Growing More Rice with Less Water: An Overview of Research in Liuyuankou Irrigation System, Henan Province, China

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ABSTRACT

China, with a large part of its population dependent on rice production, is promoting water saving irrigation techniques based on alternate wetting and drying (AWD) of the paddy soils. AWD techniques and other water-saving irrigation (WSI) practices are currently being adopted in different parts of China. However, there are a number of research questions surrounding the nature and success of adoption in China. At the same time there is growing interest in WSI technologies outside of China. To address these questions, we initiated research in the Zhanghe Irrigation System (ZIS) in Hubei Province in 1999. In 2001 the research was extended for four years and to include the Liuyuankou Irrigation System (LIS).

The ultimate goal of our research is to promote water 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. The project assesses the impact of water saving technologies on water savings and water productivity at field, system, and sub-basin level. At field-level controlled experiments are conducted in conjunction with farm surveys designed to assess the financial benefits of WSI. Continuously flooded rice is compared with three different systems of water-saving irrigation – AWD, saturated soil culture with raised beds (SSC), and aerobic rice varieties and culture. Field results are being scaled up to determine whether the water-saving potential of alternative management practices at field level results in water saving at irrigation system, and sub-basin levels.

The successful implementation of WSI requires a high degree of technical and institutional infrastructure to assure that water is delivered to farmers on time. The effects of policies, institutions, management practices and infrastructure on the allocation and utilization of water and on the incentive to adopt water-saving practices at farm level and at system levels are being studied.

The initial results based on research being conducted at both ZIS and LIS are site specific. To extrapolate the findings to other areas with differing conditions, a generic modeling approach (crop growth simulation, hydrology) is being developed that can link interactions between scales (field, system, and sub-basin) and between various important factors that may lead to real water savings. The results of this study will serve the growing demand for research and knowledge on alternative strategies for water savings in China and countries outside of China.

1. INTRODUCTION

The demand for freshwater for industrialization and domestic urban needs is growing rapidly. Less water will be available in the future for agriculture and for rice. Yet, more rice will be needed to feed a growing population. China is facing with an intense competition for limited water supplies for various uses. The per capita freshwater availability in China is only one-third of the world's average (Wang, 2000) and it is becoming increasingly difficult to develop new fresh water sources. Much of the water will have to come from water savings – and rice, a water intensive crop, is a major target for such savings.

On-farm water-saving practices have been scientifically developed over time to reduce irrigation application requirements and to improve the growing conditions, thereby increasing yield. Particularly in China a lot of research is done on *water-saving irrigation* (WSI) practices (Wang, 1992; Mao, 1993; Peng et al. 1997) contributing to the spread of *alternate wetting and drying* (AWD) irrigation in south China (Li et al.1999).

Over the past years considerable insights were gained, but many new issues remain to be researched in order to fully understand and quantify the multiple-scale effects on water saving and water-use productivity of WSI in China, and to derive implications for extension to other areas.

Problems that emerged from previous research are:

- For extrapolation of field experiments that yielded site-specific experimental results, to other environments, crop growth simulation models need to be refined and calibrated in contrasting bio-physical environments.
- Water balance studies gave valuable empirical information of the use and productivity of water at different scales (farm, meso, system) and a variety of factors have been identified that lead to water savings and increases in water productivity at the irrigation system level. However to better understand the interaction and contribution of these factors additional field studies combined with modeling are required.
- To extrapolate findings to other areas with differing conditions, a generic modeling approach is needed that can link interactions between scales and between various important factors that may lead to real water savings.

The objective of this paper is to provide a background to irrigation in Kaifeng Prefecture and the Liuyuankou Irrigation System (LIS), and to give an overview of the project "Growing more rice with less water: Increasing water productivity in rice-based cropping systems", which addresses the above mentioned problems. Other papers presented at this forum will provide more details on various aspects of the research and the research findings to date.

The project is located in Zhanghe Irrigation System, Hubei Province and in Liuyuankou Irrigation System, along the Yellow River in Henan Province. In this paper the focus will be only on Liuyuankou Irrigation System.

2. INTRODUCTION TO KAIFENG AND LID

To place the project area, Liuyuankou Irrigation District (LID), within an historical perspective and to better understand the current situation, we have initially gathered information on Kaifeng and data on trends in water use and allocation among sectors, and in crop production and yields covering the period 1968 to 2000. Data have been gathered for the entire Kaifeng City Prefecture and for the LID, one of four irrigation districts within the prefecture.

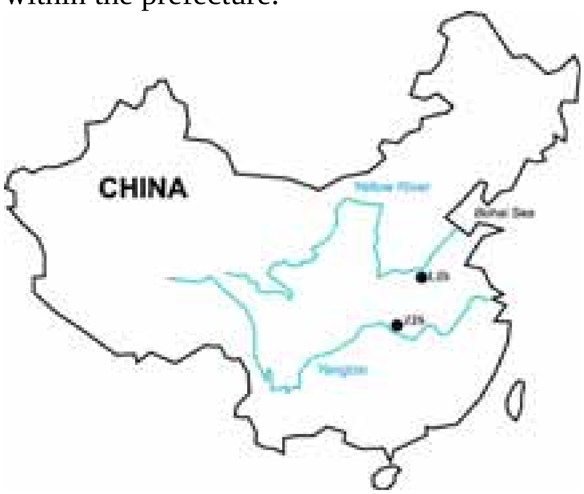


Figure 1. Location of LIS and ZIS in China.

2.1. Introduction to Kaifeng City Prefecture

Kaifeng City Prefecture is located on the south bank of the Yellow River, 70 km east of Zhengzhou the capital of Henan Province (Fig. 1). Kaifeng was the capital of seven dynasties and till 1854 the capital of Henan Province. Kaifeng City Prefecture consists of five counties and five urban districts with 94 towns or townships. The total area is 6644 km^2, including 363,300 ha of cultivated land. There are four irrigation districts in Kaifeng City Prefecture, from west to east, Zhaokou, Heigangkou, Liuyuankou and Sanyizhai Irrigation District. The designed gross irrigated area is 337,000 ha. By the end of the year 2000 the actual irrigated area was 327,000 ha, accounting for 90% of the cultivated land in Kaifeng City Prefecture. About 133,000 ha (40% of the actual irrigated area) is directly irrigated by Yellow River water.

The total population of Kaifeng City Prefecture is 4.57 million if which 3.77 million live in the rural areas. Kaifeng City is, apart from the Yellow River flood plane, located in the Huaihe River basin. The main soil textures in the flood plain are sandy loam and loam with an interlayer of clay. The elevation is 75 – 65 masl. The Yellow River bed is about 12 m higher than the alluvial plane of Kaifeng City Prefecture, which makes it easy to divert water by gravity to the irrigation districts.

Kaifeng is located in the semi-arid and semi-humid climate zone. There is a distinct division into four seasons and a clear influence from the southeast monsoon. The annual rainfall is 530 mm (IWMI water and climate atlas) and varies greatly from month to month and from year to year. Around 70% of the annual rainfall is concentrated in the flooding season from June to September (IWMI water and climate atlas). The annual average temperature is 14 ºC and annual reference evapotranspiration is 1150 mm (IWMI water and climate atlas). The main crops are rice, soybean, corn and peanuts, and in the winter season wheat.

2.2. Introduction to Liuyuankou Irrigation District

In 1958 Heigangkou Irrigation District was constructed and the current LID was part of the tail end of this system. In 1966 a new headwork at the Yellow River was constructed close to the village of Liuyuankou and the tail end of Heigangkou Irrigation District was renamed Liuyuankou Irrigation District and operated independently.

The irrigation district development can be divided into four stages.

1. First stage from 1958 to 1961:
   Yellow River water was diverted without limitation and flood irrigation method was practiced. The drainage ditches were silted and the groundwater table rose (in some areas up to 0.2 m below the surface), resulting in secondary salinization in a vast area.
2. Second stage from 1962 to 1964:
   Yellow River diversion for agriculture was completely abandoned, because of secondary salinization in the area. According to some investigations in 1962 about 49% of the gross cultivated land was severely affected by secondary salinization and farmers reported that the whole area looked white from salt.
3. Third stage from 1965 to 1987:
   Yellow River diversion for irrigation was resumed gradually. In 1965 rice growing was tested and found to be successful. In 1967 a drainage system was built which made it possible to leach salts out of the area. Farmers planted rice, basically the only crop that could survive the high groundwater tables and the salt was leached.
4. Fourth stage started from 1988:
   The irrigation district developed very fast in this period. From 1985 to 1988 a drought occurred and caused a decrease in rainfed crop production, but irrigated crop production increased. From this results local governments and farmers realized the importance of Yellow River water diversion for agriculture. In 1988 the south main canal was extended across the Longhai Railway, and the Yellow River water is conveyed to drainage and recharge ditches and then pumped for irrigation. From 1990 to 1992 and from 1996 to 1998, the Provincial Government invested heavily in construction canals and structures in the northern part of LID.

At the moment LID covers a total area of 56,100 ha (source: digitized maps in GIS and remote sensing). The total cultivated area is around 30,900 ha, of which 7,649 ha (Liuyuankou Irrigation System documents) is irrigated by gravity with Yellow River water. It is not easy to establish an exact figure for the area irrigated by gravity irrigation, but remote sensing data indicate that it might be around 12,000 ha (north of the railway) (Fig. 2). The total population is 293,500 in 11 townships and 82 villages in Kaifeng suburb, Kaifeng County and Qi County.

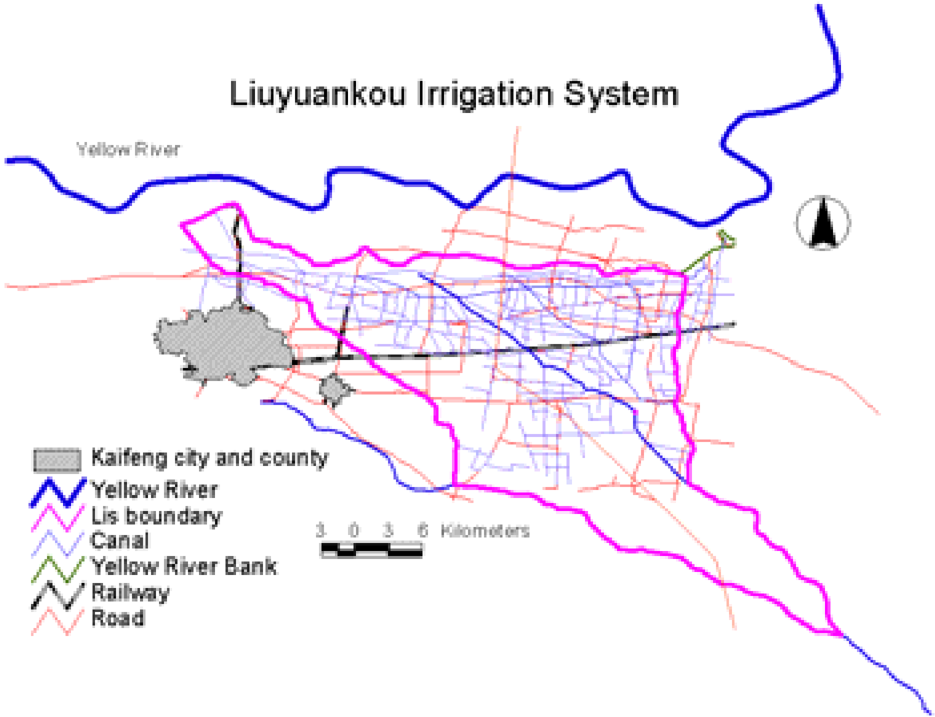


Figure 2. Layout of Liuyuankou Irrigation System.

The irrigation system consists of one trunk canal of 18 km long, three main canals with a total length of 34 km, two sub-main canals with a total length of 7.4 km and 13 branch canals with a total length of 66.2 km. There are around 290 hydraulic structures.

3. TRENDS IN WATER ALLOCATION AND CROPPED AREA, 1967-2000

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% in 1968 and 8% in 1978 to 37% by 2000 (Fig. 3). The percentage of water use for agriculture correspondingly decreased from 87% in 1968 to 63% in 2000. However the total irrigation water use has not declined as groundwater extraction by all sectors has increased from 151 million m^3 in 1968 to 1.2 billion m^3 in 2000 (Fig. 4). The percentage of total groundwater extraction used for the industrial and domestic sector increased from 3% in 1968 and 5% in 1978 to 35% by 2000 and picked up rapidly in the 1990ties. The increase in groundwater use 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 1500 million m^3 in 2000, an increase of more than 70%.

At the end of the 70ties there is a sharp decline in agricultural water use (Fig. 3) and Yellow River diversions (Fig. 4). A similar trend, although less obvious can be seen for the Yellow River diversion for Henan Province as presented by Dong et al. for this forum. It is not clear why the decline in diversions is more pronounced in Kaifeng City Prefecture, but looking into more detail to LIS Yellow River diversions (Fig. 6) the same trend of declining diversions can be seen. Most likely the other irrigation systems in

Kaifeng City Prefecture faced similar problems as Liuyuankou Irrigation System, old and deteriorated structures and lack of canal maintenance and a different institutional environment after the reforms.

Figure 3. Water use by sector in Kaifeng City Prefecture (1968-2000).

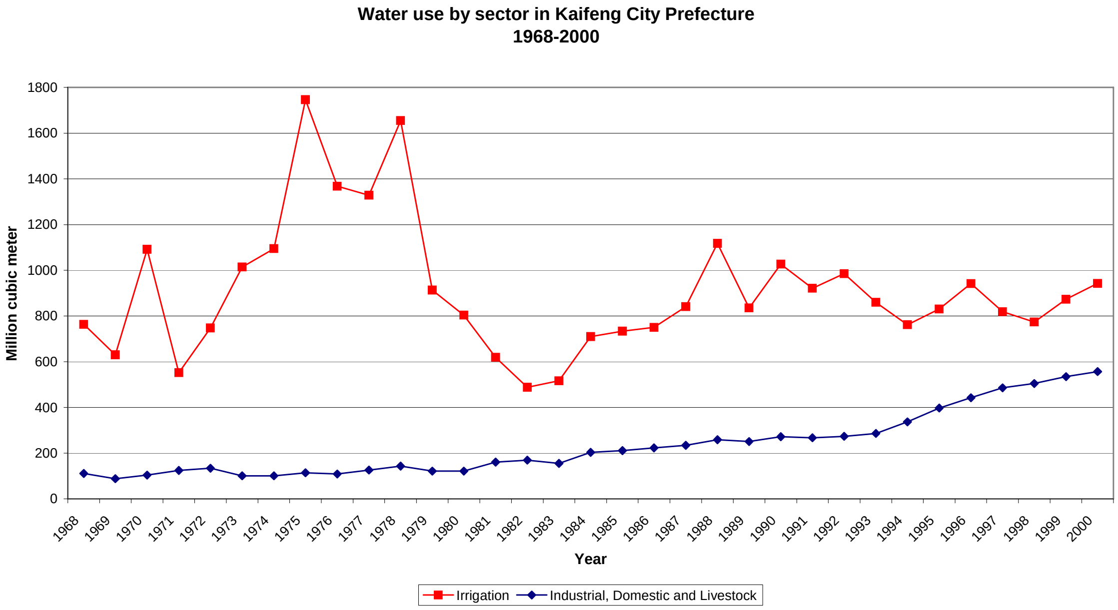


Figure 4. Water use by source in Kaifeng City Prefecture (1968-2000).

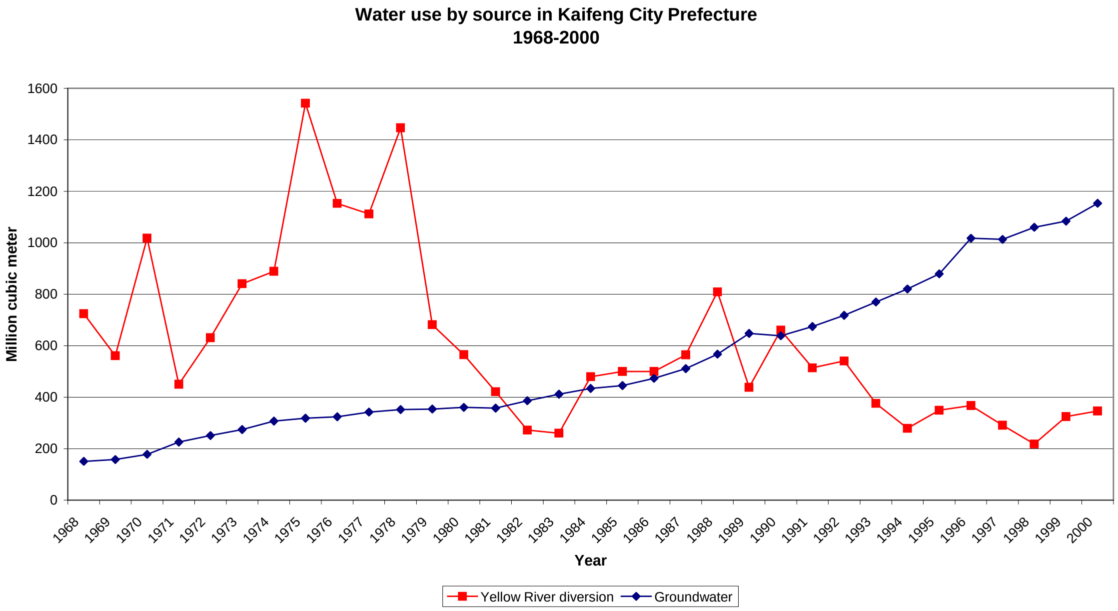


Figure 5 shows the trend over time of the planted area of wheat and wheat production in Kaifeng City Prefecture. The planted wheat area in Kaifeng City Prefecture increased over time, especially during the early 1980ties, contrary to the trend over time of the planted area of wheat in LIS (Fig. 8). Most of the expansion occurred by 1985 and the wheat area was largely stagnant from 1985 to 1998.

Figure 5. Planted area of wheat and production in Kaifeng City Prefecture (1968-1998).

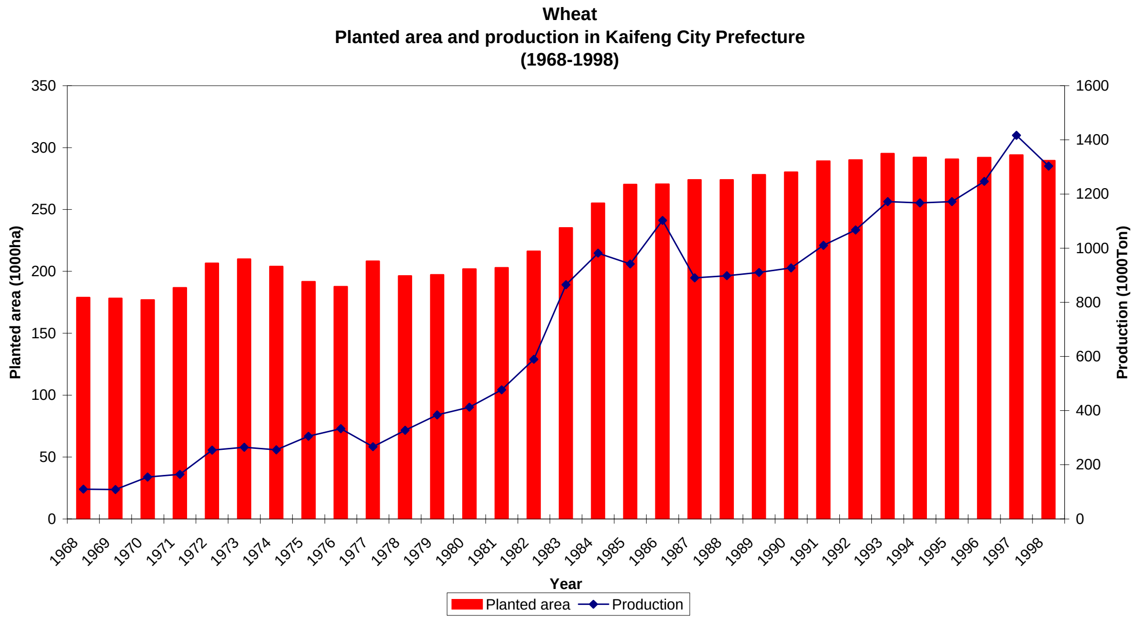


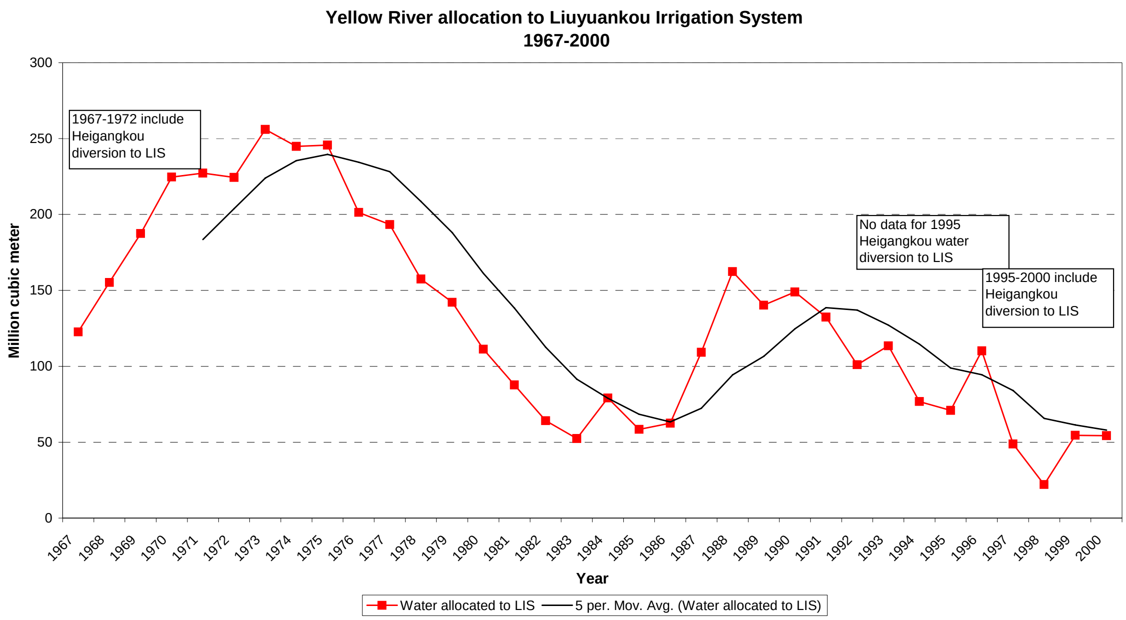
Figure 6 describes the trends of development stage three and four (see section 2.2) of Liuyuankou Irrigation System. The water allocation to LIS (Fig. 6) includes direct diversion from Liuyuankou headwork and diversion from Heigangkou Irrigation System. Yellow River diversions for irrigation were resumed gradually from 1965 onwards. In 1965 rice growing was tested and found to be successful and in 1967 a drainage system was built which made it possible to leach salts out of the area. Farmers planted rice, basically the only crop that could survive the high groundwater tables and the salt was leached. In the period 1968 -1973 (most likely also in 1967) there was water diverted from Heigangkou Irrigation System to LIS. In the 1970ties a lot of water was diverted from the Yellow River. There was no water fee for LIS or for the farmers.

Half way the 1970ies the trend reversed and water diversions dropped dramatically. The structures in LIS were about twenty years old and most of the structures made from brick and wood were in a bad condition and some gates and control structures were out of order. After the great reforms of 1979 the country opened up and townships didn't have enough resources for canal maintenance as they did before 1979. The canals and structures deteriorated even more and the discharge to the canals was reduced to keep them from breaching and maintain canal security.

In 1982 water fee collection was introduced, both for LIS to be paid to the Yellow River Conservancy Commission and for the farmers to be paid to LIS. Since the introduction of the water fee collection LIS has more money to spend on maintenance and better operation.

From 1985 to 1988 a drought occurred and caused a decrease in rainfed crop production, however irrigated crop production increased. Local governments and farmers realized the importance of Yellow River water diversion for agriculture. From 1985 to 1989 the Henan Provincial government and Kaifeng City Prefecture invested heavily in LIS to improve the “engineering facilities”. In 1988 the south main canal was extended across the Longhai Railway, and the Yellow River water is conveyed to drainage and recharge ditches and then pumped for irrigation.
In the period 1995-1998 the Yellow River changed its course to the north and it was very difficult for LIS to divert water. LIS cleaned the link canal with Heigangkou Irrigation System and received water this way.

Figure 6. Yellow River water allocation to Liuyuankou Irrigation System (1967-2000).



There is no data available about the groundwater use in LIS, however the number of wells in Kaifeng County (covering a major part of LIS) can be used as an indicator for the increased groundwater use. The increase in wells in Kaifeng county follows exactly the same pattern as in Kaifeng City Prefecture, where there is a strong correlation between number of wells and groundwater used. Therefore it is save to assume that the trend in groundwater use in Kaifeng County will be similar as in Kaifeng City Prefecture.

Figure 7. Planted area of paddy in Liuyuankou Irrigation System (1967-2000).

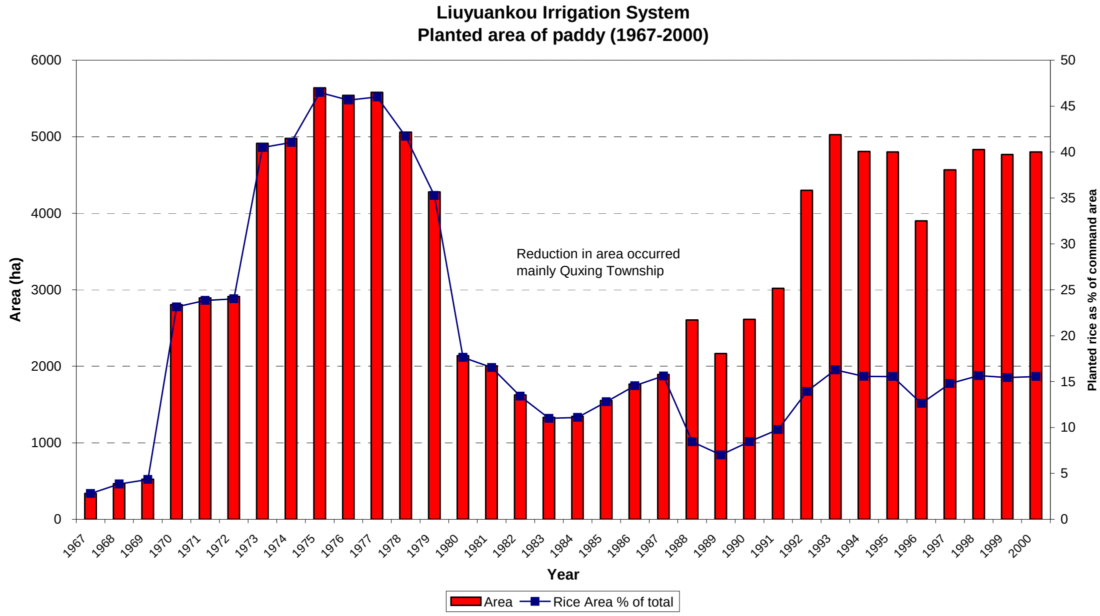


Figure 7 shows the rice area over time in LIS. When comparing water allocation to LIS (Fig. 6) and rice area planted it becomes very clear that there is a strong link between the two up to 1988.

From around 1965 Yellow River diversion resumed gradually and rice growing was tested and found to be successful. However most farmers where not familiar with rice growing practices, but planted rice, which was basically the only crop that could survive the high groundwater tables. The government and agricultural training institutes encouraged farmers to grow rice. The planted area of rice increased enormous in the 1970ties.

By the end of the 70ties the amount of water that could be diverted to LIS was reduced due to deteriorated structures and lack of canal maintenance. Most of the rice was cultivated in two townships (Duliang and Quxing township). During the gradual reduction of diversions, the townships went frequently to the county government to complain and find a solution for the water shortage. However at the end Quxing township, at the tail-end, had to give up areas with paddy cultivation, because of lack of water. The rice cultivation during the period 1979 – 1989 was mainly located in Duliang township.

Around 1985 the trend reversed and the rice area increased again. Heavy investments in LIS infrastructure improved the water availability and the extension of the south main canal increased the command area and rice area of LIS. The percentage of rice area in the command area of LIS is more or less stable since half way the 1980ties, which a small drop just after the extension of the south main canal. The area south of the railway is mainly irrigated by pumping and less rice is grown here.

Figure 8. Planted area of wheat in ha and as percentage of the command area, Liuyuankou Irrigation System (1967-2000).

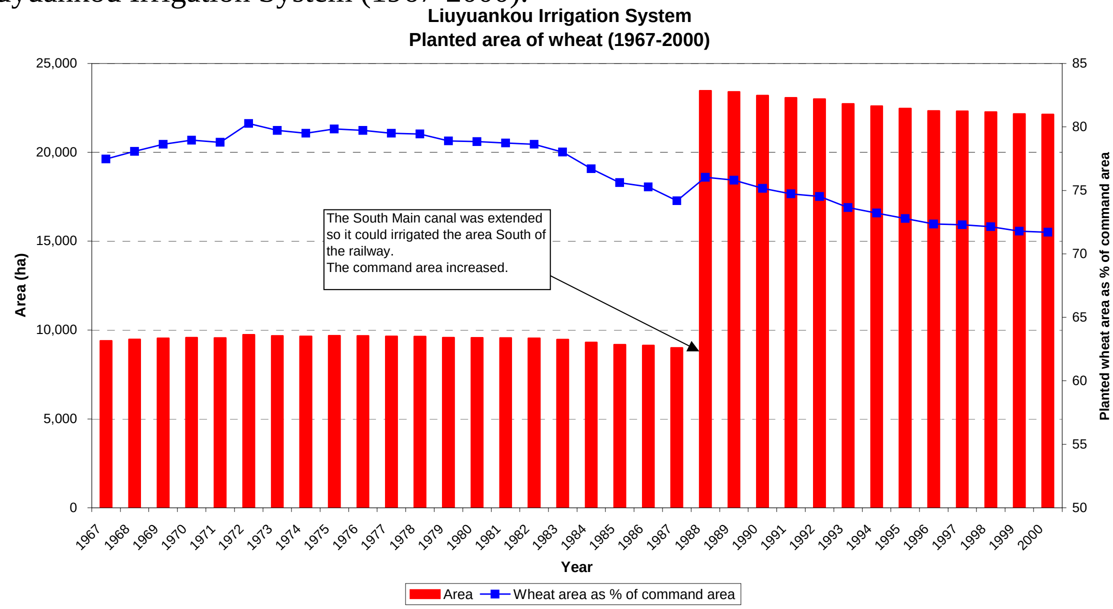


Figure 8 shows the area of wheat in LIS over time. Striking is the enormous increase in area in 1988. A similar increase is observed for other main crops as cotton and maize. In 1988 the south main canal was extended south of the railway and the command area of LIS increased. Additionally in the late 80ties the definition of irrigated area changed from purely served by gravity irrigation to gravity and pumping irrigation. A similar jump in irrigated area can be seen for Henan Province where in the 80ties about 467,000 ha was irrigated which suddenly jumped to 1,200,000 ha irrigated area.

According to local sources the cultivated area remained fairly constant over time and is expected to decrease slightly over time due to population pressure and urbanization. We see this trend in the area planted by wheat as a percentage of the total command area (Fig. 8). However to the planted area of wheat in Kaifeng City Prefecture (Fig. 5) shows a steady increase over time and as expected there is no jump in 1988 as in LIS.

Table 1 shows the planted area of major crops on Kaifeng City Prefecture and average annual growth rates (3 years moving average) and table 2 gives the same for Kaifeng County, which covers a large part of Liuyuankou Irrigation System. The annual growth rates for wheat and soybean show a similar trend both in Kaifeng City Prefecture and Kaifeng County. 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. His seems particularly true for Kaifeng City Prefecture where the annual growth rates for cotton and peanut are higher, especially in the period 1978-1985, than in Kaifeng County. In Kaifeng County the corn area remained fairly stagnant, contrary to Kaifeng City Prefecture where there is a significant reduction in area.

Table 1. Area of major crops in thousands of hectares and annual average growth rates (3 years moving average), Kaifeng City Prefecture (1978-1998).

Year	Wheat	Corn	Soya	Cotton	Peanut	Rice
1978	196	93	34	34	13	8
1985	270	76	48	76	66	5
1998	290	66	25	86	86	9
Annual growth[1] (%), 1978-85	3.6	-1.7	9.0	16.2	19.4	-7.2
Annual growth[1] (%), 1985-98	1.1	-1.0	-5.5	0.3	5.1	4.8
Annual growth[1] (%), 1978-98	2.0	-1.2	-0.6	5.6	9.9	

[1] Three years moving average, except for rice.

Table 2. Area of major crops in thousands of hectares and annual average growth rates (3 years moving average), Kaifeng County (1978-1998).

Year	Wheat	Corn	Soya	Cotton	Peanut	Rice[1]
1978	38	18	8	4	6	
1985	51	16	12	6	18	
1998	59	17	5	9	27	
Annual growth[2] (%), 1978-85	2	0.1	11.5	9.0	11.4	
Annual growth[2] (%), 1985-98	1.3	0.7	-7.7	0.1	4.9	
Annual growth[2] (%), 1978-98	1.5	0.5	-1.4	3.2	7.1	

[1] No data available about area planted with rice.
[2] Three years moving average.

Similar data is available for LIS (table 3), however caution should be taken by comparing this data set with the data from Kaifeng City Prefecture and Kaifeng County. The biggest problem in the LIS data set is the expansion of the command area in 1988, which gives a distortion in the absolute amount of ha in the period 1985-1998. Even if the planted area is taken as a percentage of the total command area caution should be taken, because a different type of area, with lesss gravity irrigation, was added to LIS. Contrary to Kaifeng City Prefecture and Kaifeng County the annual growth rate of the area planted by wheat shows a slight decrease in LIS. The annual growth rate of the planted area of corn is very high in the period 1978-1985 contrary to Kaifeng County where the growth rates are marginal and Kaifeng City Prefecture where there is a negative growth rate for corn.

As in Kaifeng City Prefecture the area planted to cotton has expanded at the expense of food crops like soybean. The annual growth rate for the period of 1978-1985 for cotton is very high for LIS, and much higher than Kaifeng County, but very much in line with Kaifeng City Prefecture. The planted area of soybean in LIS started decreasing already in the period 1978-1985, much earlier than in Kaifeng County and Prefecture.

The dramatic reduction in rice area after the reforms to less than one-third of the 1978 value in 1985, is discussed above, and was due to a reduction in Yellow River water diversions to LIS causing serious water shortage induced by lack of canal maintenance and a different institutional environment.

Table 3. Area of major crops in thousands of hectares and as percentage of command area and annual average growth rates (3 years moving average), LIS (1978-1998).

Year	Wheat		Corn		Soya		Cotton		Rice	
	1000 ha	% of total	1000 ha	% of total	1000 ha	% of total	1000 ha	% of total	1000 ha	% of total
1978	9.6	79	2.1	17	2.2	18	1.2	10	5.1	42
1985	9.2	76	3.2	26	1.3	11	3.2	26	1.6	13
1998	22.3	72	6.2	20	1.0	3	9.8	32	4.8	16
Annual growth[1] (%), 1978-85	-0.5	-0.5	15.5	15.5	-7.0	-7.0	15.3	15.3	-17.4	-17.4
Annual growth[1] (%), 1985-98	6.9	-0.5	5.0	-2.3	-2.1	-8.9	9.0	2.1	9.2	1.6
Annual growth[1] (%), 1978-98	4.3	-0.5	8.6	3.6	-3.8	-8.2	11.7	6.6	-1.0	-5.5

[1] Three years moving average.
No data available about area planted with peanuts.

Data about yield and production for Kaifeng City Prefecture, counties and LIS is available, but more detailed analysis has to be done to calculate exact changes and trend over time. However as in China in general, yields have increased rapidly in the past 20 years. Most of the yield growth occurred in the first few years after the reforms, but yields have continued to increase after 1985.

Without a detailed analysis on yield and production trends, calculations on changes in water productivity over time are even more problematic. In the first years after reforms, agricultural water use declined sharply, primarily due to reduced diversions from the Yellow River. 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. Since 1985, however, agricultural water use has been essentially constant in Kaifeng City Prefecture, as has 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, not improved water management techniques. Further analysis is needed to establish detailed trends over time and explain the reason for these trends.

4. GROWING MORE RICE WITH LESS WATER

The project “Growing more rice with less water: Increasing water productivity in rice-based cropping systems” officially initiated in July 2001 for a period of four years. It is an extension of an earlier research project conducted in 1999-2000 in Zhanghe Irrigation System, Hubei Province north of the Yangtze River. For the current study, a second site was added in China at Liuyuankou Irrigation System, Henan Province just south of the Yellow River.

The ultimate goal of our research is to promote water 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 (IWMI et al., 2000).
The project is structured around four well-defined sub-projects:

- *Sub-project 1* focuses on farm-level agronomic and financial assessment of AWD and under controlled field experiments compares continuously flooded rice with three different systems of water-saving irrigation – AWD, SSC and aerobic.
- *Sub-project 2* assesses the water-saving potential of alternative management practices at farm, irrigation system, and sub-basin levels.
- *Sub-project 3* studies the effect of policies, institutions, management practices and infrastructure on the allocation and utilization of water and on the incentive to adopt water-saving practices at farm level and at system levels.
- *Sub-project 4* focuses on the extension of water saving practices

This project enhances our knowledge of the water-saving potential of alternative technologies and the conditions under which these technologies can be successfully adopted. A better understanding is established on how farm-level water saving practices impact water-savings at the system level for specific conditions and on the specific links between farm-level water saving practices and factors such as policies, institutions, and infrastructure which facilitate or provide incentives for water saving.
The models developed in this project provide the framework for evaluating the impact of on-farm and regional water management options for other regions and conditions. Finally, the results of this study serve the growing demand for research and knowledge on alternative strategies for water saving in China and countries outside of China.

The project has a timeframe of four years of which the fourth year is mainly reserved for extension and dissemination of our research findings.

4.1. Preliminary results

The project is still ongoing and few final results are presented in this paper, but some preliminary results, mainly of 2001, are presented. For a detailed description of the first results see IWMI et al. (2002). Other papers at this forum will report on more recent results.

Sub-project 1

The results of field experiments indicate that water saving irrigation, especially flush irrigation and partially rainfed systems, can significantly reduce the amount of irrigation water compared with farmer’s practices without affecting yields. This implies that there is a possibility to reduce the amount of water diverted to rice in the study sites. However, we need to be cautious in interpreting these results, since they are site specific and care must be taken in extrapolation. First, our results were obtained in relatively small sub-plots in farmer fields that allowed us to keep 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 experiments conducted in Huibei in 2001 showed that there was hardly or no effect of aboveground water regime on crop performance, because

of the shallow water table. Therefore the location of the main experiment for 2002 was moved to an area with a deeper groundwater table.
More study is needed on the interaction between irrigation and groundwater table depths before recommendation for large-scale application of water-saving irrigation techniques can be made. With wide-scale adoption of water-saving irrigation techniques, the groundwater tables may fall 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 affects groundwater tables.

Sub-project 2
No final results are ready for sub-project 2. The main activities consisted of conducting water balance studies at different spatial scales and collecting and analyzing data in preparation for modeling. Four different spatial scales were identified for water balance measurements: field scale (rice), meso-scale, north of the railway scale and whole LIS to determine scale effects of water saving and productivity. Remote sensing was used for land use classification and determination of actual evapotranspiration (seasonal). Digitized maps in a GIS are used together with the remote sensing data to establish baseline maps for the modeling work. A surface and ground water interaction model will be developed and be linked with the field and meso scale studies for evaluation of possible upscaling strategies.

Subproject 3
Long term time-series data (1968-2000) have been collected for LIS and Kaifeng City on water use (surface and ground) by different sectors, area and yield of major crops. Section 3 above is based on this data. A survey of 60 farms was conducted to determine the yields and water use for rice, corn, and cotton. The data for both of these studies is still being analyzed to determine trends in water productivity.

Sub-project 4
A wide range of activities both within and closely linked to the project facilitated the extension of our research results and has helped to strengthen our research capacity.
These include meeting with stakeholders to present and discuss our findings, publications and press interviews, training activities, team member participation in workshops, and creation of a water-saving irrigation platform on the web. Several team members are also involved in complementary research activities.

5. CONCLUDING REMARKS

The differences in trends of diverted water and planted area of crops shows how important it is to look beyond the irrigation system level, in this case Liuyuankou Irrigation System, to a larger regional scale, Kaifeng County and more important Kaifeng City Prefecture. It tells us that understanding trends over time on irrigation system scale is not possible without adequate knowledge about regional trends and driving factors behind it.

To calculate the water productivity over time on a regional, Kaifeng City Prefecture, and irrigation system, Liuyuankou Irrigation system, scale a more detailed analysis of yield, production and agricultural water use (groundwater and Yellow River diversions) is needed.

The scope of this paper was not to present detailed results of the project “Growing more rice with less water: Increasing water productivity in rice-based cropping systems”, but the present an overview of the structure of the project, its objective and research conducted so far. Some detailed results are presented in different papers at this forum. The first preliminary results of field experiments indicate that water saving irrigation, can significantly reduce the amount of irrigation water compared with farmer’s practices without affecting yields. This implies that there is a possibility to reduce the amount of water diverted to rice in the study sites. However, caution is needed in interpreting these results, since they are site specific and care must be taken in extrapolation. No detailed “up scaling” analysis is conducted yet, and more data is needed on irrigation system scale water balances to model the implications of the first field scale results. Establishing irrigation system scale water balances and model the regional surface water and groundwater hydrology will be our next step to better understand the links between field scale water saving and irrigation system scale implications of these water savings.

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