

Rice impact in Henan irrigation districts along the lower Yellow River reaches

Dong Bin^{1,3}, Liang Zhichen², Ronald Loeve³, David Molden³, Yang Baozhong²

1. Department of Irrigation and Drainage College of Water Resources and Hydropower, Wuhan University, Wuhan, 430072, P.R. China
2. Henan Provincial Water Conservancy Research Institute, Zhengzhou, 450003, P R China
3. International Water Management Institute (IWMI), P.O. Box 2075, Colombo, Sri Lanka. Phone + 94 1 787404, fax + 94 1 786854, e-mail IWMI@cgiar.org

Abstract

The Henan Province, located in the lower reaches of the Yellow River Basin, is one of the staple areas of food production in China. There are 26 large and medium-sized irrigation districts along the river and the total area irrigated by Yellow River water is 523.56 thousand hectares, of which 85 thousand hectares are paddy fields, accounting for 16% of the total irrigated area in Henan.

Traditionally, the deep flooding irrigation method is used and the field irrigation duty during rice growing season is about 1500 - 1800mm, so a large quantity of water diverted from the river is used for rice production. However, the shortage of water resources in the Yellow River Basin has become very serious, therefore the rice culture in the irrigation districts and its impact on Yellow River water diversion are worthwhile to pay attention and discuss.

This paper firstly has an introduction of the Henan irrigation districts along the Yellow River reaches and the current status of rice culture in the irrigation districts. Then, the major impacts of rice cultivation are summarized according to the data collected from some main irrigation districts. Finally, the trend of rice cultivation at the irrigation districts is discussed, and some appropriate management options are suggested.

1. Introduction

The Yellow River basin is the cradle of Chinese civilization and irrigation has been practiced here for thousands of years. With a length of 5464 km and a drainage area of about 752,000 km², the Yellow River is the second largest river in China. The annual average runoff is 58 billion m³. It flows through nine provinces and autonomous regions before reaching the Bohai Sea, supporting on its way a population of over 130 million people, mostly farmers. The basin is divided into three distinct sections: the upper, middle and lower reaches.

The Henan Province is located in the upper and middle stretch of the lower reaches of the Yellow River. The River passes through the middle and north parts of the province, from the west Lingbao City to the east Taiqian County, with a length of 711 km. The river drainage area in Henan Province is about 36,200 km², accounting for 5.1% of the total river drainage area and 21.7% of the total provincial area. The Yellow

River water is the main sources for the agricultural production in the Henan irrigation districts along the Yellow River reaches.

2. The Henan irrigation districts along the Yellow River reaches

The completion of the People's Victory Canal (PVC) in 1952 was the prelude to the diversion of water from the Yellow River for the irrigation districts along the Yellow River reaches. After nearly fifty years' development, there are at the moment 26 large and medium-sized irrigation districts along the Yellow River, covering an irrigated area served by gravity irrigation of about 523,560 ha (See Table 1) (Wang and Chen, 1995; Feng et al., 1996). Most of the area along the Yellow River is alluvial plain.

Table 1. Irrigated area of the irrigation districts along the Yellow River (2000).

Location	Name	Designed irrigated area (10 ³ ha)			Actual irrigated area (10 ³ ha)
		by canal water	by ground water	Sub-total	
South bank of the Yellow River	Huayuankou	16.13	0	16.13	1.10
	Yangqiao	18.27	0	18.27	11.20
	Sanliuzhai	17.53	0	17.53	6.45
	Zhaokou	53.33	185.33	238.67	67.20
	Heigangkou	12.47	3.80	16.27	8.33
	Liuyuankou	12.47	18.47	30.93	10.53
	Sanyizhai	38.67	198.00	236.67	30.00
	Huangheqiu	10.53	0	10.53	2.96
North bank of the Yellow River	Baimaquan	7.20	0	7.20	3.20
	Wujia	24.00	0	24.00	6.47
	People's Victory canal	59.33	10.67	70.00	39.80
	Di'nan	16.67	0	16.67	7.47
	Handongzhuang	22.47	0	22.47	19.38
	Xiangfuzhu	23.73	0	23.73	8.49
	Dagong	26.67	209.33	236.00	10.84
	Xinzhuang	11.00	0	11.00	6.10
	Shitouzhuang	14.67	2.20	16.87	7.90
	Qiuchun	50.00	60.00	110.00	32.30
	Nanxiaodi	30.00	40.00	70.00	24.14
	Wangchun'gu	8.67	0	8.67	4.96
	Penglou	18.27	0	18.27	11.07
	Xingmiao	8.67	0	8.67	11.13
	Yuzhuang	3.47	0	3.47	2.01
	Manzhuang	9.00	0	9.00	3.49
	Wangji	3.47	0	3.47	3.81
	Shunkou	6.87	0	6.87	3.29
Total	26	523.56	727.80	1251.36	343.62

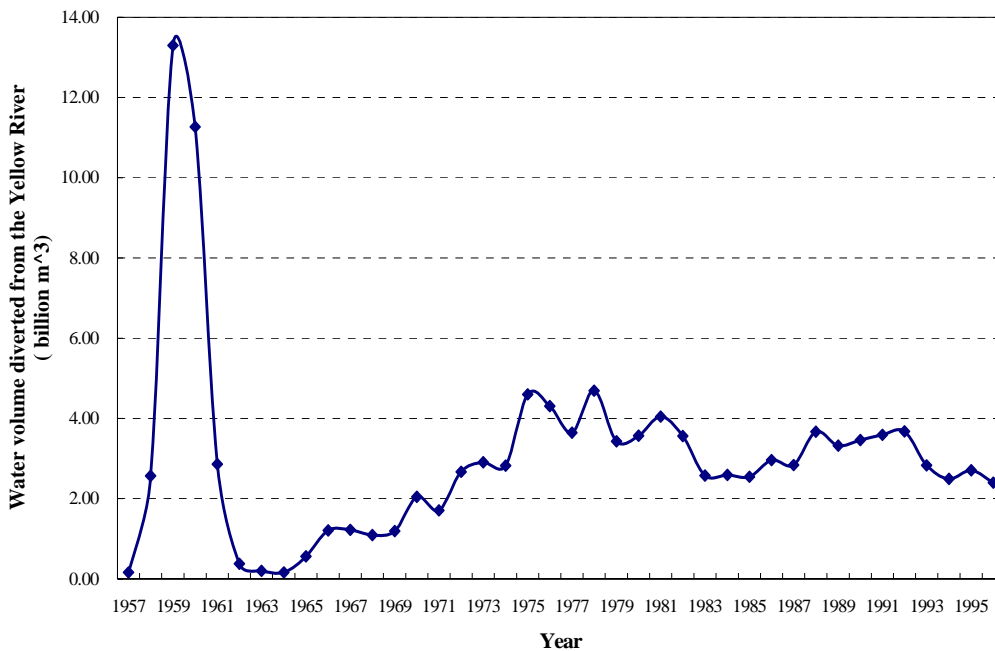
The Henan irrigation districts along the Yellow River are located in the Pacific monsoon climate zone, classified as semi-humid warm temperate. The climate characteristics are that the spring is dry and windy, the summer is wet (often leading to waterlogging problems), and a dry period in the late fall and winter. The annual sunshine hours are 2200-2300 hours and the annual temperature is 14-15 °C. The annual rainfall varies from 560 mm in the north to 670 mm in the south, but the seasonal distribution of rainfall is quite uneven, with more than 70% of the annual

rainfall concentrated from June through September. The mean annual runoff is about 1.32 billion m³, but the capacity of local water regulation projects is limited and most of the runoff cannot be used effectively.

In these irrigation districts, the annual average groundwater storage is about 3.91 billion m³, and the groundwater recharge is mainly from infiltration of rainfall, seepage of rivers and canals and deep percolation of irrigation water. If the double calculated water volume is considered,

The annual total amount of water resources available is 4.03 billion m³, calculated by adding up the surface water resources and groundwater storage and subtracting the groundwater storage directly recharged surface water resources. The water supply per irrigated hectare is about 3200m³/ha (Feng, et al., 1996).

At the moment the Yellow River is a practical source of water supply to the irrigation districts, but the road of the Yellow River water utilization was tortuous, especially in the 1960s (Figure 1). Through the rehabilitation of projects and the construction of new water diversion systems in 1950s, there was a rapid increase in irrigated area and much water was diverted to the irrigation districts along the Yellow River. Data shows that the irrigated area increased from 37.5 thousand ha in 1957 to 2.17 million ha at the end of 1959, an increase of about 58 times in only two years. In the consecutive two years 1959~1960, the water volume diverted was 13.3 billion m³ and 11.27 billion m³, respectively, about 83 times and 70 times more than in 1957 (0.16 billion m³) (Wang and Yang, 1986). During this period, the Great Leap Forward, the focal point was how to expand the irrigated area and to improve agricultural production,



so some drainage canals were used for the Yellow River water diversions and several reservoirs were constructed in the plain.

Figure 1. Annual water diverted from the Yellow River to the Henan irrigation districts (1957 - 1996).

Excessive water was diverted to the irrigation districts and the flooding irrigation method was used widely. However there was a lack of experience in large-scale irrigation management and drainage related problems in the irrigation districts. Additionally the large-scale programs were poorly planned and sometimes not completed. This combination resulted in a considerable groundwater table rise, since the excess irrigation water and rainfall could not drain out of the areas. Consequently, waterlogging and salinity occurred and rendered large areas unproductive. Data shows that the total salt-affected cultivated area in the irrigation districts increased from 138.7 thousand ha in 1957 to 330.7 thousand ha in 1962 and yields were severely affected. In the PVC the average crop yield was only 2.9 t/ha, below the level of 1952 (Wang and Yang, 1986).

Being fully aware of the gravity of the situation, the Henan Provincial Government ordered the closure of most of the water diversion systems along the Yellow River in 1962 and the irrigation districts were asked to control the salinity. In the following four years (1962 - 1965), the irrigation districts launched a movement for waterlogging and soil salinity control, the total salt-affected agricultural area reduced to 233.3 thousand ha in 1965, and gradually the management and development of irrigation districts were on the right track. After 1965 the irrigation districts resumed operation and the agricultural production grew steadily. With the rapid development of industry and urbanization in the river basin, the amount of water diverted from the Yellow River to the irrigation districts has been reduced since 1990s, and it is expected to decline even more in the future (Yang, 2001).

The irrigation districts along the Yellow River reaches are the main agricultural production base in Henan Province. The main grain crops are winter wheat, summer maize and rice. The main cash crops are cotton, peanuts, sesame and beans. There are two grain harvests in one year and the cropping intensity is 1.78. In 2000 the winter wheat planting area was 482 thousand hectares in the irrigation districts, accounting for 10% of the provincial planting area; but the irrigation districts produced 2.90 million tons of wheat, which is 13% of the total provincial wheat production.

The rice cultivation in the irrigation districts along the Yellow River commenced in 1950s. The rice production was 106.8 thousand tons in 1950, and increased up to 280 thousand tons in 1982, almost tripling in three decades. In the same period, the percentage of rice planting area in the irrigation districts compared to the total provincial rice area increased from less than 3% to 16%. In 2000, the rice planting area was about 85 thousand hectares, and the total rice production was 606 thousand tons in the irrigation districts. Rice production more than doubled compared to 1982 and is almost six times as much as in 1950. In 2000 the irrigation districts produced about 19% of the total provincial rice production (HPWRB, 2000). Now some irrigation districts along the Yellow River, such as Liuyuankou Irrigation District (LID) and Heigangkou Irrigation District (HID) in Kaifeng City, the People's Victory Canal in Xinxiang City where rice is produced have become known as "Home of the Yellow River rice" because of the high quality.

3. Rice culture in Henan irrigation districts along the Yellow River reaches

Henan irrigation districts along the Yellow River have a history of more than 40 years of rice cultivation since the PVC began to grow rice with Yellow River water in 1956. To solve the soil salinity problem in the low-lying land downstream of the irrigation district and behind the Yellow River bank, experiments were conducted in the PVC and it was found that growing rice in the low-lying land is a successful measure for salinity control (Niu and Liu, 1987). The successful measures were tried and promoted in the other irrigation districts along the Yellow River, and the rice area expanded rapidly. For example, the rice area in the PVC increased from around 10 thousand ha in the early 1980s to 16.7 thousand ha in 1999, which accounted for one third of the designed irrigation area served by canal water. In 2000 the rice planting area was 85 thousand ha in the Henan irrigation districts along the Yellow River, and has remained stable around this number. The rice area is mainly distributed over the PVC, LID, HID and twelve other irrigation districts out of the total of twenty-six districts in the province. These fifteen irrigation districts make up 90% of the total rice area in the province. The average rice yield in the Henan irrigation districts along the Yellow River is high with 7.1 ton/ha. In the PVC the average yield was even higher up to 8.3 ton/ha.

In the fifteen irrigation districts growing rice flood irrigation is the most widely used method. A typical feature of this method is that a relative high water layer is kept on the soil surface of the rice fields throughout the main growing season. Based on the measured data from the Huibei Irrigation Experiment Station located in the LID, and other research (Chen, 1995; Feng et al., 1996 and Li et al., 1997), the crop growth stages and current irrigation scheduling for rice in the irrigation districts are summarized in Table 2.

Table 2. Crop growth stages and irrigation scheduling for rice in the Henan irrigation districts along the Yellow River reaches.

Crop growth stages	Average dates	Number of irrigation applications	Irrigation depth (mm)	Irrigation duties (mm)
Growing rice seedlings	1 - 10 May	1	120	120
Land preparation, transplanting	10 - 25 Jun	1	300	1470
Germination to tillering	26 Jun - 31 Jul	4	340	
Elongating, booting	1 - 20 Aug	2	250	
Heading, flowering	21 - 31 Aug	2	200	
Milking ripening	1 - 20 Sep	2	380	
Yellow ripening	21 - 30 Sep			
Harvesting	1 - 10 Oct			
Total		12		1590

4. Rice impact in the Henan irrigation districts along the Yellow River

Based on analysis of experimental data, documents and research reports collected from the irrigation districts and the ACIAR project conducted in the LID, the major

impacts are summarized and presented below.

4.1. The impact on the cropping pattern

Before rice was planted on a large scale in the irrigation districts along the Yellow River, there was only upland crop cultivation, wheat in winter plus maize, cotton or beans in summer. After the construction of the irrigation systems and successful experiments on rice cultivation, the rice area expanded continuously and the percentage of rice compared to the total cropping area increased. The cropping system evolved from only dry-land crops to rice plus dry-land crops in some irrigation districts. For example, the first three years (1967 - 1969) after the LID became operational, less than 5% of the cropping area in summer was rice; but in 1970s, the rice area increased rapidly, accounting for up to 57% of the total cropping area in summer in 1976 (Figure 2). At the end of the 1970ties the structures in LID 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. Additionally there were serious problems with sediment depositions. The water diversion from the Yellow River was reduced to keep the canals from breaching and to maintain canal security. The reduced Yellow River diversions resulted in a decline of rice area in the 1980s, and the rice area became less than 20% of the total area planted under summer crops. After the completion of the rehabilitation of LID at the end of the 1980s the rice area gradually increased to up to 5000 ha in 1993. The average rice area over the 1990s was again at similar levels as in the 1970s. A field survey in the LID showed that if the water supply is enough local farmers prefer to grow rice over maize, cotton and other upland crops, because of the high yield, high quality and high price of rice. Affected by the short supply of the Yellow River water resources, the water diverted to the LID and other irrigation districts has been reduced and limited the further expansion of the rice area. Considering the growing water shortage in the Yellow River basin it is most unlikely that the current percentage of rice area of 10% to 20% in some irrigation districts will expand in the future.

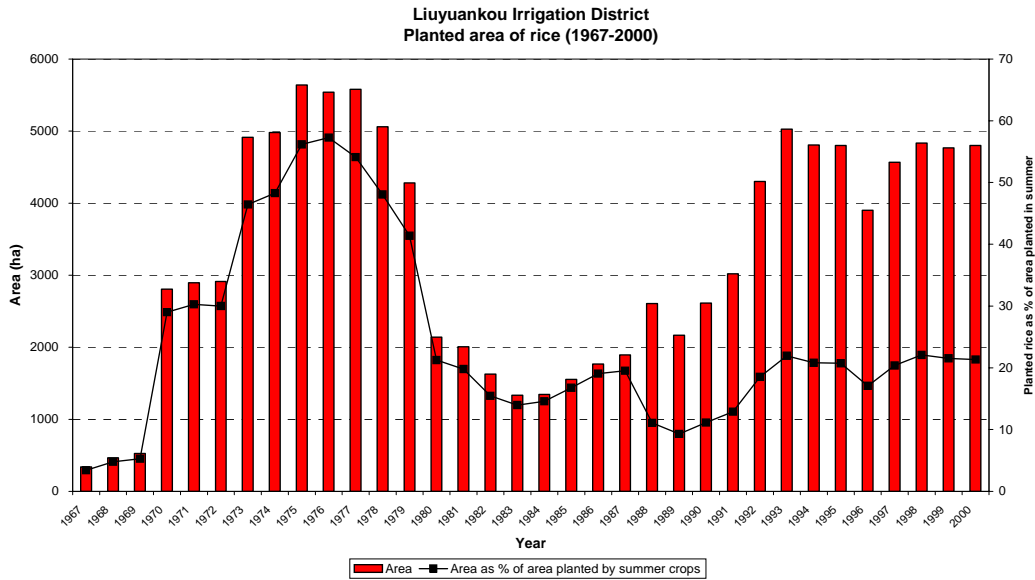


Figure 2. The annual rice area and percentage in the LID (1967 - 2000).

4.2. The impact on the irrigation water volume diverted from the Yellow River

The annual rainfall of around 600mm is not enough to support rice cultivation in the irrigation districts along the Yellow River, so it is a need to divert Yellow River water for supplemental irrigation. Compared with maize and cotton the irrigation duty of rice is about ten times as high. With the expansion of the rice area and the change of the cropping pattern, the water volume diverted from the Yellow River to the irrigation districts increased sharply. For example in the PVC the annual irrigation water volume was 150 MCM in the early stage when only upland crops were planted. After the large-scale introduction of rice the irrigation schedule changed and the annual irrigation water volume became much larger and reached as an average 500 MCM in the 1990s. This volume still could not meet the water demand. During the summer irrigation season the actual water requirement at the PVC was $90\text{m}^3/\text{s}$, but the discharge in the Yellow River was less than $200\text{m}^3/\text{s}$ and the available discharge for to the irrigation district was sometimes below $10\text{m}^3/\text{s}$. A similar story can be found in LID where the annual irrigation water volume was 123 MCM in 1967 before the rice introduction and reached up to more than 250 MCM in the mid 1970s when rice cultivation was fully introduced.

The wide gap between water supply and demand in the PVC made the inequality between rice and upland crops, upstream and downstream users more serious resulting in a reduction of irrigated area and benefits.

4.3. The impact on sediment transported from the Yellow River to the irrigation districts

As the Yellow River is the most important water resource for the irrigation districts, the total diverted water volume over the past 40 years (1957 – 1996) is estimated to be around 122 billion m³, at the same time, the total volume of sediment brought to the irrigation districts was 1.87 billion tons (Zhang et al., 1999).

Water diversions from the Yellow River are certain to bring sediments to the irrigation districts. Not only the water volume diverted, but also the time of diversion determines the amount of sediment. According to measured data from 1951 to 1990 by the Huayuankou Hydrological Station, the sediment concentration in the runoff is very high during the flooding season (July to September). The annual average value ranged from 34.5 to 54.1 kg/m³. To avoid depositing more sediments to the irrigation and drainage systems during the flooding season, the irrigation districts would in general close the gate and reduce the water diversion from the Yellow River. However, the main rice-growing season occurs at the same period as the flooding season, from July to September. When not enough water is diverted to meet the rice crop water requirements during this period, the rice will suffer from water stress and the yield will be reduced. This conflict of optimizing rice water demand and sediment reduction is serious and difficult to resolve.

It is difficult to quantify the volume of sediment deposited in the irrigation districts due to a lack of detailed measurements, but an estimate can be made by using irrigation duties of summer crops and sediment volume transported in this period, based on the measurements from the PVC and other irrigation districts (see Table 3) (Niu and Liu, 1987; Feng et al., 1996; Li et al., 1997).

Table 3. Irrigation duties of summer crops and sediment transported in PVC and other irrigation districts.

Month	Avg. sediment concentration	Net irrigation duty			Gross irrigation duty			ET			Sediment transported		
	(kg/m ³)	(mm)			(mm)			(mm)			(t/ha)		
		Maize	Cotton	Rice	Maize	Cotton	Rice	Maize	Cotton	Rice	Maize	Cotton	Rice
4	12.3	90			225			16			27.7		
5	11.8			120			300		74	26			35.4
6	13.5	90	75	300	225	188	750	101	105	99	30.4	25.3	101.3
7	44.1			340			850	113	146	135			374.9
8	45.2	75		450	188		1125	109	158	165	84.8		508.5
9	34.5			380			950	97	101 ¹	125 ¹			327.8
Total		165	165	1590	413	413	3975	420	600	550	115	53	1348

¹ ET value in September and October.

The irrigation water efficiency is 0.40.

The result in table 3 shows that the sediment transported is 53 ton/ha for cotton irrigation and 115 ton/ha for maize irrigation per irrigation season, but for rice it is almost 1350 tons/ha, about 12 times and 25 times that of maize and cotton respectively. The depth of sediment deposition in a paddy field can reach 100 mm if it assumed that all sediment would accumulate in the fields.

The distribution of sediment transported to the irrigation districts is as follows: 13% in the settling basins, 31% in irrigation canals, 41% in fields and 13% in the drainage canals (Zhang et al., 1999). Fine sediments deposited in the fields can function as a fertilizer and is good for crop growth, but the sediments deposited in the irrigation and drainage systems would negatively influence the irrigation districts' operation and it is very difficult to cope with. The sediment deposition has caused some environmental problems in the irrigation districts and is a heavy burden. It is necessary to have comprehensive measures to solve the problem of sediment deposits before thinking about a possible further expansion of the rice area, or the benefits from additional rice cultivation cannot compensate for the costs of sediment removal.

4.4. The impact on the groundwater table and upland crops in surrounding area

The measured data from the Huibei station in 2001 and 2002 demonstrated that after the land preparation, the deep percolation contributed to the groundwater and the water table began to rise in the rice area. During the rice-growing season from July to September, the groundwater table is very shallow, normally about 20 cm below the field surface. After entering the yellow ripening and harvesting stage, the field will dry naturally and the groundwater table falls very quickly.

The experimental data from the PVC showed that the area 400 m around the paddy fields was influenced: the groundwater table rose, and the mineralization degree increased with slight secondary salinization, this had a negative effect on upland crop growth. In the area 200 m around the paddy fields, the upland crops suffered waterlogging and there was a yield reduction. For this reason, the intercepting drains are necessary to separate the paddy rice area and upland crop area, and to prevent groundwater flow into the surrounding areas.

4.5. The impact on the groundwater recharge with the Yellow River water

The rapid development of industrial and agricultural production has resulted in over-drafted groundwater aquifers and a fast decline of the groundwater table since 1980s, and created large drawdowns known technically as "cones of depression" in the north and east of Henan Province. Water diversions from the Yellow River for groundwater recharge is an important way to solve water shortage in the areas along the Yellow River. For this purpose, the Henan Provincial Government made a plan to develop 1.20 million ha of farmland irrigated by Yellow River water, of which 733 thousand ha by groundwater and 467 thousand ha by gravity irrigation (Wang and Chen, 1995). According to the development plan, more surface water will be delivered to farmlands far away from the Yellow River to reduce the groundwater withdraw in these locations and to ensure a groundwater table rise. This development plan will limit future expansion of rice areas close to the Yellow River.

At the moment, most paddy fields are located in the upstream part of the irrigation districts and irrigated by gravity irrigation. Though the rice does not consume more water (ET) than maize and cotton (See Table 3), and does not deplete more water from the Yellow River, it does require more deliveries with sometimes limited (economical) options for reusing the water. In fact, the present rice irrigation practices in LIS

contributes to groundwater recharge because of the water ponding in rice fields. Future plans should recognize the present usefulness of rice fields in recharging groundwater.

5. Discussion on the future trend in rice cultivation

As mentioned above, the original intention to introduce rice at a large-scale was for salinity control and land reclamation in the irrigation districts, so future development of rice cultivation will still be linked with salinity control. A recent general survey in 26 irrigation districts revealed that the total salt affected area is estimated to be about 32.5 thousand ha, of which more than half, about 18.8 thousand ha, are located in Sanyizhai and Zhaokou irrigation districts. Considering the soil salinity control need and local farmers' practices, the rice area will expand to a certain degree in some irrigation districts.

The flooding irrigation method practiced by most of farmers in the irrigation districts applies a large amount of water to the rice fields (Table 2). This amount is much higher than in other regions where water saving irrigation techniques have been adopted. This excess water use in some areas resulted in a lower water availability downstream. Therefore the introduction and spread of water saving irrigation practices are of great important to save water in the upstream areas and reallocate water to downstream areas short of water, thereby increasing the existing low irrigation water productivity of around 0.4 to 0.55 kg/m³ water diverted. Based on experimental results and experiences of water saving irrigation, the following water saving irrigation regime for rice, termed "the shallow water irrigation method" (Table 4), is recommended by the Henan Provincial research team on water saving irrigation (Feng et al., 1996).

Table 4. Water regimes on paddy fields under shallow water irrigation method.

Growth stage	Lower limit before irrigation	Upper limit after irrigation	Extra limit after rainfall	State of field water
Transplanting	15mm	20mm	20mm	Shallow water layer
Revival of green	100% SMC ¹	50mm	80mm	Shallow water layer
Early and middle tillering stages	80% SMC	50mm	100mm	Wet
Late tillering stage	70% SMC	20mm	40mm	Dry field
Elongating to flowering	90% SMC	50mm	120mm	Shallow water layer
Milk ripening	80% SMC	50mm	120mm	Wet
Yellow ripening	Dry field	Dry field	Dry field	Dry field

¹ SMC: saturated moisture content.

The shortage of the Yellow River water resources has changed the mode of diversion of the Yellow River water for irrigation from only gravity irrigation to gravity irrigation plus groundwater irrigation, and the Henan Provincial Government has laid a strong emphasis on Yellow River water diversion for groundwater recharge. Under these circumstances, the rapid and large-scale expansion of rice area is limited. There is evidence that paddy fields with well-drained soils and without salinity risk are being converted into upland crops in some irrigation districts. The pragmatic approach for rice cultivation development in the Henan irrigation districts along the Yellow River is to control the extent of the rice area, popularize water saving irrigation techniques for rice and improve the irrigation benefit.

6. Conclusion

The development of rice cultivation in the irrigation districts along the Yellow River reaches is not a simple and isolated issue and involves many aspects, such as salinity control, water saving irrigation, water resources availability, groundwater recharge and irrigation benefits of the overall system. In view of the limited water resources and the Henan Provincial development plan, keeping the existing rice area stable at the level of 80 to 85 thousand ha and improving the economic and social benefits of the irrigation districts seem to be the most practical and effective way forward.

For all the irrigation districts along the Yellow River reaches the cropping pattern and extent should be compatible with the water resources available. Regardless of the conditions a change of the cropping pattern and extent of rice cultivation will have an impact on the irrigation district's development, and could possibly endanger the sustainable development of the irrigation districts. Therefore, the irrigation districts managers should coordinate the dynamic relations between demand and supply; fully achieve the efficient utility of the limited water resources through rational distribution. This is a strategic guiding principle on the development of irrigation districts.

Acknowledgements

This research is part of the Project "Growing More Rice with Less Water: Increasing Water Productivity in Rice-based Cropping Systems" funded by the Australian Center of International Agricultural Research. (ACIAR) The research is conducted by a team of scientists and practitioners from Wuhan University, the Zhanghe Irrigation Administration Bureau, Henan Provincial Water Conservancy Research Institute, Kaifeng Yellow River Diversion Management Section, Huibei Water Conservancy Experimental Station, Liuyankou Irrigation District Management Division, the International Rice Research Institute (IRRI) in the Philippines, the International Water Management Institute (IWMI) in Sri Lanka, and Commonwealth Scientific and Industrial Research Organization (CSIRO) in Australia.

References

- Chen Yuming, Guo Guoshuang, Wang Guangxin. 1995. Main crop water requirement and irrigation of China. Beijing, Water Conservancy and Power Press. March, 1995.
- Feng Changhai, Hu Kuiji and Zhang Zhichuan. 1996. Study on the comprehensive measures of water saving irrigation in Henan. December, 1996.
- HPWRB (Henan Provincial Water Resources Bureau). 2000. Almanac of Henan Water Resources.
- Li Chenghui, Yuan Guangyao, Zhang Yufang. 1997. The theory and practice of water & salt monitoring prediction in irrigation district. Zhengzhou, Press of Water Conservancy of the Yellow River. August 1997.
- Niu Lifeng, Liu Haozhi. 1987. The 30 years irrigation development with the Yellow River water in the People's Victory Canal. Beijing, Water Conservancy and Power Press. March, 1987.
- Wang Shiyong, Chen Zhipeng. 1995. Research Report on the model of the Yellow River Water Storage and Irrigation Project and related issues. December, 1995.

- Wang Zhibin, Yang Guoshun. 1986. History of Henan Yellow River. Zhengzhou: the Yellow River Conservancy Commission (YRCC), April 1986.
- Yang Baozhong. 2001. Study on the model of the Yellow River Water storage and irrigation project. Thesis for Master's Degree, Wuhan University.
- Zhang Zhichuan, Li Lingxiu and Zhang Zhan. 1999. Study on the sediment treatment and utilization in the New Sanyizhai Irrigation District. November, 1999.