Exploration and evaluation of effective integrated water management in the development of agricultural production systems

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Because of the scarcity of water resources in its different regions, the Yellow River Basin has significant projects balancing water supply and demand for the northern regions of China. In the higher reaches, the agricultural production systems are expected to improve under the national strategic policy. However, between regions there exist different economic conditions and management requirements in the implementation of sustainable agricultural development. Yet the same water policies and management issues are applied for the whole river when logically different policies should be designed for the varying environmental conditions and socio-economic conditions of the river basin.

This paper seeks a way to identify an effective integrated management of water resources in the context of sustainable development of agricultural production in the Yellow River Basin and the relationships between the planning system and policy implementation in practice with respect to water use in the agricultural production systems at basin level in China.

The paper also examines whether the significant principles within integrated water management and their influence on the consideration of institutions are sufficiently specific and appropriate to the chages in the agricultural production system and economic value of improvements to integrated water resources management at basin level.

Keywords: integrated water management, development, agriculture

1. Introduction

Best water practice aims to maximize innovation in pursuit of environmental, economic and governance goals such as the improvement of efficiency of water use for agricultural production and restrictions on pollution to ensure long term economic development and improved quality of human life. Whether sustainable development is realized closely related to agriculture for farming groups in the Yellow River Basin, which relies on the capacity building of development as advantages to balance the limitations (i.e. climate change, flooding, drought) under the current situation of economic development. Water scarcity threatens agriculture and food security production, farmlands becomes lost to industrial development and urban spread, water shortage led by increasing water demand, and resources contaminated over wide areas in particular, in the relatively dry north. The pressures produce opportunities to improve more efficient water use. The Chinese government has paid close attention to sustainable development of water utilization. Those issues are high on the government's priority list and agenda in terms of economic development in the areas including improvement of efficiency of water use in irrigation, building capacity of facilities for tackling a weak irrigation management and increasing the value of farmers' production. Agricultural practice in the Yellow River Basin concerns water management at basin level in organizing against poverty and climate change.

This can provide an understanding of the relationship between the water utilization pattern and socio-economic conditions existing in the Yellow River Basin to explore practicable policy and methods for the improvement of efficient water utilization in future agricultural production.

1.1. Physical environment

Figure 1. Yellow River (Yellow River Commission, 2008)

The Yellow River is the second largest river lying on the north side of the Bayankala Mountain on the Qinghai-Tibet Plateau; the river has a total length is 5,464 km. The Yellow River Basin (YRB) has a drainage area of 795,125 km2 accommodating 110,08 million people. The cultivated land is 12 million hectares. It is well known as a sediment-laden river, average annual sediment inflow to downstream is 1.6 billion ton with sediment content 35kg/m^3. Every year, an average of 400 million tons of sediment is deposited on the lower reach of the Yellow River, which results in raising of river bed. The river channel downstream is 4-7 meters higher than the ground outside the river on average; the maximum is up to 13m higher. The Yellow River basin has complex landforms. To its north is the sea and to its west is the plateau. Between the west and the east, the height difference forms distinct climates, which produces challenges for farming groups, water policy and its implementation. This also causes the economy to lag behind in the upper reaches of the river basin. So, it is of great significance to intensify the development of the agricultural economy, make full use of the land and light-heat resources, upgrade the agricultural production, get rid of poverty as quickly as possible and improve the ecological environment for the exploitation of the western region, the sustainable development of the nation's economy and the society, and the strengthening of national unity (Yellow River Commission, 2004).

1.2. Water consumption

The utilization rate of the Yellow River's water resource is about 50%, a higher level compared with other big rivers. The annual consumption of the runoff of the Yellow River reached 28~29 billion m³ in the 1980s; for example, the industry and rural consumption is about 1.1 billion cubic meters, the rest was consumed by irrigation.

Irrigation State. The total irrigated area in 1949 was about 800,000 hm^2 in the Yellow River Basin and lower reach, and expanded to7.126 million km^2 in 1990, among which, 5.125 million km^2 was benefited by the surface water constituting 72% of the total irrigation. 2.001 million km^2 was benefited by the well irrigation constituting 28% of the total (Yellow River Commission, 2004). The benefits of the irrigation by the Yellow River are summarized in Table 1.

Table 1. The contribution of the Yellow River to Agriculture

Years	Product	Money value	Investment
1950 - 1995	Grain 254.855 billion kg, cotton 2.58 billion kg, oil-bearing cropping 7.05 billion kg, sugar beetroot 10.254 billion kg.	179.74 billion RMB based on the price of the same year	42 billion RMB, the ratio of investment and benefits is 1:4 with good economic benefits.

Source: Yellow River Commission, 2004

Water demand of area urban and industry. The water supply work in the Yellow River basin has a long history. Much infrastructure has been built for solution of the water demand of Beijing, Tianjin and the major cities and townships along the river. However, water demand of urban area and the development of industry are increasing, which re-allocates water resources to meet the needs of the industrial sector. In other words, water use is reducing in agricultural irrigation and water resources re-allocated to industries. Large-scale industries mostly rely on the river water. For example, In 1990, the industries and urban water uses accounted for 6.48 billion m^3 including industrial uses 5.15 billion m^3 (79%), and urban uses 1.33 billion m^3, (21%) (Yellow River Commission, 2000) (Table 2).

Table 2. Industry and urban water uses of eight provinces along the Yellow River in 2000.

province	total						industry		urban	
	Water uses			Water consumption			Water use	Water consump-tion	Water use	Water consump-tion
	Sub-total	Percent-age(%)	Ground water	Sub-total	percen-tage	Ground water				
Qinghai	3.50	5.4	2.37	2.65	5.9	1.80	3.11	2.34	0.39	0.31
Gansu	11.18	17.3	6.63	7.26	16.2	4.30	9.81	6.37	1.37	0.89
Ningxia	5.28	8.1	4.23	3.56	7.9	3.02	4.52	3.04	0.76	0.52
InnerMon-golia	4.94	7.6	3.16	4.79	10.7	3.12	4.14	4.02	0.80	0.77
Shanxi	8.90	13.7	7.68	8.90	19.8	7.68	7.08	7.08	1.82	1.82
Shaanxi	10.24	15.8	8.36	5.14	11.5	4.18	6.60	3.31	3.64	1.83
Henan	13.53	20.9	6.19	5.33	11.9	1.40	11.03	3.89	2.50	1.44
Shandong	7.24	11.2	2.40	7.24	16.1	2.4	5.26	5.26	1.98	1.89
Whole river	64.81	100	41.02	44.87	100	27.90	51.55	35.31	13.26	9.56

Source: Yellow River Commission, 2000

Water pollution. The growth of population and rapid development of industry and agricultural production, a great deal of industrial sewage has been directly drained into the river without treatment which results in reduced water quality for irrigation although a number of treatment works, monitoring stations, and 30 analysis laboratories where built up for pollution control.

Based on monitoring data of the River Commission (1990), 2.1 billion ton of sewage had been drained into the river in the early part of the 1980s. Since 1990s, sewage drained into the river has sharply increased up to 4.17 billion ton. The severe water quality pollution aggravates the shortage of water resources to a certain extent. Water shortage and water pollution are limitations which restrict agricultural development in the Yellow River Basin.

1.3. Irrigation facilities

China's annual GDP growth averaged 8.6 percent during the last two decades. With this growth, over 250 million people have been life out of poverty since the 1970s. The World Bank also advised that in terms of economic performance, China was one of the most successful countries in the world during 1997 to 2001 with steady progress (World Bank, 2002). This means that China achieved a high rate of poverty reduction and has been the first country making significant progress to meet the aims of the MDGs of 50% reduction

in poverty in the last ten years but the progress depends upon industrial development relying on a cost to environmental resources. The pressure to eliminate poverty means that there exists a comparative lack of funding for the implementation of investment of water facilities; this is a factor restricting water management in farming practice. Shiva has advised that the limitation of economic development is set by poverty reduction (Shiva, 2002). However, the outcomes of rapid growth also transfer negative affects to water use and produced a need to control water pollution and resources saving relying both on water policy implementation and or financial capacity for irrigation facilities building at basin level.

Many reservoirs in the tributaries and projects for irrigation and water supply were built for development; thus the irrigation area has increased from 12 million mu (1hectare = 15 mu) in 1950 to 110 million mu now, including 37 million mu out of the basin. 70 per cent grain and most economic crops are produced in these areas, which only accounts for 46 per cent of the total area of the basin. It also solves the water problem for 27.27 million farmers (Yellow River Commission, 2000). However, the consolidation of weak reservoirs and the construction of facilities nearby important cities still have a long way to go to meet the needs of agricultural irrigation. This also suggests that it is necessary to enhance the construction of hydrological measurement facilities and equipment, and hydrological prediction service systems. Industrial structure may be adjusted to impose restrictions on developments with heavy water-use and heavy pollution and to promote water-saving.

2. Experience of water saving

A system was set up to encourage farmers to develop water saving project. Coordinating the water demand and supply of the multi-users in different areas could be essential principal for the Yellow River basin in the past decades. It requires that implementation of water-saving measures should be carried out and formulated for individual water usage which may be related to implementing water Permits System for implementing total water volume usage in control for the Yellow River basin. For example, in 1998, China stipulated a unified management and regulation system, which formulates the regulation principle, limits of authority, usage application and examination and approval, and the

water usage monitoring and supervision. Meanwhile, China's central government has increased water saving investment to support farming projects in order to accordant agricultural water demands but it still does not meet the requirements of the current situation. The sub-national governments at different levels should also arrange financial sources for farm water saving projects. The lessons of water usage in irrigation have suggested that water price is too lower, resulting in irrigation as the major reason for water waste in use. The re-adjustment of water use price is necessary to respond to the changes of water supply costs. However, low price of agricultural product is the reason for low efficiency of water use in irrigation in the Yellow River basin. It is important to improve water management, which is one of essential practice for effective water use and saving in the different regions of the River basin. At the same time, the innovation of water saving technology has been paid close attention by the government during the last decade. This is related to local economic conditions, geographical position and farming culture in the regions of the river basin in terms of farming practices; for example, the central government has made efforts to establish a mechanism of water price but this is not paid such attention by local government with little awareness among the farming group. Moreover, the current economic conditions are not supportive to increasing water price in agriculture if farmers are encouraged to carry on farming actives. This becomes a contradiction at present among farming groups, water managers and the local governments in the context of different objectives.

3. Integrated water resources management

The system of integrated management aims for sustainability of water resources management and development and includes the legal framework, policy, legislation and implementation for water conservation, saving and protection and intensifying the management. This can also help set water use priorities, specify permitted water practices and fee systems and define other regulatory policy mechanisms to save water and strengthen demand management. For example, in order to prevent water pollution, the Chinese government has adopted integrated management for pollution control, as outlined in the Annual Report 2000 by the State Council, summarized as follows:

- adhere to the policy of simultaneous attention to water saving development, protection and management;
- make integrated precautions for economy, technology and administration, and law;
- utilize planning, optimal allocation, total control and unified control of water quality;
- improve the work on soil erosion control and give energetic support to construction of agricultural water conservancy projects.

(Zhang 2001)

According to the system of integrated management, the central government has attached importance to agricultural water use. However, it is not easy to improve agricultural irrigation by closing industrial enterprises, which can make high impacts on employment. The achievement of implementation of the sustainability of water governance relies on an integrated water management at local level. IWM deals with the issues of water use and resources management, water pollution problems and water policy and legislation. In fact, the benefits of integrated management for water pollution control are wide ranging, including efficient water management and development in irrigation. The system of integrated management is not only a useful tool to deal with the issues relating to the water environment, and it also parallels economic development, protecting natural ecosystems and providing appropriate environmental services and satisfying social values (Thomas, 1996).

Meanwhile, water conservation, including saving and protection is most important, and water saving is an effective method to alleviate the contradiction between supply and demands in relation to techniques and measures used for focusing on raising the efficiency of irrigation. Rain resources must be fully adapted to guard against water shortage. This may suggest that the adjustment of agricultural planting structure be highly considered in order to save water. For example, it is necessary to consider not undertaking any agricultural project that consumes more water and causes serious pollution.

Water-saving in agriculture, industry and life must be emphasized. And different water functional areas must be plotted to control the pollution load and water quality

deterioration in the cross-over on borders of different provinces in the river basin. Different departments should strengthen the co-operation to manage and protect uniformly the water yield and the water quality. The unified management of water resources is an important method to solve water shortage in the Yellow River. Considering the requirements of water quantity and quality in different aspects, i.e. life, production and ecology etc., a comprehensive plan must be made which can provide a rational regulation and scientific management. To alleviate the deficiency of water resources radically, according to the principle of water saving, the planning and construction must be made as soon as possible. This suggests that ecological construction and water-soil conservation should be carried as the preferential policy and utilize coercive measure of water saving.

Despite China's large and increasing budget for poverty reduction there is a long way for China to go to eliminate poverty completely. This pressure influences China's water use and development.

4. Progress in local water use and management

While groundwater use and management in agriculture has been improved by the governmental efforts since 1990s in comparison with the 1980s the improvement still is not enough in terms of operation. Nevertheless, compared with the rapid growth of economic development in China, this represents considerable improvement in agriculture. Consideration of the diversity of situations in rural areas must be made when addressing water use issues for implementation of economic instrument in agriculture, such as poverty reduction, farming conditions, economic development, awareness and techniques adoption and application.

Various authors have argued for the importance of good governance in *inter alia* achieving progress in agricultural water use. Grindle (2004) argues that good governance can improve all service sectors of the society in a nation and also assist the necessary changes in the development of social and political culture and policy decision making, while maintaining growth to assist economic development and poverty reduction. The government of a nation should play a positive role in producing responsibility and accountability for water management (Gleick *et al,*. 2002). Certainly, implementation of

good governance is related to many aspects of practice not only within the conditions usual in developing countries but also when addressing their specific situations such as the objectives of economic development, poverty reduction, and environmental protection, against a background of population increase. The achievement of water governance in poverty reduction has moved on and produced new challenges of water pollution control at basin level. Mol and Carter (2006) state that China has developed its environmental governance system and fitted its planned economy to its reform of the approaches to environmental policy, regulations and legal system to attain more sustainable development of state, market and civil affairs.

In addition, the Chinese government has paid great attention to agricultural water use and developed a number of policy concerns for local governance, such as cancellations of agricultural tax, investment of technology application and provision of funding to support farmers establishing water facilities.

However, the key question is how to improve aquifer use in agricultural production that can be implemented through village levels in practice. It is necessary to innovate a suitable vehicle to deliver its objectives to ground root levels across the river basin.

5. Challenges

With the development of economy and society, the contradictions between supply and demand of water show that inefficient water use and low price of agricultural products have been a basic restricting factor of the sustainable development of economy and society in the Yellow River Basin, such as the loss of water and soil and the deterioration of water environment not yet controlled effectively. Furthermore, the Yellow River Commission has estimated that the pollution discharge in the whole basin will exceed 6.5 billion m^3 in 2010. At the same time the pollution caused by fertilizer will spread further.

6. Conclusions

Water resource degradation and over capacity of exploitation increase challenges for agricultural food production in the Yellow River Basin. Consideration of environmental policy and environmental reserves for protection of water resources depends upon whether there the economy has developed at a certain level. Economic diversification and strength can promote environmental reforms including improvement of water practice.

To realize the sustainable utilization of water resources, the optimized distribution, conservation and saving must be intensified.

Drought and flooding produce unusual situations with high pressures in the context of climate change in terms of operation. Hu (2006) has suggested that 'the solution lies in a sophisticated and integrated economic system of incentives and penalties, technological innovation and education to produce a sense of awareness and communal responsibility towards pollution control'.

References

Grindle. M., (2004) 'Good enough governance: poverty reduction and reform in developing countries' in *Governance,* Vol. 17, No. 4, Oxford, Blackwell Publishing, pp. 525-548.

Gleick, P. and Burns, W. *et al*., (2002) *The World's Water 2002-2003: The Biennial Report on Freshwater Resources*, London and Washington, Island Press, pp.170-171.

Hu, C. (2006) 'The challenges of water pollution control at basin level in China in the context of the Millennium Development Goals' *The Conference of the Global Water Governance System*, Bonn.

Mol, P. and Carter, N. (2006) 'China's environmental governance in transition' in *Environmental Politics,* Vol. 15, No. 2, Oxford, Taylor & Francis, pp. 149-170.

Shiva, V. (2002) *Water Wars: Privatization, Pollution and Profit,* London, Pluto Press, p. 15.

Thomas, P. R. (1996), 'Integrated environmental management' in *Reaching the Unreached: Challenges for the 21st Century*, 22nd WEDC Conference, Australia.

World Bank, (2002), *Urban Environment* (On December 19, 2002, the World Bank's Board of Executive Directors discussed the World Bank Group's Country Assistance Strategy (SAS) for the People's Republic of China covering the period 2003-2005), Beijing.

Yellow River Commission (2004), the Reason and Countermeasure of "Secondary Hanging River" of Lower Yellow River, *Yellow River*, Conservancy Press.

Yellow River Commission (2008), the First Water and Sediment Regulation of Yellow River, Yellow River Conservancy Press.

Yellow River Commission (1999), the change of water and sediment and analysis of the evolvement of channel in the Lower Yellow River since 1986, *Yellow Rive*, Yellow River Water and Hydropower Press.
Yellow River Commission (2000), *Yellow River Sediment*, Yellow River Water and Hydropower Press.
Zhang, M., (2001), *Water Resource Development and Utilization in the Yangtze Valley, Anhui,* EPA of Anhui.