb/month) for each of the 5 station staff members. There is no general rebate to the village, but farmers who assist with the grain collection and handling have their fee obligations adjusted downward.

Labor mobilization

In addition to the cash collected from farmers as irrigation service fees, significant contributions toward irrigation system maintenance come from the compulsory labor contribution still required of the rural Chinese population. This labor contribution makes up an important part of the total maintenance requirement of irrigation systems in western Hunan.

In Dayong county, a county-wide meeting is held in mid-October each year prior to the winter maintenance period. This meeting is attended by the leaders of the county's 34 townships, key project leaders, WCB leaders and the county governor. The relatively high status of the participants on this list indicates the importance of the meeting. Its purpose is to report on the previous winter's maintenance work and to plan work for the coming winter. At the meeting, labor requirements for maintaining the county's public facilities, principally irrigation systems and roads, are discussed and a quota assigned to each of the townships. Within the township, labor quotas are levied on individual villages on the basis of the amount of irrigated land within them at the nominal rate of 10 labordays/mu. However, all village residents are required to provide quota labor – not just those families working irrigated land.

In 1987 the requirement for maintenance labor in Dayong county was determined to be 2.06 million labor-days. Most but not all of this labor was allocated to irrigation system maintenance. In fact, however, only 1.36 million person-days of labor were actually performed, about two-thirds of the requirement. Officials of the WCB feel that it is more difficult to mobilize such public service

labor since the production responsibility system was implemented in the early eighties. They suggest that about 60% of the farmers contribute assigned labor, and about 10% contribute nothing. The remaining 30%, generally wealthier farmers, pay the village a fee *in lieu* of contributing their own labor. Currently the rate for this payment is 3 Rmb per person-day of work obligation. The village then has responsibility to arrange for a substitute worker.

In addition to maintaining existing infrastructure facilities, quota labor is also used in the construction of new system facilities. Although less important than in the early and mid seventies, contributed manual labor still makes an important contribution to new construction. In Dayong, fees paid in lieu of the labor obligation mentioned above are used to hire workers for this 'basic construction' work, since paid labor is easier to obtain and more highly motivated. In addition workers with technical skills are hired from outside the area, if necessary, at a rate of 5 Rmb/day or more.

Revenue and expenditure

Although subsidies for irrigation system operation and maintenance are available from various government units, irrigation districts are encouraged and expected to cover their O&M costs directly. The basic principle is 'use water to sustain water' which suggests that irrigation districts should be self-supporting. In 1988, for example, the amount of public money available to all of Dayong county for maintenance and construction totalled 1.6 million Rmb, with 0.1 million coming from the county and the balance of 1.5 million from the prefecture and the province. This amount is down in absolute terms from 2.2 million Rmb 5 years ago, demonstrating the reduction in government support, with its value eroded further by inflation during that period.

To meet O&M requirements, systems often turn to a variety of income sources. In Maochi, for example, irrigation fees contribute 40000 Rmb to total system revenues (10%) while other sources supply 370000 Rmb. These other sources include hydropower revenues (both self-generated power and water use fees from another branch of the WCB which operates additional generating units), fish production in the reservoir, supply of domestic water to the city of Dayong, and the sale of fruit from a citrus orchard on the slopes above the reservoir. The breakout of operational costs is as follows.

Salaries	220000 Rmb
Hydropower operation, office, utilities	100000 Rmb
General maintenance	20000 Rmb
Maintenance of main canal	20000 Rmb
City taxes	20000 Rmb
Compensation to farmers losing land to reservoir	30000 Rmb
Total	410000 Rmb

In the small Changhong system where revenues totalled 23000 Rmb last year, irrigation fees provided 9000 Rmb (39%) and hydropower 1000 Rmb (4%) while the 27300 kg of fish raised in the reservoir contributed 13000 Rmb (57%). The system has 3 contract employees who are principally occupied with the fishery operation. After paying their salaries and other expenses, about 7000 Rmb remains for system maintenance expenses. In other small-scale systems the reservoir operator is said to be given the right to use the reservoir for fish production in exchange for his management services.

Construction

Methods

Construction of medium scale systems in the Wulin area seems to date mostly from the late 1960s and the 1970s. This was the heyday of the labor-intensive 'mass movement' construction of rural public works, and most of the systems visited had employed this form of labor in their construction. For example the earthfill dam impounding Longtanhe reservoir in Fenghuang county, designed to serve 3700 ha, is said to have been constructed in just 95 days in 1974 through the efforts of 40000 people mobilized for the purpose. The 11 stone masonry arches of a 400 m long aqueduct in the same system were built in just 9 hrs by 1000 people around the same time. The aqueduct still bears the inscription 'Mao Tse-tung's thought is always breathing.' There have been some concerns raised about the quality of the work done in this fashion, however, and we were told that some of the reservoirs in Dayong county cannot be completely filled because of safety concerns.

The three medium dams visited were intended to provide services in addition to irrigation. All three had one or more low-head hydropower turbines which operate during the irrigation season. Flood control and fishery were other common objectives.

Costs

Construction costs for the systems visited were obtained in very general terms. These were examined to try to see

- what the approximate/ha cost of constructing each system was and what it would be at today's price levels; and
- how important mass movement labor was in building these systems.

The Sa Reservoir system had a price tag of 10 million Rmb when planned in the early 1970s, presumably including the cost of the very small 750 KW hydropower station. So far, 8 million Rmb has been spent on the reservoir (completed in 1975) and canals to irrigate 1100 ha out of a planned 2600. The cash cost of the planned construction (assuming no cost escalation beyond the 10 million Rmb estimate) is thus 3846 Rmb/ha, while the actual cost for the area currently irrigated is 7273 Rmb/ha, nearly double the original estimate. In constant terms, that amounts to 10276 (1987) Rmb/ha for the system as built.

Because data were not obtained concerning the amount of labor contributed for the construction of the Sa Reservoir system, a labor contribution equivalent to the average for the other two systems was assumed in preparing Table 6, as explained in the notes to the table. This addition raises the per hectare costs given above by an amount dependent on how the labor was valued.

The Maochi system has so far cost 15.3 million Rmb to construct, including 3.7 million Rmb for the 5400 KW hydropower station. In addition, 8 million person days were said to have been supplied by mass movement labor during construction in the mid and late seventies. In this case, each laborer was given a modest 0.40 Rmb/day subsistence payment for meals, which is included in

Table 6. Cost[a] of irrigation system development, 1987 price levels.

System		Sa reservoir	Maochi	Huangshi reservoir
Year of completion		1975	late 70s	1972
Total cost (million Rmb)	a)	11.3[b]	16.2	94.7
	b)	14.1	20.7	115.0
	c)	18.3	27.4	145.5
Cost/ha (Rmb/ha)	a)	10276	5523	4304
	b)	12818	7058	5227
	c)	16636	9350	6615
Cost/ha (US$/ha)	a)	2761	1484	1156
	b)	3444	1896	1404
	c)	4470	2512	1777
Share of labor cost (%)	a)	0	0	0
	b)	20	22	18
	c)	38	41	35

Scenarios: a) wage rate equal 0 Rmb/day
b) wage rate equal 0.40 Rmb/day
c) wage rate equal 1.00 Rmb/day

[a] All cost figures are reported at 1987 price levels. Reported Rmb figures were converted to 1987 Rmb by inflating them to 1987 with the national income deflator. Figures reported in dollars were then converted at the official exchange rate for 1987.

[b] It was assumed that the 8 million (current) Rmb spent on the reservoir did not include an imputed labor cost. For scenario b the total cost was increased by an amount sufficient to include a labor component equal to 20% of the new total. This implied that 7 million person days of labor would have been contributed. Scenario c then assumes this same 7 million person days of labor.

the cash cost figure. System engineers estimated that the wage rate of an agricultural laborer at that time was about 1 Rmb/day. The total cash cost of the irrigation system, excluding the cost of the hydropower facility, thus becomes 19.6 million (current) Rmb or 6683 Rmb/ha irrigated.

For the Huangshi Reservoir system, construction expenditures totaled 67 million Rmb at (Phase I) completion in 1972 when it irrigated 22000 ha. In current terms, the cash cost of construction was thus 3045 Rmb/ha. In addition 36 million labor-days were expended in the construction.

Table 6 shows these costs converted to 1987 price levels. In addition, the *total* cost of each system is estimated for three different shadow wage rates at the time of construction. Scenario a gives the cash cost described above in terms of 1987 prices for Sa and Huangshi Reservoir systems, while case b represents this value for Maochi.

For Huangshi and Maochi Reservoir systems, system costs increase by 54% and 69%, respectively when the opportunity cost of mass movement labor is raised from 0 to 1 Rmb/day. When labor is valued at the higher rate, it makes up between 35% and 41% of the total system construction cost. This labor is clearly an important contribution to the construction of these systems.

In constant 1987 dollar terms, costs of construction range from around $1200/ha to almost $4500, depending on the system and the value assigned to the labor. When the higher labor prices are assumed, the values of total cost/ha are very consistent with those currently prevailing elsewhere in Asia. When this labor is assumed to have had no alternative use, then costs/ha tend to be somewhat below the average.

The Wulin area is not an easy one in which to construct irrigation systems. Because of the region's disjointed Karst topography, service areas consist of a number of non-contiguous areas and distribution networks are complex (see Fig. 2 on p. 200). Maochi, for example, includes 42 tunnels with a total length of 8.2 km, 31 syphons totalling 4.2 km, and 11 pumping stations. This complexity raises the cost of the distribution networks significantly. In Huangshi Reservoir system, the need to lift water to reach certain sections of the service area results in a net power deficit, with 6000 KW of installed generating capacity at the damsite and 10100 KW of installed surface pumping capacity within the service area.

Financing

Financing for construction has come from a mixture of sources. The provincial government has typically put up the lion's share of the cash portion of the cost. In the Sa Reservoir system the province provided a two-thirds share, with the county, township and village providing the remainder. In Maochi, the province has provided 11 million Rmb of the 15.3 million Rmb expended to date, or 72%, and will supply the 3.3 million Rmb necessary to complete the system as well, though local people will be asked to contribute an additional 800000 days of labor. Other contributions for Maochi include 3.0 million Rmb (20%) from the WCB, 1.22 million Rmb (8%) from the county, and 0.2 million Rmb (1%) from the prefecture, where percentages refer to cash costs only.

Table 7. Design and actual irrigated areas of selected systems.

System	Dam completion date	Design irrigated area (ha)	Actual irrigated area (ha)	Area incomplete (%)
Huangshi Res.	1959	27300	22000	19
Longtanhe Res.	1974	3700	2300	38
Sa Res.	1975	2600	1100	58
Maochi Res.	1978	3900	2900	26

Investment to date in the Huangshi Reservoir system is 67 million Rmb, with 29% of that coming from the national government and 21% from local government sources. The remaining 50% came from commune (township) savings and from agricultural bank loans taken out by the brigades (villages). These loans were said to have been repaid by the time the communes were abolished in 1978. Construction began in 1958, was halted for 6 years between 1959 and 1965, and then resumed to complete the power station and a major portion of the canal network by 1972. A portion of the originally-designed canal network remains unbuilt. In addition to the cash costs, 36 million labor days were contributed by area residents.

In all medium and large systems visited, portions of the design area remain unserved by canals. These areas range from 20% to 56% of the design area, as shown in Table 7. A number of reasons were advanced for these shortfalls. Most commonly mentioned was the failure to receive full project funding even decades after reservoir completion. In some cases, there may have been cost overruns and no supplemental funding was forthcoming. It may be also that a portion of this area could not be served even with additional canal construction, because of an inadequate water supply, given current operation efficiency levels. Huangshi Reservoir system, which was serving 80% of its design area upon system completion in 1972, now irrigates only 66% of design area because of deterioration and failures in the conveyance system. The problem of incomplete systems is apparently well-known since national government policy has emphasized completion of facilities whose construction had begun over new starts on a number of occasions over the past 30 years. The problem persists, however, at significant cost to the economy, as small additional investments in system completion can take advantage of large existing investments in dams and large canals.

Prior to 1985, government investment contributions were made as grants, with no repayment required. Under new directives effective in that year, future advances for such construction must be repaid. The result of this in Dayong, according to WCB personnel, is that they have proposed no new projects since 1985 and have no plans to do so. One reason for their reluctance is that power rates, which are set by the state, have not been increased for some time and power generation, felt essential to repay investment costs, does not generate sufficient revenue. Although a similar policy applies to small-scale system construction, small systems are far less affected by the repayment provision, since engineering services are provided by the WCB at no charge and construction costs are met very largely by contributed labor from the villages.

In the Wulin area, which is not, for the most part, connected with the provincial power grid, most reservoir projects include a hydropower component. For small-scale reservoirs which will be managed by the local village, financing is available from the government and design services are provided by the WCB for minihydro facilities. Prior to 1985 such financing was also provided on a grant basis. Since then financing is through loans, with the interest rate dependent on the relative wealth of the area. In Dayong county the current rate was said to be 3.3%, which is clearly concessional in the face of an inflation rate currently running around 20%.

Water management

Under the overall direction of the WCB in medium and large reservoir systems is a Reservoir Management Division (RMD). This division has the responsibility of managing the water in the reservoir, delivering it to the various users, and maintaining the reservoir and major canals and structures. As indicated earlier, it is expected to cover the costs associated with this with the revenue it generates. Hydropower facilities may be under their control, though often larger installations are the responsibility of another branch of the WCB. In these cases, the RMD receives a fee from the power generation unit for the use of the water.

At the other end of the system, water distribution to irrigators is managed by the village, which is also usually responsible for remitting fees to the provider of the water. In medium systems, the interface between these two is direct.

In the large Huangshi Reservoir system, another set of management units is interposed between the two. These units, also called water management stations, are branches of the 19 different township governments represented in the Huangshi service area and operate a total of 59 stations. They receive water from the RMD, combine it with water from smaller local sources, and deliver it to villages for distribution to farmers. Facilitating the wholesale transfer of water from the RMD to the township water management stations are a set of 19 RMD water management stations, one per township.

These RMD stations deliver measured quantities of water to the township stations, for which the townships are charged volumetrically. The township stations also are said to measure the quantity of water delivered to villages volumetrically. Below this level, the villages estimate water deliveries to farmers by timing them, but without monitoring the flow rate.

At the village level, one person in each production team is designated as the water manager. Each of the 59 township stations has 3 to 7 staff members, including 1 staff member deputed from the WCB. The 19 stations run by the RMD are each staffed by 3 to 5 persons. The RMD employs a total of 312 people, including the 75 or so people manning the 19 water management stations. This gives a total staff of around 600 people, not including village-level managers, for the 18,000 ha system or about 3.33 persons/100 ha. This is more than double the upper limit for systems of this size range suggested by the government in 1965 as reported by Nickum, and about ten times the average levels reported by Bos & Nugteren (1983) generally for systems of this size. This may represent the price paid for a relatively sophisticated system of allocation and volumetric water charges.

Conclusions

The decade of the 1970s was an active period for irrigation system construction in the Wulin Mountain area. Since that time, the pace of construction appears to have slackened, and emphasis has shifted to the financial viability of already constructed systems. Many medium and large reservoir systems remain incomplete decades after being commissioned, a problem shared with India and other countries in the region.

Mass movement labor was an important contributor to this construction, making up a third or more of system costs, depending on how the labor is valued. Total/ha system costs are roughly consistent with those in other Asian countries when contributed labor is valued at estimated farm wage rates, but less than average if zero labor opportunity cost is assumed.

Reasons for the decline in investment in new systems include

- the reduced emphasis being placed on mass movement labor and the reduced willingness of rural residents to provide it,
- the 1985 change in financing policy requiring repayment of capital amounts advanced by national and provincial governments previously provided on a grant basis, and
- possible diminishing returns owing to the fact that roughly two-thirds of the agricultural land in the area is already irrigated.

This percentage might actually be higher if the rapidly-growing area irrigated under private pumpsets were fully accounted for.

Heavy emphasis currently rests on financial self-reliance of schemes as denoted by the slogan, 'let water support water.' This has led to a proliferation of secondary income-generating enterprises associated with irrigation system management. Often these secondary enterprises generate a larger share of total income than does the irrigation service itself. Irrigation fee collection is stressed, and while collection levels are said to be high, collection income figures suggest some caution in drawing this conclusion.

Fee levels for rice generally fall into the $12 to $20/ha/yr range, intermediate to those prevailing, for example, in Pakistan at $8.50/ha for two crops of rice and the Philippines at $45/ha for double cropped rice. Collection of fees is typically handled by the village through the civil administrative structure and forwarded to the Water Conservancy Bureau. Charges are usually levied on a per unit area basis but one large system employs a more complicated system which had both fixed and variable components. Included in the variable component are both a volumetric charge and a power charge where pumping was required.

Water allocation at lower system levels is also delegated to the village in many cases, with the WCB serving as a wholesale provider of water. In the case of the large system visited, a separate government department acts as a middleman between the WCB and the village in delivering water and collecting charges.

Irrigation in the Wulin Mountains is extensively developed and financial management of irrigation is a high priority. System managers have considerable autonomy and are experimenting with interesting organizational and financial structures and rules to achieve the goal of operational self-reliance. The results of the experience they are accumulating with these innovations could provide very useful empirical guidance to others in the area and the region who are also moving out of a construction/growth phase and becoming increasingly concerned with system management tools and techniques and with financial self-reliance.

References

Bos M.G. & Nugteren J. 1983. On Irrigation Efficiencies. Wageningen, International Institute for Land Reclamation and Improvement.

Hunan Provincial Statistics Bureau. 1987. Hunan Statistical Yearbook, 1987. Changsha, China Statistical Press.

Nickum J.E. 1982. Irrigation Management in China: A Review of the Literature. World Bank Staff Working Paper 545. Washington, D.C., World Bank.

Svendsen M., Adriano M. & Martin E. 1990. Financing Irrigation Services: A Philippine Case Study of Policy and Response. Washington, D.C., IFPRI, draft.

Irrigation and Drainage Systems 4: 215-229, 1990

Modelling water control needs for diversified cropping

PETER G. McCORNICK & RAMCHAND N. OAD

[1]*Department of Agricultural Engineering, University of Alberta, Edmonton, Alberta T6G 2H1 Canada;* [2]*Department of Agricultural and Chemical Engineering, Colorado State University, Fort Collins, Colorado 80523, USA*

Received 28 December 1989; accepted 5 September 1990

Key words: crop diversification, irrigation, management, rice, simulation

Abstract. The background and concepts of water control for crop diversification in rice-based irrigation systems are discussed. Water control is described in terms of the irrigation event volumes and intervals between irrigation events. The development of the WACCROD model to simulate these water control parameters under selected agroclimatic conditions is described. The simulation model can recommend irrigation event volumes and intervals for various dry season cropping patterns in rice-based irrigation systems. Also, the application of the model to a general situation at field level of a 'typical' rice based irrigation system is reported.

Introduction

This paper is the first in a series reporting research into irrigation water control requirements of diversified cropping in rice-based agriculture. The background and the main concepts applied, including the development of a simulation model (WACCROD), are presented. The analysis of water control for crop diversification, including the application of the simulation model to an Indonesian case study, is covered in the next paper of this series (McCornick & Oad 1991).

Diversified cropping is defined in this research as the practice of growing wet season paddy rice followed by a mix of paddy rice and non-rice crops in the next, usually drier, season. The advantages of such a cropping system are that farmers can grow rice, which is economically and socially important to Southeast Asian farmers, and they can grow other crops to improve family nutrition levels and to earn cash. The non-rice crops can usually make better use of lower water supplies in the drier season (Oad 1982).

Water control is defined in this research as the capability of an irrigation system management to match the available water supplies to the demand (Oad & Podmore 1989). In the case of crop diversification the demand changes from