WORKING PAPER 54

Growing More Rice with Less Water: Increasing Water Productivity in Rice-Based Cropping Systems

Progress of Research,
1 July 2001 to 30 June 2002

International Water Management Institute

FUTURE HARVEST
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International Water Management Institute (IWMI)
International Rice Research Institute (IRRI)
Wuhan University (WHU)
CSIRO Land and Water Griffith Laboratory (Australia)

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ACRONYMS USED

ABARE	Australian Bureau of Agricultural and Resource Economics
ACIAR	Australian Centre for International Agricultural Research
ASNS	Alternately submerged/non-submerged regime
AWD	Alternate wetting and drying irrigation technique
BHE	Bureau of Hydraulic Engineering
BIM	Bureau of Irrigation Management
CAU	Chinese Agricultural University, Beijing
CCAP	Center for Chinese Agricultural Policy
CF	Continuous flooding
CGIAR	Consultative Group on International Agricultural Research
CIMMYT	Centro Internacional de Mejoramiento de Maize y Trigo, Mexico
CS	Continuously submerged
CSIRO	Commonwealth Scientific and Industrial Research Organization
DAT	Days after transplanting
DSR	Direct seeded rice
EHWPMB	East Henan Water Projects Management Bureau
EMC	East main canal
ET	Evapotranspiration
FI	Flush irrigation
FIA	Farmer Irrigation Association
GCRPS	The ground cover rice production system
GIS	Geographic information systems
GMC	General main canal
GPS	Global positioning system
HD	Han dao
HELP	Hydrology for the Environment, Life, and Policy
HPWCRI	Henan Provincial Water Conservancy Research Institute
HZAU	Huazhong Agricultural University
IARI	Indian Agricultural Research Institute
IGP	Indo-Gangetic Plain
IPSWAR	International Platform for Saving Water in Rice
IRRI	International Rice Research Institute, Philippines
IWMI	International Water Management Institute, Sri Lanka
LAI	Leaf area index
LID	Liuyuankou Irrigation District
LIS	Liuyuankou Irrigation System
MC	Main canal
MODFLOW	MODular three-dimensional finite-difference groundwater FLOW model
MWR	Ministry of Water Resources
N	Nitrogen

NARS	National agricultural research system
NCIDD	National Center of Irrigation and Drainage Development, China
NMC	North main canal
NSW	New South Wales
OFC	Other field crops
O&M	Operation and maintenance
ORYZA	Crop growth model
PAU	Punjab Agricultural University
PI	Panicle initiation
PRF	Partially rain-fed
RB	Raised beds
RF	Rain-fed
RMB	Chinese Yuan
RS	Remote sensing
RW	Rice-Wheat
RWC	Rice-Wheat Consortium
RWS	Relative water supply
SEBAL	Surface Energy Balance Algorithm for Land
SMC	South main canal
S&P	Seepage and percolation
SRI	System for rice intensification
SSC	Saturated soil culture irrigation technique
SSC-RB	Saturated soil culture on raised beds
SWAGMAN	Farm-scale hydrologic economic model
TPR	Transplanting of rice seedlings
TTWS	Technology Transfer for Water Savings
UPLB	University of the Philippines at Los Baños
UPRIIS	Upper Pampanga River Intergrated Irrigation System
WHU	Wuhan University
WJX	Wenjiaxiang
WOTRO	Netherlands Foundation for the Advancement of Tropical Research
WRB	Water Resources Bureau
WSI	Water Saving Irrigation
WUE	Water-use efficiency
YR	Yellow river
YRDMD	Kaifeng Yellow River Diversion Management Section
ZAU	Zhejiang Agricultural University, China
ZIAB	Zhanghe Irrigation Administration Bureau
ZID	Zhanghe Irrigation District
ZIS	Zhanghe Irrigation System, Hubei, China

1. EXECUTIVE SUMMARY

The objectives of this project are to study the potential impact of water-saving irrigation (WSI) techniques on water savings and water productivity at field, system, and subbasin level and to assess the potential of technologies for widespread adoption.

The project is a follow-on to *Impact of Water Saving Techniques in China* (LWR1/98/66) that focused on the Zhanghe Irrigation System (ZIS) in Hubei Province and it has been expanded to include a second site in the drier Yellow river basin, the Liuyuankou Irrigation System (LIS) in Henan Province, and the Lower Murrumbidgee Catchment in Australia. An Australian partner, Commonwealth Scientific and Industrial Research Organization (CSIRO) was added to the team comprising the International Rice Research Institute (IRRI), International Water Management Institute (IWMI), Wuhan University (WHU) to strengthen our modeling and analytical capacity.

The project is structured around four well-defined subprojects dealing with a) farm- and field-level assessment of different water-saving techniques, b) system- and subbasin-level hydrological impacts of farm-level adoption, c) the effects of policies, institutions, management practices, and infrastructure on the allocation and utilization of water and on the incentives to adopt, and d) the extension of water saving practices.

Research Activities

Although the project began officially on July 1, 2001 the research, in fact, began following the end-of-project workshop in Wuhan in March 23–25, 2001. The team had a briefing and planning meeting in Kaifeng and identified potential research sites in LIS so that both ZIS and LIS could meet the spring planting dates. A second planning workshop was held at IRRI in April 2002 to review current progress and it set the agenda for the coming year. On the whole, all subprojects completed all the activities scheduled in the project document.

Subproject 1

The results of the 2001 field experiments indicate that WSI techniques, especially flush irrigation (FI) and partially rain-fed (RF) systems, can significantly reduce the amount of irrigation compared with farmer's practices without affecting yields. However, we need to be cautious in interpreting these results, particularly because of the shallow groundwater tables at both sites. Reducing the water flows and seepage in the canals, for example, through canal lining, could affect the groundwater tables. Under saturated conditions, the aerobic rice varieties gave significantly lower yields than the hybrids, and at the Tuanlin site (ZIS) the yield reduction was severe due to stem-borer attack. Field experiments are being continued at ZIS and LIS in 2002 and plans are afoot to use the data in the coming year to run the ORYZA2000 model for scaling-out the experimental results.

Subproject 2

At Zhanghe, the water balance for all scales including the main canal command area and the whole basin was established for the year 2000. Remote sensing and the use of *surface energy balance algorithm for land* (SEBAL) were used to calculate evapotranspiration (ET) and estimate yields. The results show clearly that ZIS is very effective in capturing and using rainfall and runoff. Approximately 12 percent of the combined rainfall and irrigation water flows out of the basin. But a further reduction in drainage outflows from ZIS may have negative downstream effects. The scope for additional real water savings in the Zhanghe Irrigation District (ZID) is limited.

At LIS, the main activities consisted of conducting water balance studies and collecting and analyzing data in preparation for modeling. Analysis using remote sensing is underway. More ground truth verification is needed. A series of digitized maps in GIS format have been prepared. Extensive training has been conducted on modeling at LIS and in Australia. Water balance measurements will continue at LIS during the coming year. A working surface-water and groundwater interaction model will be developed. Then this model will be linked with the field and meso-scale studies for evaluation of possible upscaling strategies.

In the Murrumbidgee watershed the work on farm modeling to determine recharge for different land uses is well advanced and the conceptualization of the nodal network hydrologic-economic model has been completed. The ACIAR-related hydrology work has helped Lower Murrumbidgee Catchment gain recognition as "First Global Reference Basin Status" by the UNESCO/WMO program on Hydrology for the Environment, Life, and Policy (HELP). Please see: http://www.clw.csiro.au/research/agriculture/irrigated/help/

Subproject 3

One important outcome of the April planning workshop was the decision to drop objective 3.1 as the needed data for analysis could not be obtained. Instead it was agreed to focus on the development and impact of farmer irrigation associations (FIAs) in Zhanghe. Survey work will be undertaken in ZIS in the coming year.

Long-term time-series (1968-2000) had been collected for LIS and the Kaifeng city on sector water use, area and yield of crops. A survey of 60 farms was conducted at LIS to determine the yields and water use for rice, corn and cotton. The data for both of these LIS studies are still being analyzed.

Subproject 4

A wide range of activities has helped strengthen our research capacity, publicize our work and extend our research results. These activities include meeting with stakeholders to present and discuss our findings, publications and press interviews, training activities, and the participation of team members in workshops. Several team members are also involved in complementary research activities. The next planning workshop will be held in Kaifeng in May 2003 in conjunction with the First International Yellow River Forum sponsored by IWMI and the Yellow River Commission.

Related Activities

As interest in water-saving technologies has grown, the number of complementary research and conference activities related to our project has increased. Team members have not only presented our findings at several workshops in the past year but are also involved in the planning of new research initiatives. Two activities are particularly worth mentioning in this executive summary.

- In April 2002, participants at the Water-Wise Workshop sponsored by IRRI and the Wageningen University agreed to establish an International Platform for Saving Water in Rice (IPSWAR) to facilitate the exchange of information on water saving research in rice-based cropping systems in Asia. Please see: http://www.irri.org/ipswar/about_us/ipswar.htm

- A new project "Potentials for Water-Saving Technologies in Rice Production: An Inventory and Synthesis of Options at the Farm Level" is being developed by IRRI in collaboration with IWMI, CIMMYT, Wageningen, CSIRO (Griffith) and various NARS in China, India and the Philippines. It will be funded for 3 years under IWMI's program for Comprehensive Assessment of Water Management in Agriculture. The objective is to carry out a stock-taking and synthesizing exercise covering various water-saving technologies for rice in Asia.

If properly integrated with our own research activities, these activities should be of immense value in extending our findings.

2. PROGRESS OF RESEARCH WORK

This project is a follow-on to *Impact of Water Saving Techniques in China (*LWR1/98/66) involving a research team composed of personnel from WHU, IRRI and IWMI. The initial research was focused on the ZIS in Hubei Province. The results are reported in Barker et al. 2001.

This project has been both expanded and strengthened by a) including a second site, LIS, in the drier environment of the Yellow river basin, b) exploring the water saving potential of two additional techniques, c) giving more attention to modeling to facilitate extrapolation of findings to other environments, and d) adding an Australian partner, CSIRO and a site in the Murrumbidgee watershed to strengthen our analytical and modeling capacity.

This report documents the research work done during the first year of our project. The project officially began in July 2001. However, the work was initiated immediately following the end-workshop of the first project in Wuhan, March 23-25, 2001 so that our two sites could meet the spring planting dates.

On March 26, the research team took the train from Wuhan north to Zhengzhou to initiate work on the new LIS. On March 27, we held discussions in Kaifeng where we were briefed by local staff from the Yellow River Management Division, LIS, Kaifeng city and County Water Resources Bureau, East Henan Water Projects Management Bureau, Huibei Water Conservation Experiment Station, and the Kaifeng City Bureau of Hydrology. The team members spent the next 3 days making field and office visits to obtain additional information and to begin identifying research sites.

2.1. Objectives of the Project

The ultimate goal of our research is to promote water saving management techniques in rice-based irrigation systems that sustain the environment and allow crop production to be maintained or increased in the face of growing demands for competing uses of water.

To accomplish this goal the project is organized around four subprojects, each with its own specific objectives:

Subproject 1 (field scale)

To assess yields, profitability and on-farm water balance components of three different systems of WSI: alternate wetting and drying (AWD), saturated soil culture on raised beds (SSC-RB) and aerobic rice variety with continuously flooded rice.

Subproject 2 (scaling up)

To scale up and assess the impact of alternate water saving and management practices at the farm, irrigation system and subbasin level.

Subproject 3 (policies, institutions and management)

To analyze the policies, technical infrastructure, institutions and decision-making practices that encourage on-farm and system water saving and reuse in ZIS and LIS.

Subproject 4 (extension of research results)

To begin to identify those regions where the potential for water saving and increased water productivity appears greatest, and to promote water saving practices and policies in those regions.

2.2. Research Activities

The crop-related research findings reported in this section are principally for the 2001 rice-growing season. Other activities include a) water balance, b) development and training in groundwater models, c) remote sensing, d) the analysis of long-term trends in cropping patterns, agricultural water productivity and inter-sectoral water allocations for LIS and Kaifeng city, and e) preparations for the 2002 rice-growing season.

The activities for subproject 1 are summarized by rice crop season, 2001 and 2002. Activities for subproject 2–3 are reported separately for ZIS and LIS. In the case of subproject 2, activities in Australia are also reported.

A 2-day workshop was held at IRRI on April 12 and 13 following the "Water-Wise" workshop and was attended by most of the research team. Each subproject reported on its research activities and findings and there were lengthy discussions on various problems encountered. The decision was made to change the activity under subproject 3.1 (see section 2.2.6 for details). Plans were discussed for the coming year. It was agreed that Randy Barker should travel to China in May to report our research findings to our stakeholders in ZIS and LIS and to seek their opinions.

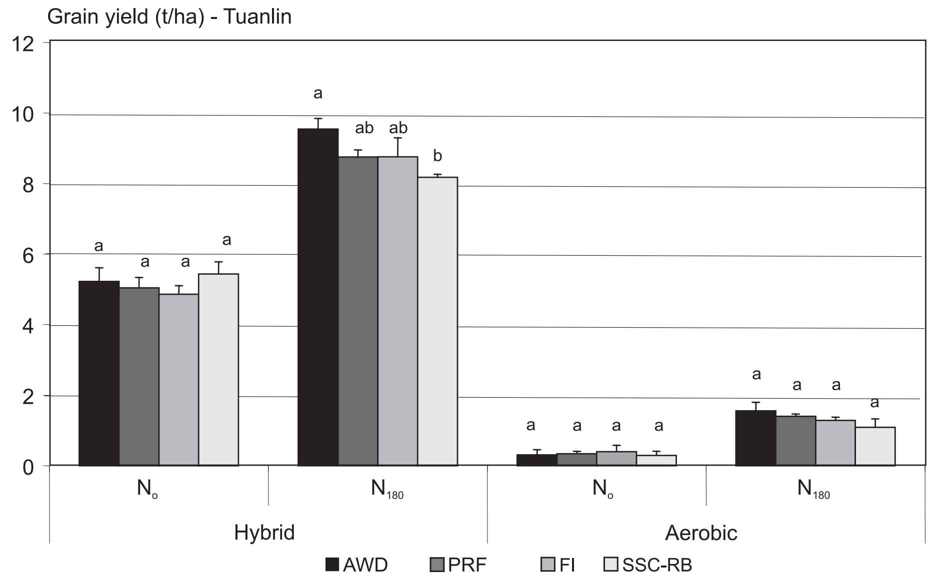
2.2.1. Subproject 1: Experiments in ZIS and LIS, 2001

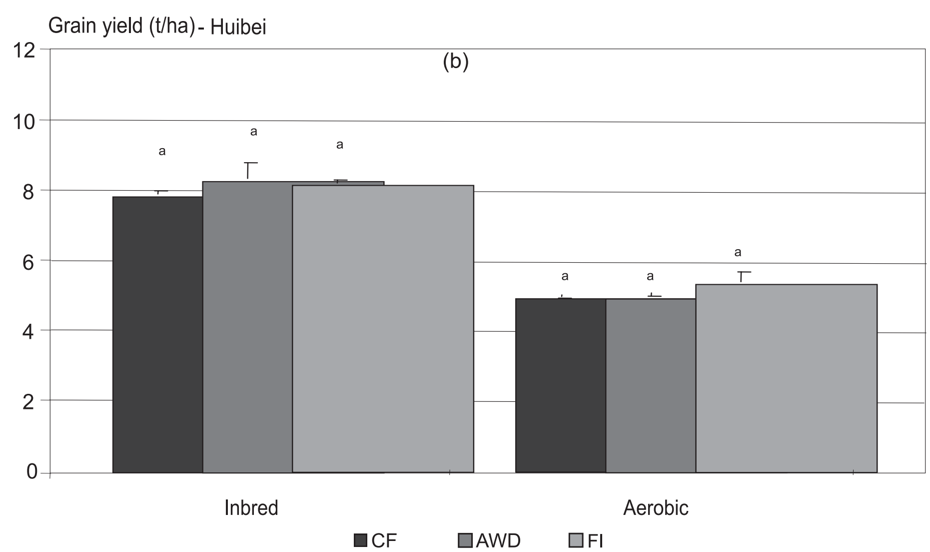
The objective of this research was to compare the effects of WSI regimes on yield, irrigation water input, water balance components and water productivity of aerobic and conventional rice varieties. The experiments were carried out in Tuanlin, Hubei Province, and in Huibei, Henan Province. The main plots at each site were irrigation water management regimes, ranging from rain-fed to continuously flooded irrigation. In the subplots, hybrid rice variety 2you-725 was compared with aerobic rice variety HD502 at Tuanlin; and inbred variety 90247 with aerobic rice variety HD502 at Huibei. The experiment in Tuanlin included two N-fertilizer treatments (180 kg N ha^{-1} and no N fertilizer) in the sub-subplots. The aerobic rice variety at Tuanlin was heavily infested with stem-borer, while that at Huibei yielded significantly less than the inbred rice variety due to reduced tillering and duration, in all water regimes (figure 2.1). Rice yields did not differ significantly among water treatments.

Continuous flooding had the highest irrigation water inputs, followed by alternate wetting and drying irrigation, saturated soil culture in raised beds, flush irrigation in aerobic soil, and rain-fed treatments (figure 2.2). Flush irrigation and rain-fed rice had the highest irrigation and total water productivity.

The lack of significant differences in rice yield between water treatments was probably due to shallow groundwater tables at both sites (figure 2.3). The shallow groundwater table depth in these experiments has implications for extrapolating the effects of the WSI treatments to larger spatial scales.

Figure. 2.1. Mean grain yields in Tuanlin and Huibei.





AWD = alternate wetting and drying, PRF= partially rain-fed, FI = flush irrigation, SSC-RB= saturated soil culture on raised beds, and CF=continuous flooding. (Note: The above acronyms and meanings are the same for figures 2.2 to 2.3.) N0 = zero nitrogen and N180=180 kg N ha^{-1}. In each variety and N treatment in Tuanlin and each variety in Huibei, columns with the same letters are not significantly different at 5% level.

Figure. 2.2. Mean water balance components in the period from transplanting to harvest in Tuanlin (N=6, in hybrid rice, from 2 N treatments and 3 replicates) and in Huibei (N=6, from 2 varieties and 3 replicates).

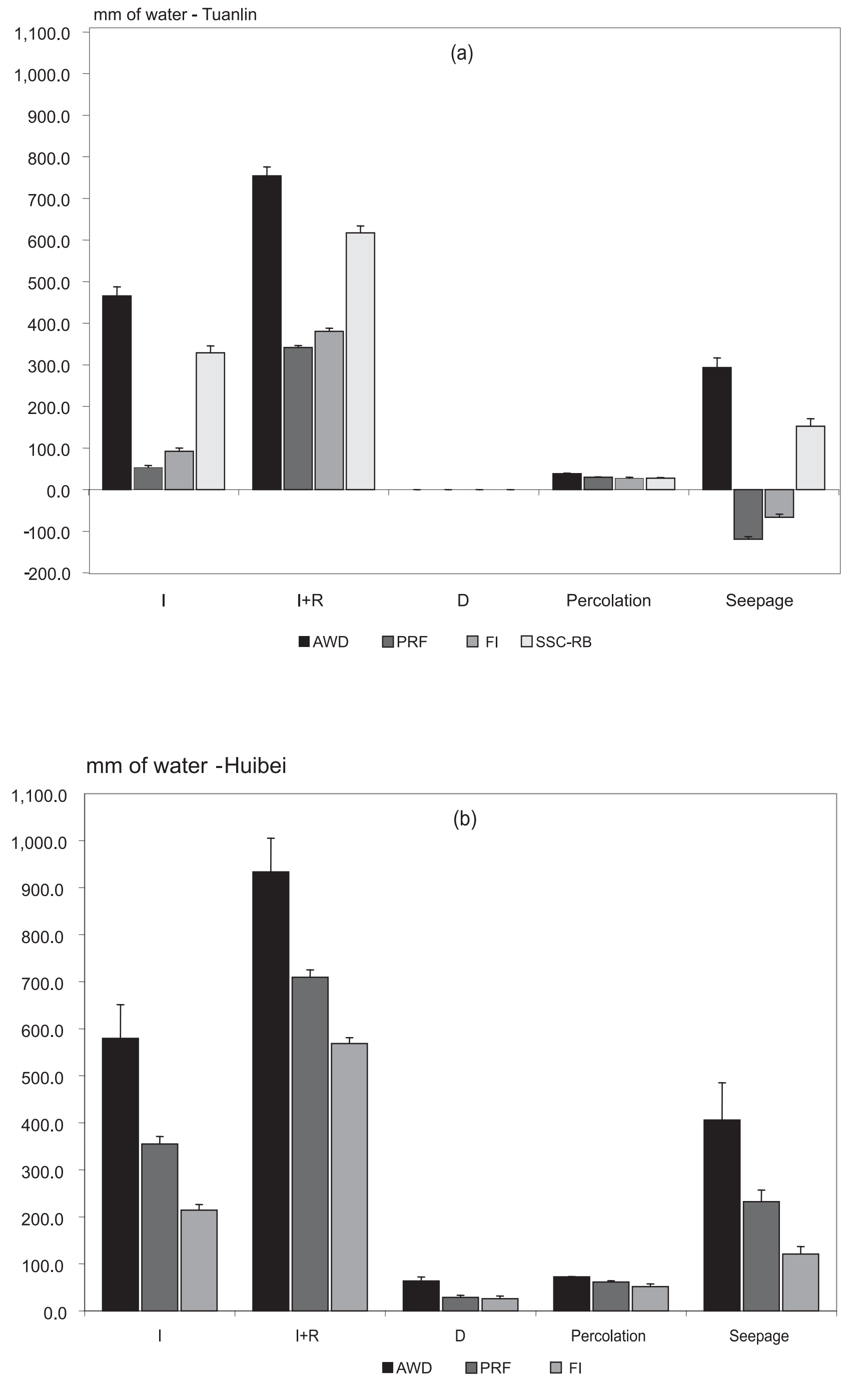
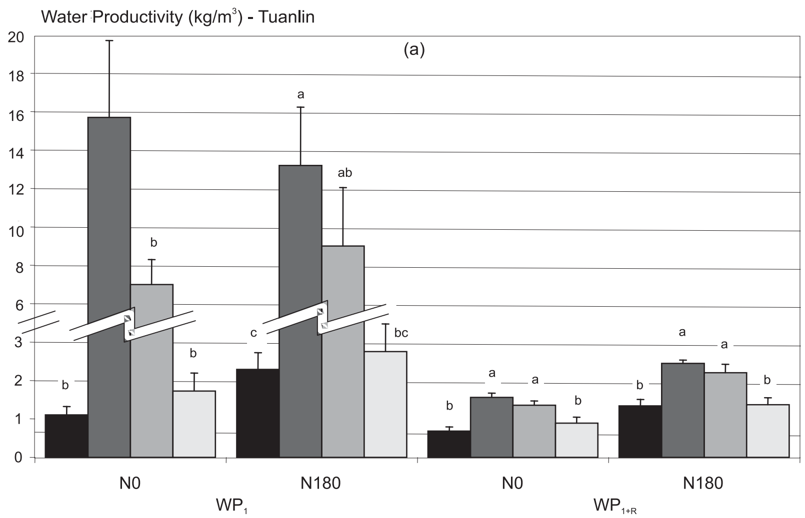
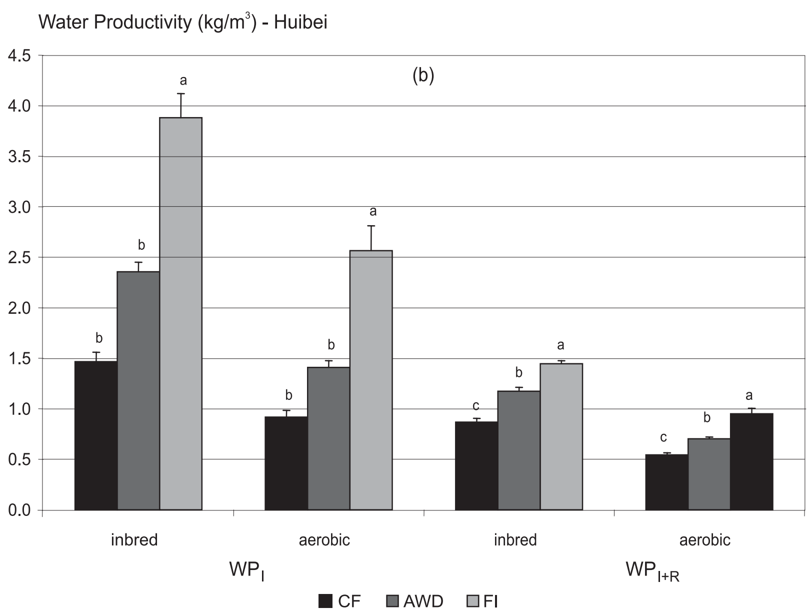


Figure. 2.3. Water productivities with respect to irrigation (WP_I) and to total water input (WP_{I+R}) in different water and nitrogen treatments (in hybrid rice) in Tuanlin and in different water treatments and varieties in Huibei. (In each nitrogen treatment in Tuanlin and variety in Huibei, columns with the same letters are not significantly different at 5% level.)





WSI, especially FI and PRF systems, can significantly reduce the amount of irrigation compared with farmers' practices, without affecting rice yield. This implies that there is a possibility to reduce the amount of water diverted to rice in the study sites. These findings and their implication are, however, site-specific and care must be taken in extrapolating them. First, our results were obtained in relatively small subplots in farmer fields that allowed us to keep the irrigation time short and the irrigation application efficient. In larger fields, the irrigation time is longer, which may result in larger seepage and deep-percolation losses. Second, at our sites, the groundwater tables were very shallow and the rice plants could directly take up groundwater to meet their demands for transpiration. The shallow groundwater tables in our experimental sites may be the result of continuously ponded water in surrounding rice fields that recharge the groundwater through deep percolation. The shallow groundwater table depth in these experiments has implications for extrapolating the effects of the WSI treatments to larger spatial scales. More study is needed on the interaction between irrigation and groundwater table depths before recommendation for large-scale application of WSI techniques can be made. With wide-scale adoption of WSI techniques, the groundwater tables may go down because of less groundwater recharge from the rice fields. Furthermore, seepage from unlined irrigation canals in our study areas may also recharge groundwater. Reducing the water flows in the canals may reduce seepage and effects on groundwater tables.

2.2.2. Subproject 1: Experiments in ZIS and LIS in 2002

Tuanlin, ZIS

The experiments conducted from 1999 to 2001 showed that there was hardly any, or no, effect of the aboveground water regime on crop performance because of the shallow water table. The main experiment this year was moved to a higher location close to the Tuanlin experimental station. The depth of the groundwater table will be kept around 1 m below field level by constructing two interception drains. This year we will have the following three activities in Tuanlin:

- An experiment on effects of different water regimes and nitrogen input on hybrid and aerobic rice at terraces 2 and 3 adjacent to the experimental station.
- Validating the findings of previous years by comparing AWD and RF treatments at the old site.
- Farmers' participatory testing of direct seeded aerobic rice on terrace 1 adjacent to the experimental station.

Activity 1. Main Experiment: Comparing the Effect of Water and N-Fertilizer Regimes on Performance of Hybrid and Aerobic Rice Varieties

The objectives of this study were to do the following:

- Compare rice responses to three water regimes under deep groundwater table: a) AWD, b) purely RF, and c) FI without standing water (aerobic soil).

- Evaluate the effect of groundwater level on the water balance components of the water (saving) regimes and compare the results with last year's balance under the shallow groundwater level.

- Compare the performance of aerobic and conventional hybrid varieties under different irrigation regimes.

- Investigate the soil N supply under different hydrological conditions and varieties.

The design of the experiment is a split-split-plot design in 4 replications. The main plots consisted of water regimes (AWD, purely RF, FI without standing water). In the subplots, V1 = hybrid variety (2you-725) and V2 = aerobic variety (HD 502) were assigned while in the sub-subplots, Nitrogen treatments 0-N and 180-N were assigned.

Fertilizers will be applied to assure there is no nutrient deficiency. The procedure followed in monitoring crop, soil and water parameters was the same as in 2001.

Activity 2. Validation of Experiments Conducted at Tuanlin

The objective of this trial was to validate the results of experiments conducted in previous years. The trial was laid out in randomized complete block design with two treatments: W1 = farmers' practice of AWD and W2 = purely RF; no irrigation, except during land preparation and transplanting.

This trial was to be managed by farmers. All cultural practices were the same as farmers' practices. The variety to be used was 2you-725 or any other locally available hybrid variety. Grain yield was the only measurement to be taken on the crop. The fertilizer amounts applied and dates of fertilizer application would be monitored. The dates of phenological development would be recorded.

Activity 3. Testing of Aerobic Rice in Farmers' Fields

Aerobic rice variety HD502 was tested in a farmer's field between the main experiment and the wall of the Tuanlin Experimental Station. Only grain yield would be monitored in this trial.

Huibei, LIS

The experiments conducted in Huibei 2001 showed that there was little, if any, effect of aboveground water regime on crop performance because of the shallow water table. Thus the location of the main experiment for this year was moved to an area south of the railway (Pan Luo Village, Xing Long Township) with a deeper water table. This year we have the following three activities in Huibei:

Activity 1

Experiment on effects of different water regimes and conventional inbred and aerobic rice at the new site. Effect of water and phosphorus on P uptake and grain yield. Zero N micro-plots within main experiment for determination of N-use efficiency and apparent recovery.

Activity 2

Simple experiment to determine potential yields and performance of inbred and aerobic variety in shallow water table conditions where rice can be kept continuously flooded.

Activity 3

Assist Prof. Wang Huaqi's group in farmers' participatory testing of direct seeded aerobic rice on selected farmers' fields.

Activity 1. Main Experiment: Comparing Effects of Different Water Regimes and Varieties (Inbred and Aerobic)

The objectives of activity 1 were:

- To compare responses of conventional and aerobic varieties to four water-stress regimes using flush irrigation (FI) without standing water.

- To study field water balance components in the four water regimes.

The experiment was conducted in a split-plot design with four replications (see figure 2). The main plots consisted of 4 irrigation regimes, W1 (FI, when soil water potential reaches –10 kPa), W2 (FI at –30 kPa), W3 (FI at –70 kPa) and W4 (RF with survival irrigation). The subplots consisted of 2 varieties, V1 (inbred variety, 90247) and V2 (aerobic variety, HD 502). Since the two varieties were to be transplanted at different dates, plastic sheets were installed to separate the subplots.

Additional Trials in Activity 1

Zero N micro-plots. In addition to the original plan, a 2 m x 4 m micro-plot with 0-N application was made in each subplot for determination of N-use efficiency and N-apparent recovery. Micro-plots were surrounded by bunds with plastic lining (30 cm below and 20 cm above the soil surface). Fertilizer application rates and timing for P, K, Zn and Fe are the same as in the main experiment. Water management is also the same as in the main experiment. Plant samples for chemical analysis will be taken as in the main experiment.

Water x phosphorus experiment. A side experiment adjacent to the main experiment was set up. This involves water x phosphorus treatments in split-plot design with 3 replications. The main plot is composed of two water treatments, W1 and W3 whose water regimes are similar to the main experiment. Subplots consist of 0-P (P0) and 100 kgP/ha (P100).

Water management is the same as in W1 and W3 in the main experiment. Fertilizer application rates for other elements are also similar to those of the main experiment. The variety used was HD 502. Measurements are similar to those of the main experiment. Tensiometers were installed at each main plot for indicating irrigation timing.

Activity 2. Simple Experiment to Determine Potential Yields and Performance of Inbred and Aerobic Variety in Shallow Water Table Conditions Where Rice Is Continuously Flooded

The objective of this study was to compare inbred and aerobic rice under potential conditions and compare them with last year's results. The experiment was conducted near the railway. The experiment was laid out in a randomized complete block design with three replications. The treatments were inbred rice 90247 (V1) and aerobic rice HD502 (V2). The field was prepared using standard techniques (with puddling) and with transplanting of rice seedlings (TPR). AWD will be imposed in both varieties with "mid-season drainage." There should be no water stress in either variety. Inbred rice was transplanted on June 15 while aerobic rice was transplanted on June 2, 2002. Fertilize rates and timing were the same as in activity 1. Perched water table depth, groundwater table depth, irrigation amount, sequential samplings for biomass and final yield *will be monitored.*

Activity 3. Farmer's Participatory Testing of Aerobic Rice

There were three sites identified namely:

- Shang-zhai, Duliang town (near the gas plant): 1 aerobic rice, 1 cotton and 1 maize.
- Same village as above. 1 aerobic rice, 1 maize and 2 lowland rice.
- Pan-Luo Village, Xing-long town (near activity 1): 2 aerobic rice, 1 maize and 1 cotton.

Most of the farmers have individual pumps so that the irrigation amount can be measured provided the pumps are calibrated. We requested the station staff to calibrate the pump discharge at least twice during the season. The same fertilizer application rates will be followed as in experiment 1.

Data on general properties of soils and weather: In both sites, samples for general soil characteristics will be taken before the first fertilizer application. Characteristics include *soil texture, CEC, exchangeable-K, -Na, -Ca, and –Mg, pH (KCl), pH (H_2O) in 1:1 soil:water, base saturation, soil organic matter content (or %C), total N* and *available-P.* Weather data will be collected from Tuanlin and Huibei stations, including minimum and maximum temperatures, irradiation (or sunshine hours), wind speed, rainfall, and vapor pressure (or relative humidity in combination with wet bulb temperature).

2.2.3. Subproject 2: Zhanghe

In ZIS, we continued measuring surface-water flows in the Tuanlin pilot area. Additionally, we included a larger meso-site to have a better perception of how water productivity changed over scale. For this larger meso-site we depended on secondary data from the Third Main Canal Administration. The data are not yet complete and analysis on this scale has still to be done.

We established the water balance on all scales, including the main canal command areas and the whole subbasin for the year 2000. For the larger scales, remote sensing (RS) was used as a tool and SEBAL (Surface Energy Balance Algorithm for Land) was used to calculate the ET (see Chemin et al. forthcoming, for more details). On the larger scales, the yield was estimated with the help of RS.

The results showed clearly that the ZIS with its possibilities of capturing rainfall and runoff in all the reservoirs within the system is very effective in capturing and using water productively. The surprising result was that only 12 percent of the combined rainfall and irrigation water releases flow out of the basin. A further reduction in drainage outflow from the ZIS may have negative downstream effects. The scope for additional real water savings in the ZID is limited. The results clearly indicate that scale effects are important for understanding and planning for water savings and water productivity.

2.2.4. Subproject 2: Liuyuankou

Surface Flow Component

Site selection. Four different scales were identified for water balance measurements: field scale (rice) (three fields), meso-scale, north of the railway scale, and the whole LIS. All boundaries were determined and measured with the Global Positioning System (GPS). Additionally, six micro-sites for the upland were selected south of the railway.

Measurements. After the boundary determination all the measuring points were identified and located with the GPS. The type of measuring structures was determined (most structures were cutthroat flumes, and some V-notch weirs) and all the measuring structures (14 for micro-sites, 24 for meso-sites and 13 for larger meso-sites) were constructed. In addition, the staff from the LIS lined a 600-m canal. At the micro- and meso-scale the surface flow measurements were done twice a day. For the larger meso-site (north railway track) and the LIS the surface flow measurements were done once a day. Due to the high sediment load of the irrigation water a current meter was used to calibrate the flow discharge in some measuring points. Before land preparation and after harvest, the soil water content in micro-sites was measured. Altogether 18 piezometers were installed in the meso-sites for groundwater table monitoring and were measured once every 3 days.

Remote sensing. Three Landsat 7 satellite images were bought for land use classification, and ET, biomass and yield calculation. The first preliminary results are ready, but more ground truth verification is needed. Furthermore, the exact boundaries of the LIS are to be included into the analysis to have a better estimate of the volume of ET and the total rice yield within the LIS. After the collection of spatially distributed rainfall data the water balance for the whole LIS can be established and the water productivity for rice can be calculated. It will be harder to calculate the water productivity for the other crops in the area because although the fields are small the diversity of crops is great.

Digitized maps. Detailed maps (#39) of the LIS area were collected in China. All maps are digitized and geo-referenced and are available in a GIS format.

Groundwater component. Shabaz Khan visited the LIS from 25 February to 10 March to develop the conceptual models at different scales, conduct training (discussed in section 4), and develop a work plan for further data collection and analysis. The data collection and analysis following his visit are described below.

Analysis of piezometric transect data. Seven sets of piezometric transect data were collected by the project team. Details of these data sets are given in table 2.1.

Table 2.1. Information of basic well lines.

No.	Location	Data period	Number of wells	Length (m)
BWL-1	West crossing the railway	May 1981–Dec.1992	28	4,832
BWL-2	East crossing the railway	Jan.1981–Jun.1986	28	4,740
BWL-3-1	Near east main canal, up left of meso-side; north to south	Jul.1981–Dec.1983, Jan.1985–May 1986	19	1,164.1
BWL-3-2	Near east main canal, up left of meso-side; west to east	Jul.1981–Dec.1983, Jan.1985–May 1986	15	789
BWL-3-3	Near east main canal, up left of meso-side; west to east	Jul.1981–Dec.1983, Jan.1985–May 1986	15	788
BWL-4	Baliwan	Jun.1985–Sep.1997	16	1,620
BWL-5	Xiaohe	Jan.1986–Aug. 1997	13	2,150

These data are currently being modeled using MODFLOW by Mr. Luo Yufeng, one of the M.Sc. students at the WHU under supervision by Cui Yuanlai and Shahbaz Khan. Mr. Yufeng will visit Australia for 6 weeks starting October 2002 to finish these studies.

Analysis of pump-testing data. Raw data on one historic pumping test has been digitized to evaluate adequacy of aquifer properties previously determined using the leaky aquifer theory. These data are being analyzed using a radial flow model.

Analysis of slug tests. Seven slug tests were carried out for the meso-site and 5 slug tests for the basic well lines 4 and 5. These data have been analyzed using the Bouwer and Rice Method to determine hydraulic conductivity of shallow soil layers. For the meso-sites the range of hydraulic conductivities varied between 2 and 44 mm/day and for the basic well lines 4 and 5 the range of values is 17 mm/day to 360 mm/day. These data are being used along with the other deep pumping tests and bore-logs to quantify lateral groundwater flows in the LIS area.

Lumped water balance studies. During a 2.5-month visit to CSIRO Griffith, Dr. Cui Yuanlai studied crop water requirement, surface water availability and groundwater requirements to meet crop demand for the LIS area. The delivery and loss parameters for the LIS channel system were based on related LIS literature values.

2.2.5. Subproject 2: Murrumbidgee

The following activities were carried out in Australia:

1. The ACIAR-related hydrology work has helped Lower Murrumbidgee Catchment gain "First Global Reference Basin Status" recognition by the UNESCO/WMO program on Hydrology for Environment, Life and Policy (HELP). Further details are available on: http://www.clw.csiro.au/research/agriculture/irrigated/help/

2. The Murrumbidgee component has a project steering committee, which reviewed project progress during three meetings held in August and December 2001 and in July 2002. Members of the steering committee included representatives from the Murrumbidgee Irrigation, Department of Land and Water Conservation, NSW Agriculture and CSIRO.

3. The GIS databases of aquifer lithology, soils, rice areas, channels and rivers, piezometric levels for different aquifers and hydraulic properties of aquifers have been completed.

4. A 3-dimensional surface-water-groundwater interaction model of the MIA has also been developed. This model contains detailed representation of surface-water features as well as groundwater dynamics of the study area.

5. Preliminary calibration of the surface-water-groundwater interaction model has been accomplished. The preliminary results show good comparison between the computed and observed hydraulic heads at a number of monitoring positions.

6. Three-dimensional visualizations of bedrock and alluvium isopacks have been developed to help understand groundwater dynamics.

7. The study area has been divided into a number of management zones and data loggers have been installed for detailed monitoring for 30 key shallow piezometers. These data are being measured on a 6-hourly basis and will be used to refine model parameters, such as unconfined storage and interaction between aquifers.

8. Data on water supply have been processed for each of the management zones.

9. Detailed SWAGMAN Farm model runs have been made for each of the management zones to determine recharge for different land uses.

10. Conceptualization of the nodal network hydrologic economic model has been completed.

2.2.6. Subproject 3: Zhanghe

An important outcome of the workshop of the research team at IRRI in April 2002 was the decision of the team (including leaders from all subprojects) to recommend that activity 3.1 from subproject 3 be replaced with an alternative activity that would better contribute to the fulfillment of the overall project goals. There are two reasons for this change: shortcomings of the original idea, which have become clearer with more experience and an attractive alternative that would better contribute to the overall project objectives.

In terms of shortcomings, our discussions led us to conclude that, because the factors determining water use are so complex, the impact of any change at the farm level (be it technology or institutions) is best compared on a "before and after" basis, if possible. Though in theory it is possible to assess the effect of an intervention by comparing two sites that are identical in important respects except for the intervention, in practice this is exceedingly difficult. For one parameter or another (e.g., topography, soil type, off-farm income sources), it nearly always turns out that any two chosen sites are different in important respects other than the intervention. This makes it very difficult, if not impossible, to assess the effect of the intervention. Our activity 3.1 as initially planned in the project document is an example of a cross-site approach, not a "before and after" approach.

Furthermore, activity 3.1 also envisioned collecting detailed data on water use from multiple sources from a large number of farmer groups. Analysis of the data from subproject 2 in the first project has just been completed, and our recent meeting have made us appreciate how difficult it was to construct these water balances.

At the same time, we discovered that farmer irrigation associations (FIAs) are spreading quite rapidly, much more rapidly than we had so far realized. This gives us a tremendous opportunity to study the effects these FIAs have on water productivity and farmer participation. The first FIA in China was established in the ZIS, and several more have since followed in many other irrigation districts. The first few FIAs in the ZIS were usually established due to specific conflicts among farmers and, by all accounts, these few initial FIAs have been successful at improving water productivity. Because of these successes, many new FIAs are being established each year in the ZIS, and many observers expect them also to increase water productivity. However, it is not clear that the experiences of the first few FIAs are applicable to other farmer groups, even within the ZIS. Are the first few FIAs merely a collection of several specific success stories, or will FIAs consistently generate increases in water productivity? In other words, do FIAs help primarily to address very site-specific (but relatively rare) problems, or do they address generic, widespread problems? This is an important question, as many donors (and farmers) are putting substantial capital into financing the widespread establishment of FIAs. Thus, it would be helpful to have a better understanding of the benefits and costs of these organizations.

Activity 3.1 has been revised as follows:

Objectives. To quantify the impact of FIAs in the ZIS on water productivity, irrigated area, farmer participation, and the benefits and costs to farmers and to the irrigation system.

Scientific output. Analyzing benefits and costs of FIAs from the perspective of the farmer and the system, with particular focus on the potential for saving water, increasing water productivity and expanding the irrigated area.

Potential application. Extending FIAs as a potential institutional innovation for increasing water productivity.

Because the FIAs are just starting, it would be possible for us to collect good quality data from the recent past on area, yields, water diversions and other key variables. We could then compare these data for the recent past with what happens in the next few years to make an assessment of the effects of FIAs on water productivity, fee collection and farmer participation. Our proposed methodology is contained in the work plan for 2002–2003.

In May 2002, Hong Lin, Pie Moya, David Dawe and Randy Barker in conjunction with officials of the ZIS conducted preliminary interviews with FIAs in the ZIS. The objective was to provide the basis for designing a questionnaire that will help determine the effects of FIAs on water productivity and on the collection of water fees. The group also conducted preliminary interviews with farmers and irrigation group leaders in the ZIS on the role of ponds in the adoption of water-saving technologies in rice production. These interviews will provide the basis for questionnaire design later this year.

2.2.7. Subproject 3: Liuyuankou Irrigation System

We collected and organized long-term time series (1968–2000) for the Kaifeng City Prefecture on water use (surface water and groundwater) by different sectors, area and yield of major crops. Professor Hong Lin of WHU conducted this activity with assistance from Guo Mao and Fang Xinhua of the Yellow River Water Diversion Division, Kaifeng city.

Changes in cropping pattern. The area and yield of major crops have changed remarkably over the past 30 years. Since the economic reforms in 1978, the area planted to winter wheat has expanded from 196,000 hectares to 290,000 hectares in 1998. However, most of this expansion had occurred by 1985; wheat area was largely stagnant from 1985 to 1998 (table 2.2). Among the summer crops, corn was historically the most important. Since the reforms, however, the area planted to cotton and peanut has expanded at the expense of food crops like corn and soybean and, today, these cash crops are more important than corn. Again, most of the transition was complete by 1985. As in China in general, yields of these crops have increased rapidly in the past 20 years. Most of this yield growth occurred in the first few years after the reforms but yields have continued to increase after 1985.

Table 2.2. Area of major crops, Kaifeng city, 1978–98 with annual average growth rates in selected periods.

	Wheat	Corn	Soya	Cotton	Peanut	Rice
1978 (1,000 ha)	196	93	34	34	13	8
1985 (1,000 ha)	270	76	48	75	66	5
1998 (1,000 ha)	290	66	24	86	86	9
Growth, 1978-85-(%)	4.7	-2.9	5.0	11.7	26.6	-7.2
Growth, 1985-98-(%)	0.5	-1.1	-5.1	1.1	2.1	4.8

During the past 30 years, the industrial and domestic sectors have captured a larger share of total water use, with their share rising from 13 percent in 1968 and 8 percent in 1978 to 37 percent by 2000 (figure 2.4). The percentage of water use for agriculture correspondingly decreased from 87 percent to 64 percent in 2000. The total irrigation water use has not declined, however, because groundwater extraction by all sectors has increased from 151 million m^3 in 1968 to 1.15 billion m^3 in 2000 (figure 2.5). This has allowed industrial and domestic demand to be met without cuts in supplies for agriculture. It is not clear how much longer this trend is sustainable. The total water use in Kaifeng has increased from 876 million m^3 in 1968 to 1,500 million m^3 in 2000, an increase of more than 70 percent.

Changes in water productivity. In the first 5 years after reforms, agricultural water use declined sharply, primarily due to reduced diversions from the Yellow river. One major reason for this decline in water use was that large amounts of water from the Yellow river (and its associated sediments) were diverted for land reclamation in this area from 1973 to1978. Once this strategy ended, water use declined sharply. However, by 1985, the total agricultural crop area had increased to 650,000 hectares (an increase of 13% compared to 1978) at levels of water use that were similar to those prevailing in 1968, before the land reclamation strategy began. This suggests that there were improvements in water productivity (in terms of planted area per unit water utilized) in the first few years after reforms, above and beyond those due to the end of the land-reclamation strategy.

Since 1985, however, agricultural water use has been essentially constant like agricultural crop area. Agricultural output has increased but it has been due entirely to increased yields per unit area. Thus, any gains in water productivity between 1985 and 1998 are most likely due to improved varieties and increased use of inputs such as fertilizer, and not to improved water management techniques.

Figure 2.4. *Water use by sector in Kaifeng, 1968-2000.*

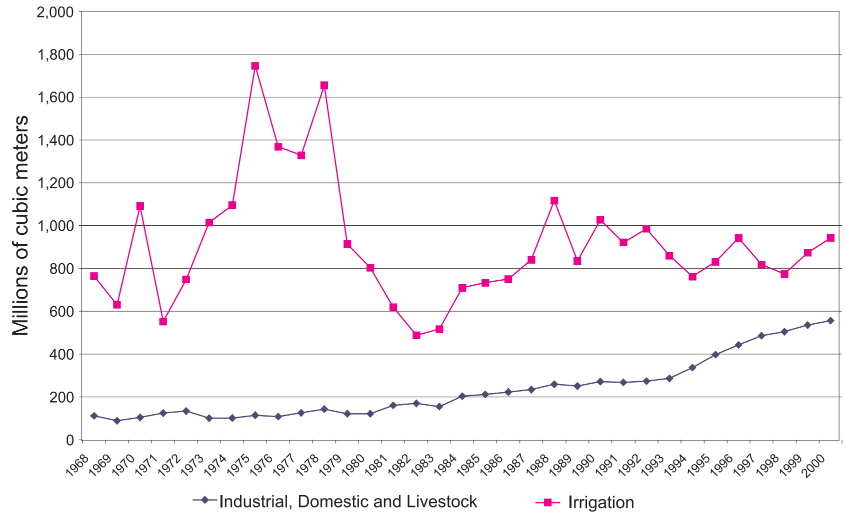
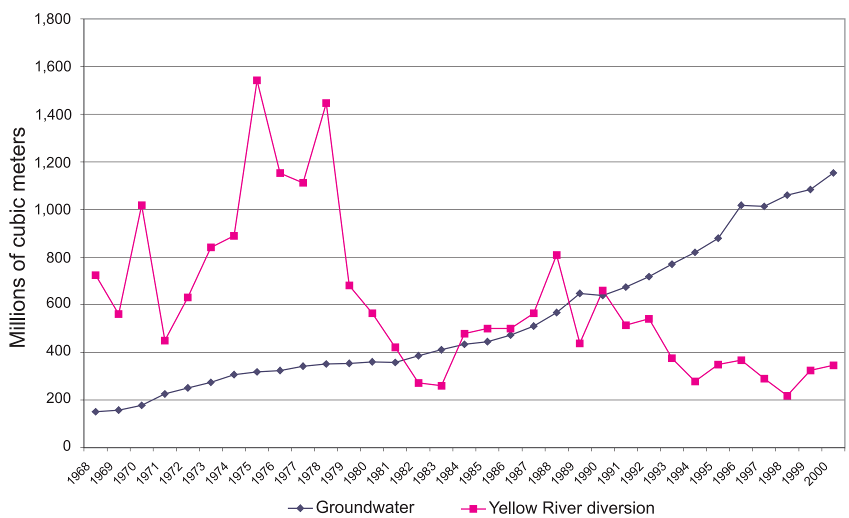


Figure 2.5. Water use by source in Kaifeng, 1968-2000.



Farm survey in LIS. We conducted a survey of 60 farmers in the LIS to determine yields and water use for rice, cotton and corn. Follow-up surveys will be conducted later this year to determine the relative profitability of these crops. Similar data will be collected for peanuts and soybean both of which are also important crops in this area. Pie Moya of IRRI traveled to the LIS in October 2001 for survey training and to assist Hong Lin with implementation of the survey.

2.2.8. Subproject 4: Extens ion of Research Results

A number of activities within, and closely linked to, the project will facilitate the extension of our research results. These include a) publications and press interviews, b) meetings with stakeholders, c) training, d) participation of team members in workshops, and e) the creation of a WSI platform on the web.

Research reports, papers and press interviews. More than a dozen research reports and papers were produced during the year, many of them presented at various workshops (see section 8). In addition, T. P. Tuong conducted an interview series on the project for the World Radio for the Environment.

Meetings with stakeholders. In May, Randy Barker, Hong Lin and Dong Bin traveled to the Zhanghe Irrigation System (ZIS) and Kaifeng (LIS) to report to our ZIS and LIS partners the findings of our research and to have discussions and feedback. At the ZIS, Chen Chongde, Deputy Chief Engineer, in referring to our graph showing decline in water use for agriculture and increase in water use for other purposes said that we had put ZIS on the international map. In Kaifeng, we were joined by Zhongping Zhu from the IWMI staff. TV reporters were also on hand. The discussions were particularly lively and lasted for more than 3 hours. Zhongping Zhu raised a number of important issues. Zhu began by saying that he was very impressed with the project in general and that he would be very happy if we could achieve this level of collaboration, dialogue and interaction in the other projects IWMI was undertaking in China. He indicated that the results of this project and what was said in the final report would be a valuable input into the policy dialogue in the Yellow River Commission. He then raised a number of issues as follows:

- What percent of the cultivated land is irrigated? We indicated that the remote sensing analysis by Wim Bastiaanssen should help answer this question and that Ronald Loeve plans to do some ground truth verification of Wim's results during his visit in June.

- How much outflow is there from the experimental fields? The 400-mm value for rice seems extremely low.

- What evidence is there that the Yellow River Diversion recharges groundwater? There is a need to filter out rainfall and groundwater recharge from irrigation. How can this be done? Groundwater modeling must be complemented with local knowledge to guide the model. This information on recharge is important for the Yellow River Commission policy.

- How do we face the fact that less water will almost certainly be diverted from the Yellow river in the future as demands grow elsewhere? Should we reduce irrigated area (as in Victory canal) or reduce the supply of water to existing areas?

- Although our focus is on irrigation, there should be room in our report for environmental concerns and impacts. For example, there are wastewater issues from the electrical power plant discharge and the paper plant in Qixian County. There were other issues such as heights of dykes along the Yellow river. Even if there are no in-depth studies we should at least address some of these issues.

Training. There were four training activities in Australia as follows:

1 *Shabaz Khan's visit to the Liuyankou Irrigation System (LIS) from 25 February to 10 March 2002.* Khan provided a LIS geo-spatial hydrological database to Dr. Cui Yuanlai and Mr. Lou Yufeng. A number of hands-on-training sessions were held on the following aspects:

- Working with the spatial information project, using rivers, towns, banks, channels and other themes.

- Incorporation of piezometeric data, using geographic coordinates and adding other attributes.

- Retrieval and reporting of geo-spatial information.

- Use of geo-spatial databases to input hydrological attributes.

Khan also had detailed discussions on water balance studies at different scales and on how to achieve a lumped and spatially distributed water balance at the system scale.

Finally, Khan held a seminar to the faculty and students of the Huanghe Technology College, Kaifeng. This presentation was attended by a number of individuals from the local water industry as well. Khan presented examples of SWAGMAN and hydrological models from Australia and Japan.

2. *Henan-Hubei Group Study Tour to Australia, 30 March–12 April 2002.* Fourteen researchers from Henan and Hubei Province participated in the study tour. A number of site visits and discussions were held. The objectives were to:

- Exchange progress on the project.

- Investigate farm irrigation and rice research in Australia.

- Investigate the policies and practices for the management of river basin water.

- Investigate the policies for supporting an international cooperative project of on-farm irrigation.

3. *Dr. Cui Yuanlai visited CSIRO Griffith from 11 March to 13 May 2002*. The activities included:

- Studying crop water requirements, surface water availability, and groundwater requirements to meet crop demand for the LIS area. A draft CSIRO technical report of lumped water balance was under review and will be refined by October 2002.

- Refining a GIS database and developing hydro-geological models of the LIS system to help assess system-scale water use efficiency.

4. *Dong Bin was at IWMI from 18 January to 19 March 2002.* He came with a computer and suitcase full of data. Together with Ronald Loeve he designed a database for all the data collected in the LIS. Dong Bin translated all the data from Chinese into English, put them into the database and started the first analysis and crosschecking of numbers. Some first preliminary results of the surface-water balance of the LIS were presented at the end of his stay.

Participation of team members in workshops. Team members attended three workshops closely related to our work and presented papers. A brief description of each of these workshops is presented in section 4.

Creation of a water-saving irrigation platform in the web. Participants in the Water-Wise Workshop held at IRRI from 8 to 11 April 2002 agreed to establish an IPSWAR. This will facilitate the exchange of information among scientists conducting water-saving research in different locations (see section 4.3).

3. PLANS FOR 2002–2003

The work plans for each subproject are listed below. As we move into the second year of the project, greater emphasis will be given to the work on modeling at both the field and the system level.

In May 2003, IWMI and the Yellow River Commission will sponsor the First International Yellow River Forum. We will be presenting five papers at the forum on our research in the LIS. In conjunction with this forum, the project will hold its annual planning workshop. Most plans discussed in this section were reviewed at our April 2002 planning workshop.

3.1 Subproject 1

The experiments implemented and described in section 2.2.2 are part of the work plan for 2002. The experiments are ongoing and the crops will be harvested at the end of September or early October 2002.

In 2002-2003, undisturbed soil samples for pF curve determination will be taken from puddled and non-puddled soil at four depths: 0-20 cm, 20-40 cm, 40-60 cm and 60-80 cm at both sites. At the same depth hydraulic conductivity [mm d^{-1}] will also be determined for puddled and non-puddled soil. These data will be used in running the ORYZA2000 model. Depending on the results of the experiment in 2002, plans for experiments in 2003 will be prepared in early 2003.

3.2 Subproject 2

All measurements will continue to be taken as in the previous year. Extra attention will be given to the measurements of surface water and the problems with the high sediment load in the water. Structures will be calibrated more often with a current meter and cleaned more often to remove excess sediments obstructing the flow of water.

Additional information will be collected on the use and organization of the well south of the railway line as well as on the Yellow river diversions, crop area and production.

By the beginning of 2003 a refined lumped water balance of the LIS with input from the regional groundwater model should be ready and the analysis of lateral groundwater flow from the Yellow river completed. With this information further integration of the measurements of surface water and groundwater modeling is possible.

For the groundwater modeling component of this subproject, the following activities will be undertaken:

- Refinement of lumped water balance and GIS reports by October 2002.

- Radial flow analysis of the data on pumping tests to determine the range of unconfined aquifer parameters completed by October 2002.

- Analysis of lateral flow completed by December 2002.

- Working on the regional surface-water and groundwater interaction model, to be completed by September 2002 to March 2003.

- Links of the regional surface-water-groundwater interaction model with the field and the ongoing meso-scale studies for evaluation of possible up-scaling strategies to be completed by March 2003.

3.3 Subproject 3

The tentative work plan consists of the following:

Prof. Hong Lin (WHU) is currently visiting IRRI (August 2002) to analyze long-term time series on water use and crop area and yields in the LIS and Kaifeng city.

- Follow-up survey of farmers to determine the relative profitability of various crops in the LIS - October 2002.

- Finalize questionnaires on the use of ponds and costs and benefits of FIAs in ZIS - October 2002.

- Conduct surveys on ponds and FIAs in the ZIS (November 2002 - March 2003).

The methodology for our proposed more-detailed study of FIAs in Zhanghe is as follows:

Our first step will be to provide a descriptive analysis (backed up with some quantitative data) of three of the first few FIAs in the ZIS and the beneficial effects they have had. We will also assess the costs of establishing these organizations and compare them with the benefits.

Our second step will be to test the hypothesis that more recently established FIAs increase water productivity, irrigated area and farmer participation. To do this, we will collect data on several years, both before and after the establishment of the FIAs, on a) rice area and yield for specific villages, b) water diversions from the ZIS, and c) water from pumping stations and rainfall. We will also conduct interviews with randomly selected farmers from these FIAs to understand their opinions and feelings about the FIAs, e.g., Do they feel they now receive a better quality of irrigation services? Do they feel they now have more voice in irrigation affairs? Are these benefits worth any additional costs they must now bear?

3.4 Subproject 4

The following activities are scheduled for the coming year:

1 The 24th International Rice Research Conference (IRRC) to be held in Beijing from 16 to 19 September 2002 will be part of the "International Rice Conference" (www.cgiar.org/irri/irc2002). Several scientists from our ACIAR project will attend/present papers at the IRRC (Tuong, Dawe, Bouman, Humphreys, Li Yuanhua) and will present selected results from the project.

2 The first International Yellow River Forum jointly sponsored by IWMI and the Yellow River Commission will be held in Zhengzhou from 12 to 16 May 2003. This will give us an opportunity to highlight our research on the LIS in neighboring Kaifeng. Our annual planning workshop will be held in conjunction with this event. The five papers to be presented at the Yellow River Forum will involve most of our team as coauthors.

3 A complementary project, "Potentials for Water-Saving Technologies in Rice Production: An Inventory and Synthesis of Options at the Farm Level" is being developed by IRRI in collaboration with IWMI, CIMMYT, Wageningen, CSIRO (Griffith) and various NARS in China, India and the Philippines. This project is funded for 3 years under IWMI's Comprehensive Assessment Program and will involve several members of our ACIAR team. This project should greatly facilitate the task of identifying regions where various water-saving technologies are suitable (see section 5.1 for more details).

4. RELATED WORKSHOPS

Interest in water-saving technologies is spreading rapidly in Asia and, hence, there is a growing interest in the findings of our own research work. In this section we report briefly on three workshops in which members of our research team were involved.

4.1 Workshop on Modeling Rice-Wheat Cropping Systems at CSIRO Land and Water, Griffith, Australia, February 25-28, 2002

This workshop focused on the ACIAR project in the Indo-Gangetic Plain. However, this project and our project in China are both investigating water management/bed layouts for rice and how to model their impacts on water productivity. (Section 5.1 reports on a proposal to link more closely the research on water-saving technologies in China and the Indo-Gangetic Plains). Romy Cabangon attended this conference and presented a paper by Cabangon, Lu and Tuong titled "Bed Experiments at IRRI and China: A Report" (see section 8 for full references).

4.2 International Conference on System of Rice Intensification (SRI) at the Chinese National Hybrid Rice Research and Development Center, Sanya, Hainan Island, China, April 1-4, 2002

This conference was organized by the Cornell International Institute for Food, Agriculture and Development, the Chinese National Hybrid Rice Research and Development Center, the China National Rice Research Institute, and the Association Tefy Saina, Madagascar.

SRI has been heralded as a new system with potential for raising yields and saving water. Dong Bin attended the conference and provides the following summary:

There were approximately 60 participants, and reports were presented by 17 countries, most in the initial stages of research. SRI is a set of practices and can be summarized in terms of three principles:

- Transplanting young seedlings, usually 8 to 12 days' old but certainly less than 15 days' old. Early transplanting preserves the genetic potential for profuse tillering and root growth. Traditionally, the farmers transplanted 30-35 days' old seedlings.

- Single seedling or two seedlings in a clump and planting seedlings with wide spacing. The space of 25 cm x 25 cm is recommended. But soil that is rich in biological terms and wider spacing (30 cm x 30 cm up to 50 cm x 50 cm) with fewer plants will give a higher yield. Traditionally, there were three or more seedlings in a clump with a space of about 10 cm x 10 cm.

- Maintain moist but aerated soil during the growth seasons by alternate wetting and drying irrigation or by application of small amounts of water daily to keep the field moist but never saturated.

The practices and advantages and disadvantages of SRI are listed below. The reported advantages of the SRI practice are:

- Less requirement of seeds than for traditional practice.

- Increase in tillering and higher number of effective tillers. The averages of 20-30 tillers per plant are easy to obtain, and some well-managed fields reach 50-70 tillers per plant.

- Grains per panicle are higher.

- Water saving is more than 50 percent.

- Rice yield increased by 50 to 100 percent and yields of even 100 to 300 percent have been achieved.

The reported disadvantages of the SRI practice are:

- Labor requirement is higher than for traditional practice.

- Organic fertilizer is not usually available.

- Weed growth is more than in traditional practice.

After the SRI conference, Dong Bin reports that he went to the ZIS and talked to the staff of the Tuanlin Experimental Station about SRI practices. They were very interested in it and asked him to send some materials.

Mr. Wang, Head of the Station and other members of the staff decided to do SRI experiments this year. Detailed arrangements for experiments have been made and the experiments will be carried out in several small plots (2 m x 2 m each). If the results are good they will continue in another year.

4.3 Workshop on Water-Wise Rice Production, IRRI, April 8-11, 2002

In April, 2002 the "Water Work Group of the Irrigated Rice Research Consortium" and the "Water-Less Rice Project" led by the Plant Research International of Wageningen University and Research Center coorganized the Water-Wise Rice Production Workshop. The workshop was hosted by the International Rice Research Institute. Other projects and consortia present included our project, "Growing More Rice with Less Water," "Ground Cover Rice Production System," "System of Rice Intensification" and the "Rice Wheat Consortium." Altogether there were 75 participants from 12 countries.

The workshop addressed the problem of water shortage in rice production in Asia and field-level technologies and management practices designed to save water and increase water productivity.

The workshop participants also endorsed the creation of an International Platform for Saving Water in Rice (IPSWAR) to facilitate exchange of information on water-saving research in rice-based cropping systems in Asia. Please see *http://www.irri.org/ipswar/about_us/ipswar.htm*

The proceedings of the workshop will be published as a book in 2003. The relevant ACIAR chapters in the proceedings include a) The effect of irrigation management on yield and water productivity of inbred, hybrid, and aerobic rice varieties by Lu, Cabangon, Tuong, Belder, Bouman, and Castillo, b) Water-use of alternatively submerged/nonsubmerged irrigated lowland rice by Belder, Bouman, Spiertz, Lu, and Quilang, and c) Field-level saving in ZIS and the impact on system level by Loeve, Dong, and Molden (see section 8 for full references).

5. RELATED PROJECTS IN THE PLANNING STAGE

There are three projects currently being planned which link closely with our work in China. Members of our research team will most likely be involved in these projects, which will facilitate the coordination among projects.

5.1 Potentials for Water-Saving Technologies in Rice Production: An Inventory and Synthesis of Options at the Farm Level

This project is being developed by IRRI in collaboration with IWMI, CIMMYT, Wageningen, CSIRO (Griffith) and various NARS in China, India and the Philippines. It will be funded for 3 years under IWMI's program for Comprehensive Assessment of Water Management in Agriculture. The objective is to carry out a stocktaking and synthesizing exercise covering various water-saving technologies for rice in Asia. The project will help integrate the research on water-saving technologies being carried out in India and China by a number of institutions and funded by ACIAR and other sources. Anticipated outputs include an "Inventory" book, a description and comparative analysis of farm-level WST, and a "Synthesis" book identifying the potentials and target domains of selected water-saving technologies and exploring the impact of adoption at higher spatial aggregation levels.

5.2 Water Saving and the Transition of Rice-Based Agro-Eco-Systems

This 3-year project is being developed by the Wageningen University in collaboration with Plant Research International and three universities in China and will be submitted for funding to WOTRO in the Netherlands. The research site will be the ZIS. The research is designed to build on our research experience and it is anticipated that, in addition to providing data, IWMI and IRRI will provide technical support. The objectives are to develop a) an integrated biophysical and bioeconomic modeling approach to support policy decisions in water-scarce rice-based systems, and b) procedures for designing cropping systems for increasing water productivity in nonflooded rice-based systems.

5.3 Institutions and Policies for Improving Water Allocation and Management in the Yellow River Basin

This 3-year project has been submitted to ACIAR by the Center for Chinese Agricultural Policy (CCAP), Australian Bureau of Agricultural and Resource Economics (ABARE) and IWMI. The overall goal of the project is to increase the productivity and sustainability of water use in the Yellow river basin by establishing equitable institutional arrangements that promote efficient water use and management. The specific objectives are to collect data on physical and socioeconomic characteristics, and on legal and institutional systems in the basin and to use these data to develop a simulation model to guide the development of more effective institutional arrangements and policy instruments.

6. CONCLUSION

The project is off to a very good start. Essentially all of the activities planned for the first year were successfully completed, the only exception being revision in one of the objectives of subproject 3 explained in the text. The interest in our research is growing by leaps and bounds and team members have been involved in a number of workshops and activities, which are helping to publicize our work.

7. LIST OF PARTICIPANTS

International Rice Research Institute (IRRI)

Dr. T.P. Tuong	Water Management Engineer
Dr. B.A.M. Bouman	Water Scientist
Dr. David Dawe	Economist
Ms. Pie Moya	Associate Scientist
Mr. Romeo Cabangon	Assistant Scientist
Mr. Paul Belder	Affiliate Research Scholar

International Water Management Institute (IWMI)

Dr. Randolph Barker	Principal Researcher
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Dr. Liz Humphreys	Senior Research Scientist
Dr. Shahbaz Khan	Research Director
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Dr. Cui Yuanlai	Associate Professor
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Mr. Dong Bin	Lecturer
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Miss. Chen Xiuhong	Lecturer
Miss. Zhu Xiuzhen	Ph.D. student
Mr. Yu Feng	Ph.D. student
Mr. Luo Yufeng	M.Sc. student
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Prof. Yang Baozhong	Senior Engineer, Section Chief
Mr. Liang Zhichen	Engineer

Kaifeng Yellow River Diversion Management Section (YRDMD) (Kaifeng)

Mr. Guo Mao	Senior Engineer + Vice Chief
Mr. Ma Shaojun	Engineer + Section Chief
Mr. Wang Furui	Senior Engineer + Vice Chief
Mrs. Fang Xinghua	Assistant Engineer

Huibei Water Conservancy Experimental Station (Kaifeng)

Mr. Wang Benjun	Director
Mr. Feng Yaohua	Deputy Director
And 18 staff	

Kaifeng City Hydrology Bureau (Kaifeng)

Mr. Rong Xiaoming	Chief Engineer

National Center for Irrigation and Drainage Development

Prof. Li Yuanhua	Deputy Director General

East Henan Water Project Bureau

Mr. Liu Junxiang	Director

Henan Provincial Water Resources Bureau (HPWRB)

Mr. Gao Jinsheng	Engineer, Department of Science and Technology, HPWRB
Mr. Feng Zong	Engineer, Department of Irrigation and Drainage, HPWRB

Kaifeng City Water Resources Bureau

Mr. Guo Guangping	Deputy Director

Kaifeng County Water Resources Bureau

Mr. Liu Yuhai	Director

Liuyuankou Irrigation District Management Division

Mr. Hao Niansheng	Director
Mr. Shi Xuewu	Deputy Director

Zhanghe Irrigation System (ZIS)

Mr. Cheng Chongde	Senior Engineer
Miss. Zhang Shijiu	Deputy Director, Department of Water Allocation, ZID
Mr. Liu Ming Zhong	Director, 4th Main Canal
Mr. Zhao Bin	Deputy director, 4th Main Canal
Mr. Song Daying	Head, Wenjiaxiang Section, 4th Main Canal
Mr. Wu Wenhai	Deputy Head, Wenjiaxiang Section, 4th Main Canal
Mr. Mao Ronggang	Head, Section in tail-end 4th Main Canal/Former Head, Wenjiaxiang Section, 4th Main Canal

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Mr. Wang Jianzhang	Director
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8. PUBLICATIONS AND REPORTS

Project Publications

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