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Farmers, agencies and irrigation systems: a comparison of two village schemes in the Bakel Department in Senegal

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Key words: farmer-agency relation, irrigation systems, water management, water use

Abstract. The irrigation schemes of the villages Gandé and Galladé in the Bakel Department in Senegal are managed by a farmer association and an agency. The agency had to install, repair and maintain motorpumps, assist in the lay-out of canals, structures and parcels, and to provide fuel and other inputs on credit. Associations had to manage the irrigation systems and repay the agency in time and in proportion to amounts of inputs received.

The Gandé association and the agency came frequently into conflict, because the level of agency support was low, and the association did not repay in time. The Galladé association and the agency did not come into conflict, because the level of agency support was satisfactory, and the association repaid in time. Repayment depended on profitability of irrigation, which was lower in Gandé than in Galladé, because consumption of water and fuel were in Gandé two times higher than in Galladé. This was not so much caused by differences in water management, but because of differences in physical and technical characteristics of the irrigation systems.

Introduction

Adams (1977, 1985) reported that irrigation was introduced in the Bakel Department along the Senegal river in Senegal in 1974, on the initiative of local farmers, with technical and financial support of OXFAM and War on Want. In each participating village, an association of male and femal farmers was formed, which laid out and managed an irrigation system. Soon the SAED (Société d'Aménagement et d'Exploitation du terres du Delta et des vallées du fleuves Sénégal et Falemé) and USAID (United States Agency for International Development) got involved in this irrigation development in the Bakel Department. This agency had to install, repair and maintain motorpumps, to assist in the lay-out of canals, structures and parcels, and to provide fuel and other inputs like NOK credit. Associations had to manage the irrigation system and to repay the agency in time and in proportion to the amounts of inputs received.

Keller et al. (1982), Miller (1985) and Bloch (1986) reported on a number of associations having difficulties with repayment. According to them and Adams (1985) this was caused by high costs and low benefits of irrigation. Ni Van Nguyen (1982) stated that inefficient irrigation water use, resulting in high fuel costs, was a common problem in the Bakel Department. As reasons for low irrigation efficiencies he considered water management constraints such as lack of proper irrigation scheduling, insufficient knowledge on water rights and on soil-water-plant relations, lack of well disciplined organization of irrigation, and the tendency of farmers to over irrigate their fields. Keller et al. (1982) argued that high irrigation water requirement was caused by technical deficiencies such as wrong choice of motorpumps, imperfect or absent surveys on topography and soil physics, and inadequate leveling and shaping of canals and plots. Droy et al. (1977) noted that irrigation was developed on 'fondé' soils with high infiltration rates. Keller et al. (1982) and Adam's (1985) considered high infiltration rates as a cause of high use of water and fuel.

The irrigation schemes of Gandé and Galladé will be comparatively analyzed on the relation between associations and the agency, the use of water and fuel, water management, and the physical and technical characteristics of the irrigation systems.

The Gandé association and the agency came often into conflict, because the level of agency support was low, and the association did not repay the agency in time. The Galladé association and the agency did not come into conflict, because the level of agency support was satisfactory and the association repaid in time. Repayment depended on profitability of irrigation, which was in Gandé lower than in Galladé, as the result of differences in use of water and fuel, which were in Gandé two times higher than in Galladé. This was not so much caused by differences in water management, but rather by differences in physical and technical characteristics of the irrigation systems.

Materials and methods

The research was conducted by Eveline van der Linden in Galladé and by Arjen Snaterse in Gandé, from October 1983 till May 1984, during the dry season. The researchers and their assistants lived in the villages and were present on the systems when irrigation took place. Every irrigation day they recorded: motorpump running hours; use of fuel; pumped discharge; plots irrigated, and irrigation times; canals, structures and tools used; overflow of and leakage through dikes; persons present and their activities. Pumped discharges were determined on the basis of volumes and filling times of the stilling basins. Also were measured: dimensions of structures, canals, dikes, parcels and plots, and infiltration rates. The canal system was measured with a levelling instrument. Infiltration rates were measured with gauges immediately after irrigation in

closed plots until all water was infiltrated. Communication between associations and the agency on the irrigation systems and in the villages was recorded. Additional data were gathered through interviews and informal talks with farmers and agency personnel, and through study of documentation.

Results: irrigation schemes of Gandé and Galladé

Villages, associations and irrigation systems

Figure 1 presents a map of the Senegal river and the location of the villages Gandé and Galladé. The villages counted respectively about 500 and 600 inhabitants. Local sources of livelihood were rainfed and flood recession agriculture, and, since 1974, irrigated agriculture. Gandé and Galladé cultivated, respectively 40 and 4 ha flood recession river beds during the dry season of 1983/84. Irrigation association members were adult male and female farmers, descending from all castes in the villages. The association of Gandé counted 54 female and 21 male members, and the association of Galladé consisted of 144 female and 38 male members. In 1975/76, when SAED and USAID got involved in irrigated agriculture, the association of Gandé counted 160 female and 55 male farmers, and the association of Galladé consisted of 137 female and 47 male members. Participation in irrigated agriculture had declined with 65% in Gandé, and had remained the same, with a little shift from male to female, in Galladé, because irrigated agriculture in Gandé was less profitable than in Galladé.

Figures 2 and 3 show the irrigation system of Gandé and Galladé. The system of Gandé covered 6 ha, of which 5 ha were irrigable. To the west of the system 3 ha of parcels were uncultivated because they were not irrigable. South of the

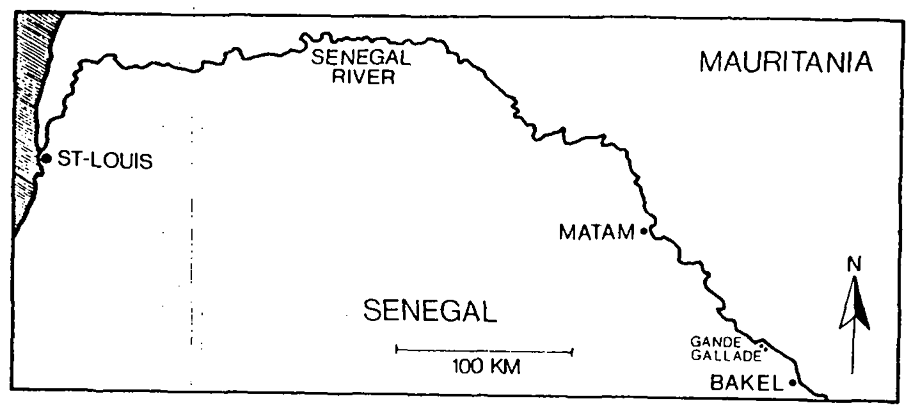

Fig. 1. Senegal river.

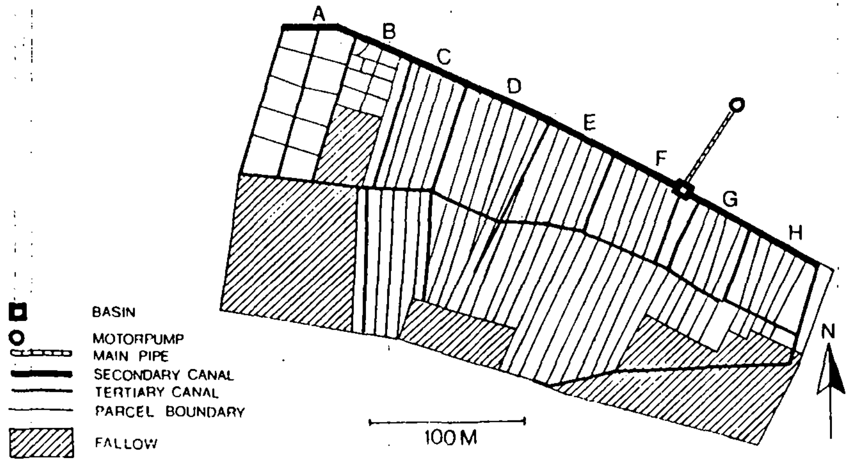

Fig. 2. Irrigation system of Gandé (1983/84).

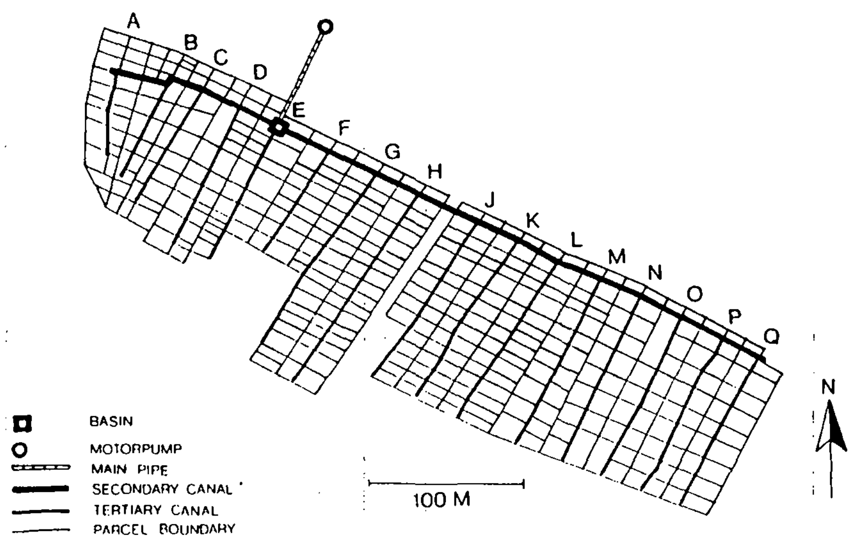

Fig. 3. Irrigation system of Galladé (1983/84).

system an extension of 10 ha had failed. The system of Galladé covered 5 ha, which were all irrigable. The system of Galladé was the only completely cultivated and irrigated system in the Bakel Department; all other systems were partly fallow. The research was executed during the dry season. Mainly corn, and also some vegetables (especially onion and cabbage, but also salad, tomato, carrot and aubergine), were cultivated in both irrigation systems.

Relation between farmer associations and the agency

The association of Gandé and SAED/USAID came frequently into conflict. Sources of conflict were repayment, replacement of the motorpump, and expansion of the irrigation system. The association did not repay the agency in time and owed the agency about US $4.000, which equals the amount of fuel used during three dry season campaigns of corn. The eight years old motorpump had broken down, and was not repaired in time by the agency, which caused water shortage and damage to the crop. The association had requested the agency to deliver a new motorpump, but the agency only agreed to do so on conditions of repayment, and expansion of the irrigation system, to make the investment cost effective: the concept was to irrigate 20 ha with one motorpump. The association refused to repay because irrigation was not profitable. The association did not want to enlarge the irrigation system because farmers were not increased (many had abandoned irrigation already) and because there was no proper site. Expansion south of the system had failed because the secondary canal was running upwards in the direction in which water was planned to flow. In absence of the irrigation engineer, and without topographic survey, map, design and leveling instrument, the agency's construction team had started digging the secondary canal, claiming that it could construct well functioning canals by eye.

The association of Galladé and SAED/USAID did not come into conflict because the association repaid the agency in time. The association owed the agency only US $52. Because irrigation was profitable, the association wished further expansion of the irrigated area and discussed this with the agency. After some problems with the seven years old motorpumps, the agency installed a new motorpump, with which the system could be irrigated twice as fast, to the satisfaction of the association.

Use of water and fuel

Table 1 presents the use of water and fuel. The registration period in Galladé covers one campaign, from the first irrigation before sowing till the last irrigation before harvest. All crops were about in the same growing stage. This was not the case in Gandé. After the motorpump breakdown, which caused water shortage and damage to the crop, cropping was continued on some parcels, but a new crop was started on other parcels.

Table 1 shows that the use of water and fuel per ha, were in Gandé over two times higher than in Galladé. Though other costs and benefits of irrigated agriculture were not systematically measured, some rough estimates can be given. Costs for motorpump spare parts, sowing seeds, fertilizers and pesticides

Table 1. Use of water and fuel in irrigation schemes.

	Gandé	Galladé
Start of registration period	16-11-83	26-11-83
End of registration period	27-03-84	05-04-84
Number of days	133	127
Average irrigated area (ha)	2.0	4.7
Pumping hours	240	321 (a) 42 (b)
Motorpump discharge (l/s)	50	31
Use of water (m^3)	40972	45231
Use of water (mm)	2049	963
Consumption of fuel (l/hour)	5.2	3.1 (a) 6 (b)
Consumption of fuel (l)	1248	1247
Costs of fuel (US $)	900	900
Costs of fuel (US $/ha)	450	192

a: Old motorpump
b: New motorpump

Not all water pumped is consumed.
The fuel used, however, is consumed.

could amount to US $160 per dry season. Thus, fuel costs were the greatest costs, especially in Gandé. The first motorpump was financed by the agency. It was expected that the associations would establish funds for financing the second and following motorpump. The value of irrigated production/ha per dry season could vary between US $400 and 800, though it could drop to some tens of US $ in case of motorpump calamities, water shortage and damage to crops.

Water management

Table 2 shows irrigation dates of sections of parcels. For Gandé only data for individual plots (sections C–H) are presented and not data for collective plots (sections A–B), because growing stages and irrigation scheduling differed between individual and collective plots.

A rotational water distribution was practiced. After each rotation an irrigation free period started, in which moisture conditions of soil and crop were checked, on the basis of which was decided when the next rotation had to start.

One secondary and two tertiary canals were in use at the same time. Canals, structures, dikes and dams were continuously and intensively checked, cleaned and repaired during irrigation, to prevent and reduce conveyance and distribution losses. In Gandé, 4 to 6 plots between 2 successive tertiary canals were irrigated at the same time. In Galladé, 2 to 4 plots at both sides of 2 successive tertiary canals were irrigated at the same time.

Table 2. Irrigation dates of sections of plots.

Gandé Date	Section C	D	E	F	G	H	Galladé Date	Section A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q
161183					O		171283	O	O	O	O	O											
17						O	18						O	O	O	o							
18	O						19									*	O	O	O				
19		O					20													O	O	O	O
20			O	o			27	O	O	O	O	O											
21				*			28						O	O	O	O							
27					O		29										O	O	O	O			
28						O	31													O	O	O	
30	O						070184	o															
0112		O					08	*	O	O	O	O	O	O									
02			o				09								O	O	O	O	o				
03				O			10												*	O	O	O	O
11					O		18	O	O	O	O	O	O	o									
13						O	19							*	O	O	O						
14	o						21											O	O	O			
15		O					22														O	O	O
16			O				29	O	O	O	O	O	O	O									
17				O			30								O	O	O	O					
25					O		31												O	O	O	O	O
26						O	0602	O	O	O	O	O											
30		o					07						O	O	O	O							
31		O	o				08										O	O	O				
010184				*			09													O	O	O	O
12		o					14	O	O	O	O	o											
13				O			15					*	O	O	O								
16					O		16									O	O	O	O				
17						O	18													O	O	O	O
18			o				23	O	O	O	O	O											
25		o					25						O	O	O	O							
26				O			26										O	O	O	o			
0202					o	o	27													*	O	O	O
06				o			0304–	O	O	O	O	O	O	O	O								
07			o				04									O	O	O	O	O	O	O	O
110	O	O	O	O	O	O																	
							12												O	O	O	O	O
							20						O	O	O	O	O	O					

Irrigations: O = complete; o = partial; * = complementary; – = new motorpump.

Actual Irrigation Gifts (AIG's) to parcels were not measured. But Average Pumped Irrigation Gifts (APIG's) to plots can be calculated as the quotient of pumped volumes and irrigated surfaces. Pumped Irrigation Gifts are Actual

Table 3. Average pumped irrigation gifts and irrigation intervals.

	Sum pumped volumes (m³)	Average irrigated surface (m²)	Sum APIG (mm)	Number of gifts	APIG per gift (mm)	Average irrigation interval (days)
Gandé						
A	9303	2809	3311	13	255	8.8
C–F	17309	15591	1110	7	159	12.9
G–H	5658	6605	857	6	143	15.0
Rest	8704	3440	2530			
Total	40972					
Galladé						
A–E	10055	14222	707	11	64	9.3
F–J	12502	15739	749	12	66	9.3
K–N	12933	14041	921	12	75	9.3
O–Q	8628	8178	1055	14	75	9.3
Rest	1059					
Total	45231					

Irrigation Gifts plus conveyance and distribution losses in canals. These losses partly reach no plots at all (e.g. infiltration in canal beds), and partly reach plots that are not in turn according the schedule. APIG's and Average Irrigation Intervals are presented in Table 3.

From Table 3 the following appears. First, irrigation gifts in Gandé were 2 to 4 times greater than in Galladé, which suggests that field application efficiency was in Gandé much lower than in Galladé. Irrigation intervals were in Gandé only 0.9 to 1.5 times greater than in Galladé. This illustrates in more detail that water use in Gandé was much higher than in Galladé. Secondly, the variation in APIG's between sections in Gandé was greater than in Galladé. Comparing sections far from the motorpump with sections near the motorpump: in Gandé, the APIG for section A was 1.8 times greater than for sections G–H, while in Galladé, the APIG for section K–N was only 1.2 times greater than for section A–E. This suggests that conveyance and distribution efficiency in Gandé was lower than in Galladé.

The irrigation systems of Gandé and Galladé consisted respectively for a quarter and a third of the surface of collective plots, cultivated by the association as a whole. The rest of the plots was used by individual male and female members of the association. In Gandé, collective plots (section A–B), male plots (sections C–F) and female plots (sections G–H) were distributed as separate parts on the system. In Galladé, collective, male and female plots were mixed over the system.

In both schemes irrigation was planned and executed by the male members of the associations. In Galladé three male working groups were formed with fixed memberships. Each irrigation day, another working group irrigated that part of the system which was in turn according the schedule. Working groups came in turn in a fixed order. There was no fixed relation between working groups and parts of the system. Control over irrigation of a plot was not in hands of the individual user, but in hands of a group of mostly other users.

In Gandé, collective and female plots were also irrigated by three male working groups, in the same organizational way as in Galladé. But male plots in Gandé were irrigated by the individual users themselves.

In Galladé, the average surface of a plot was 150 m². It took 10 to 20 min to irrigate a plot, and individual irrigation could not be organised efficiently. In Gandé, the average surface of a plot was 1150 m², it took 3 to 8 hours to irrigate it, and individual irrigation could be organised efficiently.

In some cases male users in Gandé tried to get more water by closing interdikes in their plots, which did not happen during irrigation of collective plots and women's plots in Gandé and also not during irrigation in Galladé. But irrigation gifts for male plots (sections C–F) were only somewhat larger than for female plots (sections G–H) in Gandé (Table 3).

Differences in use of water and fuel between both systems are not so much caused by differences in water management.

Physical and technical characteristics of the irrigation systems

The motorpump combination in the irrigation systems of Gandé and Galladé consisted of a 2 cylinder Lister motor and a Godwin centrifugal pump. The lifting height was in both systems 12.5 m at the lowest river level. Water was transported by steel pipes from the motorpump to the stilling basin, with losses of some liters per second, roughly estimated. Differences in use of water and fuel between the irrigation systems of Gandé and Galladé were not caused by differences in efficiency of motorpumps and pipes, but by differences in physical and technical characteristics of canals and plots.

Both irrigation systems were laid out very close to the Senegal river on relative homogeneous light 'fondè' soils with average in filtration rates of 75 mm/hr. An individual plot in Gandé was laid out as two strips, separated by tertiary canals parallel to the secondary canals. The average area of a strip was 450 m². A plot in the irrigation system of Galladé was laid out as a block with an average area of 150 m². Irrigation of a strip in Gandé took 1 to 4 hours, while irrigation of a block in Galladé took only 10 to 20 min. This explains why the field application efficiency was lower in Gandé than in Galladé, and why irrigation gifts were greater in Gandé than in Galladé.

Apart from differences in the layout of plots, Gandé and Galladé also differ in the layout and dimensions of canals and dikes, having an impact on the technical functioning of the systems.

Firstly the systems differ in the layout of secondary canals. Based on the dimensions of these canals, it can be calculated, using the Manning formula, that the capacity of the secondary canal in Gandé is about 3 $n^{-1}.l.s^{-1}$ and in Galladé about 4.5 $n^{-1}.l.s^{-1}$, in which n is the resistance factor. If $n \approx 0.030$ (well maintained canals) the capacity of the canals would be about 100 and 70 $l.s^{-1}$ respectively. Average discharges of the old motorpumps in Gandé and Galladé were 45 and 31 $l.s^{-1}$. Due to heavy weed growth in canals, especially in Gandé, capacities were thus highly reduced with $n \approx 0.07$. Differences in weed growth also resulted in frequent overflow of the secondary canal in Gandé, while this seldom occurred in Gallade. Installation of a new motorpump in Galladé with a discharge of 60 $l.s^{-1}$ necessitated deepening the canal and raising its dikes. Top width of canal dikes of the secondary canal in Gandé was 0.33 m and 0.52 m in Galladé. This explains why leakage through these canal dikes was greater in Gandé than in Galladé. Overflow and leakage of the secondary canal was reduced partly in Gandé by lining sections E and F (see Fig. 2). However, it was estimated that sections A and B only received half of the pumped discharge.

Secondly the systems differ in respect to tertiary canals. The original topography of the irrigated area of Gandé was much more uneven in Gandé than in Galladé. Due to adaptation of the layout to the existing topography parts of the tertiary canals in Gandé run upwards and thus cause overflow.

Conclusions and recommendations

This paper analyzed the irrigation schemes of the villages Gandé and Galladé in Bakel Department, Senegal. Each scheme was managed by a farmer association and an agency. The motorpump and canal system were managed by the association. Services which the agency had to provide to the association included: installation, repair and maintenance of the motorpump, assistance in the lay-out of the canals, structures and parcels, and delivery on credit for fuel and other inputs. The association had to repay the agency in time and in proportion to the amount of inputs used.

The association of Gandé and the agency came often in conflict, because the association did not repay in time, which was the main reason why the agency did not want to replace the defective, old motorpump by a new one. The association of Galladé and the agency did not come into conflict, because the association repaid in time, which was the main reason why the agency replaced the deficient old motorpump. Repayment depended on profitability of irrigation, which was in Gandé much lower than in Galladé, because use of water and fuel were in Gandé two time higher than in Galladé. This was not so much caused by differences in water management, but rather by differences in the physical and technical characteristics of the irrigation systems.

Infiltration rates were high, and the area of plots was in Gandé greater than in Galladé, which made field application losses in Gandé higher than in Galladé. Conveyance losses by leakage and overflow were in Gandé higher than in Galladé because the topography in Gandé was less regular than in Galladé, because dimensions of canals and dikes were smaller in Gandé than in Galladé, and because plant growth in canals was more intensive in Gandé than in Galladé.

For the development of the type of irrigation schemes analyzed in this paper the following recommendations can be given. Conflict-poor and economic-well performing irrigation schemes require amongst other things technically-sound hardware. This means that the irrigation systems have to be properly surveyed, designed and constructed. The detailed survey of topography, soil-physics and other relevant physical characteristics should not be omitted. These physical characteristics have to be exactly measured, and should not be roughly guessed by eye. All too often rough guesses prove to fail, and result in wrongly dimensioned hardware and inefficient irrigation water use.

Irrigation-systems with a design discharge of about 50 l/s, on soils with high infiltration rates of about 75 mm/hr, need an intensive network of tertiary canals, small plots of about 150 m^2, of which not more than about 4 should be irrigated at the same time. The top-width of dikes along secondary canals should be at least 0.50 m.

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Innovations in irrigation management and development in Hunan province
Financial autonomy, water wholesaling, turnover to farmers, mass movement labor

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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 – Renmimbi (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